

NEW POSTCRANIAL BONES OF *ELASMOTHERIUM PEII* FROM SHANSHENMIAOZUI IN NIHEWAN BASIN, NORTHERN CHINA

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ABSTRACT

Elasmotherium or the Giant Siberian Unicorn is quite common in Siberia and adjacent regions during the Quaternary Period, but it only appeared in very few sites of Early Pleistocene age in northern China. In the past century, quite a number of specimens of *Elasmotherium* were recovered in Nihewan Basin, most of which are disarticulated postcranial bones, among which the tibia was absent. Recently, not only dental materials, but also a nearly complete tibia and other podial as well as metapodial bones of *Elasmotherium* were recovered in Nihewan Basin. In morphology, the new specimens are quite distinct from those of the Russian species, especially in the form of Mc III, astragalus and cuboid, but their measurements are within the ranges or slightly smaller than those of the Russian *Elasmotherium*, and can be assigned to the species *E. peii*. The newly recovered bones are also very different from those of other fossil rhinos in their prominently larger sizes and the forms of Mc III and astragalus. The species *E. peii* co-existed with *Canis chihliensis*, *Pachycrocuta* sp., *Mammuthus trogontherii*, *Coelodonta nihowanensis*, *Proboscidea parvirostris* sp., *Equus sanmeniensis*, *Sus lydekkeri*, *Paracamelus* sp., *Eucladoceros* sp., *Spirocerus wongi*, *Gazella sinensis* and *Bison palaeosinensis*, in a region that can be dated back to more than 1.2 Ma and represents a shrub-steppe environment.

Keywords: *Elasmotherium*, tibia, Early Pleistocene, Shanshenmiaozi (Nihewan Basin), China

RÉSUMÉ

NOUVEAUX OS POST-CRÂNIENS D'*ELASMOTHERIUM PEII* DE SHANSHENMIAOZUI DU BASSIN DE NIHEWAN, CHINE DU NORD

Elasmotherium ou la Licorne géante de Sibérie est assez commune en Sibérie et dans les régions adjacentes pendant le Quaternaire, mais elle est rarement observée dans le Pléistocène inférieur de Chine du Nord. Au siècle dernier, un certain nombre d'ossements d'*Elasmotherium* ont été récoltés dans le bassin de Nihewan, qui sont pour la plupart des éléments post-crâniens isolés, parmi lesquels le tibia était absent. Récemment, du matériel dentaire, mais aussi un tibia presque complet et quelques os du tarse ainsi que des os métapodiaux d'*Elasmotherium* ont été découverts sur le site de Shanshenmiaozi, dans le bassin de Nihewan. La morphologie de ces ossements est tout-à-fait distincte de l'espèce russe, surtout dans la forme du Mc III, de l'astragalus et du cuboïde. Les dimensions restent néanmoins proches ou légèrement inférieures à celles de l'*Elasmotherium* russe et ces ossements ont été attribués à l'espèce *E. peii*. Les nouveaux os récupérés sont aussi radicalement différents de ceux d'autres rhinocéros fossiles en particulier par leur très grande taille, la morphologie du troisième métacarpien et de l'astragale. L'espèce *E. peii* a bien coexisté avec *Canis chihliensis*, *Pachycrocuta* sp., *Mammuthus trogontherii*, *Coelodonta nihowanensis*, *Proboscidea parvirostris* sp., *Equus sanmeniensis*, *Sus lydekkeri*, *Paracamelus* sp., *Eucladoceros* sp., *Spirocerus wongi*, *Gazella sinensis* et *Bison palaeosinensis*, et la localité peut être datée de plus de 1,2 Ma et représente un environnement de steppe à buissons.

Mots-clés: *Elasmotherium*, tibia, Pléistocène inférieur, Shanshenmiaozi (bassin de Nihewan), Chine

1 - INTRODUCTION

Elasmotherium is the most specialized taxon among the rhinocerotids, whose fossil remains are very scanty in China as only isolated teeth and a few postcranial bones from some sites in northern China were reported in the past century (Teilhard de Chardin & Piveteau, 1930; Teilhard de Chardin, 1942; Chow, 1958; Chia & Wang, 1978; Huang & Ji, 1984; Deng & Zheng, 2005), most of which lack a definite provenance.

In the recent years, the excavations at the Shanshenmiaozi (SSMZ) Site and Heitugou Site resulted in some recoveries of *Elasmotherium* fossils, some of which have been reported by Tong *et al.* (2014). The more recently recovered specimens from SSMZ are going to be described in this study. The significance of the new finds lies at their definite provenance and the first recovery of the tibia material of *Elasmotherium* in China.

The SSMZ site lies at the neighboring hill slope of Xiaochangliang, a well-known Paleolithic site in Nihewan

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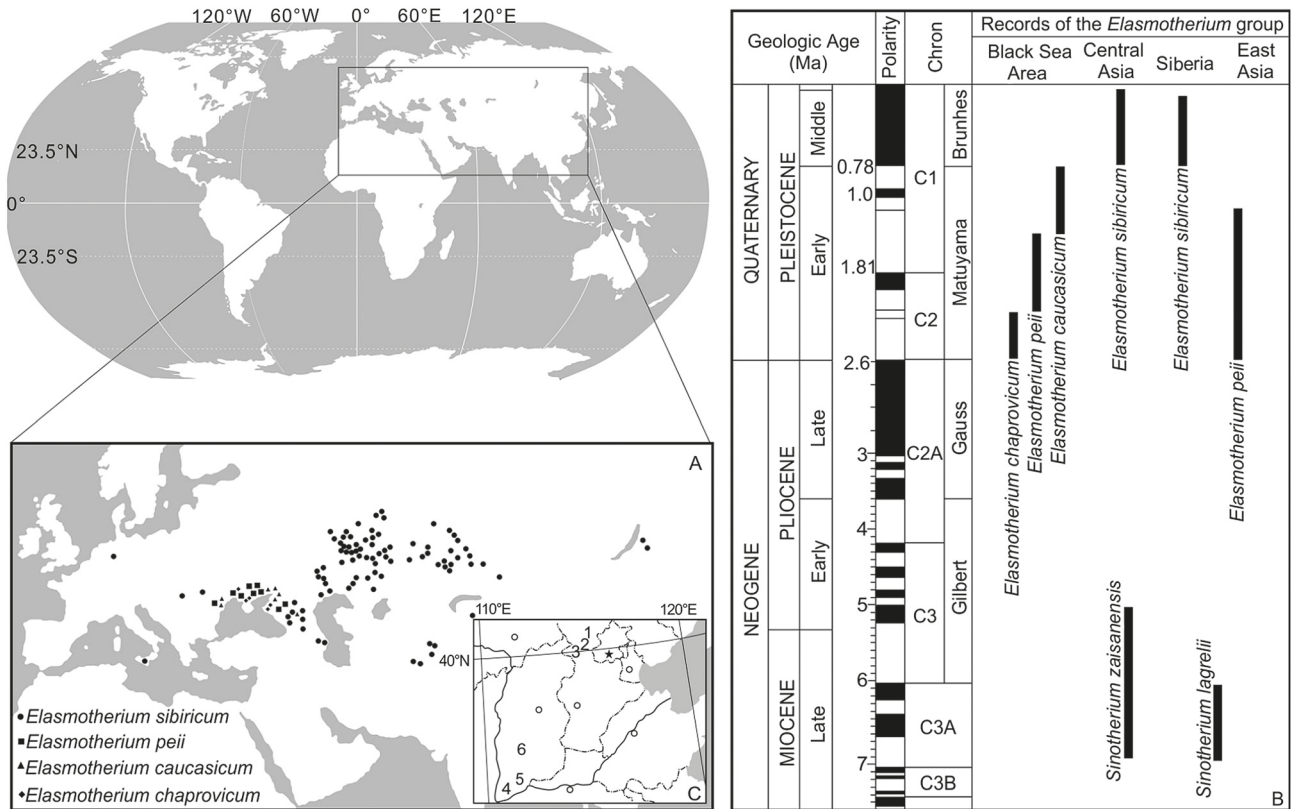


Fig. 1: Spatial (A) and temporal (B) distributions of *Elasmotherium*, with details of the Chinese sites (C) of *E. peii*.

1/ Xiashagou; 2/ SSMZ; 3/ Heitugou; 4/ Xihoudu; 5/ Sanmenxia; 6/ Shanxi but without location details. Data for *Elasmotherium* sites outside China are after Shvyreva (2016)

Fig. 1 : Répartition spatiale (A) et temporelle (B) d'*Elasmotherium*, avec les détails des sites chinois à *E. peii* (C).

1/ Xiashagou ; 2/ SSMZ ; 3/ Heitugou ; 4/ Xihoudu ; 5/ Sanmenxia ; 6/ Shanxi. Les données pour les sites à *Elasmotherium* à l'extérieur de la Chine sont d'après Shvyreva (2016)

Basin, Hebei Province in northern China (fig. 1). Based on the stratigraphic correlation in the field, the fossil-bearing sand-silt bed at the new locality is a little higher than the cultural layer at Xiaochangliang site (Tong *et al.*, 2011; Liu *et al.*, 2016), whose paleomagnetic age is about 1.36 Ma BP (Zhu *et al.*, 2001).

The mammalian taxa associated with *Elasmotherium peii* at SSMZ are as follows: *Lepus* sp., *Ochotona* sp., *Canis chihliensis*, Pantherinae gen. et sp. indet., *Pachycrocuta* sp., *Mammuthus trogontherii*, *Coelodonta nihowanensis*, *Proboscidea* sp., *Equus sanmeniensis*, *Sus* sp., *Eucladoceros* sp., *Spirocerus wongi*, *Gazella sinensis* and *Bison palaeosinensis* (Tong *et al.*, 2011), which represents a shrub-steppe environment; furthermore, a metatarsal bone of *Paracamelus* was recovered in 2015 and a metacarpal bone of *Alactaga* was recovered in the 2016 season.

The SSMZ site bears quite rich and well-preserved fossils, such as *Canis chihliensis* (Tong *et al.*, 2012), *Coelodonta nihowanensis* (Tong & Wang, 2014), *M. trogontherii* (Tong, 2012; Tong & Chen, 2016; Chen & Tong, 2016) and *B. palaeosinensis* (Tong *et al.*, 2016), which formed the early assemblage of the *Mammuthus-Coelodonta* faunal complex.

2 - FOSSIL MATERIALS

The fossil materials are given in table 1.

3 - METHODS, TERMINOLOGY AND ABBREVIATIONS

The classification system above the species level is after Antoine (2002). The terminology is mainly after the following references: Guérin (1980), Antoine (2002) and Prothero (2005). The method of measurements is according to the following authors: Guérin (1980), Mazza (1988), Antoine (2002) and Prothero (2005). All the dimensions are in millimeter.

The abbreviations are given below:

- Institutional abbreviations—IVPP, Institute of Vertebrate Paleontology and Paleoanthropology; MNHN, Muséum National d'Histoire Naturelle; NHW, Nihewan (= Nihowan); SSMZ, Shanshenmiaozui; TNP, Tianjin Natural History Museum (= Musée Hoang ho Pai ho).

- Anatomical abbreviations—H, height; L, length; W, width; DT prox, proximal transverse diameter; DAP prox, anteroposterior diameter of the proximal end; DT dia, transverse diameter of the shaft; DAP dia, anteroposterior diameter of the shaft; DT dist, distal transverse diameter; DAP dist, anteroposterior diameter of the distal end; DT artic dist, transverse diameter of the distal articular surface; DAP arti dist, anteroposterior diameter of the distal articular surface.

Materials	Field No.	Catalog No.	Context information	Locality	Horizon	Repository	References
Left ulna	N-15-188	V23590.1	H27-5	SSMZ	Early Pleistocene	IVPP	This paper
Right Mc III	N-15-211	V23590.2	I27-6	SSMZ	Early Pleistocene	IVPP	This paper
Right Mc IV	N-15-147	V23590.3	H28-5	SSMZ	Early Pleistocene	IVPP	This paper
Left magnum	N-15-061	V23590.4	G30-3	SSMZ	Early Pleistocene	IVPP	This paper
Left magnum	N-15-077	V23590.5	G28-5	SSMZ	Early Pleistocene	IVPP	This paper
Right tibia	N-15-021	V23590.6	G29-3	SSMZ	Early Pleistocene	IVPP	This paper
Left astragalus	N-16-118	V23590.7	L19-13	SSMZ	Early Pleistocene	IVPP	This paper
Right cuboid	N-16-027	V23590.8	J23-8	SSMZ	Early Pleistocene	IVPP	This paper
Left Mt IV	N-07-121	V23590.9	E4-7	SSMZ	Early Pleistocene	IVPP	This paper
Mt IV	N-15-136	V23590.10	H29-4	SSMZ	Early Pleistocene	IVPP	This paper
3rd phalanx of toe III	N-06-wai	V23590.11	Outside of square	SSMZ	Early Pleistocene	IVPP	This paper
Right scaphoid	N-11-029	V 20128.3	G23-7	SSMZ	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left magnum	N-08-080	V 20128.2	I16-4	SSMZ	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left Mc IV	N-08-075	V 20128.1	I16-4	SSMZ	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left m3	2008-11-09(3)	V 20129.8	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left m2 or m3	1	V 20129.7	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Right m2	2	V 20129.6	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Right p4	6	V 20129.5	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Right M3	4	V 20129.4	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Right M2	7	V 20129.3	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Right M1	8	V 20129.2	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left DP4	2008-11-09(5)	V 20129.1	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)
Left scaphoid	N-12-Test-05	V 20128.4	Test trench	Heitugou	Early Pleistocene	IVPP	Tong <i>et al.</i> (2014)

Tab. 1: Recently recovered fossils of *Elasmotherium peii* from Nihewan Basin.

Tab. 1 : Fossiles d'*Elasmotherium peii* récemment récoltés dans le bassin de Nihewan.

4 - SYSTEMATIC PALEONTOLOGY

4.1 - SYSTEMATICS

Mammalia Linnaeus, 1758

Perissodactyla Owen, 1848

Rhinocerotidae Owen, 1840

Subfamily Elasmotheriinae Bonaparte, 1845

Genus *Elasmotherium* Fischer von Waldheim, 1808

Elasmotherium peii Chow, 1958

1930. *Elasmotherium* sp.–Teilhard de Chardin & Piveteau, p.29-30.

1958. *Elasmotherium inexpectatum*–Chow, p.139, Pl I-B.

1958. *Elasmotherium* cf. *inexpectatum*–Chia & Wang, p. 35–37, Pls. XIV-1 and XV-1.

2002. *Elasmotherium caucasicum*–Antoine, p.43-45. Partial.

2005. *Elasmotherium caucasicum*–Deng & Zheng, p.110-121.

4.2 - COMPARATIVE DESCRIPTIONS

4.2.1 - Ulna

The distal end and the olecranon are not preserved, and the anconeal process is partially broken; the trochlear notch and most part of the shaft are preserved. It distinguishes itself from other Quaternary rhinos by a larger size. In general, the shaft is not so strongly bent

backward and the mid-shaft has a triangular cross section. The anterior surface of the proximal part is strongly flared medially, which makes the articulation facet much wider (fig. 2: 1a; tab. 2). The surface of the semi-lunar notch is bifid at the lower part, and the medial part is oblique and strongly projecting medially, while the external part runs parallel to the sagittal plane of the shaft. Between the two branches of the trochlear facet, there exists the pit-like radial notch. There is a notch at each edge of the anterior face just below the trochlear surface, while the lateral one has a higher positioned than the medial one, and both of them should be corresponding with the interosseous space of forearm (spatium interosseum antebrachii proximale). Just below the medial notch, there exists a prominent nutrient foramen. The antero-medial edge is forming a sharp ridge. Both the medial and lateral surfaces are quite smooth and without any prominent structures, except the longitudinal trench along the antero-medial ridge at the medial surface.

4.2.2 - Magnum

It resembles the magnum of other Quaternary rhinos except its larger size (fig. 2: 2a-2d; tab. 2). In anterior view, the upper and lateral margins of the front face are relatively straight, while the inferior margin is roundish. The whole surface is convex and with some nutrient foramina. In dorsal view, three facets can be observed, scaphoid and unciform facets in the front, and the lunar

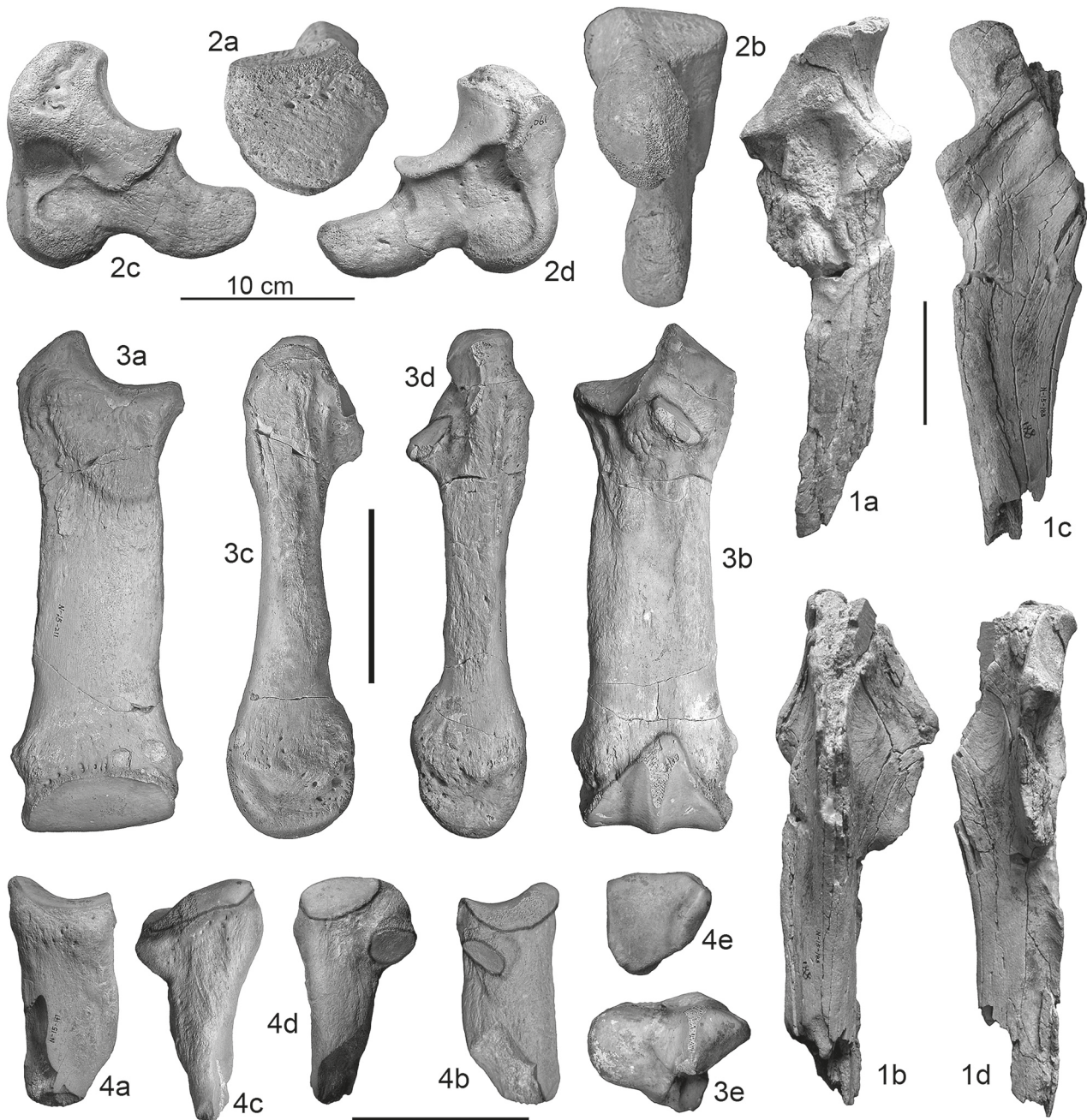


Fig. 2: Forelimb bones of *E. peii* from Shanshenmiaozui

1/ Left ulna (V23590.1); 2/ left magnum (V23590.4); 3/ right Mc III (V23590.2); 4/ right Mc IV (V23590.3). 1a, 2a, 3a and 4a, anterior views; 1c, 2d and 4c, lateral views; 1b, 2b, 3b and 4b, posterior views; 1d, 2c, 3c and 4d, medial views; 3e and 4e, proximal views.

Fig. 2 : Ossements des membres antérieurs d'*E. peii* de Shanshenmiaozui. 1/ Cubitus gauche (V23590.1) ; 2/ magnum gauche (V23590.4) ; 3/ Mc III droite (V23590.2) ; 4/ Mc IV droite (V23590.3). 1a, 2a, 3a and 4a, vue antérieure ; 1c, 2d and 4c, vues latérales ; 1b, 2b, 3b and 4b, vue postérieure ; 1d, 2c, 3a and 4d, vue médiale ; 3e and 4e, proximales vues.

facet is located higher and more backward, after which is the elongated posterior tubercle (or volar process), and it is quite straight rather than bended as in other Quaternary rhino taxa. In lateral view, the unciform and the Mc III as well as the lunar facets can be observed; the unciform facet is slope-like, while the Mc III is deeply concave and the lunar facet is convex and roundish; the volar process is beak-like and its inferior border is deeply concave. In medial view, the trapezoideum facet can be observed, which is continuous with the Mc III facet; the concavity of the Mc III facet is much shallower than those of the primitive elasmothere taxa (Antoine, 2002: p.200-201).

In ventral view, only the concave Mc III facet and the volar process can be observed, the antero-medial corner of the facet is roundish rather than rectangular as in *E. sibiricum*. Between the facets, the surface is rough and with some nutrient foraminae. It differs from that of *E. sibiricum* in the invisibility of the Mc III facet in lateral view, and the more deeply concave Mc III facet and the inferior notch of the volar process.

4.2.3 - Metacarpal III

It is somewhat larger than those of other Quaternary rhinos and is also slightly different in morphology (fig. 2:

Dimensions		<i>E. peii</i>		<i>E. caucasicum</i>		<i>E. sibiricum</i>	<i>E. chaprovicum</i>	<i>Elasmotherium</i> sp.	<i>C. antiquitatis</i>
		This paper	Tong <i>et al.</i> (2014)	Deng & Zheng (2005)	Shvyreva (2016)	Shvyreva (2016)	Shvyreva (2016)	Guérin (1980)	Guérin (1980)
Ulna	L	>400	-	-	-	633 [§]	-	-	456-543 (494.45) [◇]
	DT olecr	-	-	-	-	-	-	-	57-102 (84.23)
	DAP olecr	-	-	-	-	-	-	-	90-120 (106.41)
	DT artic prox	>131.18	-	-	-	153 [§]	-	-	75-109 (92.45)
	DAP prox	-	-	-	-	-	-	-	121-195 (159.13)
	DT dia	60,3	-	65,7	-	-	-	-	44-68 (55.44)
	DAP dia	59,58	-	-	-	-	-	-	41.5-60 (51.83)
	DT dist	-	-	84,5	-	-	-	-	41-67 (53.78)
DAP dist	-	-	-	-	-	-	-	60-92 (76.2)	
Magnum	L (DAP)	131,54	86,2	-	-	105.9-128.5	-	-	79-113 (100.36)
	H anterior face	56.89-59.29	74,7	-	-	40.6-60.7	-	-	39-58 (50.93)
	W anterior face	63.24-64.96	66,6	-	-	58.1-75.2	-	-	-
Mc III	L	257	-	260-290.5	289	272.5-287.4 (277.59) [◇]	-	278,5	162-213 (189.03)
	DT artic prox	82,07	-	-	-	-	-	-	-
	DT prox	83,7	-	86-95.3	ca 90	88.6-100.00 -94,1	-	92,5	59.5-79 (68.24)
	DAP prox	66,22	-	63.4-75.4	-	67.00-74.5 -70,95	-	66	42.5-61.5 (52.2)
	DT dia	62,43	-	69.4-76	-	57.00-74.6 -68,55	-	70	46-66 (56.44)
	DAP dia	29,19	-	-	-	29.1-35.4 -32,48	-	-	23-36.5 (28.71)
	DT dist	85,76	-	105,7	99	90.00-99.8 -92,3	-	95	57.5-74 (65.75)
	DT artic.dist	73,39	-	77-87.2	-	61.7-88.00 -80,68	-	-	49-65 (56.1)
DAP dist	62,39	-	64-70.5	-	53.00-72.4 -66,93	-	-	44-57.5 (50.78)	
Mc IV	L	-	-	-	244	227.0-234.2	-	226	126.5-176.5 (151.13)
	DT prox	56,74	-	66.1-69.5	-	61.0-70.0	59,5	68,5	41-62.5 (53.33)
	DAP prox	58,46	-	72-78	74	61.8-67.7	59	66	39-52 (44.96)
	DT dia	>47.87	-	-	62,5	55.6-60.7	52	-	32-46 (37.58)
Tibia	L	>537	-	-	-	465 [§] -578 [§]	-	508-558	323.5-433 (381.12) [◇]
	DT prox	-	-	-	-	170 [#]	-	170-172	111-163 (133.44)
	DAP prox	-	-	-	-	-	-	178	87-157.5 (136.81)
	DT dia	82,3	-	-	-	80 [#]	-	-	59-82.5 (70.07)
	DAP dia	73,5	-	-	-	-	-	-	51-77 (63.23)
	DT dist	132	-	-	-	-	-	136-141	92-127 (106.76)
	DAP dist	108	-	-	-	-	-	105-111.5	70-98 (82.27)
Astragalus	DT max	125	-	122-134	123.6-160.2 -140,6	123.7-137.5 -132,7	122	123-130	84-112 (95.72)
	H	107	-	101-113	104.6-143.7 -126,22	110-115.6 -113,76	108	102-115	77-102 (86.96)
	DT artic.dist	102	-	101-112.2	-	-	-	-	68-91 (80.93)
	DAP artic dist	61	-	66.2-68.5	-	-	-	-	42-79 (51.30)
	DT dist	105,5	-	107.6-109	113.4-142.4 -125,06	110.0-122.5 -117,9	115	-	75-97 (85.11)
Cuboid	L	96,26	91.0 [□]	98.2-98.3	-	102.1-102.7	-	-	58.5-79 (70.99)
	W	59,3	57.0 [□]	56-62	-	64.0-64.1	-	-	42.5-57 (48.75)
	H max	69,5	-	68-77.8	-	-	-	-	46.5-67.5 (60.26)
	DT artic prox	51,96	-	59-60.5	-	-	-	-	38-53 (47.44)
	DAP artic prox	71,47	-	69.5-74	-	-	-	-	42-58 (50.85)
	H face ant	58,19	55.5 [□]	58.4-63.4	-	57.9-58.2	-	-	35-50 (43.99)
Mt IV	L	-	-	-	-	225.8-226.5	-	-	127-155 (144.85)
	DT prox	66,54	54,22	-	-	72.2-73.4	-	-	41-57 (46.45)
	DAP prox	65,27	53,96	-	-	77.0-78.0	-	-	37-51.5 (44.29)
	DT dia	<52.29	-	-	-	50.0-50.8	-	-	24-40 (30.56)
3 rd phalangx of 3 rd toe of the pes	H	49,45	-	-	-	45.9-49.0	-	-	-
	DT prox	>98.77	-	-	-	87.8-88.1	-	-	-
	DAP prox	39,5	-	-	-	-	-	-	-
	DT artic prox	>97	-	-	-	-	-	-	-
	DT dist	>103.39	-	-	-	125.0-135.0	-	-	-

Gaudry & Boule (1888); ◇ mean; □ Shvyreva (2016); § measured by the author from Pl. XII of Shvyreva (2016)

Tab. 2: Measurements of postcranials of *Elasmotherium peii*, compared with related taxa (in mm).

Tab.2 : Mesures postcraniales d'*Elasmotherium peii*, comparées à des taxons proches (en mm).

3a-3e; tab. 2). It is broad, flat and straight, and with expanded extremities. There are five facets at the proximal end: the medial banded facet is tiny and in contact with Mc II, the biggest facet contacts magnum, the lateral top facet contacts with unciform, the lateral and posterior facets articulate with Mc IV. In dorsal view, the magnum facet is deeply concave and the unciform (uncinate) facet prominently elevated; the distal articular surface is lower than that of *E. sibiricum*. In posterior view, the outline of the distal articular surface is pointed rather than roundish as in *E. sibiricum*. The specialties of the Mc III of *E. peii* lie at the antero-posteriorly expanded distal end and the much lower situated Mc IV lateral facet as well as the upward tapering of the postero-distal trochlea.

4.2.4 - Metacarpal IV

It is obviously smaller than Mc III; the body is obviously bent, with a pronounced notch on the lateral side (fig. 2: 4a-4e; tab. 2). There are four facets at the proximal end: the biggest one is in contact with unciform, the two medial facets articulate with Mc III, but the lateral facet is in contact with the vestigial Mc V. This Mc IV specimen matches well with the Mc III specimen described above, and it is likely that they belong to the same individual. The broken shaft shows that there is no medullary cavity in Mc IV. The lateral Mc V facet is quite large, which means the Mc V is quite big, compare to the rudimentary ones in the extant rhino species and in the woolly rhinos (*Coelodonta* spp.).

4.2.5 - Tibia

The nearly complete tibia only with partial proximal end (cnemial crest and the lateral condyle) broken off (fig. 3: 1a-1e; tab. 2) represents the only tibia specimen of *Elasmotherium* ever discovered in China. The tibia is obviously larger than those of other Quaternary rhinos. The shaft is not a trihedral form as in the ordinary rhinos, but with a nearly roundish cross section, and it becomes broad and antero-posteriorly compressed near the distal end.

The anterior part of the proximal end is nearly completely broken off. It seems that the cnemial crest only occurs at the upper third part, but their details are uncertain; the situation of the tuberosity groove (for patellar ligament) is not clear. In proximal view, only the articular facet of the medial condyle remains, which surface is not convex or slope-like as in the ordinary rhinos, but slightly concave as in the elephant. In posterior view of the proximal end, there exists a small isolated facet behind the medial condyle, which is facing to the popliteal notch and hanging above the popliteal fossa (as indicated by the arrow in fig. 3:1b), but its function is still uncertain. The popliteal fossa is slightly concave, the popliteal line and the muscular lines are not too prominent, and the nutrient foramen is not detected. The medial outline is not as straight as in *Coelodonta*, but slightly concave instead. At the distal end, the inferior margin is wave-like in anterior view; at the medial-posterior side, a tongue-shaped process erupts and extends downward,

but not as far as in *E. sibiricum*, and it is housed in the saddled groove of astragalus. In distal view, the outline is almost rectangular and with the posterior edge slightly shorter; the articular surface is composed of two longitudinal grooves and an intermediate ridge, all of which contact with the astragalus; the medial groove is relatively narrow and deep; the intermediate ridge is nearly anteroposteriorly oriented. In lateral view, both the proximal and the distal articular surfaces incline anteriorly; most part of the lateral face, except the upper third, has rough surface, which means the fibula once co-ossified with the tibia, and partial fibula still remains on the tibia near the distal end. In medial view, the surface is smooth and without any special structure.

4.2.6 - Astragalus

The astragalus is almost intact, which is prominently larger than those of the usual rhinocerotids (fig. 3: 2a-2c; tab. 2). In dorsal view, both of the superior and inferior borders are saddle-like, but the saddles are less pronounced as in *E. sibiricum*; the trochlea is not symmetric with the lateral ridge being much broader and slightly higher than the medial one. The medial and lateral ridges are parallel to each other, and both of them are parallel to the long axis of the limb bone; the fibular facet on the extremely lateral part is moderately developed. The neck of the astragalus is shorter than those of other Quaternary rhinocerotids and higher medially than laterally, and the medial side bears a prominent tuberosity.

In plantar view, three distinct articular surfaces can be observed: the proximal calcaneal, sustentacular, and distal calcaneal facets, and there exists a narrow groove between the former two facets, which is different from that of the *E. sibiricum*. The proximal calcaneal facet is the largest and with a transverse trench. The sustentacular facet is a small oval facet, but is not as flat as in other rhinos. Whereas the distal calcaneal facet looks like a drop of water and is confluent with the cuboid facet of the distal end. The two calcaneal facets are not so distantly separated as in other rhinocerotids. In lateral view, lateral part is strongly antero-posteriorly compressed, and the fibular facet extends along the anterior border. In distal view, two facets can be distinguished, a much larger medial one for the navicular and a narrower lateral one for the cuboid. The former is mainly transversely convex but antero-posteriorly concave at the anterior part; the lateral facet is flat to slightly convex. The two facets consist of a large irregular four-sided polygonal continuous surface, and the anterior edge of which is the longest and wave-like, the latero-posterior edge is the second longest and nearly straight. Concerning the astragali of *E. caucasicum*, Schvyreva (2016) proposed that they are larger and slenderer, and the distal ends are narrower than those of *E. sibiricum* and *E. chaprovicum*.

4.2.7 - Cuboid

The cuboid's dorsal face looks cubical and full of nutrient foramens (fig. 3: 3a-3e; tab. 2). The proximal

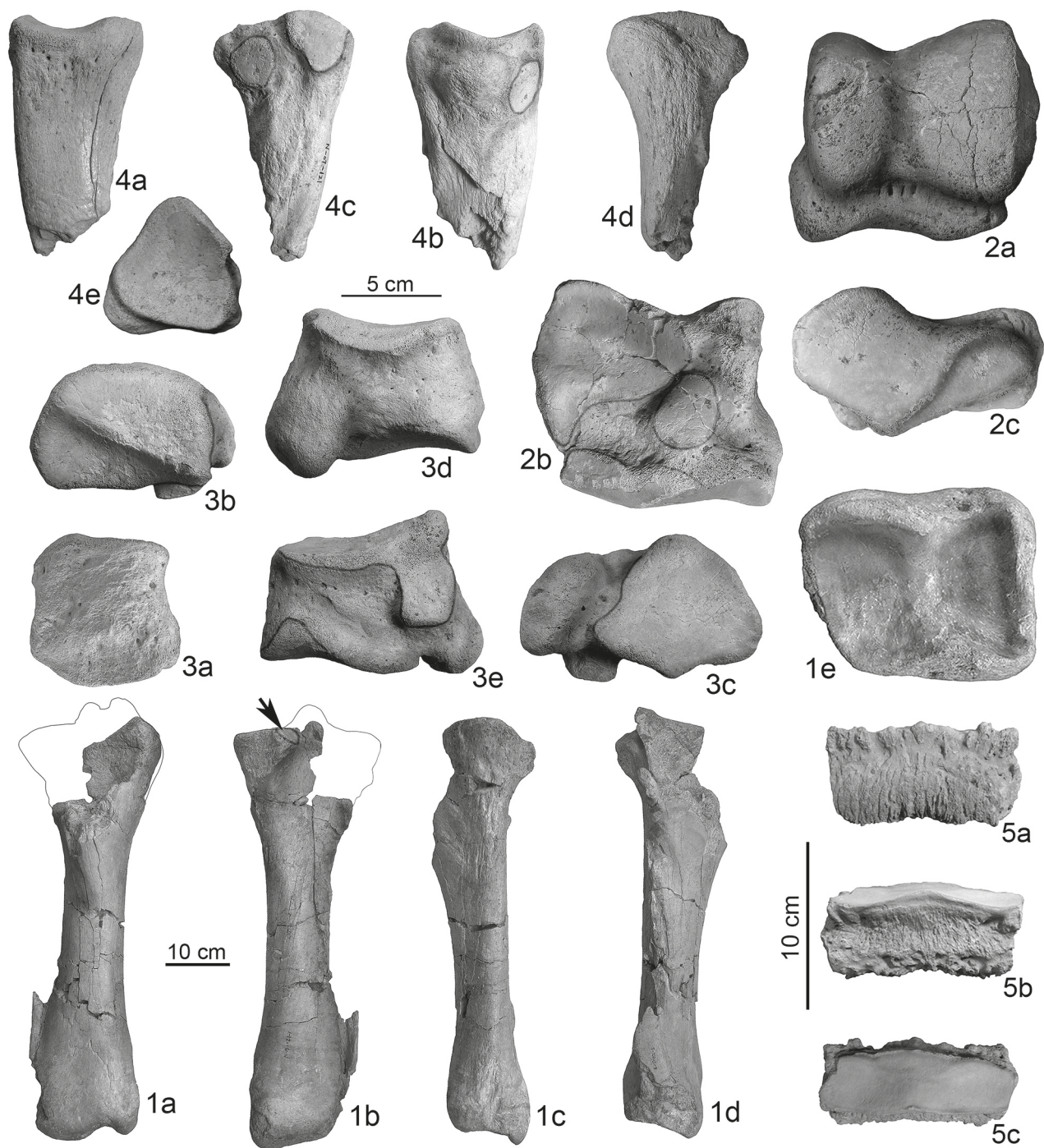


Fig. 3: Hindlimb bones of *E. peii* from Shanshenmiaozui.

1/ Right tibia with partial fibula (V23590.6); 2/ left astragalus (V23590.7); 3/ right cuboid (V23590.8); 4/ partial left Mt IV (V23590.9); 5/ the distal phalanx of toe III of the pes (V23590.11). 1a, 3a and 4a, anterior views; 1b, posterior view; 1c, 3e and 4c, medial views; 1d, 3d and 4d, lateral views; 2a, 3a and 5a, dorsal views; 2b, 4b and 5b, plantar views; 1e, 2c and 3c, distal views; 3b, 4e and 5c, proximal views.

Fig. 3 : Ossements des membres postérieurs d'*E. peii* de Shanshenmiaozui. 1/ Tibia droit avec péroné partiel (V23590.6) ; 2/ Astragale gauche (V23590.7) ; 3/ parallélépipède droit (V23590.8) ; 4/ Mt IV gauche (V23590.9) ; 5/ la troisième phalange de l'orteil III du pied (V23590.11). 1a, 3a et 4a, vue antérieure ; 1b, vue postérieure ; 1c, 3e et 4c, vue médiale ; 1d, 3d et 4d, vues latérales ; 2a, 3a et 5a, vue dorsale ; 2b, 4b et 5b, vues plantaires ; 1e, 2c et 3c, vues distales ; 3b, 4e et 5c, vues proximales.

facet is slightly transversely concave and composed of two facets : the lateral calcaneum facet and the medial astragalus facet. In medial view, the larger upper facet is in contact with the navicular, and the bottom facet which is confluent with the distal Mt IV facet is articulating with the ectocuneiform. The volar process is quite pronounced. In distal view, the only articular facet with

Mt IV and the volar process can be observed; the facet has a general triangular outline but with a bulge at the medial edge, which is different from that of *E. sibiricum*.

4.2.8 - Mt IV

The available Mt IV specimen is obviously smaller than Mt III and only with the proximal part preserved

(fig. 3: 4a-4e; tab. 2). The dorsal face is rough and with nutrient foramina at the upper part. In proximal view, the saddled facet for cuboid is antero-posteriorly concave and with a triangular outline. In medial view, there are two roundish facets for Mt III, the upper one is larger and confluent with the cuboid facet; there is a groove between the two facets. The posterior part of the proximal end is protruded prominently. The broken shaft shows that there is no medullary cavity in Mt IV.

4.2.9 - Ungual (third) phalanx of digit III

Nearly intact except but broken at two sides (fig. 3: 5a-5c; tab. 2). In proximal view, the articular facet for the 2nd phalanx is slightly convex in the middle part and concave at two sides, and the outline is a narrow rectangle, which means the anterior and posterior surface are nearly parallel. The anterior surface is very rugose, and full of grooves at the distal part and tubercles at the proximal part, between which there exists a concave belt. In posterior view, the superior edge is smooth and elevated in the middle point; the distal part is full of nutrient foramina, and the distal edge is uneven.

5 - COMPARISONS AND DISCUSSIONS

The genus *Elasmotherium* was established by Fischer von Waldheim in 1808, and the type species is *Elasmotherium sibiricum*. Borissiak (1914) erected the other species *Elasmotherium caucasicum* which is characterized by the existence of postfossette on the upper teeth and was regarded as more primitive (Noskova, 2001); but other scholars thought that postfossette will definitely appear in the early stage of abrasion of the tooth and the latter is a synonym of the former (Teryaev, 1948). Investigation of new material from an Early Pleistocene Tamanian mammal assemblage at Sinaya Balka, near the Black Sea, shows that *E. caucasicum* differs from *E. sibiricum* by its relatively elongated teeth-row and P4, bigger teeth, and an S-shaped metaconid. It is likely that *E. caucasicum* is ancestral to *E. sibiricum* as it retains some primitive dental features, notably (1) a postfossette basin on the upper teeth, (2) a less sinuous enamel layer of the external wall of ectoloph, (3) irregular fold of the enamel (the peaks of the fold have the different height) (Noskova, 2001).

The first acknowledgement of the *Elasmotherium* fossils from Nihewan Basin of Hebei Province in North China was reported by Teilhard de Chardin and Piveteau (1930). In 1958, Chow established two new species: *Elasmotherium inexpectatum* Chow, 1958 and *E. peii* Chow, 1958 based on specimens from Shanxi Province in North China. The recently recovered teeth and foot bones of *Elasmotherium* from Shanshenmiaozui and Heitugou represent the best fossil materials ever recovered in Nihewan Basin. Especially the tooth specimens represent the first discovery in Nihewan Basin. Based on the dental morphology and dimensions, the elasmothere fossils recently discovered can be referred to the species

E. peii which was regarded as a valid species name, and all the Early Pleistocene elasmothere fossils in China can be included in this species (Tong *et al.*, 2014). Therefore, the associated skeletal materials of this study also can be referred to the species *E. peii*, which can be distinguished from the Eurasian species *E. caucasicum* in quite a number of dental characters (Tong *et al.*, 2014), but the comparisons in postcranial skeletons are not available, because of the shortage of fossil materials; up to date, only the 6th cervical vertebra, scapula, humerus, radius and astragalus have been acknowledged for *E. caucasicum* (Schvyreva, 2016), and only partial ulna and radius, tibia and the extremities have been known for *E. peii*.

Compared with other Quaternary non-*Elasmotherium* rhinos, the *E. peii* from Nihewan is different not only in its larger size, but also in the following morphological features: tibia with more straight posterior edge and less developed intercondylar tongue of the distal end and a more roundish cross section of the shaft; the astragalus has a shorter neck with the proximal and the distal calcaneal facets not too widely separated; the Mc III has a much lower positioned lateral facet for Mc IV; the cuboid has a less developed volar process.

The tibia of *Elasmotherium* is the longest among all the rhinocerotids, which is only slightly shorter but stouter than that of the lesser giant rhinoceros *Juxia sharamurenensis* (Qiu & Wang, 2007) and even longer than that of some mammoth (Ziegler, 2001). Therefore, it is certain that *Elasmotherium* was the largest rhino during the late Cenozoic, whose body size is as large as a male Asian elephant (Prothero *et al.*, 1989). Shvyreva (1995) compared the length of the major segments of the limb bones of *Elasmotherium* with the counterparts of other rhinos, and the result shows that most of the elements, especially radius, tibia, astragalus and metapodials, are remarkably elongated or enlarged, but the humerus and ulna are only slightly longer than those of the other Quaternary rhinos. Among all the rhinocerotid taxa, the humeral length seems relatively stable.

Although the existence of Mc V was deduced according to the Mc IV lateral facet in the Nihewan fossils, the real fossil of Mc V was recovered for *E. sibiricum* (Schvyreva, 2016: PI-XIV). Moreover, the Mc V is also rudimentary in some taxa of the Paleogene paraceratheres (*Turpanotherium elegans*) but was pretty well developed in other Paleogene paraceratheres taxa (*Juxia sharamurenensis*) (Qiu & Wang, 2007) and the Miocene aceratherini genus *Plesiaceratherium* (Young, 1937). In the extant rhinos, all of the four genera also have the vestigial Mc V, but they are functionless (Guérin, 1980); Antoine (2002) once gave a thorough analysis on the rudimentary Mc V.

The elasmothere is a special group not only for its specialized cranial and dental morphologies, but also for its patched geographical distributions. Up to 1995, about 129 localities of *Elasmotherium* were known (Shvyreva, 1995), the majority (102) of which are *E. sibiricum* sites and five more Late Pleistocene localities were added in the recent years (Kosintsev, 2014). Shvyreva's data only

included two Chinese localities. *Elasmotherium* densely occurred in the western Siberia and the Black-Caspian Seas region, but they also sparsely appeared in western Europe (Fortelius & Heissig, 1989), Mediterranean Islands and Transbaikal region as well as northern China (Schvyreva, 2016) (fig. 1), although the presence of *Elasmotherium* in the Mediterranean Islands is highly questioned (Guérin, 1980; Antoine, 2002). One of the richest collections of *Elasmotherium* fossils is in the Vernadsky Museum, which included ca. 70 specimens (Zhegallo *et al.*, 2002).

In China, fossil records of *E. peii* are limited to Early Pleistocene as known to date and only recovered at six localities. The primitivities and the old geological settings of the Chinese *Elasmotherium* fossil suggest that it's very probable that the earliest *Elasmotherium* animal could have appeared in China.

Compared with the European and Siberian *Elasmotherium* fossils, the specimens of *E. peii* from Nihewan are different in the following aspects: thicker but less crimped enamel layer, metaconid much more developed, upper teeth more elongate, M3 smaller than M2, metastyle less developed and metaloph fused with ectoloph in M3, lophs more developed in upper teeth. In addition, the Chinese material is also different from *E. sibiricum* with relatively less hypsodont teeth, thicker enamel and prominent root. The recent biostratigraphic study shows that the *Elasmotherium*-bearing strata are exclusively of an Early Pleistocene age in China (Tong *et al.*, 2014). The differences between the Nihewan specimens and the ones from other regions lie in both dental and postcranial characters.

E. chaprovicum is characterized by relative massiveness; a low talus (astragalus) with a narrow trochlea of talus and a wide distal portion; with massive metapodial bones; teeth with thick rough enamel and irregularly folded (Titov, 2008; Schvyreva, 2015). The species was put at the root of the phylogenetic lineage of the *Elasmotherium* species and occupied a time span between 2.6-2.2 Ma.

The European fossils of *E. peii* has an early closure of the roots; the prolonged existence of an open postfossette; with presence of a collar on the back wall of the tooth, the lingual parts of the protoloph and metaloph strongly bend backward; a clear differentiation of the crown and root (Schvyreva, 2015). The fossils of *E. peii* in Europe mainly occurred in the Psekups faunistic complex in Moldova (David & Eremeico, 2003), which geological range is 2.2-1.1 Ma (Schvyreva, 2015).

The teeth of *E. caucasicum* have lost the collar and have a more pronounced prismatic shape; with later closure of the pulp cavity and with postfossette; with disorderly growth and greater tortuosity of enamel. The species *E. caucasicum* appeared in the Taman faunistic complex which geological time interval is 1.1-0.8 Ma (Schvyreva, 2015), and which overlaps with that of *E. peii* to some extent.

E. sibiricum displays a shortening of dental series by reduction of the number of premolars; the molars, despite great wear, have open roots; the enamel of the

upper and the lower teeth are thinner with strong folding; the early closure and disappearance of the postfossette is typical; all teeth have a slightly curved shape of the prism, without tooth root (Schvyreva, 2015). *E. sibiricum* appeared in the following faunistic complexes: the Tiraspol (0.8-0.4 Ma) in Moldova, the Syngil (0.4-0.3 Ma) in Ukraine and the Khazar (0.3-0.2 Ma) in the Volga-Ural regions of Russia (Schvyreva, 2015); furthermore, quite a number of Late Pleistocene records of *E. sibiricum* have also been reported in recent years (Kosintsev, 2014) and some of them even could survive as late as ca. 29 ka BP in Kozhamzhar in Central Asia (Shpansky *et al.*, 2016).

According to the comparisons on the odontometric data (Titov, 2008; Schvyreva, 2016), it seems that *E. sibiricum* is prominently odontometrically smaller than the other species of the genus *Elasmotherium*, but the later three species are not easy to be distinguished among themselves mainly because of the shortage of specimens for *E. chaprovicum* and *E. peii*.

Although the *Elasmotherium* fossils were mainly recovered in the western Siberia and the Black-Caspian Seas regions, this genus has evolved from *Sinootherium* in China during the Late Neogene (Chow, 1958; Prothero *et al.*, 1989; Deng *et al.*, 2013) or at least has the closest affinities to *Sinootherium* (Fortelius & Heissig, 1989; Antoine, 2002, 2003). Cerdeño (1998) even combined the genus *Sinootherium* into the genus *Elasmotherium*. Although the morphological evidences support the *Sinootherium*-deriving of *Elasmotherium*, the temporal and spatial hiatuses between *Sinootherium* and *Elasmotherium* are still existing (fig. 1). In China, cranial material of *Sinootherium lagrelii* was discovered in recent years, but the latest occurrence of the species was dated back to 7-6 Ma (Xue *et al.*, 2006; Deng *et al.*, 2013). In recent decades, a new species, *Sinootherium zaisanensis*, and other records of *Sinootherium* were also reported from northern Tajikistan and southern Kazakhstan respectively, and their geological ages are 7-5 Ma (Bayshashov, 1986; Sotnikova *et al.*, 1997), but they still cannot be directly linked to *Elasmotherium*.

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REFERENCES

- ANTOINE P.-O., 2002 - Phylogénie et évolution des Elasmotheriina (Mammalia, Rhinocerotidae). *Mémoires du Muséum National d'Histoire Naturelle*, **188**, 1-359.
- ANTOINE P.-O., 2003 - Middle Miocene elasmotheriine Rhinocerotidae from China and Mongolia: taxonomic revision and phylogenetic relationships. *Zoologica Scripta*, **32**, 95-118.
- BAYSHASHOV B.-U., 1986 - A new species of *Sinotherium* from the Pliocene of Kazakhstan. *Paleontological Journal*, **20**, 83-88. [in Russian]
- BORISSIAK (=BORISJAK) A., 1914 - Sur la dentition d'*Elasmotherium caucasicum* n. sp. *Bulletin de l'Académie Impériale des Sciences de St.-Pétersbourg, VI Série*, **8** (9), 555-586. [in Russian]
- CERDEÑO E., 1998 - Diversity and evolutionary trends of the Family Rhinocerotidae (Perissodactyla). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **141**, 13-34.
- CHEN X. & TONG H.-W., 2016 - On the hindfoot bones of *Mammuthus trogontherii* from Shanshenmiaozui in Nihewan Basin, China. *Quaternary International*, **445**, 50-59.
- CHIA L.-P. & WANG C., 1978 - *Hsihoutu—A Culture Site of Early Pleistocene in Shansi Province*. Cultural Relics Publishing House, Beijing, 85 p. [in Chinese with English summary]
- CHOW M.-C., 1958 - New elasmotherine rhinoceroses from Shansi. *Vertebrata Palasiatica*, **2** (2-3), 131-142. [in Chinese with English summary]
- DAVID A. & EREMEICO N., 2003 - Findings of *Elasmotherium* cf. *peii* (Chow Minchen, 1958) from sediments of Early Pleistocene (Upper Villafranchian) at Salcia (Republic of Moldova). In A. Petculescu & E. Ştiucă (eds.), *Advances in Vertebrate Paleontology*, Hen to Panta, Bucharest, 17-24.
- DENG T. & ZHENG M., 2005 - Limb Bones of *Elasmotherium* (Rhinocerotidae, Perissodactyla) from Nihewan (Hebei, China). *Vertebrata Palasiatica*, **43** (2), 110-121.
- DENG T., WANG S.-Q. & HOU S.-K., 2013 - A bizarre tandem-horned elasmotherine rhino from the Late Miocene of northwestern China and origin of the true elasmotherine. *Chinese Science Bulletin*, **58** (15), 1811-1817.
- FISCHER G., 1808 - *Programme d'Invitation à la séance publique de la Société Impériale des Naturalistes de Moscou*, 1-28.
- FORTELIUS M. & HEISSIG K., 1989 - The phylogenetic relationships of the Elasmotheriini (Rhinocerotidae, Mamm.). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie*, **29**, 227-233.
- GUÉRIN C., 1980 - Les Rhinocéros (Mammalia, Perissodactyla) du Miocène Terminal au Pléistocène Supérieur en Europe Occidentale: Comparaison avec les espèces actuelles. *Documents du Laboratoire de Géologie de Lyon*, **79** (1-3), 1-1185.
- HUANG W.-P. & JI H.-X., 1984 - A brief of Quaternary mammalian fossils of the Sammenxia District. *Vertebrata Palasiatica*, **22** (3), 230-238. [in Chinese with English summary]
- KOSINTSEV P.A., 2014 - *Elasmotherium sibiricum* Fisher (1808): new data on the period of existence and geographic range. In A.V. Borodin, E.A. Markova & T.V. Strukova (eds.), *The Quaternary of the Urals: global trends and Pan-European Quaternary records, International conference INQUA – SEQS 2014 (Ekaterinburg, Russia, September 10-16, 2014)*. UrFU, Ekaterinburg, 67-68.
- LIU P., WU Z.-J., DENG C.-L., TONG H.-W., QIN H.-F., LI S.-H., YUAN B.-Y. & ZHU R.-X., 2016 - Magnetostratigraphic dating of the Shanshenmiaozui mammalian fauna in the Nihewan Basin, North China. *Quaternary International*, **400**, 202-211.
- MAZZA P., 1988 - The Tuscan Early Pleistocene rhinoceros *Diceros rhinus etruscus*. *Palaeontographia Italica*, **75**, 1-87.
- NOSKOVA N.G., 2001 - Elasmotheriinae – evolution, distribution and ecology. In G. Cavarretta, P. Gioia & M. Mussi (eds.), *The World of Elephants*. Consiglio Nazionale delle Ricerche, Roma, 126-128.
- PROTHERO D.R., 2005 - *The evolution of North American Rhinoceroses*. Cambridge University Press, Cambridge, 218 p.
- PROTHERO D.R., GUÉRIN C. & MANNING E., 1989 - The history of Rhinocerotidae. In D.R. Prothero & R.M. Schoch (eds.), *The evolution of Perissodactyls*. Oxford University Press, New York, 322-340.
- QIU Z.-X. & WANG B.-Y., 2007 - *Paraceratheres fossils of China*. *Palaeontologia Sinica New Series C*, **29**, 1-396. [in Chinese with English summary]
- SHVYREVA A.K., 1995 - History of the rhinoceros *Elasmotherium*. G. N. Prozriteleva & G.-K. Prave, Stavropol, 1-106. [in Russian]
- SCHVYREVA A.K., 2015 - On the importance of the representatives of the genus *Elasmotherium* (Rhinocerotidae, Mammalia) in the biochronology of the Pleistocene of Eastern Europe. *Quaternary International*, **379**, 128-134.
- SCHVYREVA A.K., 2016 - *The Elasmotheriinae of Pleistocene Eurasia*. Pechatniy Dvor Publishes, Stavropol, 1-218. [in Russian]
- SHPANSKY A.V., ALIYASSOVA V.N. & ILYINA S.A., 2016 - The Quaternary Mammals from Kozhamzhar Locality (Pavlodar Region, Kazakhstan). *American Journal of Applied Sciences*, **13** (2), 189-199.
- SOTNIKOVA M.V., DODONOV A.E. & PEN'KOV A.V., 1997 - Upper Cenozoic bio-magnetic stratigraphy of Central Asian mammalian localities. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **133** (3-4), 243-258.
- TEILHARD C.P. & PIVETEAU J., 1930 - Les mammifères fossiles de Nihewan (Chine). *Annales de Paléontologie*, **19**, 1-134.
- TEILHARD DE CHARDIN P. & LEROY P., 1942 - *Chinese fossil mammals*. Institut de Géo-Biologie, Pékin, **8**, 1-142.
- TERYAEV V.A., 1948 - Geological position of the forehead-crested rhinoceros (*Elasmotherium*). *Sovetskaya Geologiya*, **34**, 81-89. [in Russian]
- TITOV V.V., 2008 - *Late Pliocene large mammals from Northeastern Sea of Azov Region*. SSC RAS Publishing, Rostov-on-Don, 259 p. [in Russian]
- TONG H.-W., 2012 - New remains of *Mammuthus trogontherii* from the Early Pleistocene Nihewan beds at Shanshenmiaozui, Hebei. *Quaternary International*, **255**, 217-230.
- TONG H.-W., HU N. & HAN F., 2011 - A preliminary report on the excavations at the Early Pleistocene fossil site of Shanshenmiaozui in Nihewan Basin, Hebei, China. *Quaternary Sciences*, **31**, 643-653. [in Chinese with English summary]
- TONG H.-W., HU N. & WANG X.-M., 2012 - New remains of *Canis chihliensis* (Mammalia, Carnivora) from Shanshenmiaozui, a Lower Pleistocene Site in Yangyuan, Hebei. *Vertebrata Palasiatica*, **50** (4), 335-360.
- TONG H.-W., WANG F.-G., ZHENG M. & CHEN X., 2014 - New Fossils of *Stephanorhinus kirchbergensis* and *Elasmotherium peii* from the Nihewan Basin. *Acta Anthropologica Sinica*, **33** (3), 369-388. [in Chinese with English summary]
- TONG H.-W. & WANG X.-M., 2014 - Juvenile skulls and other post-cranial bones of *Coelodonta nihewanensis* from Shanshenmiaozui, Nihewan Basin, China. *Journal of Vertebrate Paleontology*, **34** (3), 710-724.
- TONG H.-W. & CHEN X., 2016 - On newborn calf skulls of Early Pleistocene *Mammuthus trogontherii* from Shanshenmiaozui in Nihewan Basin, China. *Quaternary International*, **406** (Part B), 57-69.
- TONG H.-W., CHEN X. & ZHANG B., 2016 - New fossils of *Bison palaeosinensis* (Artiodactyla, Mammalia) from the steppe mammoth site of Early Pleistocene in Nihewan Basin, China. *Quaternary International*, **445**, 250-268.
- XUE X.-X., ZHANG Y.-X. & YUE L.-P., 2006 - Paleoenvironments indicated by the fossil mammalian assemblages from red clay-loess sequence in the Chinese Loess Plateau since 8.0 Ma B.P. *Science in China Series D*, **49** (5), 518-530.
- YOUNG C.C., 1937 - On a Miocene mammalian fauna from Shantung. *Bulletin of the Geological Society of China*, **17**, 209-243.
- ZHEGALLO V.I., KALANDADZE N.N., SHAPOVALOV A.V., BESSUDNOVA Z.A., NOSKOVA N.G. & TESAKOVA E.M., 2002 - On the extinct rhinoceroses of genus *Elasmotherium*. *Vernadsky Museum Novitates*, **9**, 39-47. [in Russian]
- ZIEGLER R., 2001 - An extraordinary small mammoth (*Mammuthus primigenius*) from SW Germany. *Stuttgarter Beiträge zur Naturkunde. Serie B, Geologie und Paläontologie*, **300**, 1-41.
- ZHU R.-X., HOFFMAN K.A., POTTS R., DENG C.-L., PAN, Y. X., GUO B., SHI C.-D., GUO Z.-T., YUAN B.-Y., HOU Y.M. & HUANG W.-W., 2001 - Earliest presence of humans in Northeast Asia. *Nature*, **413**, 413-417.