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甘肃灵台小石沟晚中新世—上新世小哺乳动物生物地层[1)]

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摘要 根据发现的大量小哺乳动物化石，将甘肃灵台小石沟 72074(4)地点剖面划分出 4 个生物地层带．I 带与榆社马会组化石组合相当，为中新世晚期；II 带、III 带及 IV 带代表中国上新世较为完整的小哺乳动物生物地层层序．

关键词 甘肃灵台小石沟，上新世，小哺乳动物，生物地层学

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近 20 年来，中国晚新生代哺乳动物地层学的研究多以地方动物群的排序及哺乳动物分期工作为主(李传夔等，1984；邱占祥等，1990；童永生等，1995；Qiu et al., 1999)．然而，被排序的动物群中仅有不到一半是以地层实体为基础的，化石在年代表中的相对位置主要根据动物群中各分类单元的系统发育关系来确定(Tedford, 1995)．由于受特殊地理环境的影响，中国晚新生代哺乳动物尤其是小哺乳动物具有强烈的地方特色，广域性的生物年代序列并不完全适合于中国。因此，寻找连续地层剖面并研究其所含哺乳动物化石的分布规律，确立中国晚新生代完整的生物地层层序，并借助磁性地层学进一步完善中国的生物地层年代表已成为国内外同行们的共识(Tedford, 1995; Flynn et al., 1997；童永生等，1995；郑绍华等，2000)．

甘肃灵台雷家河村附近的文王沟和小石沟剖面地层相当连续，大量小哺乳动物化石的发现为晚中新世—早更新世生物地层学研究提供了理想的条件。郑绍华等(2000)及张兆群等(2000)初步报道了文王沟剖面的生物地层划分，但由于岩相限制，该剖面中相当于早上新世层位的小哺乳动物化石较少。在距离文王沟剖面约 1km 的小石沟 72074(4)地点剖面，大量化石的发现可以弥补这一时段的不足。

小石沟剖面化石的采集方法与文王沟剖面的方法一样，首先去除剖面表层风化物，开挖出新鲜剖面，按岩性将厚 35.9m 的剖面划分出 11 个大的层位及 26 小层，平均每小层取土样约 500kg 进行筛洗．为避免出现上下层混样，每小层取完样品后均清理干净，再取下层样品，保证了样品层位的准确性。经室内选样和整理研究，小石沟剖面共发现小哺乳动物化石 43 种。

本文将详细描述小石沟剖面的地层及小哺乳动物化石在地层中的分布，结合文王沟

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剖面讨论晚中新世—上新世生物地层的划分并在该地区初步建立起上新世生物地层层序。至于文王沟、小石沟 3 个剖面分带及层位对比将在下一篇文章中详加阐述。

1　地层划分与剖面描述

小石沟剖面位于甘肃灵台雷家河村东南约 1km，距离文王沟剖面约 1km(郑绍华等，2000，图 1)。沉积物以河湖相为主，沉积韵律清楚可分。因此剖面的分层以一个完整的沉积旋回为一层，各层内按照岩性又细分为不同的小层。剖面实测厚度 35.9m。

马兰黄土覆盖

L1. 棕红色粘土，含少量的钙质结核　1.1m

L2. 棕黄色砂砾石，砂砾石成分以钙质结核为主，砾径 0.1～2cm，平均 0.5cm，分选好，磨圆度好，胶结松散　0.30m

L3.　2.20m

L3-1 棕红色粉砂岩、灰绿色泥岩及棕黄色砂砾石　0.64m

L3-2 灰绿色泥岩　1.10m

L3-3 棕黄色砂砾石，砾石成分以钙质结核为主，含少量花岗岩、片麻岩等成分，砾径 0.5～2cm，分选度中等，磨圆好，胶结坚硬，地形上成陡坎　0.46m

L4.　3.20m

L4-1 灰绿色泥质粉砂岩，含大量钙质结核，结核大小均一，砾径约 0.5cm　0.70m

L4-2 灰绿色泥岩，或相变为棕黄色、灰褐色泥质粉砂岩，夹钙质结核为主的砂砾石透镜体　2.20m

L4-3 灰白色砂砾石层，砾石以钙质结核为主，含极少量花岗岩、变质岩成分，钙质胶结坚硬，地形上成陡坎　0.30m

L5.　3.90m

L5-1 棕褐色泥质粉砂岩　0.50m

L5-2 棕黄色砂砾石，厚度变化较大，分选差，钙质胶结，砾径较均一(约 0.5cm)　0.50m

L5-3 灰绿色泥岩、棕褐色泥质粉砂岩　1.10m

L5-4 厚层砂砾石，以钙质结核为主，分选好，砾径均一，泥质胶结，坚硬，地形上成陡坎，中间夹少量的泥岩透镜体。该层的中上部夹有少量中—大型的花岗岩、变质岩砾石　1.80m

L6.　4.70m

L6-1 上部灰褐色，棕黄色粉砂岩夹灰绿色泥岩，下部纯净的灰绿色泥岩　2.40m

L6-2 灰褐色泥岩　1.40m

L6-3 灰白色砂砾石，钙质结核为主，夹少量花岗岩、片麻岩等砾石　0.90m

L7.　2.80m

L7-1 棕黄色、灰褐色泥质粉砂岩，夹薄层砂砾石透镜体，含少量的大型花岗岩砾石(砾径大于 20cm)　2.40m

L7-2 棕黄色砂砾石，砂砾石由花岗岩、片麻岩、钙质结核等组成，砾石磨圆度较好，分选差，松散胶结　0.40m

L8. 6.90m

L8-1 灰褐色泥质粉砂岩，夹钙质结核层 1.50m

L8-2 灰绿色泥岩 0.60m

L8-3 灰绿色、土黄色、棕黄色泥岩，含大量植物遗迹 2.00m

L8-4 灰褐色泥质粉砂岩、底部为砂砾石层，厚度变化快，砾石以花岗岩、片麻岩为主，少量砾径可达 15cm，磨圆度好，分选差，松散胶结 2.80m

L9. 4.10m

L9-1 棕红色、棕黄色粉砂岩、泥岩 2.30m

L9-2 棕黄色砂砾石，砂岩与砾石层交错分布、夹少量的粉砂岩。砂砾石成分以花岗岩、片麻岩、石英岩等为主、同时有少量的钙质结核，砾石磨圆度好，分选中等，胶结较坚硬 1.80m

L10. 灰褐色泥质粉砂岩、下部夹少量的灰绿色泥岩 3.00m

L11. 3.70m

L11-1 紫红色粘土 0.60m

L11-2 棕红色、棕黄色泥质粉砂岩、底部有 20cm 砂砾石层、砂砾石成分以钙质结核和下伏白垩系泥岩角砾为主 3.10m

--------- 假整合 ---------

白垩系泥岩

2 与文王沟剖面的对比

从小石沟剖面的沉积序列分析，该剖面包含了 4 个较大的沉积单元。L11～L10 层与 L1～L2 层分别为紫红色或红色粘土为主，此种类型的红色粘土在灵台任家坡附近非常发育，根据孙东怀等(1998)研究，代表了风成沉积为主的沉积类型；L9 至 L3 层为河湖相沉积，从沉积物的物质来源判断，又可分为两种类型：下部 L9 至 L7 层中含大量花岗岩、片麻岩砾石，砾石砾径大，磨圆度好，代表了远距离高能搬运过程，根据作者的初步考察与区域地质资料，灵台周边地区没有明显的岩浆岩与变质岩出露，这些砾石可能来源于南部的秦岭地区；L6 层至 L3 层中砾石组成以小型钙质结核占主导地位，代表了不同沉积环境下的近距离低能搬运过程。

根据野外的观察测量以及对沉积环境的分析，小石沟剖面的 L1～L2 相当于文王沟 93001 地点剖面的 WL12 与 WL13 层；L3～L7 可与 WL14～WL15 层对比；L8～L9 与 WL16 大体相当；由于砾石层沉积前对下部层位的剥蚀程度可能存在的差异，L10～L11 与文王沟剖面的对比目前尚未解决。

3 生物地层带的划分

根据小哺乳动物化石的进化水平及在地层中的分布(图 1)，小石沟剖面从下向上可分为 4 个生物地层带。

I 带：地层单元为 L11～L8。主要组成分子为：*Occitanomys pusillus*, *Occitanomys* n.

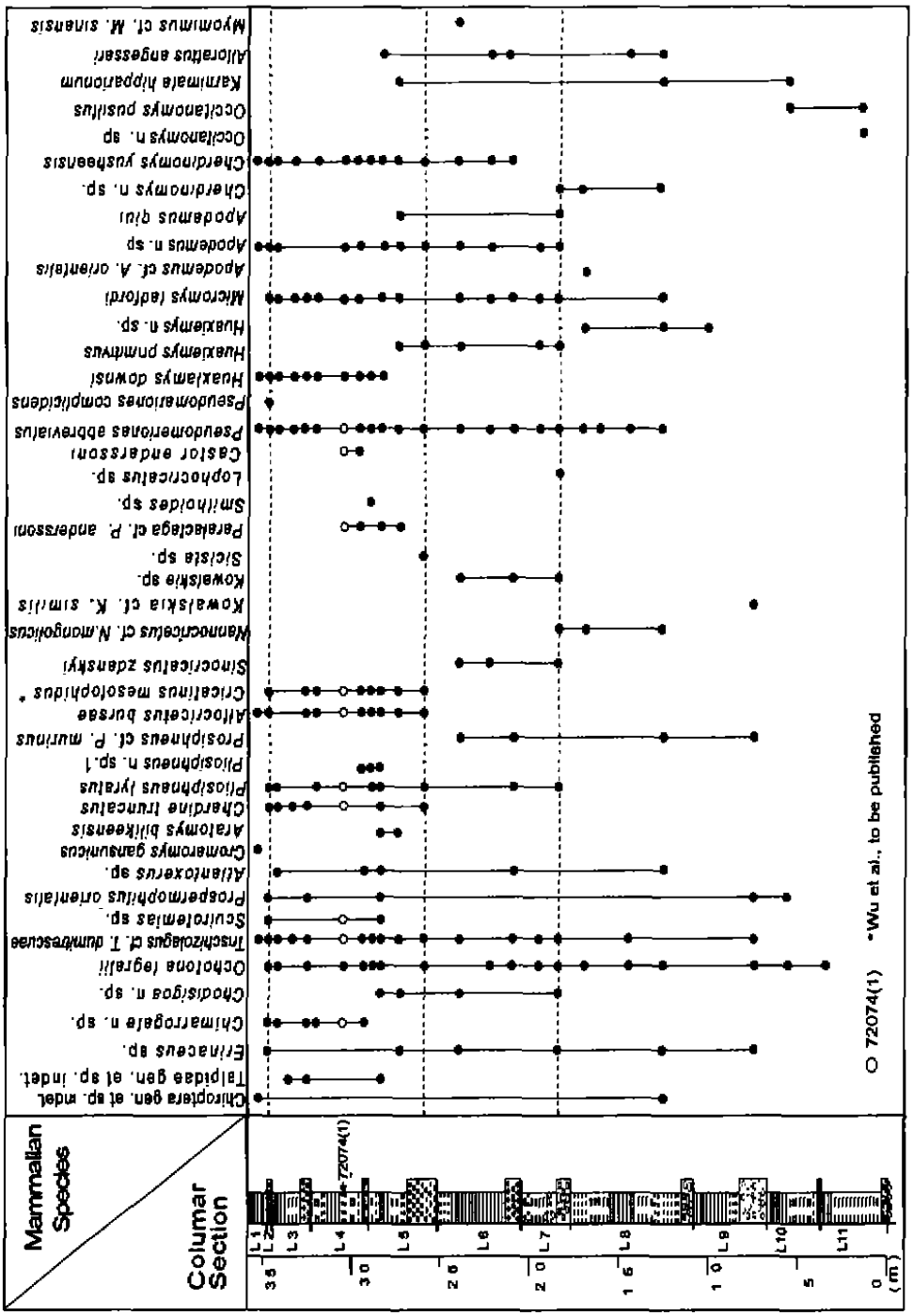

图1　小石沟72074(4)地点剖面小哺乳动物化石在地层中的分布

Fig.1　Distribution of micromammals in the Xiaoshigou section

sp., *Karnimata hipparionum*, *Huaxiamys* n. sp., *Micromys tedfordi*, *Apodemus* cf. *A. orientalis*, *Allorattus engesseri*, *Pseudomeriones abbreviatus*, *Nannocricetus* cf. *N. mongolicus*, *Prosiphneus* cf. *P. murinus*, *Trischizolagus* cf. *T. dumitrescuae*, *Ochotona lagrelii* 等。其中 *Trischizolagus* cf. *T. dumitrescuae*, *Micromys tedfordi*, *Allorattus engesseri* 等为最早的出现记录。

II 带：地层单元为 L7～L6。主要组成分子为：*Chodisigoa* n. sp., *Trischizolagus* cf. *T. dumitrescuae*, *Ochotona lagrelii*, *Pliosiphneus lyratus*, *Prosiphneus* cf. *P. murinus*, *Sinocricetus zdanskyi*, *Nannocricetus* cf. *N. mongolicus*, *Pseudomeriones abbreviatus*, *Huaxiamys primitivus*, *Micromys tedfordi*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys* n. sp., *Chardinomys yusheensis*, *Allorattus engesseri* 等。其中 *Chodisigoa* n. sp., *Pliosiphneus lyratus*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys yusheensis*, *Huaxiamys primitivus* 为各自的最早出现记录；*Prosiphneus* cf. *P. murinus*, *Sinocricetus zdanskyi*, *Chardinomys* n. sp. 等最后绝灭。

III 带：地层单元为 L5～L3。该带化石种类与数量明显增加，主要组成分子有：Talpidea gen. et sp. indet., *Erinaceus* sp., *Chimarrogale* n. sp., *Ochotona lagrelii*, *Trischizolagus* cf. *T. dumitrescuae*, *Prospermophilus orientalis*, *Atlantoxerus* sp., *Aratomys bilikeensis*, *Chardina truncatus*, *Pliosiphneus lyratus*, *Allocricetus bursae*, *Cricetinus mesolophidus*, *Paralactaga* cf. *P. anderssoni*, *Pseudomeriones abbreviatus*, *Huaxiamys downsi*, *Micromys tedfordi*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys yusheensis*, *Karnimata hipparionum*, *Allorattus engesseri* 等。*Chimarrogale* n. sp., *Aratomys bilikeensis*, *Chardina truncatus*, *Allocricetus bursae*, *Cricetinus mesolophidus*, *Huaxiamys downsi* 等的出现分别为其最早的化石记录，并同时伴随着 *Huaxiamys primitivus*, *Karnimata*, *Allorattus engesseri* 等种类的最后出现。

IV 带：地层单元为 L2～L1。*Trischizolagus* cf. *T. dumitrescuae*, *Cromeromys gansunicus*, *Allocricetus bursae*, *Pseudomeriones abbreviatus*, *Pseudomeriones complicidens*, *Huaxiamys downsi*, *Chardinomys yusheensis*, *Apodemus* n. sp. 等为主要组成分子。

4 生物地层带讨论与对比

I 带：该剖面的 L11～L10 层产出少量具原始特征的鼠科种类显示出其时代可能较早，如第 11 层发现少量 *Occitanomys* n. sp.，其 M1 上具发育的 t12，tlbis 缺失，t3 无后刺，t3～t5 不连接，显示出其所具有的原始性状，与文王沟 93001 和 93002 地点剖面的 I 带发现的同种标本相当，该种在进化水平上较 Turolian 早期的 *O. sondaari* 进步，与 Turolian 中期的 *O. adroveri* 相当（张兆群等，2000）。但考虑到标本和种类少，暂时与上部的 L9～L8 层产出的化石归为同一组合。

目前已知最为原始的 *Huaxiamys* n. sp. 从剖面的 L9 层出现，在文王沟 93001 地点剖面中出现在 WL20 与 WL21 层（郑绍华等，2000），在 93002 地点剖面延续时限较长，从 CL8 至 CL2 层（张兆群等，2000）。

Kanimata hipparionum 曾发现于内蒙古二登图(Storch, 1987)和榆社的马会组及高庄组(Tedford et al., 1991)，文王沟 93001 地点剖面上仅发现于 WL17 层以下的层位(郑绍华等，2000)，在 93002 地点剖面上也发现于层位相当的 I 带。在本剖面上主要发现于 LI0 层与 L8 层，并向上延续至 L5 层。

Micromys tedfordi 与二登图动物群中的 *Micromys chalceus* 相比较，个体明显较大，MI 有 5 个齿根，具 t7 和 tI2。在榆社盆地该种发现于高庄组与麻则沟组(吴文裕等，1992)。在灵台从本剖面的 L8 层开始出现向上延续至 L2 层，最高出现层位为文王沟 93001 地点剖面的 WLI0 层。

Apodemus cf. *A. orientalis* 标本较少，只发现于 L8 层，此种大量出现在二登图与榆社的马会组。

内蒙古比例克发现的大型鼠科化石种类 *Allorattus engesseri* (Qiu and Storch, 2000)从 L8 层出现，延续至 L5 层。

Pseudomeriones abbreviatus 在本剖面最低发现于 L8 层，在文王沟 93001 地点剖面则最低从下部的 WL20 层就开始出现。该种的地理分布范围较广，中国已发现于甘肃庆阳、泾川、山西榆社及内蒙古二登图、比例克等地，国外主要有希腊 Ano Metechi 3 地点、阿富汗 Pul-e Charkhi 地点等(Sen, 1983, 1998; 张兆群，1999)。

L9 层出现低冠鼢鼠化石 *Prosiphneus* cf. *P. murinus*，该种在榆社盆地只发现于马会组(Tedford et al., 1991)。

兔形类中的 *Trischizolagus* 从 L9 层开始出现一直延续至文王沟剖面的 WL10 层。该属分布范围较广，曾发现于希腊、罗马尼亚、法国，阿富汗、蒙古等地，除蒙古标本可能为中新世晚期或上新世早期外(Flynn and Bernor, 1987)，欧洲主要发现于上新世早期(Radulesco and Samson, 1967; Sen, 1983; Bruijn et al., 1970)。

另外二登图动物群中 *Nannocricetus mongolicus* 与 *Kowalskia similis* 在此带有少量出现。

张兆群等(2000)根据 *Occitanomys* 的原始性状及 *Karnimata* 演化水平的对比，认为文王沟两地点的 I 带可能相当于保德期中期。本带化石除下部层位发现少量的原始类型 *Occitanomys* 外，动物化石组合中，大型的 *Micromys* 开始出现，最原始的 *Chardinomys* 从 *Occitanomys* 演化出来，*Allorattus* 开始出现等显示出此化石带应当晚于文王沟两地点剖面的 I 带，可能相当于保德期晚期。与山西榆社盆地的马会组化石组合共有 *Ochotona lagrelii*、*Prosiphneus* cf. *P. murinus*、*Pseudomeriones abbreviatus*、*Kanimata hipparionum*、*Apodemus orientalis* 等，它们的时代应大致相当。

II 带：除 *Occitanomys*、*Apodemus* cf. *A. orientalis*、*Kowalskia* cf. *K. similis* 等外，I 带化石组合中其他种类几乎全部延续至 II 带，同时大量进步种类开始产生。

Apodemus n. sp. 取代 *Apodemus* cf. *A. orientalis* 大量出现，与后者相比较该种显示出明显进步的特征：个体大，齿冠高，所有 MI 标本上具 t7，tI 具发育的后刺，t3 相对于 t2 前置。

Chardinomys 发生了重要转化，由 *Chardinomys* n. sp. 演化出 *C. yusheensis*：MI 上 t3～t5～t4 的连接完全形成，其与牙齿纵轴夹角明显增大，t5 趋于梭形，个体增大，MI 齿根数目由 3 个增加到 4 个等。

Huaxiamys 发生了重大转换，I带开始出现的 *Huaxiamys* n. sp. 逐渐退出，*H. primitivus* 产生：M1 上 t1～t2～t1bis 的脊形化可作为重要标志。

Micromys tedfordi 从本带开始大量出现。

I带开始出现的 *Prosiphneus* cf. *P. murinus* 在此带逐渐绝灭，代之出现齿冠较高、个体较大的 *Pliosiphneus lyratus*。

从化石组合上，该化石带与文王沟 93002 地点剖面的 II 带共有 *Huaxiamys primitivus*、*Micromys tedfordi*、*Allorattus engesseri*、*Sinocricetus zdanskyi*、*Nannocricetus* cf. *N. mongolicus*、*Pseudomeriones abbreviatus*、*Trischizolagus* cf. *T. dumitrescuae*、*Ochotona lagrelii* 等。因此，可以认为此两地点的 II 带可直接对比。该化石带的底部与二登图动物群 (Fahlbusch et al., 1983; Storch, 1987; Wu, 1991; Qiu, 1987) 共有 *Ochotona lagrelii*、*Pseudomeriones abbreviatus*、*Nannocricetus* cf. *N. mongolicus*、*Kowalskia* cf. *K. similis*、*Sinocricetus zdanskyi*、*Karnimata hipparionum* 等而大体相当。榆社盆地此时段化石种类少，无法详细比较。

III 带：I 带或 II 带开始出现的鼠科种类如 *Apodemus* n. sp.、*Micromys tedfordi*、*Chardinomys yusheensis*、*Pseudomeriones abbreviatus*、*Trischizolagus* 等在本带内继续生存繁衍，达到繁盛期。而 "*Karnimata*" *hipparionum* 与 *Allorattus engesseri* 则逐步走向灭绝。

Huaxiamys primitivus 在此带内最后绝灭，进步种类 *H. downsi* 产生，吴文裕等 (1992) 对两个种的进化关系有过详细研究。

仓鼠中，*Allocricetus bursae* 与 *Cricetinus mesolophidus* 从本剖面的第 5 层开始大量出现，分别代表了各自的最早化石记录。

Chardina truncatus 的出现标志着鼢鼠的演化进入了一个新的阶段。凹枕型鼢鼠由此开始在华北地区繁盛、分化 (郑绍华，1997)。

发现于内蒙古比例克的 *Aratomys bilikeensis* 从第 5 层开始出现，据 Qiu and Storch (2000) 研究对比该种较蒙古早上新世化石地点 Chono-Khariakh 的 *A. multifidus* 原始。为该属已知最原始种。

榆社盆地高庄组南庄沟段与醋柳沟段产出的小哺乳动物化石 *Chardina truncatus*、*Chardinomys yusheensis*、*Huaxiamys downsi*、*Apodemus qiui*、*Allocricetus* 等与该带化石可较好的对比，其时代应大体相当。

IV 带：此带鼠科种类明显减少，仅 *Huaxiamys downsi*、*Chardinomys yusheensis*、*Apodemus* n. sp.、*Micromys tedfordi* 等 4 种从 III 带延续上来。文王沟 93001 地点剖面 IV 带出现的特征性种类 *Cromeromys gansunicus* 与 *Pseudomeriones complicidens* 分别从本剖面的第 1 层与第 2 层出现。*Pseudomeriones complicidens* 与 *P. abbreviatus* 在 L2 层共存，93001 地点剖面 IV 带最后出现的 *Chardina truncatus*、*Cricetinus mesolophidus*、*Huaxiamys downsi*、*Chardinomys yusheensis* 等也发现于本带内；而 93001 地点剖面 WL11 层开始出现的 *Mesosiphneus intermedius*、*Yangia*、*Eospalax*、*Borsodia*、*Chardinomys louisi* 等则没有发现。因此从化石组合对比上，该带应相当于文王沟 93001 地点剖面 IV 带下部。

5　甘肃灵台上新世生物地层层序

从以上对生物带的划分及讨论，可以看出小石沟 72074(4)地点剖面的小哺乳动物化石呈现出较强延续性，不同化石种类的演化线路清晰，为生物地层层序的建立提供了理想的基础资料。结合文王沟两地点剖面可更加充实完善起以小哺乳动物为主的上新世生物地层层序。

根据小哺乳动物化石的分析与对比，小石沟 72074(4)地点剖面的 I 带化石组合与榆社马会组组合相当，晚于文王沟 93001 地点剖面的 I 带，其时代应相当于中新世晚期。II 带与 III 带相当于文王沟 93001 地点剖面的 WL14～WL15 层，落在吉尔伯特负极性期内(郑绍华等，2000)，而 IV 带与文王沟 93001 地点剖面的 WL12～WL13 层相当，对应于文王沟剖面的 IV 带(高斯正极性期)下部。因此小石沟 72074(4)地点剖面的 II 带、III 带与文王沟剖面的 IV 带基本上代表了上新世完整的生物地层序列(表 1)。换言之，甘肃灵台上新世地层以小哺乳动物化石为依据可初步划分为 3 个较为连续的生物地层带。进一步的磁性地层学工作将为更精确的中国上新世生物年代表提供年代学对比依据。

表1　甘肃灵台上新世小哺乳动物生物地层带

Table 1　Pliocene micromammalian biostratigraphical zones of Lingtai, Gansu

Epoch	Biozone	Stratigraphic unit	Micromammal taxa		
			FAD	LAD	Dominant
Pliocene	Upper	WL12～WL7	*Ochotonoides complicidens*, *Mesosiphneus*, *Youngia omegodon*, *Cromeromys gansunicus*, *Borsodia*, *Bahomys*, *Pseudomeriones complicidens*, *Chardinomys louisi*	*Mesosiphenus*, *Pseudomeriones*, *Paralactaga*, *Micromys tedfordi*, *Chardinomys yusheensis*	*Ochotonoides complicidens*, *Mesosiphneus*, *Cromeromys*, *Borsodia*, *Pseudomeriones complicidens*, *Chardinomys louisi*, *Apodemus dominans*
	Middle	L5～L3	*Aratomys*, *Allocricetus bursae*, *Chardina truncatus*, *Huaxiamys downsi*	*Karnimata*, *Alloratus*, *Huaxiamys primitivus*	*Trischizolagus dumitrescuae*, *Ochotona*, *Chardina truncatus*, *Allocricetus bursae*, *Crieetulus mesolophidus*, *Pseudomeriones abbreviatus*, *Huaxiamys downsi*, *Chardinomys yusheensis*
	Lower	L7～L6	*Chodisgoa*, *Pliosiphneus lyratus*, *Apodemus* n. sp., *Chardinomys yusheensis*	*Prosiphaeus murinus*, *Chardinomys* n. sp.	*Ochotona lagrelii*, *Allorattus*, *Micromys tedfordi*, *Apodemus* n. sp.

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LATE MIOCENE-PLIOCENE BIOSTRATIGRAPHY OF XIAOSHIGOU SECTION, LINGTAI, GANSU

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Key words Lingtai, Gansu, Pliocene, biostratigraphy, micromammals

Summary

1 Introduction

Since 1980s, the Chinese Neogene biochronological sequence has been erected mainly by mammal faunas and their evolutionary stages (Li et al., 1984; Qiu and Qiu, 1990; Tong et al., 1995; Qiu et al., 1999). But some of them can not be convinced for lacking of continuous stratigraphic records. It is now becoming most important to look for some continuous geological sections that produce rich fossil and can be relatively easily calibrated by paleomagnetic dating to enhance the precision of the biochronological sequence in China. The sections in Wengwanggou and Xiaoshigou gullies of Lingtai, Gansu Province showed the potential for more detailed work of the period ranging from late Miocene to early Pleistocene (Zheng, 1994).

After further work on the Wenwanggou sections, a large amount of small mammal fossils were found and the primary biostratigraphic zones were erected in the sections (Zheng and Zhang, 2000; Zhang and Zheng, 2000). In this paper, the main attention is put on the Xiaoshigou section (72074(4)), which covers the interval from late Miocene to Pliocene. From this section there are totally 43 species of small mammals recognized, which distributed almost in every layer, and they could be ideal compensation for some intervals of Wengwanggou sections which produced relatively rare fossils.

2 Lithostratigraphic division and correlation

The section of Loc. 72074(4) (fig. 1) includes four major sedimentological cycles. The dark red or red clay represented by L11～10 and L1～2, are eolian sediments, which is very similar to the Red Clay of Renjiapo section (Sun et al., 1998). From L9 to L3, there developed mainly fluvial-lacustrine sediments. By the source materials

of the sediments, they can be subdivided into two units: L9～L7 and L6～L3. The former has conglomerates of granite and metamorphic rocks with large sized pebbles, reflecting long distance and high-energy transportation; the latter has conglomerates mainly composed of carbonate nodules, reflecting a short distance low-energy transportation.

According to measurements and correlation, the L1～L2 of 72074(4) section can be roughly correlated to part of the WL12 and WL13 of Loc. 93001 Section. The L3～L6 is probably simultaneous to the WL14～15. The L7～L8 may be correlated with WL16. The L10～11 should be correlated to the sediments below WL16.

3 Biostratigraphic division

By the occurrence of fossil taxa and their phylogenetic relationships, the Loc. 72074(4) section can be divided into 4 continuous biostratigraphic zones:

Zone I: L11～L8. This zone is composed of *Occitanomys pusillus*, *Occitanomys* n. sp., *Karnimata hipparionum*, *Chardinomys* n. sp., *Huaxiamys* n. sp., *Micromys tedfordi*, *Apodemus* cf. *A. orientalis*, *Allorattus engesseri*, *Pseudomeriones abbreviatus*, *Nannocricetus* cf. *N. mongolicus*, *Prosiphneus* cf. *P. murinus*, *Trischizolagus* cf. *T. dumitrescuae*, *Ochotona lagrelii* etc. Of them the *Trischizolagus* cf. *T. dumitrescuae*, *Micromys tedfordi*, *Allorattus engesseri* etc. are the earliest record respectively.

Zone II: L7～L6. The dominant elements in this zone are *Chodisigoa* n. sp., *Trischizolagus* cf. *T. dumitrescuae*, *Ochotona lagrelii*, *Pliosiphneus lyratus*, *Prosiphneus* cf. *P. murinus*, *Sinocricetus zdanskyi*, *Nannocricetus* cf. *N. mongolicus*, *Pseudomeriones abbreviatus*, *Huaxiamys primitivus*, *Micromys tedfordi*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys* n. sp., *Chardinomys yusheensis*, *Allorattus engesseri* etc. Of them the *Chodisigoa* n. sp., *Pliosiphneus lyratus*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys yusheensis*, *Huaxiamys primitivus* etc. are the earliest records and *Prosiphneus* cf. *P. murinus*, *Sinocricetus zdanskyi*, *Chardinomys* n. sp. the latest.

Zone III: L5～L3. The diversity of taxa and abundance of fossil materials increase significantly in this zone. There are mainly Talpidea gen. et sp. indet., *Erinaceus* sp., *Chimarrogale* n. sp., *Ochotona lagrelii*, *Trischizolagus* cf. *T. dumitrescuae*, *Prospermophilus orientalis*, *Atlantoxerus* sp., *Aratomys bilikeensis*, *Chardina truncatus*, *Pliosiphneus lyratus*, *Allocricetus bursae*, *Cricetinus mesolophidus*, *Paralactaga* cf. *P. anderssoni*, *Pseudomeriones abbreviatus*, *Huaxiamys downsi*, *Micromys tedfordi*, *Apodemus* n. sp., *Apodemus qiui*, *Chardinomys yusheensis*, *Karnimata hipparionum*, *Allorattus engesseri* etc. The earliest records of taxa are *Chimarrogale* n. sp., *Aratomys bilikeensis*, *Chardina truncatus*, *Allocricetus bursae*, *Cricetinus* cf. *C. mesolophidus*, *Huaxiamys downsi* etc., while *Huaxiamys primitivus*, *Kanimata*, *Allorattus engesseri* gradually died out at the same time.

Zone IV: L2～L1. In this zone there mainly found *Trischizolagus* cf. *T.*

dumitrescuae, *Cromeromys gansunicus*, *Allocricetus bursae*, *Pseudomeriones abbreviatus*, *Pseudomeriones complicidens*, *Huaxiamys downsi*, *Chardinomys yusheensis*, *Apodemus* n. sp. etc. The characteristic taxa from Loc. 93001 section, *Cromeromys gansunicus* and *Pseudomeriones complicidens* were also found from this zone.

4 Biostratigraphic correlation and discussion

Zone I: There discovered few materials of *Occitanomys* n. sp. that can be compared with the materials from Zone I of both Wenwanggou sections. By the primitive characters, it might suggest earlier in age. Considering too few specimens and lacking of other fossil evidence, the fossils from L11～L10 are temporally combined with those from L9～L8, and are included into the same biostratigraphic zone.

This zone is characterized by more derived fossil components than the Zone I of Wengwanggou Sections. Excluding the primitive *Occitanomys*, there occurred large sized *Micromys*, most primitive *Chardinomys* that evolved from *Occitanomys*, and *Allorattus* that has been discovered from Bilike. This zone can be correlated with the assemblage of Mahui Fm. of Yushe Basin by sharing *Ochotona lagrelii*, *Prosiphneus* cf. *P. murinus*, *Pseudomeriones abbreviatus*, *Kanimata hipparionum*, *Apodemus* cf. *A. orientalis* etc.

Zone II: Except *Occitanomy*, *Apodemus* cf. *A. orientalis*, *Kowalskia* cf. *K. similis* etc., almost all other elements of zone I survived into this zone, and there developed some new species. The *Chardinomys* n. sp. derived into the *Chardinomys yusheensis*, the *Huaxiamys* n. sp. into *Huaxiamys primitivus*. The large sized *Micromys tedfordi* increased significantly in number. The *Pliosiphneus* cf. *P. murinus* died out, and lager sized, higher crowned *Pliosiphneus lyratus* replaced its ecological niche. This zone can be correlated with the zone II of Loc. 93002 section by sharing *Huaxiamys primitivus*, *Micromys tedfordi*, *Allorattus engesseri*, *Sinocricetus zdanskyi*, *Nannocricetus* cf. *N. mongolicus*, *Pseudomeriones abbreviatus*, *Trischizolagus* cf. *T. dumitrescuae*, *Ochotona lagrelii* etc. The Ertemte fauna can be correlated with fossil assemblage of lower part of this zone.

Zone III: In this zone, the *Karnimata hipparionum*, *Allorattus* died out gradually. The more derived *Huaxiamys downsi* evolved from *Huaxiamys primitivus*, and the ancestor species as the latest occurrence. The *Allocricetus bursae* and *Cricetinus mesolophidus* first occurred from the L5. The first occurrence of *Chardina truncatus* initialized the booming of the siphneids especially the Mesosiphneinae in North China. The *Aratomys bilikeensis* found from Bilike first occurred from the L5 of the section, which might be the most primitive species of the genera till now.

The fossil assemblage from Nanzhuanggou and Culiugou Member of Gaozhuang Fm. can be directly correlated with this zone by sharing *Chardina truncatus*,

Chardinomys yusheensis, *Huaxiamys downsi*, *Apodemus qiui*, *Allocricetus* etc.

Zone IV: The species number of murids decreased significantly. Only *Huaxiamys downsi*, *Chardinomys yusheensis*, *Apodemus* n. sp., *Micromys tedfordi* survived into this zone. The first occurrence of *Cromeromys gansunicus* and *Pseudomeriones complicidens* characterized this zone and can be correlated with the lower part of Zone IV of Loc. 93001 section.

5 Pliocene biostratigraphic sequence of Lingtai

By the analysis of the biostratigraphic zones, it is evident that the faunal assemblages of different zones of this section show strong continuity by evolutionary stages of different taxa.

The zone I, by comparing with the fauna of Mahui Fm., and by the evolutionary stage of different taxa, is most possibly of Late Miocene in age. The zone II～III could be correlated lithologically with the WL14～WL15, which was calibrated by the paleomagnetic data of the Gilbert reversal stage. The Zone IV of 72074(4) section can be correlated with part of the Zone IV of Loc. 93001 section, which totally falls into the Gauss normal stage. So, the complete Pliocene biostratigraphic zones in the Lingtai area can be represented by Zone II～III of 72074(4) section and Zone IV of Loc. 93001 section (Table 1). In other sense, the Pliocene of North China could be divided into three continuous biostratigraphic zones.

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