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中国新近纪哺乳动物生物年代学[1)]

邓 涛
（中国科学院古脊椎动物与古人类研究所 北京 100044）

摘要：基于迄今为止发现的包括大型和小型哺乳动物在内的动物群资料，中国的新近纪被划分为7个哺乳动物期和13个哺乳动物群单位（NMU）。现在，通过对大量新化石地点和新化石记录的研究，中国的新近纪NMU已经得到显著的充实。这些新资料的重要意义在于极大地促进了我们对动物群转换和分期界线标定的认识。最近几年来，中国的新近纪哺乳动物分期变得更加精细，这主要得益于古地磁地层学的广泛应用，使得这些分期之间的界线能够进行准确的校正和定年。越来越多的古地磁分析资料使中国的新近纪哺乳动物群在与欧洲的动物群进行对比时有了一个良好的标尺。因此，本文主要依据哺乳动物化石和古地磁测年数据在中国的新近纪哺乳动物群单位和欧洲的新近纪哺乳动物分带（MN）之间进行对比。

关键词：中国，新近纪，哺乳动物分期，古地磁测年，对比
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CHINESE NEOGENE MAMMAL BIOCHRONOLOGY

DENG Tao
(*Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences* Beijing 100044)

Abstract Seven land mammal ages and thirteen mammal faunal units (NMU) are recognized for the Chinese Neogene based on updated large and small mammal faunas. Nowadays, NMU has been strongly broadened by data from new localities and new taxa in China. The significance of these new data is that they are beneficial toward our understanding of mammal turnovers and boundary calibrations. In recent years, the Chinese Neogene mammal ages have become more accurate with the introduction of magnetostratigraphy, which has enabled ages to be calibrated and well-dated at their boundaries. Increasingly abundant paleomagnetic measurements make a good calibration for the correlation of the Chinese Neogene mammalian faunas with their European counterparts. As a result, this paper compares and correlates NMU to the European Neogene mammal zones (MN), based primarily on mammalian fossils and paleomagnetic datings.

Key words China, Neogene, mammal age, paleomagnetic dating, correlation

The sequence of the Chinese Neogene mammalian faunas has been frequently revised since it was established by Chiu et al. (1979), until the latest discussion of Qiu et al. (1999). Formerly, the Chinese Neogene faunas were separated into six horizons by Chiu et al. (1979), including three Miocene and three Pliocene horizons. Based on a series of fruitful studies of Li et al. (1984), Qiu (1989), Qiu and Qiu (1990, 1995), Tong et al. (1995), and Qiu et al. (1999), a more accurately defined sequence of the mammalian faunas for the Chinese Neogene

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has been proposed. The Chinese Neogene Mammal Faunal Units (NMU) were established to correlate to the European Neogene Mammal Zones (MN), and include eleven Miocene units and two Pliocene units (Qiu et al., 1999; Deng and Downs, 2002; Qiu and Li, 2003; Wang and Qiu, 2004). For lack of accurate absolute ages, however, the positions of the Chinese mammalian faunas in the chronological chart and their correlations to the European faunas were determined mainly by evolutionary levels of mammals. In MN zones, each unit shows a sufficient difference from adjacent faunal components that can be more or less easily recognized. These faunal components are thought to be stable throughout each unit, without large changes occurring (Mein, 1999). For each NMU, a series of species or genera are regarded as characteristic forms on the basis of the correlation to the European taxa. Usually, NMU deals with the first appearance datum (FAD) of mammals at the generic level. Some of these genera are immigrants, and their entry into China of-

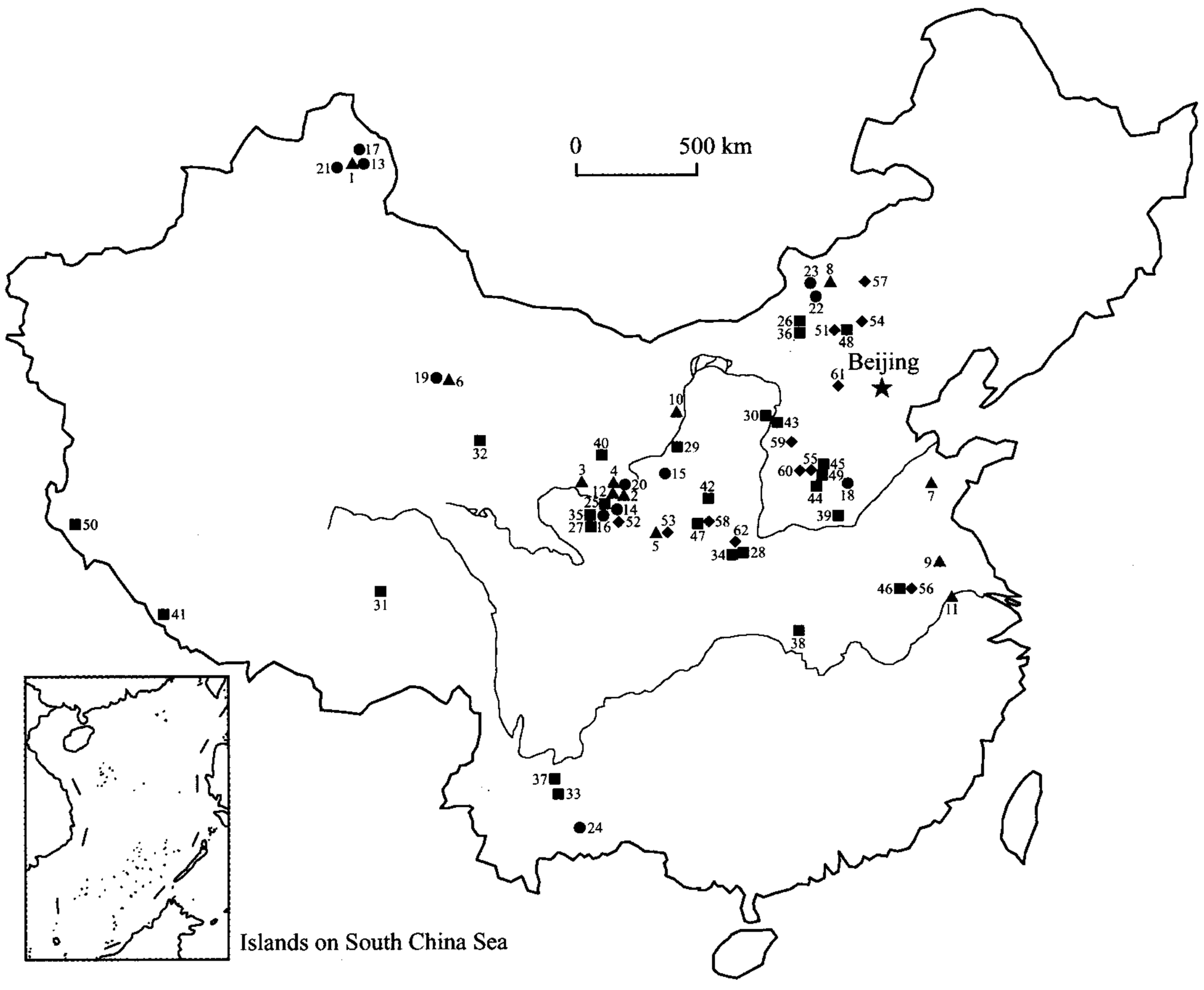

Fig. 1 Distribution of the Neogene mammal localities in China

Early Miocene (▲): 1. Suosuoquan, 2. Gaolanshan, 3. Xiejia, 4. Zhangjiaping, 5. Qin'an, 6. Xishuigou, 7. Shanwang, 8. Gashunyinadege, 9. Sihong, 10. Wuertu, 11. Fangshan, 12. Duitinggou; Middle Miocene (●): 13. Top Suosuoquan, 14. Wangshijie, 15. Dingjiaergou, 16. Laogou, 17. Halamagai, 18. Jiulongkou, 19. Tiejianggou, 20. Quantougou, 21. Kekemaideng, 22. Tairum Nor, 23. Tunggur, 24. Xiaolongtan; Late Miocene (■): 25. Guonigou, 26. Amuwusu, 27. Dashengou, 28. Bahe, 29. Wuzhong, 30. Wangdaifuliang, 31. Bulong, 32. Toson Nor, 33. Shihuiba, 34. Lantian, 35. Yangjiashan, 36. Shala, 37. Yuanmou (Xiaohe, Leilao, Zhupeng), 38. Duodaoshi, 39. Luwangfen, 40. Songshan, 41. Gyirong, 42. Qingyang, 43. Baode, 44. Danangou, 45. Hounao, 46. Laodong, 47. Leijiahe, 48. Ertemte, 49. Jiayucun, 50. Zanda; Pliocene (◆): 51. Harr Obo, 52. Shilidun; 53. Dongwan; 54. Bilike, 55. Gaozhuang, 56. Huainan, 57. Gaotege, 58. Renjiagou, 59. Hefeng, 60. Mazegou, 61. Daodi, 62. Youhe

ten marks the beginning of a unit. For example, FAD of *Hipparion* is characteristic for NMU 8.

Qiu and Qiu (1995) assigned the main localities and faunal lists for each Chinese mammalian age. Later, Qiu et al. (1999) revised and appended these localities and lists, and chose a representative fauna for each NMU. This way, each taxon of the representative fauna is important for the related unit. Tong et al. (1995) subdivided the Chinese Neogene mammalian ages and listed the first and last records of different genera for each mammalian age. In Qiu et al. (1999), the text provided an estimated age for each NMU, based predominantly on the correlation to the age of each corresponding European MN zone.

The precise correlations between the Chinese and European mammalian ages based on more accurate datings will increase our ability to recognize mammal migrations between China and Europe. For example, Mein (2003) indicated that the rodent genera appeared in Asia generally earlier than their European relatives, which provides evidence for the direction of migrations. Asia acted as a faunal dispersal center for Europe during the Neogene, and the great majority of the exchanges were migrations from Asia into Europe. China was one of the four main dispersal centers (China, Kazakhstan, Pakistan and Anatolia) during the Neogene.

In recent years, field works have result in an explosive growth of new knowledge of the Neogene localities in China (Table 1; Fig. 1), and the Chinese Neogene mammal ages have become more accurate with the introduction of magnetostratigraphy, which has enabled ages to be calibrated and well-dated at their boundaries. Increased paleomagnetic studies yield a good calibration for the correlation of the Chinese Neogene mammalian faunas with the European faunas. The European MN zones have definite paleomagnetic durations and absolute ages (Steininger et al., 1996; Steininger, 1999). As a result, MN zones are regarded as a correlated reference in order to discuss the Chinese Neogene biochronology in this paper (Table 1, 2; Fig. 2).

Table 1　Chinese and European Neogene subdividions with NMU and MN respectively

Epoch		China			Europe	
		Age	NMU	Representative fauna	MN	Age
Late	Pliocene	Mazegouan	13	Mazegou	16	Villanyian
Early	Pliocene	Gaozhuangian	12	Gaotege	15	Ruscinian
				Gaozhuang	14	
Late	Miocene	Baodean	11	Ertemte	13	Turolian
			10	Baode	12	
				Shihuiba	11	
		Bahean	9	Bahe	10	Vallesian
			8	Guonigou	9	
Middle	Miocene	Tunggurian	7	Tunggur	7/8	Astaracian
			6	Dingjiaergou	6	
		Shanwangian	5	Wangshijie	5	Orleanian
			4	Shanwang	4	
				Xishuigou	3	
Early	Miocene	Xiejian	3	Zhangjiaping	2	Agenian
			2	Xiejia		
			1	Suosuoquan	1	

1　Xiejian

Li et al. (1984) named the Early Miocene Xiejian Age based on the Xiejia fauna as the representative, corresponding to the Agenian (MN 1 ~2) of the European land mammal ages. Qiu and Qiu (1990) extended the top of the Xiejian to correlate to MN 3. Tong et al. (1995) reconfirmed the correlation of the Xiejian to the Agenian with a duration corresponding to MN 1 ~2.

Time (Ma)	GPTS (GTS 2004)	Epoch	Mammalian faunas of China: Paleomag dating	Correlation	Age	NMU	Europe: MN	Europe: Age
	C2r.2r	Quaternary		Nihewanian			17	
3	C2An.1n 2n 3n	Pliocene Late	Leijiahe V, Youhe Mazegou (C2An.3n~1n) Renjiagou, Hefeng	Daodi	Mazegouan	13	16	Villanyian
4	C2Ar	Pliocene Early	Leijiahe IV	Gaotege	Gaozhuangian	12	15	Ruscinian
	C3n.1r 2r		Gaozhuang (C3n.2r~1n) Leijiahe III	Bilike Huainan			14	
5	4n		Shilidun, Dongwan	Harr Obo				
	C3r		Leijiahe II, Jiayucun Zanda	Ertemte	Baodean	11	13	Turolian
6	C3An.1n		Lantian, Hounao	Laodong				
	2n		Leijiahe I, Danangou					
7	C3Ar		Baode (Loc. 30), Qin'an A1	Qingyang		10	12	
	C3Br.2r		Gyirong Upper Yuanmou	Songshan Luwangfen				
	C4n.2n		Qin'an A2	Duodaoshi				
8	C4r.1n 2r	Late	Lower Yuanmou Yangjiashan	Shala Shihuiba			11	
9	C4An			Toson Nor	Bahean	9	10	Vallesian
	C4Ar.1n 2r		Dashengou, Bahe	Wangdaifuliang Bulong, Wuzhong				
10	C5n.1r					8	9	
	2n			Amuwusu				
11	C5r.1r 2r		Guonigou	Xiaolongtan	Tunggurian	7	7/8	Astaracian
	3r		Qin'an A3	Kekemaideng				
12	C5An.2n C5Ar.1r		Tunggur (Moergen)					
	3r		Tairum Nor					
13	C5AAr	Miocene Middle						
	C5ABn					6	6	
14	C5ACn		DH9903, 9905	Quantougou Jiulongkou Laogou, Halamagai				
	C5ADn C5ADr			Dingjiaergou				
15	C5Bn.1r				Shanwangian	5	5	Orleanian
	C5Br		Qin'an A4	Wangshijie Top Suosuoquan				
16	C5Cn.1n 2n 3n							
17	C5Cr		Duitinggou, DH9914	Gashunyinadege		4	4	
	C5Dn		Qin'an A5	Fangshan				
	C5Dr		Shanwang (K-Ar dating)	Sihong, Wuertu				
18	C5En		Xishuigou					
	C5Er							
19	C6n	Early	Qin'an A6			4	3	
	C6r							
20	C6An.1r		Qin'an A7		Xiejian	3	2	Agenian
	2n		Zhangjiaping					
	C6Ar		Xiejia			2		
21	C6AAr.1r			Gaolanshan				
	2r		Suosuoquan					
22	C6Bn.1r					1	1	
	C6Br							
	C6Cn.1n							
23	2n							
	3n	Oligocene		Tabenbulukian			MP 30	Chattian

Fig. 2 Subdivision and correlation of the Chinese Neogene mammalian faunas

Table 2 Sequences of the Neogene mammalian localities in stratigraphic regions of China

NMU	Xinjiang	Tibet Plateau①	Gansu		Nei Mongol	Shaanxi Ningxia	Shanxi	Northern China②	Eastern China③	Southern China④	MN
			Linxia-Lanzhou	Lingtai-Qin'an							
13				Renjiagou		Youhe	Mazegou Hefeng	Daodi			16
12				Leijiahe IV	Gaotege						15
			Shilidun	Leijiahe III Dongwan	Bilike Harr Obo		Gaozhuang		Huainan		14
11		Zanda		Leijiahe II Leijiahe I	Ertemte	Lantian	Jiayucun Hounao Danangou		Laodong		13
10		Gyirong	Songshan	Qin'an A1 Qingyang Qin'an A2			Baode (Loc. 30)	Luwangfen		U. Yuanmou Duodaoshi	12
			Yangjiashan		Shala					L. Yuanmou Shihuiba	11
9		Toson Nor Bulong	Dashengou			Wangdaifuliang Bahe Wuzhong					10
8			Guonigou		Amuwusu						9
7	Kekemaideng			Qin'an A3	Tunggur Tairum Nor					Xiaolongtan	7/8
6	Halamagai	Tiejianggou (DH9903, 05)	Quantougou Laogou			Dingjiaergou		Jiulongkou			6
5	Top Suosuoquan		Wangshijie	Qin'an A4							5
4			Duitinggou	Qin'an A5	Gashunyinadege Wuertu			Shanwang	Fangshan Sihong		4
		Xishuigou		Qin'an A6							3
3			Zhangjiaping	Qin'an A7							2
2		Xiejia	Gaolanshan								
1	Suosuoquan										1

① Tibet, Qinghai, and western part of Gansu; ② Hebei, Henan, and Shandong; ③ Jiangsu and Anhui; ④ Yunnan and Hubei.

1.1 NMU 1 (= MN 1)

The base of MN 1 falls at the base of Chron C6Cn. 2n, identical with the GSSP of the base of the Neogene, and the top of MN 1 falls at the base of Chron C6AAr. 2r (Steininger, 1999). As a result, the duration of MN 1 is from 23. 0 Ma to 21. 7 Ma (Lourens et al. , 2004).

In China, the Suosuoquan fauna from the lower part of the Suosuoquan Formation in the Ulungur River area, Xinjiang, has been correlated to MN 1 (Qiu et al. , 1999). In Qiu et al. (1999), the Suosuoquan fauna was mainly composed of small mammals. Ye et al. (2001) revised and added small mammals, and included a few large mammals. According to revised determinations from the Suosuoquan localities, most Oligocene taxa are suppressed, and this locality is of Neogene age (Ye et al. , 2003). Meng et al. (in press) subdivide the mammalian fossils from the lower part of the Suosuoquan Formation into three assemblages, and Suosuoquan II is the closest to the lower boundary of the Neogene. Paleomagnetic measurements indicate that Suosuoquan II is from Chron C6Bn. 1n and C6AAr. 3r, with an age of 21. 9 ~ 21. 7 Ma.

Insectivores at Suosuoquan show FAD of *Metaxallerix* in China. In fact, the best indicator for the Suosuoquan fauna is the insectivore *Metexallerix junggarensis*. It is more advanced than *M. hsandagolensis* from the Late Oligocene in Mongolia, and more primitive than *M. gaolanshanensis* from the Early Miocene in the Lanzhou Basin. Among lagomorphs and rodents, we note the survival of *Sinolagomys* associated together with FAD of *Cricetodon*, *Atlantoxerus*, *Palaeosciurus*, and *Prodistylomys* (Ye et al. , 2001).

1.2 NMU 2 ~ 3 (= MN 2)

The base of MN 2 falls at the base of Chron C6AAr. 2r, and the top of MN 2 falls at the base of Chron C6r, with a duration from 21. 7 Ma to 20. 0 Ma (Steininger, 1999; Lourens et al. , 2004).

Recent paleomagnetic measurements demonstrate that the Xiejia section in Huangzhong, Qinghai, records 18 normal and 17 reversed polarity zones. These polarity zones correspond very well to those between Chron C5Bn. 2n and C7n. 1n in the time scale of Lourens et al. (2004). The geological age of the Xiejia Formation is 17. 32 ~ 21. 58 Ma by the inter-interposition method. The Xiejia fauna is from Chron C6Ar, with an age of about 21 Ma, corresponding to MN2 (Wu et al. , 2006). Assemblage 7 of the Qin'an section in Gansu is from Chron C6An. 1n, with an age of 20. 2 Ma (Guo et al. , 2002). Paleomagnetic analyses of the Lanzhou Basin, Gansu, indicate that the Zhangjiaping fauna may be 20. 5 Ma (Qiu et al. , 2001). Therefore, the Xiejia and Zhangjiaping faunas, and Assemblage 7 of Qin'an can be correlated to MN 2 chronologically.

Based on mammal comparisons, the Gaolanshan fauna from Lanzhou, Gansu, is correlated to the lower part of MN 2 (Qiu et al. , 1999). The Jiaozigou fauna from Dongxiang, Gansu, which was previously correlated to MN 2 (Qiu et al. , 1999), is now considered to be a Late Oligocene fauna (Qiu et al. , 2004a, b; Deng, 2004a; Deng et al. , 2004a, b).

The faunal lists of Xiejia, Gaolanshan, and Zhangjiaping are specified in Qiu et al. (1999). Wang et al. (2005) identified the carnivorous mammals of the Zhangjiaping fauna at the specific level, including *Hyaenodon weilini* and *Ictiocyon* cf. *I. socialis*. Assemblage 7 of Qin'an includes *Distylomys* sp. and *Litodonomys* sp. (Guo et al. , 2002).

The Xiejia and Gaolanshan faunas are very similar to those of Shargaltein and Taben-buluk in composition, with LAD of *Tsaganomys* at Gaolanshan. They are characterized by the dominant role of the ctenodactylids over the other forms. However, their forms are certainly more progressive than those of the Oligocene faunas. This can clearly be seen in the profuse development of advanced species of the same Oligocene genera, like *Sinolagomys*, *Parasminthus*, and *Yindirtemys*. A few forms that can be compared with those of the Suosuoquan fauna are *Metexallerix*, *Atlantoxerus*, and *Aprotodon* (Qiu et al. , 1999).

The first appearance of the proboscidean fossils is known from Zhangjiaping. It is represented by a piece of tusk and some foot bones, including an astragalus and a calcaneus. The Zhangjiaping fauna is also characterized by the presence of relict Oligocene forms. For example, its *Hyaenodon* specimens represent the largest and most aberrant of the genus, and its tataromyids, giant rhinos and *Aprotodon*, are also the relict forms of the Asian Paleogene (Qiu et al., 2001). Carnivorous mammals show LAD of *Hyaenodon*, and FAD of *Ictiocyon* at Zhangjiaping (Wang et al., 2005).

2 Shanwangian

Li et al. (1984) named the early Middle Miocene Shanwangian Age based on the Shanwang fauna as the representative, corresponding to the Orleanian (MN 3 ~ 5) of the European land mammal ages. Tong et al. (1995) confirmed the definition of the Shanwangian as being correlated to the Orleanian, but adjusted it to belong to the late Early Miocene and the early Middle Miocene.

2.1 NMU 4 (= MN 3 ~ 4)

The base of MN 3 falls at the base of Chron C6r, and the top of MN 3 falls at the base of Chron C5Dr, with a duration from 20.0 Ma to 18.0 Ma (Steininger, 1999; Lourens et al., 2004).

Qiu et al. (1999) did not indicate any mammalian fauna to correlate to MN 3. Wang et al. (2003a, b) determined the Xishuigou fauna from the Danghe area, Gansu, to belong to the Early Miocene, including the fossil localities DH9902, 9909 ~ 9911, and 9914. A reinterpretation of the palaeomagnetic studies by Gilder et al. (2001) implies that the main fossil horizons of the Xishuigou fauna are correlated to Chron C6n ~ C5En, with an age of 19.5 ~ 18.5 Ma. The paleomagnetic analysis of Sun et al. (2005) for the Tiejianggou section in the Danghe area indicates that the mammalian fauna represented by DH9902 is from Chron C5En, and therefore, it can be correlated to MN 3. The localities DH9909 ~ 9911 at Xishuigou also belong to this period, but DH9914 corresponds to Chron C5Cr and is correlated to MN 4. Assemblage 6 of the Qin'an section in Gansu is from Chron C6n, with an age of 19.4 Ma (Guo et al., 2002), so it may be correlated to MN 3.

The Xishuigou fauna includes *Sayimys obliquidens*, "*Kansupithecus*" sp., *Platybelodon dangheensis*, *Turcocerus* sp., *Amphimoschus* cf. *A. artenensis*, and *Kinometaxia guangpui* (Wang et al., 2003a, 2004). Assemblage 6 of Qin'an includes *Distylomys* cf. *qianlishanensis*, *D. tedfordi*, *Litodonomys* sp., *Prodistylomys* cf. *P. kansuensis*, and *Sinolagomys* cf. *S. ulunguensis* (Guo et al., 2002).

The Xishuigou fauna is characterized by FAD of *Platybelodon*. *Platybelodon dangheensis* from Xishuigou is apparently more primitive than the Middle Miocene *Platybelodon grangeri* in Asia and the Early Miocene *Platybelodon* sp. in Africa (Wang and Qiu, 2002). *Kinometaxia guangpui* is a recently discovered basal mustelid carnivoran from the Xishuigou fauna (Wang et al., 2004). The cranial morphology of this new Chinese form suggests membership in the leptarctines, a group of markedly hypocarnivorous taxa, mostly confined to the Miocene of North America. It bridges a morphological gap between European and North American taxa, and supplies an important piece to the puzzle of the zoogeography of basal mustelids.

The base of MN 4 falls within Chron C5Dr, and the top of MN 4 falls within Chron C5Cr, with a duration from 18.0 Ma to 17.0 Ma (Steininger, 1999).

Qiu et al. (1999) considered that the Shanwang fauna from Linqu, Shandong, might be correlated to MN 5. On the other hand, Chen and Peng (1985) dated the K-Ar age of the basalt under the diatomite of the Shanwang Formation as 18.05 ±0.55 Ma. If this age is close to the age of

the Shanwang fauna, this fauna should be correlated to MN 4 (Deng et al., 2003). Qiu et al. (2001) considered that the Duitinggou fauna from Lanzhou, Gansu, should correspond to MN 4 ~5. According to a paleomagnetic correlation (see Qiu et al., 2001, fig. 6), the horizon of the Duitinggou fauna is approximately situated in the lower part of Chron C5Cr, so it may be correlated to the upper part of MN 4. Assemblage 5 of the Qin'an section in Gansu is within Chron C5Dr, with an age of about 17.6 Ma (Guo et al., 2002), so it can be correlated to MN 4.

Based on mammal comparisons, the Sihong and Fangshan faunas from Jiangsu, and the Wuertu fauna from Nei Mongol (Inner Mongolia) can be well correlated to MN 4 (Qiu et al., 1999). The Gashunyinadege fauna from Nei Mongol may correspond to MN 4 ~5 (Qiu and Wang, 1999).

No new information has been added to the lists of the Duitinggou, Wuertu, and Sihong faunas given in Qiu et al. (1999). The Shanwang fauna has had additions and a revision of taxa since Qiu et al. (1999). The added species are *Lusorex taishanensis* (Storch and Qiu, 2004), *Sciurus lii*, *Oriensciurus linquensis* (Qiu and Yan, 2005), and *Sinapriculus linquensis* (Liu et al., 2002). The revised species is *Tamiops asiatica* (Qiu and Yan, 2005). The components of the Gashunyinadege fauna are listed in Qiu et al. (2006, this issue). Assemblage 5 of Qin'an includes *Ansomys* sp., *Atlantoxerus* sp., *Sayimys minor*, *Sinolagomys* sp., and *S.* cf. *S. ulungurensis* (Guo et al., 2002).

The insectivore *Lusorex* occurs only at Shanwang. The lagomorph *Alloptox* first appears at Sihong. In Europe, FAD of *Democricetodon* has long been proved a very useful indicator of MN 4. Among rodents, the correlated Chinese faunas to MN 4 are characterized by FAD of *Democricetodon*, *Megacricetodon*, *Youngofiber*, and *Neocometes* at Sihong, *Leptodontomys*, *Keramidomys*, *Democricetodon*, and *Megacricetodon* at Gashunyinadege, *Protalactaga*, *Democricetodon*, and *Megacricetodon* at Wuertu, and *Tamiops* and *Sciurus* at Shanwang. *Oriensciurus* occurs only at Shanwang, *Diatomys* does at Shanwang and Sihong, and *Spanocriceton* does at Fangshan. Primates show FAD of *Dionysopithecus* at Sihong. Carnivores show FAD of *Pseudaelurus*, *Cynelos* and/or *Ysengrinia* at Sihong, and *Amphicyon*, *Phoberocyon*, and *Ursavus* at Shanwang (Qiu, 2003b).

2.2 NMU 5 (= MN 5)

The base of MN 5 falls within Chron C5Cr, and the top of MN 5 falls at the base of Chron C5Bn.1r, with a duration from 17.0 Ma to 15.0 Ma (Steininger, 1999).

To date, only Assemblage 4 of the Qin'an section in Gansu has an absolute age that corresponds to MN 5 in China. It is from Chron C5Br, with an age of 15.5 Ma (Guo et al., 2002). Nevertheless, Guo et al. (2002) indicated that this assemblage is highly similar to the Tunggur fauna, and correlative to MN 7/8 depending on the faunal components.

Based on mammal comparisons, the mammalian fauna from the top of the Suosuoquan Formation in the Ulungur River area, Xinjiang, is similar to the Halamagai fauna from the overlying Halamagai Formation, but lacks *Platybelodon* and *Stephanocemas*, which are most common at the base of the Halamagai Formation. As a result, the top fauna of the Suosuoquan Formation may be correlated to MN 5 (Ye et al., 2001). The Wangshijie fauna from the Dongxiang Formation in the Linxia Basin, Gansu, has the same feature. Its components are similar to those of the Laogou fauna from the overlying Hujialiang Formation, but its *Anchitherium* and *Hispanotherium* are obviously smaller than those at Laogou, and it lacks *Platybelodon grangeri* that is common at Laogou. Similarly, the Wangshijie fauna may be correlated to MN 5 (Deng et al., 2004b).

Assemblage 4 of Qin'an includes *Mioechinus* sp., *Alloptox gobiensis*, *Ansomys* sp., *Cricetodon* sp., *Desmatolagus* sp., and *Gobicricetodon* sp. (Guo et al., 2002). The top fauna of the Suosuoquan Formation is listed in Ye et al. (2001). The Wangshijie fauna includes *Hemicyon*

sp. , *Gomphotherium* sp. , *Anchitherium* sp. , *Hispanotherium matritense*, *Alicornops laogouense*, and *Chalicotherium* sp. (Deng et al. , 2004b; Deng, 2004b).

NMU 5 is characterized by FAD of the rhinocerotids *Hispanotherium* and *Alicornops* at Wangshijie. The known earliest species of *Hispanotherium*, *H. beonensis*, occurs at Montréal-du-Gers (MN 4) in France (Antoine, 1997, 2002). The next earlier species *H. matritense* is distributed widely in Spain, Portugal and southern France as well as in China during MN 5. The known earliest *Alicornops* was discovered from Wintershof-West (MN 3) in Germany (Ginsburg and Guérin, 1979). *Alicornops* and *Hispanotherium* dispersed eastward from Europe and reached China of East Asia in MN 5.

3 Tunggurian

Li et al. (1984) named the late Middle Miocene Tunggurian Age based on the Tunggur fauna as the representative, corresponding to the Astaracian (MN 6 ~ 8) of the European land mammal ages. Tong et al. (1995) further confirmed the definition of the Tunggurian.

3.1 NMU 6 (= MN 6)

The base of MN 6 falls at the base of Chron C5Bn. 1r, and the top of MN 6 falls at the base of Chron C5ABn, with a duration from 15. 0 Ma to 13. 5 Ma (Steininger, 1999).

In China, the fossil localities with a definite age that correlate to MN 6 are DH9903 and 9905 in the Danghe area, Gansu. The paleomagnetic measurements of Sun et al. (2005) for the Tiejianggou section show that the two localities are within Chron C5ACr, with an age of 14. 2 Ma.

Based on mammal comparisons, many Chinese mammalian faunas are correlated to MN 6, such as the Dingjiaergou fauna from Tongxin, Ningxia, the Jiulongkou fauna from Cixian, Hebei, the Halamagai fauna from the Ulungur River area, Xinjiang (Qiu et al. , 1999), the Laogou fauna from Linxia, Gansu (Deng, 2003, 2004b), and the Quantougou fauna from Lanzhou, Gansu (Qiu, 2000, 2001).

The fossils of DH9903 and 9905 include only *Heterosminthus intermedius* and *Litodonomys xishuiensis* from the middle part of the Tiejianggou Formation. Wang et al. (2003a, b) considered that the two species should belong to the Early Miocene on the phylogenetic level, so they reinterpreted the paleomagnetic result of Gilder et al. (2001) for the Xishuigou section and correlated the Tiejianggou localities to Chron C5Cr.

Caementodon tongxinensis and *Huaqingtherium qiui* of the Dingjiaergou fauna are referred to *Hispanotherium matritense* by Deng (2003). In recent years, some new discoveries have expanded the components of the Halamagai fauna, and the new faunal list is in Ye et al. (2001). Wu et al. (2003) described *Pliopithecus bii* from Halamagai. No new information has become available for the Jiulongkou fauna since Qiu et al. (1999). The Laogou fauna is listed in Guan (1988) and Deng (2003, 2004b). The Quantougou fauna is listed in Qiu (2000, 2001). Qiu et al. (2001) suggested that the Quantougou fauna might be slightly older than the Tunggur fauna from Nei Mongol.

Taken as a whole, the faunas of NMU 6 are very similar to that of Sansan in France (Qiu et al. , 1999). Rodent faunas of MN 6 are characterized in all European localities by the co-occurrence of two species of *Megacricetodon* (Mein, 1999). In China, *Megacricetodon* has been discovered from Dingjiaergou, Laogou, and Quantougou. Rodents show FAD of *Mellalomys*, *Myocricetodon*, *Plesiodipus*, and *Ganocricetodon* at Quantougou. Among insectivores and lagomorphs, we note the presence of *Schizogalerix* and *Sinomylagaulus*, which seem to be restricted to Halamagai (Bi et al. , 1999; Ye et al. , 2001). The primate *Pliopithecus* occurs at Dingjiaergou, Laogou and Halamagai (Deng, 2003; Wu et al. , 2003). Two new perissodactyls occur:

the rhinocerotid *Acerorhinus* at Halamagai, and *Dicerorhinus* at Jiulongkou. Artiodactyls show FAD of the suid *Kubanochoerus* and *Listriodon* at Dingjiaergou and Laogou. *Platybelodon* began to develop considerably during this period. Abundant fossils of *Platybelodon* have been discovered from Dingjiaergou and Laogou.

3.2 NMU 7 (= MN 7/8)

The base of MN 7/8 falls at the base of Chron C5ABn, and the top of MN 7/8 falls at the base of Chron C5r. 1n (Steininger, 1999). As a result, the duration of MN 7/8 is from 13. 5 Ma to 11. 6 Ma (Lourens et al., 2004).

Traditionally, the Tunggur fauna from Nei Mongol has been the typical representative correlated to MN7/8 (Qiu et al., 1999). Wang et al. (2003) considered that the mammalian fossils from the Tunggur Tableland have two beds: the lower bed is the Tairum Nor fauna, and the upper bed is the *Platybelodon* fauna. Paleomagnetic studies of two key sections at Moergen small mammal locality and at Tairum Nor locality suggest a correlation in Chron C5Ar. 3r through part of Chron C5r. 3r, with an age range of 11. 8 ~ 13 Ma. As a result, the *Platybelodon* and the Tairum Nor faunas from the Tunggur Tableland are within MN 7/8. In addition, Assemblage 3 of the Qin'an section in Gansu is from Chron C5r. 3r, with an age of 11. 8 Ma (Guo et al., 2002), so it also is correlated to MN 7/8.

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

The discovery at Tairum Nor has added some small mammal taxa to the Tunggur fauna, including *Tachyoryctoides* sp. of Tachyoryctoididae and *Distylomys tedfordi* of Distylomyidae. Some large mammals of the Tunggur fauna have been revised and added, such as *Plithocyon teilhardi* of Ursidae, ?*Aelurocyon* sp. and *Sthenictis* sp. of Mustelidae, and *Sansanosmilus* sp. of Nimravidae(Wang et al., 2003). Assemblage 3 of Qin'an includes only *Prosiphneus qinanensis* at the specific level (Zheng et al., 2004). The components of the Xiaolongtan fauna have not changed since Qiu et al. (1999). The Kekemaideng fauna includes *Platybelodon* sp., *Brachypotherium* sp., ?*Chilotherium* sp., *Kubanochoerus* sp., *Dicrocerus grangeri*, and *Turcocerus kekemaidengensis* (Ye et al., 1999, 2001).

For this period at Tunggur, insectivores show FAD of *Yanshuella* and *Quyania*; rodents show LAD of *Tachyoryctoides*, *Microdyromys*, and *Megacricetodon*; lagomorphs show LAD of *Alloptox* and *Bellatona*; carnivores show LAD of *Plithocyon*; proboscideans show LAD of *Platybelodon*; perissodactyls show LAD of *Anchitherium* and *Hispanotherium*; and artiodactyls show LAD of *Kubanochoerus*. Some taxa are found only in the Tunggur fauna, such as the insectivore *Proscapanus*, and the carnivore *Leptarctus*. At Qin'an, rodents show FAD of *Prosiphneus*.

4 Bahean

Li et al. (1984) named the Late Miocene Bahean Age based on the Bahe fauna as the representative, corresponding to the Vallesian (MN 9 ~ 10) of the European land mammal ages. Pei et al. (1963) named the Baodean based on the classical Baode *Hipparion* fauna. Li et al. (1984) arranged the Baodean to correspond to the latest Miocene or the Turolian (MN 11 ~ 13) of the European land mammal ages. Qiu and Qiu (1990) considered that the Bahean had no obvious divisional difference from the Baodean, and it should join to the latter. Tong et al. (1995) adopted this viewpoint and correlated the Baodean to both the Vallesian and Turolian so that the Baodean represented the whole Chinese Late Miocene. Zhang et al. (2002) and Wang and Qi (2005) suggested that the Chinese Late Miocene was still subdivided into the Bahean and Baodean of Li et al. (1984).

4.1 NMU 8 (= MN 9)

The base of MN 9 falls at the base of Chron C5r. 1n, and the top of MN 9 falls at the base of Chron C4Ar. 3r (Steininger, 1999). As a result, the duration of MN 9 is from 11. 6 Ma to 9. 7 Ma (Lourens et al., 2004).

According to paleomagnetic measurements, the Guonigou fauna from Dongxiang, Gansu is within Chron C5r. 1r, with an age of 11. 1 Ma, corresponding to MN 9 (Deng, 2005c).

Based on mammal comparisons, the Toson Nor fauna from the Qaidam Basin, Qinghai, and the Amuwusu fauna from Jurhe, Nei Mongol, are considered to correlate to MN 9. The Toson Nor (formerly Tossun Nor) fauna of Bohlin (1937) has been regarded as the Chinese early Late Miocene fauna and correlates to MN 9. The main reason for this is the presence of relict Middle Miocene forms, such as *Lagomeryx*, *Stephanocemas*, and *Dicrocerus*. However, recent studies show that these Middle Miocene elements have not been collec-ted from the same horizon as the *Hipparion* fauna (Deng and Wang, 2004a, b). In fact, the Bohlin's fossils were collected from different horizons in a 5000 m-thick section, so it is wrong that they were united into one fauna. As a result, the *Hipparion* fauna at Toson Nor bearing *Hipparion weihoense*, *H.* cf. *H. chiai*, *H. teilhardi*, and *Acerorhinus tsaidamensis* should be correlated to MN 10. The Amuwusu fauna from Nei Mongol is correlated to MN 9 (Qiu et al., 1999). The same problem exists in the Amuwusu fauna: its Middle Miocene *Anchitherium* was actually collected from the lower sandstones rather than the red beds bearing *Hipparion*.

The Guonigou fauna includes *Dinocrocuta gigantea*, *Machairodus* sp., *Tetralophodon* sp., *Hipparion dongxiangense*, *Chilotherium* sp., *Parelasmotherium simplum*, *P. linxiaense*, and *Shaanxispira* sp. (Deng, 2001b; Deng et al., 2004a, b). The components of the Amuwusu fauna are listed in Qiu et al. (2006, this issue).

In Europe, the beginning of MN 9 is defined by FAD of *Hipparion*. In China, the known earliest species of *Hipparion* is *H. dongxiangense* from the Guonigou fauna. *H. dongxiangense* is smaller than *H. parvum* and is the smallest known species of *Hipparion* in China. Its characteristic structures of the hypocone and the hypocone groove frequently occur among the Middle Miocene hipparionines from North America, but are infrequent among the late hipparionines (Qiu and Xie, 1998). For this period, rodents show FAD of *Ochotona*, *Tamiasciurus*, and *Castor*, and LAD of *Heterosminthus*, *Gobicricetodon*, *Plesiodipus*, and *Democricetodon* at Amuwusu. At Guonigou, carnivores show FAD of *Dinocrocuta* and *Machairodus*; proboscideans show FAD of *Tetralophodon*; perissodactyls show FAD of *Hipparion*, *Chilotherium* and *Parelasmotherium*; and artiodactyls show FAD of *Shaanxispira*.

4.2 NMU 9 (= MN 10)

The base of MN 10 falls at the base of Chron C4Ar. 3r, and the top of MN 10 falls at the base of Chron C4r. 2r, with a duration from 9. 7 Ma to 8. 7 Ma (Steininger, 1999).

According to paleomagnetic measurements, the Dashengou fauna from Linxia, Gansu, is within Chron C4Ar. 2r, with an age of 9. 5 Ma, corresponding to MN 10 (Deng, 2005c). Paleomagnetic data also indicate that the faunal record from the Bahe Formation in Lantian, Shaanxi, is best preserved between 9. 9 ~ 7. 7 Ma (Kaakinen, 2005), which proves that the traditional Bahe fauna can be correlated to the late Vallesian (MN 10) indeed.

The Wangdaifuliang fauna from Fugu, Shaanxi, is also correlated to MN 10 (Qiu et al., 1999), but its faunal features are apparently inconsistent with the originally published paleomagnetic age (Xue et al., 1995). Currently, the Fugu section is undergoing paleomagnetic remeasurements. Based on mammalian comparisons, the Bulong fauna from Biru, Tibet, and the Wuzhong fauna from Ningxia are correlated to MN 10 (Qiu and Qiu, 1990).

The components of the Bulong and Wuzhong faunas have no changes in recent years. Since Qiu et al. (1999), many taxa have been found and described at Dashengou, Bahe, and Wang-

daifuliang, including large and small mammals. The Dashengou fauna is listed in Deng et al. (2004a, b). Wang and Qiu (2004) described *Promephitis parvus* and *P. hootoni*, and Deng (2005b) studied *Iranotherium morgani* from Dashengou. In recent years, many mammalian taxa have been found from the Bahe Formation (Zhang et al., 2002; Qiu et al., 2004a, b; Chen and Zhang, 2004; Andersson and Werdelin, 2005; Chen, 2005; Li and Zheng, 2005; Zhang et al., 2005). The same situation has occurred for the Wangdaifuliang fauna (Xue et al., 1995; Zhang and Xue, 1996; Wang, 1997; Qiu et al., 1999; Deng, 2000, 2001a; Wang and Qiu, 2004; Zhang, 2005; Zhang et al., 2005).

During this period, rodents show FAD of *Abudhabia*, *Progonomys*, *Paralactaga*, *Salpingotus*, and *Cardiocranius*, and LAD of *Protalactaga* and *Myocricetodon* at Bahe (Qiu et al., 2004a, b; Li and Zheng, 2005); carnivores show FAD of *Promephitis* at Wangdaifuliang and Dashengou, and *Adcrocuta* at Bahe, and LAD of *Dinocrocuta* at Dashengou, Wangdaifuliang and Bahe; perissodactyls show FAD of *Iranotherium* at Dashengou (Deng, 2005b); and artiodactyls show FAD of *Hezhengia* and *Miotragocerus* at Dashengou and Wangdaifuliang (Qiu et al., 2000; Zhang, 2005), and *Lantiantragus* and *Dorcadoryx* at Bahe (Chen and Zhang, 2004; Chen, 2005).

At the specific level, *Hipparion weihoense* and *H. chiai* are the important representatives in this period. These two species of *Hipparion* are recorded not only at Dashengou, Bahe and Wangdaifuliang, but also at Toson Nor (Deng and Wang, 2004b). These *Hipparion* species have a large size, deep preorbital fossae far from the orbit, and narrow and long protocones. These characters show that both species apparently belong to the *H. primigenius* group, and the hipparionines of this group in Europe and Africa are predominantly Vallesian in age (Qiu et al., 1987).

5 Baodean

In this paper, the Baodean Age belongs to the late Late Miocene and corresponds to the Turolian (MN 11 ~ 13) of the European land mammal ages.

5.1 NMU 10 (= MN 11 ~ 12)

The base of MN 11 falls at the base of Chron C4r. 2r, and top of MN 11 falls at the base of Chron C4n. 2n, with a duration from 8. 7 Ma to 8. 0 Ma (Steininger, 1999).

According to paleomagnetic measurements, the Yangjiashan fauna from Linxia, Gansu, is within Chron C4r. 1n, with an age of 8. 3 Ma, corresponding to MN 11 (Deng, 2005c). The strata bearing *Lufengpithecus hudienensis* in Yuanmou, Yunnan, contain abundant mammalian fossils, and the two sections at Xiaohe and Leilao have upper and lower fossiliferous beds yielding *Lufengpithecus*. Paleomagnetic analyses show that the lower fossiliferous beds at Xiaohe and Leilao record Chron C4r. 1r, with an age of 8. 2 ~ 8. 1 Ma, corresponding to MN 11. The upper fossiliferous beds at Xiaohe and Leilao can be correlated to MN 12 based on paleomagnetic data. However, all fossils from Xiaohe and Leilao are regarded as one mammalian fauna, with no distinction between those from lower or upper beds (Qi and Ni, 2006)

Based on mammal comparisons, the Shihuiba fauna from Lufeng, Yunnan, is correlated to MN 11 (Qiu and Storch, 1990; Wang and Qi, 2005). The Shala fauna from Nei Mongol is probably correlated to MN 11 ~ 12 (Qiu and Wang, 1999).

The Yangjiashan fauna is listed in Deng et al. (2004a, b). Wang and Qiu (2004) described *Promephitis parvus* and *P. hootoni* from Yangjiashan. The mammalian fossils from the *Lufengpithecus* localities in Yuanmou are very diversified, due to the mixture of the lower and upper fossiliferous beds correlated to MN 11 and 12, respectively, and they are listed in Qi and Ni (2006). Since Qiu et al. (1999), some new taxa of small mammals have been added to the

Shihuiba fauna, including *Sciurotamias wangi*, *Tamiops* sp., *Callosciurus* sp., *Dremomys primitivus*, *Miopetaurista asiatica*, *Hylopetodon dianense*, and *Yunopterus jiangi* (Qiu, 2002; Qiu and Ni, 2006). Wang and Qi (2005) established a new species of *Hystrix* in this fauna, *H. lufengensis*. The components of the Shala fauna are listed in Qiu et al. (2006, this issue).

Insectivores show FAD of *Paranourosorex* at Shala. Rodents show FAD of *Sinocricetus*, *Nannocricetus*, *Kowalskia*, *Lophocricetus*, *Microtoscoptes*, *Sicista*, and *Spermophilus* at Shala, *Hystrix*, *Kowalskia*, *Yunomys*, *Brachyrhizomys*, *Yunopterus*, and *Hylopetodon* at Shuihuiba, *Tamiops*, *Ratufa*, and *Pliopetaurista* at Yuanmou, and *Hystrix* at Yangjiashan and Shihuiba. Primates show FAD of *Sinoadapis*, *Laccopithecus*, and *Lufengpithecus* at Shihuiba, and *Indralo-ris* and *Yuanmoupithecus* at Yuanmou. Carnivores show FAD of *Agriotherium* at Yangjiashan, *Indactos* at Shihuiba, and *Vishnucyon*, *Pseudarctos* and *Vishnuictis* at Yuanmou, and LAD of *Amphicyon* at Shihuiba and Yuanmou. Perissodactyls show FAD of *Subchilotherium* at Yuanmou, and the absolute domination of *Chilotherium* at Yangjiashan. Artiodactyls show FAD of *Yunnanochoerus* and *Dorcabune* at Shihuiba, *Molarchoerus* at Yuanmou, and *Microstonyx* at Yangjiashan.

The base of MN 12 falls at the base of Chron C4n. 2n, and the top of MN 12 falls at the base of Chron C3An. 2n, with a duration from 8. 0 Ma to 6. 6 Ma (Steininger, 1999).

The paleomagnetic measurements for the Jijiagou section in Baode, Shanxi (Yue et al., 2004b), show that the main fossiliferous bed (Loc. 30) of the Baode fauna corresponds to Chron C3Ar, with an age of 6. 6 ~ 7. 00 Ma, and can be correlated to MN 12. The *Hipparion* fauna from Gyirong, Tibet, has been correlated to the Baode fauna. Actually, recent paleomagnetic data indicate that the fossiliferous bed in Gyirong is situated within Chron C3Bn, with an age of 7. 0 Ma (Yue et al., 2004a). As mentioned above, the paleomagnetic measurements show that the upper fossiliferous beds of the *Lufengpithecus* localities in Yuanmou correspond to Chron C3Br. 1n at Xiaohe and Chron C3Br. 1r at Leilao, with an age of 7. 1 ~ 7. 2 Ma (Yue et al., 2004c), so they can be correlated to MN 12. The paleomagnetic measurements of Zhu et al. (2005) for the Zhupeng section in Yuanmou also indicate that the mammalian fauna with *Lufengpithecus* corresponds to Chron C3Br. 2r or C3Br. 3r, i. e. within the interval 7. 38 ~ 7. 43 Ma or 7. 17 ~ 7. 34 Ma, also corresponding to MN 12. Assemblage 1 of the Qin'an section in Gansu is from Chron C3Ar, and Assemblage 2 is from Chron C4n. 2n (Guo et al., 2002), so that both of them correspond to MN 12.

Based on mammalian comparisons, the Qingyang fauna from Gansu, the Songshan fauna from Tianzhu, Gansu, the Luwangfen fauna from Xinxiang, Henan, and the Duodaoshi fauna from Jingmen, Hubei, are correlated to MN 12 (Qiu and Qiu, 1990).

The components of the Qingyang, Songshan, Luwangfen and Duodaoshi faunas have no changes in recent years. Since Qiu et al. (1999), only one new species, *Indarctos zdanskyi*, has been established in the Baode fauna (Qiu and Tedford, 2003), and not any taxon has been added to the Gyirong fauna. Assemblage 1 of Qin'an includes *Alilepus* cf. *A. annectens*, *Ochotona* sp., *Pararhizomys hipparionum*, and *Prosiphneus licenti*, and Assemblage 2 includes *Ochotona* sp. and *Prosiphneus haoi* (Guo et al., 2002; Zheng et al., 2004; Zhang et al., 2005).

The NMU 10 faunas are undoubtedly the most significant Cenozoic fossil assemblage due to their taxonomic diversity, quantity of specimens, and the range of distribution. This productive stratigraphic unit is referred to as the *Hipparion* red clays, with a multitude of localities found in Shanxi, Shaanxi, Henan, and Gansu (Qiu and Qiu, 1995). They are so similar to the classic *Hipparion* faunas, like Maragha, Pikermi and Samos, that there are few doubts about their contemporaneity (Qiu et al., 1999).

5.2 NMU 11 (= MN 13)

The base of MN 13 falls at the base of Chron C3An. 2n, and top of MN 13 falls within

Chron C3r, with a duration from 6.6 Ma to 5.3 Ma (Steininger et al., 1996; Steininger, 1999).

The basal part of the Gaozhuang Formation in Yushe, Shanxi yielding the Jiayucun fauna has a reversed polarity, and is thus calibrated with the base of Chron C3r, somewhere between 5.9 and 5.3 Ma. The Hounao-Danangou fauna is from the upper part of the Mahui Formation in Yushe Basin, which is calibrated with Chron C3An. 1n + 2n, with a duration of approximately 6.6 ~ 5.9 Ma (Qiu et al., 1999). As a result, the Jiayucun and Hounao-Danangou faunas can be correlated to MN 13. The mammalian fossils from the Leijiahe I and II in Lingtai, Gansu, have a duration from 6.6 Ma to 4.9 Ma (Zheng and Zhang, 2001), corresponding to MN 13. The *Hipparion* fauna from the Tuolin Formation in Zanda, Tibet, has a paleomagnetic age of about 6.2 ~ 5.3 Ma, so it should be correlated to MN 13 (Li and Li, 1990). Paleomagnetic data indicate that the faunal record from the Lantian Formation in Lantian, Shaanxi, is best preserved between 6.8 ~ 6.0 Ma (Kaakinen, 2005).

Based on mammal comparisons, the Ertemte fauna from Huade, Nei Mongol, is the typical representative correlated to MN 13 (Qiu et al., 1999). The Laodong fauna from Huainan, Anhui, is considered to correlate to MN 13 (Jin, 2004).

The components of the Jiayucun and Hounao-Danangou faunas have not changed since Qiu et al. (1999). In the Ertemte fauna, only the jerboa *Paralactaga anderssoni* is revised into *P. suni* by Qiu (2003a). The mammalian fossils of the Lantian Formation are listed in Zhang et al. (2002). Andersson and Werdelin (2005) studied the carnivores from the Lantian Formation. The mammalian fossils of Leijiahe I and II are listed in Zheng and Zhang (2001). Cui (2003) described *Chardinomys lingtaiensis* and *C. primitivus* from Leijiahe I and II. At the specific level, the mammalian fossils from Zanda include only *Palaeotragus microdon* and *Hipparion zandaense* (Zhang et al., 1981; Li and Li, 1990). The Laodong fauna is listed in Jin et al. (1999). Jin (2004) described *Pliopentalagus huainanensis* and *Alilepus lii* from Laodong.

In this period, rodents show FAD of *Chardinomys*, *Micromys*, *Huaxiamys*, and *Allorattus* at Leijiahe, *Microtodon*, *Dipus* and *Eozapus* at Ertemte, and LAD of *Pseudaplodon* at Ertemte. Lagomorphs show FAD of *Trischizolagus* at Leijiahe, and *Pliopentalagus* at Laodong. In the Yushe Basin, carnivores show FAD of *Nyctereutes*, *Eucyon*, and *Pachycrocuta*, and LAD of *Adcrocuta* and *Indarctos*; proboscideans show FAD of *Stegodon*; perissodactyls show LAD of *Sinohippus*; and artiodactyls show FAD of *Paracamelus*.

6 Gaozhuangian

Li et al. (1984) named the Jinglean and Youhean of the Early and Late Pliocene based on the Jingle and Youhe faunas as the representatives, respectively, corresponding to the Ruscinian (MN 14 ~ 15) of the European land mammal ages. Qiu and Qiu (1990) considered that the characteristics of the Jingle fauna were unclear, and suggested that the Yushean should substitute for the Jinglean and Youhean, corresponding to the European Ruscinian and early Villanyian (MN 14 ~ 16). The National Commission on Stratigraphy of China (2001) divided the Chinese Pliocene again into two ages: the Early Pliocene was named as the Gaozhuangian based on the Gaozhuang fauna, corresponding to the Ruscinian (MN 14 ~ 15), and the Late Pliocene was named as the Mazegouan based on the Mazegou fauna, corresponding to the early Villanyian (MN 16).

NMU 12 (= MN 14 ~ 15) The base of MN 14 falls within Chron C3r, and the top of MN 14 falls at the base of Chron C2Ar, with a duration from 5.3 Ma to 4.2 Ma (Steininger et al., 1996).

According to paleomagnetic measurements, the Shilidun fauna from Guanghe, Gansu is within Chron C3n. 4n with an age of 5.0 Ma, corresponding to MN 14 (Deng, 2005c). The

Gaozhuang fauna from the Nanzhuanggou and Culiugou Members of the Gaozhuang Formation in the Yushe Basin, Shanxi, is from Chron C3n. 2r to C3n. 1n, corresponding to MN 14 (Flynn et al., 1995). The mammalian fossils from the Leijiahe III in Lingtai, Gansu, have a duration from 4. 9 Ma to 4. 2 Ma (Zheng and Zhang, 2001), corresponding to MN 14. The mammalian fossils from a depth of 36 ~ 11 mm at the Dongwan section in Qin'an, Gansu, have a duration from 5. 3 Ma to 4. 2 Ma (Hao and Guo, 2004), corresponding to MN 14.

Based on mammal comparisons, the Bilike and Harr Obo faunas from Huade, Nei Mongol, can be correlated to MN 14 (Qiu and Li, 2003). The Huainan (Xindong) fauna from Anhui may be correlated to MN 14, and it is slightly earlier than the Bilike fauna (Jin and Zhang, 2005).

The complete lists of the Gaozhuang and Huainan faunas have not been published to date. In the Harr Obo fauna, only *Paralactaga anderssoni* was recently revised into *P. suni* by Qiu (2003a). The Shilidun fauna is listed in Deng et al. (2004a, b). Deng (2005a) studied *Shansirhinus ringstromi* from Shilidun. The mammal fossils of Leijiahe III are listed in Zheng and Zhang (2001) for micromammals and Chen (2002) for macromammals, respectively. Cui (2003) described *Chardinomys primitivus*, *C. lingtaiensis*, and *C. yusheensis* from Leijiahe III. The components of the Bilike fauna are listed in Qiu and Storch (2000). The mammalian fossils from a depth of 36 ~ 11 mm at the Dongwan section in Qin'an include *Prosiphneus eriksoni*, *Pliosiphneus lyratus*, and *Ochotona* sp. (Hao and Guo, 2004).

In this period, rodents show FAD of *Petenyia*, *Sulimskia*, *Sinozapus* and *Aratomys* at Bilike, *Mimomys* and *Chardina* at Leijiahe, *Pliosiphneus* at Dongwan, *Mesosiphneus*, *Germanomys* and *Mimomys* in Yushe, and *Promimomys* at Xindong; and LAD of *Prosiphneus* at Leijiahe, and *Leptodontomys* and *Keramidomys* at Harr Obo. In the Yushe Basin, lagomorphs show FAD of *Hypolagus*; carnivores show FAD of *Ursus*, *Vulpes*, and *Chasmaporthetes*; and proboscideans show FAD of *Sinomastodon*.

The base of MN 15 falls at the base of Chron C2Ar, and the top of MN 15 falls within Chron C2An. 3n, with a duration from 4. 2 Ma to 3. 4 Ma (Steininger et al., 1996).

The mammalian fossils from Leijiahe IV in Lingtai, Gansu, have a duration from 4. 2 Ma to 3. 6 Ma (Zheng and Zhang, 2001), corresponding to MN 15. The mammals from the Leijiahe IV are listed in Zheng and Zhang (2001) for micromammals and Chen (2002) for macromammals, respectively.

Based on mammal comparisons, the Gaotege fauna from Nei Mongol is correlated to MN 15, and its components are listed in Li et al. (2003).

7　Mazegouan

As mentioned above, the National Commission on Stratigraphy of China (2001) named the Late Pliocene as the Mazegouan Age, corresponding to the early Villanyian (MN 16) of the European land mammal ages.

NMU 13 (= MN 16)　The base of MN 16 falls within Chron C2An. 3n, and the top of MN 16 falls at the base of Chron C2r. 2r, with a duration from 3. 4 Ma to 2. 6 Ma (Steininger et al., 1996).

The mammalian fossils from the Mazegou Formation at Yuncu in Yushe, Shanxi, are from Chron C2An. 3n ~ C2An. 1n (Flynn et al., 1995). The mammalian fossils from Leijiahe V in Lingtai, Gansu, have a duration from 3. 6 Ma to 2. 6 Ma (Zheng and Zhang, 2001). The Renjiagou fauna from Lingtai, Gansu, has an age of 3. 4 ~ 3. 5 Ma (Zhang et al., 1999). The Hefeng fauna from Jingle, Shanxi, has the same age as the Renjiagou fauna (Yue and Zhang, 1998). The Youhe fauna from Weinan, Shanxi, has a paleomagnetic age of 3. 15 ~ 2. 6 Ma (Yue and Xue, 1996). These faunas correspond to MN 16 chronologically.

Based on mammal comparisons, the Daodi fauna from the Nihewan Basin, Hebei is correlated to MN 16 (Cai et al., 2004).

The elements of the Mazegou fauna have not changed in recent years. The mammalian fossils from Leijiahe V are listed in Zheng and Zhang (2001). The Renjiagou fauna includes *Chardinomys* sp., *Nyctereutes sinensis*, *Hipparion houfenense*, *Paracamelus* sp., *Gazella* sp., *G. blacki*, and *Antilospira licenti* (Zhang et al., 1999). No new information can be added in the Hefeng and Youhe faunas recently. The Daodi fauna is listed in Cai et al. (2004). Tomida and Jin (2005) revised *Pliopentalagus nihewanensis* from Daodi into *Trischizolagus nihewanensis*.

In this period, rodents show FAD of *Yangia*, *Cromeromys*, *Allophaiomys*, *Hyperacrius*, *Eospalax*, and *Allosiphneus* at Leijiahe, *Borsodia* and *Ungaromys* at Hefeng and Mazegou; and LAD of *Pliosiphneus* and *Chardina* at Leijiahe, and *Mesosiphneus* at Daodi. Logomorphs show FAD of *Ochotonoides* at Mazegou. Carnivores show FAD of *Canis*, *Felis*, *Lynx*, *Homotherium*, and *Panthera* at Mazegou; and LAD of *Metailurus* at Hefeng. Proboscideans show FAD of *Archidiskodon* at Mazegou. Artiodactyls show FAD of *Dama* and *Rusa* at Mazegou.

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