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内蒙古中部新近纪动物群的演替与生物年代[1)]

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摘要:内蒙古中部地区陆相新近系出露广、含化石丰富。对这一地区新近纪的研究,可以追溯到20世纪初期瑞典地质学者安特生(J. G. Andersson)、法国古生物学者德日进(P. Teilhard de Chardin)和以美国探险家安德鲁斯(R. C. Andrews)为首的美国自然博物馆中亚考察团分别对二登图、高特格和通古尔的考察与化石采集。他们的开拓性工作使这些地方成为中国十分重要的新近纪经典地点。特别是通古尔,由于其产出的化石丰富、具有中中新世动物群的特征,已引入中国地质年表,作为新生代中一个“阶”的名称。最近20多年对这一地区新近纪生物地层学的研究又取得了很大的进展,新发现了数个不同时代的化石地点和层位,同时采集到大批哺乳动物化石标本。

内蒙古中部各地点化石层的厚度一般不大,但所含的哺乳动物化石种类多、材料丰富。由于具有这一特点,使其化石组合能比较接近地反映短期内动物群体的结构面貌,较客观地指示沉积时期的生态环境。利用这些组合进行动物群相对时代的确定,以及对其生态环境的恢复无疑都会很有意义。但是,这里的地层缺乏测试绝对年龄的材料,化石组合间少见有直接的叠置关系,使得在这一地区建立独立的动物群时间顺序,确定动物群的演替序列和生物年代只能更多地依赖于对动物系统发育和动物群体变化的研究。

本文对这一地区各地点发现的哺乳动物化石组合进行了审定,提供了最新的动物群名单;根据默尔根地点上部层位产出的化石组合特征,提议把该组合命名为铁木钦动物群;通过对哺乳动物系统发育关系的分析,将动物群进行先后排序,并阐述了这些动物群在各生物年代的演替特征;同时展示了各动物群与有关岩石地层和磁性地层的关系。文中进一步认定了苏尼特左旗的嘎顺音阿德格动物群为内蒙古中部地区现知新近纪动物群中的最早代表,其后依次为推饶木动物群、默尔根动物群、铁木钦动物群、阿木乌苏动物群、沙拉动物群、宝格达乌拉动物群、二登图动物群、哈尔鄂博动物群、比例克动物群、高特格动物群。内蒙古中部被认为是新近纪生物年代学研究的重要地点,在地质时代上这一哺乳动物群系列跨越了新近纪中新世至上新世的大部分时段。其中的嘎顺音阿德格动物群具有中国陆生哺乳动物年代山旺期的典型特征;推饶木动物群、默尔根动物群、铁木钦动物群构成的广义通古尔动物群,正是定义东亚中中新世陆生哺乳动物年代的依据;阿木乌苏动物群、沙拉动物群、宝格达乌拉动物群和二登图动物群符合保德期动物群的含义;比例克动物群和高特格动物群具有榆社期动物群的性质。虽然目前还无法根据这些动物群对我国陆生哺乳动物年代的时限进行精确界定,

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但依某些动物阶元(主要为科和属一级)的最早迁入或在该区的最早出现,以及在该区地层中的最后出席,概述了内蒙古中部地区新近纪动物群所指示的哺乳动物年代特征,并分别把通古尔期和保德期细分为3个和4个非正规亚期。

深入的研究,包括在这一地区发现新的化石层位和材料,不仅会为内蒙古中部地区生物年代的厘定提供更多的资料,而且有助于完善中国新近纪地质年代的内涵。

关键词:内蒙古,新近纪,哺乳动物,动物群演替,生物年代

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FAUNAL SUCCESSION AND BIOCHRONOLOGY OF THE MIOCENE THROUGH PLIOCENE IN NEI MONGOL (INNER MONGOLIA)

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Abstract　Neogene terrestrial deposits with rich fossil record are widespread in central Nei Mongol. The paucity of demonstrable superpositional sequence of assemblages and the lack of absolute dates, however, make recognition of the faunal succession and dating of the biochronology rely mainly on studies of faunal composition and evolution. The diversified faunas and new discoveries made in the last more than 20 years in this area afford an opportunity to further understand the phylogeny of mammals. The present work reviews the faunas, presents the updated faunal lists, and defines the biochronology through the analysis of the assemblages, although magnetostratigraphy is also considered when available. The faunal succession in the central Nei Mongol has assumed a prominent place in the development of a biochronology for the Neogene, covering parts of the Miocene Shanwangian, Tunggurian and Baodean, and the Pliocene Yushean of the Chinese Land Mammal Age. Informal subdivisions are suggested for Tunggurian and Baodean where it seems clearly indicated by the faunal succession. Although we are not able to propose boundary definitions for these ages, we utilize the first appearance and last occurrence of certain taxa in this region to characterize each age. Continued study of the succession, including discovery of new assemblages, will provide more data for the refinement of the biochronologic scale in this area, and for the establishment of more precise Neogene geochronologic subdivision in China.

Key words　Nei Mongol, Neogene, mammal, faunal succession, biochronology

1　Introduction

In central Nei Mongol, Neogene terrestrial deposits are widespread, with dense fossil records. On account of its abundant mammal remains, the area has attracted the attention of geologists and paleontologists. Investigations of fossil mammals in this area can be dated back to the early part of last century, when explorations by Swedish geologist J. G. Andersson, French paleontologist P. Teilhard de Chardin, and American scientists of the American Museum Central Asiatic Expeditions were carried out at Ertemte, Gaotege and Tunggur, respectively (Fig. 1; Andersson, 1923; Teilhard de Chardin, 1926a, b; Andrews, 1932). These pioneering works not only initiated geological and biostratigraphic studies in this area, but also rendered these places as important classic Neogene localities in China. Furthermore, the collections from Tunggur, representing the richest in the Chinese middle Miocene faunas, became the basis of the Tunggurian land mammal age in East Asia. After a long discontinuation of field work because of wars and political instabilities, a series of investigations were continuously carried out in the last 25 years. In the last decade, particularly, quite a number of new localities with fossiliferous deposits were found in this region (Meng et al., 1996; Qiu and Wang, 1999; Qiu and Storch, 2000). These localities produced a number of faunal sequences spanning four land mammal ages (Shanwangian through Yushean), but they are rather scattered with usually short fossil-bearing sections. This poses a difficult problem in dating of the biochronology, and the proposed temporal succession of faunas often lacks independent age control. In view of the paucity of demonstrable superpositional sequence of assemblages and of independent dating, faunal succession must rely heavily on studies of phylogenetic relationship and faunal change.

The Miocene mammal faunal succession in this area was initially discussed by the first two authors of the present paper (Qiu and Wang, 1999). Since then, important additions, including new localities and materials, were made by the present authors. These Neogene assemblages, with highly diverse and abundant materials, appear to represent most spans of Miocene and Pliocene. In addition, they are from a limited area, show stable community structure, and exhibit overall gradual changes in generic composition through geologic time. It is likely that these assemblages are from a single biogeographic region with a relatively stable ecosystem. This is a circumstance conducive to minimize ecologic or zoogeographic complications in the recognition of faunal succession and biochrons. Thus, in-depth studies of these assemblages will help not only to recognize the faunal succession in the central Nei Mongol, but also to understand the definition and characterization of the Chinese Neogene biochronology.

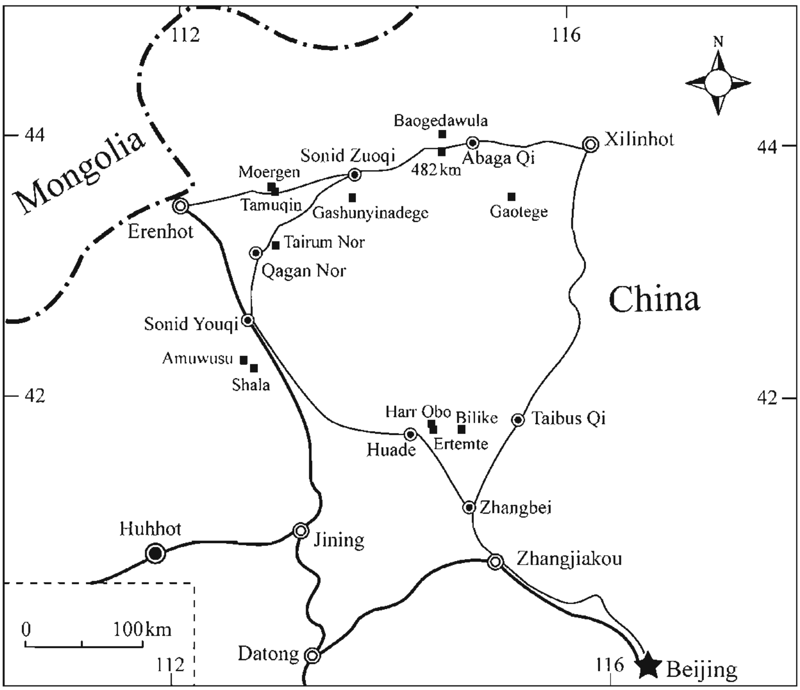

Fig. 1 Geographic location of the fossil localities in the central Nei Mongol

The purpose of this work is to seriate the faunas found in the central Nei Mongol, to define and characterize their biochronology through the analysis of the assemblage, and to integrate the faunal evidence with isotopic ages and magnetostratigraphy. The term "Fauna" used in this paper, with the exception of "Tunggur Fauna", is restricted, referring to an essentially contemporaneous assemblage derived from a limited geographic area and almost corresponding to the "Local Fauna" used by some American scientists (Tedford et al., 1987). The Tunggur Fauna is used for the diverse samples from the Tunggur Formation in the Tunggur Tableland, and obviously covers a certain period of time. The "earliest appearance" and the "latest occurrence" used are the local first appearance and the last occurrence of certain taxa or immigrants in this region. The updated faunal lists are presented as an appendix in this paper, and for faunal descriptions the reader is referred to papers by relevant authors.

2 The faunal succession

2.1 Gashunyinadege

Gashunyinadege is a valley located about 35 km southwest of Sonid Zuoqi (Sunitezuoqi) (GPS location 43°33′39.2″N, 113°32′51.9″E). The sediments, consisting mainly of reddish and yellowish sandy clays, are exposed along several gullies of the valley on gentle hills of granite basement. Exposed thickness of the beds varies from one to eight meters. The reddish silty clays in the middle part are fossiliferous.

The Gashunyinadege fauna was initially recognized and assigned a late Oligocene/early Miocene age by Meng et al. (1996). Important taxonomic additions to the fauna were made several times by the present authors, in collaboration with Y. Tomida and Y. Kimura, but two genera reported by Meng and others, *Metexallerix* and *Sayimys*, have not been found in the subsequent works. The specimen originally referred to *Sayimys*, evidently should belong to an upper molar of *Tachyoryctoides*. The assemblage contains at least 40 taxa of mammals, most of which are small mammals ranging from the late Oligocene to middle Miocene of Eurasia (Appendix). *Prodistylomys*, *Tachyoryctoides*, *Ansomys*, *Parasminthus* and *Megacricetodon* are common taxa in the fauna. In the 28 recognized genera, *Metexallerix*, *Amphechinus*, *Prodistylomys*, *Tachyoryctoides*, *Microdyromys*, *Pseudotheridomys*, *Parasminthus*, *Desmatolagus* and *Sinolagomys* occur frequently in the late Oligocene or early Miocene, whereas *Proscapanus*, *Mioechinus*, *Ansomys*, *Prodryomys*, *Keramidomys*, *Leptodontomys*, *Ligerimys*, *Heterosminthus*, *Democricetodon*, *Megacricetodon*, *Alloptox* and *Bellatona* occur in the early or middle Miocene.

The presence of numerous Oligocene elements and the absence of typical genera of middle Miocene such as *Protalactaga*, *Gobicricetodon*, *Plesiodipus* and *Platybelodon* suggest that the Gashunyinadege Fauna is the oldest Neogene assemblage so far known in central Nei Mongol.

2.2 Tunggur

The name Tunggur was derived from a freshwater well known as Gur Tung Khara Usu, and now refers to the Tunggur Tableland where the Tunggur Formation is actually or potentially exposed (Spock, 1929; Andrews, 1932; Wang et al., 2003). At the end of 1920s, sensational collections, including the well known shovel-tusked elephant *Platybelodon grangeri*, were made by the American Museum Central Asiatic Expeditions in the tableland. Exploration in the recent years have resulted in our relocation of classic localities, collection of new fossil materials, establishment of lithological and biostratigraphic criteria for correlation, and measurements of two paleomagnetic sections (Qiu et al., 1988; Qiu, 1996; Qiu and Wang, 1999; Wang et al., 2003). 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 tableland. The lower unit is characterized by rather uniform red or lavender mudstones interrupted by a channel sandstone along the southern rim of the tableland named Tairum Nor, and is also exposed at the lower part of the Aletexire section in the northern rim. Both units are fossiliferous.

The Tunggur Fauna, also known as the *Platybelodon* fauna, is proposed here to serve as a faunal unit (s. l.) to include all the assemblages from the Tunggur Formation. The assemblage is composed of 77 forms of mammals (Wang et al., 2003), representing the most diverse and abundant middle Miocene fauna in China. On the basis of composition of the mammals, three subordinate faunas can be differentiated for the Tunggur Fauna.

2.2.1 The Tairum Nor Fauna

Based on the collection from Aletexire and Tairum Nor in the lower unit of the Tunggur Formation, Qiu and Wang (1999) proposed the Tairum Nor Fauna. Among the 20 genera of mammals, most of them are commonly known in the entire Tunggur Formation, but *Tachyoryctoides* and *Distylomys* in the small mammals, and *Leptarctus*, *Aelurocyon* (?) and *Sthenictis* in the larger mammals are not seen elsewhere in the Formation. Both *Tachyoryctoides* and *Distylomys* are present in the Gashunyinadege Fauna, or the faunas of Oligocene and early Miocene in North China. In addition, *Atlantoxerus*, *Heterosminthus*, *Gobicricetodon*, *Tunguricti*s and *Stephanocemas* in the fauna demonstrate more primitive morphologies (Wang et al., 2003).

2.2.2 The Moergen Fauna

The Moergen Fauna is here defined on the basis of mammals from the channel sandstones and mudstones in the lower part of upper unit of the Tunggur Formation, mainly including the collections from the classic localities, such as the Wolf Camp, the *Platybelodon* Quarry, and also localities mostly excavated in last 20 years, such as Moergen (MOII), Huerguolajin, Aoershun Chaba, and the upper red beds of Tairum Nor section (Roadmark 346 and 492 localities, etc.). The fauna is composed of 61 taxa of mammals, forming the basis of the faunal characterization of the middle Miocene and typify the Tunggurian land mammal age. Among the 51 recognized genera, many are commonly known in the middle Miocene of the Holarctic Region, such as *Mioechinus*?, *Desmanella*, *Anchitheriomys*, "*Monosaulax*", *Leptodontomys*, *Keramidomys*, *Microdyromys*, *Miodyromys*, *Heterosminthus*, *Protalactaga*, *Plesiodipus*, *Gobicricetodon*, *Megacricetodon*, *Democricetodon*, *Alloptox*, *Bellatona*, *Platybelodon*, *Listriodon*, *Stephanocemas*, *Lagomeryx*, *Micromeryx*, *Dicrocerus* and *Turcocerus*. Of these, *Heterosminthus*, *Plesiodipus*, *Megacricetodon*, *Democricetodon*, *Alloptox*, *Bellatona*, *Platybelodon*, *Lagomeryx*, *Stephanocemas*, *Micromeryx* and *Dicrocerus* predominate the fauna. Thirty seven genera in this fauna, amounting to nearly two-third of the total, occur in the European Miocene faunas, and 14 show affinities with North Africa, but only six with southern Asia (Siwalik). About one-third of the total genera are cogeneric to North America, of which nine genera are also known from Europe.

2.2.3 The Tamuqin Fauna

Tamuqin is the Chinese translation of a Mongolian name for the grassland on the center of Tunggur Tableland. The assemblage from the grayish mudstone and greenish marl on the top of the Moergen section (MOV of Qiu, 1996) is here proposed to establish a new fauna. The fauna is small and consists of only 15 species of small mammals, of which 14 were collected by screen-washing in 1986 (Qiu, 1996), and one (*Steneofiber* sp.) found in 2005. Except *Ansomys* and *Steneofiber*, all the genera recognized can be seen in the assemblage from the channel sands in the lower part of the same section (MOII). However, distinct compositional and morphological differences between the two assemblages can be detected. Especially, the Tamuqin Fauna contains more advanced species of gobicricetodontines, *Gobicricetodon robustus* and *Plesiodipus progressus*, and more derived *Bellatona forsythmajori*. Magnetic stratigraphy exhibits that the two horizons (MOII and MOV), producing the Moergen and the Tamuqin faunas respectively, are approximately 0.5 m.y. apart (Wang et al., 2003).

2.3 Amuwusu

Amuwusu is located approximately 13 km west of Zhurihe, Sonid Youqi (Suniteyouqi) (42°22′03.1″N, 112°44′27.3″E). The small exposures are consisted of reddish mudstones and grayish yellow channel sandstones, with a total thickness of less than 10 m. Fossil remains produced from the fluvial sandstones in this locality are not very diverse, but include both large and small mammals.

The assemblage is composed of 34 forms of mammals (Appendix). Among the 24 identifiable genera, 17 can be found in the Tunggur Fauna. However, *Plesiodipus*, *Megacricetodon*, *Alloptox*, *Bellatona*, and *Platybelodon*, dominant in the Tunggur Fauna, are absent in the assemblage. The fauna is signified by the appearance of *Castor*, *Paralactaga*, *Prosiphneus*, *Sinozapus*, *Bellatonoides*, and *Ictitherium*. Of these, *Castor*, *Paralactaga*, *Prosiphneus*, and *Ictitherium* frequently occur in the faunas of late Miocene and Pliocene, and *Bellatonoides* is thought to be a likely ancestor to late Cenozoic Asian *Ochotona*. It is clear that the Amuwusu Fauna represents a transitional fauna between the Tunggur Fauna of middle Miocene and the faunas of late Miocene.

2.4 Shala

Shala is situated about 7 km southwest of Zhurihe, Sonid Youqi (42°19′58.0″N, 112°52′17.0″E). The exposure consists of 5 m of grayish red and yellow sandstones and mudstones. Remains of mammals, mainly of small mammals, occur in the channel sandstones on the top of the section. The quarry was found by Qiu Zhanxiang and others in 1986, and most materials from this site were screen-washed by the first two authors (Qiu and Wang) in the field seasons of 1996 and 2000.

Altogether, 34 forms of mammals have been recognized in the assemblage (Appendix). Among the 28 recognized genera, eleven share either with the Tunggur Fauna or the Amuwusu Fauna, and 20 with the latest Miocene or Pliocene faunas, such as the Ertemte fauna and the Bilike fauna (see below). All archaic genera of early and middle Miocene, that survived in the Amuwusu Fauna, such as "*Monosaulax*", *Heterosminthus*, *Protalactaga*, *Democricetodon* and *Gobicricetodon*, are absent in the assemblage. On the other hand, quite a number of the genera from Shala are commonly known in late Miocene and Pliocene faunas, such as *Prospermophilus*, *Sinotamias*, *Lophocricetus*, *Dipus*, *Kowalskia*, *Sinocricetus* and *Ochotona*. *Lophocricetus*, *Sinocricetus*, *Prosiphneus* and *Ochotona* are the predominant forms.

2.5 Baogedawula

This locality is about 3 km northeast of Baogedawula Sumu, Abaga Qi (44°08′33.8″N, 114°35′41.6″E). The exposure consists of grayish white and yellow sandy mudstones and sandstones, and the whole section is about 100 m thick. The deposits, named the Baogedawula Formation, are covered by a thick layer of basalts on the top, which was dated 7.11 ± 0.48 Ma (sample B48 of Luo and Chen, 1990). Remains of *Hipparion* fauna was first reported from the grayish white sandy mudstones at the middle part of the formation by a geological team from the Bureau of Geology and Mineral Resources of Nei Mongol Autonomous Region (1991). More materials were collected by the authors in the field seasons of 1996, 2000 and 2002.

Tentative identifications of the assemblage include 22 taxa of mammals (Appendix). Compared to the well documented micromammal faunas in central Nei Mongol, the Baogedawula Fauna seems to represent a relatively incomplete assemblage of micrommamals, and as such is difficult to grasp its characteristics as a representative association for the area and the time of its origin. Such a relatively poor record might be the results of depositional or sampling biases. Based on five forms of small mammals collected in 1996, the first two authors correlated the assemblage with the Shala Fauna (Qiu and Wang, 1999). However, the present updated faunal list demonstrates that the Baogedawula Fauna is readily distinguished from the Shala Fauna. Although the fauna shares some genera with that of Shala, such as *Lophocricetus*, *Paralactaga*, *Dipus*, *Kowalskia*, *Sinocricetus*, *Microtoscoptes*, *Prosiphneus* and *Ochotona*, it contains some new comers, such as *Parasoriculus*, *Nannocricetus*, *Pararhizomys*, *Hansdebruijnia*, *Abudhabia* and *Alilepus*. Among these, *Hansdebruijnia*, *Abudhabia*, *Pararhizomys* and *Alilepus* belong to the families Muridae, Gerbillidae, "Rhizomyidae" and Leporidae, respectively, which are unknown in the previous mentioned, earlier assemblages from central Nei Mongol, but are known or commonly known in the latest Miocene and Pliocene faunas. In addition, *Paralactaga*, *Microtoscoptes* and *Ochotona* show more advanced status than those from Shala. It is likely that the Baogedawula Fauna is more derived than the Shala Fauna. *Lophocricetus* and *Microtoscoptes* are relatively common in this assemblage.

2.6 Ertemte

Ertemte is located 4 km southeast of the county town Huade (41°52′59.5″N, 114°05′53.6″E). Lacustrine deposits are restricted within a small area approximately several hundred meters southeast of the small hill Ertemte. Fossil-bearing bed is in a layer of light grey to brown, calcareous sandy clay or clayey sand, 20 ~ 80 cm in thickness and 1 ~ 3 meters below the surface. It was discovered and first excavated by Andersson and his Chinese collectors in 1919 ~ 1920 (Andersson, 1923). Based on 240 identifiable specimens, Schlosser (1924) described the whole fauna (44 mammal species). The collections made Ertemte as one of the most important Neogene reference localities in East Asia. In 1980 new excavations and screen-washing operations were carried out in this quarry by paleontologists from China and Germany (Fahlbusch et al., 1983). As a result, more than 10 000 specimens were collected and at least 25 species of small mammals were added to the fauna. The materials collected have been mostly described by the Chinese and German paleontologists in the last twenty years (Fahlbusch, 1987, 1992; Fahlbusch and Moser, 2004; Qiu, 1985, 1987, 1991, 2003; Storch, 1987, 1995; Storch and Qiu, 1983; Wu, 1985, 1991).

The Ertemte assemblage is composed of at least of 73 species of mammals, representing a fairly diverse and abundant Neogene fauna in China. Except *Pararhizomys*, all the identifiable Baogedawula genera can be seen in this assemblage. Nevertheless, the Ertemte Fauna exhibits more advanced nature of the species of the shared genera. Numerous genera unknown in the preceding faunas are present in the assemblage. These include *Erinaceus*, *Zelceina*, *Alloblarinella*, *Paenepetenyia*, *Cokia*, *Paenelimnoecus*, *Pseudaplodon*, *Petinomys*, *Dipoides*, *Myomimus*, *Eozapus*, *Brachyscirtetes*, *Microtodon*, *Apodemus*, *Orientalomys* and *Micromys*, etc. In addition, one of the notable features of the fauna is the high diversification of insectivores and myomorph rodents. Ground squirrels and lophate cricetids increased in diversity and abundance, and murids begin to reach their maximum generic diversity in Nei Mongol. *Yanshuella* and *Sorex* of insectivores, *Prospermophilus*, *Sicista*, *Lophocricetus*, *Sinocricetus*, *Nannocricetus*, *Kowalskia*, *Microtodon*, *Prosiphneus* and *Micromys* of rodents, and *Ochotona* of lagomorphs are very common. *Lophocricetus*, *Microtodon*, *Prosiphneus* and *Ochotona* are predominant in the assemblage. A moderate assemblage of large mammals were known from Ertemte (Schlosser, 1924), and these were supplemented by additional materials collected in the 1980s. Judging from Schlosser's original faunal list, the Ertemte large mammal assemblage has such late Miocene carnivorans as modest-sized *Promephitis alexejewi* (as opposed to larger forms in the Chinese Pliocene; see Wang and Qiu, 2004) and ictithere hyaenid, but conspicuously lacks canids. In fossil horses, *Hipparion mongolicum* (*Hipparion richthofeni* race *mongolicum* Schlosser, 1924) is restricted to Ertemte and Harr Obo (below) only, but it seems to represent the late member of the subgenus *Hipparion* (*Hipparion*) in China and may have survived to the latest Miocene (Qiu et al., 1987). Certain "advanced elements" are also present in Ertemte, such as species of *Meles* and *Martes* that are close to modern taxa and advanced *Procapreolus* (Qiu and Qiu, 1990: 250).

2.7 Harr Obo

The locality was first described by Andersson, and produced only several remains of perissodactyls and artiodactyls (Andersson, 1923; Schlosser, 1924). According to Andersson, the fossil site is situated 2 km WSW of Harr Obo hill, 3 km north of Ertemte. During the field works in 1980, about 1 000 teeth of small mammals were collected by the Chinese and German scientists from a pile of matrix dug out from an irrigation well of seven meters deep. The site, called Harr Obo 2, lies 300 m north of the village of Gongweizi (very close to the site as described by Andersson). Neither the stratigraphic position nor the thickness is known. The sediments washed are of reddish brown marl and fine to coarse-grained sand (Fahlbusch et al., 1983).

The faunal composition at Harr Obo corresponds to the Ertemte Fauna in all the more frequently occurring elements of small mammals (45 taxa). Probably due to the less quantity of washed matrix at this site, a few of the rare Ertemte species are missing. Minor differences of the two assemblages are the presence of *Trischizolagus* and *Rhagapodemus* in the Harr Obo, and slightly more derived features seen in some taxa, such as *Ochotona* and *Brachyscirtetes* (Storch, 1987; Qiu, 1987, 2003). *Trischizolagus* and *Rhagapodemus* are currently considered to be the Pliocene elements in the Palearctic Region (also see below). Thus, the Harr Obo fauna is probably slightly younger than the Ertemte Fauna, but a possibility of sampling bias can not be excluded.

2.8 Bilike

The locality Bilike is situated about 1.5 km south of the village Bilike, Huade (42° 08′ 11.5″N, 114°29′35.0″E). The sediments of the section consist of more than 10 m of gray-brownish red silt and sandy clay. Remains of mammals, mainly of small mammals, concentrated in thin layers and lenses of grayish green silt and brownish gray silty clay in the middle part of the section. Associated with the remains of small mammals are fragments of *Hipparion*, proboscideans and cervids. The quarry, also called Longgupo, was found by Qiu Zhanxiang and others in the 1970s, and most materials were collected in the field seasons of 1986 and 1991 (Qiu, 1988; Qiu and Storch, 2000). The material of small mammals from this quarry has been described by Qiu and Storch (2000).

The Bilike fauna, dominated by micromammals, is composed of 50 species from 41 genera, which is the most taxonomically diverse Pliocene micromammalian fauna in China. The assemblage shows strong similarities to the Ertemte fauna in its dominance of myomorph rodents and the high diversity of insectivores, and shares half of the genera with the latter. However, it shows distinct compositional differences from the Ertemte. Among insectivores, *Desmana*, *Petenyia*, *Lunanosorex*, *Parasoriculus* and *Sulimskia* replaced *Zelceina*, *Alloblarinella*, *Paenepetenyia*, *Cokia* and *Paranourosorex*; among rodents, archaic genera like *Pseudaplodon*, *Leptodontomys*, *Microtoscoptes* and *Hansdebruijnia* disappeared, and advanced ones, such as *Aratomys*, *Chardinomys*, *Huaxiamys* and *Allorattus* appeared; among lagomorphs, *Alilepus* was completely replaced by *Trischizolagus*. In addition, some commonly known members in the Ertemte, *Prospermophilus*, *Lophocricetus*, *Anatolomys* and *Microtodon*, for example, are quite rare or absent. A striking faunal change is the disappearance of two families, Aplodontidae and Eomyidae, present in Ertemte, and the appearance of the typically Pliocene family Arvicolidae in Bilike. *Sorex*, *Parasoriculus*, *Myomimus*, *Sicista*, *Dipus*, *Sinocricetus*, *Nannocricetus*, *Kowalskia*, *Aratomys*, *Prosiphneus*, *Apodemus*, *Micromys*, *Trischizolagus* and *Ochotona* are fairly common. Dominant genera in this assemblage are *Sicista*, *Aratomys*, *Prosiphneus* and *Ochotona*. *Aratomys* is abundant as are the genera *Lophocricetus* and *Microtodon* in Ertemte.

2.9 Gaotege

The Geotege locality is an isolated hill about 70 km southwest of Xilinhot and 50 km southeast of Chagannoer Sumu, Abag Qi (43°29′55.3″N, 115°26′38.3″E). Sediments at this site, exceeding 70 m in thickness, are predominantly a series of light-colored siltstone and mudstone from fluvio-lacustrine deposits. Four layers, mainly of the grayish siltstones at the middle part of

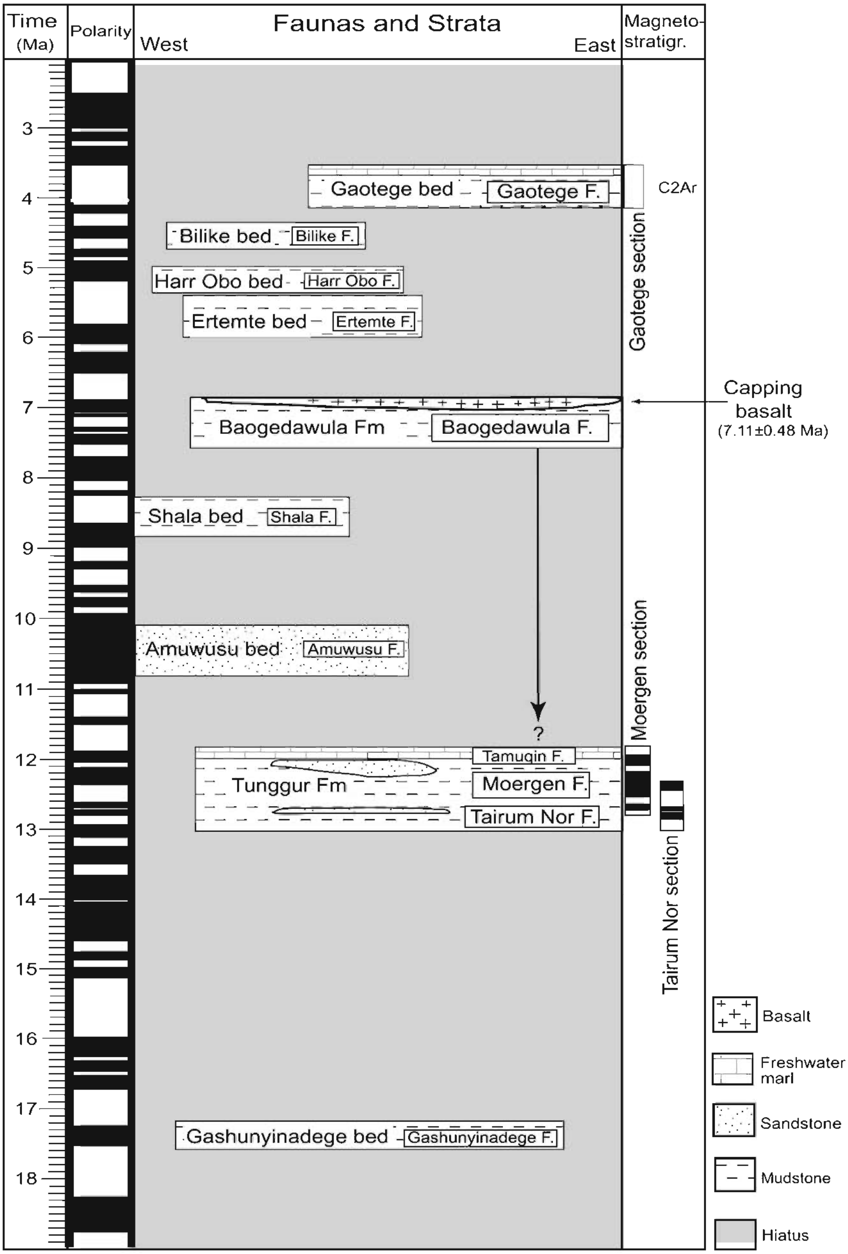

Fig. 2 Relationships of faunas within lithostratigraphic units, and available magnetostratigraphic columns and radiometric date in central Nei Mongol

the section, are fossiliferous. Teilhard de Chardin and Licent made a small collection in 1924 (Teilhard de Chardin, 1926a, b). The present authors have revisited the locality several times since 2000. Numerous material and important taxonomic additions for the fauna were made in the seasons of 2002 and 2003.

The Gaotege fauna consists of 46 taxa, dominated by small mammals (Li et al., 2003). The fauna is similar to the Ertemte, Harr Obo and Bilike faunas in community structure and composition of small mammals. However, in contrast to the Ertemte and Harr Obo faunas, it is closer to the Bilike Fauna in sharing 13 of the 15 families, nearly 90% of the genera and about half of the species, and in containing some typical Pliocene elements which are absent in Ertemte and Harr Obo, for example, *Desmana*, *Aratomys*, *Chardinomys* and *Huaxiamys*. The Gaotege assemblage can be differentiated from the Bilike fauna by the absence of the family Gliridae and the genera *Lophocricetus*, *Kowalskia* and *Orientalomys*, which are frequently present in the late Miocene and early Pliocene faunas of North China, and by the occurrence of *Sciurotamias* and *Sinocricetus* sp. nov. In addition, the Gaotege Fauna shows a marked drop in insectivore, sciurid and zapodid diversity, and a rise in dipodid and murid (*Chardinomys* and *Huaxiamys*) when compared with those from Bilike. It is likely that the fauna is slightly more derived than that of Bilike, representing the youngest one in central Nei Mongol. *Dipus*, *Nannocricetus*, *Aratomys*, *Prosiphneus*, *Micromys*, *Chardinomys* and *Huaxiamys* of rodents, and *Ochotona* of lagomorphs are common. The fauna is predominated by *Aratomys*, *Prosiphneus*, *Chardinomys* and *Ochotona*.

Fig. 2 shows the relationships of the faunas within the lithostratigraphic units, and the available magnetostratigraphic columns and radiometric data.

3 Biochronology

The Chinese Neogene biochronologic framework was initiated by Chiu (Qiu) and others in 1979 and has been refined and modified significantly (Chiu et al., 1979; Li et al., 1984; Qiu and Qiu, 1995; Tong et al., 1995; Qiu et al., 1999). It was first developed by seriating mammal faunas based mainly on the stage of evolution of mammals and faunal correlation, especially with respect to those from Europe. Currently, four Miocene ages, Xiejian, Shanwangian, Tunggurian and Baodean, and one Pliocene age, Yushean, are recognized (Table 1). Applicability of the mammal ages is demonstrable over a large area equivalent to the Palearctic regions of Asia, including most of China, Mongolia, and parts of Kazakhstan and Siberia.

Nevertheless, the Chinese mammal ages remain poorly dated, loosely defined sequential units with diffuse boundaries due to the paucity of independent dating and imprecise definition and characterization of biological assemblages. It is clear that more assemblages with fewer faunal differences are desired to interpolate into the seriation, in order to close the faunal gaps and raise the precision of biochronology. The central Nei Mongol faunal succession, with high faunal diversity and representing four of the five mammal ages in the Neogene within a limited area, will provide important information and offer a better precision for the perceived biochronology of China.

3.1 Shanwangian

This mammal age was proposed by Li et al. (1984) based on the classic Shanwang Fauna and the Sihong Fauna. Tong et al. (1995) defined the Shanwangian as the initiation of great diversification of myomorph rodents, the complete replacement of archaic carnivores by modern ones, the further decline of perissodactyls, and the flourish of ruminants. The Gashunyinadege Fauna shows the same feature in Rodentia. Although the fauna contains some genera of Oligocene origin, it is more closely affiliated to Shanwangian rather than Xiejian because of the occurrence of some genera originated in the Miocene. In addition, it shares with Shanwang or Sihong faunas several genera, such as *Ansomys*, *Microdyromys*, *Democricetodon*, *Megacricetodon* and *Alloptox*. Qiu and Qiu (1995) correlated Sihong and Shanwang to Zone MN4 and MN5 of Europe, respectively. The co-occurrence of *Desmanella*, *Proscapanus*, *Miodryomys*, *Pseudotheridomys*, *Keramidomys*, *Leptodontomys*, *Ligerimys*, *Eutamias*, *Eumyarion*, *Democricetodon* and *Megacricetodon* in the Gashunyinadege Fauna, which also show close affinities with those from Europe, seems to suggest such a correlation.

Table 1 Mammalian biochron of central Nei Mongol

Time in Ma	Chronostratigraphy		Mammal age		Central Nei Mongol: Fauna	Central Nei Mongol: Main diagnostic taxa	Relevant fauna in China	MN zone
	Pliocene	Middle	Yushean	M			Daodi	16
	Pliocene	Early	Yushean	E	Gaotege	*Sciurotamias* Sinocricetus* sp. nov.*	Mazegou	15
					Bilike	*Desmana* Lunanosorex* Myomimus+ Lophocricetus+*	Gaozhuang	
5					Harr Obo	*Kowalskia+ Aratomys* Chardinomys* Huaxiamys* Allorattus* Trischizolagus**	CL5~4 (Lingtai)	14
	Miocene	Late	Baodean	L.st	Ertemte	*Alloblarinella* Leptodontomys+Myomimus* Eozapus* Microtodon* Pseudomeriones* Microtoscoptes+ Micromys* Apodemus* Alilepus+*	Mahui	13
				L	Baogedawula	*Parasoriculus* Pararhizomys* Nannocricetus* Alilepus* Abudhabia* Hansdebruijnia* Hyaenictitherium**		12
				M	Shala	*Paranourosorex* Ansomys+ Keramidomys+ Miodyromys+ Sicista* Dipus* Kowalskia* Sinocricetus* Lophocricetus* Microtoscoptes* Ochotona**		11
10				E			Bahe	10
					Amuwusu	*"Monosaulax"+ Castor* Heterosminthus+ Sinozapus* Paralactaga* Protalactaga+ Democricetodon+ Prosiphneus* Desmatolagus+Bellatonoides* Plithocyon* Ictitherium**		9
		Middle	Tunggurian	L	Tamuqin	*Steneofiber* Gobicricetodon robustus* Megacricetodon+ Plesiodipus progressus* Alloptox+ Bellatona+*	Chetougou	7+8
				M	Moergen	*Desmanella+ Mioechinus* Heterosminthus* Protalactaga* "Monosaulax"* Anchitherium* Lagomeryx* Kubanochoerus**	Kekemaid. Xianshuihe	
15				E	Tairum Nor	*Tachyoryctoides+ Distylomys+ Anchitheriomys* Gobicricetodon* Plesiodipus* Tungurictis* Platybelodon* Stephanocemas* Dicroceros**	Tongxin Halamagai	6
		Early	Shanwangian				Shanwang	5
					Gashunyin-adege	*Amphechinus+ Prodistylomys+ Leptodontomys* Keramidomys* Parasminthus+ Democricetodon* Megacricetodon* Sinolagomys+*	Sihong	4
20							Suosuoquan (upper)	3
			Xiejian				Xiejia	2
							Suosuoquan (lower)	1
	Oligoc.	Late	T. blukian				Taben Bluke	MP30

* the earliest appearance; + the latest occurrence.

The Gashunyinadege micromammal fauna can be characterized by the earliest appearance of *Desmanella*, *Proscapanus*, *Mioechinus*, *Mongolosorex*, *Ansomys*, *Prodryomys*, *Miodyromys*, *Microdyromys*, *Leptodontomys*, *Keramidomys*, *Ligerimys*, *Sinotamias*, *Heterosminthus*, *Democricetodon*, *Megacricetodon*, *Alloptox* and *Bellatona*; and the last occurrence of *Amphechinus*, *Pseudotheridomys*, *Parasminthus*, *Eumyarion* and *Sinolagomys*.

Differences in composition among the Gashunyinadege, Shanwang and Sihong faunas are probably resulted from regional differences and sampling biases. The Gashunyinadege Fauna can be roughly comparable to the assemblage from the upper part of Suosuoquan Formation in the Junggar Basin of Xinjiang, with *Megacricetodon* and *Alloptox* in common, but lacking *Platybelodon* and *Stephanocemas* commonly known in the middle Miocene.

3.2 Tunggurian

Li et al. (1984) suggested the Tunggurian age be based on the Tunggur Fauna from the Tunggur Tableland, and Tong et al. (1995) presented biologic characterization of the age as: the major radiation of Proboscideans; the diversification of ruminants; the earliest appearance of the families Dipodidae and Hyaenidae, and the genera *Plesiodipus*, *Platybelodon*, etc, as well as the last occurrence of Ctenodactylidae, Tachyoryctoididae, *Megacricetodon*, *Alloptox*, *Hemicyon*, *Plesiaceratherium*, etc. In this work we propose a locally informal subdivision of the Tunggurian into an earlier, middle and later phases. Each phase is defined and characterized biologically as the following. The combined characterization of the three phases can serve as a modified definition of the Tunggurian age as a whole.

The early Tunggurian is based on the Tairum Nor Fauna from Aletexire and Tairum Nor in the lower unit of the Tunggur Formation. It is characterized by the earliest appearance of *Anchitheriomys*, *Atlantoxerus*, *Gobicricetodon*, *Plesiodipus*, *Leptarctus*, *Tungurictis*, *Sansanosmilus*, *Stephanocemas*, *Dicroceros*, and *Platybelodon*, the latest occurrence of Ctenodactylidae and Tachyoryctoididae. The Tairum Nor Fauna is distinguishable from the classic Tunggur assemblages from northern and western edges of the Tunggur Tableland (except the lower part of the Aletexire section) in its retention of a few holdover genera from Oligocene and presence of some new forms that are more primitive in morphology. The fauna shows close affinities with the Tongxin Fauna of Ningxia and the Halamagai Fauna from the Halamagai Formation of Xinjiang in sharing quite a number of genera, especially in having the joint occurrence of *Tachyoryctoides*, *Alloptox*, *Sansanosmilus*, and *Platybelodon*. Both the Halamagai and Tongxin faunas are considered to be allied to MN6 of Europe (Ye et al., 2001).

The middle Tunggurian includes the Moergen Fauna and the assemblages from the lower part of upper unit of Tunggur Formation. This phase is characterized by the earliest appearance of Dipodidae, *Yanshuella*, *Quyania*, "*Monosaulax*"; the latest occurrence of *Proscapanus*, *Desmanella*, *Mongolosorex* and *Miodyromys*. The main characteristic of the fauna is the dominance of the Myomorpha in Rodentia, the absence of many ancient genera of Oligocene origin, such as *Amphechinus*, *Distylomys*, *Tachyoryctoides*, *Parasminthus* and *Sinolagomys*. The dominance of the cricetids and prevalence of *Heterosminthus* in the Rodentia are also considered characteristic for the fauna. *Mioechinus*, "*Monosaulax*", *Heterosminthus*, *Plesiodipus*, *Megacricetodon*, *Democricetodon*, *Alloptox*, *Bellatona*, and *Platybelodon* flourished to a high degree. A MN8 equivalence for this phase is suggested by the assemblage from Moergen II (Qiu, 1996). The Quantougou Fauna from the upper part of Xianshuihe Formation in Gansu, the assemblages from the Chetougou and Xianshuihe formations in Qinghai, and the Kekemaideng Fauna from the Kekemaideng Formation in Xinjiang are correlative faunas in this phase primarily based on the identity of their mammals compared with those of the Moergen II.

The late Tunggurian is only represented by the Tamuqin Fauna from the top of the Moergen section. It is characterized by the earliest appearance of *Steneofiber* and the more advanced species of gobicricetodontines, *Gobicricetodon robustus* and *Plesiodipus progressus*; the more derived morphology in some taxa, such as *Bellatona*; the latest occurrence of *Plesiodipus*, *Megacricetodon*, *Alloptox* and *Bellatona*. In view of these advanced species and the derived status of other taxa, it seems reasonable to regard the Tamuqin Fauna as a representative of the late phase of Tunggurian.

3.3 Baodean

Li et al. (1984) defined the Baodean age based on the *Hipparion* faunas primarily from some classic localities of northern China, including Baode of Shanxi, Qingyang and Wudu of Gansu, Ertemte of Nei Mongol, and the hominoid fauna of Lufeng, Yunnan. As for the definition and characterization of the Baodean, Tong et al. (1995) emphasized the further diversification of myomorph rodents with the appearance of Muridae and Siphneidae (Myospalacinae) in North China and Rhizomyidae and Hystricidae in South China, the abundance of Hyaenidae, Felidae and Mustelidae, the dominance of *Hipparion* and *Chilotherium* in Perissodactyla, and the high flourish of Proboscidea and Artiodactyla. The Amuwusu, Shala, Baogedawula and Ertemte faunas from central Nei Mongol possess comparable components with the *Hipparion* faunas mentioned above. On the basis of the characters of these assemblages, the following four phases can be recognized as an informal subdivision of the Baodean in central Nei Mongol.

The early Baodean is represented by the Amuwusu Fauna and characterized by the earliest appearance of Siphneidae, *Castor*, *Sinozapus*, *Paralactaga*, *Bellatonoides* and *Ictitherium*; the latest occurrence of "*Monosaulax*", *Heterosminthus*, *Protalactaga*, *Democricetodon*, *Gobicricetodon*, *Desmatolagus*, *Plithocyon*, *Dicroceros*, and *Anchitherium*. The Amuwusu Fauna is considered to be the earliest late Miocene fauna in China, equivalent to MN9 ~ 10 of Europe (Qiu and Qiu, 1995). The earliest late Miocene age is also marked by the last occurrence of several genera that survived from Tunggurian time, such as "*Monosaulax*", *Heterosminthus*, *Protalactaga*, *Democricetodon* and *Desmatolagus*. It shares *Eutamias*, *Protalactaga* and *Paralactaga* with the Bahe Fauna of Shaanxi, but the latter seems to be somewhat younger for its presence of Muridae, *Lophocricetus*, *Ochotona* and *Hipparion*.

The Shala Fauna is in the middle Baodean phase, and is characterized by the earliest appearance of *Paranourosorex*, *Prospermophilus*, *Pliopetaurista*, *Lophocricetus*, *Sicista*, *Dipus*, *Cardiocranius*, *Kowalskia*, *Sinocricetus*, *Microtoscoptes*, *Anatolomys* and *Ochotona*; the latest occurrence of *Ansomys*, *Miodyromys*, *Microdyromys* and *Keramidomys*. The fauna has *Eutamias*, *Paralactaga*, *Lophocricetus*, *Cardiocranius* and *Ochotona* in common with the Bahe Fauna, but it is slightly younger than the latter in having some advanced genera like *Paranourosorex*, *Prospermophilus*, *Dipus*, *Kowalskia*, *Sinocricetus* and *Microtoscoptes*, and in lacking some taxa commonly known from the middle Miocene, such as *Protalactaga* and *Myocricetodon*.

The Baogedawula Fauna represents the late Baodean, which is closely allied to the preceding Shala Fauna. This phase is defined by the earliest appearance of the immigrants Gerbillidae (*Abudhabia*), Muridae (*Hansdebruijnia*) and "Rhizomyidae" (*Pararhizomys*). It is characterized by the earliest appearance of *Parasoriculus*, *Nannocricetus*, and reappearance of Leporidae (*Alilepus*) after a long hiatus in Asia during Oligocene and Miocene. Immigration of murids into the central Nei Mongol was an important event in this region, but it happened later than in the Bahe area. An MN12 equivalence of the late Baodean was suggested by the presence of the primitive *Hansdebruijnia* and earliest occurrence of *Microtoscoptes* (Storch and Ni, 2002; Mein, 1999).

The latest Baodean, represented by the Ertemte Fauna, is characterized by the earliest appearance of *Zelceina*, *Alloblarinella*, *Paenepetenyia*, *Cokia*, *Paenelimnoecus*, *Pseudaplodon*, *Petinomys*, *Myomimus*, *Eozapus*, *Brachyscirtetes*, *Microtodon*, *Pseudomeriones*, *Micromys*, *Apodemus* and *Orientalomys*; the limited occurrence of *Paranourosorex*, *Pliopetaurista* and *Ana-*

tolomys; the dominance of *Yanshuella*, *Sorex*, *Lophocricetus*, *Sinocricetus*, *Microtodon*, *Prosiphneus*, *Micromys* and *Ochotona*; the latest occurrence of Aplodontidae and Eomyidae, *Sinotamias*, *Eozapus*, *Microtoscoptes*, *Hansdebruijnia* and *Alilepus*. Detailed description of the main groups suggests an upper Turolian or MN13 equivalent age for the fauna (Storch, 1987, 1995; Wu, 1991; Fahlbusch, 1992). The assemblages from the Mahui Formation and the lower part of Gaozhuang Formation of Yushe, Shanxi share most of their genera with Ertemte (Flynn et al., 1997).

3.4 Yushean

Qiu and Qiu (1995) proposed the Yushean age based on the Gaozhuang and Mazegou faunas from Yushe, Shanxi, and referred the Bilike Fauna to this age. Tong et al. (1995) defined the Yushean by the earliest appearance of Arvicolidae, Caninae, Camelidae, *Chardinomys*, *Hypolagus*, *Trischizolagus*, *Chasmaporthetes*, etc; the drastic decline or extinction of some genera of Baodean origin, such as *Microtoscoptes*, *Microtodon*, *Lophocricetus*, *Adcrocuta* and *Ictitherium*.

The Bilike Fauna is older than the assemblage from the upper Gaozhuang Formation, and is considered to be an early Yushean age equivalent to early Ruscinian or MN14 of Europe (Qiu and Storch, 2000). The fauna is characterized by the earliest appearance of *Desmana*, *Petenyia*, *Lunanosorex*, *Parasoriculus*, *Sulimskia*, *Tamiasciurus*, *Aratomys*, *Chardinomys*, *Huaxiamys*, *Allorattus* and *Trischizolagus*; the latest occurrence of Gliridae, *Parasoriculus*, *Lophocricetus*, *Kowalskia*, *Anatolomys* and *Orientalomys*. The assemblage from CL5 ~ 4 or III of Loc. 93002 Section of Lingtai, Gansu, with the presence of *Chardinomys*, *Huaxiamys*, *Allorattus* and *Trischizolagus*, most closely approaches the Bilike Fauna rather than the Ertemte Fauna as suggested previously (Zhang and Zheng, 2000; Zheng and Zhang, 2001), because of the absence of these taxa in Ertemte.

The Gaotege Fauna (Li et al., 2003) demonstrates close community structure and composition of taxa with the Bilike Fauna. Characterization of the fauna includes the earliest appearance of *Sciurotamias* and *Sinocricetus* sp. nov.; the disappearance of Gliridae, *Lophocricetus* and *Orientalomys*. This plus the more derived character states in some species indicates that the Gaotege is younger than the Bilike and is the youngest fauna known from this area. It is likely that the Gaotege Fauna should be included in the early Yushean, equivalent to the lower MN15 of Europe, because they are distinctly different from the late Yushean faunas like the Daodi, Mazegou and Jingle faunas in North China.

4 Isotopic and magnetostratigraphic constraints

Basalt sheet-flows and cinder cones have been known to be associated with sediments in central Nei Mongol since Teilhard de Chardin's (1926a) pioneering geologic reconnaissance in the area of Huiteng River (Chiton Gol) and Dalai Lake (Dalai-noor). However, it wasn't until the early 1990s did enough isotopic dates become available to give a first indication of their age ranges (Luo and Chen, 1990). $^{40}K/^{40}Ar$ dates suggest that there were up to five episodes of local eruptions ranging from 14.57 ± 0.36 Ma (excluding dates of drilling cores from subsurface rocks) to as young as 0.33 ± 0.25 Ma south and west of Xilinhot. Of above mentioned fossil localities, only two are associated with basalts. One is the Gaotege locality. Unfortunately, no direct superpositional relationship is present for the Gaotege beds, which are only a few kilometers away from nearest basalts. The other is the Baogedawula Formation.

The Baogedawula Formation forms a tableland east of the village of Baogedawula and is capped by a layer of basalt ranging from 10 ~ 25 m near the eruption centers to 1 ~ 2 m toward the periphery of the craters. Radiometric dating from a sample in Bayanmende (B48) provides an age of 7.11 ±0.48 Ma, which was also correlated to the basalts near Baogedawula (Luo and Chen, 1990). Assuming little or no hiatus between the Baogedawula Formation and the overlying basalt, the Baogedawula Formation would be approximately between 7 ~ 7.5 Ma, a result consistent with our faunal analysis above.

In recent years, we have begun to systematically sample fossiliferous strata for paleomagnetic analysis. A preliminary result was published for the Tunggur Formation (Wang et al., 2003), which was correlated to the magnetozones C5Ar.3r through part of C5r.3r, with an age range of 11.8 ~ 13 Ma. This interpretation, however, was hampered by difficulties in sampling the coarse-grained upper section and by the lack of an observable contact between the upper (northern) and lower (southern) beds of the Tunggur Formation. Faunally, the Tairum Nor Fauna seems to indicate an age of around 14 ~ 15 Ma (Fig. 2). If so, a depositional hiatus may have to be entertained between the Tairum Nor red bed and the northern Tunggur Tableland exposures, a problem that needs to be resolved in future studies.

More recently, we have also sampled the relatively thick beds in Gaotege, one of only two sections in central Nei Mongol Neogene with thickness in excess of 50 m. Measurements of 49 sites at a density of 1 ~ 2 m yield a section of completely reversed polarities (detailed results will be published elsewhere by O'Connor et al., in review). Given the thickness of approximately 60 m of the Gaotege beds that must represent a substantial duration (presumably more than 100 000 to 200 000 years in duration for most of short reversed chrons in Pliocene), the best correlation seems to be the longest reversed Chron C2Ar (3.6 ~ 4.2 Ma) in the early Pliocene, a conclusion consistent with our faunal analysis above.

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Appendix

Gashunyinadege

Insectivora
- Talpidae
  - *Desmanella* sp.
  - *Proscapanus* sp.
- Soricidae
  - cf. *Mongolosorex* sp.
- Heterosoricinae indet.
  - Soricinae indet.
- Erinaceidae
  - *Mioechinus*? cf. *M. gobiensis*
  - *Amphechinus* sp.
  - Erinaceidae indet.

Rodentia
- Ctenodactylidae
  - *Prodistylomys/Distylomys* sp.
- Tachyoryctoididae
  - *Tachyoryctoides* sp.
- Aplodontidae
  - *Ansomys* sp. 1
  - *Ansomys* sp. 2
  - *Ansomys* sp. 3
- Gliridae
  - *Prodryomys* sp.
  - *Miodyromys* sp.
  - *Microdyromys* sp.
- Eomyidae
  - *Keramidomys* sp.
  - *Pseudotheridomys* sp.
  - cf. *Eomys* sp.
  - Eomyidae indet.
  - *Leptodontomys* sp.
  - *Ligerimys* sp.
- Sciuridae
  - *Eutamias* sp.
  - *Sinotamias* sp.
- Zapodidae
  - *Parasminthus* cf. *P. parvulus*
  - *Parasminthus* cf. *P. tangingoli*
  - *Heterosminthus* sp.
- Cricetidae
  - *Eumyarion* sp.
  - *Democricetodon* sp. 1
  - *Democricetodon* sp. 2
  - *Megacricetodon* sp.

Lagomorpha
- Ochotonidae
  - *Desmatolagus* ? sp.
  - *Sinolagomys* sp.
  - *Alloptox* sp.
  - *Bellatona* sp. ?

Carnivora
- Mustelidae indet.

Amuwusu

Insectivora
- Talpidae
  - *Yanshuella* cf. *Y. primaeva*
- Soricidae
  - Soricinae indet.
  - Heterosoricinae indet.
- Erinaceidae
  - *Mioechinus*? *gobiensis*
  - Erinaceidae indet.

Rodentia
- Aplodontidae
  - *Ansomys* sp.
  - Meniscomyinae indet.
- Gliridae
  - *Microdyromys* sp. 1
- Eomyidae
  - *Keramidomys* sp.
  - *Leptodontomys* sp. 1
  - *Leptodontomys* sp. 2

Castoridae
"Monosaulax" sp.
Castor sp.
Sciuridae
Eutamias cf. *E. ertemteensis*
cf. *Miopetaurista* sp.
Zapodidae
Heterosminthus cf. *H. orientalis*
Sinozapus sp.
Dipodidae
Protalactaga cf. *P. graubaui*
Paralactaga sp.
Cricetidae
Democricetodon sp.
Cricetidae indet.
Gobicricetodon sp. 1
Gobicricetodon sp. 2
Siphneidae
Prosiphneus qiui
Lagomorpha
Ochotonidae
Desmatolagus? sp.
Bellatonoides sp.
Ochotonidae indet.
Carnivora
Hyaenidae
Ictitherium sp.
Ursidae
Plithocyon cf. *P. teilhardi*
Perissodactyla
Equidae
Anchitherium sp.
Rhinocerotidae indet.
Artiodactyla
Cervidae
Micromeryx sp.
Dicroceros sp.
Proboscidea indet.

Shala
Insectivora
Talpidae
Yanshuella primaeva
cf. *Asthenoscapter* sp.
Soricidae
Paranourosorex sp.
Sorex cf. *S. ertemteensis*
Soricinae indet.
Erinaceidae
Erinaceidae indet.
Rodentia
Aplodontidae
Ansomys sp.
Gliridae
cf. *Prodryomys* sp.
Miodyromys sp.
Microdyromys sp. 1
Microdyromys sp. 2
Eomyidae
Keramidomys sp.
Leptodontomys sp. 1
Leptodontomys sp. 2
Sciuridae
Eutamias cf. *E. ertemteensis*
Prospermophilus cf. *P. orientalis*
Sinotamias sp.
Pliopetaurista sp.
Zapodidae
Lophocricetus cf. *L. gansus*
Sicista sp.
Sinozapus sp.
Dipodidae
Paralactaga sp. 1
Paralactaga sp. 2
Dipus sp. nov.
Cardiocranius sp.
Cricetidae
Kowalskia sp.
cf. *Sinocricetus* sp.
Sinocricetus sp.
Microtoscoptes sp.
cf. *Microcricetus* sp.
Anatolomys sp.
Cricetidae indet.
Siphneidae
Prosiphneus sp.
Lagomorpha
Ochotonidae
Ochotona cf. *O. lagreli*

Baogedawula
Insectivora
Soricidae
Parasoriculus sp.
Erinaceidae
Erinaceidae indet. 1
Erinaceidae indet. 2
Rodentia
Gliridae
Gliridae indet.
Zapodidae
Lophocricetus cf. *L. gansus*
Dipodidae
Paralactaga sp.
Dipus sp. nov.
Cricetidae
Kowalskia sp.
Nannocricetus sp.
Sinocricetus sp.
cf. *Sinocricetus* sp.
Microtoscoptes sp.
Cricetidae indet.
"Rhizomyidae"
Pararhizomys sp.
Muridae
Hansdebruijnia perpusilla
Gerbillidae
Abudhabia sp.
Siphneidae
Prosiphneus sp.
Lagomorpha
Leporidae
Alilepus sp.
Ochotonidae
Ochotona cf. *O. lagreli*
Carnivora
Hyaenidae
Hyaenictitherium hyaenoides
Perissodactyla
Equidae
Hipparion sp.
Artiodactyla
Giraffidae
Palaeotragus sp.