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泥河湾发现的板齿犀肢骨化石1)

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摘要: 板齿犀属(*Elasmotherium*)由Fischer (1808)根据在西伯利亚发现的材料建立,模式种为西伯利亚板齿犀(*E. sibiricum*)。板齿犀是一种很特别的犀牛,以其巨大的体型和强壮的额角为特征。目前板齿犀有两个有效种,即 *E. sibiricum* 和高加索板齿犀(*E. caucasicum*)。板齿犀的地理分布范围包括俄罗斯、阿塞拜疆、乌兹别克斯坦、蒙古和中国,时代为更新世。在中国,德日进等曾报道了在泥河湾发现的板齿犀的一块牙齿碎片和几件肢骨,但未进行详细的描述和深入的讨论(Teilhard de Chardin and Piveteau, 1930)。后来周明镇(1958)又根据山西的零星材料建立了板齿犀的两个新种。不过,中国的这些板齿犀材料最近都被Antoine (2002,2003)归入到 *E. caucasicum* 中。在俄罗斯的西伯利亚南部曾发现过相当丰富的 *E. sibiricum* 的化石材料,其中包括不少完整的头骨(Fischer,1808,1809)。另一方面,最早发现于亚速海南岸地区的 *E. caucasicum* 材料不多,主要是一些孤立的牙齿和齿列,肢骨特别少(Borissiak,1914)。在天津自然博物馆收藏的泥河湾化石标本中有一些桑志华采集的板齿犀的肢骨材料,以远端肢骨为主。此前在中国的板齿犀类方面只有对通古尔的西班牙犀(*Hispanotherium*)部分肢骨的研究发表(Cerdeño,1996)。本文描述和讨论了泥河湾的板齿犀肢骨材料,包括1件桡尺骨(THP 20355)、3件腕舟骨(THP 20325,20326,20336)、2件月骨(THP 20328,20337)、1件三角骨(THP 20338)、2件小多角骨(THP 20330,20341)、4件钩骨(THP 20333,20327,20329,20339)、3件第三掌骨(THP 20342,20343,20332)、2件第四掌骨(THP 20318,20319)、3件距骨(THP 20303,20308,20310)、1件跟骨(THP 20311)、2件跗舟骨(THP 20305,20322)、2件骰骨(THP 20304,20306)、2件第二蹠骨(THP 20316,20317)。早更新世早期的泥河湾动物群中已知包括云簇犀(*Dicerorhinus yunchuensis*)、泥河湾披毛犀(*Coelodonta nihowanensis*)和 *E. caucasicum* 三种犀牛,但前两种犀牛的体型远小于板齿犀,所以仅从肢骨的尺寸上就可以很好地区别它们。泥河湾的这批材料增加了我们对 *E. caucasicum* 的了解,它与 *E. sibiricum* 在肢骨方面有很多相似性状,如桡骨上容纳腕伸肌的沟宽深,第三掌骨前视可见对头状骨关节面,第四掌骨的近端关节面呈三角形,第五掌骨退化,掌骨上附着腕伸肌的止端显著,距骨对腓骨的关节面倾斜、距骨颈低到中等、滑车与远端关节面的夹角轻度倾斜、对蜗突关节面具长大的舌状延伸、对载距突关节面与对跟骨的外下关节面分离,跟骨对胫骨关节面存在、跟结节粗大、附着腓长肌的止端平滑,肢骨细长,掌骨和蹠骨的中央直嵴低平、骨干上附着骨间肌的止端长但无远端后侧结节。另一方面,这两种板齿犀也存在一些差别,如 *E. caucasicum* 的尺骨远端没有对桡骨的第二关节面,而 *E. sibiricum* 有; *E. caucasicum* 的钩骨未显示有第五掌骨与其关节,而 *E. sibiricum* 钩骨上对第五掌骨的关节面还与对三角骨的关节面联合; *E. caucasicum* 距骨上对腓骨的

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关节面凹陷,而 *E. sibiricum* 平坦。对比已知的少量 *E. caucasicum* 肢骨,泥河湾标本在性状和尺寸上与其完全一致,进一步证明将这些标本归入 *E. caucasicum* 是可信的。从泥河湾材料我们还了解到板齿犀属的一些未知性状,如骰骨近端呈三角形、跗舟骨顶视呈矩形、距骨的宽/高比达 1.21、厚/高比达 0.74、对骰骨关节面具后侧突起等。此前的支序分析表明 *Elasmotherium* 是板齿犀类中最进步的一个属,泥河湾标本所显示的大多数性状确实是进步的,但仍然有一些原始性状。在板齿犀的两个种中,*E. caucasicum* 可能比 *E. sibiricum* 更进步,不过这两个种实际上相当接近。板齿犀类不是一个丰富的犀科类群,然而特别的是在中国有较多的发现,包括几个大型的属,如 *Elasmotherium*、中华板齿犀(*Sinotherium*)、副板齿犀(*Parelasmotherium*)、宁夏犀(*Ningxiatherium*)和伊朗犀(*Iranotherium*),但都很少有肢骨化石发现。将泥河湾的材料与已知的少量 *Parelasmotherium* 和 *Iranotherium* 的肢骨相比,显示后两个属不比 *Elasmotherium* 进步,这与对它们系统关系的分析结果吻合。*E. caucasicum* 细长的远端肢骨与其高冠和釉质褶皱丰富的颊齿相一致,指示它是干旷草原的硬草取食者。

关键词: 河北泥河湾,早更新世,板齿犀,肢骨

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LIMB BONES OF ELASMOTHERIUM (RHINOCEROTIDAE, PERISSODACTYLA) FROM NIHEWAN (HEBEI, CHINA)

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Abstract Limb bones (mainly distal elements) of *Elasmotherium caucasicum*, which belong to the Nihewan collection in Tianjin Natural History Museum, are described and discussed in detail herein. Previously, the material of *Elasmotherium* was relatively rare, especially its limb bones. The rhinocerotid fossils from the Nihewan fauna include *Dicerorhinus yunchuensis*, *Coelodonta nihowanensis*, and *Elasmotherium caucasicum*, but the first two species are much smaller than the last one in size. The material from Nihewan reveals additional limb bone characters for the genus *Elasmotherium*. Compared with the known limb bones of *E. caucasicum*, the specimens from Nihewan are identical with them. On the basis of the limb bones of *E. caucasicum* from Nihewan, a more complete comparison shows that *E. caucasicum* and *E. sibiricum* have many common characters but some differences in morphology. Most characters of the limb bones of *E. caucasicum* from Nihewan are derived, but some are primitive, which is consistent with its phylogenetic position.

Key words Nihewan (Hebei, China), Early Pleistocene, elasmothere, limb bone

The genus *Elasmotherium* was named by Fischer (1808) according to the material discovered from Siberia, and *E. sibiricum* is its type species. *Elasmotherium* is a peculiar rhinoceros, characterized by its very large size and huge frontal horn. Until now, two species of *Elasmotherium* have been accepted as valid, *E. sibiricum* Fischer, 1809 and *E. caucasicum* Borissiak, 1914. The geographical distribution of *Elasmotherium* includes Russia, Azerbaijan, Uzbekistan, Mongolia and China, and the stratigraphical distribution is from Early to Late Pleistocene (Fischer, 1808, 1809; Borissiak, 1914; Teilhard de Chardin and Piveteau, 1930; Chow, 1958; Beljaeva, 1958; Antoine, 2002). In China, Teilhard de Chardin and Piveteau (1930) and Teilhard de Chardin and Leroy (1942) reported a Nihewan fragmentary tooth and several limb bones as *Elasmotherium* sp., but they did not describe and discuss them in detail. Chow (1958) described two new species, *Elasmotherium inexpectanum* and *E. peii* on the basis of some teeth from Shanxi. Antoine (2002,

2003) referred *Elasmotherium* sp. from Nihewan as well as *E. inexpectanum* and *E. peii* from Shanxi into *E. caucasicum*.

Many fossils of *E. sibiricum*, including a lot of complete skulls, were discovered in southern Russia. On the other hand, the material of *E. caucasicum* is relatively rare, especially its limb bones. *E. caucasicum* was first described from the southern bank of Azov, including many isolated teeth and tooth rows. Rhinocerotid limb bones are significant to determine systematic positions and ecological behaviors. The Nihewan collection preserved in Tianjin Natural History Museum includes some limb bones (mainly distal elements) of *Elasmotherium* collected by Licent during June and July of 1929. Actually, detailed and complete descriptions on skeletons of Chinese rhinocerotid fossils are sparse (Yan and Heissig, 1986; Deng, 2002a). For the Chinese elasmotheres, only some limb bones of *Hispanotherium* from Tunggur, Nei Mongol were described (Cerdeño, 1996). Herein these important limb bones of *Elasmotherium* from Nihewan are described and discussed.

Terminology follows Sisson (1953), and the measurements are according to Guérin (1980) and given in mm. Abbreviations used in text: ant. = anterior; APD = anteroposterior diameter; art. = articular; dis. = distal; H = height; L = length; m. = muscle; max. = maximal; med. = medial; mid. = middle; min. = minimal; prox. = proximal; TD = transverse diameter; THP = prefix to the vertebrate fossils of the Tianjin Natural History Museum; tub. = tuberosity; W = width.

Family Rhinocerotidae Owen, 1845

Subfamily Rhinocerotinae Dollo, 1885

Tribe Elasmotheriini Dollo, 1885

Genus *Elasmotherium* **Fischer, 1808**

Elasmotherium caucasicum **Borissiak, 1914**

(**Figs.** 1～3)

Lectotype PIN 31 and PIN 5, series of P4～M3 and p3～m3 belonging to one individual, which were described by Borissiak (1914) and designated by Antoine (2002). The lectotype is preserved in the Paleontological Museum of the Russian Academy of Sciences in Moscow.

Described specimens Radius and ulna: THP 20355 (right) without olecranon and distal extremity of radius; scaphoids: THP 20325 (left), THP 20326 (right), and THP 20336 (right); semilunates: THP 20328 (right), and THP 20337 (right); pyramidal: THP 20338 (left) with broken medial surface; trapezoids: THP 20330 (right), and THP 20341 (left); unciforms: THP 20333 (left), THP 20327 (left), THP 20329 (right) with broken lateral surface and without posterior surface, and THP 20339 (right) without posterior surface of proximal part. Mc III: THP 20342 (right), THP 20343 (right), and THP 20332 (right) without distal extremity; proximal extremities of Mc IV: THP 20318 (left), and THP 20319 (left); astragali: THP 20303 (left), THP 20308 (right), and THP 20310 (right); calcanea: THP 20311 (right) with broken proximal extremity; naviculars: THP 20305 (left), and THP 20322 (right) with broken proximal surface of posterior part; cuboids: THP 20304 (left), and THP 20306 (right); proximal extremities of Mt II: THP 20316 (left), and THP 20317 (left).

Locality and horizon Nihewan in Yangyuan, Hebei; early Early Pleistocene.

Description Radius: The shaft is robust. The articular surface to humerus is papilionaceous and divided by a smooth sagittal crest, and its medial part is obviously larger than its lateral one. The articular surfaces for ulna are concave, and the lateral proximal tuberosity is well developed. The gutter for the extensor carpi is deep and wide. Measurements (THP 20355): TD prox. = 142.7.

Ulna: The shaft is robust and has three edges. The anconeus process is obtuse and rounded, and the semilunar notch is comparatively shallow. The two articular surfaces to radius under the semilunar notch are convex. The distal extremity is broad, with a larger and somewhat rounded lateral facet for pyramidal and a smaller and triangular medial facet with a pointed posterior margin for semilunate. On the distal medial surface, one and only facet for radius is rounded and deeply concave, with a rough crest along its upper border. Measurements (THP 20355) : TD mid. = 65.7; TD. dis. = 84.5.

Scaphoid (Fig. 1.1) : The body is very broad, with deeply concave proximal surface whose medial and posterior edges are relatively high. The postero-proximal facet for semilunate is absent. The distal articular surface is flat in front, concave behind, and divided by a transverse crest into two facets for trapezoid and magnum, respectively. The lateral surface bears two facets for semilunate on its anterior part; the upper facet is narrow, and the lower one is semicircular, connected with the flat distal facet for magnum; between the two facets for semilunate it is broadly excavated and slightly rough. On the lateral surface of THP 20325, a large and rounded facet for semilunate is situated on its posterior part, above which it is widely and deeply grooved (Fig. 1.1b), but THP 20336 lacks this facet. The posterior and medial surfaces are rough and strongly tuberculate, especially the posterior one. Measurements (THP 20325, 20326, 20336) : L = 119.5, 113, 108; W = 79, - , 86.2; H = 82, 78, 75.4; L prox. art. = 77, 70, 65; W prox. art. = 77, - , 89; L dis. art. = - , 81, 89; W dis. art. = ～46, ～42, 45.3.

Semilunate (Fig. 1.2) : The body is somewhat wedge-shaped, wider in front than behind. The proximal articular surface to the middle distal facet of radius is broadly saddle-shaped. The distal articular surface is smaller, convex in front, concave behind, and divided by a high central crest into two facets for magnum and unciform, respectively. The medial surface has upper and lower scaphoid facets; the upper facet is small, the lower facet is large and relatively concave, and between the two facets it is narrowly and deeply excavated and slightly rough. The lateral surface is similar to the medial one for pyramidal; the upper facet is weak, and the lower facet is large and rectangular; between the two facets it is widely and shallowly excavated and rough. The posterior surface bears a strong tuberosity on its lower part. The anterior surface is keeled in shape. Measurements (THP 20328, 20337) : L = 109.5, 110.2; W = 83, 83; H = 83, 81; H ant. = 93.2, 90.2.

Pyramidal: The body is irregular in shape. The proximal and distal articular surfaces, respectively for radius and unciform, are concave, but the distal one is smaller and shallower. The anterior surface is flat and rough. The lateral surface is rough, with a big prominence on its lower part. The posterior surface is rough and undulate. Measurements (THP 20338) : APD = 91.8; TD = 75; H = 80.4.

Trapezoid (Fig. 1.3) : The body is cashew-shaped. The proximal articular surface to scaphoid is widely concave. The lateral facet for magnum is irregularly pentagonal, and so big that it occupies almost the whole lateral surface. The anterior surface is rough, with a big tuberosity on its lower part and an asymmetrical border on its upper part. On the medial surface, a large facet is continuous with the proximal facet for scaphoid, and a rough and shallow depression on its anterio-inferior corner is constricted backward. The distal articular surface is large and concave for Mc II. Measurements (THP 20330, 20341) : L = 62.5, 67; W = 44, 44.3; H = 52.8, 58.

Unciform (Fig. 1.4) : The body is somewhat wedge-shaped. On the posterior surface, the tubercle on its lower part is oval. The proximal articular surface is convex and divided by a high central crest into two facets for semilunate and pyramidal, and this crest disappears gradually backward. Between the proximal surface and the posterior tubercle it is triangularly excavated. The distal surface is large and long. On the medial surface, the facet for magnum is narrow and long. The lateral surface is narrow, without the facet for Mc V, and the anterior surface is rough. Measurements (THP 20327, 20329, 20333, 20339) : L absolute = 142, - , 118.4, 124.3; L anatomic = 106.5, - , 96.5, 102.6; W = 112.8, 98.2, 104, 94.5; H = 88, 70, 77.3, 71.

Mc III (Fig. 2.1) : The straight shaft is prolate in cross section, and its lateral and medial

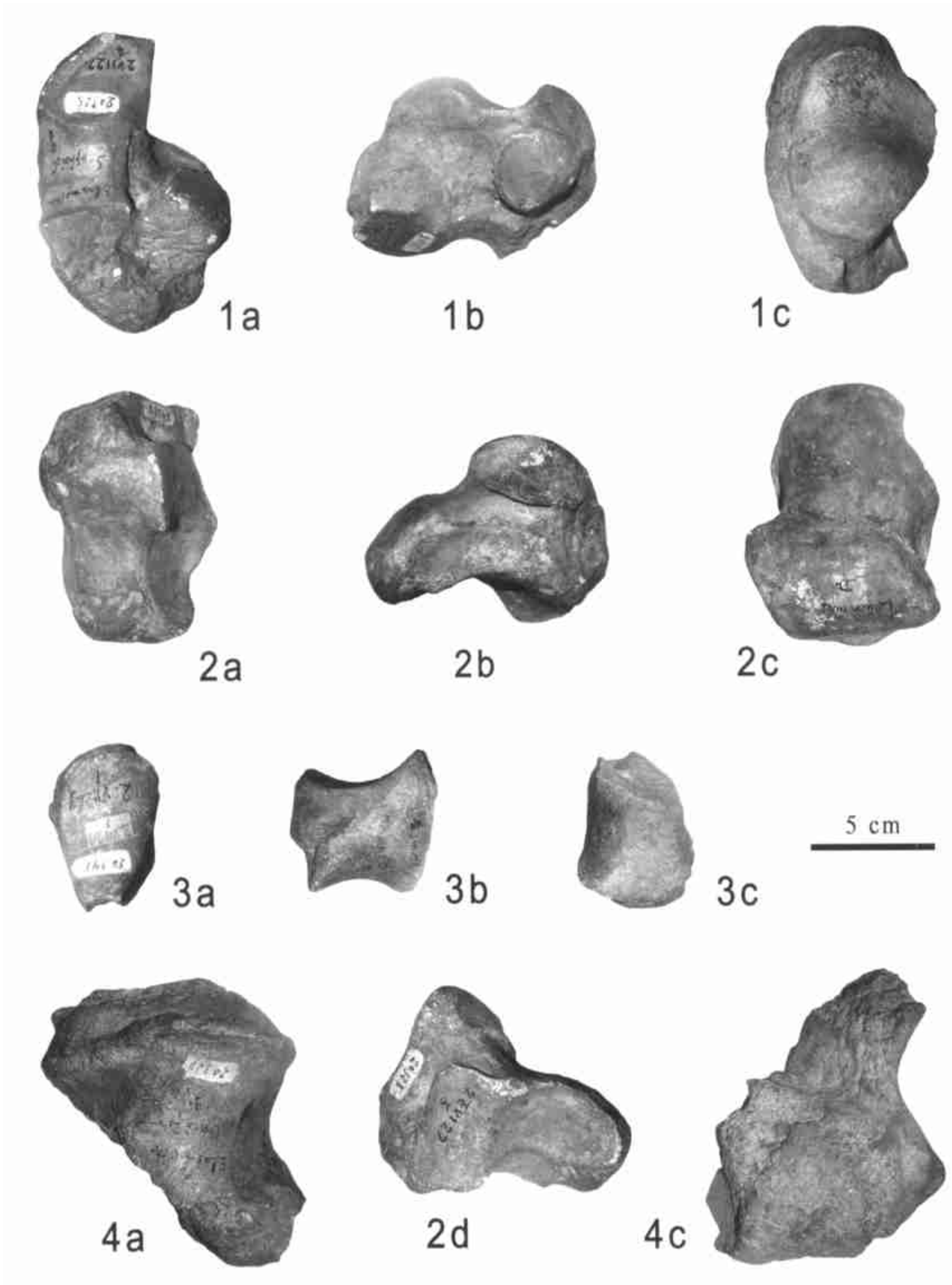

Fig. 1 Carpals of *Elasmotherium caucasicum* from Nihewan (Hebei, China)
1. left scaphoid, THP 20325; 2. right semilunate, THP 20328; 3. left trapezoid, THP 20341;
4. left unciform, THP 20327
a. distal view; b. lateral view; c. proximal view; d. medial view

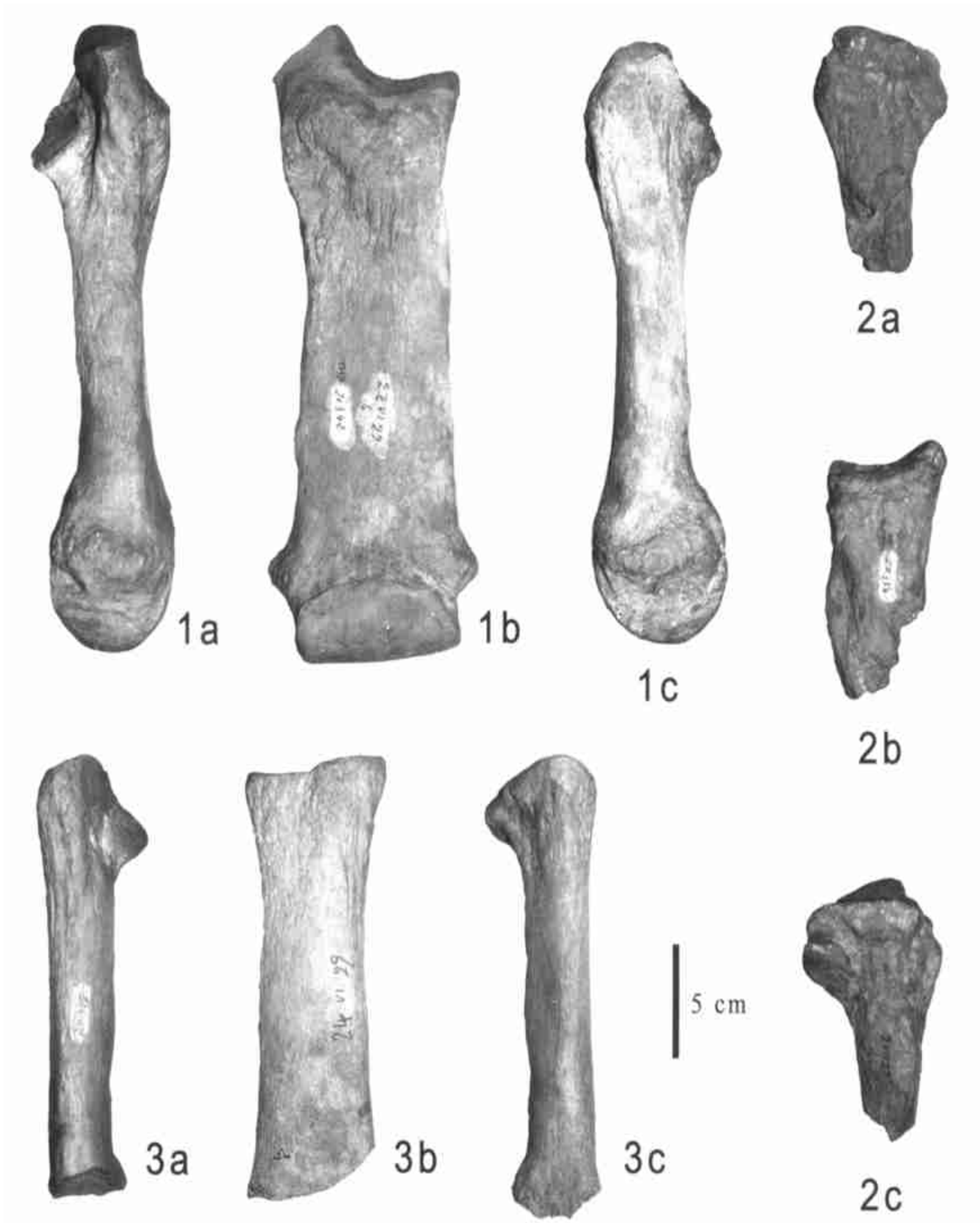

Fig. 2　Metapodials of *Elasmotherium caucasicum* from Nihewan (Hebei, China)
1. right Mc III, THP 20342; 2. left Mc IV, THP 20318; 3. left Mt II, THP 20317
a. lateral view; b. anterior view; c. medial view

borders have a similar thickness. The posterior surface is concave from side to side, and has a rough ridge on either side, proximally. The lateral border of the shaft is rough on its upper 3/4 but smooth on the distal 1/4, while the medial border is smooth only on its distal 1/6. On the proximal surface, the medial facet for magnum is large, convex, visible in anterior view, and separated by a high ridge from the lateral facet for unciform, which is convex and obliquely trapeziform. On the proximal lateral surface, the anterior facet for Mc IV is flat, narrowly triangular, separated by a ridge from the proximal facet for unciform, and has a ridge under it; the posterior facet for Mc IV is flat, oval, strongly projected backward, and has a well-developed medial tuberosity. The metacarpal tuberosity is highly projected on its lateral part, and vertically extended on its medial part. On the distal extremity, the upper margin of the articular surface is curved; the sagittal ridge is weak, absent on the anterior side, and wide on the posterior side. On the distal anterior side, the lateral and medial condyles are weak so that the articular surface is large and smooth, while on the posterior side, they are slightly lower than the sagittal ridge. The lateral and medial fossae are semicircular, and surmounted by a well-developed tubercle for the collateral ligament. Measurements (THP 20332, 20342, 20343): L = -, 290.5, 260; TD prox. = 95.3, 95, 86; APD prox. = 69.7, 75.4, 63.4; TD mid. = 76, 74, 69.4; APD mid. = 35.8, 35.5, 30; TD dis. max. = -, 105.7, 91.8; TD dis. art. = -, 87.2, 77; APD dis. = -, 70.5, 64.

Mc IV (Fig. 2.2): The shaft is thick, slender, and curved medially in its proximal extremity. The lateral and medial borders are very rough proximally. The proximal articular surface is somewhat triangular and medially oblique, and a crest separates it from the narrow anterior medial facet for Mc III. The posterior medial facet for Mc III is large, rounded, and strongly projected backward to form the rear-most end of the bone, and it has a long distance from the proximal articular surface and a wide and deep notch from the anterior facet for Mc III. The anterior proximal tuberosity is well developed. The facet for Mc V is absent. Measurements (THP 20318, 20319): TD prox. = 66.1, 69.5; APD prox. = 72, 78.

Astragalus (Fig. 3.2): The body is short and broad, with a broad and shallow trochlea tali whose collum is about 10 mm long. On the distal surface, the facet for cuboid has a posterior stop. On the lateral surface, the facet for fibula is concave. The lateral ridge has a marked edge, while the medial one is very smooth. On the medial surface, the distal tuberosity is narrow and extends downward to reach the margin of the distal surface. On the posterior surface, the facet for cochlear process is expanded and concave, with a tongue-like distal extension; the facet for sustentaculum tali is somewhat rounded, slightly oblique inward, and connected with the facet for cochlear process but separated from the lateral lower facet for calcaneus. Measurements (THP 20303, 20308, 20310): TD = 122, 125, 134; H = 102.5, 101, 113; APD med. = 71.6, 75, -; TD dis. art. = 101, 104, 112.2; APD dis. art. = 68.5, 66.2, -; W trochlea = 82, 67.5, 85; TD dis. max. = 109, 107.6, 117.3.

Calcaneus (Fig. 3.1): The body is short and robust. The calcaneal tuber is massive, with a broad and rough posterior surface and a projected ridge on its lateral and medial lower margins. On the lateral surface, a smooth insertion for longus fibular muscle is present. The sustentaculum tali is horizontally narrow and strongly projected inward. The facet for astragalus under the sustentaculum tali is rounded, slightly concave, and separated from the small facet for navicular by a wide and shallow notch. The tarsal groove is wide and shallow. The anterior border is concave in its length and smooth in its upper part. The cochlear process is very weak, under which the facet for astragalus is large and triangularly convex, with a small facet for tibia. The tarsal sinus is small. The posterior border is undulate, very wide in its upper part, and not constricted in its middle part. Measurements (THP 20311): APD tub. = 108.7; TD min. = 61.3.

Navicular (Fig. 3.3): The body is rectangular in proximal view, and flattened from above downward. On the proximal surface, the facet for astragalus is concave, the lateral non-articular depression is weak, and the facet for calcaneus is narrow and long. The distal surface is convex, and the non-articular groove between the facets for meso- and ectocuneiforms is oblique and weak. The continuous anterior and medial borders are rough. On the posterior border, the medial prominence is large and situated proximally, while the lateral one is small and situated distally. The lateral border is oblique, with the upper facet for cuboid well-developed, a weak lower facet for

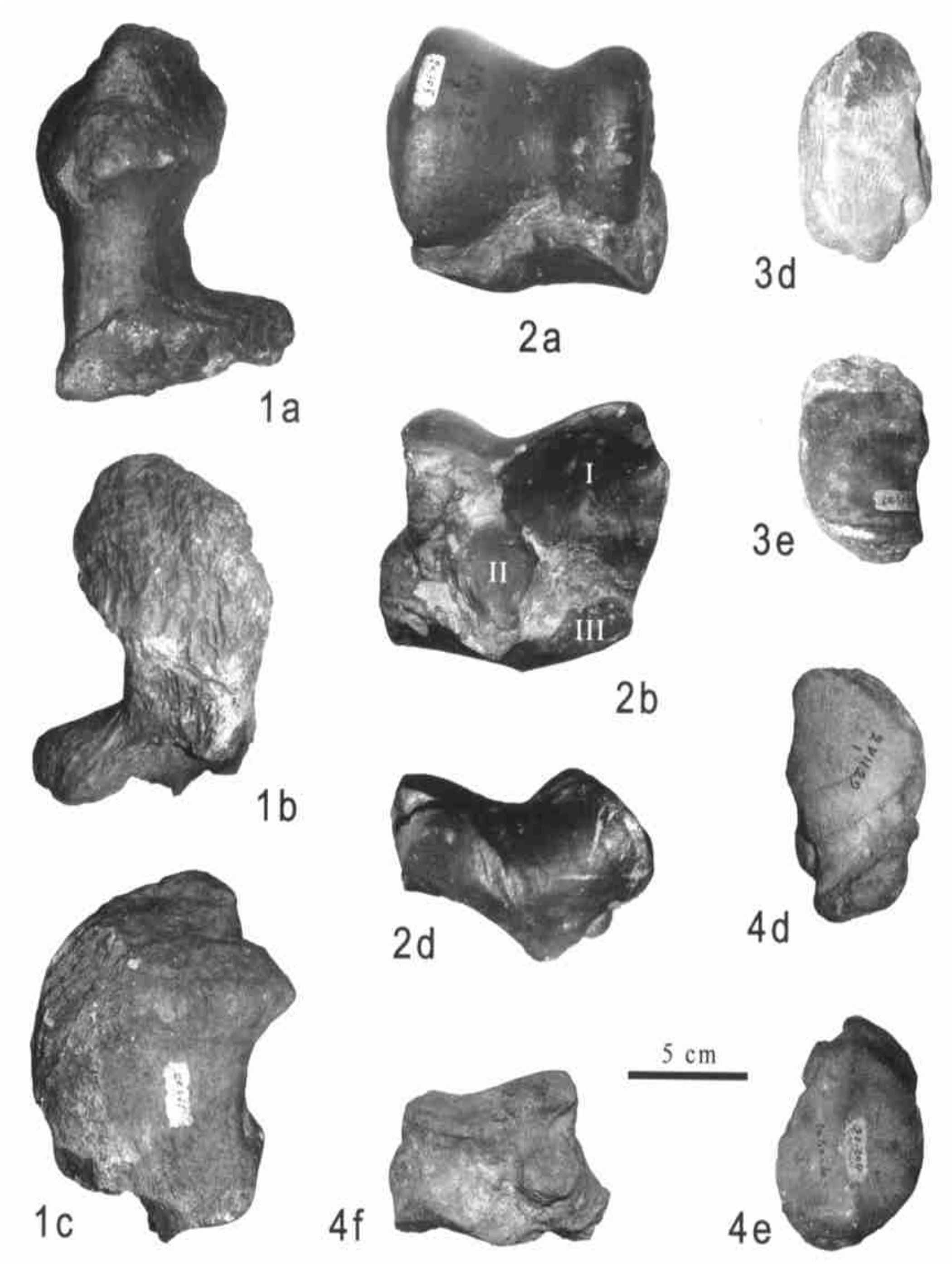

Fig. 3　Tarsals of *Elasmotherium caucasicum* from Nihewan (Hebei , China)
1. right calcaneus , THP 20311 ; 2. right astragalus , THP 20308 ; 3. left navicular , THP 20305 ; 4. left cuboid , THP 20304
a. anterior view ; b. posterior view ; c. lateral view ; d. distal view ; e. proximal view ; f. medial view
I. facet for cochlear process ; II. facet for sustentaculum tali ; III. lateral lower facet for calcaneus

cuboid, and a large concave and rough surface between the two facets. Measurements (THP 20305, 20322): L = 83, 94; W = 58, 56; H = 40, 40.

Cuboid (Fig. 3.4): The proximal surface is large, triangular and slightly concave, and a continuous central crest separates it into two facets for calcaneus and astragalus. The distal articular surface is large and concave, and a wide and shallow groove is situated between the surface and the posterior tuberosity for plantar ligament. On the medial surface, the anterior facet for navicular is well developed but the posterior navicular facet is very weak; the anterior facet for ectocuneiform is very small and the posterior ectocuneiform facet is almost absent. The groove for tarsal canal is wide. Measurements (THP 20304, 20306): L = 98.3, 98.2; W = 62, 56; H = 77.8, 68; TD prox. art. = 59, 60.5; APD prox. art. = 69.5, 74; H ant. = 63.4, 58.4.

Mt II (Fig. 2.3): The shaft is slender. The lateral and medial borders are relatively rough in their proximal 3/4, and they have a similar thickness. On the posterior surface, there is a wide and low ridge along either side of its proximal 2/3, and a marked wide groove is situated between the ridges. The anterior surface is relatively smooth. The proximal articular surface is fan-shaped and slightly concave, with a weak anterior tuberosity, especially in its lateral part. On the proximal lateral surface, the anterior facet for Mt III is approximately rectangular and situated upward, while the posterior one for Mt III is somewhat rounded, situated downward, and strongly projected backward; a narrow connection joins them and a deep and triangular depression lies inferior to them. A wide and shallow depression is situated between the proximal articular surface and the posterior facet for Mt III. Measurements (THP 20316, 20317): TD prox. = 70.7, 72.4; APD prox. = 53, 59.5; TD mid. = ~53, 54.5; APD mid. = 29.3, 34.5.

Comparison and discussion For the named species of the genus *Elasmotherium*, many specimens are attributed to *E. sibiricum*, including a lot of complete skulls, but few are described for *E. caucasicum*. On the other hand, both species lack complete skeletons, which limits knowledge about their limb bones, especially for *E. caucasicum*. In the Nihewan collection of Licent in Tianjin Natural History Museum, there is no dental or skull material of *Elasmotherium*. Chow (1958) described a tooth fragment of *Elasmotherium* sp. from Nihewan in the collection of Institute of Vertebrate Paleontology and Paleoanthropology, which was noticed by Teilhard de Chardin and Leroy (1942).

The rhinocerotid fossils from the early Early Pleistocene Nihewan (Xiashagou) fauna include *Dicerorhinus yunchuensis*, *Coelodonta nihowanensis*, and *Elasmotherium caucasicum* (Teilhard de Chardin and Piveteau, 1930; Chow, 1963; Kahlke, 1969; Qiu and Qiu, 1995; Antoine, 2002; Deng, 2002b; Qiu et al., 2004). The sizes of *D. yunchuensis* and *C. nihowanensis* are much smaller than that of *E. caucasicum*. Teilhard de Chardin and Piveteau (1930) compared the radius, semilunate and Mc III between *C. antiquitatis* and *E. caucasicum*, and showed that the former is about 30~40 percent smaller than the latter. *C. nihowanensis* is smaller than *C. antiquitatis* (Deng, 2002b; Qiu et al., 2004). The material of *D. yunchuensis* from Nihewan is teeth and no assured limb bones. Judging from the dimensions of a skull of *D. yunchuensis* from Yushe, Shanxi (Chow, 1963), the size of this species is close to the extant *Ceratotherium simum* (Guerin, 1980, tab. 2), but the limb bones of the latter are much smaller than those of *E. caucasicum*. For example, the Mc III of *C. simum* is about 50 percent shorter and about 30 percent narrower than that of *E. caucasicum* from Nihewan (Guerin, 1980, tab. 19; Teilhard de Chardin and Piveteau, 1930, p. 20). As a result, the limb bones of *D. yunchuensis* should be obviously smaller than those of *E. caucasicum*. Therefore, we can distinguish the limb bones of *E. caucasicum* from other rhinoceros species in the Nihewan assemblage according to their enormous size, which are completely identical with the measurements of *Elasmotherium* in Guerin (1980, Tab. 121).

On the basis of the limb bones of *E. caucasicum* described in this paper, we can compare this species with *E. sibiricum* more completely. The two species have many common limb bone characters, such as a deep and wide gutter for the extensor carpi on radius, a visible facet for magnum in anterior view of Mc III, a triangular proximal surface of Mc IV, a vestigial Mc V, and salient insertion for carpal extensor of metacarpals; an oblique orientation of the facet for fibula, a low or moderate collum tali, a slightly oblique angle between the trochlea and the distal surface, a high tongue-like extension of the facet for cochlear process, and an independent lateral lower facet for calcaneus from the facet for sustentaculum tali on astragalus; a tibia-facet present, a massive calcaneal tuber, and a smooth insertion for longus fibular muscle on calcaneus; slender limbs, low and smooth intermediate relief of metapodials, and a long insertion of m. interossei but no postero-distal tubercle on the diaphysis of metapodials.

On the other hand, the limb bones between the two species show some differences in morphology. The ulna of *E. caucasicum* has no second distal facet for radius, while *E. sibiricum* has one. The unciform of *E. caucasicum* has no facet for Mc V, while *E. sibiricum* has one to connect with the proximal facet for pyramidal. The fibular facet on the astragalus of *E. caucasicum* is concave, but that of *E. sibiricum* is flat.

Compared with the known limb bones of *E. caucasicum* from southern Siberia, the specimens from Nihewan are identical with them, such as an absent postero-proximal facet for semilunate, a flat facet for magnum in lateral view, and same anterior and posterior heights on scaphoid; an asymmetrical proximal border in anterior view on trapezoid, a vestigial Mc V, a salient insertion for the extensor carpalis on metacarpals, an acute distal end and a keeled shape of the anterior surface on semilunate, no facet for Mc V on unciform, slender limbs, and low and smooth intermediate relief on metapodials.

The material from Nihewan also reveals additional limb bone characters for the genus *Elasmotherium*, such as a triangular proximal surface of cuboid, and a rectangular cross section of navicular in proximal view; a TD/H ratio averaging 1.21, an APD/H ratio averaging 0.74, and a posterior stop on the facet for cuboid on astragalus.

According to cladistic analyses for elasmotheres, the genus *Elasmotherium* is the most derived (Cerdeño, 1995; Antoine, 2002). In fact, most characters of the limb bones of *Elasmotherium* from Nihewan are derived, but some are primitive compared with other elasmotheres (Antoine, 2002). These primitive characters include a deep and wide gutter for the extensor carpi of radius, absence of second distal facet for ulna on radius, and a visible facet for magnum in anterior view on Mc III; an expansion of facet for cochlear process, an independent lateral lower facet for calcaneus from facet for sustentaculum tali, a posterior stop on the facet for cuboid on astragalus; massive calcaneal tuber, no postero-distal tubercle on the diaphysis of metapodials, a long insertion of m. interossei on metapodials, identical anterior and posterior heights of scaphoid, an acute distal end and a keeled shape of the anterior surface on semilunate, and slender limbs.

Between the two species of *Elasmotherium*, *E. caucasicum* may be more derived than *E. sibiricum*, since the unciform has no facet for Mc V, and the astragalus has a concave facet for fibula on the former. On the other hand, *E. caucasicum* is very close to *E. sibiricum*. Borissiak (1914) was hesitant when he created this species, and Ringström (1924) also indicated that differences between them are very small and their sizes are similar. Comparisons of limb bones dependent on the material from Nihewan show that *E. caucasium* is indeed close to *E. sibiricum*.

Elasmotheriini is not very abundant as a rhinocerotid group, but its fossils are comparatively well represented in China, especially including several of the largest genera, such as *Elasmotherium*, *Sinotherium*, *Parelasmotherium*, *Ningxiatherium*, and *Iranotherium* (Teilhard de Chardin and Piveteau, 1930; Killgus, 1923; Ringström, 1924; Chow, 1958; Chen, 1977; Qiu and Xie, 1998; Deng, 2001, in press). In contrast to *Parelasmotherium schansiense* described by Killgus (1923), *Parelasmotherium linxiaense*, *Sinotherium lagrelii*, *Ningxiatherium longirhinus*, and *Iranotherium morgani* have no limb bones found in China. Another elasmothere genus, *Hispanotherium* has a wider distribution in China (Zhai, 1978; Yan, 1979; Guan, 1988, 1993;

Cerdeño, 1996; Deng, 2003, 2004), however, only *H. tungurense* has limb bones found from Tunggur in Nei Mongol. The size of *Hispanotherium* is much smaller than that of *Elasmotherium*, so their limb bones can be easily distinguished.

The limb bones of *P. schansiense* include only a calcaneus plus astragalus and a radius plus ulna preserved in Tübingen, Germany (Killgus, 1923; Ringström, 1924). *I. morgani* has some limb bones discovered from Maragha, Iran (Mecquenem, 1908). All known characters of limb bones of *P. schansiense* and *I. morgani* are not more derived than those of *E. caucasicum*, which is consistent with their phylogenetic positions (Cerdeño, 1995; Antoine, 2002). Combined with hypsodont cheek teeth with much cement and strong enamel plications, the slender distal limb bones of *E. caucasicum* indicate that it is cursorial and dwells in an open steppe as a typical grazer.

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