Chapter 21

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Chapter 21

Oligocene/Miocene Beds and Faunas from Tieersihabahe in the Northern Junggar Basin of Xinjiang

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ABSTRACT

A mid-Tertiary rock sequence at the Tieersihabahe locality from the Ulungur River area in the northern Junggar Basin, Xinjiang Province, China, is described. The study introduces three late Oligocene/Early Miocene faunas from the continuous section of the ''Ulunguhe'' and Suosuoquan formations within the sequence, and discusses the age determination, faunal correlation, and existing problems concerning the formations and faunas. The ''Ulunguhe'' fauna at the Tieersihabahe locality is late Oligocene in age, correlative to the Taben Buluk fauna. The 99005 fauna is probably Oligocene–Miocene transitional. The Suosuoquan fauna is regarded as early Miocene, so the Oligocene/Miocene boundary would be contained in the continuous section at the Tieersihabahe section.

INTRODUCTION

Since Bohlin (1937, 1942, 1946) first reported late Oligocene faunas from the Shargaltein Gol and Taben Buluk areas of Gansu Province, China, other late Oligocene faunas have come to light in China only in recent decades. These are the Yikebulage (Wang et al., 1981), late Taoshuyuanzi (Zhai, 1978), Saint Jacques (Wang et al., 1981), and Xiagou faunas (Qiu et al., 1997; Wang and Qiu, 2000). Early Miocene faunas are relatively newly known in China. The Xiejia fauna, the first named early Miocene fauna of China, was reported 20 years ago (Li and Qiu, 1980) from Xining Basin, Qinghai Province. It has been considered to represent the earliest Miocene of China since its discovery, and is still regarded as the namesake of the earliest Miocene biochron (Höck et al., 1999; Qiu et al., 1999). Other early Miocene faunas reported more recently include the Lanzhou (Qiu and Gu, 1988), Jaozigou, Zhangjiaping (Qiu et al., 1990), and Wuertu faunas (Wang and Wang, 1989). A fauna from the Hongliugou Formation of Haiyuan County, Ningxia, is also considered to be early Miocene (Wang et al., 1994).

Of the late Oligocene and early Miocene faunas in China, the Suosuoquan fauna from the northern Junggar Basin of Xinjiang remains controversial in age determination. Some workers regarded the Suosuoquan fauna as Late Oligocene (Tong, 1989; Tong et al., 1990, 1995; Wang, 1997a, 1997b; Wu et al., 1998b), whereas others (Qiu and Qiu, 1990) correlated it, on the basis of occurrences of *Sinolagomys* and a brachyericine hedgehog, to the Lanzhou fauna and considered both faunas to represent the earliest Miocene of China. The Suosuoquan assemblage was later recorrelated to the Xiejia fauna and considered to be slightly younger than the earliest Miocene Lanzhou fauna (Qiu and Qiu, 1995). Additional specimens collected in the last two years led Qiu et al. (1999) to conclude that the Suosuoquan fauna is the representative local fauna of the earliest Miocene in China.

In studying late Oligocene and early Mio-

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cene faunas, considerable attention has focused on pinning down the Oligocene/Miocene boundary in the terrestrial Tertiary of China. In this regard, much progress has been made in the Lanzhou area during the last decade (Qiu et al., 1990, 1997; Flynn et al., 1999; Wang and Qiu, 2000). The continuous mid-Tertiary rock sequence in the Lanzhou area permits a comprehensive boundary stratigraphic study, whereas in other areas, such as Xining and Taben Buluk, a boundary study is relatively difficult owing to problems resulting from either isolated outcrops, complex geology, or poor stratigraphic control of sparse fossils. To the northwest of Lanzhou, promising sections containing the Oligocene/Miocene boundary have now been discovered from the northern Junggar Basin of Xinjiang. These provide an additional opportunity to tackle the boundary issue in a geographically interesting region.

Terrestrial sediments of the Mesozoic and Tertiary are widely distributed in northern Xinjiang, as first revealed by geological investigations conducted in the 1950s by a team from the Geological Survey of Xinjiang Province (Tong et al., 1990; Wei and Tong, 1992). Fossil mammals then collected from this area were fragmentary and were often associated with poor or no locality and stratigraphic data (e.g., Chow, 1957, 1958). During the last three decades more extensive geological and paleontological studies of the Tertiary in northern Xinjiang have been accomplished (Wu, 1973; Peng, 1975; Peng and Wu, 1983; Chen, 1988; Wu, 1988; Qi, 1989; Tong, 1989; Wang and Qi, 1989; Ye, 1989). However, our field experience continues to show that we are still at an early stage in understanding the geology, stratigraphy, and paleontology of northern Xinjiang.

Since 1995, we have been working in Xinjiang, primarily along the banks of the Ulungur River in the northern Junggar Basin (fig. 21.1). During this period of fieldwork, we have confirmed the presence of late Cretaceous, Eocene, Oligocene, and Miocene terrestrial deposits in this region. A large number of mammal fossils from several localities form the basis of a series of papers describing new fossils and rock sequences (Wang et al., 1998; Wu et al., 1998a, 1998b, 2000; Bi, 1999, 2000; Bi et al., 1999; Meng et al., 1999, 2001; Ye et al., 1999, 2000).

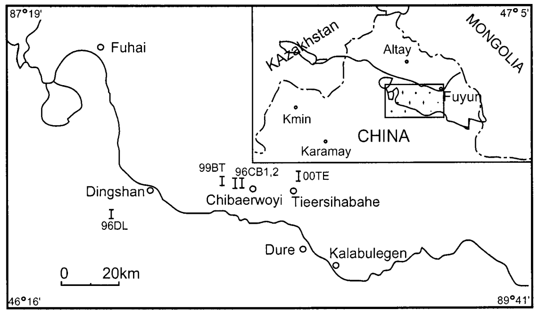

Fig. 21.1. Location map of localities and sections. Measured sections correspond to those illustrated in figure 21.3.

Here we present a preliminary biostratigraphic study of additional sections measured along the 15-km Tieersihabahe-Chibaerwoyi cliffs (TCC), with focus on rock units and faunas pertinent to the issue of the Oligocene–Miocene boundary.

The outcrops ranging from the late Oligocene to middle Miocene along the TCC are extensively exposed (fig. 21.2). This area was first explored in 1982 by a field team from the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Chinese Academy (Tong et al., 1987, 1990). It was previously believed that sediments along the TCC contain three units: the basal, late Cretaceous ‘‘Ulunguhe’’ Formation, the late Oligocene Suosuoquan Formation, and the middle Miocene Halamagai Formation, separated one from another by disconformities. Our field investigations provide persuasive fossil evidence for the age determination of these rock units and show that the previous age determination of the ‘‘Ulunguhe’’ Formation is incorrect and that the Suosuoquan Formation ranges probably from earliest Miocene to early middle Miocene.

In this study, we introduce the early Miocene Suosuoquan and late Oligocene ‘‘Ulunguhe’’ formations by providing a description of the sequence at the Tieersihabahe locality, brief histories of study, and persisting problems for these rock units. We compile three faunal lists for the two rock units, including the late Oligocene Tieersihabahe fauna, ?late Oligocene/earliest Miocene fauna from locality 99005, and early Miocene Suosuoquan fauna. We discuss the related biostratigraphic

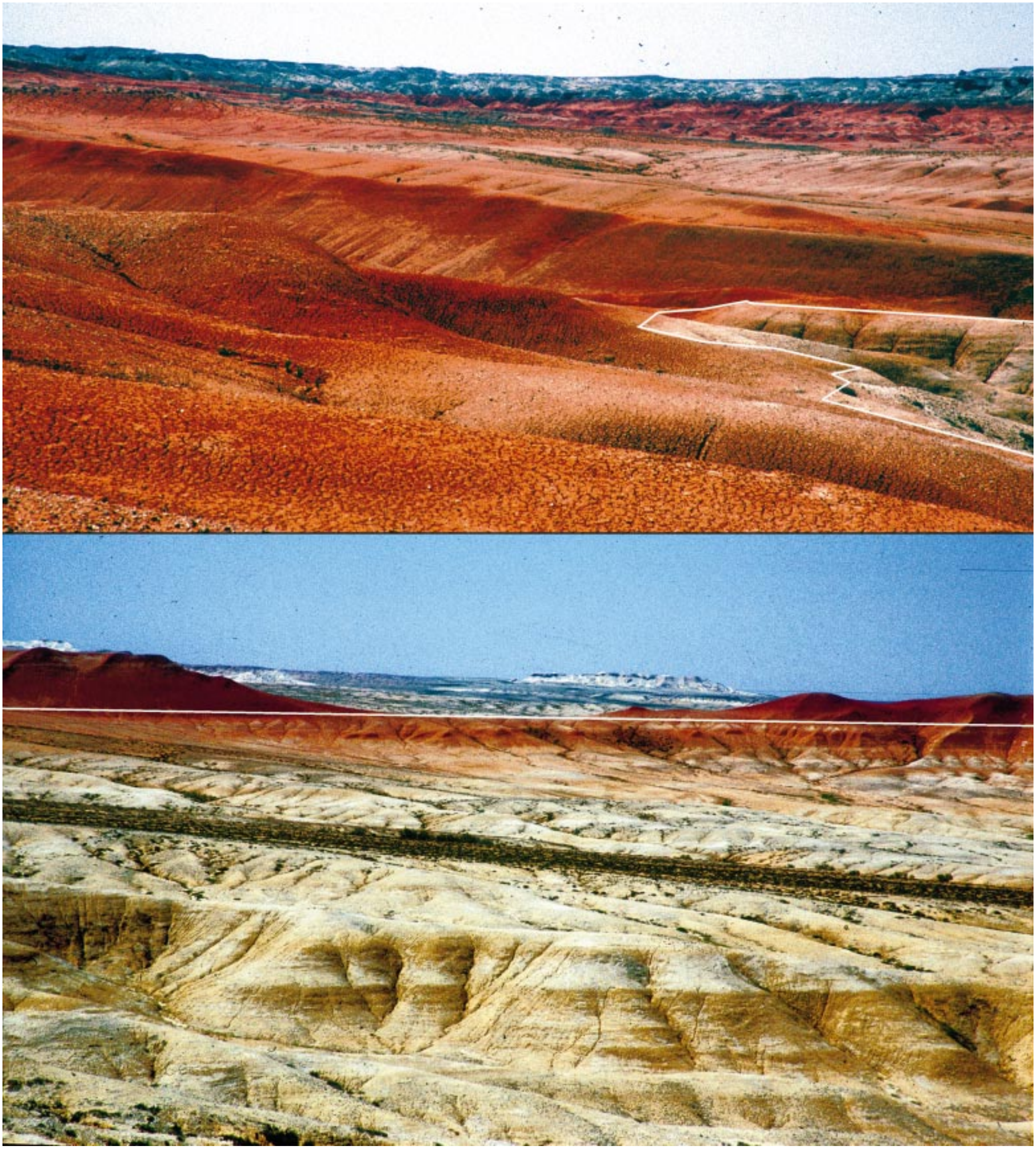

Fig. 21.2. Views of the TCC cliffs at the Tieersihabahe locality. The white line in top and bottom photographs indicates the lithological boundary between the ''Ulunguhe'' Formation (lower, light-colored beds) and the Suosuoquan Formation (red beds). The lithological boundary is tentatively considered as the Oligocene/Miocene boundary. The light-colored beds overlying the Suosuoquan red beds in the top photograph are the middle Miocene Halamagai Formation. Note the gradual change of color from the ''Ulunguhe'' beds to the Suosuoquan beds.

issues that are relevant to the faunas and the Oligocene/Miocene boundary.

ROCK SEQUENCE AT TIEERSIHABAHE

Figure 21.3 displays four stratigraphic sections measured along the TCC on the north bank of the Ulungur River and one from the Duolebulejin on the south bank of the river. The description of the sections from the Duolebulejin was given in Ye et al. (2000). Parts of the sequence from the Tieersihabahe were also reported in that paper. In the 2000 sea-

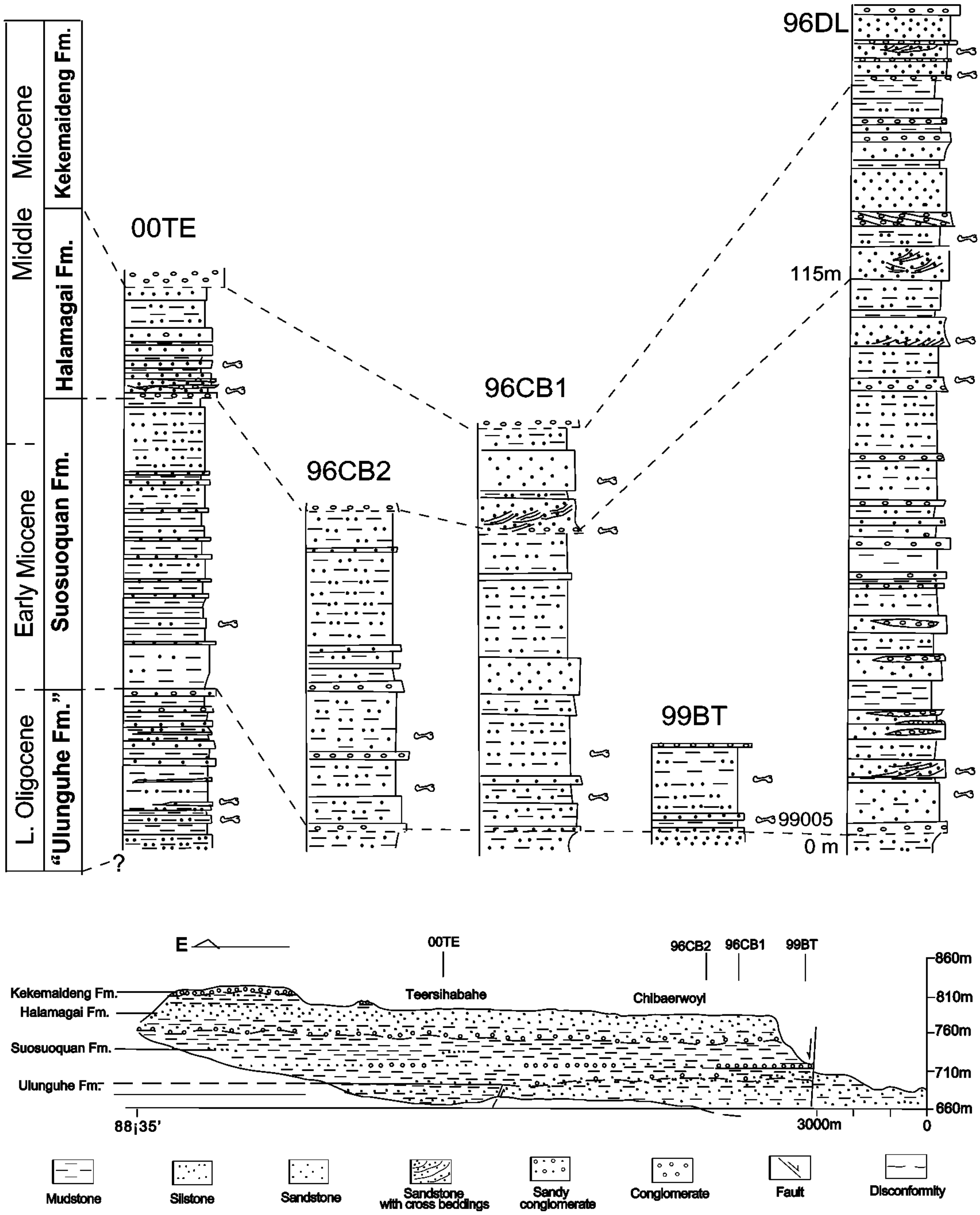

Fig. 21.3. Measured sections from the Tieersihabahe-Chibaerwoyi cliffs (TCC) in the northern Junggar Basin, showing the lithology, formation boundaries, occurrences of fossils, and thickness in meters. The sequence at the Tieersihabahe locality (00TE) is described in the text. Section 96DL is from the Duolebulejin area on the south bank of the Ulungur River (fig. 21.1), and other sections are drawn to the same scale.

son, we made a more detailed measurement of the entire sequence at the Tieersihabahe in the hope that this may help to provide a starting point to address the issue of the Oligocene/Miocene boundary in the region. Although our focus is on the Suosuoquan Formation and the ''Ulunguhe'' Formation, which we believe encompass the Oligocene/Miocene boundary, we nonetheless present the description of the complete sequence in table 21.1. Good badland exposures make the main rock units at the TCC traceable in the field; their lateral extension and superpositional relationships are clear.

SUOSUOQUAN FORMATION

The Suosuoquan Formation, the most distinctive Tertiary rock unit in Northern Xinjiang, is characterized by a set of reddish sandy mudstones that varies little in lithology over a large area. The formation was originally called the Suosuoquan series by geological mapping team 631 from the Xinjiang Geological Survey (Peng, 1975; Tong et al., 1987, 1990; Wu et al., 1998b) and has been universally accepted since its proposal. Sediments of the Suosuoquan Formation and its fauna have been found as far north as the Jimunai area, near the border with Kazakhstan, in Xinjiang. The best exposure of this formation is concentrated in the Ulungur River region (fig. 21.1). The thickest deposits of the Suosuoquan Formation are exposed in the Duolebulejin area on the south bank of the Ulungur River, and measure up to 115 m thick. In this area, sediments of the Suosuoquan Formation are coarser than those found on the northern bank of the river. The top beds of the Suosuoquan Formation in Duolebulejin embrace two layers of grayish green sandstone (Wu et al., 1998b; Ye et al., 2000). These sandstones are lithologically similar to the overlying Halamagai Formation and yield fossils common to the middle Miocene Halamagai fauna (Wu et al., 1998b). In addition, there is no indication of significant sedimentary hiatus between the two formations. Therefore, we consider that the Suosuoquan Formation in the Duolebulejin region is continuous with the overlying Halamagai Formation and that the latest deposits of the Suosuoquan Formation are early middle Miocene in age.

At the TCC, however, the Suosuoquan Formation is 60 to 70 m thick. Not only is the sandstone seen at the top of the Suosuoquan Formation in the Duolebulejin area absent, but there is also an erosion surface on top of the formation. Moreover, basal conglomerates occur at the bottom of the Halamagai Formation, suggesting a disconformity between the two formations in the TCC. Erosion of the uppermost Suosuoquan sediments before deposition of the middle Miocene Halamagai Formation is probably a factor in the difference in rock thickness of various areas.

Geological investigations in 1958 recorded contacts of the Suosuoquan Formation with the underlying ''Ulunguhe'' Formation in conformity, disconformity, or unconformity from place to place (Peng, 1975). Our field investigations reveal that the Suosuoquan Formation rests unconformably on the Paleozoic basement in the Jimunai area, conformably on late Oligocene beds at the Tieersihabahe area, and probably disconformably on Eocene or Oligocene beds in the Halamagai area (see below). In the area we investigated, the only place where the Suosuoquan Formation possibly lies on Mesozoic beds is at the northern bank of the Ulungur River about 2 km north of Kalabulegen village. However, although the red beds exposed in this area are lithologically similar to and previously considered as the Suosuoquan Formation (Tong et al., 1990), no field parties have found any fossil confirming the age assessment of those red beds.

In several localities from Jimunai to the Ulungur River, fossils typical of the Suosuoquan fauna occur in the lower part of the formation at roughly the same distance from the base of the formation. Possibly the basal surface of the Suosuoquan Formation, although overlying rocks of different ages, represents a roughly equal chronological plane. Although the Suosuoquan fossils are distributed over a wide area, the richest concentration, in terms of number of species and specimens, is in the Chibaerwoyi locality of the TCC. In the TCC area, three beds containing vertebrate fossils have been discovered from the lower part of the Suosuoquan Formation,

TABLE 21.1

Complete Sequence of Section at the Tieersihabahe

	—— End point of the Tieersihabahe section: 46°39.434′N, 88°28.745′E ——	
	KEKEMAIDENG FORMATION	
55.	Earthy yellow fluvial sands and conglomerates	3.5 m
	—— Disconformity ——	
	HALAMAGAI FORMATION	
54.	Grayish white fine sandstone; local calcareous cement	3.0 m
53.	Grayish green muddy siltstone	5.5 m
52.	Grayish yellow coarse sandstone containing fine gravel	2.4 m
51.	Grayish green muddy siltstone	0.9 m
50.	Grayish white sandstone with calcareous cement at bottom	2.1 m
49.	Earthy yellow sandy mudstone; gray-green on weathered surface	1.1 m
48.	Light grayish green medium-grained (quartzarenite) sandstone with mammal fossils	2.5 m
47.	Grayish green sandy mudstone with rusty yellow nodules	0.8 m
46.	Grayish green sandy gravel with layers of sandstone; contains mammal fossils	5.1 m
	—— Disconformity ——	
	SUOSUOQUAN FORMATION	
45.	Dense, brownish red mudstone, dense without bedding structures; capped with a 40-cm layer of earthy yellow mudstone	2.1 m
44.	Reddish brown mudstone with quartz gravel, grades upward to siltstone	12.7 m
43.	Reddish brown muddy sandstone and coarse sandstone interbedded with mudstone	3.8 m
42.	Brownish red mudstone, grading upward to siltstone	4.5 m
41.	Yellowish brown muddy coarse sandstone, with fine gravel	1.0 m
40.	Brownish red mudstone	1.0 m
39.	Brownish red sandy mudstone	1.0 m
38.	Brownish red siltstone with quartz chips	3.0 m
37.	Reddish brown muddy coarse sandstone	0.7 m
36.	Brownish red mudstone	2.8 m
35.	Brownish coarse sandstone with fine gravel	1.0 m
34.	Reddish brown mudstone with quartz chips, grades upward to siltstone	4.7 m
33.	Yellowish brown muddy coarse sandstone with gravel	0.8 m
32.	Reddish brown mudstone	1.0 m
31.	Brownish coarse sandstone with fine gravel	1.0 m
30.	Reddish brown mudstone	2.5 m
29.	Reddish brown sandy mudstone with quartz chips	3.0 m
28.	Reddish brown silt mudstone	1.5 m
27.	Reddish brown muddy siltstone with scattered fine gravel, mammal fossils	1.5 m
26.	Reddish brown sandy mudstone	3.0 m
25.	Reddish brown mud-sand gravel	0.5 m
24.	Reddish brown dense mudstone with quartz gravel	9.0 m
	—— Conformable contact ——	
	"TIEERSIHABAHE" FORMATION	
23.	Brown muddy sandstone or coarse sandstone with fine gravel	0.8 m
22.	Brown dense mudstone without bedding	4.2 m
21.	Earthy yellow muddy coarse sandstone with gravel	1.4 m
20.	Brown dense mudstone without bedding	0.7 m
19.	Earthy yellow muddy sandstone with fine gravel	0.6 m
18.	Yellowish brown mudstone, dense, no bedding, with quartz chips	1.3 m
17.	Yellowish brown coarse sandstone with gravel	2.4 m
16.	Yellowish brown mudstone locally containing light red nodules of mudstone	1.6 m
15.	Yellowish brown coarse sandstone, with gravel and thin lenses of mudstone	2.4 m
14.	Light yellowish brown dense mudstone with quartz chips	0.8 m
13.	Yellowish brown muddy coarse sandstone and mudstone fragments	0.4 m
12.	Yellowish brown mudstone with quartz chips and thin sandstone	1.5 m
11.	Earthy yellow sandstone with fine gravel	0.85 m
10.	Yellowish brown dense mudstone	0.45 m
09.	Earthy sandstone with fine gravel; weathered surface grayish white	0.5 m
08.	Yellowish brown dense mudstone	0.8 m
07.	Same as unit 9	0.6 m
06.	Same as unit 8	1.3 m
05.	Earthy yellow siltstone, grading upward to fine sandstone; mammal fossils	3.0 m
04.	Dark grayish green calcareous mudstone	0.6 m
03.	Earthy yellow siltstone, with mammal fossils	0.9 m
02.	Same as unit 4	3.0 m
01.	Earthy yellow siltstone, locally containing rusty yellow nodules	1.5 m
	(base not exposed)	
	—— Starting point of the Tieersihabahe section: 46°40.422′N, 88°28.259′E ——	

at 4, 7–12, and 14–21 m from the base of the formation. The upper two levels are separated from each other by a meter of coarse sandstone. Fossils from the two levels are basically the same, and are lumped into one assemblage, named the Suosuoquan Fauna.

The lowest fossil assemblage in the Suosuoquan Formation was found at site 99005, a few kilometers west of the Chibaerwoyi main locality. As shown below, the composition of this assemblage is different from that of the overlying Suosuoquan fauna; it probably represents a distinct, earlier assemblage. Being in an early stage of study, we do not name this fauna here, but simply refer to it by its locality in number.

The age determination of the Suosuoquan Formation was based primarily on faunal correlation and has been unstable without new fossils available. It was considered either middle Miocene or early Miocene (Peng, 1975; Tong et al., 1990) or late Oligocene (Tong et al., 1987, 1990). It was also regarded as ranging from late Oligocene to early middle Miocene (Wu et al., 1998b) or from earliest Miocene to middle Miocene (Ye et al., 2000); the latter view gains further support from the discovery of the 99005 fauna (see below).

‘‘ULUNGUHE’’ FORMATION

The ‘‘Ulunguhe’’ (Ulungu-he meaning Ulungur-River) Formation is a set of light-colored fluvial sediments that underlie the Suosuoquan Formation in northern Xinjiang. Its definition and age remain most controversial. To reflect the uncertainty, we place the name in quotation marks throughout the text.

The ‘‘Ulunguhe’’ Formation is derived from the ‘‘Ulunguhe’’ series first used by the 631 mapping team in the 1950s (Tong et al., 1987, 1990; Wei and Tong, 1992). The type locality and section of the formation were not originally specified, but were later assumed to be in the Ulunguhe area and were most likely located near the Halamagai village (Tong et al., 1987, 1990). The age of the formation was believed to be Oligocene in early studies (Tian et al., 1959, and Jiang, 1959, in Tong et al., 1990) or Eocene and Oligocene collectively (Peng, 1975). Vertebrate fossils, including *Amia* and *Lophialetes* cf. *expeditus* (Peng, 1975), support an Eocene/Oligocene age. However, Wu (1973) reported dinosaur specimens of *Yaxartosaurus* from the ‘‘Ulunguhe’’ Formation at a locality 2 km north of Kalabulegen village, and suggested Cretaceous age of the ‘‘Ulunguhe’’ Formation at that locality. With the discovery of the dinosaur, Peng (1975) then pointed out two possibilities concerning the nature of the ‘‘Ulunguhe’’ Formation at the Kalabulegen locality: (1) the beds yielding the dinosaur specimens are late Cretaceous Ailike Formation, or (2) some dinosaurs survived into the early Tertiary. Peng (1975) was convinced by his field observation that the sediments in question were the ‘‘Ulunguhe’’ Formation and did not rule out possibility 2.

Additional reptile fossils were collected in 1982 from Kalabulegen, including *Tyrannosaurus* sp., Coelurosauria indet., *Yaxartosaurus* sp., and *Bactrosaurus* sp. (identified by Zhao Xijing in Tong et al., 1987, 1990). Based on these fossils, the late Cretaceous age of the sediments at Kalabulegen was again corroborated. Tong et al. (1987, 1990) believed that the lithology and sequence of the Kalabulegen ‘‘Ulunguhe’’ Formation were similar to those of the ‘‘Ulunguhe’’ Formation at the presumed type locality Halamagai; therefore, they considered the age of ‘‘Ulunguhe’’ Formation there to be late Cretaceous as well. Accordingly, Tong et al. (1987, 1990) regarded the light-colored sediments underlying the Suosuoquan Formation at the TCC as late Cretaceous ‘‘Ulunguhe’’ Formation. Nonetheless, Tong et al. restricted the late Cretaceous ‘‘Ulunguhe’’ Formation to those exposures in the Ulunguhe area and were unsure about the age of ‘‘Ulunguhe’’ Formation in other areas.

Our fieldwork indicates that the nature of ‘‘Ulunguhe’’ Formation is much more complex than previously thought. Although further investigation is needed to clarify the controversies surrounding the ‘‘Ulunguhe’’ Formation, we offer the following observations from our field investigations.

First, we found fragmentary dinosaur and other reptilian specimens in the light-colored beds at the Kalabulegen locality, confirming the dinosaur report of Wu (1973) and Tong (1989) and Tong et al. (1990). These sediments rest on the dark-colored Paleozoic basement that is exposed along riverbanks, and are overlain by reddish sandy mudstone currently believed to be the Suosuoquan Formation. However, because no fossil has been found from the red beds, the age of the red beds is uncertain. In addition, there is no exposure that shows the contact relationship between the two rock units. Therefore, there is no sufficient evidence to establish the stratigraphic correlation between the sediments subjacent to the Suosuoquan Formation at Kalabulegen and other areas.

Second, during field seasons of 1998–2000, we discovered a new fauna in the presumed ‘‘Ulunguhe’’ Formation that conformably underlies the Suosuoquan Formation at Tieersihabahe locality. The fossils are found 22.6 m below the Ulunguhe/Suosuoquan boundary. We have identified about 30 species from 7 mammalian orders. This new fauna demonstrates that the light-colored sediments under the Suosuoquan Formation at Tieersihabahe are not late Cretaceous in age, contra Tong et al. (1987, 1990), but are late Oligocene (see below). Through the rock sequence from bottom up, sediments change from dark grayish, greenish mudstone at the lowest part, to yellowish and brownish, and then to the red beds of the Suosuoquan Formation (fig. 21.2). It is clear that the late Oligocene beds at Tieersihabahe are continuous with the overlying Suosuoquan Formation. These beds have rhythmically repeating units that contain rounded gravels, primarily of quartz. The dinosaur-yielding beds at Kalabulegen lack the rhythmical structure and contain particles that are little rounded and are of complex origins. Although the beds under the reddish sediments of the Suosuoquan Formation are generally recognized by their ‘‘light’’ color, they are lithologically different in sedimentary structure and composition. Therefore, we believe that the beds underlying the Suosuoquan Formation at Tieersihabahe represent a different rock unit from that yielding dinosaurs at Kalabulegen, although both units are currently called ‘‘Ulunguhe’’ Formation.

Third, we have found specimens of a primitive ctenodactyloid rodent, *Advenimus*, from the light-colored sediments under the Suosuoquan Formation near Halamagai village. These sediments were also regarded as ‘‘Ulunguhe’’ Formation and probably are included in the type section, according to Tong et al. (1987, 1990). The rodent fossils suggest an age of late early Eocene. Sediments yielding the rodent fossils are similar to those in the Tieersihabahe locality, but are more greenish in color and contain coarser conglomerates. We consider that these beds probably underlie those at Tieersihabahe.

To sum up, relationships of the ‘‘Ulunguhe’’ Formation at Halamagai, Kalabulegen, and Tieersihabahe are unclear. Our current understanding is that the name ‘‘Ulunguhe’’ Formation has been applied to different rock units in northern Xinjiang. These rock units, although all light in color, differ in their sedimentary structure and composition as well as in fossil content. It appears that the conventional view that the ‘‘Ulunguhe’’ Formation encompasses Eocene and Oligocene beds (Peng, 1975) remains sound, although further division of these beds is possible. The light sediments yielding dinosaurs at the Kalabulegen locality should not be considered as ‘‘Ulunguhe’’ Formation, but may represent a new rock unit. For this study, we will focus on the section at Tieersihabahe and refer to its sediments containing the late Oligocene fauna as ‘‘Ulunguhe’’ Formation.

THE TIEERSIHABAHE FAUNA

Fossils were discovered from the ‘‘Ulunguhe’’ Formation underlying the Suosuoquan Formation at the north foot of the cliffs called Tieersihabahe. As mentioned above, these beds were previously considered to be late Cretaceous ‘‘Ulunguhe’’ Formation until the discovery of the late Oligocene fauna at site 98023 (46°40′ N, 88°28′ E) in 1998. Surface collecting at several sites of the same horizon and screenwashing of sediments at sites 98023, 98024, and 98035 in 1998–2000 seasons generated numerous specimens, primarily of small mammals. On the basis of these fossils, we name the Tieersihabahe fauna after the local name of the cliffs. While additional concentrate of washed sediment is being sorted, in table 21.2 we list the taxa currently identified.

Tieersihabahe fauna shares the following species with the late Oligocene Taben Buluk

TABLE 21.2
Taxa Currently Identified in the Tieersihabahe Fauna

Insectivora
Erinaceidae
Amphechinus kansuensis
A. minimus
A. cf. *A. rectus*
Talpidae gen. et sp indet.
Heterosoricinae gen. et sp. indet.
Crocidosoricinae gen. et sp. indet.
Chiroptera family unidentified
Lagomorpha
Ochotonidae
Sinolagomys major
S. kansuensis (and *S. gracilis*?)
Desmatolagus sp. (*D. shargaltensis*?)
D. gobiensis
Desmatolagus sp. nov. (larger than *D. robustus*)
Rodentia
Sciuridae
Eutamias sp.
Sciuridae gen. et sp. indet.
Aplodontidae
Ansomyinae gen. et sp. nov. (fig. 21.4a, b)
Cricetidae
Eucricetodon sp. nov. (fig. 21.4d, e)
Eomyidae
Pseudotheridomys asiaticus (fig. 21.4f)
Dipodidae
Parasminthus tangingoli
P. asiaecentralis
Bohlinosminthus parvulus
Plesiosminthus sp. nov. (fig. 21.4g)
Litodonomys sp. (fig. 21.4c)
Tachyoryctoidinae
Tachyoryctoides obrutschewi
Myoxidae
Vasseuromys (= *Glirulus* sp., Wu et al., 2000)
Ctenodactylidae
Yindirtemys cf. *Y. deflexus*
Y. ambiguus
Artiodactyla
Cervoidea
Eumeryx sp. (large)
Eumeryx sp. (small)
Bovidae gen. et sp. indet.
Perissodactyla
Hyracodontidae
Indricotherium sp.
Leptictida
Didymoconidae
Didymoconus sp.

and Shargaltein Gol faunas: *Amphechinus kansuensis*, *A. minimus*, *A.* cf. *A. rectus*, *Sinolagomys major*, *S. kansuensis* (probably *S. gracilis* as well), *Desmatolagus gobiensis*, *D.* sp. (possibly *D. shargaltensis*), *Parasminthus tangingoli*, *P. asiae-centralis*, *Bohlinosminthus parvulus*, *Tachyoryctoides obrutschewi*, *Yindirtemys ambiguus*, *Eumeryx* sp., and *Didymoconus* sp. *Pseudotheridomys asiaticus* found in Tieersihabahe (fig. 21.4f) was originally based on specimens from the late Oligocene Saint Jacques locality, Nei Mongol (Inner Mongolia; Wang and Emry, 1991). *Yindirtemys deflexus* commonly occurs in the late Oligocene of China (Wang, 1997a), and is larger than *Yindirtemys* cf. *Y. deflexus* from Tieersihabahe.

There are many aplodontid specimens that certainly represent a new, primitive species of the subfamily Ansomyinae Qiu, 1987. The lower m1 of this new taxon is comparable to that of *Ansomys shantungensis* (?*Prosciurus shantungensis* Rensberger and Li, 1986; see Qiu, 1987) known from only an m1 from the late Oligocene Shahejie Formation at Dongying of Shandong. The cheek teeth of our specimens have a lower degree of lophodonty than the middle Miocene species of *Ansomys* from Xiacaowan, Shanwang, and Tunggur areas (Qiu, 1987, 1996; Qiu and Sun, 1988). In addition, the mesostyle is not fully crested to close the trigon basin on the labial side of upper cheek teeth (fig. 21.4a, b).

The specimens of *Eucricetodon* also represent a new species that differs from known species of the genus from Europe and Asia. *Parasminthus tangingoli*, *P. asiae-centralis*, and *Bohlinosminthus parvulus* of the Dipodidae are also reported from the Xiagou fauna from the lower member of the Xianshuihe Formation, Lanzhou Basin (Wang and Qiu, 2000). *Litodonomys* sp. (fig. 21.4c) is similar to *Litodonomys huangheensis* (Wang and Qiu, 2000) from Xiagou, but much larger and with more developed mesolophid. *Plesiosminthus* sp. (fig. 21.4g) from Tieersihabahe shows some features typical of the genus, such as grooved upper incisor, upper molar with three roots, and the metaloph of upper molars connecting with the hypocone. *Plesiosminthus* was previously considered a European genus (Hugueney and Vianey-

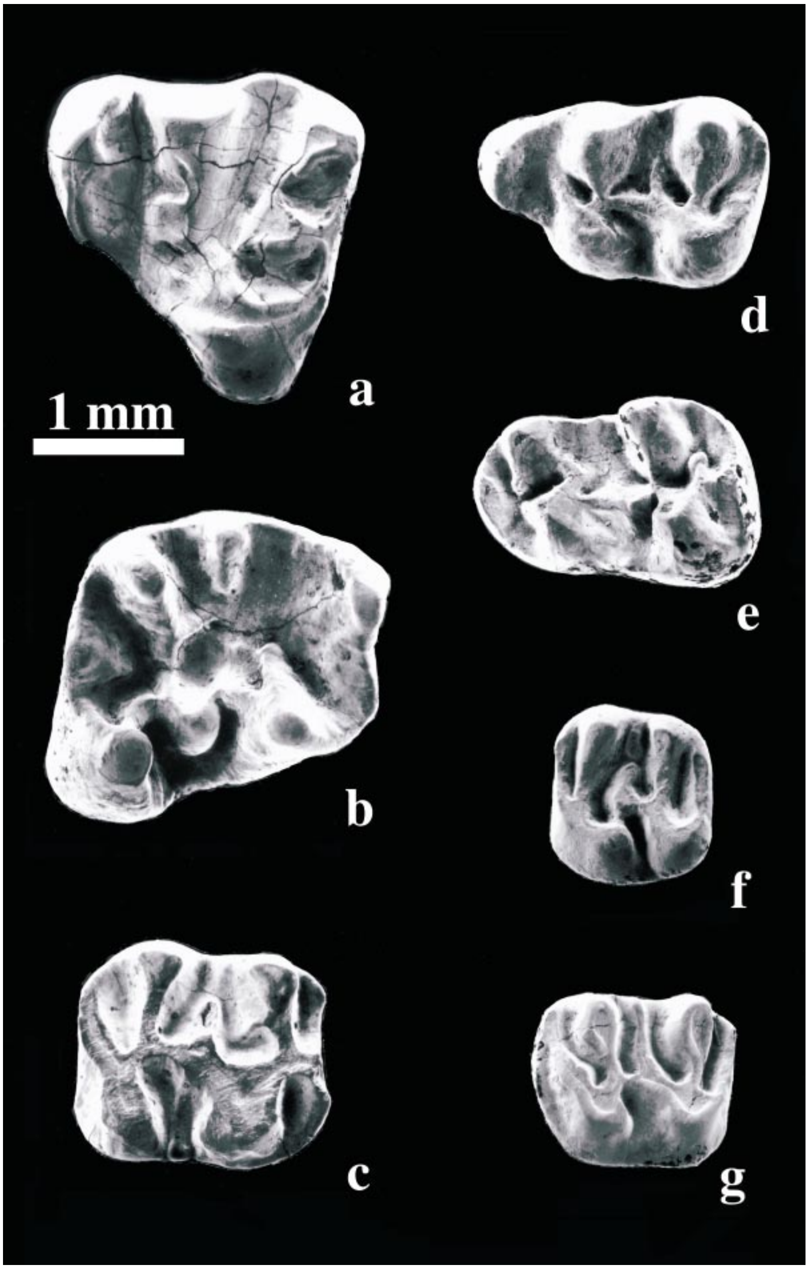

Fig. 21.4. **a, b,** Left P4 and right m1 of Ansomyinae gen. et sp. nov. **c,** Right m2 of *Litodonomys* sp. **d, e,** Left M1 and right m1 of *Eucricetodon* sp. nov. **f,** Left M1(or M2) of *Pseudotheridomys asiaticus*. **g,** Left M1 of *Plesiosminthus* sp. All specimens come from the Tieersihabahe fauna.

Liaud, 1980). Among the known species, the Tieersihabahe specimens are more similar to the European *P. myarion* and *P. promyarion* in morphology and size. Other specimens of *Plesiosminthus* reported from Biozone D of the Loh Formation of Mongolia (Höck et al., 1999) and from the Aral Formation of the Altynshokysu locality (Lopatin, 1999) further indicate the presence of this taxon in the late Oligocene and early Miocene of Asia.

Didymoconus, *Eumeryx*, and *Indricotherium* from the Tieersihabahe fauna are common taxa in the Oligocene of Asia (Russell and Zhai, 1987; McKenna and Bell, 1997). Based on the composition of fossils, it is convincing that the Tieersihabahe fauna is most closely correlative to the Taben Buluk fauna. The Tabenbulukian land mammal age of China has been correlated to late Oligocene European Chattian and North American Arikareean (Qiu and Qiu, 1995; Tong et al., 1995; Lucas et al., 1998). Therefore, by faunal correlation, we consider the Tieersihabahe fauna late Oligocene in age, noting that most of the Chinese land mammal ages need to be calibrated by dating methods independent of mammal evolution.

Höck et al. (1999) have conducted a multidisciplinary analysis of the lithology, biostratigraphy, and chronology of the Tertiary beds in the Valley of Lakes, Mongolia. Their biostratigraphic research, based primarily on rodents, has resulted in recognition of seven biozones (A, B, C, C1, D, D1, E) within the Hsanda Gol and Loh formations in the studied area. Höck et al. were able to correlate biozones C and C1 of the Hsanda Gol and Loh formations with the Taben Buluk fauna of China. Because the Tieersihabahe fauna is also correlative to Taben Buluk, as we show above, we consider that the Tieersihabahe is correlative to biozones C and C1 from Mongolia. With dating data of the basalt from the Mongolian sequence (Höck et al., 1999), the age of the beds containing the Tieersihabahe fauna is estimated to range from 28 to 24 Ma.

The fauna from the Aral Formation of Kazakhstan has attracted great attention recently (Lopatin, 1994a, 1994b, 1995, 1996, 1999, 2000; Lucas et al., 1998), but its age remains controversial. It is considered early Miocene or late Oligocene (Lopatin, 1996; see Lucas et al., 1998, for a review). At this stage of research, we defer comparison of these faunas until further work is accomplished in both areas.

THE FAUNA AT SITE 99005

Site 99005 is found about 4 m above the base of the Suosuoquan Formation, west of the Chibaerwoyi area and northeast of Botamoyin (fig. 21.1). Numerous skeletal fragments and isolated teeth of small mammals are found in lenses of sands in the red beds of the Suosuoquan Formation by surface collecting and screenwashing. Taxa represented by specimens obtained so far are listed in table 21.3.

TABLE 21.3
Taxa Currently Identified in the Fauna at Site 99005

Insectivora
Erinaceidae
Amphechinus sp.
Lagomorpha
Ochotonidae
Sinolagomys cf. *S. kansuensis*
Rodentia
Dipodidae
Plesiosminthus sp.
Litodonomys sp. (large)
Litodonomys sp. (small)
Heterosminthus sp. (large, fig. 21.5f, g)
Heterosminthus sp. (small, fig. 21.5h, i)
Eomyidae
Pseudotheridomys sp.
Cricetidae
Democricetodon sp. (fig. 21.5d, e)
Tachyoryctoidinae gen. et sp. nov.
Sciuridae
Sciuridae gen. et sp. A
Sciuridae gen. et sp. B
Carnivora
Palaeogale sp.

Sinolagomys cf. *S. kansuensis* is common in the 99005 fauna. *Pseudotheridomys* and *Plesiosminthus* from Tieersihabahe persist in the 99005 fauna. Although *Litodonomys* and *Heterosminthus* are also present in the Taben Buluk and Xiagou faunas (Wang and Qiu, 2000), the species from site 99005 are further diversified and are more derived than those of the Xiagou fauna. There are two species of *Heterosminthus* from site 99005 (fig. 21.5f, i), of which the large species is larger than *H. lanzhouensis* from Xiagou, whereas the small species is smaller than *H. lanzhouensis*. In both species from site 99005, the posterior cingulum on M1 is fully developed and cheek teeth are narrower but longer than those of *H. lanzhouensis*, suggesting a higher degree of specialization. There are

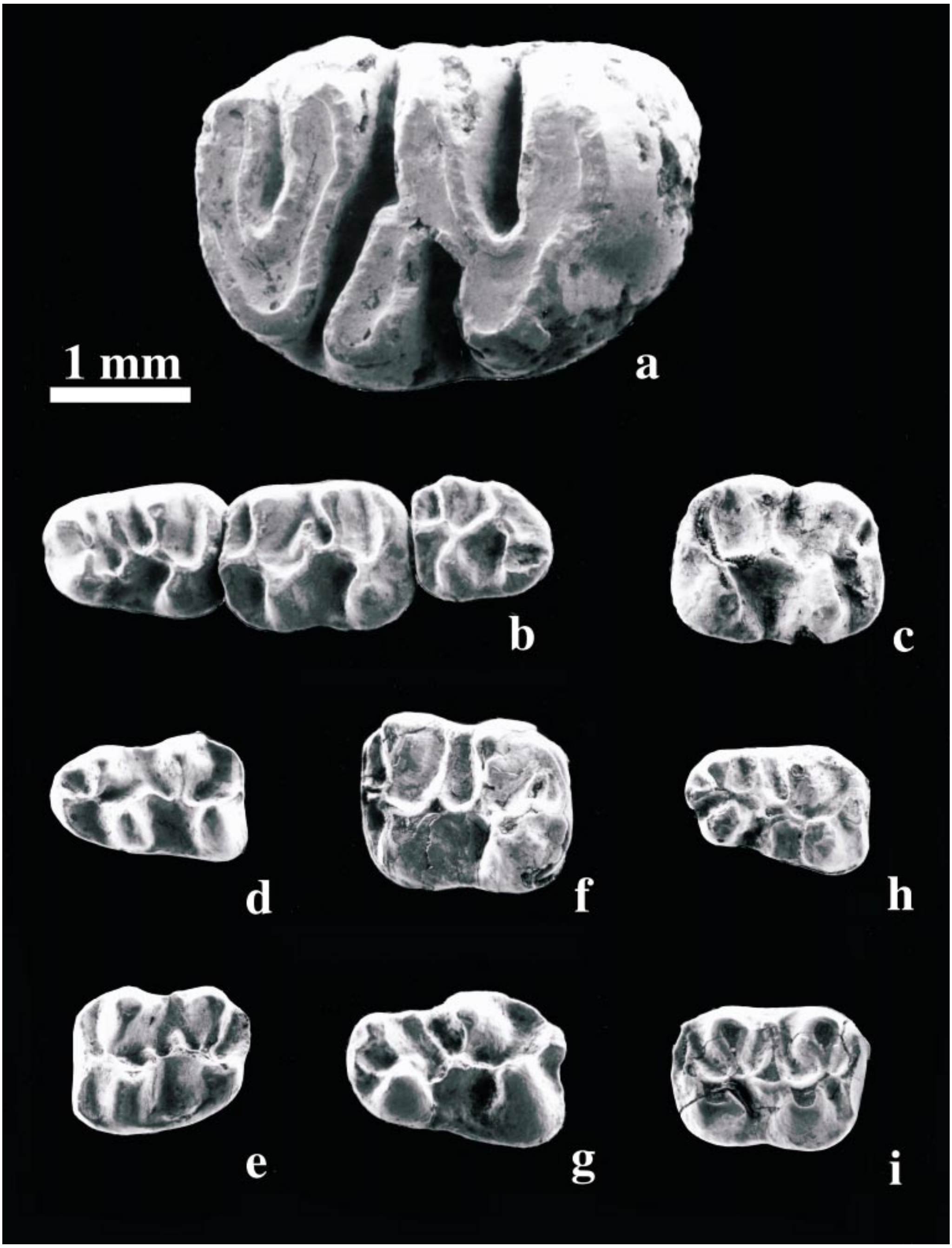

Fig. 21.5. **a,** Right M1 of Tachyoryctoidinae gen. et sp. nov. **b,** Left m1–3 of *Litodonomys* sp. nov. **c,** Left m2 of *Litodonomys* sp. (large species). **d, e,** Left m1 and left M2 of *Democricetodon* sp. **f, g,** Right M1 and left m1 of *Heterosminthus* sp. 1 (large species). **h, i,** Left m1 and left M1 of *Heterosminthus* sp. 2 (small species). **a** and **b** are from the Suosuoquan fauna; **c–i** are from the 99005 fauna.

also two species of *Litodonomys* from the 99005 fauna, which differ from *L. huanghensis* of Xiagou both in morphology and size (Wang and Qiu, 2000).

The earliest species of *Democricetodon* in Europe is MN4 in age (Kälin, 1999; Mein, 1999), a member of the first wave of modern cricetid immigrants from Asia to Europe (Fahlbusch, 1964) after the ''cricetid vacuum'' (Daams and Freudenthal, 1988). Specimens of this genus have been reported from the Oligocene–Miocene transition (Biozone D) and the early-middle Miocene (Biozone D1) in the Loh Formation of Mongolia, represented by M1 in both cases (Höck et al., 1999: figs. 21/4, /7). The specimen from Biozone D is by far the earliest record of *Democricetodon* in the world. Although lack of M1 in our collection prohibits comparison with the Mongolian material, the size and generally primitive morphology of cheek teeth from the 99005 fauna (fig. 21.5d, c) match the M1 from Biozone D of the Loh Formation.

Tachyoryctoides sp. from 99005 fauna is represented by an M1 and a broken m3. It is more derived than *T. obrutschewi* in being larger and having closely spaced lophs that define narrow valleys. The 99005 specimens are similar in size to *T. kokonorensis* from the Xiejia fauna, China, and from Biozone D of the Loh Formation, Mongolia (Höck et al., 1999), but limited material from these sites prevents further comparison.

In general, the species from the 99005 site at the Chibaerwoyi show a mixed late Oligocene and early Miocene assemblage. For those genera that are common in the late Oligocene, the 99005 species often display more derived conditions. We tentatively regard the Xiagou fauna to be younger than the Tieersihabahe but older than the 99005 fauna.

Democricetodon, Plesiosminthus, Heterosminthus, Tachyoryctoides, Litodonomys, and probably *Pseudotheridomys* are shared with the Hsanda Gol and Loh formations and the 99005 fauna is probably correlative to Biozone D of the Loh Formation in Mongolia. The lower stratigraphic position and faunal composition indicate that the 99005 fauna is slightly older than the Suosuoquan fauna. The age of the 99005 fauna could be either latest Oligocene, or earliest Miocene.

TABLE 21.4
Suosuoquan Taxa from the Tieersihabahe-Chibaerwoyi Cliffs

Insectivora
Erinaceidae
Amphechinus bohlini
A. cf. *A. minimus*
Metexallerix junggarensis
Lagomorpha
Ochotonidae
Sinolagomys ulungurensis
Rodentia
Sciuridae
Atlantoxerus sp.
Palaeosciurus sp.
Ctenodactylidae
Prodistylomys sp.
Tachyoryctoidinae gen. et sp. nov. (fig. 21.5a)
Cricetidae
Cricetodon sp. nov.
Dipodidae
Parasminthus sp. nov.
Litodonomys sp. nov. (fig. 21.5b)
Litodonomys spp. (A, B, C)
Carnivora
Palaeogale cf. *P. sectoria*
Perissodactyla
Rhinocerotidae
Aprotodon sp.
Artiodactyla
Cervidae gen. et sp. indet.

THE SUOSUOQUAN FAUNA

The Suosuoquan fauna was discovered in 1982, and most fossils were found mainly from site 82503 at Chibaerwoyi. However, most of the specimens collected in 1982 are stratigraphically poorly controlled. Our field investigations since 1996 recovered numerous new specimens, associated with precise occurrences in several sections. The list in table 21.4 includes material we collected from TCC.

The Suosuoquan Formation was originally estimated as Miocene in age based on presumed occurrence of *Gomphotherium* sp. (= *Serridentinus* sp., Peng, 1975) from the lower beds. Our field investigations, however, have never produced any specimens of *Gomphotherium*. All specimens of *Gomphotherium* that we know come from the middle Miocene Halamagai Formation. Because the locality presumably generating the *Gomphotherium* specimen cited by Peng was not identified, we cannot verify the occurrence, and it likely came from the overlying Halamagai Formation.

A good collection of mammals from the Suosuoquan Formation was made in 1982 by an IVPP field team. Based on those fossils, particularly *Sinolagomys ulungurensis* (Tong, 1989), *Prodistylomys xinjiangensis* (Wang and Qi, 1989), and *Tachyoryctoides* sp., Tong et al. (1990) correlated the Suosuoquan fauna with that of Taben Buluk (Bohlin, 1937, 1942, 1946). Nonetheless, these authors noticed that the species from the Suosuoquan fauna are more derived than those from Taben Buluk. Subsequently, the Suosuoquan fauna has been regarded as either late Oligocene (Tong et al., 1995; Wang, 1997a; Wu et al., 1998b), latest Oligocene (Wang, 1997b), earliest Miocene (Qiu et al., 1999; Ye et al., 2000), or early Miocene (Qiu and Qiu, 1995). With additional studies of Suosuoquan species in comparison to those from the new Tieersihabahe and 99005 faunas, the age estimate of the Suosuoquan fauna can be further updated.

In the Suosuoquan fauna, the lagomorph *Sinolagomys ulungurensis* (Tong, 1989) is the dominant species. This species is more derived than *S.* cf. *S. kansuensis* from the 99005 fauna in having a wider talonid, nearly the same width of the trigonid. *Metexallerix junggarensis* is more primitive than *M. gaolanshanensis* Qiu and Gu, 1988, from the Gaolanshan fauna of Lanzhou (Bi, 1999), suggesting that the Suosuoquan fauna is older than Gaolanshan (Qiu et al., 1999). *Amphechinus bohlini* Bi, 2000, is most comparable despite differences to *A. kansuensis* from Taben Buluk among known species of the genus.

The Tachyoryctoidinae gen. et sp. nov. differs significantly from late Oligocene *Tachyoryctoides obrutschewi*. It is smaller and more derived than the specimens of Tachyoryctoidinae from the 99005 fauna in having deeper valleys between more closely packed lophs.

Dipodids are further diversified. There is one species of *Parasminthus* that is notably larger than *P. asiae-centralis* and differs in morphology from the latter. Four species have been tentatively assigned to the genus *Litodonomys*. One of the four species is larger than *L. huangheensis* from the Xiagou fauna. On its cheek teeth the ectolophid extends more obliquely, the protoconid and hypoconid are more crested, and the m3 is shortened. In contrast to the diverse dipodids, several taxa typical of the late Oligocene faunas, such as Ctenodactylidae, are absent in the Suosuoquan fauna.

The occurrence of *Aprotodon* and absence of proboscidean fossils indicate that the Suosuoquan fauna is no younger than the Zhangjiaping fauna (Qiu et al., 1999), which has proboscidean fossils and is correlated to the upper part of European MN2. Therefore, the Suosuoquan fauna is probably of early Miocene age, older than the Gaolanshan fauna but younger than the 99005 fauna and considerably younger than the Tieersihabahe fauna. It is unclear how the Suosuoquan fauna correlates to any of the biozones of Höck et al. (1999). By its relationship with the 99005 fauna, which is considered correlative to Biozone D, the Suosuoquan fauna may fill the biostratigraphic gap between Biozone D and D1 in the Hsanda Gol and Loh formations (Höck et al., 1999).

THE OLIGOCENE/MIOCENE BOUNDARY

Given the lithology, stratigraphic relationships and faunal correlations, it can be concluded that the Oligocene/Miocene boundary is contained in the Tieersihabahe section. The biostratigraphic evidence indicates that the boundary should be somewhere in the 35-m-thick beds between the Tieersihabahe fauna and the Suosuoquan fauna within the section, but we cannot precisely pinpoint the boundary based only on fossil evidence. As discussed in previous sections, the boundary can be immediately below, above, or within the beds yielding the 99005 fauna. For convenience, we tentatively place the Oligocene/Miocene boundary at the lithological transition of the ‘‘Ulunguhe’’ and Suosuoquan formations. Further biostratigraphic investigation and, most importantly, evidence independent of faunal evolution such as paleomagnetic sequence, may help to define the boundary placement in this section.

Since the discoveries of the Xiejia, Gaolanshan, and Suosuoquan faunas, the latest Oligocene and earliest Miocene sequence of mammalian ages in China has been frequently modified, which results in a shift of the Oligocene/Miocene boundary. This situation is attributable to several factors that hamper faunal correlation, such as dominant endemic species in an isolated fauna with a limited number of fossils (e.g., Xiejia). In this regard, the three (at least) mammal faunas within a continuous rock sequence at Tieersihabahe provide an excellent opportunity to study the Oligocene/Miocene boundary in China and Asia.

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