

柴达木盆地晚中新世三趾马化石¹⁾

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摘要: Bohlin 描述的柴达木动物群中的三趾马材料非常少,仅能证明三趾马在这个地点的存在。近年来新的野外考察在这一地区发现了更多的三趾马化石材料,至少包括 3 个种,即 *Hipparion* cf. *H. chiai*、*H. weihoense* 和 *H. teilhardi*。*H. cf. H. chiai* 和 *H. weihoense* 在柴达木盆地的发现进一步证实了晚中新世早期(保德早期)动物群在这个地区的存在。柴达木盆地的 *H. teilhardi* 基本上与 *H. cf. H. chiai* 和 *H. weihoense* 产自同一层位,其时代也应为保德早期。*H. cf. H. chiai* 和 *H. weihoense* 在柴达木盆地的发现为该地区在晚中新世早期为草原型环境的判断提供了更多的证据。*H. teilhardi* 更细长的远端肢骨也是对开阔环境的一种适应性状。

关键词: 柴达木盆地, 新近纪, 三趾马, 地层对比

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Bohlin (1937) 发现的柴达木动物群一直被认为属于中国三趾马动物群的最早层位,是晚中新世早期的代表,约与欧洲 MN9 带的下部相当(邱占祥、邱铸鼎,1990;Qiu and Qiu, 1995;Qiu et al., 1999)。Bohlin (1937) 描述了柴达木动物群中的 22 种哺乳动物化石,但三趾马的材料非常少,牙齿仅有 3 枚(两枚破碎的上乳颊齿和 1 枚下臼齿),肢骨也很破碎,包括 1 件肱骨远端、2 件桡骨(1 件保留近端和远端、1 件保留远端)、1 件掌骨的远端和近端、1 件胫骨远端、2 件破损的距骨、2 件第一中趾骨、3 件第二中趾骨和 1 件蹄骨。Bohlin 的标本太少且破碎,因此他未能鉴定到种,笼统定名为 *Hipparion* sp., 他认为这些材料只是足够证明三趾马在这个地点的存在。

近年来新的野外考察结果显示 Bohlin (1937) 描述的柴达木动物群可能仅代表盆地剖面中的一部分(Wang et al., 2000; Wang and Wang, 2001; 邓涛、王晓鸣,2004)。已知脊椎动物化石层位横跨中中新世到上新世,不产化石的地段还包括更新及更老的地层(图 1)。Bohlin 的化石无疑混杂有中中新世中期及晚期的成分,因此给人以偏早的三趾马动物群的感觉。幸运的是我们在这一地区发现了更多的三趾马化石材料,包括相当数量的牙齿,有助于更精确地鉴定到属种。这些三趾马材料还对柴达木的生物地层与时代提供了新的依据。本文即报道在柴达木地点新发现的三趾马化石材料,化石地点的位置见邓涛、王晓鸣(2004,图 1)。

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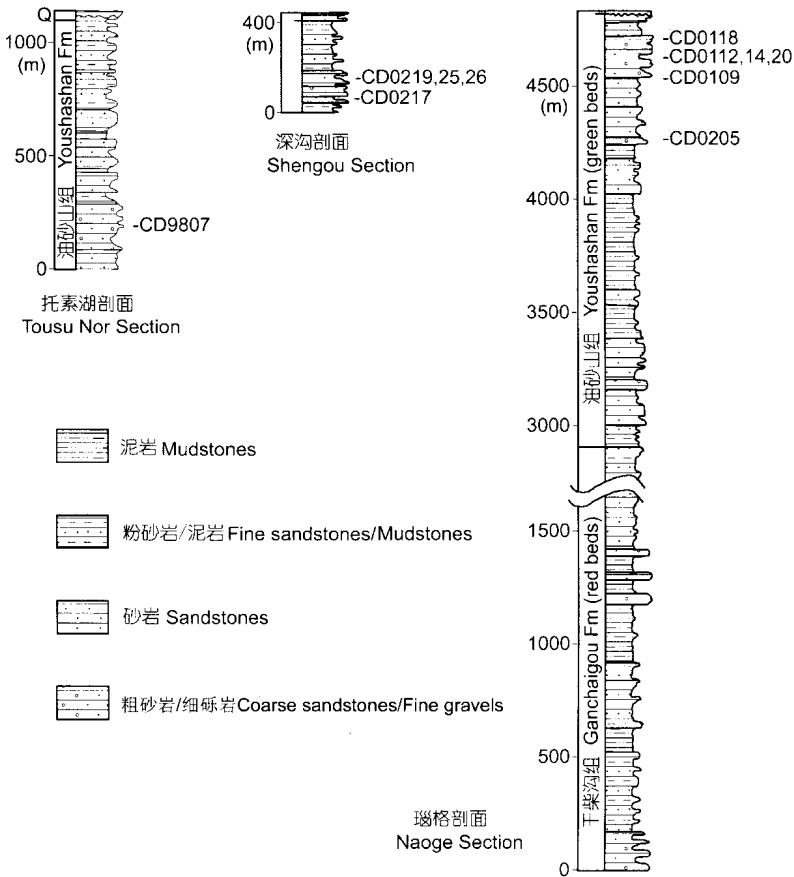


图 1 柴达木盆地新生代地层柱状剖面图

Fig. 1 Column sections of the Cenozoic strata in the Qaidam Basin

1 化石记述

贾氏三趾马相似种 *Hipparion cf. H. chiai* Liu et al., 1978

(图 2.1, 3.1~5; 表 1~3)

材料 V 14011, 右 P3 (图 2.1), 外壁缺失, 齿冠高度尚有 48 mm, 采自 CD0219; V 14012.1, 左 Mc III 近端 (图 3.1), V 14012.2, 左 Mc III 远端 (图 3.2), 这两件标本可能属于同一枚 Mc III, 采自 CD0219; V 14013, 右第二中指骨 (图 3.3), 采自 CD0112; V 14014.1, 左跟骨 (图 3.5), 完整, 采自 CD0219; V 14014.2, 左跟骨远端残部, 采自 CD0219; V 14015.1, 右距骨, 风化较重, 采自 CD0225; V 14015.2, 右距骨 (图 3.4), 采自 CD0113。

产地及地层 青海省海西蒙古族藏族自治州柴达木盆地东北缘, 深沟地点 (CD0219、0225, 邱铸鼎采), 瑙格地点 (CD0112, 陈善勤采; CD0113, 赵京生采), 德令哈市南 46 km。产于绿色粉砂岩中, 晚中新世上油砂山组。

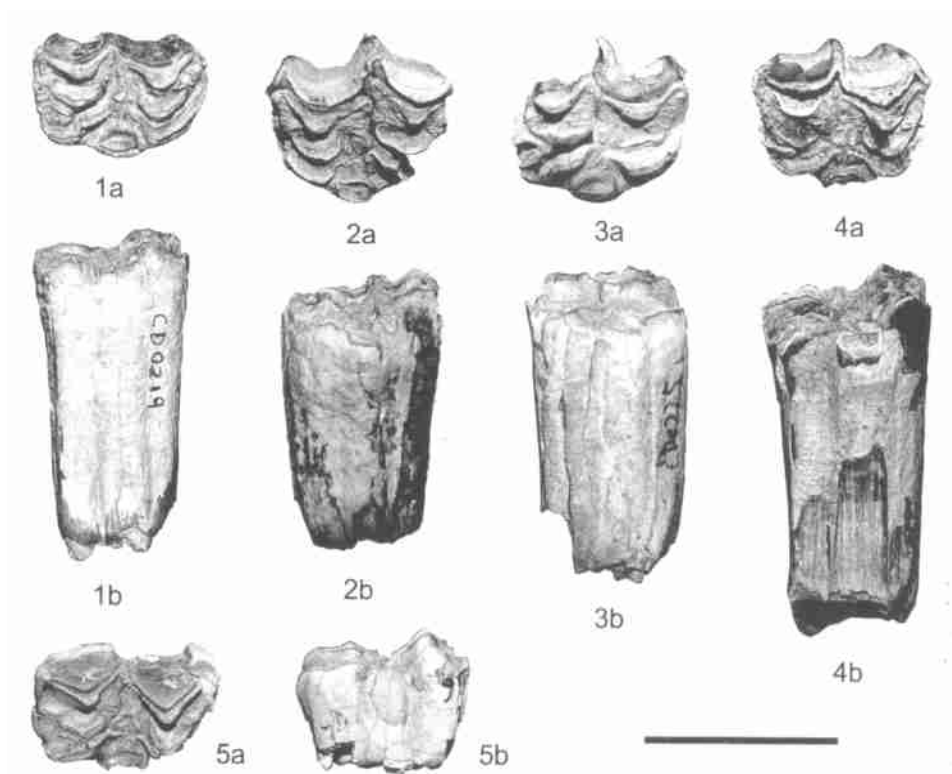


图2 柴达木盆地贾氏三趾马相似种和渭河三趾马的上颊齿化石

Fig. 2 Upper cheek teeth of *Hipparion* cf. *H. chiai* and *H. weihoense* from the Qaidam Basin

1. *H. cf. H. chiai*, V 14011, 右 right P3; 2~5. *H. weihoense*, 2. V 14040, 左 left P4, 3. V 14016.2, 右 right P4, 4. V 14016.3, 右 right M1, 5. V 14016.1, 右 right DP4;
a. 嚼面视 occlusal view, b. 唇面视 labial view; 比例尺 scale bar = 3 cm

表1 柴达木盆地贾氏三趾马相似种和渭河三趾马的上颊齿测量

Table 1 Measurements of the upper cheek teeth of *H. cf. H. chiai* and *H. weihoense* from the Qaidam Basin (mm)

Species	<i>H. cf. H. chiai</i>	<i>H. weihoense</i>				
No.	V 14011	V 14016.1	V 14016.2	V 14040	V 14016.3	V 14016.4
Teeth	P3	DP4	P4	P4	M1	M1
Length	25.7	29.7	26	28.4	27	23.8
Breadth		18.4		25.1	22	
Protocone length	6.5	6	7	7.7	7.2	7.2
Protocone index	25.3	20.2	26.9	27.1	26.7	30.3

对比与讨论 柴达木的三趾马牙齿化石几乎都是单个的颊齿,给鉴定带来困难。但它们的一些性状是相当特征的,能够给较准确的鉴定提供重要线索。当然,由于材料确实太少,也不排除这些单个牙齿属于同种的可能性。这枚 P3 (V 14011) 显然与在陕西蓝田发现的 *H. chiai* (刘东生等,1978) 接近,它们的共同特征包括:原尖扁长,斜向,中间凸,磨蚀强烈时也不深陷入“湾”内;次附尖刺向外伸;原尖前方无小刺;次尖沟发达;褶皱粗大,数量相对较少。V 14011 的原尖前端圆而后端尖,而邱占祥等(1987)认为 *H. chiai* 的原尖

两端,特别是前端较尖。然而,刘东生等(1978)描述 *H. chiai* 的“所有颊齿的原尖皆成扁长的椭圆形,两端尖角不显著”。实际上,原尖两端尖(刘东生等,1978,图版 28,图 1A)和前圆后尖(同上,图 2)两种情况都存在。V 14011 仅有 1 枚马刺,而刘东生等(1978)认为 *H. chiai* 的马刺通常有两枚。但单马刺的情况在 *H. chiai* 的前臼齿上也可见到,如刘东生等(1978,图版 28,图 2)显示的 P2 就只有一枚马刺。柴达木的这枚 P3 的次尖收缩倒是比蓝田标本都更强烈,但被邱占祥等(1987)归入 *H. chiai* 的邱铸鼎(1979)描述的甘肃安程村的三趾马颊齿上也发育次尖收缩。V 14011 的原尖略短(6.5 mm),原尖指数为 25.3,而蓝田 *H. chiai* 的 P3 的原尖指数为 31.8~40.7(刘东生等,1978)。基于上述的异同,我们将 V 14011 鉴定为 *H. cf. H. chiai*。

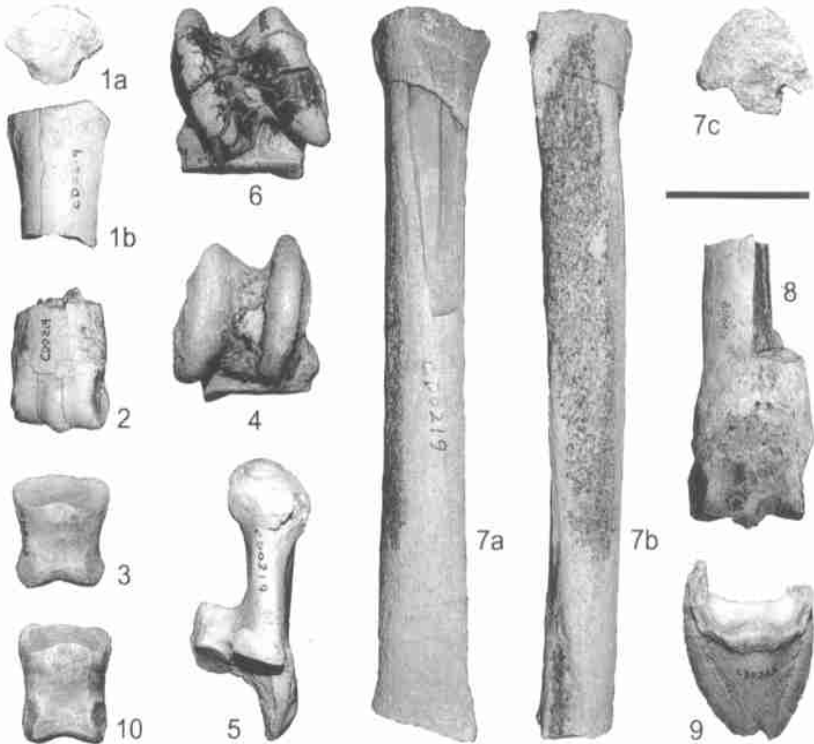


图 3 柴达木盆地三趾马的肢骨化石

Fig. 3 Limb bones of *Hipparion* from the Qaidam Basin

- 1~5. *H. cf. H. chiai*, 1. V 14012.1, 左 left Mc III 近端 proximal, a. 近端关节面视 proximal view, b. 背面视 dorsal view; 2. V 14012.2, 左 left Mc III 远端 distal, 背面视 dorsal view; 3. V 14013, 右第二中指骨 right fore 2nd Ph III, 背面视 dorsal view; 4. V 14015.2, 右距骨 right astragalus, 前视 anterior view; 5. V 14014.1, 左跟骨 left calcaneus, 前视 anterior view; 6~9. *H. weihoense*, 6. V 14019, 左距骨 left astragalus, 前视 anterior view; 7. V 14020.1, 右 right Mt III, a. 背面视 dorsal view, b. 外侧视 lateral view, c. 近端关节面视 proximal view; 8. V 14020.2, 右 right Mt III 远端 distal, 背面视 dorsal view; 9. V 14018, 右前中蹄骨 right fore 3rd Ph III, 顶视 top view; 10. *H. teilhardi*, V 14025, 右第二中趾骨 right hind 2nd Ph III, 背面视 dorsal view; 比例尺 scale bar = 5 cm

表 2 柴达木盆地三趾马的掌、跖骨和指、趾骨测量
Table 2 Measurements of the metapodials and phalanges of Hipparion
from the Qidam Basin (mm)

Bones No.	Mc III V 14012	Distal Mc III V 14017	Mt III V 14020.1	Distal Mt III V 14020.2	2nd Ph III V 14013	2nd Ph III V 14025	2nd Ph III V 14285	3rd Ph III V 14018
1					37.5	39	39	58
2					28	30	30	73
3			27		28.5	29	29	40
4			26		35.4	34	35.3	56.6
5	35		41		23	22.4	25	21
6	24.5		33.5		33	31.4	31.1	38.5
7	29		37					~ 170
8	12		8					
8'	4.5							
9	0		4					
10	34	38		39				
11	31.5			37.5				
12	25	27		32.5				
13	20.5	24.5		26				
14	22	25.5		29.3				

注:测量项的编号和含义依 Eisenmann (1986) Measures according to Eisenmann (1986).

表 3 柴达木盆地三趾马的跗骨测量
Table 3 Measurements of the tarsals of Hipparion from the Qidam Basin (mm)

Bones No.	Calcaneus V 14014.1	Calcaneus V 14014.2	Astragalus V 14015.1	Astragalus V 14015.2	Astragalus V 14019
1	102		57	58.5	61.5
2	67.4		57	55.3	58
3	43.5		58.2	55.6	57.1
4	18.2	19.8	25.4	28.2	31
5	30.5		39	41.2	44.7
6	47.5		30.4	31	34.3
7	43.5	48	42.4	45	48

注:测量项的编号和含义依 Eisenmann (1986) Measures according to Eisenmann (1986).

在柴达木盆地各个地点采集到一些三趾马的肢骨材料,比较零散和破碎。对于三趾马而言,一般来说肢骨在种的鉴定上往往比较困难(邱占祥等,1987)。柴达木盆地未发现有三趾马完整的骨架,也无连接在一起脚骨,使鉴定更加困难。在本文所涉及的3个种中,*H. weihoense* 的原始描述中没有肢骨材料;*H. chiai* 有一些破碎的肢骨,但没有性状描述,只有部分测量数据(刘东生等,1978)。*H. teilhardi* 仅有1枚 Mt III (邱占祥等,1987)。我们主要通过在不同地点与牙齿化石的共生情况来作一个大致的判断,并与其他三趾马

的肢骨资料对比。

Mc III (V 14012) 与鉴定为 *H. cf. H. chiai* 的右 P3 (V 14011) 共生。蓝田的 *H. chiai* 材料中包括一枚 Mc III (V 3116.9), 在与 V 14012 可以对比的测量项中, V 3116.9 的近端宽 35.6 mm, 远端宽约 30 mm, 两件标本相当接近(表 2)。Bohlin (1937, textfigs. 176, 182) 也有一件保留远端和近端的 Mc III 标本(Nr. 493), 其近端宽度为 37 mm, 远端宽度为 34 mm, 与 V 14012 非常接近, 它们的近端关节面形态也很相似, 应属于同种。第二中指骨 (V 14013) 的归属没有十分可靠的理由, 它可能比蓝田 *H. chiai* 的中指骨大, 后者有一件标本的测量, 但没有区分前后(刘东生等, 1978)。V 14013 明显小于 *H. primigenium* 的第二中指骨(Bernor et al., 1997, tab. 6. 17), 更小于 *H. houfenense* 的第二中指骨(邱占祥等, 1987, 表 16)。从比例上看, V 14013 的近端宽度小于骨体最大长度, 而 *H. primigenium* 正相反, 骨体最大长度小于近端宽度, 它们显然属于不同的类型, 前者可能是对更开阔环境的一种适应性状, 如 *H. houfenense* 也与柴达木标本为同一类型(邱占祥等, 1987, 表 16)。保德地点的第二指骨通常也是长度大于宽度, 而河南和山西东南部的一些标本则是长度小于宽度(Bohlin, 1937, textfigs. 200~204)。

两件跟骨标本(V 14014.1 和 V 14014.2) 与鉴定为 *H. cf. H. chiai* 的牙齿共生, 它们的尺寸都不大, 因此可能属于 *H. cf. H. chiai*。这两枚跟骨比 *H. primigenium* 最小的跟骨标本还小(Bernor et al., 1997, tab. 7. 6), 且中部特别窄扁。Gromova (1952) 曾提到三趾马与真马的跟骨有 10 点不同, 但邱占祥等(1987) 认为只有两点区别, 其中之一是远端关节面在三趾马中近直长条形, 后部变窄, 但不特别明显; 真马的前半部特别宽, 前、后部之间在内缘由一收缩分开。从柴达木的这件跟骨看, 上述的这一点区别也不可靠。他们指出的另一点区别是, 真马载距突内面前部都有一条纵沟, 它穿过载距突远端关节面内缘的中部, 形成凹槽; 三趾马没有这个特征。从柴达木标本看, 后一条区别确实存在, 但并不是很截然, 柴达木标本的这个部位也有凹陷, 只是未形成明显的凹槽。

距骨(V 14015.1) 与鉴定为 *H. weihoense* 的牙齿共生, 而距骨 V 14015.2 与 V 14015.1 的大小和形态相当一致, 所以这两枚距骨可能都与 *H. weihoense* 同层。另一方面, 这两枚距骨与上述可能为 *H. cf. H. chiai* 的跟骨(V 14014.1 和 V 14014.2) 在大小上相配, 而 *H. cf. H. chiai* 也与 *H. weihoense* 同层, 因此我们判断这两枚距骨可能属于 *H. cf. H. chiai* 而非 *H. weihoense*。与跟骨一致, 这两枚距骨都小于 *H. primigenium* (Bernor et al., 1997, tab. 7. 5), 更明显小于 *H. houfenense* (邱占祥等, 1987, 表 13)。Bohlin (1937, textfigs. 188~191) 有两件距骨标本, Nr. 467 较大, 而 Nr. 500 较小。Nr. 467 的大小和形态与 V 14015.1 和 V 14015.2 相似, 可以归为同种。Nr. 500 相当小, 其最大长度比 V 14015.1 短 10 mm, 但这也未超出一个种的变异范围, 如 *H. primigenium* 距骨标本的最大长度可相差 11.9 mm (Bernor et al., 1997, tab. 7. 5), 所以 Nr. 500 仍然有可能属于 *H. cf. H. chiai*。

渭河三趾马 *Hipparion weihoense* Liu et al., 1978

(图 2. 2~5, 3. 6~9; 表 1~3)

材料 V 14016.1, 右 DP4 (图 2.5), 前壁破损, 采自 CD0226; V 14016.2, 右 P4, 外壁缺失(图 2.3), 采自 CD0225; V 14040, 左 P4 (图 2.2), 次尖处残破, 产自 CD0109; V 14016.3, 右 M1 (图 2.4), 前壁破损, 齿冠高度尚有 61 mm, 采自 CD0225; V 14016.4, 右 M1, 牙齿从中

央破裂,只保留分开的内半部和外壁,采自 CD0206;V 14017,右 Mc III 远端,内髁缺失,采自 CD0215;V 14018,右前中蹄骨(图 3.9),蹄骨角破损,采自 CD0225;V 14019,左距骨(图 3.6),完整,采自 CD0205;V 14020.1,右 Mt III,缺失远端(图 3.7),采自 CD0219;V 14020.2,右 Mt III 远端(图 3.8),采自 CD0118;V 14285,左第二中趾骨,远端残破,采自 CD0109。

产地及地层 青海省海西蒙古族藏族自治州柴达木盆地东北缘,深沟地点(CD0215,王晓鸣采;CD0219、0225,邱铸鼎采;CD0226,颜光普采),瑙格地点(CD0109,邱占祥采;CD0118,王伴月采;CD0205,王晓鸣采;CD0206,邱铸鼎采),德令哈市南 46 km。产于绿色粉砂岩中,晚中新世上油砂山组。

对比与讨论 *H. weihoense* 的颊齿与 *H. chiai* 有一些共同的特征,如原尖扁长,磨蚀强烈时不深入“湾”内。另一方面,刘东生等(1978)指出了一些这两个种之间的区别,邱占祥等(1987)又作了补充。在与本文有关材料方面,*H. weihoense* 不同于 *H. chiai* 的特征包括:尺寸较大,颊齿的褶皱更复杂,原尖不倾斜,两端圆,次附尖刺由后窝后壁前伸,齿冠较高。柴达木的这 5 枚颊齿与蓝田的 *H. weihoense* 的对应颊齿相当一致,也具有上述与 *H. chiai* 不同的特征。它们与 *H. weihoense* 的一致性还表现在颊齿侧面微向内弯,釉质褶皱粗大,双马刺,外壁强烈内凹,次尖收缩无或微弱,次尖沟在前臼齿上宽大而在臼齿上窄长等方面。V 14016.3 的原脊刺很少,这一点与蓝田标本有些不同。

前已述及,Bohlin 的柴达木三趾马牙齿材料非常少,他所展示的内容仅有一个后窝以及一个原尖带马刺的插图(Bohlin, 1937, textfig. 166)。他认为上颊齿原尖的形态和釉质的褶皱与 Sefve (1927, fig. 13) 描述的山西保德戴家沟的 *H. richthofeni* 的 M2 非常相似。他图示的后窝的特征是后窝刺发达,次附尖刺从后窝后壁前伸,也与 *H. weihoense* 相似。但 Bohlin 标本的原尖形态宽圆,与我们这次发现的 3 个种的窄扁的原尖都不同。Sefve (1927) 的 *H. richthofeni* 已被 Zhegallo (1971) 修订为 *H. forstenae*,其时代与 *H. teilhardi* 相同,为晚中新世晚期(邱占祥等, 1987)。但 Bohlin 的材料确实太过破碎,无法做到准确的鉴定。

Mc III 远端(V 14017)比蓝田的 *H. chiai* 标本宽(刘东生等, 1978),与 *H. primigenium* 接近(Bernor et al., 1997, tab. 6. 13),可能属于体型较大的 *H. weihoense*。前中蹄骨标本(V 14018)与鉴定为 *H. weihoense* 的牙齿化石共生。蓝田地点记述有一枚 *H. chiai* 的“趾骨 III”,但其度量为长 37 mm,宽 36 mm,这两个数据指示不清,可能有误:所谓长度无论是指蹄骨前长(表 2 测量项 1)或蹄骨前后径(表 2 测量项 2)都太小,如指关节前后径(表 2 测量项 5)又太大;所谓宽度如指蹄骨宽(表 2 测量项 4)则太小,而如指关节宽(表 2 测量项 6)则表明蓝田的 *H. chiai* 蹄骨比柴达木标本小。V 14018 与 *H. primigenium* 的前中蹄骨在大小上接近,主要表现在有相近的长度和高度,但二者也有明显的区别,V 14018 在背面长度、背面与底面夹角以及关节宽度三个方面远远小于 *H. primigenium*。从尺寸考虑,我们将柴达木的这枚蹄骨归属于 *H. weihoense*。Bohlin (1937, textfigs. 205, 206) 记述了一件三趾马的中蹄骨(Nr. 532),它比 V 14018 小得多,可能属于 *H. cf. H. chiai*。

Mt III 标本(V 14020.1)与鉴定为 *H. cf. H. chiai* 的一枚 P3 (V 14011) 共生。蓝田的 *H. chiai* 材料中包括一枚 Mt III (V 3116.9),在与柴达木标本可以对比的测量项中,蓝田标本的近端宽约 32 mm,中段宽 21.5 mm,中段厚 23.2 mm,V 14020.1 显然比其粗壮(表 2)。由于在柴达木地点 *H. cf. H. chiai* 和 *H. weihoense* 与蓝田地点一样产出于同一层

位,而后的个体明显大于前者,因此这件 Mt III 可能属于 *H. weihoense*。Mt III 标本(V 14020.2)的测量(表 2)远大于蓝田地点的 *H. chiai* 的 Mt III 的相同测量项(后者的远端关节宽度为 37.5 mm × 27 mm),因此 V 14020.2 也可能属于 *H. weihoense*。上述两枚 Mt III 标本(V 14020.1 和 V 14020.2)都小于 *H. teilhardi* 的 Mt III (V 8241;邱占祥等,1987,图版 XL,4)。

距骨(V 14019)的尺寸大于 V 14015.1 和 V 14015.2,形态上也不同于后两件标本,它们之间的区别还包括:滑车外峭略宽于内峭,其远端与远端关节面之间的颈部较窄,为 9.5 mm,峭间沟宽浅;远端对骰骨关节面较长,对舟骨关节面隆突而连续,无横行沟;蹠面对跟骨的 4 个关节面中,内面上下宽度近等,中央无收缩;外上面的上部边缘与外峭后边缘之间有间隔,外下面长,为前下角圆滑的三角形;距骨内面的远侧隆起突出弱,近侧隆起较宽。因此 V 14019 有可能属于 *H. weihoense*。V 14019 与 *H. primigenium* 的距骨在大小上接近(Bernor et al., 1997, tab. 7.5),而小于 *H. houfenense* (邱占祥等,1987),但 V 14019 的滑车宽度不仅大于 *H. primigenium*,也大于 *H. houfenense*。第二中趾骨(V 14285)与鉴定为 *H. weihoense* 的 P4 (V 14040)共生,且它远大于蓝田 *H. chiai* 的第二中趾骨(刘东生等,1978),因此应该属于 *H. weihoense*。Bohlin (1937, textfig. 202)的一枚第二中趾骨与 V 14285 一致,可能也属于 *H. weihoense*。

德氏三趾马 *Hipparion teilhardi* Qiu et al., 1987

(图 3.10,4;表 2.4)

材料 V 14021,右下颌水平支残段(图 4.6),保存破碎的 p4、较完整的 m1 和 m2、以及刚萌出的 m3,采自 CD9807;V 14041,右下颊齿列(图 4.1),保存 p3 和全部臼齿,有部分内、外侧水平支残块,产自璠格绿砂岩之上;V 14042,右下颌水平支残块(图 4.5),保留 p4 和 m1,产自 CD0114;V 14022.1,左 p2 (图 4.4),采自 CD0120;V 14022.2,左 m1 (图 4.3),前壁破损,采自 CD0120;V 14022.3,左 m1 (图 4.2),牙齿上部的下前附尖及次尖外壁处破损,采自 CD0120;V 14023,右胫骨远端,采自 CD0120;V 14024,右外楔骨,采自 CD0217;V 14025,右第二中趾骨(图 3.10),采自 CD0120。

产地及地层 青海省海西蒙古族藏族自治州柴达木盆地东北缘,托素湖北岸地点(CD9807,王伴月采),怀头塔拉村东南 25 km。深沟地点(CD0217,颜光普采),璠格地点(CD0114,赵京生采;CD0120,冯文清采),德令哈市南 46 km。产于绿色粉砂岩中,晚中新世上油砂山组。

表 4 柴达木盆地德氏三趾马的下颊齿测量

Table 4 Measurements of the lower cheek teeth of *H. teilhardi*

Teeth No.	from the Qidam Basin			(mm)							
	p2	p3	p4	m1			m2		m3		
	V 14022.1	V 14041	V 14042	V 14022.2	V 14022.3	V 14021	V 14042	V 14041	V 14041	V 14041	
Length	30.4	28.6	25.4	25.5	23.2	25.4	25	25.5	27.3	27	30
Breadth	13.4	15	14	14.4	13	11.8	13.6	14.4	11.6	13.7	11.4
Postflexid L.	13	14.7	12.7	13	12	10	11	11.5	9.5	9.8	11
Postflexid I.	42.8	51.4	50	51	51.7	39.4	44	45.1	34.8	36.3	36.7

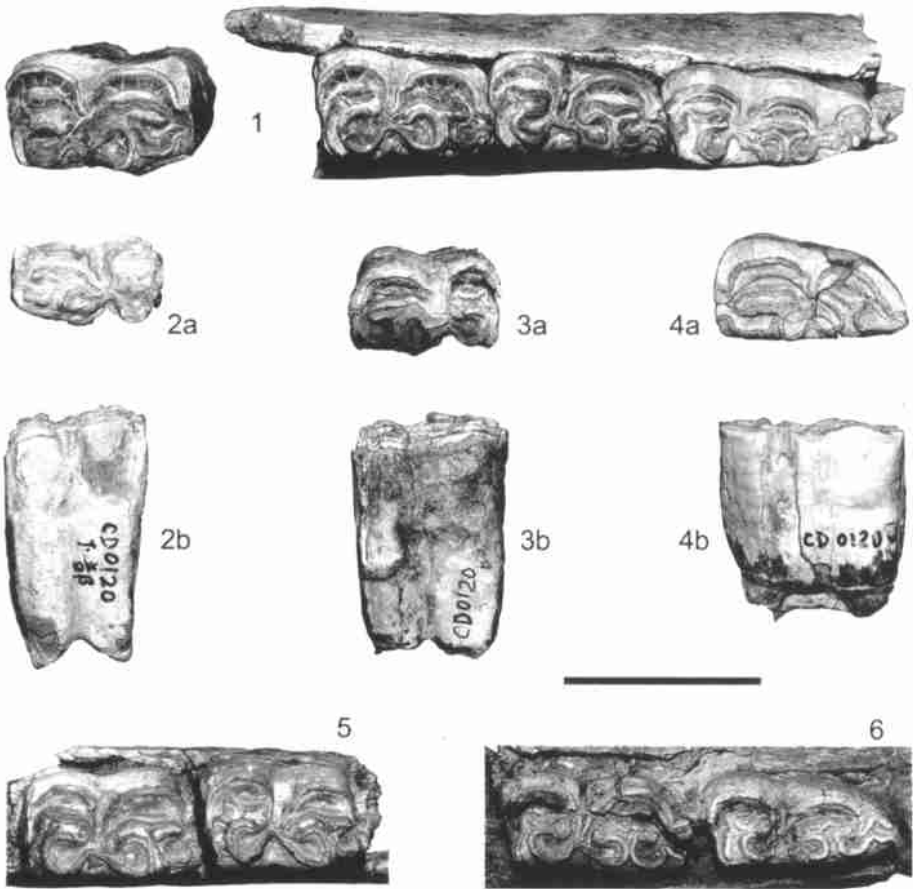


图4 柴达木盆地德氏三趾马的下颊齿化石

Fig. 4 Lower cheek teeth of *Hipparion teilhardi* from the Qaidam Basin

1. V 14041, 右 right p3 and m1 ~ m3, 嚼面视 occlusal view; 2. V 14022.3, 左 left m1;
3. V 14022.2, 左 left m1; 4. V 14022.1, 左 left p2; 5. V 14042, 右 right p4 ~ m1, 嚼面视 occlusal view; 6. V 14021, 右 right m1 ~ m2, 嚼面视 occlusal view
- a. 嚼面视 occlusal view; b. 唇面视 labial view; 比例尺 scale bar = 3 cm

对比与讨论 邱占祥等(1987)根据 Teilhard de Chardin 和 Licent 在陕西横山油房头采集的材料建立了新种 *H. teilhardi*, 他们描述的这个种下颊齿的性状包括外壁圆隆; 双叶相对较短, 下后尖圆形, 但下后附尖内后角稍尖; 前臼齿的内谷近 V 形; 臼齿的内谷稍宽, 外谷深; 下原附尖较发育。上述柴达木的下颊齿标本除下原附尖不太发育这一点之外, 其余特征都与 *H. teilhardi* 相同, 特别是臼齿内、外谷和 m3 下次小尖的形态都是相当独特和一致的。实际上, 油房头的一些下颊齿的下原附尖也不太发育, 如 V 8236 的前臼齿和 m3 (邱占祥等, 1987, 图版 XL, 2, 插图 55)。

在柴达木发现的肢骨标本中, 右胫骨远端(V 14023)与鉴定为 *H. teilhardi* 的 3 枚下颊齿共生, 因此它们有属同种的可能。V 14023 的远端宽度为 61 mm, 厚度为 42 mm。蓝田有一枚 *H. chiai* 的胫骨远端标本, 宽度为 52 mm, 厚度为 37 mm, 明显小于 V 14023。 *H. pri-*

*migenium*的胫骨远端宽度平均为 71.1 mm,厚度平均为 45 mm (Bernor et al., 1997, tab. 7.4),大于 V 14023,而从 Mt III 的尺寸看,*H. teilhardi* 长于 *H. primigenium*。前已述及,东亚草原型的三趾马比欧洲森林型的三趾马肢骨更纤细,如 *H. houfenense* 的 Mt III 也长于 *H. primigenium*,而前者的胫骨远端也小于后者(邱占祥等,1987,表 12,14)。Bohlin (1937) 也有一件胫骨远端(Nr. 453),其宽度为 63 mm,厚度为 42 mm,几乎与 V 14023 一致,显然也应属于 *H. teilhardi*。柴达木的外楔骨标本(V 14024)厚 11 mm,宽 39.6 mm,深 32.2 mm,比 *H. primigenium* 的外楔骨(Bernor et al., 1997, tab. 7.9)略小,看来也是与较小的胫骨远端相适应。

右第二中趾骨(V 14025)与 *H. teilhardi* 的 3 枚下颊齿和右胫骨远端(V 14023)共生,我们也把它归入这个种。V 14025 与上述 *H. weihoense* 的第二中趾骨(V 14285)的大小和比例相似,但形态上有较大差别。V 14025 和 V 14285 都远大于蓝田 *H. chiai* 的第二中趾骨(刘东生等,1978),但小于 *H. primigenium* (Bernor et al., 1997, tab. 7.15)。从比例上看,柴达木的这两枚第二中趾骨的近端宽度小于骨体最大长度,而 *H. primigenium* 正相反,骨体最大长度小于近端宽度。与第二中指骨一致,更细的中趾骨可能是对开阔草原的一种适应性状,因而不同于森林型的 *H. primigenium*。

2 地层与生态意义

Bohlin (1937) 最初描述哺乳动物的文章几乎未提到产出化石的地层状况。他等到 1960 年才初步描述了托素湖附近的地层。遗憾的是该文章至今几乎鲜为人知。而没见到这篇文章的后人不得不暂时假设“柴达木动物群”全部出自一个层位。事实上 Bohlin 的所谓“柴达木动物群”产自厚达 5 000 m 的剖面。因此把柴达木化石笼统归为一个时代的动物群无疑与现实相去甚远。

Bohlin 在柴达木采集化石集中在两个地区。一个是托素湖西北连接可鲁克湖与托素湖之间的小河(Bohlin 称“Noringen Göl”)的北岸边。该点化石全部在 1931 年 10 月采集。化石集中在靠近湖边的下部层位(Bohlin, 1960, fig. 12),近年来重复采集基本可以验证其准确层位。化石出产层位总厚度不超过几十米。但托素湖地点仅产出少量化石,包括 Bohlin (1937) 描述的 316 到 357 号化石。Bohlin 在此点仅找到三趾马的一个第二中趾骨(Nr. 352)。另一地区是 Bohlin 称作巴润乌拉山的地点,化石全部在 1932 年 5 月采,包括除上述 316~357 号以外的所有材料。该地点距托素湖以西 10 km 左右,但该点的地层则远比托素湖的厚得多。Bohlin 的 165 号营地是 1932 年的化石采集的汇集点,而营地附近的地层厚达 5 000 m 以上。Bohlin 的化石多来自剖面中部绿色砂岩中,但该砂岩的厚度按 Bohlin 自己的粗略估计也达 2 000 m 以上。

由于近年来我们在柴达木地区发现了更多的三趾马化石材料,到目前为止,柴达木的三趾马化石至少包括 3 个种,即 *H. cf. H. chiai*、*H. weihoense* 和 *H. teilhardi*。

H. chiai 和 *H. weihoense* 发现于陕西蓝田的灞河组(灞河动物群:刘东生等,1978; Zhang et al., 2002)和甘肃临夏盆地的柳树组中部(大深沟动物群:邓涛等,2004; Deng et al., 2004)。*H. chiai* 还被发现于甘肃秦安程村(邱占祥等,1987)和陕西府谷老高川的下化石层(喇嘛沟动物群:Xue et al., 1995)。邱占祥等(1987)认为 *H. chiai* 和 *H. wei-*

hoense 的眶前窝距眼眶较远并相当深,原尖扁长,表明它们无疑都是 *H. primigenium* 型的,最接近从北美迁徙过来的祖先。它们被归入同一个亚属 *Hipparion* (*Hippotherium*),而在欧洲和非洲的 *H. primigenium* 型三趾马都是 Vallesian 期的。他们还认为 *H. chiai* 下颊齿前谷的前外角比后外角尖细,更向外伸,而这个特点存在于北美早期的三趾马中,如 *H. tehonense* (MacFadden, 1984, fig. 38)。因此,*H. chiai*,可能还有 *H. weihoense* 是亚洲大陆上保存着较多北美三趾马特征的种,所以它们的时代应该较早。

李传夔等(1984)将灞河动物群与欧洲晚中新世早期的 Vallesian 期对比。邱占祥和邱铸鼎(1990)以及童永生等(1995)进一步确认了这个对比关系。大深沟动物群中包括的 *Dinocrocuta gigantea*、*Acerorhinus hezhengensis*、*Chilotherium wimani*、*Hezhengia bohlini* 和 *Miotragocerus* sp. 等也代表较早的时代(邱占祥等,1987,2000;邓涛,2000,2001),所以被认为应相当于欧洲 Vallesian 的晚期(Qiu et al., 1999;邓涛等,2004;Deng et al., 2004)。Xue et al. (1995)根据古地磁年龄认为喇嘛沟动物群相当于 Turolian 早期,但从动物群性质看,它应与大深沟动物群同时,可能早于晚中新世晚期(Qiu et al., 1999;邓涛,2000,2001)。因此,*H. chiai* 和 *H. weihoense* 显然生存于晚中新世早期,即相当于欧洲的 Vallensian 期。

邱占祥、邱铸鼎(1990)和 Qiu et al. (1999)认为 Bohlin (1937)的“柴达木动物群”应属晚中新世早期,代表中国三趾马动物群的最早层位,约与欧洲 MN9 带的下部相当。他们的理由是,这个动物群中已有三趾马出现,但还保留了一些中中新世安琪马动物群中的残余分子(如柄杯鹿等)。如果仅以三趾马出现的层位而论,这个结论仍旧成立,但究其所据的原因则完全不对了。将 Bohlin 描述的所有类群都笼统归入一个动物群显然是造成这种错觉的主因。Bohlin 采集的化石有可能跨越 2 000 m 长的剖面,其漫长时代跨度所造成的混乱可想而知。

近年来我们在柴达木的野外工作已逐渐开始建立起盆地内生物层序的框架。中中新世、晚中新世和上新世的分段及其包含的动物群已初见轮廓。中中新世动物群的确存在(Wang et al., 2000;Wang and Wang,2001),其中的 *Hispanotherium matritense* 并不与晚中新世三趾马动物群中的 *Acerorhinus tsaidamensis* 同层(邓涛、王晓鸣,2004),后者代表了柴达木动物群中相当于 Vallesian 期的层位。本文描述的 *H. cf. H. chiai* 和 *H. weihoense* 进一步证实了晚中新世早期(保德早期)动物群的存在。实际上,*H. cf. H. chiai* 和 *H. weihoense* 在 CD0219 地点也与 *A. tsaidamensis* 共生。因此,含 *H. cf. H. chiai* 和 *H. weihoense* 的璠格剖面的上部及深沟剖面的时代都可能是晚中新世早期。

H. teilhardi 此前仅在陕西横山油房头一个地点发现,标本由 Teilhard de Chardin 和 Licent 在早期采集,其地层没有进一步的详细工作(Teilhard and Licent, 1924),邱占祥等(1987)仅认为可能为保德期。从形态上讲,*H. teilhardi* 似乎与北美某些类型相似,如 *Neohipparion affine*,表现出相当原始的性状(邱占祥等,1987)。柴达木盆地的 *H. teilhardi* 基本上与 *H. cf. H. chiai* 和 *H. weihoense* 产自同一层位(璠格剖面的上部及深沟剖面)。而托素湖剖面下部出现的 *H. teilhardi* 也暂以保德早期处理为好。同样理由,在无其他证据之前,陕西横山油房头的 *H. teilhardi* 也应归做晚中新世早期。

根据柴达木盆地晚中新世早期沉积中发现的 *A. tsaidamensis*,我们判断当时气候温暖而湿度低,呈半干旱状态,以草原为主,有部分林带和灌丛存在(邓涛、王晓鸣,2004)。在蓝田地点,*H. chiai* 和 *H. weihoense* 的层位中齿冠较高、个体较大的羚羊占相当数量,长颈

鹿为半高冠的 *Palaeotragus*, 缺乏猪和鹿, 代表了草原性的生活环境 (刘东生等, 1978)。显然, *H. cf. H. chiai* 和 *H. weihoense* 在柴达木盆地晚中新世早期的发现进一步证实了对当地当时草原环境的判断。柴达木盆地晚中新世的 *Dicerorhinus ringstromi* 善于奔跑 (Guéin, 1980), 适应于干旷草原的生活 (Ringström, 1924)。前面的分析也表明 *H. teilhardi* 的远端肢骨可能更细长, 是对开阔环境的一种适应性状, 与共生的 *D. ringstromi* 代表了动物群中的奔跑型动物。

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LATE MIOCENE HIPPARION (EQUIDAE, MAMMALIA) OF EASTERN Q Aidam BASIN IN QINGHAI, CHINA

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Summary

Fossil mammals collected from the northeastern Qaidam Basin by Swedish vertebrate paleontologist Birger Bohlin represent the first scientifically documented *Hipparion* (three-toed horse) fauna in the Tibetan Plateau. Fossil mammals from Qaidam represent a modest diversity of 22 taxa, but *Hipparion* materials are rather fragmentary, consisting of three dental fragments along with a few isolated postcranial elements. Despite such meager materials, the upper tooth fragments preserve typical *Hipparion* structures, such as an isolated protocone, and the presence of this important Late Miocene horse has not been in doubt since Bohlin's (1937) description of the "Qaidam Fauna." Mixed with the *Hipparion* horses, however, are also Middle Miocene taxa, such as basal deer *Lagomeryx* and *Stephanocemas*. Problems therefore arise in attempting to assign an age for the fauna. Bohlin's (1937) original descriptions of the Qaidam mammals did not place them in a stratigraphic context, until more than 20 years later when he (Bohlin, 1960) published a brief description of the Qaidam geology. Unfortunately, most recent authors were unaware of this latter geologic summary, and as a result, all taxa were tacitly assumed to belong to a single fauna in treating the chronology of the Qaidam mammals (Qiu and Qiu, 1990, 1995; Qiu et al., 1999). By such an assumption, it is logical to regard the "Qaidam Fauna" as belonging to the earliest Late Miocene because of its possession of typical Late Miocene three-toed horse along with primitive deer that must have been Middle Miocene "leftovers."

In recent years, we have begun to systematically revisit the Qaidam mammal localities and to place newly collected materials in a modern stratigraphic context. It quickly becomes obvious that a substantial part of Bohlin's "Qaidam Fauna" must have been collected from a long section of 2 000 m (total thickness > 5 000 m at some local sections) that surely spans a considerable duration of time (Wang et al., 2000; Wang and Wang, 2001). More significantly, we have collected much better *Hipparion* materials in several localities. We are thus in a position to tease out certain components of the "Qaidam Fauna" on the basis of the morphological attributes of the *Hipparion*. Our findings confirm the existence of an early Late Miocene fauna in Qaidam, which was mixed with Middle

Miocene faunas in previous studies without stratigraphic reference. Newly discovered *Hipparion* tends to bear primitive morphologies of the genus, signaling its close affinities to the North American ancestors. Such primitive morphologies are often associated with early Late Miocene strata equivalent to the European Vallesian age. Middle Miocene elements, such as *Lagomeryx* and *Stephanocemas*, are not associated with *Hipparion*.

1 Systematic paleontology

Hipparion cf. *H. chiai* Liu et al., 1978

Hipparion fossils from Qaidam are mostly isolated teeth, which cause some difficulties in comparisons. Certain characteristics preserved in the materials, however, provide important clues in the identification. The single P3 (V 14011) is apparently close to the type materials of *H. chiai* from Lantian, Shaanxi (Liu et al., 1978). They share common features such as an elongate, diagonally oriented protocone that bulges in the middle. The protocone will not sink into the "bay" even after extensive wear. The pli hypostyle extends outwards. No pli is present in front of the protocone. Hypoconal grooves are well-developed, and enamel plications are strong but few in numbers. The protocone of V 14011 is rounded anteriorly and pointed posteriorly, in contrast to Qiu et al.'s (1987) characterization of *H. chiai* that has pointed protocones, particularly on the anterior end. However, Liu et al.'s (1978) descriptions indicated that "protocones of all cheek teeth have flattened, oval outlines with inconspicuous angles on either ends." Actually, both situations exist, i. e., pointed protocones on either ends (Liu et al., 1978, pl. 28, fig. 1A) or rounded anteriorly and pointed posteriorly (Liu et al., 1978, pl. 28, fig. 2). V 14011 has only one pli caballine, whereas Liu et al. (1978) suggested that *H. chiai* often has two. However, a single pli condition in the premolars of *H. chiai* is not uncommon, such as on the P2 in Liu et al. (1978, pl. 28, fig. 2). The P3 from Qaidam has a hypocone that is more strongly reduced than those from Lantian. On the other hand, a similar reduction is also seen in the horses from Chengcun (Qin'an, Gansu) described by Qiu (1979) and subsequently referred to *H. chiai* by Qiu et al. (1987). The protocone in V 14011 is somewhat short (6.5 mm), with a protocone index of 25.3, while the protocone index of *H. chiai* from Lantian is 31.8 ~ 40.7 (Liu et al., 1978). On the basis of the above-mentioned similarities and differences, V 14011 is referred to *H. cf. H. chiai*.

Postcranial materials from Qaidam are isolated and fragmentary. For *Hipparion*, postcranials are usually difficult to identify to species (Qiu et al., 1987). There are no articulated skeleton or complete feet in the Qaidam horses, making the identification even more difficult. Previously, *H. weihoense* had no limb bones, whereas *H. chiai* had some fragmentary limbs but no diagnostic characters were given except some measurements (Liu et al., 1978). *H. teilhardi* had a single Mt III (Qiu et al., 1987). We can only make some preliminary judgments based on associations of dental remains.

The Mc III (V 14012) is from the same locality as the right P3 (V 14011). Materials from Lantian also include a Mc III (V 3116.9). Among comparable measurements, V 3116.9 has a width of 35.6 mm proximally and 30.0 mm distally, dimensions that are similar to V 14012 (Table 2). Bohlin (1937, textfigs. 176, 182) also described a Mc III (Bohlin's Nr. 493) from Qaidam, with a width of 37 mm proximally and 34 mm distally—very close to those of V 14012. The morphology of the proximal articulation surface is also very similar, indicating conspecific status. The identity of the 2nd Ph III (V 14013) is not based on reliable morphological grounds. It is probably larger than that from Lantian; the latter is measured but the authors did not distinguish if it belongs to front or hind limbs (Liu et al., 1978). V 14013 is obviously smaller than that of *H. primigenium* (Bernor et al., 1997, table 6.17), and is much smaller than that of *H. houfenense* (Qiu et al., 1987, table 16). In terms of proportions, the proximal width of V 14013 is less than the maximum

length of this bone, in contrast to that in *H. primigenium* that is just the opposite. These proportions obviously belong to different types of feet. The former is probably adapted to more open environments, such as is the case for *H. houfense* (Qiu et al., 1987, table 16). The 2nd Ph III from Baode, Shanxi Province also commonly has the proportion of length greater than its width, as compared to the inverse relationships in specimens from Henan and southeastern Shanxi (Bohlin, 1937, textfigs. 200 ~ 204).

Two calcanea (V 14014. 1 and 14014. 2) also co-occur with the P3 of *H. cf. H. chiai*. Their dimensions are not very big, thus probably belonging to this species. The two calcanea are smaller than even the smallest of *H. primigenium* (Bernor et al., 1997, table 7. 6). Furthermore, their middle portion is very narrow. The astragalus (V 14015. 1) occurs in the same locality as some teeth of *H. weihoense* (see below). V 14015. 2 is nearly identical, in size and shape, to V 14015. 1, and localities for these two specimens may be correlative. On the other hand, these two astragali seem to match with the above calcanea (V 14014. 1 and 14014. 2). We judge the astragali to be more likely to belong to *H. cf. H. chiai*. As in the calcanea, the two astragali are smaller than those of *H. primigenium* (Bernor et al., 1997, table 7. 5), and much smaller than those of *H. houfense* (Qiu et al., 1987, table 16). Bohlin (1937, textfigs. 188 ~ 191) mentioned two astragali (a larger Nr. 467 and a smaller Nr. 500). Nr. 467 is similar to V 14015. 1 and 14015. 2 in size and morphology, and may be referred to the same species. Nr. 500 is rather small, with a maximum length 10 mm shorter than that of V 14015. 1. However, this small size does not exceed the variation of a single species. For example, astragali in *H. primigenium* can have length differences of up to 11.9 mm (Bernor et al., 1997, table 7. 5). Therefore, it is still possible that Nr. 500 belongs to *H. cf. H. chiai*.

Hipparion weihoense Liu et al., 1978

Hipparion weihoense and *H. chiai* share some characters, such as an elongate protocone that does not sink into the "bay" after heavy wear. On the other hand, Liu et al. (1978) pointed out some distinctions between these two taxa, which were further supplemented by Qiu et al. (1987). In terms of morphological features that are present in the materials described in this paper, *H. weihoense* differs from *H. chiai* in larger size, more elaborate plications in cheek teeth, protocone not slanted, protocone with rounded anterior and posterior ends, pli hypostyle extending forward from posterior wall of postfossette, and relatively high crowns. The five cheek teeth from Qaidam are morphologically consistent with corresponding teeth of *H. weihoense* from Lantian and differ from those of *H. chiai* in above characteristics. Furthermore, the Qaidam specimens share additional details with *H. weihoense*, such as a slightly inward curve on labial surfaces of cheek teeth, enamel plications big and strong, double pli caballine, external wall strongly concave, weak or absent of hypoconal constriction, hypoconal groove wide on premolars but narrow and slender on molars, etc. V 14016. 3 has few pli protoloph, a feature that is different from specimens in Lantian.

As outlined in the introduction, Bohlin has only meager materials to deal with and he included only a figure (Bohlin, 1937, textfig. 166) that shows a postfossette and a protocone with a pli caballine. He suggested that the protocone morphology and enamel plications of the Qaidam materials are very similar to M2 of *H. richthofeni* described by Sefve (1927, fig. 13) from Daijiagou (Baode, Shanxi). However, Bohlin's specimen shows a broad and rounded protocone, differing from the slender and narrow protocones in the three species described herein. Sefve's (1927) *H. richthofeni* was referred to *H. forstenae* by Zeghallo (1971), which has a similar age relationship as *H. teilhardi*, i. e., late Late Miocene (Qiu et al., 1987). Bohlin's materials are too fragmentary to be accurately identified.

The distal Mc III (V 14017) is wider than that of *H. chiai* from Lantian (Liu et al., 1978), and is close to *H. primigenium* (Bernor et al., 1997, table 6. 13). It probably belongs to the larger-sized *H. weihoense*. The fore 3rd Ph III (V 14018) came from the same locality as dental mate-

rials of *H. weihoense*. A "3rd Ph III" from Lantian was referred to *H. chiai*, but it has measurements of 37 mm long and 36 mm wide. These measurements are poorly defined and may be in error: the length, whether being the anterior length (Table 2, Measure 1) or greatest anteroposterior length (Table 2, Measure 2), are far too short; the length, whether being the articular anteroposterior diameter (Table 2, Measure 5), is far too long; the breadth, whether being the greatest breadth (Table 2, Measure 4), is far too narrow; the breadth, whether being the articular breadth (Table 2, Measure 6), indicates that the 3rd Ph III of *H. chiai* from Lantian is smaller than the Qaidam specimen. V 14018 is close in size to *H. primigenium*, such as the length and height, but differs from *H. primigenium* in smaller length of dorsal surface, smaller angle between dorsal and plantar surfaces, and smaller width of articular faces. From size considerations, we place this phalanx in *H. weihoense*. Bohlin (1937, textfigs. 205, 206) described a 3rd Ph III (Nr. 532); it is substantially smaller than V 14018 and probably belongs to *H. cf. H. chiai*.

The Mt III (V 14020. 1) is recovered from the same locality as one P3 (V 14011) of *H. cf. H. chiai*. Materials of *H. chiai* from Lantian also include a Mt III (V 3116. 9). Of the comparable measurements, the specimen from Lantian has a proximal width of approximately 32 mm, mid shaft width of 21.5 mm, and mid shaft thickness of 23.2 mm. V 14020. 1 is obviously more robust (Table 2). *H. cf. H. chiai* and *H. weihoense* from Qaidam occur in the same level, as did those from Lantian. *H. weihoense* is clearly larger than *H. chiai*. Thus the Qaidam Mt III is likely to belong to *H. weihoense*. Measurements for V 14020. 2 (Table 2) are far larger than those of *H. chiai* from Lantian (the latter has a distal articular width of 37.5 × 27 mm). Thus, V 14020. 2 probably also belongs to *H. weihoense*. Both of these two metatarsals are smaller than that of *H. teilhardi* (V 8241; Qiu et al., 1987, pl. XL, 4). The astragalus (V 14019) is larger than V 14015. 1 and 14015. 2, and also differs in other morphological attributes. V 14019 thus is referred to *H. weihoense*. V 14019 is close in size to that of *H. primigenium* (Bernor et al., 1997, table 7.5), but smaller than that of *H. houfenense* (Qiu et al., 1987). However, the trochlear width of V 14019 is not only larger than that of *H. primigenium*, it is also larger than that of *H. houfenense*. The 2nd Ph III (V 14285) occurs in the same locality as a single P4 (V 14040) of *H. weihoense*, and it is far larger than that of *H. chiai* from Lantian (Liu et al., 1978). We thus refer this phalanx to *H. weihoense* as well. Bohlin (1937, textfig. 202) figured a 2nd Ph III, which is consistent with V 14285 and probably also belongs to *H. weihoense*.

Hipparion teilhardi Qiu et al., 1987

Qiu et al. (1987) established a new species, *Hipparion teilhardi*, based on materials from Youfangtou (Hengshan, Shaanxi) collected by Teilhard de Chardin and Licent. Qiu et al. delineated the following characters for the lower cheek teeth: labial wall curving laterally, relatively short double-knot, rounded metaconid, metastylid posterolingual angle pointed, premolar linguaflexid nearly V-shaped, molar linguaflexid slightly widened, ectoflexid deep, and protostylid well-developed. Except the not so well-developed protostylid, the Qaidam lower teeth are similar to those of *H. teilhardi*, especially in the morphologies of the linguar and ectoflexid on the molars and m3 hypoconulid. In fact, protostylids are poorly developed in certain cheek teeth from Youfangtou, e. g., the premolars and m3 on V 8236 (Qiu et al., 1987, fig. 55, pl. XL, 2).

Among limb bone specimens, the right distal tibia (V 14023) was recovered from the same locality as three lower cheek teeth of *H. teilhardi*. Lantian produced one distal tibia of *H. chiai*, which has a width of 52 mm and depth of 37 mm, apparently smaller than V 14023. Tibii of *H. primigenium* typically average 71.1 mm in width and 45 mm in depth at distal ends (Bernor et al., 1997, table 7.4), larger than V 14023. In terms of Mt III dimensions, *H. teilhardi* is longer than that of *H. primigenium*. As previously stated, the grassland-adapted *Hipparion* from East Asia have more slender limbs than those of forest-adapted horses in Europe. For example, Mt III of *H. houfenense* is longer than that of *H. primigenium*, and the distal end of tibia of the former is also smaller

than that of the latter (Qiu et al. , 1987 , tables 12 , 14) . Bohlin (1937) also collected a distal tibia (Nr. 453) , which has a width of 63 mm and depth of 42 mm , nearly identical to those of V 14023 and thus belonging to *H. teilhardi* . Ecto-cuneiforme from Qaidam (V 14024) is also somewhat smaller than that of *H. primigenium* (Bernor et al. , 1997 , table 7.9) , and is consistent with a smaller distal tibia.

The right 2nd Ph III (V 14025) is produced from the same locality as three lower cheek teeth and right distal tibia (V 14023) of *H. teilhardi* . V 14025 is similar in size and proportions to that of *H. weihoense* (V 14285) , but differs morphologically. V 14025 and 14285 are both far larger than that of *H. chiai* (Liu et al. , 1978) , but smaller than in *H. primigenium* (Bernor et al. , 1997 , table 7.15) . The two 2nd Ph III from Qaidam have a proximal width shorter than its maximum length , exactly opposite to that of *H. primigenium* , which has a shorter length compared to its proximal width. A more slender Ph III is probably an adaptation for open grasslands , in contrast to a more forested landscape for *H. primigenium* .

2 Biostratigraphy and paleoecological comments

Three species of *Hipparion* are recovered from the Qaidam Basin so far: *H. cf. H. chiai* , *H. weihoense* , and *H. teilhardi* . The first two species were found in the Bahe Fauna of the Bahe Formation in Lantian , Shaanxi (Liu et al. , 1978 ; Zhang et al. , 2002) and Dashengou Fauna in the middle part of the Liushu Formation in Linxia , Gansu (Deng et al. , 2004) . *H. chiai* was also produced in Chengcun (Qin 'an , Gansu) (Qiu et al. , 1987) and in the Lamagou Fauna from the lower fossiliferous layer of Laogaochuan (Fugu , Shaanxi) (Xue et al. , 1995) . Qiu et al. (1987) indicated that *H. chiai* and *H. weihoense* have deep and distally located preorbital fossa and elongated protocone , characters suggesting their relationships to the *H. primigenium* group , which is close to its North American ancestors. They are included within the subgenus *Hipparion* (*Hippotherium*) . The *H. primigenium* group in Europe and Africa are all from the Vallesian age. Furthermore , they also pointed out that the anterolabial corner of the preflexid is more sharply pointed than its posterolabial corner in *H. chiai* , a character seen in some early *Hipparion* horses of North America , such as *H. tehonense* (MacFadden , 1984 , fig. 38) . Therefore , *H. chiai* , and possibly also *H. weihoense* , is an Asiatic species that preserves many characters of North American three-toed horses. Such a morphological combination suggests a primitive stage of evolution and indicates an early age.

Li et al. (1984) compared the Bahe Fauna with those of the European Vallesian. Qiu and Qiu (1990) and Tong et al. (1995) further confirmed such a correlation. The Dashengou Fauna from Linxia Basin includes *Dinocrocota gigantea* , *Acerorhinus hezhengensis* , *Chilotherium wimani* , *Hezhengia bohlini* , and *Miotragocerus* sp. , taxa that often occur relatively early (Qiu et al. , 1987 , 2000 ; Deng , 2000 , 2001) and equivalent to the European late Vallesian (Qiu et al. , 1999 ; Deng et al. , 2004) . Xue et al. (1995) paleomagnetically correlated the Lamagou Fauna with GPTS chrons equivalent to the European early Turolian. However , from the stand point of faunal characteristics , Lamagou should be contemporaneous with the Dashengou Fauna , earlier than late Late Miocene (Qiu et al. , 1999 ; Deng et al. , 2000 , 2001) . Consequently , *H. chiai* and *H. weihoense* apparently belong to the early Late Miocene , i. e. , equivalent to the European Vallesian.

Qiu and Qiu (1990) and Qiu et al. (1999) considered Bohlin 's (1937) "Qaidam Fauna" as belonging to the early Late Miocene , representing the earliest assemblage among the Chinese *Hipparion* chronofauna and being approximately equivalent to the lower part of the European mammal zone MN9. They reasoned that the appearance of *Hipparion* in combination with leftover elements of the Middle Miocene *Anchitherium* chronofauna (such as *Lagomeryx* , etc.) must have indicated an early stage of the *Hipparion* Fauna. Such a correlation , when restricted to the currently known *Hipparion*-producing part of the beds , is still correct but obviously for the wrong reasons. Mixing faunal

components of different ages from Bohlin's collections is the main cause of such an illusion. Fossils collected by Bohlin may have spanned more than 2 000 m of the local strata at Barun Ula, with great potential for confusing the age relationship if one is not careful to tease out the individual faunal components.

In recent years, we have begun to establish a biostratigraphic framework in the eastern Qaidam Basin. We are able to differentiate vertebrate faunas that represent Middle Miocene, Late Miocene, and Pliocene ages. Outlines for faunas in the Middle Miocene are beginning to emerge (Wang et al., 2000; Wang and Wang, 2001). In addition to such primitive deer as *Lagomeryx* and *Stephanocemas*, perhaps the most typical Middle Miocene form is *Hispanotherium matritense* found near the red mudstone/green sandstone transitional layer east of the Naoge camp. This rhino is only found in the Middle Miocene of Eurasia and does not co-occur with *Acerorhinus tsaidamensis* (Deng and Wang, 2004). The latter seems mainly occur in the Late Miocene part of the strata. *Hipparion* horses described in this paper confirm the presence of an early Late Miocene fauna (Chinese early Baodean land mammal age) in Qaidam. In fact, *H. cf. H. chiai* and *H. weihoense* were found in the same locality (CD0219) as *A. tsaidamensis*. We thus infer that the upper section in the Naoge area and much of the section in the Shengou area, both producing *H. cf. H. chiai* and *H. weihoense*, are early Late Miocene in age.

Hipparion teilhardi was previously found in a single locality—Youfangtou (Hengshan, Shaanxi). The holotype was collected by Licent and no exact stratigraphic record is available. Morphologically, *H. teilhardi* seems similar to certain forms from North America and is to a certain extent close to *Neohipparion affine* (Qiu et al., 1987). *H. teilhardi* from Qaidam is roughly from the same beds as *H. cf. H. chiai* and *H. weihoense* (upper part of the Naoge section and the Shengou section). The single lower jaw from the lower part of the Tuosu Nor section is also better treated as early Baodean. For the same reason, the type material of *H. teilhardi* from Youfangtou, for lack of evidence to the contrary, should also be referred to early Late Miocene.

Based on *Acerorhinus tsaidamensis* from the early Late Miocene of the Qaidam Basin, we have inferred a warm and semi-dry environment with grassland predominant and occasional forest and bushes (Deng and Wang, 2004). Among ungulates from the beds that produce *H. chiai* and *H. weihoense* in Lantian, Shaanxi, gazelles are relatively high-crowned and large-sized, the giraffe *Palaeotragus* is somewhat high-crowned, and suids and cervids are absent. These are all indications of a grassland environment (Liu et al., 1978). The presence of *H. cf. H. chiai* and *H. weihoense* in Qaidam further confirms our judgment of a grassland. The Late Miocene *Dicerorhinus ringstromi* is relatively cursorial (Güéin, 1980), adapted to life in dry grasslands (Ringström, 1924). Above analysis also shows that the distal limbs of *H. teilhardi* are probably rather slender and better adapted to open environments, and it belongs to a more cursorial fauna.

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