第45卷 第3期
2007年7月

古脊椎动物学报
VERTEBRATA PALASIATICA

pp.232－245
figs.1－2

蔚县盆地牛头山(铺路)剖面晚上新世/早更新世小哺乳动物[1)]

蔡保全[1] 郑绍华[2] 李 强[2]

(1 厦门大学历史学系 厦门 361005)

(2 中国科学院古脊椎动物与古人类研究所 北京 100044)

摘要：牛头山(=铺路)剖面6个含化石层位中,第3、6、9和第12层为晚上新世,第15、16层为早更新世。晚上新世以 *Hypolagus*, *Nannocricetus mongolicus*, *Sinocricetus progressus*, *Mesosiphneus*, *Pliosiphneus*, *Pseudomeriones complicidens*, *Micromys tedfordi* 等的最后绝灭为特征;早更新世以 *Allophaiomys deucalion*, *Yangia* 等的出现为特征。根据岩石地层和小哺乳动物组合分析,该剖面上新世/更新世界限应在第12-13层之间。根据动物组合或动物群的对比,将牛头山剖面、钱家沙洼村的洞沟剖面与小水沟剖面、东窑子头村的大南沟剖面及稻地村的老窝沟剖面的不同层位进行了时代排序。

关键词：蔚县盆地,牛头山;晚上新世/早更新世;小哺乳动物

中图法分类号：Q 915.862 **文献标识码**:A **文章编号**：1000-3118(2007)03-0232-14

杜恒俭等(1988)描述的"蔚县北水泉镇铺路剖面"经笔者2005年考察,实际位于牛头山上,由于牛头山比铺路更为人所知和更确切一些,故改称为牛头山剖面。该剖面位于铺路村南约1 km的公路旁,向东南与东窑子头大南沟剖面直线距离约1.2 km,两者都在宣(化)—蔚(县)公路东侧。

杜恒俭等(1988)描述了牛头山上新统红粘土层以上、具板状交错层理的灰黄色砂砾石层以下43.18 m厚、11个层位的"稻地组"剖面,并从其第3和第9层采得了较为丰富的上新世小哺乳动物化石。由于蔡保全于1986年从第9层采得一件被描述成"*Mimomys* cf. *youhenicus* Xue, 1981"的标本(郑绍华、蔡保全,1991),引起笔者对该剖面的兴趣。它可能是泥河湾地区除钱家沙洼村的洞沟剖面(郑绍华等,2006)外的又一套晚上新世/早更新世地层。杜恒俭等(1988)所描述的剖面并不完整,2005年,笔者在其顶部向上补测,测得完整剖面总厚度为82 m,分为23层,并从其中的第6、9、12、15和第16层各筛洗到一批小哺乳动物化石,加上早期发现的第3层,总共有6个含化石层位(图1)。经初步鉴定,这些化石对于确定蔚县盆地下部地层的时代以及讨论上新世/更新世界线等问题具有十分重要的意义。

1)国家自然科学基金项目(编号:40472012)资助。

收稿日期:2007-01-10

1　地层剖面

蔚县盆地牛头山上新世—更新世剖面

23.	浅灰黄色钙板层夹粉砂,水平层理发育	4.00 m
22.	浅灰黄色砾石层,具斜层理,钙质胶结	2.30 m
21.	浅灰黄色钙板层夹粉砂,水平层理发育	3.60 m
20.	浅黄绿色粉砂质粘土	2.50 m
19.	黄褐色粉砂质粘土	5.00 m
18.	中上部灰绿色粉砂质粘土,下部为黄褐色粘土质粉砂	2.40 m
17.	黄色砾石层	0.50 m
16.	黄褐色细砂、粉砂与砾石互层。底部含小哺乳动物化石	4.40 m
15.	黄褐色细砂、粉砂。底部含小哺乳动物化石	5.10 m
14.	灰绿色粉砂质粘土	2.80 m
13.	黄褐色细砂、粉砂夹砾石薄层	3.80 m
12.	砾石层,具斜交层理,含小哺乳动物	2.50 m
11.	暗灰色粘土	1.00 m
10.	黄色砾石层与浅褐色粉砂互层。砾石分选差,呈棱角—次棱角状。含腹足类、双壳类化石	1.40 m
9.	黄色粉砂与灰色粉砂质粘土、粘土质粉砂组成两个旋回,小型槽状交错层理发育。底部含小哺乳动物及腹足类、双壳类化石,厚度变化较大,	5.50 m
8.	灰色含细砾细砂、粉砂。含腹足类、双壳类化石,厚度变化较大	7.40 m
7.	黄色角砾层,砾石成分以火山岩为主,棱角状	2.30 m
6.	底部为浅褐色砾石层,中上部为灰色、暗灰色粉砂质粘土与黄色含细砾细砂粉砂互层,产小哺乳动物、龟、鱼及软体动物化石。厚度变化较大	4.90 m
5.	浅棕红色含砾粉砂质粘土	2.60 m
4.	灰、灰黑色细砂、粉砂、粘土,底部为黄色似层状砾石层	4.50 m
3.	上部为灰黑色含粉砂粘土,下部为黄色细砾透镜体与细砂、粉砂、粘土质粉砂交互出现,小型槽状交错层理发育。底部含小哺乳动物及腹足类化石	6.30 m
2.	浅黄色细砂粉砂,含腹足类、双壳类化石	5.80 m
1.	黄灰色砾石透镜体与紫褐色含细砂粉砂粘土,钙质胶结。砾石大小混杂,分选差,次棱角状	1.40 m

------假整合-----

下伏地层:浅褐红色含砾砂质粘土夹钙板层

2　小哺乳动物组合及其时代分析

牛头山剖面中共发现小哺乳动物 30 种,分属于食虫类(2 属,2 种)、兔形类(3 属,6 种)和啮齿类(20 属,22 种)。不同层位的小哺乳动物应该代表不同时代的小哺乳动物组合(表 1)。下面以从早到晚或地层上从下到上的顺序分别对不同的动物组合的时代进行讨论。

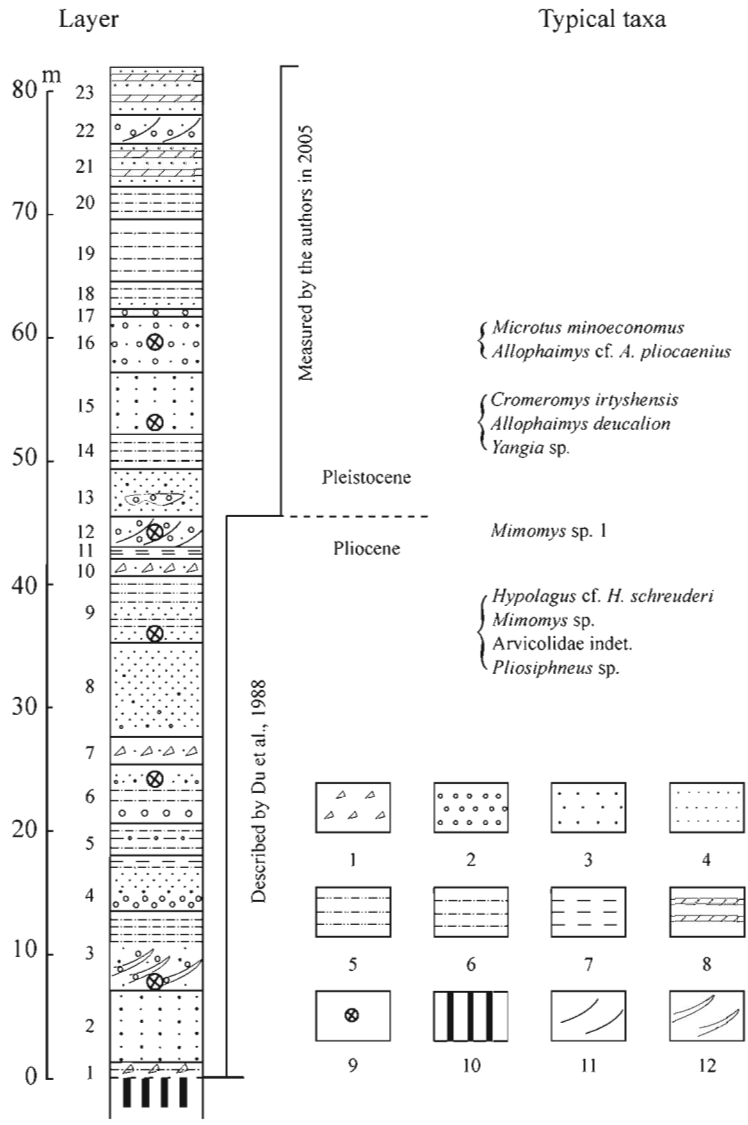

图 1 牛头山地点柱状剖面

Fig. 1 Columnar section of Niutoushan locality

1. 角砾岩 breccia；2. 砾岩 conglomerate；3. 细砂岩 fine sandstone；4. 粉砂岩 siltstone；5. 粘土质粉砂岩 clayey siltstone；6. 粉砂质粘土 silty clay；7. 粘土 clay；8. 钙板 concrete slab；9. 含小哺乳动物化石层 fossiliferous bed；10. 红粘土层 red clay；11. 斜层理 diagonal bedding；12. 槽状交错层理 cross bedding

第 3 层小哺乳动物组合 进步中华仓鼠(*Sinocricetus progressus*)在泥河湾—蔚县盆地的最晚记录是在钱家沙洼村的小水沟剖面第 4 层,估计年龄略大于 2.6 Ma(郑绍华等,2006),其最早记录是内蒙古比例克动物群,为上新世初期或 MN14(Qiu and Storch,2000)。根据动物群组成,比例克动物群的时代相当于甘肃灵台雷家河小石沟剖面的 IV

生物带或约 4.4 ~ 3.6 Ma(张兆群、郑绍华,2001;郑绍华、张兆群,2001);根据其模鼠(*Mimomys bilikeensis*)的高冠程度判断,约为 4.0 Ma(Repenning, 2003)。

表 1　牛头山剖面中的小哺乳动物化石

Table 1　Fossil small mammals from the Niutoushan (=Pulu) section

小哺乳动物 small mammals	层位 layers					
	3	6	9	12	15	16
1. *Sorex* sp.			X	X		
2. *Erinaceus* sp.			X			
3. *Ochotona* sp. (large)					X	
4. *Ochotona* sp. (small)			X	X		
5. *O.* cf. *O. nihowanica* Qiu, 1985					X	
6. *O.* cf. *O. youngi* Erbajeva & Zheng, 2005						X
7. *Ochotonoides* sp.						X
8. *Hypolagus* cf. *H. schreuderi* (Teilhard, 1940)		X	X			
9. *Cricetulus* sp.						X
10. *Nannocricetus mongolicus* Schaub, 1934		X	X			
11. *Sinocricetus progressus* Qiu & Storch, 2000	X		X			
12. *Microtus minoeconomus* Zheng & Cai, 1991						X
13. *Allophaiomys* cf. *A. pliocaenicus* Kormos, 1933						X
14. *Allophaiomys deucalion* Kretzoi, 1969					X	
15. *Mimomys* sp.	X	X	X			
16. *Mimomys* sp. 1				X		
17. Arvicolidae indet.	X	X	X			
18. *Cromeromys irtyshensis* Zazhijin, 1980			X		X	
19. ? *Borsodia* sp.					X	
20. *Mesosiphneus* sp.		X				
21. ? *Yangia* sp.					X	
22. *Pliosiphneus* sp.			X			
23. *Meriones* sp.						X
24. *Pseudomeriones complicidens* Zhang, 1999		X				
25. *Dipus fraudator* (Schlosser, 1924)				X		
26. *Paralactaga* sp.			X			
28. *A.* cf. *A. atavus* Heller, 1936			X			
29. *Micromys tedfordi* Wu & Flynn, 1992			X	X		
30. *Chardinomys nihowanicus* (Zheng, 1981)	X	X	X	X		

模鼠(*Mimomys* sp.)像泥河湾—蔚县盆地其他地点的材料一样具有相当原始的性质,曾作为"*M. orientalomys* Young, 1935"报道(蔡保全,1987;蔡保全等,2004;杜恒俭等,1988;郑绍华、蔡保全,1991)。钱家沙洼村的洞沟剖面第 2 层和小水沟剖面的第 1、2 层以及泥河湾—蔚县盆地其他晚上新世地点的 *Mimomys* 材料,可能是一新的种类,其时代在钱家沙洼村的两地点估计约在 3.2 Ma 左右(郑绍华等,2006)。

鼢科(Arvicolidae indet.)曾被记载为"*Germanomys* sp. nov."(杜恒俭等,1988),分布于泥河湾—蔚县盆地许多上新世化石地点。在钱家沙洼村的洞沟剖面第 2 层及小水沟剖面第 1、2 层的时代估计为 3.2 Ma 左右(郑绍华等,2006)。其冠面形态与西班牙 Iles Medas 地点、法国 Mas Rambault 及 Valerots 地点的"? *Germanomys* sp."(Michaux, 1971)十分相似。前两地点的时代为早 Villanyian 期,后一地点的时代为早 Biharian 期(Kowalski, 2001)。

泥河湾日进鼠(*Chardinomys nihowanicus*)的典型地点在大南沟(郑绍华,1981),为早

更新世,其层位相当于大南沟剖面的第 12 层或黄沙段的底部(蔡保全等,2004);在榆社盆地分布于从麻则沟组(约 3.5 Ma)到第四纪海眼组(Flynn et al., 1997)。在灵台雷家河剖面则分布于 4.8 ~ 3.0 Ma(崔宁, 2003)。

总起来看,第 3 层小哺乳动物组合的时代具有我国典型的晚上新世的性质。

第 6 层小哺乳动物组合 次兔(*Hypolagus*)在榆社盆地最早出现于 4.2 Ma,而施氏次兔(*H. schreuderi*)最早记录是约 3.4 Ma(Flynn et al., 1997),其最晚记录是早更新世的周口店 18 地点(Teilhard de Chardin, 1940)和山东淄博孙家山第 4 地点裂隙动物群(郑绍华等,1997)。后两地点的时代为早更新世早期。

蒙古矮仓鼠(*Nannocricetus mongolicus*)最早出现于晚中新世—早上新世的内蒙古二登图动物群(Schlosser, 1924);内蒙古比例克上新世动物群有其存在(Qiu and Storch, 2000);甘肃灵台雷家河剖面的最晚记录为 4.5 Ma(郑绍华、张兆群,2001)。钱家沙洼村的洞沟剖面第 2 层、小水沟剖面第 1、第 4 层也有其存在,估计年代为 3.2 ~ 2.6 Ma 左右(郑绍华等,2006)。

中鼢鼠(*Mesosiphneus* sp.)是臼齿带牙根的凹枕型鼢鼠,其进化水平相当于 *M. paratingi*。而后一种在榆社盆地的分布约在 3.4 ~ 3.0 Ma(Flynn et al., 1997)。

复齿假沙鼠(*Pseudomeriones complicidens*)的典型产地是甘肃宁县水磨沟,层位是午城黄土以下的粗砂层,其时代为最晚上新世(张兆群,1999)。在钱家沙洼村的洞沟剖面被推测为 3.2 Ma 左右(郑绍华等,2006)。在灵台雷家河剖面的时代分布约为 3.5 ~ 3.2 Ma(郑绍华、张兆群,2001)。

张洼沟姬鼠(*Apodemus zhangwagouensis*)的时代分布在榆社盆地为麻则沟组,约为 3.7 ~ 3.4 Ma(吴文裕、Flynn, 1992)。在钱家沙洼村的洞沟剖面的时代分布估计在 3.2 Ma 左右(郑绍华等,2006)。

模鼠(*Mimomys* sp.)、鼢科(Arvicolidae indet.)和泥河湾日进鼠(*Chardinomys nihowanicus*)的时代分布上已讨论。

总起来看,第 6 层小哺乳动物组合与第 3 层小哺乳动物组合有密切的延续性,由于层位较高,时代也相应较晚,但属种的总体面貌和进化水平仍属于晚上新世。

第 9 层小哺乳动物组合 额尔齐斯克罗麦尔鼠(*Cromeromys irtyshensis*)的典型产地(俄罗斯西西伯利亚南部)的时代为晚上新世(相当于中国的早更新世或欧洲的 MN17)(Zazhigin, 1980)。在榆社盆地大致在 3.4 ~ 2.8 Ma(Flynn et al., 1997)。

上新鼢鼠未定种(*Pliosiphneus* sp.)是该属中目前已知最进步的种类,其臼齿接近于丢失牙根的进化阶段,大致与凹枕型的 *Mesosiphneus praetingi* 处于同一进化水平,其时代应属于晚上新世。

副跳鼠(*Paralactaga*)在灵台雷家河剖面的古地磁测年记录约为 4.9 ~ 3.3 Ma(郑绍华、张兆群,2001)。

戴氏巢鼠(*Micromys tedfordi*)在榆社盆地的时代记录为 4.6 ~ 3.4 Ma(Flynn et al., 1997),在雷家河剖面约为 5.3 ~ 3.2 Ma(郑绍华、张兆群,2001),在钱家沙洼村的两剖面估计为 3.2 ~ 2.6 Ma(郑绍华等,2006)。

模鼠(*Mimomys* sp.)、鼢科(Arvicolidae indet.)、蒙古矮仓鼠(*Nannocricetus mongolicus*)

和进步中华古仓鼠(*Sinocricetus progressus*)的时代均为上新世。

总起来看,第 9 层小哺乳动物组合除食虫类和兔形类有所增加外,其余多数种类与第 6 层小哺乳动物组合相同,特别是鼢类和鼠类的进化水平显示出典型的中国晚上新世动物群的时代特征。当然,因其层位较高,其时代也比第 6 层小哺乳动物组合较晚。

第 12 层小哺乳动物组合　该组合中,伪三趾跳鼠(*Dipus fraudator*)、戴氏巢鼠(*Micromys tedfordi*)和泥河湾日进鼠(*Chardinomys nihowanicus*)是"稻地动物群"最常见的成员,而 *Mimomys* sp. 1 的进化水平与钱家沙洼村的小水沟第 4 层的较进步的 *Mimomys* 种相当。因此,该动物组合所反映的时代应是蔚县盆地内最晚上新世(郑绍华等,2006)。

第 15 层小哺乳动物组合　欧洲异费鼠(*Allophaiomys deucalion*)的典型产地是匈牙利 Villany-5 地点,被认为是欧洲 Villanyian 晚期—Biharian 早期的最早的臼齿无牙根的田鼠(Kowalski, 2001)。在俄罗斯塔曼半岛的 Tizdar 等地点的古地磁测年为 2.25 ~ 1.96 Ma(Pevzner et al., 1998)。在泥河湾马圈沟下部旧石器遗址的古地磁测年经计算为 1.66 Ma(Zhu et al., 2004)。

波尔索地鼠未定种(*Borsodia* sp.)比中华波尔索地鼠(*B. chinensis*)原始,像洞沟剖面第 7 层中的 *Borsodia* sp.,其时代为最晚上新世(郑绍华等,2006)。

额尔齐斯克罗麦尔鼠(*Cromeromys irtyshensis*)的时代如上述,属晚上新世/早更新世。

总之,第 15 层中的小哺乳动物种类虽少,但最早的、臼齿无根的鼢类的出现通常标志着中国第四纪更新世的开始。其地质时代显然早于泥河湾盆地岑家湾村马圈沟旧石器遗址 III 的 1.66 Ma(Zhu et al., 2004)。

第 16 层小哺乳动物组合　上新异费鼠(*Allophaiomys pliocaenicus*)的相似种在大南沟剖面上分布于第 6-18 层,即砂砾石段顶部—黄沙段顶部,大致在 1.8 ~ 0.8 Ma 时段(蔡保全等,2004);在蓝田公王岭蓝田猿人地点为 1.25 Ma (Ding et al., 2002)。在欧洲分布于早 Biharian 期(Kowalski, 2001)。

小根田鼠(*Microtus minoeconomus*)在大南沟剖面上分布于第 9-18 层,相当于泥河湾组的钙质砂土段中上部—黄砂段顶部,大致在 1.6 ~ 0.8 Ma(蔡保全等,2004)。

沙鼠(*Meriones*)在大南沟剖面最早出现于第 9 层,相当于泥河湾组的钙质砂土段中上部,其年代大致在 1.6 Ma 左右(蔡保全等,2004)。

总之,第 16 层小哺乳动物组合与第 15 层小哺乳动物组合几乎没有相同的种类,且其面貌发生了显著变化,如 *Microtus minoeconomus* 的最早出现,*Allophaiomys* cf. *A. pliocaenicus* 替代了 *A. deucalion*,因此其时代明显较晚。估计晚于 1.8 Ma。

3　上新统/更新统界线

从上述小哺乳动物各属种时代的分析可以看出,第 3、6、9 和第 12 层 4 个小哺乳动物组合应属晚上新世,第 15 和第 16 层应属早更新世。它们的界线应在第 12 层和第 15 层之间。

杜恒俭等(1988)根据传统的岩石地层学和生物地层学的方法,将他们建立的"稻地组"(=蔚县组)的上界或上新统/更新统界线置于本剖面第 11 和第 12 层之间,因为第 12 层的具板状交错层理的砂砾石层被视为上覆地层的底砾岩,而第 9 层含有典型的上新世哺乳

表 2 牛头山剖面、洞沟剖面和小水沟剖面晚上新世不同层位小哺乳动物组合比较

Table 2 Comparisons of the small mammalian complexes from the Late Pliocene sections of Niutoushan, Donggou and Xiaoshuigou

小哺乳动物 small mammals	牛头山 Niutoushan layers				洞沟 Donggou layers			小水沟 Xiaoshuigou layers		
	3 (a)	6 (b)	9 (c)	12 (d)	2 (A)	4 (B)	7 (C)	1 (A)	2 (A)	4 (B)
1. Soricidae indet.					X					
2. *Sorex* sp.			X	X					X	
3. *Paenelimnoecus* cf. *P. chinensis*					X					
4. *Erinaceus* sp.			X							
5. Talpidae indet.					X					
6. *Ochotona* sp.			X	X						
7. *O. minor*?										X
8. *O.* ? *erythrotis*										X
9. *O.* cf. *O. lingtaica*					X					
10. *Ochotonoides complicidens*							X			
11. *Hypolagus* sp.		X	X							
12. *Hypolagus schreuderi*										X
13. *Pliopentalagus nihewanensis*			X							
14. *Nannocricetus mongolicus*		X	X		X			X		X
15. *Sinocricetus progressus*	X		X		X				X	X
16. *Mimomys* sp.	X	X	X		X			X	X	
17. *Mimomys* sp. 1				X						X
18. *Mimomys* sp. 2										X
19. Arvicolidae indet.	X	X	X		X			X	X	
20. *Cromeromys irtyshensis*			X							
21. *Borsodia* sp.							X			
22. *Mesosiphneus* sp.		X								
23. *M. paratingi*										X
24. *Yangia omegodon*							X			
25. *Pliosiphneus* sp. nov.			X							
26. *Pseudomeriones* sp.					X					
27. *P. complicidens*		X								
28. *Dipus fraudator*				X	X		X			X
29. *Paralactaga* sp.			X							
30. *Micromys tedfordi*			X	X	X	X				X
31. *Apodemus zhangwagouensis*		X			X					
32. *A.* cf. *A. atavus*			X					X		X
33. *Chardinomys nihowanicus*	X	X	X	X	X	X		X		X

动物。这个界线显然和第 12 层目前发现上新世哺乳动物不一致。

根据 *Allophaiomys deucalion* 的进化水平和地史分布，将上新统/更新统界线置于第 12/13 层间似乎更为合理。尽管牛头山剖面与洞沟剖面相距较远，古地理环境也不可能一样，但前者的第 15 层和后者的第 11 与第 16 层均有 *A. deucalion* 和其祖先类型 *Cromeromys* 共生（郑绍华等，2006），因此它们的时代应大致相同，应属早更新世早期。

根据齿冠高度判断，牛头山第 12 层小哺乳动物组合中的 *Mimomys* sp. 1 的 M3 齿冠高度参数值较其下部层位的显然大，已达到小水沟剖面第 4 层中的同一牙齿水平，也就是说已达到界线附近的水平，因此第 12/13 层间是上新统/更新统界线的可能性更大。

表 3　牛头山和洞沟剖面早更新世不同层位小哺乳动物组合比较

Table 3　Comparisons of the small mammalian complexes from Early Pleistocene sections of the Niutoushan and Donggou

小哺乳动物 small mammals	牛头山 Niutoushan layers		洞　沟 Donggou layers		
	15(e)	16(f)	11(D)	16(E)	19(F)
1. *Ochotona* sp. (large)	X				
2. *O. magna*				X	
3. *O. youngi*			X	X	X
4. *O.* cf. *O. youngi*		X			
5. *O.* cf. *O. lingtaica*	X				
6. *O.* aff. *O. intermedia*				X	
7. *Ochotonoides* sp.		X			
8. *O. complicidens*			X		X
9. *Serricolagus* cf. *S. brachypus*				X	
10. *Spermophilus* sp.					X
11. Cricitidae indet.				X	
12. *Cricetulus* sp.		X			
13. *Cromeromys irtyshensis*	X				
14. *C. gansunicus*			X	X	
15. *Allophaiomys deucalion*	X		X	X	
16. *A.* cf. *A. pliocaenicus*		X			X
17. *Microtus minoeconomus*		X			
18. *Borsodia* sp.	X				
19. *B. chinensis*			X	X	
20. *Yangia* sp.	X				
21. *Y. trassaerti*			X		
22. *Y. tingi*				X	X
23. ? *Clethrionomys* sp.				X	
24. *Meriones* sp.		X	X		X
25. *Dipus* sp.			X		
26. *Allactaga* sp.			X		

4　与洞沟、小水沟剖面及大南沟剖面中小哺乳动物组合比较

为便于对比,这里将产自牛头山剖面第 3、6、9、12、15、16 层的动物组合视为 a、b、c、d、e、f,将产自钱家沙洼村洞沟剖面的第 2、4、7、11、16、19 层的动物组合视为 A、B、C、D、E、F(表 2-3),小水沟第 1-2、4 层的则分别归入 A、B 动物组合(郑绍华等,2006)。构成动物组合 a-c 的 *Sinocricetus progressus*、*Mimomys* sp. 、Arvicolidae indet. 和 *Chardinomys nihowanicus* 也是动物组合 A-C 的成员,因此它们在时代上是可以相互对比的。构成动物组合 e 的 *Allophaiomys deucalion* 与动物组合 E 相同,应属同一时代。构成动物组合 f 的 *Allophaiomys* cf. *A. pliocaenicus*, 指示了它的时代大致与动物组合 F 相近或相同。

此外,在东窑子头大南沟剖面第 1 层发现有 *Sorex* spp., *Soriculus* sp., *Erinaceus* sp., *Paralactaga anderssoni*, *Dipus fraudator*, *Mesosiphneus paratingi*, *Mimomys* sp., *Borsodia chinensis*, Arvicolidae indet., *Micromys tedfordi*, *Apodemus zhangwagouensis*, *Chardinomys nihowanicus*, Leporidae indet. 等 13 种(蔡保全等,2004),其中至少有 8 个属种与牛头山动物

组合 c 相同,可视为同一时代。至于第 6 层发现的 *Ochotona* sp., *Yangia tingi*, *Allophaiomys* cf. *A. pliocaenicus*, *Pitymys* cf. *P. hintoni*, *Borsodia chinensis* 和 *Chardinomys nihowanicus* 组合,其时代应与上述牛头山的 f 或洞沟的 F 相当。

因此,考虑到不同剖面的地层厚度及接触关系,在壶流河东岸,钱家沙洼的洞沟、小水沟剖面及东窑子头的牛头山、大南沟剖面各哺乳动物组合的时代顺序从早到晚大致可以排列如下:a-b-A-c(B)-d(C)-D-e(E)-f(F)动物组合。它们在地层中的分布见图 2。

5 与老窝沟剖面生物地层对比

经多次补充采集,阳原县南辛庄乡稻地村北约 750 m 的老窝沟 29 层剖面(厚 128.08 m)中的第 1、2、3、9、11、16 和第 19 层发现了小哺乳动物(蔡保全,1987,1989;蔡保

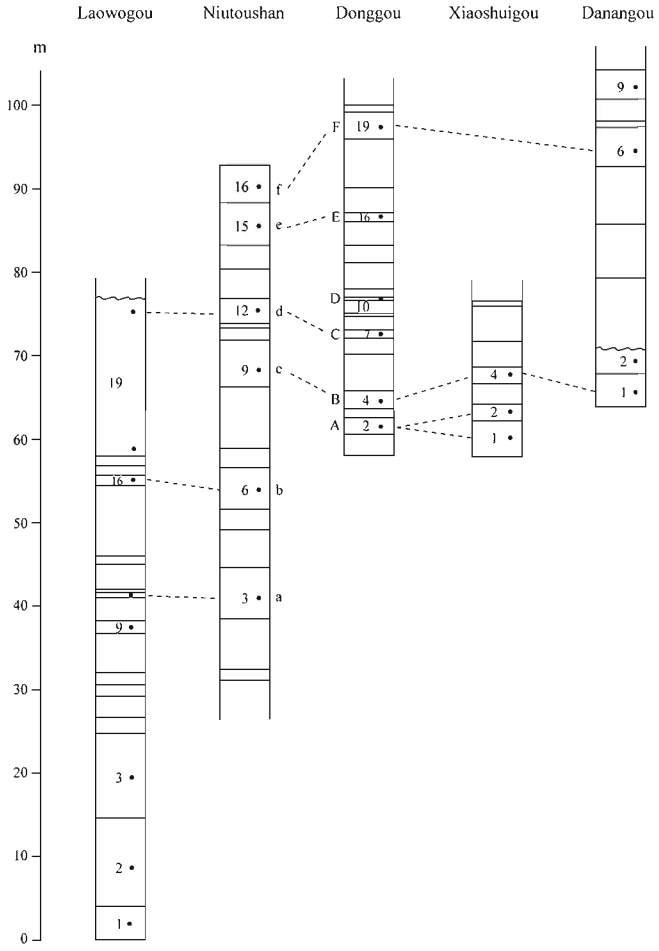

图 2 牛头山剖面与邻近地点生物地层剖面的相互关系

Fig. 2 Biostratigraphic correlation among the sections of Niutoushan, Laowogou, Danangou, Donggou and Xiaoshuigou

1, 2, 3... is stratigraphic sequence; the solid circles represent small mammal fossils

全、邱铸鼎,1993;蔡保全等,2004)。该剖面被视为泥河湾—蔚县盆地内最典型的上新世小哺乳动物生物地层剖面(张兆群等,2003)。为便于比较,现将其种类(包括新近采集的标本)在地层中的分布记述于下:

第 1 层:*Trischizolagus* sp., Cricetidae indet., *Chardinomys yusheensis*;

第 2 层:*Kowalskia* sp., *Nannocricetus mongolicus*, *Sinocricetus procressus*, Arvicolidae indet., *Chardina truncatus*, *Micromys tedfordi*, *Huaxiamys downsi*, *H. primitivus*, *Apodemus zhangwagouensis*, *Chardinomys yusheensis*;

第 3 层:*Ochotona* sp., *Nannocricetus mongolicus*, *Sinocricetus progessus*, *Mimomys* sp., Arvicolidae indet., *Pliosiphneus* sp., *Pseudomeriones complicidens*, *Micromys tedfordi*, *Apodemus zhangwagouensis*, *Chardinomys yusheensis*, *C. nihowanicus*;

第 9 层:*Paenelimnoecus chinensis*, *Nannocricetus mongolicus*, *Sinocricetus progressus*, *Mimomys* sp., *Mimomys* sp. 2, *Mesosiphneus praetingi*, *Dipus fraudator*, *Paralactaga andersoni*, *Micromys tedfordi*, *Chardinomys nihowanicus*, *Karnimata* sp., *Saidomys* sp.;

第 11 层:*Lunanosorex* cf. *L. lii*, *Nannocricetus mongolicus*, *Sinocricetus progressus*, *Mimomys* sp., Arvicolidae indet., *Mesosiphneus praetingi*, *Castor anderssoni*, *Dipus fraudator*, *Apodemus zhangwagouensis*, *Chardinomys nihowanicus*;

第 16 层:*Sorex* sp., *Ochotona* sp.;

第 19 层:*Nannocricetus mongolicus*, *Chardinomys nihowanicus*.

上述动物组合 a 与老窝沟剖面的第 11 层动物组合大致相当,因为前者的 4 个属种均为后者的成员;根据地层厚度,动物组合 b 可能与老窝沟剖面第 16 层相当,尽管后者没有可对比的化石种类。动物组合 c 在老窝沟剖面上没有相对应的动物组合。至于动物组合 d 可能与老窝沟第 19 层的上部相当,因为它们均接近上新统的顶界。

通过上述分析,牛头山剖面与壶流河两岸其他主要剖面生物地层的相互关系可以总结为图 2 所示。到目前为止,泥河湾地区最早的新生代地层应该是老窝沟剖面的第 1 层,其时代估计至少大于 3.4 Ma(张兆群等,2003)。

致谢　美国南加州大学的曾志杰(Jack Tseng)博士阅读和修改了本文的英文摘要部分,在此作者表示衷心的感谢。

PLIO-PLEISTOCENE SMALL MAMMALS FROM THE NIUTOUSHAN SECTION OF THE YUXIAN BASIN, CHINA

CAI Bao-Quan[1]　ZHENG Shao-Hua[2]　LI Qiang[2]

(1 *Department of Anthropology, Xiamen University* Xiamen 361005 caibq@163.net)

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

Key words　Niutoushan, Yuxian Basin; Plio-Pleistocene; small mammals

Summary

The Niutoushan (or Pulu) section, which was originally described by Du et al. (1988) as one of the stratotypes in erecting the "Daodi Formation", is located about one kilometer south of Pulu village, Yuxian county, and 1.2 km north of the Danangou section (Cai et al., 2004). Both the Niutoushan and the Danangou sections are on the east side of the highway connecting Xuanhua city to the Yuxian county seat.

In addition to the Donggou section near the Qianjiashawa village, the Niutoushan section potentially represents the only other record of the Pliocene/Pleistocene boundary in the Nihewan district, as indicated by the presence of derived *Mimomys* cf. *M. youhenicus*. We remeasured the Niutoushan section to develop a more complete profile in 2005. The profile was original 43.18 m measured by Du et al. (1988). As a result of our fieldwork, the profile is now 82 m, with an additional 12 stratigraphic layers (11 to 23) (see Fig. 1). Small mammals were collected from Layers 3, 6, 9, 12, 15 and 16 by screen-washing (see Table 1). The mammals from each layer represent one faunal complex with some species spanning multiple layers.

1 Chronological analysis of genera and species

The earliest record of *Hypolagus* is ~4.2 Ma, but the species, *H. schreuderi* Teilhard de Chardin, 1940, is recorded from ~3.4 Ma in the Yushe Basin (Flynn et al., 1997) to the early Pleistocene of Zhoukoudian Loc. 18 (Teilhard de Chardin, 1940) and Sunjiashan 4 of Zibo city, Shandong Province (Zheng et al., 1997).

The earliest record of *Nannocricetus mongolicus* Schaub, 1934 is Early Pliocene in the Ertemte fauna of Nei Mongol (Inner Mongolia) (Schlosser, 1924), and the youngest is estimated as 3.2 ~2.6 Ma in the Donggou and Xiaoshuigou sections (Zheng et al., 2006).

The Bilike fauna of Nei Mongol, including *Sinocricetus progressus* Qiu & Storch, 2000, was originally considered to be Early Pliocene or MN 14 (Qiu and Storch, 2000); it was subsequently correlated to the Zone IV of the Leijiahe sections, about 4.4 ~3.6 Ma based on faunal comparison (Zhang and Zheng, 2001; Zheng and Zhang, 2001), or about 4.0 Ma by the evolutionary stage of *Mimomys bilikeensis* (Repenning, 2003).

Mimomys from the Niutoushan section as well as from other localities of the Nihewan district were originally described or recorded as "*Mimomys orientalis* Young, 1935" (Cai, 1987; Cai et al., 2004; Du et al., 1988; Zheng and Cai, 1991). The present study suggests that it should be considered a new species of the genus *Mimomys*. An estimated time span of 3.2 ~2.6 Ma was given for this taxon in the Qianjiashawa sections (Zheng et al., 2006).

An arvicolid (recorded from Niutoshan as Arvicolidae indet.) was reported by Du et al. (1988) under the name of "*Germanomys* sp. nov.". This form has been discovered from many Pliocene localities in the Nihewan district. In the Qianjiashawa sections, it occurs from about 3.2 Ma (Zheng et al., 2006). A similar species from early Villanyian to early Biharian of France and Spain was reported as "? *Germanomys* sp." (Michaux, 1971).

Cromeromys irtyshensis has a late Villanyian age in the southern region of Western Siberia, Russia (Zazhigin, 1980); In the Yushe Basin it has been paleomagnetically dated at 3.4 ~2.8 Ma (Flynn et al., 1997).

Allophaiomys deucalion has a late Villanyian–early Biharian distribution in Europe (Kowalski, 2001). Furthermore, the appearance of the genus *Allophaiomys* is estimated to be 2.25 and 1.96 Ma based on the paleomagnetic data of localities Tizdar of Russia, Kryzhanovka 4 of Ukraine and Pseekups of North Caucasus (Pevzner et al., 1998). It has an age of about 1.66 Ma in Majuangou Site III of the Nihewan district (Zhu et al., 2004).

Allophaiomys pliocaenicus is of early Biharian age in Europe, but about 1.8 ~0.8 Ma in the Danangou section nearby (Cai et al., 2004) and 1.25 Ma in the Gongwangling Site of Lantian, Shaanxi (Ding et al., 2002).

Microtus minoeconomus was recorded in the Danangou section spanning Layers 9–18, or 1.6 ~0.8 Ma (Cai et al., 2004).

Mesosiphneus sp. seems to represent a similar evolutionary level as *M. paratingi*, which has an age of 3.4 ~3.0 Ma in Yushe Basin (Flynn et al., 1997).

Pliosiphneus sp. is the most advanced species of the genus because of its essentially rootless

hypsodont molar, as in that of *Mesosiphneus paratingi*. Both are of the same evolutionary stage, and are probably latest Pliocene in age.

The typical stratum yielding *Pseudomeriones complicidens* is a set of sands under the well-known Wucheng loess in the Shuimogou section of Ningxian, Gansu. It was considered to be Late Pliocene because of association with ?*Mesosiphneus teilhardi*, *Paralactaga* cf. *P. andersoni* and *Ochotona lagrelii* (Zhang, 1999). It also has a paleomagnetic date of about 3.5 ~ 3.2 Ma in the Leijiahe sections of Lingtai, Gansu (Zheng and Zhang, 2001), and 3.2 Ma in the Donggou section of Nihewan district (Zheng et al., 2006).

Micromys tedfordi has an age of 4.6 ~ 3.4 Ma in the Yushe Basin (Flynn et al., 1997), 5.3 ~ 3.2 Ma in the Leijiahe sections (Zheng and Zhang, 2001) and 3.2 ~ 2.6 Ma in the Qianjiashawa sections (Zheng et al., 2006).

Apodemus zhangwagouensis has a date of about 3.7 ~ 3.4 Ma in the Yushe Basin (Flynn et al., 1997) and 3.2 ~ 2.6 Ma in the Qianjiashawa sections (Zheng et al., 2006).

Chardinomys nihewanicus is originally recorded in Layer 12 of the Pleistocene Danangou section (Zheng, 1981; Cai et al., 2004), and also appeared about 3.2 ~ 2.6 Ma in the Qianjiashawa sections (Zheng et al., 2006). Elsewhere, it is found in the Pliocene Mazigou Fomation (about 3.5 Ma) to the Pleistocene Haiyan Formation in the Yushe Basin (Flynn et al., 1997) and 4.8 ~ 3.0 Ma in the Leijiahe sections (Zheng and Zhang, 2001).

This chronological analysis indicates that the small mammals from Layers 3, 6, 9 and 12 of the Niutoushan section should be regarded as Late Pliocene, and Layers 15 and 16 Early Pleistocene. The layers are essentially equivalent to the European early and late Villanyian, respectively.

2 The Pliocene / Pleistocene boundary

Based on the above analysis, the mammalian complexes from Layers 3, 6, 9 and 12 of the Niutoushan section are Late Pliocene, while Layers 15 and 16 are Early Pleistocene. Thus, the Pliocene/Pleistocene boundary should be situated at the level between Layers 12 and 13.

This boundary was once recorded at the level between Layers 11 and 12, with Layer 12 considered as the basal conglomerate of the upper strata (Du et al., 1988). It is obvious that this interpretation disagrees with evidence from the small mammals of Layer 12 described here.

The present analysis points to the level between Layers 12 and 13 as the boundary, because of the coexistence of *Allophaiomys deucalion* and its direct ancestor, *Cromeromys*. Both occur in Layer 15 of the Niutoushan section as well as Layers 11 and 16 of the Donggou section, which are very near the lower limit of the Pleistocene. At the same time, the M3 of *Mimomys* sp. 1 from Layer 12 of the Niutoushan section indicates the crown height being very close to the *Mimomys* from Layer 4 of the Xiaoshuigou section, which is near the upper limit of the Pliocene.

3 Comparison of the mammalian complexes from Niutoushan, Donggou, Xiaoshuigou, and Danangou sections

If the mammalian complexes from Layers 3, 6, 9, 12, 15 and 16 of the Niutoushan section are represented as faunas a, b, c, d, e and f, those from Layers 2, 4, 7, 11, 16 and 19 of the Donggou section as faunas A, B, C, D, E and F, and those from Layers 1–2 and 4 of the Xiaoshuigou section allocated to faunas A and B, respectively (see Tables 2, 3 and Fig. 2), a faunal sequence can be obtained as follows: a–b–A–c(B)–d(C)–D–e(E)–f(F). Chronologically, faunas a–d and A–C are Late Pliocene, while e–f and D–F are Early Pleistocene.

Using this faunal convention, the mammalian complex c of the Niutoushan section is equivalent to that of Layer 1 of the Danangou section (Cai et al., 2004); they share eight genera and species, including *Sorex*, *Erinaceus*, *Paralactaga*, *Mimomys* sp., Arvicolidae indet., *Micromys*

tedfordi, *Apodemus* and *Chardinomys nihowanicus*. Complex f of the Niutoushan section is comparable with that from Layer 6 of the Danangou section in having *Allophaiomys* cf. *A. pliocaenicus*.

4 Biostratigraphic correlation of Niutoushan and Laowogou sections

Seven fossiliferous layers, namely 1, 2, 3, 9, 11, 16 and 19, were successively found from the Laowogou section located 750 m northwest of Daodi village (Cai, 1977; Cai et al., 2004; Du et al., 1988; Zhang et al., 2003). The small mammals from each of these layers have been reidentified and listed in this paper. By faunal composition, the mammalian complexes from Layers 11 and 16 of the Laowogou section are almost equivalent with the mammalian complexes a and b of the Niutoushan section respectively.

Summarizing current knowledge, the earliest known Cenozoic stratum in the Nihewan district should be Layer 1 of the Laowogou section, which has an age of at least 3.4 Ma based on small mammal biochronology (Zhang et al., 2003).

References

Cai B Q (蔡保全), 1987. A preliminary report on the Late Pliocene micromammalian fauna from Yangyuan and Yuxian, Hebei. Vert PalAsiat (古脊椎动物学报), **25**(2): 124-136 (in Chinese with English summary)

Cai B Q (蔡保全), 1989. Fossil lagomorphs from the Late Pliocene of Yangyuan and Yuxian, Hebei. Vert PalAsiat (古脊椎动物学报), **27**(3): 170-181 (in Chinese with English summary)

Cai B Q (蔡保全), Qiu Z D (邱铸鼎), 1993. Murid rodents from the Late Pliocene of Yangyuan and Yuxian, Hebei. Vert PalAsiat (古脊椎动物学报), **31**(4): 267-293 (in Chinese with English summary)

Cai B Q (蔡保全), Zhang Z Q (张兆群), Zheng S H (郑绍华) et al., 2004. New advances in the stratigraphic study on representative sections in the Nihewan Basin, Hebei. Prof Pap Stratigr Palaeont (地层古生物论文集), **28**: 267-285 (in Chinese with English abstract)

Cui N (崔宁), 2003. Fossil *Chardinomys* (Muridae, Rodentia, Mammalia) from Leijiahe sections, Lingtai, Gansu. Vert PalAsiat (古脊椎动物学报), **41**(4): 289-305 (in Chinese with English summary)

Ding Z L, Derbyshire E, Yang S L et al., 2002. Stacked 2.6-Ma grain size record from the Chinese loess based on five sections and correlation with the deep-sea $\delta^{18}O$ record. Paleoceanography, **17**(3): 501-521

Du H J (杜恒俭), Wang A D (王安德), Zhao Q Q (赵其强) et al., 1988. A new Late Pliocene stratigraphic unit of the Nihewan area—Daodi Formation. J China Univ Geosci (地球科学), **13**(5): 561-568 (in Chinese)

Erbajeva M A, Zheng S H, 2005. New data on Late Miocene-Pleistocene ochotonids (Ochotonidae, Lagomorpha) from North China. Acta Zool Cracov, **48A**(1-2): 93-117

Flynn L J, Wu W Y, Downs W R, 1997. Dating vertebrate microfaunas in the late Neogene record of northern China. Palaeogeogr, Palaeoclimatol, Palaeoecol, **133**: 227-242

Kowalski K, 2001. Pleistocene rodents of Europe. Folia Quat, **72**: 3-389

Michaux J, 1971. Arvicolinae (Rodentia) du Pliocène terminal et du Quaternaire ancient de France et D'Espagne. Palaeovertebrata, **4**(5): 137-214

Pevzner M, Tesacov A, Vangengeim E, 1998. The position of the Tizdar locality (Taman Peninsula, Russia) in the magnetochronological scale. Paludicola, **2**(1): 95-97

Qiu Z D, Storch G, 2000. The Early Pliocene micromammalian fauna of Bilike, Inner Mongolia, China (Mammalia: Lipotyphla, Chiroptera, Rodentia, Lagomorpha). Senckenbergiana lethaea, **80**(1): 173-229

Repenning C A, 2003. *Mimomys* in North America. In: Flynn L J ed. Vertebrate Fossils and Their Context—Contributions in Honor of Richard H. Tedford. Bull Am Mus Nat Hist, **279**: 469-512

Sen S, Erbajeva M, 1995. Early Pliocene leporids (Mammalia, Lagomorpha) from Afghanistan. C R Acad Sci Sér II, **320**: 1225-1231

Schlosser M, 1924. Tertiary vertebrates from Mongolia. Palaeont Sin, Ser C, **1**: 1-119

Teilhard de Chardin P, 1940. The fossils from Locality 18 near Peking. Palaeont Sin, New Ser C, **9**: 1-100

Wu W Y (吴文裕), Flynn L J, 1992. New murid rodents from the late Cenozoic of Yushe basin, Shanxi. Vert PalAsiat (古脊椎动物学报), **30**(1): 17-38 (in Chinese with English summary)

Zazhigin V S, 1980. Late Pliocene and Anthropogene rodents of the south of Western Siberia. Trans Acad Sci USSR, **339**: 3-155 (in Russian)

Zhang Z Q (张兆群), 1999. Pliocene micromammal fauna from Ningxian, Gansu Province. In: Wang Y Q, Deng T eds. Proccedings of the Seventh Annual Meeting of the Chinese Society of Vertebrate Paleontology. Beijing: China Ocean Press. 167-177 (in Chinese with English summary)

Zhang Z Q (张兆群), Zheng S H (郑绍华), 2001. Late Miocene-Pliocene biostratigraphy of Xiaoshigou section, Lingtai, Gansu. Vert PalAsiat (古脊椎动物学报), **39**(1): 54-66 (in Chinese with English summary)

Zhang Z Q (张兆群), Zheng S H (郑绍华), Liu J B (刘建波), 2003. Pliocene micromammalian biostratigraphy of Nihewan Basin, with comments on the stratigraphic division. Vert PalAsiat (古脊椎动物学报), **41**(4): 306-313 (in Chinese with English summary)

Zheng S H (郑绍华), 1981. New discovered small mammals in the Nihewan Bed. Vert PalAsiat (古脊椎动物学报), **19**(4): 348-358 (in Chinese with English abstract)

Zheng S H (郑绍华), Cai B Q (蔡保全), 1991. Micromammalian fossils from Danangou of Yuxian, Hebei. In: IVPP eds. Contributions to the XIII INQUA. Beijing: Beijing Scientfic and Technological Publishing House. 100-131 (in Chinese with English summary)

Zheng S H (郑绍华), Cai B Q (蔡保全), Li Q (李强), 2006. The Plio-Pleistocene small mammals from the Donggou section of Nihewan Basin, China. Vert PalAsiat (古脊椎动物学报), **44**(4): 320-331 (in Chinese with English summary)

Zheng S H (郑绍华), Zhang Z Q (张兆群), 2001. Late Miocene-Early Pleistocene biostratigraphy of the Leijiahe area, Lingtai, Gansu. Vert PalAsiat (古脊椎动物学报), **39**(3): 215-228 (in Chinese with English summary)

Zheng S H (郑绍华), Zhang Z Q (张兆群), Liu L P (刘丽萍), 1997. Pleistocene mammals from fissure-fillings of Sunjiashan hill, Shandong, China. Vert PalAsiat (古脊椎动物学报), **35**(3): 201-216 (in Chinese with English summary)

Zhu R X, Hoffman K A, Potts R et al., 2001. Earliest presence of humans in northeast Asia. Nature, **413**: 413-417

Zhu R X, Potts R, Xie F et al., 2004. New evidence on the earliest human presence at high northern latitudes in northeast Asia. Nature, **431**: 559-562