

甘肃灵台晚中新世—早更新世生物地层 划分及其意义¹⁾

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摘要 将甘肃灵台雷家河地区 3 个剖面按生物学和地层学原理综合成一个完整的生物地层剖面,并分成 6 个生物地层带: I + II 带为保德期中晚期; III~V 带为榆社期; VI 带为泥河湾期。探讨了华北各地方动物群在雷家河剖面中的相应位置。

关键词 甘肃灵台,晚中新世—早更新世,生物地层

中图法分类号 P534.6

甘肃灵台雷家河地区自 1964 年发现哺乳动物化石以来,中国科学院古脊椎动物与古人类研究所野外考察队曾分三个阶段在该地区进行考察和发掘。第一阶段(1971~1972 年)工作的初步结论是这套介于“三趾马红土”和黄土堆积之间的河湖相地层“雷家河组”的时代为早更新世,可与榆社 II 带相对比(黄万波等, 1979); 第二阶段(1992~1993 年)野外考察的结果将“雷家河组”的时代确定为上新世(黄万波等, 1993), 其中 1993 年对文王沟 93001 和小石沟 72074(4) 地点小哺乳动物化石的分析结果, 将底部红粘土至顶部午城黄土的时代确定为晚中新世—早更新世(Zheng, 1994); 第三阶段(1998~1999 年)野外考察主要集中对 93001、93002 和 72074(4) 地点剖面逐层筛洗小哺乳动物化石, 其结果证明该地区地层时代确系晚中新世—早更新世(郑绍华等, 2000; 张兆群等, 2000; 张兆群等, 2001)。主要根据鼠科动物化石的原始性质认为 93001 和 93002 地点剖面的下部湖相堆积物的时代有可能为保德期中期或中 Turolian 期, 两地点可能缺失保德期晚期或晚 Turolian 期(张兆群等, 2000), 而 72074(4) 地点保存了保德期晚期或晚 Turolian 期的沉积(张兆群等, 2001)。

本文将按岩石地层学、生物地层学方法将 93001、93002 和 72074(4) 地点 3 个地层剖面有机地连接起来; 将该地区已发现的小哺乳动物化石名单按时代顺序进行排列; 对比华北已发现的孤立的或短时限的动物群的时代。

三个阶段所发现的大型哺乳动物化石将在此生物地层剖面的基础上另文加以研究讨论。

1) 国家重点基础研究发展规划项目(编号: G2000077707)、国家自然科学基金(编号: 49772090)及中国科学院古生物学与古人类学学科基础研究特别支持基金项目(编号: 97030)资助。

收稿日期: 2000-12-28

1 剖面的对比与衔接

雷家河地区以文王沟 93001 地点剖面最长,是本地区的主剖面。1993 年测绘到该剖面顶部的部分黄土堆积(Zheng, 1994),但因未在其上部发现化石,所以 1998 年未在上部 15m 厚的地层中采集化石,同时其下部未挖掘到基岩(郑绍华等,2000)。1999 年彻底完成了该剖面的工作,这样上部黄土地层就增加了 WL7+ ~ WL1+,下部湖相地层增加了 WL24~WL27,从而将 93001 地点剖面从下至上划分为 5 个生物地层带:I 带为 WL27~WL17;II 带为 WL16;III 带为 WL15~WL14;IV 带为 WL13~WL7;V 带为 WL6~WL1+(图 1)。

文王沟 93002 地点剖面较短,只 9 层,从下至上被分为 4 个生物地层带:I 带为 CL9~CL7;II 带为 CL6;III 带为 CL5~CL4;IV 带为 CL3~CL1。其中 I 带和 II 带从岩性上可直接和 93001 地点剖面对比,III 带相当于 93001 地点剖面的 WL15,IV 带相当于 93001 地点的 WL14 下部(张兆群等,2000)。II 带为砂砾石层,代表了一个较长时期的侵蚀或是一个较大的沉积间断。

小石沟 72074(4)地点剖面被分成 11 层和 4 个生物地层带,即 I 带为 L11~L8;II 带为 L7~L6;III 带为 L5~L3;IV 带为 L2~L1(张兆群等,2001)。由于该地点距离 93001 地点和 93002 地点稍远,且岩性差异较大,无法直接进行对比。然而 3 个地点的地层均直接覆盖于上白垩系地层之上,因此可视的同时异相;从剖面厚度看,72074(4)地点剖面相当于 93001 地点剖面的中下部层位。

从哺乳动物化石在地层中的分布看,*Cromeromys gansunicus* 和 *Pseudomeriones complicidens* 在 93001 地点的最早出现分别在 WL11 和 WL12,而 *Cricetinus mesolophidus* 和 *Huaxiamys downsi* 的最晚出现分别在 WL10 和 WL11。因此可以认为含上述种类的 L2~L1 可与 93001 地点的 WL12 相对比。这样 72074(4)地点的 IV 带可与 93001 地点 IV 带下部层位相对比。

从 *Cricetinus mesolophidus* 最早出现在 93002 地点的 CL2-2, *Huaxiamys primitivus* 及 *Allorattus engesseri* 最后出现在 93001 地点的 WL14 看,最早和最后出现的这些种类在 72074(4)地点剖面的 L5 层,因此 L5~L4 应相当于 93001 地点的 WL14 或 93002 地点的 CL3~CL1。

从 *Huaxiamys primitivus* 及 *Chardinomys yusheensis* 最早出现在 93001 地点的 WL15 和 93002 地点的 CL4, *Chardinomys* n. sp. 最晚出现在 CL3 看,含这些最早和最晚纪录的 L7~L6 应相当于 WL15 或 CL5~CL4。

由于在 L9~L8 层中最早出现的 *Trischizolagus* cf. *T. dumitrescuae*, *Nannocricetus mongolicus*, *Micromys tedfordi*, *Chardinomys* n. sp. 及 *Allorattus engesseri* 在文王沟 WL16 和 CL6 之下的层位尚未见出现,因此可以将它们填补于 WL16 和 WL17 之间或 CL6 和 CL7 之间。这也可从 *Occitanomys* n. sp. 只出现在 L11 的事实得到证明。

据上分析,可以将雷家河地区 93001、93002 和 72074(4)地点 3 个剖面进行对比(见图 1),并综合成该地区的一个相对完整的地层剖面(图 2)。

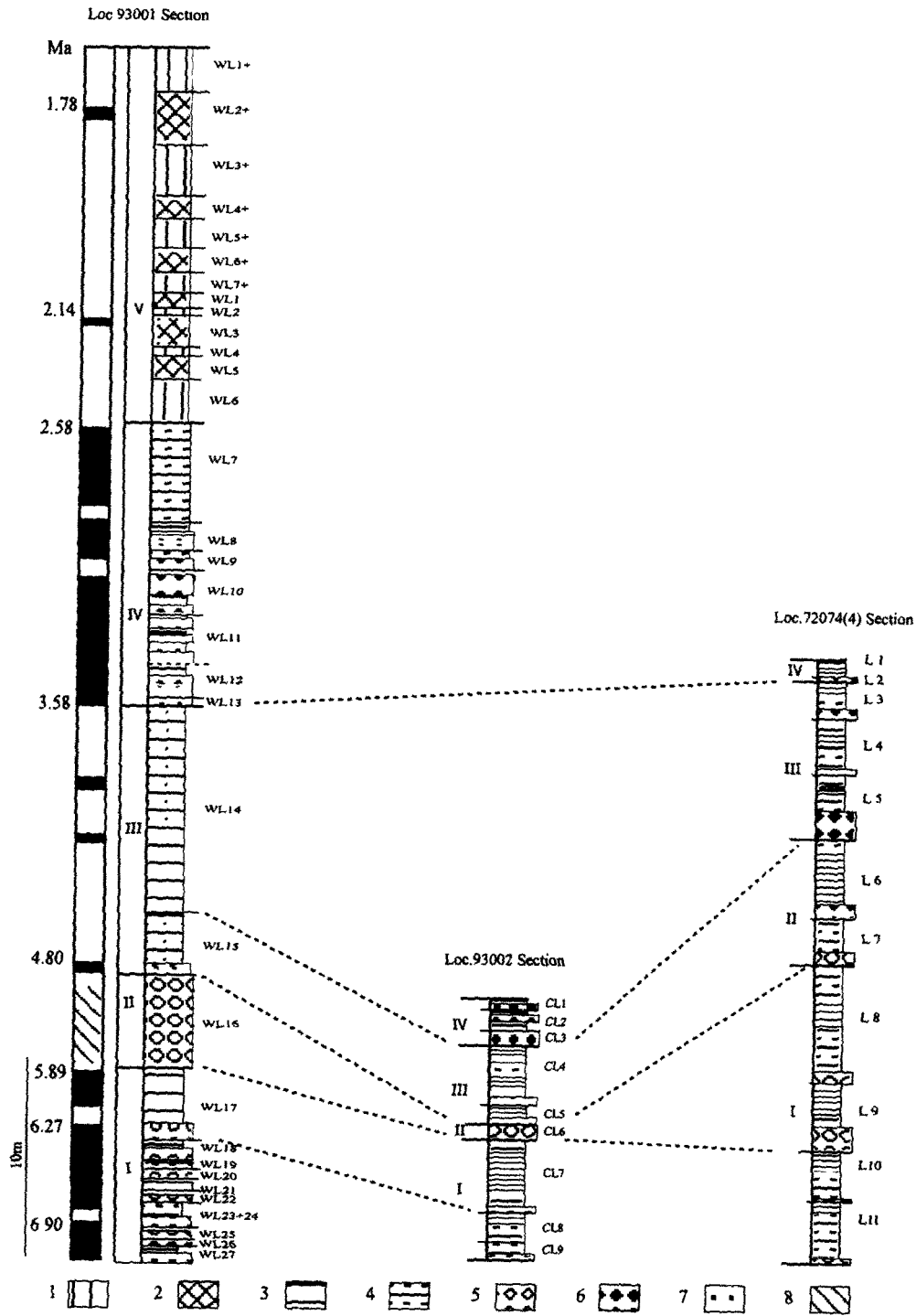


图1 甘肃灵台雷家河地区三条剖面的岩石地层学对比

Fig.1 Lithostratigraphic correlation of three sections in the Leijiaye area, Lingtai, Gansu
 1. 黄土 loess; 2. 古土壤 paleosol; 3. 泥岩 mud stone; 4. 粉砂岩 silt stone; 5. 钙结核砾岩 conglomerate with carbonate nodules; 6. 砾岩 conglomerate; 7. 砂岩 sand stone; 8. 无资料 no data

Epoch	Stages	European Faunal Units	Bio zones	Synthetic Profile	Loc.93001 Section (Zheng and Zhang, 2000)	Loc.72074 section (Zhang and Zheng, 2001)	Loc. 93002 section (Zhang and Zheng, 2000)		
Pleistocene	Nihewanian	Villanyian	VI	WL1+	V				
				WL7+				WL1	
				WL1				WL3	
				WL3				WL5	
				WL5				WL6	
				WL6				WL6	
	Pliocene	Yushean	Villanyian	V	WL7	IV			
					WL8				WL7
					WL10				WL8
					WL11				WL10
					WL12				WL11
					WL12				WL12
Ruscinian		IV	III	L3	III	WL14	III	L1	
				L4				L2	
				L5				L3	
				L6				L4	
				L7				L5	
				L7				L5	
Baodean	Turolian	II	L8	II	WL16	I	L6		
			L9				L7		
			WL17				L8		
			WL18				L9		
			WL18				L10		
			WL27				L11		
							CL1		
							CL2		
							CL3		
							CL4		
							CL5		
							CL6		
							CL7		
							CL8		
							CL9		

图2 灵台雷家河三条剖面生物地层划分与对比

Fig.2 Comparison and synthetic zonation of the three sections in the Leijiahe area, Lingtai, Gansu

2 小哺乳动物生物地层划分

根据以上地层剖面的对比,结合小哺乳动物化石属种在地层中的分布,在该地区统一划分出6个生物地层带(见图2)。各生物地层带与地层层位的对应关系如下:I带对应于文王沟93001地点的WL27~WL17层、72074(4)地点的L11~L10以及93002地点的CL9~CL7;II带对应于小石沟72074(4)地点剖面的L9~L8;III带对应于72074(4)地点剖面的L7~L6、文王沟93001地点的WL15以及93002地点的CL5~CL4;IV带对应于72074(4)地点剖面的L5~L3、文王沟93001地点的WL14以及93002地点的CL3~CL1;V带对应于文王沟93001地点的WL12~WL7层;VI带对应于文王沟93001地点的WL6~WL1+层。

雷家河地区的古地磁测定自魏兰英等(1993)的工作之后,还没有更新的研究结果。本文暂时采用这一测试结果,并依据 Berggren et al. (1995)的数据,结合已知小哺乳动物化石的年代分布作了初步的修订。

根据修订结果,将雷家河地区3个地点剖面的化石层位进行年龄标定并将发现的化石按时间顺序排列(图3)。

3 动物群对比

灵台雷家河晚中新世—早更新世综合地层剖面厚度(约78m)相当于榆社盆地相应时段地层剖面厚度(约800m)(Tedford et al., 1991)的约1/10,其所含小哺乳动物化石种类和数量却远比榆社(Flynn et al., 1997)丰富,属种间的进化线路更为清晰。这就为那些分散的孤立的动物群之间进行对比提供了一个较为可靠的时空条件,并为它们找到了一个相对适当的位置(图4)。

3.1 榆社剖面不同时段动物组合

榆社盆地是中国产哺乳动物化石最丰富的地区之一,地层顺序相对清楚,从早至晚曾被分为3个带,即榆社I、II、III带。早先发现的小哺乳动物化石个体相对较大,主要是一些产出层位不十分清楚的castorids、rhizomyids和siphneids(Teilhard, 1942)。近年中美合作的成果虽未完全发表,但主要的小哺乳动物化石在地层中的分布已显现出来(Flynn et al., 1997),由于其剖面厚度大,沉积间断较多(Tedford et al., 1991),其采样密度受到限制,因此在同一类群中属种间的相互关系还不甚明显。比较榆社和灵台剖面,可以发现许多共同点,如*Cricetinus mesolophidus*均大致分布于4.7~3.4Ma期间,*Micromys tedfordi*均发现于5.3~3.3Ma之间的层位中,多数鼯鼠类、仓鼠类和鼠类为其所共有,因此两剖面小哺乳动物所反映出的动物地理区系具有极大的相似性。

3.1.1 马会组及高庄组桃阳段动物组合

这一晚中新世时段的动物组合在雷家河剖面上显示在72074(4)地点的L9~L8,其共有的成员有*Ochotona lagrelli*, *Pseudomeriones abbreviatus*, *Prosiphneus murinus*, *Karnimata hipparionum*, *Chardinomys* n. sp.等,但在榆社未发现较原始的*Occitanomys* n.

Synthetic Profile	Biozones	Stages	European Faunal Units	Fauna of North China				
WL1+	VI	Nihewanian	Vilanyan	Heshui, Gansu (Zheng, 1976)	Xiashagou, Nihewan, Hebei (Teilhard et al., 1930)	Loc.78001, Nihewan, Hebei (Zheng, 1981)	Haiyan Fm., Yushe, Shansi (Flynn et al., 1997)	
WL3+								
WL4+								
WL5+								
WL7+								
WL1	V	Nihewanian	Vilanyan	Loc.18, CKT, Beijing (Teilhard, 1940)	Fauna A, Zibo, Shandong (Zheng et al., 1997)	Huangkan, Beijing (Huang et al., 1983)	Luochuan, Shensi (Liu et al., 1985)	
WL3								
WL5								
WL6								
WL7								
WL8	IV	Yushean	Rusman	Layer 1-2 of Loc.1, Jingle, Shansi (Zhou, 1988)	Daodi Fm, Nihewan, Hebei (Cai et al., 1993; Cai, 1987)	Ningxian, Gansu (Zhang, 1999)	Mazegou Fm, Yushe, Shansi (Flynn et al., 1997)	
WL10								
WL11								
WL12								
L3								
L4	III	Yushean	Rusman	Bilike, Mongolia (Qiu and Storch, 2000)			Nanzhuanggou and Culiugou members, Yushe, Shansi (Flynn et al., 1997)	
L5								
L6								
L7	II	Baodean	Turolian	Ertemte, Mongolia (Flynn et al., 1997)			Mahui Fm and Taoyang member, Yushe, Shansi (Flynn et al., 1997)	
L8								
L9								
WL17	I	Baodean	Turolian					
WL18								
WL27								

图4 华北主要小哺乳动物化石地点与雷家河综合剖面对比

Fig.4 Correlation of major small mammal localities of North China and the Leijiahe synthetic profile

sp. 及 *Huaxiamys*. n. sp. 等, 因此含有后两种的 93001 地点的 WL27~WL17 及 93002 地点的 CL9~CL7 动物组合可能较马会组的时代早。

3.1.2 高压组上部(南庄沟段 + 醋柳沟段)动物组合

在榆社, 这一动物组合的时段大致在 4.8~3.6Ma, 相当于雷家河 93001 地点的

WL15~WL14, 93002 地点的 CL5~CL1 及 72074(4) 地点的 L7~L3。两地共有的小哺乳动物化石种类有: *Ochotona lagrelli*, *Sminthoides*, *Cricetinus mesolophidus*, *Allocricetus*, *Chardina truncatus*, *Chardinomys yusheensis*, *Apodemus qiui*, *Micromys tedfordi* 及 *Huaxiamys downsi*。这期间, 发生了 *Chardina truncatus* 从 *C. sinensis*、*Huaxiamys primitivus* 从 *Huaxiamys* n. sp. 以及 *Chardinomys yusheensis* 从 *Chardinomys* n. sp. 分化出来的生物事件。

3.1.3 麻则沟组的动物组合

榆社盆地的这一动物组合大致在 3.6~2.6Ma 期间, 相当于雷家河 93001 地点的 WL13~WL7 及 72074(4) 地点的 L2~L1。两地共有的小哺乳动物有: *Ochotona lagrelli*, *Ochotonoides complicidens*, *Sminthoides*, *Cricetinus mesolophidus*, *Allocricetus bursae*, *A. ehiki*, *Cricetulus*, *Mesosiphneus paratingi* (相当于 *M. intermedius*), *Cromeromys*, *Chardinomys louisi* 及 *Micromys tedfordi* 等。这期间记录了一些第四纪属种的最早出现, 如 *Ochotonoides*, *Eospalax*, *Yangia*, *Allosiphneus*, *Allocricetus*, *Cricetulus*, *Bahomys*, *Cromeromys*, *Borsodia*, *Hyperacrius* 等, 同时也记录了一些属种的最后绝灭, 其中一个最重要的特点是鼯鼠类及鼯类中的白齿具齿根的属被白齿无齿根的属所取代。

3.1.4 海眼组动物组合

雷家河剖面中, 没有发现海眼组的成员如 *Yangia tingi*, *Y. epitingi*, *Chardinomys nihewanicus* 等, 但 *Cromeromys gansunicus* 及 *Borsodia chinensis* 和甘肃合水金沟动物群 (郑绍华, 1976) 相当; *Yangia tingi*, *Borsodia chinensis* 及 *Chardinomys nihewanicus* 则与泥河湾下沙沟 (Teilhard and Piveteau, 1930)、大南沟 78001 地点 (郑绍华, 1981) 的动物组合时代相当, 它们可能在 93001 地点的 WL4+~WL1+ 的时代范围之内或稍晚。通过这 3 个动物群, 则可将海眼组动物组合与 93001 地点的相当层位大体对比。

3.2 二登图动物群

二登图动物群最早为 Schlosser (1924) 所记述, 其时代被认为和匈牙利 Polgardi 动物群 (相当于欧洲的 MN13) 接近。Storch (1987) 根据其中鼠科动物的进化水平, 认为其时代在 7~5Ma 间。童永生等 (1995) 则将其置于保德期晚期或晚 Turolian 期。Qiu and Qiu (1995) 又将其置于保德期和榆社期之间。Flynn 等 (1997) 和 Qiu 等 (1999) 则认为是最晚中新世 (或 MN13)。

雷家河剖面中, 5.0Ma 左右的动物群与二登图动物群共有的成分最多, 如 *Ochotona lagrelli*, *Eutamias*, *Sicista*, *Lophocricetus*, *Paralactaga anderssoni*, *Sminthoides*, *Sinocricetus zdanskyi*, *Nannocricetus mongolicus*, *Kowalskia similis*, *K. neimengensis*, *Pseudomeriones abbreviatus*, *Prosiphneus*, *Karnimata hipparionum*, *Micromys chalceus* 及 *Apodemus orientalis* 等, 因此二登图动物群在雷家河剖面中的相应位置应属于上新世初期而不是晚中新世末期 (也见张兆群等, 2000)。

3.3 比例克动物群

比例克动物群是邱铸鼎 1986 年发现并报道的 (邱铸鼎, 1988)。其动物群的时代被认为是上新世初期 (童永生等, 1995; Qiu and Qiu, 1995; Qiu et al., 1999; Qiu and Storch,

2000)。

从进化角度上, *Chardinomys* n. sp. (M1 具 3 个齿根), 向 *C. yusheensis* (M1 具 4 个齿根) 的转换发生在 93002 地点的 CL3, 而 *Chardinomys* “*bilikeensis*” (M1 具 3~4 个齿根) 可能是一个混合种, 正好处于这一转换的时期 (张兆群等, 2000); 从共生哺乳动物看, 72074(4) 地点的 L5 与比例克共有者最多, 如 *Erinaceus*, *Trischizolagus*, *Prospermophilus orientalis*, *Atlantoxerus*, *Aratomys bilikeensis*, *Pliosiphneus lyratus Paralactaga*, *Pseudomeriones abbreviatus*, *Huaxiamys*, *Chardinomys yusheensis*, *Allorattus engesseri* 等 (张兆群等, 2001), 其中, *Aratomys bilikeensis* 最具代表性, 因为雷家河地区只在该层出现。因此, 比例克动物群的时代应在 4.4Ma 左右。

3.4 贺丰小红凹 1~2 层动物组合

小红凹地点就是 Teilhard 和 Young (1930, 1931) 的贺丰第 1 地点。因其下部红粘土底部发现了 *Gazella blacki*, *Hipparion houfenense*, *Antilospira licenti*, *Elephas* 等 6 种较进步的动物化石, 长期以来被称为“静乐红土”并作为静乐期代表中国上新世早期 (李传夔等, 1984)。通过对小哺乳动物化石的研究, 其时代被确定为上新世晚期或相当于欧洲的 MN16 (周晓元, 1988; Qiu and Qiu, 1995; Flynn et al., 1995)。

根据 *Chardinomys lousi* 在 93001 地点出现于 3.4~3.1Ma 期间以及 *Borsodia* (相当于周晓元的 *Arvicolidae* gen. et sp. indet.) 最早出现于 3.4Ma 左右及 *Mesosiphneus paratingi* (相当于周晓元的 *Prosiphneus* sp.) 的极端进步看, 小红凹 1~2 层的时代应在 3.4~3.1Ma 的时间范围内, 因其归入 *Chardinomys lousi* 的材料中混有更进步的 *C. nihewanicus* (M1 具 6 个齿根), 而也可能其时代稍晚。

3.5 稻地组动物组合

稻地组是泥河湾盆地内位于“泥河湾层”和“三趾马红土”之间的一套总厚度约 30m 的河湖相地层。其中, 小哺乳动物化石较丰富, 被称作稻地动物群 (蔡保全, 1987)。根据其中的 *Prosiphneus* sp. 的进化水平与 *P. paratingi* 相近的特点以及鼠科动物 (蔡保全等, 1993) 中的 “*Chardinomyis nihewanicus*” (= *C. lousi*) (M1 具 5 个齿根), *Micromys* aff. *M. tedfordi* 及 *Huaxiamys* cf. *H. downsi* 以及地层关系判断, 其时代在雷家河剖面中大致在 3.5~2.6Ma。这个时代被普遍认可 (邱占祥, 1990; 童永生等, 1995; Qiu and Qiu, 1995; Flynn et al., 1997)。

3.6 宁县水磨沟动物组合

甘肃宁县水磨沟 4 种小哺乳动物化石产于午城黄土以下的粗砂层中。根据其中的 *Pseudomeriones complicidens* 以及进化水平与 *Mesosiphneus praetingi* 相当的? *M. teilhardi*, 其时代被认为属上新世晚期 (张兆群, 1999)。根据 *Pseudomeriones complicidens* 与 *M. praetingi* 共生的时段, 该动物组合在雷家河剖面中的位置大致在 3.4~3.0Ma 期间。

3.7 周口店第 18 地点动物组合

该地点动物组合的时代最早被认为属泥河湾期 (狭义), 早于周口店第 13 地点、晚于

周口店第 12 地点 (Teilhard, 1940)。后根据其中的 *Allocricetus ehiki* 以及 *Allophaiomys terrae-rubrae* 的原始性质被认为早于周口店第 12 地点和狭义泥河湾期 (郑绍华, 1984; Zheng and Li, 1990; Zheng and Han, 1991)。在 93001 剖面上, *Allophaiomys terrae-rubrae* 最早出现于 3.1Ma 左右, 而其后裔 *A. pliocaenicus* 最早出现于大约 2.0Ma, 因此周口店第 18 地点动物组合的时代应早于 2.0Ma, 但不可能早到 3.1Ma, 或许将其置于早更新世早期是较合理的。

3.8 淄博孙家山 A 动物群 (1、4 地点)

该动物组合产于裂隙堆积。因其 *Brevilagus brachypus* (Zhang, 2001), *Hypolagus schreuderi*, *Sciurotamias praecox*, *Allophaiomys terrae-rubrae*, *Allocricetus ehiki* 和 *Episiphneus youngi* 和周口店第 18 地点共有而将它们视为同一时代 (郑绍华等, 1997)。根据其中的 *Allophaiomys terrae-rubrae* 及 *Hyperacrius yenshanensis* 没有与其相应的祖先 *Cromeromys gansunicus* 及 *Borsodia* n. sp. 相共生的时段在 93001 地点的 WL6~WL1, 其时代大致在 2.5~2.1Ma 范围。

3.9 怀柔黄坎动物组合

该动物组合产自洞穴堆积, 因其含有 *Episiphneus youngi* 而将其时代与周口店第 18 地点相对比 (黄万波等, 1983), 加之所含 *Allophaiomys terrae-rubrae* 及 *Hyperacrius yenshanensis* 可与淄博孙家山 A 动物群相对比 (郑绍华等, 1997)。在 93001 地点剖面上, 黄坎动物组合与孙家山 A 动物组合应占据大致相当的时间范围。

3.10 洛川拓家河、黑木沟午城黄土下部动物组合

从黄土—古土壤序列及古地磁年代判断, 洛川剖面 (刘东生等, 1985) 的 W1~3 相当于文王沟 93001 地点的 WL6; Ws~3 相当于 WL5~WL4; W1~2 相当于 WL3; Ws~2 相当于 WL1~WL2。因此, 其所含哺乳动物化石的时代与 93001 地点的上述层位应是相对应的。

致谢 本文写作过程中, 邱铸鼎、吴文裕研究员分别提供了他们收藏的内蒙古二登图、比例克及榆社盆地动物群的标本以供参照对比, 并对标本的鉴定提出意见与建议; 甘肃灵台县文化馆王义涛先生及中国科学院古脊椎动物与古人类研究所周伟、董守朋先生参加野外的调查与发掘工作, 在此一并致谢。

LATE MIOCENE-EARLY PLEISTOCENE BIOSTRATIGRAPHY OF THE LEIJIAHE AREA, LINGTAI, GANSU

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Summary

Since the first discovery of mammalian fossils in 1964 from the Leijiahe area, Lingtai, Gansu, there have been three field teams working there on the "Leijiahe Formation", which developed on the Cretaceous limestone and before accumulation of the Loess. This Formation was thought to be of Pleistocene (Huang et al., 1979), Pliocene (Huang et al., 1993) and Late Miocene to Early Pleistocene (Zheng, 1994) respectively. In 1998~1999, financed by the NSF we did more detailed biostratigraphic works on three sections, namely, Loc. 93001, 93002 and 72074(4) section (Zheng and Zhang, 2000; Zhang and Zheng, 2000, 2001). The present paper gives synthetic analysis with small mammals from the three sections and comparison with some faunas from North China.

1 Stratigraphic correlation and biostratigraphic classification

After the work with the 93001 section in 1998 (Zheng and Zhang, 2000), more horizons added up in 1999, therefore, the Zone I of Loc. 93001 section includes WL27~WL17, and the Zone V includes WL6~WL1 + in this section (Fig. 1)

By lithostratigraphic and biostratigraphic correlation with the three sections, a composite profile is setup (Fig. 2) in this area.

In this area, there reorganized 6 biostratigraphic zones according to the small mammal fossils. According to the paleomagnetic results (Wei et al., 1993), an explanation was adopted here temporally, pending new data. There can be tentatively recognized 2 zones of Late Miocene, 3 zones of Pliocene and 1 of Early Pleistocene.

2 Faunal comparison

An almost complete stratigraphic section in the Leijiahe area, calibrated by paleomagnetic dating, supplies an ideal framework for comparison with isolated faunas, and comparison with other long sequence sections, such as that of Yushe basin.

1) Yushe Basin: The small mammal fossil assemblage from Mahui Fm and Taoyang member of Gaozhuang Fm can be compared with the complex from L9~L8 in the 72074(4) section by sharing: *Ochotona lagrelli*, *Pseudomeriones abbreviatus*, *Prosiphneus murinus*, *Karnimata hipparionum*, and *Chardinomys* n. sp. etc. Some primitive species, such as *Occitanomys* n. sp., and *Huaxiamys* n. sp., found from WL27~WL17 of Loc. 93001 and CL9~CL7 of Loc. 93002 have no records from Yushe, which suggests the former horizons maybe lower. The Upper Gaozhuang Fm (Nanzhuanggou and Culiugou member) dated roughly to 4.8~3.6Ma, can be correlated with the WL15~WL14 of Loc. 93001, CL5~CL1 of 93002 and L7~L3 of Loc. 72074(4). There both produced: *Ochotona lagrelli*, *Sminthoides*, *Cricetinus mesolophidus*, *Allocricetus*, *Chardina truncatus*, *Chardinomys yusheensis*, *Apodemus qiui*, *Micromys tedfordi*, and *Huaxiamys downsi*. The Mazegou assemblage dated 3.6~2.6Ma, can be compared with that from WL13~WL7 of Loc. 93001 and L2~L1 of 72074(4). Some characteristic taxa from Mazegou Fm, such as

Ochotona lagrelli, *Ochotonoides complicidens*, *Sminthoides*, *Cricetinus mesolophidus*, *Allocrietus bursae*, *A. ehiki*, *Cricetulus*, *Mesosiphneus paratingi* (compared with *M. intermedius*), *Cromeromys*, *Chardinomys louisi* and *Micromys tedfordi* are also found from Lingtai. From the Leijiahe sections, there did not find some taxa, such as *Yangia tingi*, *Y. epitingi*, *Chardinomys nihewanicus* that are abundance from Haiyan Fm of Yushe. However, *Cromeromys gansunicus* and *Borsodia chinensis* were found from Heshui, Gansu. The assemblage of *Yangia tingi*, *Borsodia chinensis* and *Chardinomys nihewanicus* was also found from Xiashagou, Nihewan, and Danangou Loc. 78001. They all can be correlated with the WL4 + ~WL1 + of the 93001 section.

2) Ertemte Fauna: This fauna was originally described by Schlosser (1924), and thought to be compared with the Polgardi fauna (MN13). By the evolutionary level of fossil murids, Storch (1987) thought this fauna of about 7~5Ma. From the Leijiahe sections, most Ertemte elements discovered in the horizons of about 5.0Ma, e.g. *Ochotona lagrelli*, *Eutamias*, *Sicista*, *Lophocricetus*, *Paralactaga anderssoni*, *Sminthoides*, *Sinocricetus zdanskyi*, *Nannocricetus mongolicus*, *Kowalskia similis*, *K. neimengensis*, *Pseudomeriones abbreviatus*, *Prosiphneus*, *Karnimata hipparionum*, *Micromys chalceus* and *Apodemus orientalis* etc. Therefore, the Ertemte fauna can be compared with that of Early Pliocene in the Leijiahe sections.

3) Bilike Fauna: This fauna was first studied by Qiu (1988). Its age was basically thought as Early Pliocene (Tong et al., 1995; Qiu and Qiu, 1995; Qiu et al., 1999; Qiu and Storch, 2000). By the evolutionary stage, the turnover from *Chardinomys* n. sp. (M1 with 3 roots) to *C. yusheensis* (M1 with 4 roots) occurred at the time of CL3 of Loc. 93002. The *Chardinomys* described as a new species "*bilikeensis*" with 3~4 roots on M1 might be a composite. The complex from L5 of Loc. 72074(4) has at most same elements with the Bilike fauna by sharing: *Erinaceus*, *Trischizolagus*, *Prospermophilus orientalis*, *Atlantoxerus*, *Aratomys bilikeensis*, *Pliosiphneus lyratus*, *Paralactaga*, *Pseudomeriones abbreviatus*, *Huaxiamys*, *Chardinomys yusheensis*, *Allorattus engesseri* (Zhang and Zheng, 2001). Among them, the *Aratomys bilikeensis* is the typical element that is only recorded from this horizon. So, the age of Bilike fauna is probably ca. 4.4Ma.

4) Mammal complex from Layer 1~2 of Loc. 1, Jingle: The age of "Jingle Red Clay" of Loc. 1, first studied by Teilhard and Young (1930, 1931), was recently thought to be late Pliocene and comparable to the European MN16 (Zhou, 1988; Qiu and Qiu, 1995; Flynn et al., 1995). The *Chardinomys louisi* named by specimens from the sand at the base of the Jingle Red Clay, occurred in Loc. 93001 at ca. 3.4~3.1Ma; Arvicolidae gen. et sp. indet. described by Zhou is most probably same with the *Borsodia* with earliest record from Lingtai at about 3.4Ma. And combined with the occurrence of extremely derived *Mesosiphneus paratingi* (*Prosiphneus* sp. of Zhou), the layer 1~2 of Loc. 1, Jingle, should be about 3.4~3.1Ma. However, some materials of *Chardinomys louisi* described by Zhou with 6 roots on M1, which might be *C. nihewanicus*, suggest that its age is also possible slightly later.

5) Daodi fauna: The Daodi fauna was found by Cai (1987) from a set of fluvial sediments between the "Hipparion Red Clay" and "Nihewan Bed", with abundant small mammal fossils. By the evolutionary stage of "*Prosiphneus* sp.", which is equivalent to *M. paratingi*, "*Chardinomys nihewanicus*", possibly *C. louisi* (M1 with 5 roots), *Micromys* aff. *M. tedfordi*, and *Huaxiamys* cf. *H. downsi*, the age of this fauna should be roughly the same with Zone V of Lingtai, about 3.5~2.6Ma.

6) Ningxian Faunal complex: There found 4 species from coarse sand layer below the Wucheng Loess. By the most derived *Pseudomeriones complicidens* and evolutionary stage of ? *M. teilhardi*, which is comparable with *Mesosiphneus praetingi*, its age was

thought to be late Pliocene (Zhang, 1999). Compared with the Leijiahe sections, this fauna could be at 3.4~3.0Ma, by the coexistence of these two species.

7) Loc. 18, CKT: By the primitiveness of *Allocricetus ehiki* and *Allophaiomys terrae-rubrae*, this fauna was thought to be Nihewanian stage (Sensu Stricto) (Zheng, 1984; Zheng and Li, 1990; Zheng and Han, 1991). From the Loc. 93001 section, *Allophaiomys terrae-rubrae* occurred from about 3.1Ma, its descendant *A. pliocaenicus* first occurred at ca. 2.0Ma. Therefore the age of Loc. 18 is most probably of Early Pleistocene, earlier than 2.0Ma.

8) Fauna A of Zibo: This fauna includes fossils from two localities, Loc.1 and Loc.4 of fissure fillings. By the same elements: *Brevilagus brachypus* (Zhang, 2001), *Hypolagus schreuderi*, *Sciurotamias praecox*, *Allophaiomys terrae-rubrae*, *Allocricetus ehiki*, and *Episiphneus youngi* with that of Loc. 18, CKT, this fauna was thought to be equivalent in age with the latter fauna (Zheng et al., 1997). By the occurrence of *Allophaiomys terrae-rubrae* and *Hyperacrius yenshanensis*, absence of their ancestor species *Cromeromys gansunicus* and *Borsodia* n. sp., its age should be of 2.5~2.1Ma compared with the WL6~WL1 of Loc. 93001.

9) Huangkan, Beijing: This fauna includes *Episiphneus youngi*, *Allophaiomys terrae-rubrae* and *Hyperacrius yenshanensis*, which can be comparable with the fauna A of Zibo. It should be compared in the same period as the latter in the Loc. 93001 section.

10) Luochuan Fauna: By the loess-paleosol sequence and the paleomagnetic dating, the WL6~WL1 of Loc. 93001 can be correlated to the W11~Ws2. The age of fossils should also be the same.

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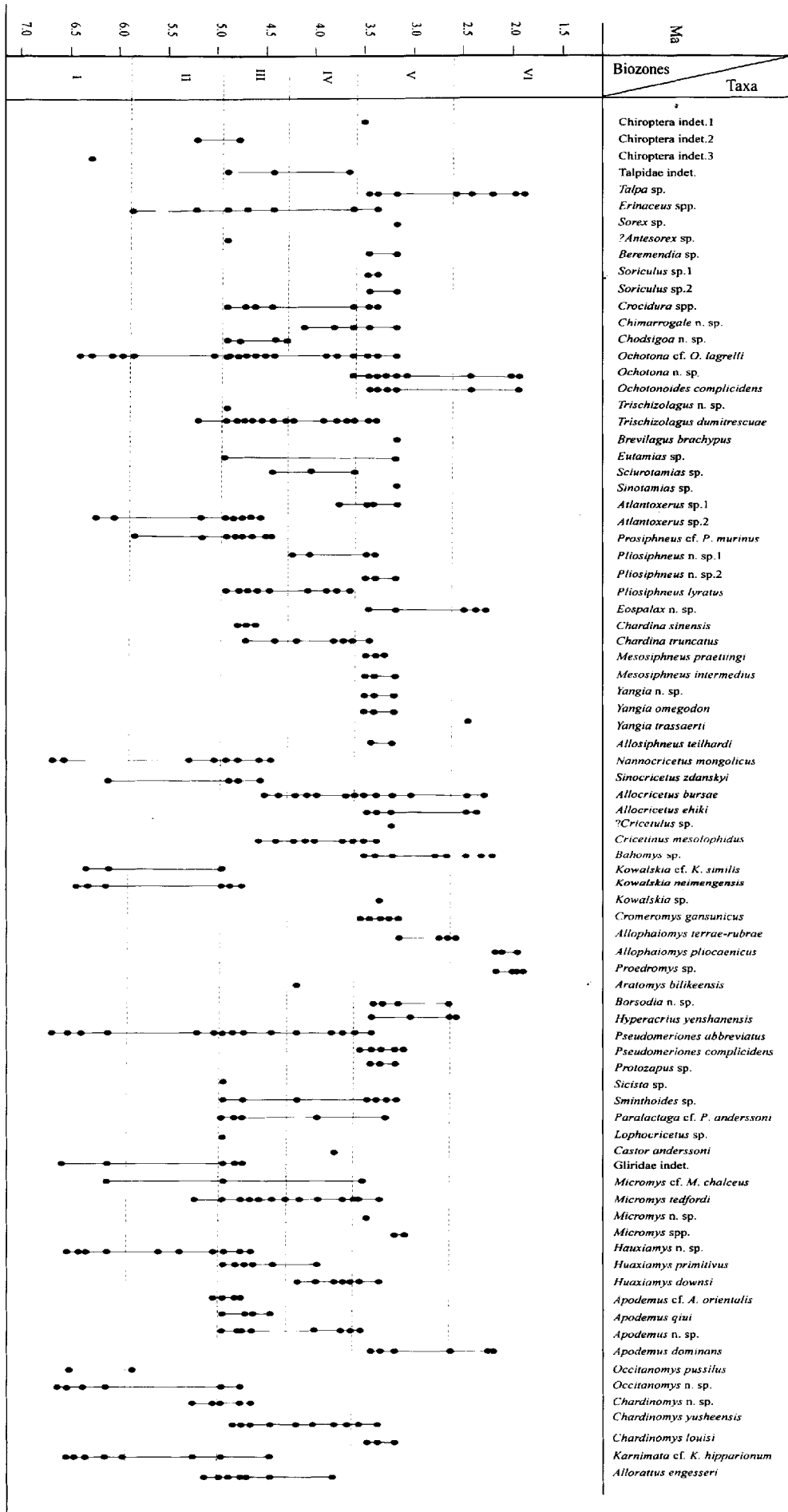


图 3 灵台小哺乳动物化石的时代分布
Fig. 3 Chronological distribution of small mammals from Lingdat, Gansu