第 43 卷 第 1 期
2005 年 1 月

古 脊 椎 动 物 学 报
VERTEBRATA PALASIATICA

pp. 49～60
figs. 1～3

新疆布尔津盆地晚始新世—早渐新世岩石及生物地层[1)]

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摘要: 布尔津盆地中的第三纪地层过去被称为“乌伦古河组”。该套地层的岩性组合独特,不同于乌伦古河流域该组命名剖面的乌伦古河组。依据布尔津县城西北 20 km 处的额尔齐斯河北岸出露的地层剖面,建立两个岩石地层单位:下部额尔齐斯河组和上部克孜勒托尕依组。额尔齐斯河组为一套富含铁质的色彩鲜艳的碎屑堆积,克孜勒托尕依组是一套浅黄绿色砂岩夹杂色泥岩地层。克孜勒托尕依村附近的建组剖面为一连续沉积剖面,含有 3 个确切的哺乳动物化石层位、5 个化石地点。最下部化石层含有典型的始新世 Ergilian 期哺乳动物,其余两个层位的化石均属早渐新世 Shandgolian 期哺乳动物。因此,该剖面为一 Ergilian Shandgolian (晚始新世—早渐新世) 过渡时期的地层剖面,是进一步研究该过渡期哺乳动物群替代及 Ergilian/ Shandgolian 地层界线的理想剖面。

关键词: 新疆布尔津盆地,晚始新世—早渐新世,建组,哺乳动物地层

中图法分类号: P534. 611 **文献标识码**: A **文章编号**: 1000 - 3118(2005)01 - 0049 - 12

布尔津盆地位于新疆准噶尔盆地西北缘,是与哈萨克斯坦斋桑盆地相邻的现代盆地之一。长期以来,包括布尔津盆地在内的准噶尔盆地北缘出露的大片新生代地层,都被归为含义不清的“乌伦古河组”(吴绍祖,1973;彭希龄,1975;赵喜进,1982;彭希龄、吴绍祖,1983;童永生等,1990;魏景明、童永生,1992;新疆维吾尔自治区地质矿产局,1993;中华人民共和国地质图:吉木乃、布尔津幅,1982[2)])。1998 年本课题组在准噶尔盆地铁尔斯哈巴合和哈拉玛盖乡之南的萨尔多依拉的“乌伦古河组”中分别发现了晚渐新世与早始新世等不同时代的地层(叶捷等,2000, 2001a,b; 2003a,b; 吴文裕等,2000;孟津等,2001a,b; Daxner-Höck and Wu, 2003)。为进一步弄清“乌伦古河组”的时代和分布规律,1999 年始,作者等对布尔津盆地(在 1∶20 万地质图“吉木乃、布尔津图幅”的区域内)的“乌伦古河组”做了地层和古生物考察工作。1999 年就在布尔津县附近额尔齐斯河沿岸的原“乌伦古河组”地层中,发现了晚始新世和早渐新世的哺乳动物化石(叶捷等,2002;Wu et al., 2004)。该地层的岩性组合也与乌伦古河流域哈拉玛盖乡之南的乌伦古河组命名剖面中的岩性组合明显不同。因此,有必要对“乌伦古河组”作重新研究并建立新的地层单位。本文旨在正式建组,根据岩石学和古生物学证据,作者将该地区原“乌伦古河组”分解成两个新的岩

1) 国家自然科学基金项目(编号:40172010)资助。

2) 新疆维吾尔自治区地质局区域地质调查大队,1982. 中华人民共和国地质图,吉木乃、布尔津幅。

收稿日期:2004 - 06 - 23

石地层单位。

在布尔津县城西北 20 km 处的克孜勒托尕依剖面(简称 KZ2002),岩石地层连续,含晚始新世和早渐新世的哺乳动物,且上下化石层位关系清楚,很可能跨越始新世/渐新世界线,是研究我国和亚洲地区陆相始新世/渐新世界线地层的理想地点。这些新的发现不仅有助于北疆地区基础地质和地层工作的深入,也对全球范围始新世/渐新世界线附近生物及环境演变的研究提供了新的证据和内容。

1 岩石地层

布尔津县城西北约 20 km 处的额尔齐斯河北岸的新生代地层发育(图 1)。

该套地层的下部由风化表面色彩鲜艳的砂、泥岩组成,中部以富含铁质的砂岩为主,上部为黄绿色砂岩夹杂色泥岩(图 2)。其岩性组合与乌伦古河流域哈拉玛盖乡之南的乌伦古河组的最初命名剖面[1)]中的岩性组合明显不同。典型的乌伦古河组是一套浅灰绿色厚层砂岩夹灰黄色的厚层含砂泥岩,风化表面总体为灰白色(叶捷等,2001a)。该套地层与相邻的斋桑盆地中的新生代地层的岩性也明显不同。据 Emry 等(1998)记述,斋桑盆地中的新生代地层以湖相堆积为主,纹理层发育,含有丰富的介形类、轮藻类和软体动物化石。因此,布尔津盆地中的这套新生代地层是不同于周边地区新生代地层的独特沉积。这套地层在岩性上可划分为两个岩石地层单元,分别将其命名为下部的额尔齐斯河组和上部的克孜勒托尕依组(图 3)。

建组剖面选在克孜勒托尕依村以北,位于布尔津县城西北约 20 km 处的额尔齐斯河北岸。剖面起点:N47°50.024′,E86°40.729′;剖面终点:N47°50.479′,E86°40.912′。实测剖面自上而下为:

第四系

29. 灰白色河床相砾岩,砾石以脉石英为主,分选较差 12 m

--------平行不整合--------

克孜勒托尕依组(总厚度 64.5 m)

28. 灰绿色泥岩,下部含河狸等小哺乳动物化石(XJ200203 地点) 7.5 m
27. 黄绿色泥质粉砂岩,风化表面为红棕色 3 m
26. 黄绿色泥质细砂岩 3 m
25. 黄砂岩 11 m
24. 灰绿色为主的杂色泥质粉砂岩 1 m
23. 黄绿色中、细粒泥质砂岩 4.8 m
22. 红棕色泥岩,相当于 XJ200303 化石点层位 1.7 m
21. 黄绿色砂岩,局部岩性较粗 8.1 m
20. 灰绿色含砂泥岩,风化表面为红棕色 5.3 m
19. 黑色锰质粉砂岩,含两栖犀等奇蹄类化石(XJ99027 地点) 0.7 m
18. 灰绿色含砂泥岩,下部较粗为粉砂岩 2.4 m

1) 唐克义,1955. 准噶尔盆地北部哈拉玛盖—依希白拉泉区石油普查地质报告(1∶20 万及 1∶50 万)(地质部新疆维吾尔自治区地质局 631 队第 4 分队,内部报告)。
彭希龄,1957. 石油工业部新疆石油管理局地质调查处准噶尔盆地地质综合研究(内部报告)。

17. 黄绿色细砂岩,局部粒度较粗为粗砂岩　　8.5 m
16. 浅灰绿色中、粗砂岩夹土黄色泥质细砂岩　　6 m
15. 土黄色泥质细砂岩　　1.5 m

——整合——

额尔齐斯河组(总厚度大于 55.5 m)

14. 浅灰绿色泥质粉砂岩,顶部富铁质　　2.5 m
13. 浅灰紫色为主的条纹状泥质粉砂岩与灰黄色中粒砂岩互层　　6.5 m
12. 浅灰绿色中、粗粒砂岩　　3 m

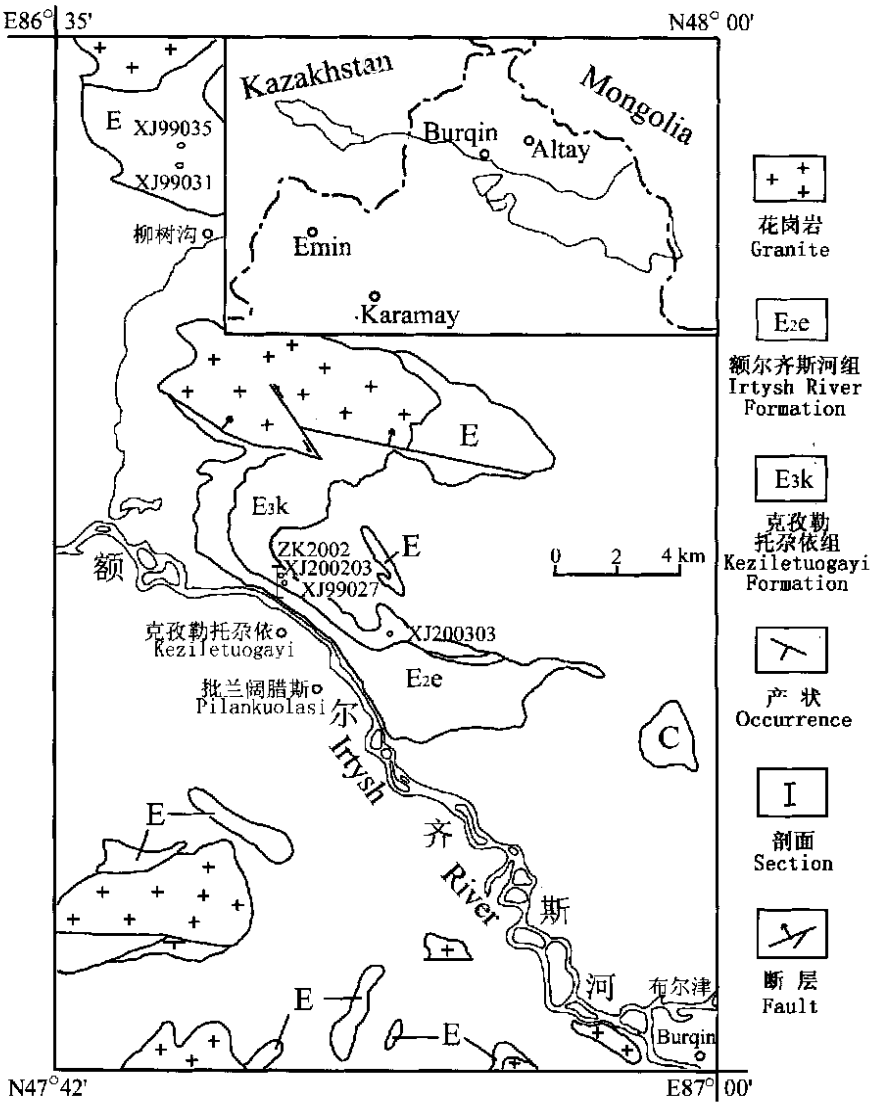

图 1　新疆布尔津盆地地理位置及其西北部地质略图示建组剖面(KZ2002)位置及克孜勒托尔依组/额尔齐斯河组间的界线

Fig. 1　Location of the Burqin Basin and sketch geological map , showing location of measured KZ2002 section and the boundary between Keziletuogayi Fm. and Irtysh River Fm.

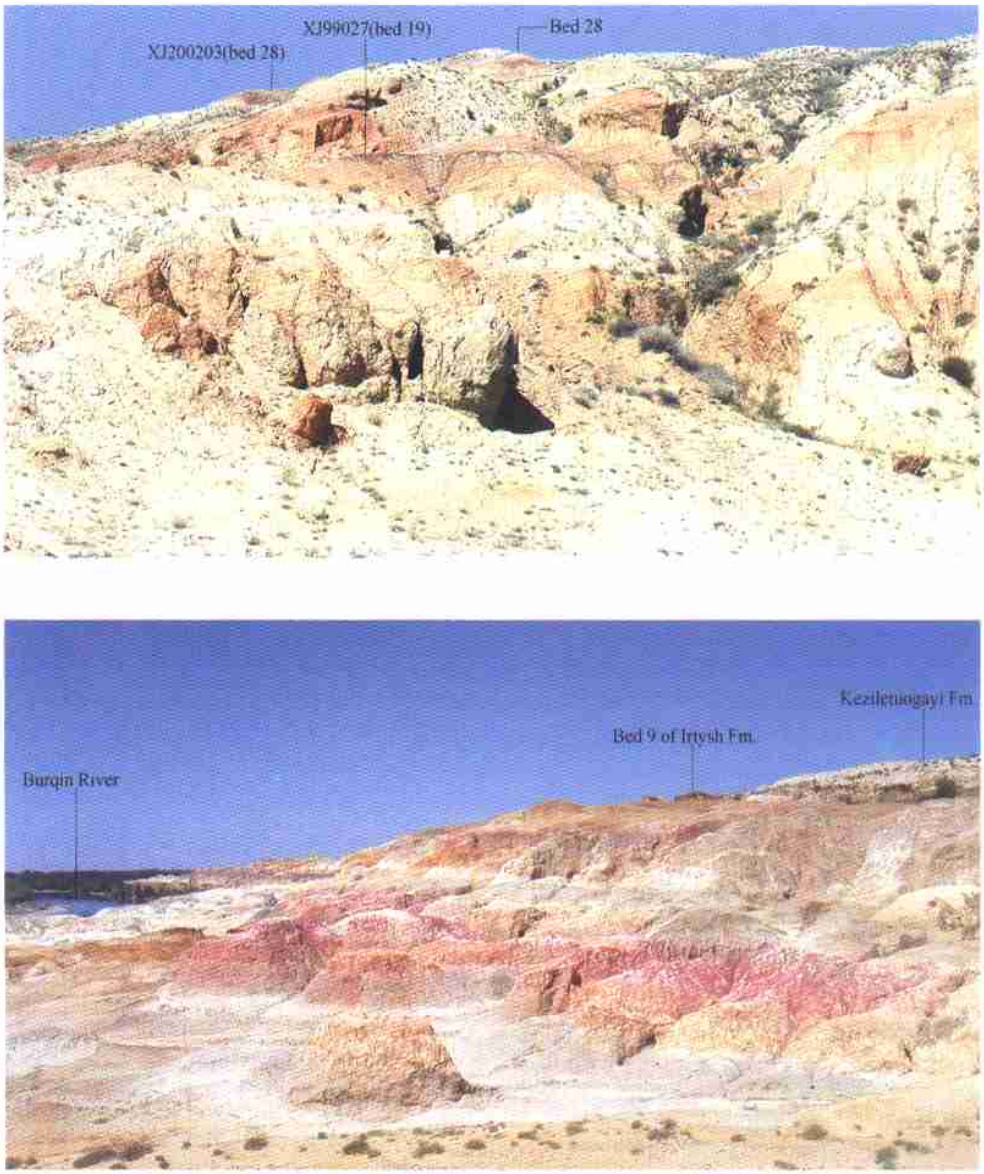

图 2 额尔齐斯河北岸克孜勒托尔依剖面(KZ2002)处克孜勒托尔依组及额尔齐斯河组地质景观

上图示克孜勒托尔依组,下图示额尔齐斯河组。由于离摄影位置低远,下图中见不到额尔齐斯河组/克孜勒托尔依组界线

Fig. 2 Views of the Irtysh River Fm. (below) and Keziletuogayi Fm. (above) at the Section KZ2002 on the north bank of the Irtysh River

The lithological boundary between two formations is beyond sight because of their far and high position

11. 浅灰绿色泥质粉砂岩,顶部富铁　1.5 m
10. 灰白色中粒砂岩,向上变细,且颜色渐发绿,交错层理发育　4.5 m
9. 含铁质条带石英细砾岩或粗砂岩　0.7 m
8. 灰白色含云母和石英颗粒泥质细砂岩,断面上可见不规则锈黄色条带,偶见小泥砾,向上粒度变粗　2.3 m
7. 浅灰白色泥岩,风化面为紫红色,具裂隙状充填物,使露头表面出现红斑状,近顶部泥岩颜色变深　7.5 m
6. 浅灰黄色泥质细砂岩　3 m
5. 锈黄色细砂岩,具斜层理　2.5 m

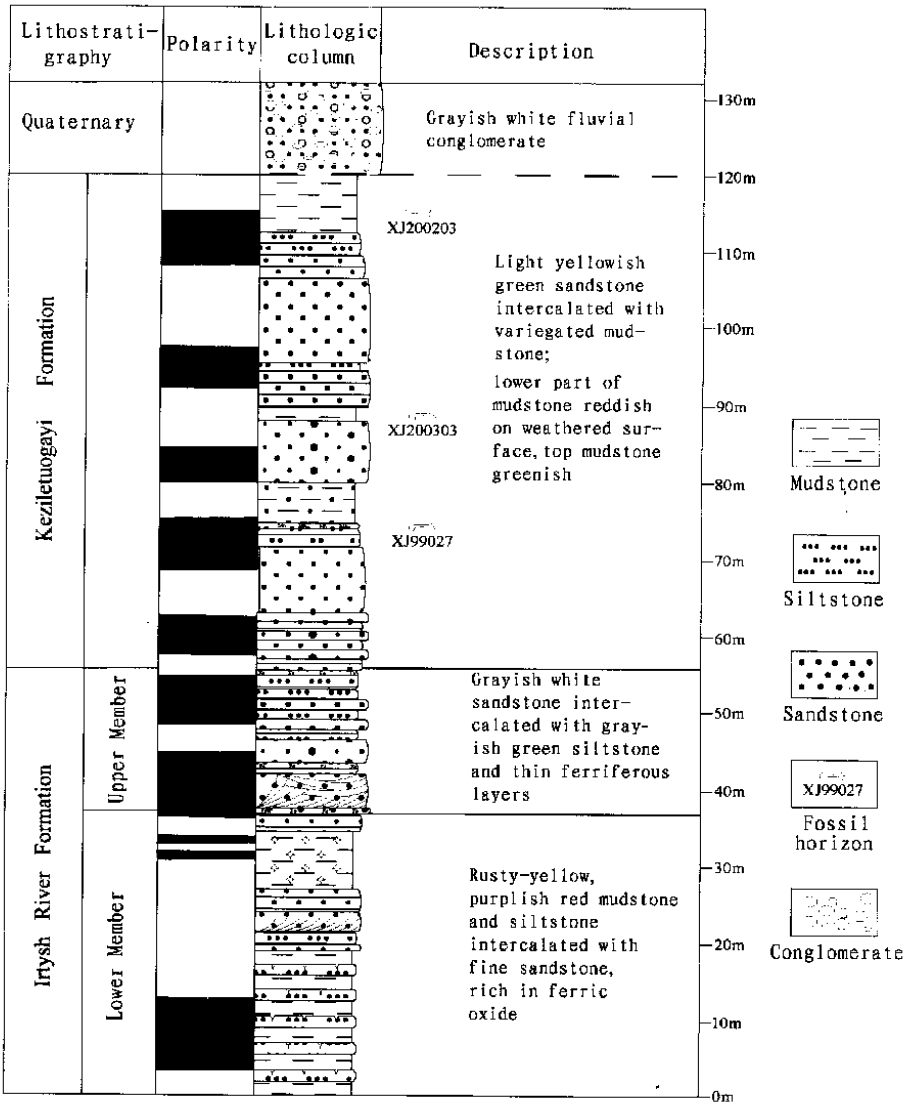

图 3　克孜勒托尕依剖面(KZ2002)柱状图示各组岩性和厚度、化石层位置及极性柱

Fig. 3　Section of Keziletuogayi (KZ2002), showing the lithology and thickness of the rock units, horizons of fossils, and paleomagnetic sequence

4. 浅灰色页片状粉砂岩夹锈黄色细砂岩,局部断面见水平微纹理,底部为一层锈色含云母细砂岩 2.5 m
3. 灰白色泥岩、粉砂岩互层,岩性同第 1 层,顶部为暗青色粉砂岩 5 m
2. 青灰色粉砂岩,断面上有呈裂隙状充填的褐黄色细砂岩 1.5 m
1. 灰白色泥岩、粉砂岩互层,未见底 可测厚度 12.5 m

额尔齐斯河组可进一步分为上、下两个岩性段。下部岩性段(1～8 层)较细,主要由泥岩、粉砂岩和砂岩组成。其中一些泥岩、粉砂岩层在沉积后曾露出水面,发生干裂,裂隙中充填了富含铁质的细砂,使其断面呈现出红褐色铁锈斑。上段(9～14 层)从含砾铁质粗砂岩层开始,向上为一套夹粉砂岩的中、粗粒砂岩,并夹有数层薄层状铁质岩。额尔齐斯河组的沉积物表面在风化后呈现出锈黄与紫红色相间的鲜艳色彩,因此很易辨认。这种鲜艳色彩应当是由于含高价氧化铁的沉积物在地层中反复出现造成的,可能是经常出现的炎热的氧化环境的产物。额尔齐斯河组分布在福海盆地以西的额尔齐斯河流域,在位于布尔津盆地西南的吉木乃盆地中也可见到该套地层的出露。在一些地点的堆积中,如在 S319 省级公路的 150 km 里程碑北侧出露的地层中,上段地层中的铁质层有增多加厚的现象。

目前尚未在额尔齐斯河组中找到化石,不可能确定其时代。根据克孜勒托尕依剖面古地磁样品测试,该段地层以反向磁极为主。考虑到其上覆地层克孜勒托尕依组的下部地层的时代为晚始新世,两组间没有明显的沉积间断,笔者推断额尔齐斯河组的时代有可能为早、中始新世。

克孜勒托尕依组是一套以浅黄绿色为主夹杂色砂泥岩地层。有些含砂泥岩风化后呈棕红色,顶部泥岩为绿色。在该组地层中已发现 3 个产哺乳动物化石的层位。在第 19 层黑色锰质粉砂岩层中(XJ99027 地点)产出以两栖犀为主的大型哺乳动物化石;在相当于第 22 层的 XJ200303 地点中,目前仅从地表采集了很少的小哺乳动物化石,其中有圆柱鼠;在第 28 层灰绿色泥岩中(XJ200203 地点)产出河狸等小哺乳动物化石。目前,克孜勒托尕依组仅见于布尔津盆地中,依据其中所产化石,克孜勒托尕依组的沉积时代为晚始新世至早渐新世。

2 哺乳动物化石组合

本文所介绍化石均产自克孜勒托尕依组,自下而上有 3 个化石层位:

1) 实测剖面第 19 层之化石点 XJ99027 (N47°50.404′, E86°40.895′)。已采集的化石均属奇蹄类,共 4 科 6 种:两栖犀科 *Cadurcodon* cf. *C. ardynensis*, Amynodontidae gen. et sp. indet., *Gigantamynodon giganteus*; 跑犀科 Indricotheriinae gen. et sp. indet.; 真犀科 Rhinocerotidae gen. et sp. indet. 和雷兽科 Brontotheriidae gen. et sp. indet.。该奇蹄类组合与云南蔡家冲动物群、内蒙古乌兰戈楚和乌尔丁鄂博动物群、蒙古的 Gua-teg、Khoer-Dzan 和 Ergilin 动物群以及哈萨克斯坦的 Kusto 动物群中的奇蹄类组成相似(叶捷等,2002)。尽管采自第 19 层的化石数量有限、种类不多,但其组合特征与晚始新世 Ergilian 期哺乳动物群的(Emry et al., 1998; Dashzeveg, 1993)一致。因此该层的哺乳动物群时代应为 Ergilian

期。

第 19 层所含孢粉组合中出现了生活在热带和亚热带的鹿藿属(*Rhynchosia*)和胡颓子属(*Elaeagnus*),没有出现代表寒冷气候的云杉和冷杉的花粉。反映了当时的气候相当温暖,甚至炎热。

2) 实测剖面第 22 层。化石点 XJ200303 (N47°49.440′, E86°43.360′)位于剖面东南 6.3 km处,仅发现 2 枚啮齿类门齿和 1 枚圆柱鼠臼齿。但依据含化石层位的岩性以及上下层位关系,我们确认该化石点与实测剖面 22 层相当,并可与实测剖面北侧约 14 km 处的另一露头上的 XJ99031 化石点(N47°57.501′, E86°38.306′)和 XJ99035 地点(N47°57.831′, E86°38.429′)的层位对比(虽然南、北露头间有花岗岩体相隔)。XJ99035 地点位于 XJ99031 的东北侧。根据初步鉴定,它们含有一些相同小哺乳动物分子,我们暂将其作为同一动物群讨论。目前从 XJ99031 和 XJ99035 地点采集到的哺乳动物化石有 7 属 8 种,分别为 *Hyaenodon* sp., *Desmatolagus* sp., *Karakoromys decessus*, *Cyclomylus lohensis*, *Cyclomylus* sp., *Cricetops dormitor*, *Eucricetodon* sp., *Plesiosminthus* sp.。这一组合与 Shandgolian 早期哺乳动物群可对比。它们以干旱型啮齿类小哺乳动物为主体,明显不同于 19 层以湿热型大哺乳动物为主的组合。

3) 实测剖面上第 28 层 XJ200203 地点(N47°50.454′, E86°40.883′)的小哺乳动物化石组合以干旱型啮齿类为主。初步的化石名单为 *Palaeoscaptor* cf. *P. acridens*, *Tupaiodon* cf. *T. morrisi*, *Desmatolagus* aff. *D. vetustus*, *Propalaeocastor irtyshensis*, *Prosciurus*? sp., Sciuridae gen. et sp. indet., *Karakoromys decessus*, *Cyclomylus lohensis*, *Cricetops dormitor*, *Eucricetodon asiaticus*, *E. caducus*, *Ulaancricetodon* cf. *U. badamae*, *Parasminthus* aff. *P. asiae-centralis*, *P.* aff. *P. tangingoli*, *Tatalsminthus* sp. nov.。动物群中的河狸是我国最早的化石记录(Wu et al., 2004)。该组合内容和进化水平与蒙古 Valley of Lakes 地区的 Shandgolian 期生物带 A (Biozone A) (Höck et al., 1999; Daxner-Höck, 2000, 2001; Erbajeva and Daxner-Höck, 2001)最接近,但时代可能稍早于生物带 A。斋桑盆地中 Podorozhnik 第 15 地点的 Buran Svita 中的哺乳动物群的时代也为 Shandgolian 期,但显然稍晚于 XJ200203 哺乳动物群。第 28 层哺乳动物群的组成与 XJ99035 及 XJ99031 地点的动物群有相似之处,但必须在对以上几个动物群都做了详细的研究之后才能进行精确的对比。

3　亚洲陆相始新世—渐新世地层界线和动物群演变

1990 年 Swisher 和 Prothero 采用单晶 Ar/Ar 绝对年龄测定法重新测定了北美陆相始新世—渐新世过渡地层年代,确定 Chadronian 期终结于约 34 Ma,从而将 Chadronian 期归入晚始新世(Swisher and Prothero, 1990)。长期以来内蒙古的 Ulangochuian 期和蒙古的 Ergilian期的年代都是与北美的 Chadronian 期对比(Romer, 1966; Russell and Zhai, 1987),随着 Chadronian 年龄的变动,该两期亦应归为晚始新世(Berggren and Prothero, 1992; Ducrocq, 1993; Wang, 1997)。依据蒙古 Hsanda Gol 组所夹玄武岩年龄测定,Shandgolian 期的时代应为早渐新世(Höck et al., 1999)。

多数学者认为中亚地区陆相始新世—渐新世界线与 Ergilian/Shandgolian 界线吻合(Berggren and Prothero, 1992; Ducrocq, 1993; Meng and Mckenna, 1998; Emry et al., 1998)。

Shandgolian 是依据蒙古中部 Valley of Lakes 地区分布的 Hsanda Gol 组中的哺乳动物群建立;Ergilian 是根据分布于蒙古东南部的 Ergilin Dzo 组中 Ergilin 段的哺乳动物群建立。尽管人们认为 Hsanda Gol 组晚于 Ergilin Dzo 组,但目前未发现该二组地层直接相接触的剖面。依据 McKenna 等 1996 年的手稿,在蒙古中部,Hsanda Gol 组直接覆盖在 Elegen 组之上,Elegen 组的岩性勉强可与 Ergilin Dzo 组对比,而且在 Elegen 组中没有发现任何哺乳动物化石。因此,Shandgolian 时段的起始期和 Ergilian 时段的终结期尚无法确定。换言之,蒙古的 Ergilian/ Shandgolian 界线并不确定,以其代表中亚地区陆相始新世—渐新世界线的条件不够成熟。

20 世纪 90 年代后半期,Emry 等(1998)在哈萨克斯坦斋桑盆地做地层与古生物考察工作时,在盆地的南、北、东侧出露的 Kusto Buran 地层单元中发现了一系列含有 Ergilian 期和 Shandgolian 期哺乳动物的化石地点。Emry 等认为 Kusto Buran 地层单元堆积连续,因而斋桑地区的 Kusto Buran 地层单元提供了研究 Ergilian Shandgolian 过渡期哺乳动物群变化的罕见的机遇,有可能在斋桑盆地解决 Ergilian/ Shandgolian 的界线问题(Emry et al., 1998, p. 310)。但我们认为,斋桑盆地中已知的各哺乳动物化石地点较为分散,一些关键的化石点相距较远(见 Emry et al., 1998, fig. 3),对利用岩石地层、所含生物化石和年代学进行综合研究有一定困难。因此还必须在斋桑盆地中继续寻找含化石的连续地层剖面。

布尔津盆地克孜勒托尕依剖面上出现了典型的 Ergilian 期哺乳动物群化石层位(第 19 层,XJ99027 地点)和典型的 Shandgolian 期哺乳动物群化石层位(第 28 层),并在离剖面不远处(XJ200303 地点)、与第 22 层相当的层位中找到了圆柱鼠类化石;而且 XJ200303 地点与在剖面之北约 14 km 处的另一露头中发现的另一个 Shandgolian 期小哺乳动物群(XJ99031, XJ99035)的层位相当。因此,克孜勒托尕依剖面无论从地层连续性和化石的丰富程度上,都可以说是我国境内研究陆相始新世—渐新世地层界线和 Ergilian Shandgolian 过渡期哺乳动物群演变的一个比较理想的剖面。也可能成为亚洲地区陆相始新世—渐新世界线层型的候选剖面。

始新世—渐新世界线不仅是一条地层对比的重要地质年代界线,也是一条研究晚始新世末期全球气温下降所引起的不同地域的"环境生物事件"发生时间的一条重要的基准线。我们的研究表明,布尔津地区晚始新世到早渐新世哺乳动物群的变化和蒙古高原同期的动物群演替"蒙古重建"(Meng and McKenna, 1998)类似,反映了从始新世的炎热潮湿环境和以大型哺乳动物为主的动物群,演变到渐新世较寒冷干旱的环境和以小哺乳动物为主的动物群。这一演变与晚始新世—早渐新世过渡期内的全球气候变化(Burchardt, 1978; Cavelier et al., 1981; Prothero and Berggren, 1992)以及欧洲的"大间断"(Grande Coupure)事件(Stehlin, 1909; Legende and Hartenberger, 1992)吻合。此外,始新世晚期布尔津地区的哺乳动物群的组成与云南蔡家冲动物群十分相似(叶捷等,2002),而进入晚渐新世后在准噶尔盆地北缘地层中的巨犀化石与巴基斯坦同时期的巨犀为同一个属(叶捷等,2003a),说明正在隆起的青藏高原尚未成为阻止中国南部与南亚地区以及中国北方哺乳动物交流的地理屏障,也没有造成高原周边地区区域性气候的明显分异。

LATE EOCENE-EARLY OLIGOCENE LITHOLOGICAL AND BIOLOGICAL STRATIGRAPHY IN THE BURQIN REGION OF XINJIANG

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Key words　Burqin Basin, Xinjiang, Late Eocene-Early Oligocene, new formations, mammalian stratigraphy

Summary

The Burqin Basin is in the northern area of Xinjiang Uygur Autonomous Region (Fig. 1). Terrestrial beds of Tertiary are exposed along the banks of the Irtysh River that runs through the region. Most of these Tertiary beds were previously considered to be the "Ulunguhe" Formation, a rock unit that was nominated at site Sa'erduoyila south of Village Halamagai in the Ulungur River Region and have been shown to include sediments of different lithologies and different ages, ranging from late Cretaceous to Oligocene (Wu, 1973; Peng, 1975; Peng and Wu, 1983; Tong et al., 1990; Wei and Tong, 1992; Bureau of Geology and Mineral Resources of Xinjiang Uygur Autonomous Region, 1993; Ye et al., 2000, 2001a,b, 2002, 2003a,b; Wu et al., 2000; Meng et al., 2001a,b; Daxner-Höck and Wu, 2003). Our investigations during the last a few years reveal that these beds in Burqin Basin are lithologically different from but biostratigraphically correlative with the Ergilian-Shandgolian sediments in Mongolia and in Zaisan Basin of Kazakhstan. The continuous sequence may span over the Eocene-Oligocene boundary. Based on their lithological and biological contents, we propose to abandon application of the name "Ulunguhe" Formation to these sediments and to divide them into two new rock units, the Irtysh River and Keziletuogayi formations. The type section (KZ2002) is 20 km northwest to the Burqin City on the north bank of the Irtysh River, north to the Keziletuogayi village. The section measured at this locality starts at N47°50.024′, E86°40.729′ (base) and ends at N47°50.479′, E86°40.912′ (top) and is described below:

Quaternary System	
29. Grayish white, fluvial, poorly sorted quartz conglomerates	12 m
----------Disconformity----------	
Keziletuogayi Formation (Total thickness: 64.5m)	
28. Grayish green mudstone, containing micromammal fossils (see below); site number XJ200203	7.5 m
27. Yellowish green mud-siltstone, reddish brown on weathered surface	3 m
26. Yellowish green muddy fine-sandstone	3 m
25. Yellowish sandstone	11 m
24. Variegated but mainly grayish green muddy siltstone	1 m
23. Yellowish green medium-fine muddy sandstone	4.8 m
22. Reddish brown mudstone (which we correlate to the bed that contains fossils at XJ200303; see below)	1.7 m
21. Yellowish green sandstone, locally coarse-sandstone	8.1 m
20. Grayish green sandy mudstone; reddish brown on weathered surface	5.3 m
19. Blackish manganese siltstone, containing primarily perissodactyls; site number: XJ99027	0.7 m
18. Grayish green sandy mudstone; lower part mainly siltstone	2.4 m
17. Yellowish green fine-sandstone, with coarse sandstone locally	8.5 m
16. Light grayish green, medium-coarse sandstone, intercalated with earthy yellow muddy	

siltstone	6 m
15. Earthy yellow muddy fine sandstone	1.5 m
——————Conformity ——————	
Irtysh River Formation (total thickness more than 55.5 m)	
14. Light grayish green muddy siltstone, capped with ferriferous layer	2.5 m
13. Light grayish purple banded muddy siltstone, intercalated with grayish yellow medium sandstone	6.5 m
12. Light grayish green, medium-coarse sandstone	3 m
11. Light grayish green, muddy siltstone, capped with ferriferous layer	1.5 m
10. Grayish white, medium-sandstone with well-developed cross-beddings and gradated finer and more greenish upwards	4.5 m
9. Fine-quartz conglomerates and coarse sandstone with ferriferous bands	0.7 m
8. Grayish white, muddy fine-sandstone with mica and quartz; grains coarser upwards; fresh surface with irregular rusty-yellow stripes; sparse mud nodules	3 m
7. Light grayish white mudstone, with fissure fillings, purplish red spots while weathered; color darker near the top of the bed	7.5 m
6. Light grayish yellow, muddy fine-sandstone	3 m
5. Rusty-yellow fine-sandstone with inclined beddings	2.5 m
4. Light grayish laminated siltstone intercalated with rusty-yellow fine-sandstone; the bottom layer rusty-yellow fine-sandstone with mica grains	2.5 m
3. Grayish white mudstone intercalated with siltstone, capped with dark green siltstone	5 m
2. Greenish gray siltstone with fine fissure fillings of brownish yellow fine sands	1.5 m
1. Grayish white mudstone and siltstone; bottom unrevealed	12.5 m

In general, Irtysh River Formation is a set of sediments in bright colours of rusty-yellow and purplish red on the weathered surface, rich in ferric oxide, and probably deposited in warm environment. This formation can be further divided into two members. The lower member (beds 1～8) consists of mudstone, siltstone and sandstone, mainly with finer grains. Some beds are rich in cracks that are filled with ferriferous fine sands; the weathered surface is reddish variegated. The upper member (beds 9～14) is primarily coarse-grained sediments and contains several ferriferous layers. So far no fossils have been recovered from this formation.

The Keziletuogayi Formation is basically light yellowish green sandstone with variegated mudstone.

Three fossil assemblages were discovered from the Keziletuogayi Formation, ranging from bottom up:

1) Fossils collected from bed 19 at site XJ99027 include *Cadurcodon* cf. *C. ardynensis*, Amynodontidae gen. et sp. indet., *Gigantamynodon giganteus*, Indricotheriinae gen. et sp. indet., Rhinocerotidae gen. et sp. indet., and Brontotheriidae gen. et sp. indet. This assemblage is dominated with perissodactyls and is similar to those of Caijiachong fauna of Yunnan, Ulan Gochu and Urdyn Obo faunas of Nei Mongol, Gua-teg, Khoer-Dzan and Ergilin faunas of Mongolia, and Kusto fauna of Kazakhstan (Ye et al., 2002). Presence of pollens of *Rhynchosia* and *Elaeagnus* suggests warm tropical or subtropical climate.

2) Only fragmentary teeth, including one cheek tooth of cylindrodontid, were collected from site XJ200303 at the level equivalent bed 22. However, based on the lithological and superpositional relationships this bed is comparable with sites XJ99031 and XJ99035 in another measured section 14 km north of the KZ2002 section. Beds at XJ99031 and XJ99035 yield several mammals, preliminarily identified as *Hyaenodon* sp., *Desmatolagus* sp., *Karakoromys decessus*, *Cyclomylus lohensis*, *Cyclomylus* sp., *Cricetops dormitor*, *Eucricetodon* sp., *Plesiosminthus* sp. This assemblage is comparable to the early Shandgolian faunas. It is dominated with small mammals and probably reflects a dry climate apparently different from that of the assemblage from bed 19.

3) The assemblage from bed 28 at site XJ200203 is also dominated with small mammals, including *Palaeoscaptor* cf. *P. acridens*, *Tupaiodon* cf. *T. morrisi*, *Desmatolagus* sp. nov. or

D. aff. *D*. *vetustus*, *Propalaeocastor irtyshensis* sp. nov., *Prosciurus*? sp., Sciuridae gen. et sp. indet., *Karakoromys decessus*, *Cyclomylus lohensis*, *Cricetops dormitor*, *Eucricetodon asiaticus*, *E. caducus*, *Ulaancricetodon* cf. *U. badamae*, *Parasminthus* aff. *P. asiae-centralis*, *P.* aff. *P. tangingoli*, *Tatalsminthus* sp. nov. Among these species, a new species of *Propalaeocastor* is the earliest castorid in China (Wu et al., 2004). This assemblage is comparable to Biozone A of Shandgolian from the Valley of Lakes of Central Mongolia (Höck et al., 1999; Daxner-Höck, 2000, 2001; Erbajeva and Daxner-Höck, 2001) and probably earlier in age. It is also similar to that of site K15 from the Buran Svita of Podorozhnik, Zaisan Basin, and should also be Shandgolian but apparently earlier.

The three assemblages suggest the late Eocene-early Oligocene transitional age for the Kezile-tuogayi Formation.

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