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# 临夏盆地晚中新世维氏大唇犀(奇蹄目,犀科)肢骨化石[1)]

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**摘要** 大唇犀(*Chilotherium* 属)是中国晚中新世三趾马动物群中占统治地位的类型,在亚洲的其他地区和南欧也有广泛的分布。然而,有关大唇犀头后骨骼的记述相当少。在山西保德和陕西府谷已经发现了丰富的大唇犀化石,但到目前为止仅有安氏大唇犀(*Ch. anderssoni*)的少量头后骨骼被记述。维氏大唇犀(*Ch. wimani*)最早发现于陕西府谷,被记述的材料仅包括头骨标本。最近我们在甘肃临夏盆地发现了大量晚中新世的 *Ch. wimani* 化石,其中不仅有众多的头骨,头后骨骼也相当丰富。本文研究的标本采自临夏盆地内众多的晚中新世三趾马动物群化石地点,包括和政县的大深沟、南阳山、大山庄、禾托和高家山,广河县的后山、兰家山、山庄、寺沟、次滩、沙地沟、阳洼铺子和桥家,以及东乡县的双拱北等。在保德的三趾马动物群中,大唇犀以 *Ch. anderssoni* 和哈氏大唇犀(*Ch. habereri*)为代表,而在临夏和府谷却是以 *Ch. wimani* 为代表。临夏盆地的三趾马动物群中共有 3 种无角犀类,即 *Ch. wimani*, *Acerorhinus cornutus* 和 *A. hezhengensis*。根据头骨材料的统计,*Ch. wimani* 在犀类中占有绝对优势,*A. hezhengensis* 和 *A. cornutus* 的个体数量很少。与此对应,动物群中的无角犀类肢骨明显可以分为 3 组,其中具中等尺寸的一组占有绝对优势。结合形态特征,占绝大多数的这组肢骨被判定应属于 *Ch. wimani*。数量很少的小型和大型的两组肢骨可能分别属于 *A. cornutus* 和 *A. hezhengensis*。本文详细记述了 *Ch. wimani* 的肢骨化石,它的前、后脚都为三趾,第三跖骨缺乏侧面对骰骨的关节面,肢骨相当短粗,其尺寸与保德发现的 *Ch. anderssoni* 接近,但粗壮程度略小于后者。*Ch. wimani* 距骨对跟骨的第二和第三关节面愈合或仅有很小的间隔。*Ch. wimani* 的头骨性状显示它是目前 *Chilotherium* 属中已知最原始的一个种,而它的肢骨粗壮程度和距骨关节面特征也表明它比其他的大唇犀种更原始。*Ch. wimani* 的肢骨尺寸也与产自保德和新安的 *Acerorhinus palaeosinensis* 接近,且后者的距骨对跟骨的关节面也是愈合的,但后者肢骨的粗壮程度小于 *Ch. wimani*。*Ch. wimani* 的肢骨更远比产自通古尔的 *Acerorhinus zernowi* 短粗。尽管 *Ch. wimani* 的前肢长于产自西班牙的 *Alicornops simorrense*,但在欧洲发现的大多数 *A. simorrense* 的肢骨都比 *Ch. wimani* 细长。所有 *Aceratherium incisivum* 的肢骨也都比 *Ch. wimani* 细长,而 *Hoploaceratherium tetradactylum* 的肢骨更是远远长于 *Ch. wimani*,相应地也更为纤细。在可以对比的肢骨中,*Plesiaceratherium gracile* 的掌、跖骨比 *Ch. wimani* 细长得多,同时前者距骨对跟骨的关节面也分得相当开。所以,在无角犀亚科中,大多数属种的肢骨都比大唇犀细长,这与它们的系统发育地位是吻合的。

**关键词** 甘肃临夏盆地,晚中新世,犀科,肢骨

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# LIMB BONES OF CHILOTHERIUM WIMANI (PERISSODACTYLA, RHINOCEROTIDAE) FROM THE LATE MIOCENE OF THE LINXIA BASIN IN GANSU, CHINA

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**Abstract** The genus *Chilotherium* was dominant among the *Hipparion* fauna of the Late Miocene in China, and it also appeared in other regions of Asia and South Europe widely. However, studies for the postcranial skeletons of *Chilotherium* are scarce. Although rich fossils of *Chilotherium* were discovered in Baode, Shanxi and Fugu, Shaanxi, only some postcranial bones of *Ch. anderssoni* were described. Recently, very abundant fossils of *Ch. wimani* were discovered from the Late Miocene of the Linxia Basin in Gansu, China, including a lot of skulls as well as postcranial skeletons. In this paper, limb bones of *Ch. wimani* are studied. The fore and hind feet of *Ch. wimani* are tridactyle, and limb bones are as short and robust as those of *Ch. anderssoni* discovered from Baode. Facets Ⅱ and Ⅲ for calcaneus on the posterior face of astragalus of *Ch. wimani* are connected to each other or separated by a narrow groove. In the subfamily Aceratheriinae, limb bones of most genera and species are longer and slenderer than those of *Chilotherium*, such as *Plesiaceratherium gracile*, *Alicornops simorrense*, *Aceratherium incisivum*, *Hoploaceratherium tetradactylum* and *Acerorhinus zernowi*. Only limb bones of *Acerorhinus palaeosinensis* are close to those of *Chilotherium*.

**Key words** Linxia Basin, Gansu, Late Miocene, Rhinocerotidae, limb bone

Ringström (1924) created the genus *Chilotherium* on the basis of the Late Miocene rhinocerotid material from northern China, including five species, but postcranial skeletons were few and incomplete. Among these species of *Chilotherium*, *Ch. wimani* was established based on the material from Fugu, Shaanxi, China, but Ringström (1924) had only several specimens, without any limb bone. Deng (2001a, b) described more fossils of *Ch. wimani* from Fugu and Linxia, so the characters of this species are recognized on more detailed and complete information. The *Hipparion* fauna from the Linxia Basin is very similar to that from Fugu, in which rhinoceroses are dominant instead of hippariones. The fossils of *Chilotherium* are the most abundant in the rhinocerotids from Linxia, including many postcranial skeletons.

In the *Hipparion* fauna of the Linxia Basin, three forms of the subfamily Aceratheriinae are discovered, including *Chilotherium wimani*, *Acerorhinus hezhengensis*, and *A. cornutus*. According to numbers of skull specimens, *Ch. wimani* is absolutely dominated among the three forms. Correspondingly, the limb bones of the subfamily Aceratheriinae from the *Hipparion* fauna of the Linxia Basin can be obviously divided into three groups, and the group of middle size is also absolutely dominated among them. Combined with morphological features, the dominant group of limb bones are determined to belong to *Ch. wimani*. According to the skull sizes of *A. hezhengensis* and *A. cornutus* (Qiu et al., 1988; Qiu and Yan, 1982), the limb bones of large size should belong to the former and ones of small size to the latter.

The limb bones of *Ch. wimani* studied here are collected from different localities in the Linxia Basin, including Dashengou, Nanyangshan, Dashanzhuang, Hetuo, Gaojiashan of Hezheng County, Houshan, Lanjiashan, Shanzhuang, Sigou, Citan, Shadigou, Yangwapuzi, Qiaojia of Guanghe County, and Shuanggongbei of Dongxiang County. A detailed field correlation proves that these localities have the same horizon, i. e. the middle-upper part of the Liushu Formation of the Late Miocene with grey orange or yellow brown silty mudstone or muddy siltstone.

The studied specimens include 2 scapulas, 10 humeri, 2 radiuses, 1 ulna, 1 scaphoid, 1 semilunate, 3 pyramidals, 1 pisiform, 2 trapezoid, 1 magnum, 1 unciform, 2 Mc Ⅱ, 3 Mc Ⅲ,

4 Mc Ⅳ, 1 complete group of fore phalanges, 10 femora, 6 patellae, 7 tibiae, 4 fibulae, 10 astragaluses, 2 calcaneuses, 3 naviculars, 1 mesocuneiform, 1 entocuneiform, 3 cuboids, 3 Mt Ⅱ, 3 Mt Ⅲ, 4 Mt Ⅳ, and 1 group of hind phalanges without 2nd and 3rd Ph Ⅱ. The material is deposited in the Hezheng Paleontological Museum in Gansu, China. Terminology follows Sesson (1953), and the measurements are according to Gu rin (1980) and given in mm. Abbreviations used in text and tables: a. = about; ant. = anterior; APD = anteroposterior diameter; art. = articular; delt. = deltoid; dis. = distal; H = height; HMV = prefix to the studied fossils of the Hezheng Paleontological Museum; L = length; max. = maximal; med. = medial; mid. = middle; min. = minimal; olec. = olecranon; prox. = proximal; TD = transverse diameter; troch. = trochanter; tub. = tuberosity; W = width.

## 1　Fore limb bones

### 1.1　Scapula (Fig. 1, a)

Scapular spine is well developed; it is triangular in shape and strongly extends backward; its free margin is thick and spinal tubercle is rough. Supraspinous fossa is wide and shallow proximally, but narrow and deep distally. Infraspinous fossa is flat and broad, and muscle lines are strong. Subscapular fossa is wide and shallow; it gradually becomes weaker upward and disappears in the middle of the bone. Anterior serrate face is narrow, concave and smooth, while posterior one projected, convex and rough. Scapular cartilage has been ossified. Anterior border is convex in middle and rough on top, with a shallow depression proximally and distally respectively. Posterior border is strongly concave and smooth on the lower half, while oblique and rough on the upper half. Vertebral margin is rounded and rough. Glenoid cavity is oval, with a wide and shallow glenoid notch. Scapular tubercle is strong and rough, and coracoid process is short and wide. Measurements (HMV 0455, 0456): H = 442, 440; APD max. = 185, 180; APD neck = 87, 89.5; TD neck = 34.5, 47.5; APD dis. = 121, 102; TD art. = 58, 61; APD art. = 71, 74.5; TD max. = 76.5, 96.

### 1.2　Humerus (Fig. 1, b; Table 1)

Lateral margin is narrow. Deltoid tuberosity is board-shaped and extends backward. Lateral condyle crest is sharp. Medial face is convex and smooth, with a teres tuberosity in middle and a clear nutrition foramen. Anterior face is quadrangular, wide and smooth on upper part, while triangular, narrow and rough on lower. There is a small rough part of deltoid tuberosity on the anterior face. Humerus crest is gradually weaker and disappeared downward. On the proximal part, humerus head is a rounded triangle approximately, and humerus fossa is narrow and small; lateral tuberosity is strong on the anterior part, but weak on the posterior; medial tuberosity is weak on both anterior and posterior parts; central crest is low and weak, with narrow and deep lateral intertuberal groove but wide and shallow medial one. On the distal part, the groove between lateral condyle and lateral epicondyle is wide and deep, while that between medial condyle and medial epicondyle narrow and

**Table 1　Measurements of humeri of** Chilotherium wimani **from the Linxia Basin**　(mm)

| Measures | HMV 0462 | HMV 0491 | HMV 0493 | HMV 1034 | HMV 1035 | HMV 1048 | HMV 1050 | HMV 1051 | HMV 1054 | HMV 1055 |
|---|---|---|---|---|---|---|---|---|---|---|
| L | 321 | 319.5 | 322.5 | 318 | 335 | 315 | 330 | 310 | 310 | 322 |
| TD prox. | 145 | 144 | 136.5 | 129 | 126.5 | 129 | 144 | 136.5 | 138.5 | 146 |
| APD prox. | 98.5 | 92 | 109.5 | 91.5 | 108 | 99 | - | 109 | 117.5 | 106 |
| TD min. | 59 | 52 | 52.5 | 54 | 56 | 56.5 | 51 | 48 | 62 | 55.5 |
| APD in TD min. | 54 | 56 | 54 | 54 | 56 | 53.5 | 55.5 | 47 | 50 | 49 |
| TD dis. | 115 | 113.5 | 112 | 113 | 117 | 112 | 115 | 111 | 119.5 | 123.5 |
| APD dis. | 95 | 98.5 | - | 93 | 91 | 90 | - | 86 | 87 | 90 |
| TD in delt. tub. | 128.5 | 128.5 | 116 | 128 | 106 | 125 | 118 | 123 | 114 | 116 |

shallow; coronoid fossa is triangular, with a rough bottom; medial epicondyle is narrow and high, while lateral one oval and low; condyloid crest is well developed, and its lower part is an oblique quadrangle; olecranon fossa is broad and deep, with straight lower margin and sharp upper one so that it is triangular in the posterior view.


Fig. 1 Long bones, scapula and patella of *Chilotherium wimani* from the Linxia Basin
a. left scapula, HMV 0455, lateral view; b. right humerus, HMV 0462, anterior view; c. left radius and ulna, HMV 1031, juvenile, lateral view; d. right radius, HMV 1038, anterior view; e~f. left tibia and fibula, HMV 0467, e. anterior view, f. posterior view; g~h. left patella, HMV 0532, g. anterior view, h. posterior view; i. right femur, HMV 1062, anterior view. Scale bar = 10 cm

**1.3　Radius** (Fig. 1, c, d)

The bone is laterally compressed and slightly curved backwards, and its anterior face is smooth, with two wide and thick ends. Forearm interosseous space is very narrow. Posterior face is smooth medially but rough laterally, with a projected tubercle on its proximal part. Side faces are smooth and convex, and the medial face is straight but lateral one is curved laterally. Proximal medial tuberosity is stronger than lateral one. Distal part has fused with ulna. Anterior depression of scaphoid facet is narrow, semilunate facet is strongly concave, pyramidal facet is broad, and pisiform facet is small and triangular. On the anterior face of distal part, medial and central grooves are narrow, but lateral one is wide. Measurements (HMV 1038, 1039): L = 278, 266; TD prox. = 91, 82; APD prox. = 50.5, 46; TD mid. = 51.5, 48.5; APD mid. = 30, 32.5; TD dis. = 84, 79.5; APD dis. = 54, 51.5; TD dis. art. = 74.5, 69; APD dis. art. = 32, 36.

**1.4　Una** (Fig. 1, c)

The bone has three edges. Side faces and lateral margin are smooth, while anterior face and medial margin are rough. Medial face is flat, but lateral one is slightly concave. Posterior margin is smooth and curved backwards. Medial proximal face is concave and smooth, while lateral one is convex and rough. Semilunar notch is broad and deep. Distal part has fused with radius, with a distinct suture between them. Measurements (HMV 1031, juvenile): L = 329; TD olec. = a. 48; APD olec. = 77; TD prox. art. = 68; APD prox. = 96; TD mid. = 46; APD mid. = 31.5; TD dis. = 52; APD. dis. = 44.5.

**1.5　Carpals**

Scaphoid (Fig. 2, a) is especially broad, with deeply concave proximal articulation whose medial edge is very high. Two lateral facets are for semilunate, and there is a rough depression between their posterior parts. Distal articulation has a sharp anteroposterior central crest to divide it into two facets for trapezoid and magnum respectively. External face is rough. Anterior face is convex, and lateral and posterior faces have tubercles. Measurements (HMV 0985): L = 62; W = 34.5; H = 43; L prox. art. = 26.5; W prox. art. = 33; L dis. art. = 44; W dis. art. = 25.

Semilunate (Fig. 2, b) is hammer-shaped, with wide anterior part and narrow posterior one. Proximal facet is saddle-backed for radius, with a marked central crest. Distal facet also is saddle-backed for magnum and unciform. Two lateral facets are for scaphoid, and there is a rough and deep depression between them. Measurements (HMV 0985): L = 55.5; W = 44.5; H = 44.5; H ant. = 45.

Pyramidal (Fig. 2, c) is irregular in shape. Proximal facet is concave for radius. Distal facet also is concave for unciform. Two small medial facets are for semilunate. Anterior and lateral faces are rough, and posterior face is oblique. Measurements (n = 3): APD = 29.5～31; TD = 34.5～35; H = 38.5～40.

Pisiform (Fig. 2, d) is a curved and rounded board, with marked neck behind anterior facets. Medial face is concave, while lateral face is convex and rough, with a wide and shallow sinew groove. Proximal facet is slightly concave for radius, while distal facet is flat for unciform. There is a smooth crest between the two facets. Measurement (HMV 0985): L = 45; W = 34; H = 34.

Trapezoid (Fig. 2, e) is cashew-shaped. Proximal facet is broad and concave for scaphoid. Two lateral facets are for magnum. Anterior face is rough, and medial face is narrow, with a transverse rough crest. Distal facet is large and concave for Mc Ⅱ. Measurements (HMV 0985, 1008): L = 33, 37; W = 21, 20; H = 21, 25.

Magnum (Fig. 2, f) is very irregular in shape, and its posterior part is narrow and rough, and strongly extends backwards, with well marked notch behind proximal process. Proximal articulation has a marked anteroposterior crest, with a large and concave medial facet for scaphoid, and a narrow and convex lateral facet for semilunate. Distal facet is very wide and concave for Mc Ⅲ, with straight medial border and concave lateral one, and with a small medial facet for Mc Ⅱ. Three small medial facets are for trapezoid, and there is a rough depression between them. Three small

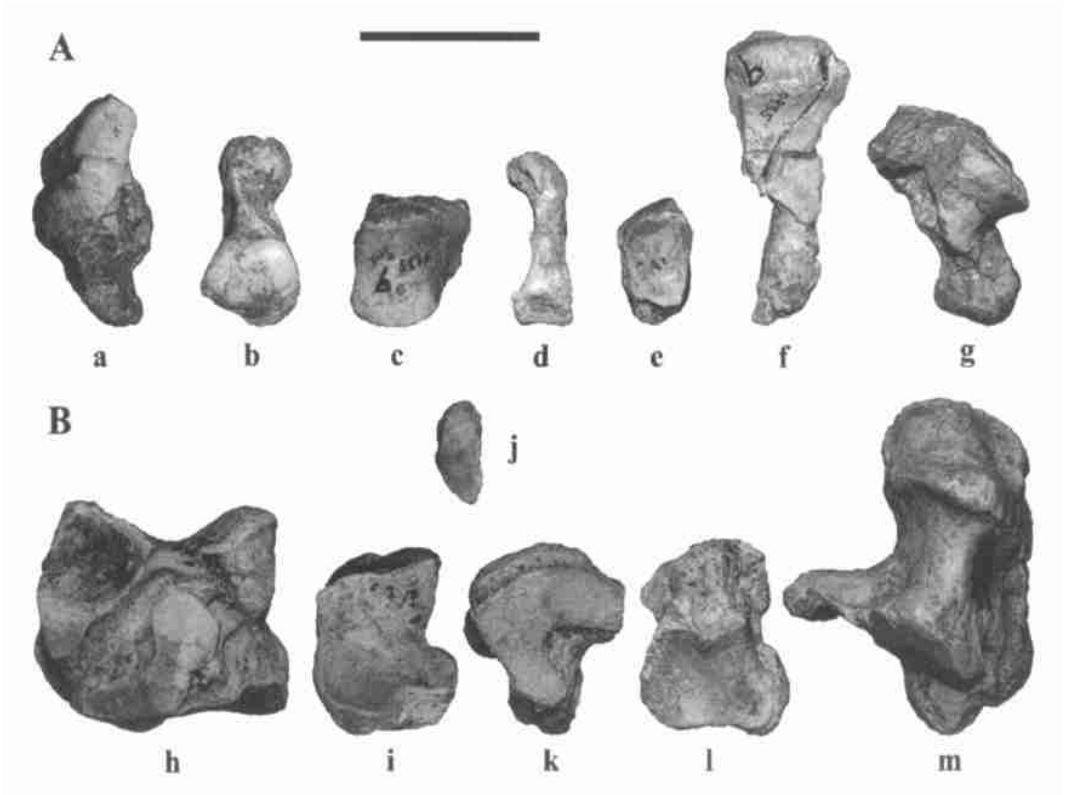


Fig. 2 Carpals and tarsals of *Chilotherium wimani* from the Linxia Basin
A. left carpals, HMV 0985: a～d, proximal view, a. scaphoid, b. semilunate, c. pyramidal, d. pisiform; e～g, distal view, e. trapezoid, f. magnum, g. unciform. B. left tarsals: h. astragalus, HMV 1021, posterior view; i. navicular, HMV 1005, proximal view; j～l, HMV 0987, j. mesocuneiform, distal view; k. entocuneiform, distal view; l. cuboid, proximal view; m. calcaneus, HMV 0531, anterior view. Scale bar = 5cm

lateral facets are for unciform. Lateral face is rough, with a central depression. Anterior face is relatively narrow and rough, with a strong transverse crest. Measurements (HMV 0985): L = 73; W = 33; H = 46; H art. = 45.

Unciform (Fig. 2, g) is wedge-shaped approximately. Tubercular process on the lower part of posterior face is well developed. Proximal articulation has a central crest to divide it into facets for semilunate and pyramidal respectively. Two distal medial facets are for Mc Ⅲ, and one small lateral facet is for Mc Ⅳ. On the medial face, two long facets and one square facet are for magnum, and there are crests between them. Lateral face is narrow, and anterior face is rough. Measurements (HMV 0985): L absolute = 48.5; L anatomic = 45; W = 31; H = 26.

**1.6 Metacarpals** (Fig. 3, A; Table 2)

Mc Ⅱ is prolate and slightly contorted medially. Lateral margin is thicker than medial one. Lower part of medial margin is convex highly. Anterior face is smooth and flat, with rough and projected proximal and distal parts. Proximal central facets are very large and slightly concave for trapezoid, and there is a high and smooth crest between them. Magnum facet is narrow and long, with a marked crest with Mc Ⅲ facet. Distal articulation for the first phalanx Ⅱ is convex and oblique medially on the anterior face, while there are two condyles and one oblique crest on the posterior face. Medial condyle is larger than lateral one, and there is a small fossa on their external face respectively.

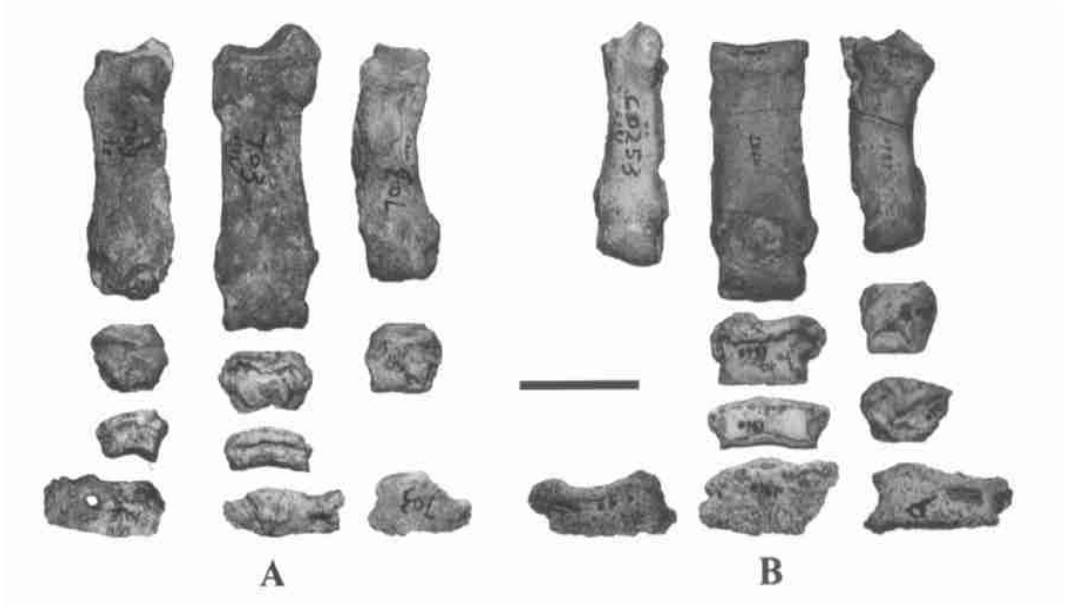


Fig. 3　Metapodials and phalanges of *Chilotherium wimani* from the Linxia Basin
A. left fore foot: 2nd Ph Ⅳ, HMV 1122; others, HMV 0985. B. left hind foot: 3rd Ph Ⅱ, HMV 1121; others, HMV 0987. Anterior view, scale bar = 5cm

**Table 2　Measurements of metacarpals of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | Mc Ⅱ | | Mc Ⅲ | | | Mc Ⅳ | | | |
|---|---|---|---|---|---|---|---|---|---|
| | HMV 0985 | HMV 1118 | HMV 0534 | HMV 0985 | HMV 0989 | HMV 0985 | HMV 0991 | HMV 0992 | HMV 0993 |
| L | 103 | 104.5 | - | 120 | 123 | 93 | 93 | 91.5 | 87 |
| TD prox. | 38 | 37 | 45 | 45 | 45 | 28.5 | 30 | 29.5 | 34.5 |
| APD prox. | 30.5 | 35 | 40 | 39.5 | - | 32 | - | - | 29 |
| TD mid. | 31 | 35 | 37 | 34 | 36.5 | 27 | 29 | 28.5 | 29 |
| APD mid. | 12.5 | 16 | 17 | 16.5 | 18 | 15.5 | 17 | 16 | 17.5 |
| TD dis. max. | 39 | 37 | 46.5 | 42.5 | 45 | 28 | 28 | 31 | 33.5 |
| TD dis. art. | 29 | 32 | - | 36 | 42 | 25.5 | 29.5 | 32 | 29 |
| APD dis. | 29 | 38 | - | 33.5 | 32.5 | 31 | 29.5 | 30 | 30 |

Mc Ⅲ is prolate and straight. Lateral margin is slightly thicker than medial one. Proximal crest is very high. Magnum facet is large and stretches markedly backward. Anterior lateral facet has a transverse crest, and posterior lateral one contacts with magnum facet. Distal articulation has a rounded upper border, and its central crest is strong.

Mc Ⅳ is relatively thick and curved laterally. Medial margin is thicker than lateral one, and it is rough and convex. It is slenderer than Mc Ⅱ. Proximal facet is trapezoid outlined, with a medial crest to limit narrow anterior medial facet. Posterior medial facet is wide, round and displaced backward, making the posterior end of the bone; it does not contact proximal facet, with a long and narrow groove between them. Mc Ⅴ facet is absent.

**1.7　Fore phalanges** (Fig. 3, A; Table 3)

Side phalanges are inclined, and side third phalanges strongly extend medially and laterally respectively. Central phalanges are symmetrical, and much wider than side phalanges.

**Table 3 Measurements of fore phalanges of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | 1st Ph Ⅱ | 1st Ph Ⅲ | 1st Ph Ⅳ | 2nd Ph Ⅱ | 2nd Ph Ⅲ | 2nd Ph Ⅳ | 3rd Ph Ⅱ | 3rd Ph Ⅲ | 3rd Ph Ⅳ |
|---|---|---|---|---|---|---|---|---|---|
| L | 25 | 23 | 26 | 19.5 | 15 | 20 | 23.5 | 18.5 | 25 |
| TD | 30 | 39 | 32 | 30.5 | 36.5 | 30.5 | 53 | 65 | 59 |
| APD | 28.5 | 25.5 | 30 | 20 | 19.5 | 20 | 17 | 22.5 | 17.5 |

Notes: 2nd Ph Ⅳ, HMV 1122; others, HMV 0985.

## 2 Hind limb bones

### 2.1 Femur (Fig. 1, i; Table 4)

The upper part is laterally compressed, with a wide and shallow depression of inverse triangle on its anterior face. The lower part is a prism with three edges and smooth posterior face. The central part has rough surface, with a low minor trochanter. Medial supracondyloid crest is weak. Third trochanter is well developed, with a curved border forward. Supracondyloid fossa is indistinct, but lateral supracondyloid crest is strong and rough. On the proximal part, femoral head is a slightly compressed hemisphere, with a strongly projected anterior margin; head cavity is wide and shallow; major trochanter is lower than femoral head, with a weak notch between its anterior and posterior parts; trochanteral crest is strong, and trochanteral fossa is deep. On the distal part, trochlear medial crest is higher and wider than lateral one, and they are slightly convergent downward; intercondyloid fossa is narrow and deep, and there is a narrow groove between condyle and crest on the same side. Two condyles are slightly divergent downwards, and they have the same level of elevation. Medial supracondyle is a high cone with three edges, but lateral one is very weak. Extensional fossa is large and broad.

**Table 4 Measurements of femora of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | HMV 0453 | HMV 0468 | HMV 0470 | HMV 0492 | HMV 0495 | HMV 1042 | HMV 1043 | HMV 1058 | HMV 1059 | HMV 1062 |
|---|---|---|---|---|---|---|---|---|---|---|
| L | 395 | 395 | 390 | 390 | 390 | 390 | 390 | 390 | 375 | 395 |
| TD head | 85 | 79 | 76 | 76.5 | 79 | 72.5 | 83 | 74 | 82 | 79 |
| APD head | 71 | 70 | 68.5 | 69.5 | 68.5 | 72 | 74.5 | - | 59.5 | 71 |
| TD prox. | 173 | 166 | 158 | 176 | 157 | 154 | 171 | 150 | 163 | 167 |
| TD min. | 72 | 66 | 68 | 75 | 68 | 64 | 74 | 65 | 59.5 | 71 |
| APD in TD min. | 49.5 | 47.5 | 44 | 40.5 | 47 | 56 | 47 | 47 | 51 | 49.5 |
| TD dis. | - | 121 | 112 | 118 | 119 | 108.5 | 117 | 111 | 115 | 120 |
| APD dis. | - | - | 134 | 125 | 137 | 138 | 133 | - | 136 | - |
| H 3rd troch. | 86 | 73 | 96 | 92 | 93 | 93 | 89 | - | 71 | 80 |
| TD 3rd troch. | 127.5 | 115 | 108 | - | 117 | 113 | 126 | - | 116 | 124.5 |

### 2.2 Patella (Fig. 1, g, h)

The bone is an irregular quadrangle. Anterior face is convex and rough. On the posterior face, vertical crest is strong and convex, and it shifts laterally so that medial concave facet is much wider than lateral one. Medial process is strongly projected, and upper and lower processes also are prominent. Lateral margin is rounded, without any process. Measurements (n = 6): L = 84.5～91; TD = 76.5～88; APD = 40～46.5.

### 2.3 Tibia (Fig. 1, e, f; Table 5)

The bone is a prism with three edges, and upper part is compressed transversely but lower part

anteroposteriorly. Its proximal and distal parts are wide, while middle part is narrow. Medial face is straight, with broad and rough upper part that rapidly becomes narrow downwards. Lateral is smooth, and popliteal line is sharp and oblique. Tibial crest is rough and gradually becomes weak downwards until disappears on a small distal tubercle. Interosseous space is wide, with a rough upper part on its margin. On the proximal part, medial condyle is larger than lateral one, and medial intercondyloid tubercle is much wider than lateral one, but both tubercles have the same length. Intercondyloid fossa is narrow and long, and popliteal notch is wide and deep. Tibial tuberosity is broad, and ligamental groove is narrow and deep. Muscly groove is wide, shallow and U-shaped. The distal part has fused fibula to form a quadrangle whose medial margin longer than lateral one, and to compose a trochlea whose crest and grooves slightly oblique anterolaterally. Medial condyle is weak. Lateral groove is wider and shallower than medial one, with a distinct suture between tibia and fibula.

**Table 5　Measurements of tibiae of** Chilotherium wimani **from the Linxia Basin**　(mm)

| Measures | HMV 0459 | HMV 0465 | HMV 0466 | HMV 0467 | HMV 0486 | HMV 0500 | HMV 1044 |
|---|---|---|---|---|---|---|---|
| L | 269 | 282 | 276 | 281.5 | 273 | 280 | 275 |
| TD prox. | 110.5 | 100 | 105 | 106 | 105 | 97 | 111 |
| APD prox. | 125.5 | 116 | 123.5 | 117 | 117 | 126 | 105 |
| TD mid. | 45 | 44 | 42 | 39.5 | 42 | 40 | 43 |
| APD mid. | 44 | 51 | 46.5 | 44 | 48 | 52 | 48.5 |
| TD dis. | 89 | 82 | 83 | 78 | 82 | 81 | 80 |
| APD dis. | 63.5 | 64 | 59 | 58 | 64.5 | 64.5 | 60 |
| TD dis. art. | 62 | 64 | 64 | 59.5 | 62 | 61 | 69 |
| APD dis. art. | 45 | 45 | 49 | 49 | 48 | 51 | 49 |

### 2.4　Fibula (Fig. 1, e, f)

The bone is prolate and slightly distort, with a smooth middle part, and its lateral margin is thicker than medial one. Fibular head is rough and strong, with straight anterior articular border and convex posterior one. Distal part is narrow and long anteroposteriorly, and has fused tibia to form lateral condyle. Measurements (n = 4): L = 229～245; TD prox. = 31～39; APD prox. = 35～50.5; TD dis. = 22～24.5; APD dis. = 43.5～54.

**Table 6　Measurements of astragaluses of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | HMV 0526 | HMV 0527 | HMV 0986 | HMV 1015 | HMV 1016 | HMV 1017 | HMV 1018 | HMV 1019 | HMV 1020 | HMV 1021 |
|---|---|---|---|---|---|---|---|---|---|---|
| TD | 72 | 72 | 72 | 80 | 77.5 | 71 | 74 | 79.5 | 74 | 74.5 |
| H | 65.5 | 62 | 67 | 61.5 | 63 | 65 | 62 | 66 | 64 | 62.5 |
| APD med. | 46 | 45 | 44 | 41.5 | 47 | 44 | 46 | 44 | - | 44.5 |
| TD dis. art. | 62 | 61 | 62 | 70 | 62 | 67 | 62.5 | 65.5 | 61 | 63.5 |
| APD dis. art. | 39 | 40 | 38 | 41 | 37.5 | 34 | 36 | 40.5 | 36 | 35 |
| W trochlea | 48 | 51 | 55 | 52.5 | 57 | 52 | 52 | 53 | 54 | 53 |
| TD dis. max. | 67 | 64.5 | 67 | 72 | 67 | 67 | 63 | 69 | 67.5 | 64 |

### 2.5　Tarsals

Astragalus (Fig. 2, h; Table 6) is short and broad, with relatively wide and deep trochlea whose lateral lip is above distal articulation. Groove between trochlea and distal facets is wide and deep, especially in middle. Lateral condyle has a marked crest, while medial one is very smooth.

Medial tubercle is large and projected, and close to distal articular border. On posterior face, Facet I is a large and concave triangle with a small down tongue; Facet II is a projected and oblique oval, and contacts with long Facet III or separates from it by a narrow groove.

Calcaneus (Fig. 2, m) is short and robust. Tuber is wide and high, with rough surface and marked transverse proximal crest. Anterior and lateral margins of tuber are projected, and posterior face is approximately square. Astragalus facets are separated. On the distal face, cuboid facet is low and slightly concave. Beak is strongly projected medially, but cochlear process is short. Tarsal groove is deep. On the lateral face, there is a large and smooth depression, but the rest part is rough. Measurements (HMV 0531, 0998): H = 90, 91.5; APD tub. = 55.5, 58.5; APD beak = 55.5, 60; TD dis. = 72, 65; TD tub. = 40.5, 36; TD min. = 38.5, 33.

Navicular (Fig. 2, i) is an irregular quadrangle, and compressed vertically. Proximal astragalus facet is long and concave. On the distal face, there is a narrow and deep notch between posterior parts of middle and external facets. Anterior and medial faces are continuous, with rough and convex lower part but smooth and concave upper part. On the posterior face, there is a wide and shallow notch. On the lateral face, there is a rough depression between two small cuboid facets. Measurements (n = 3): L = 48.5～56; W = 37～44.5; H = 23～24.5.

Mesocuneiform (Fig. 2, j) is prolate and fabaceous. Medial face is rough and convex. Proximal facet is concave for navicular. Distal facet is transversely and narrowly oval for Mt III and Mt II. Posterior face is smooth, with an oblique and narrow groove. Measurements (HMV 0987): L = 18; W = 26.5; H = 13.5.

Entocuneiform (Fig. 2, k) is triangular approximately. Two large proximal facets are for navicular. On the distal face, Mt III facet is slightly convex, with a wide and deep notch. Anterior face is convex on upper part but concave on lower part. On the medial face, there is a deep notch between Mt II facets. On the lateral face, there is a wide notch between cuboid facets. Measurements (HMV 0987): L = 50; W = 45; H = 20.

Cuboid (Fig. 2, l) has a large and slightly concave proximal facet, and there is a weak crest between posterior parts of calcaneus and astragalus facets. In HMV 0987, posterior proximal astragalus facet is short, but in HMV 1009 and 1012 long. On the distal face, Mt III and Mt IV facets are wide anteriorly but narrow posteriorly, and there is a wide and deep groove between the facets and posterior tubercle. On the medial face, there are four small facets for navicular and entocuneiform, and posterior area of navicular facet is displaced backwards, with a shallow depression. In HMV 0987, posterior medial navicular facet is large, but in HMV 1009 and 1012 small. Anterior face is rough, with a large tubercle on laterally upper part and a wide crest on medially lower part. Lateral face is rough, and it is divided into anterior and posterior parts by a wide and deep groove in middle. Posterior face is rough and convex. Measurements (n = 3): L = 53～59; W = 41～43; H = 34.5～44; TD prox. art. = 36～38; APD prox. art. = 40～52.5; H ant. = 29～32.

**2.6 Metatarsals** (Fig. 3, B; Table 7)

Mt II is robust. Lateral face has a rough upper part, and anterior and posterior faces are smooth. Proximal face is narrow, with a projected tubercle forwards. There is a marked crest between one large mesocuneiform and two small entocuneiform facets, and a wide notch between the entocuneiform facets. Distal medial and lateral tubercles are well developed, and distal articulation is similar to that of Mc II but stronger.

Mt III is flat and wide. Anterior and posterior faces are smooth, but lateral and medial faces are rough. Proximal entocuneiform facet has a very wide and deep lateral notch. Anterior Mt IV facet is lunate and posterior one is oval, and there is a wide and deep groove between them. On the distal part, lateral tubercle is stronger than medial one, and posterior side and middle crests are well developed. Anterior upper border of distal articulation is high and rounded medially but low and flat laterally.

Mt IV is short and robust, and its anterior and posterior faces are smooth but medial and lateral

ones are rough. Proximal face is large and square, with well-developed side tubercles, and lateral tubercle extends forwards to close to anterior one. The lateral tubercle of HMV 0994 is strongly projected backwards. Proximal articulation is quadrangular and long anteroposteriorly, with a marked lateral elevation; anterior medial facet is small and narrow while posterior one is long and oval, and there is a wide and shallow groove between them.

**Table 7　Measurements of metatarsals of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | Mt Ⅱ | | | Mt Ⅲ | | | Mt Ⅳ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HMV 0987 | HMV 0996 | HMV 0997 | HMV 0987 | HMV 0535 | HMV 0990 | HMV 0987 | HMV 0988 | HMV 0994 | HMV 0995 |
| L | 94 | 89 | 98 | 100 | 101 | 109 | 84.5 | 83 | 90 | 83 |
| TD prox. | 26.5 | 23 | 26 | 40 | 37 | 33.5 | 37 | 41 | 40.5 | 37.5 |
| APD prox. | 41 | 35 | 37 | 35.5 | 40 | 32 | 32 | 31 | 45 | 33 |
| TD mid. | 24 | 23.5 | 26.5 | 36 | 36 | 32 | 26 | 25.5 | 24.5 | 24 |
| APD mid. | 21 | 21.5 | 21 | 17 | 19 | 15 | 21 | 20 | 23 | 18.5 |
| TD dis. max. | 32 | 27 | 35.5 | 44 | 45 | 39 | 31 | 28.5 | 26 | 26 |
| TD dis. art. | 29 | 26.5 | 30.5 | 37 | 40 | 37.5 | 27 | 26 | 26 | 25 |
| APD dis. | 32 | 28.5 | 32.5 | 31.5 | 33.5 | 31 | 30.5 | 31 | 33.5 | 30.5 |

### 2.7　Hind phalanges (Fig. 3, B; Table 8)

Central phalanges are wide and short, but side ones are narrow and long. Central phalanges are symmetrical but side ones are inclined sideward, especially third side phalanges strongly extend.

**Table 8　Measurements of hind phalanges of** Chilotherium wimani **from the Linxia Basin** (mm)

| Measures | 1st Ph Ⅱ | 1st Ph Ⅲ | 1st Ph Ⅳ | 2nd Ph Ⅲ | 2nd Ph Ⅳ | 3rd Ph Ⅲ | 3rd Ph Ⅳ |
|---|---|---|---|---|---|---|---|
| L | 24.5 | 26 | 28 | 17 | 23.5 | 32 | 25 |
| TD | 63 | 48 | 32 | 51 | 38 | 68 | 62 |
| APD | 23.5 | 29 | 27.5 | 25 | 35 | 21 | 20 |

Notes: 3rd Ph Ⅱ, HMV 1121; others, HMV 0987.

## 3　Comparisons and discussions

*Ch. wiman* has tridactyle fore feet like *Ch. anderssoni*, without Mc Ⅴ, and both of them are different from *Hoploaceratherium tetradactylum* that has tetradactyle fore feet. The Mt Ⅲ of *Ch. wimani* has no lateral cuboid facet as that of *Ch. anderssoni*. The size of *Ch. wimani* is close to or slightly smaller than that of *Ch. anderssoni*. The limb bones of *Ch. wimani* are a little slenderer than that of *Ch. anderssoni*. The gracility indexes of radius, Mc Ⅲ, tibia and Mt Ⅲ of *Ch. wimani* are 18.5, 29.7, 14.3 and 36 respectively, while *Ch. anderssoni* 20, 33.9, 17.1 and 37.3 correspondingly. Ringström (1924) emphasized differences between *Ch. anderssoni* and other rhinocerotids in calcaneus facets of astragalus. Facets Ⅱ and Ⅲ of *Ch. anderssoni* are separated with each other in a wide interval, on the contrary, those of *Ch. wimani* are connective or separated by a narrow groove. In fact, it is variable that Facets Ⅱ and Ⅲ are connective or separate. Kaup (1834) described that these two facets of *Aceratherium incisivum* are connective, but the same species from Howenegg separate (Hünermann, 1989). Some limb bones of *Chilotherium* sp. described by Ringström (1924) are obviously longer than those of *Ch. wimani*, such as a humerus from Loc. 108 and a femur from Loc. 43. The cranial characters of *Ch. wimani* indicate that it is the known most primitive species of this genus. Correspondingly, the gracility index of limb bones as well as narrow interval between Facets Ⅱ and Ⅲ of astragalus also show that *Ch. wimani* is more primitive than other species of *Chilotherium*.

The size of limb bones of *Ch. wimani* is close to that of *Acerorhinus palaeosinensis* from Baode, Shanxi and Xin'an, Henan, and the latter also has the connective calcaneus Facets Ⅱ and Ⅲ on the posterior face of astragalus (Ringström, 1924), but the limb bones of *Ch. wimani* are more robust than those of the latter, and much shorter but more robust than those of *Acerorhinus zernowi* from Tunggur, Nei Mongol. Differing from *Ch. wimani*, *A. zernowi* has separate calcaneus Facets Ⅱ and Ⅲ in most astragalus, only two connective in 21 specimens (Cerdeno, 1996).

The humerus and radius of *Ch. wimani* are longer and slightly more robust than those of *Alicornops simorrense* from Spain, but their metacarpals are close to each other. On the contrary, the hind limb bones of the two species have the similar length and gracility (Cerdeno and Sanchez, 2000). From other localities, however, both fore and hind limb bones of *A. simorrense* are longer and slenderer than those of *Ch. wimani* (Gu rin, 1980).

The limb bones of *Ch. wimani* are markedly shorter but more robust than those of *Aceratherium incisivum* from Howenegg (Hüttermann, 1989). All of *A. incisivum* from Western Europe have longer and slenderer limb bones than *Ch. wimani*. The limb bones of *Hoploaceratherium tetradactylum* are much longer and slenderer than those of *Ch. wimani* (Gu rin, 1980).

The metapodials of *Plesiaceratherium gracile* are greatly longer and slenderer than those of *Ch. wimani* (Yan and Heissig, 1986). The astragalus of *P. gracile* has separate Facets Ⅱ and Ⅲ on its posterior face (Yan, 1983; Yan and Heissig, 1986). On the other hand, the astragalus of *Ch. wimani* has connective Facets Ⅱ and Ⅲ or separated by a narrow groove.

In conclusion, the fore and hind feet of *Ch. wimani* are tridactyle, and limb bones are as short and robust as those of *Ch. anderssoni*; facets Ⅱ and Ⅲ for calcaneus on the posterior face of astragalus are connected to each other or separated by a narrow groove. Limb bones of most genera and species in the subfamily Aceratheriinae are longer and slenderer than those of *Ch. wimani*.

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