The first description of Rhinocerotidae (Perissodactyla, Mammalia) from Xinyaozi Ravine in Shanxi, North China Postprint

Authors: DONG Wei, BAI Wei-Peng, ZHANG Li-Min

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Abstract

Abundant mammalian fossils were uncovered during the field exploration for Nihewan beds at the beginning of the 1980s along Xinyaozi Ravine at Nangaoya Township of Tianzhen County, Shanxi Province in North China and the studied taxa indicate an age of the early Early Pleistocene. Recent studies on the rhino material not yet described show that there are at least two species of rhinocerotids: Elasmotherium peii and Coelodonta nihowanensis. There might be a third taxon provisionally named as Stephanorhinus cf. S. kirchbergensis due to incompleteness of the specimens. Since its morphometric characters are between S. kirchbergensis and C. nihowanensis, it might be a variety of one of the two species although it is more similar to the former than the latter. In the same way, The rhino specimens from Xiashagou named as Rhinoceros sinensis (?) by Teilhard de Chardin and Piveteau (1930) might be a variety of S. kirchbergensis or C. nihowanensis. The rhinocerotids uncovered so far from the Early Pleistocene deposits in the generalized Nihewan Basin including two certain species and two uncertain ones. The localities yielding E. peii include Xiashagou, Shanshenmiaozhui, Daheigou and Xinyaozi; those yielding C. nihowanensis include Xiashagou, Danangou, Donggutuo, Shanshenmiaozhui and Xinyaozi. R. sinensis (?) appeared only at Xiashagou and Stephanorhinus cf. S. kirchbergensis only at Xinyaozi.

Full Text

Preamble

The First Description of Rhinocerotidae (Perissodactyla, Mammalia) from Xinyaozi Ravine in Shanxi, North China

DONG Wei[1],[2], BAI Wei-Peng[1],[2],[3], ZHANG Li-Min[1],[2],[3]

[1]Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China (dongwei@ivpp.ac.cn)
[2]CAS Center for Excellence in Life and Paleoenvironment, Beijing 100044, China
[3]University of Chinese Academy of Sciences, Beijing 100049, China

Abstract

Abundant mammalian fossils were uncovered during field exploration for Nihewan beds in the early 1980s along Xinyaozi Ravine at Nangaoya Township, Tianzhen County, Shanxi Province, North China. The studied taxa indicate an early Early Pleistocene age. Recent analysis of previously undescribed rhinocerotid material reveals at least two species: *Elasmotherium peii* and *Coelodonta nihowanensis*. A third possible taxon, provisionally identified as *Stephanorhinus* cf. *S. kirchbergensis*, is recognized based on incomplete specimens. Its morphometric characters are intermediate between *S. kirchbergensis* and *C. nihowanensis*, suggesting it may represent a variety of one of these two species, though it more closely resembles the former. Similarly, rhino specimens from Xiashagou identified as *Rhinoceros sinensis* (?) by Teilhard de Chardin and Piveteau (1930) may represent a variety of either *S. kirchbergensis* or *C. nihowanensis*.

Thus far, the Early Pleistocene rhinocerotids from the generalized Nihewan Basin comprise two confirmed species and two uncertain ones. *Elasmotherium peii* occurs at Xiashagou, Shanshenmiaozhui, Daheigou, and Xinyaozi; *Coelodonta nihowanensis* occurs at Xiashagou, Danangou, Donggutuo, Shanshenmiaozhui, and Xinyaozi. *Rhinoceros sinensis* (?) appears only at Xiashagou, while *Stephanorhinus* cf. *S. kirchbergensis* appears only at Xinyaozi.

Keywords: Xinyaozi Ravine, Tianzhen, Nihewan Basin, Early Pleistocene, Nihewan beds, Rhinocerotidae

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1. Introduction

Field exploration for Nihewan beds extended from Yangyuan County, Hebei Province, to its western adjacent area in the early 1980s by the team of Wei Qi (1997), resulting in the discovery of numerous mammalian fossil localities along Xinyaozi Ravine at Nangaoya Township, Tianzhen County, Shanxi Province, North China. These localities are geographically very close to the Xiashagou (=Hsia-sha-kou) locality that yielded the classical Nihewan fauna (Teilhard de

Chardin and Piveteau, 1930). Systematically studied fossils from Xinyaozi include *Postschizotherium intermedium* (Qiu et al., 2002), *Hesperotherium sinense* (Qiu, 2002), *Elaphurus bifurcatus*, *E. davidianus predavidianus* (Dong et al., 2019), *Muntiacus bohlini*, *Cervavitus* cf. *C. huadeensis*, *Axis shansius*, *Nipponicervus elegans*, *Cervus (Elaphus) elaphus* (Dong et al., 2020), and *Spirocerus wongi* (Bai et al., 2019). The remaining fossil collection is still under study.

The geological age of the Xinyaozi fauna is roughly contemporaneous with the classical Nihewan fauna (Qiu, 2002), with an estimated age of approximately 2.2–1.7 Ma (Liu et al., 2012). Here we systematically describe the rhinocerotid material from Xinyaozi Ravine and discuss the taxonomy of Early Pleistocene rhinocerotids from the generalized Nihewan Basin. Dental terminology follows Guérin (1980), Deng (2004), Qiu and Wang (2007), and Tong and Wang (2014). All described specimens are housed at the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (IVPP).

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2. Systematic Paleontology

Class Mammalia Linnaeus, 1758
Order Perissodactyla Owen, 1848
Family Rhinocerotidae Owen, 1840
Subfamily Rhinocerotinae Owen, 1845
Tribe Elasmotheriini Dollo, 1885
Genus *Elasmotherium* Fischer, 1808
Species *Elasmotherium peii* Chow, 1958 (Fig. 1 [Figure 1: see original paper]; Table 1)

Synonymy:
Elasmotherium sp. Teilhard de Chardin and Piveteau, 1930, p. 19–21
Elasmotherium inexpectatum Chow, 1958, p. 138–139
Elasmotherium sp. Chow, 1958, p. 139
Elasmotherium peii Chow, 1958, p. 139–141
Elasmotherium cf. *inexpectatum* Chia and Wang, 1978, p. 35–37
Elasmotherium caucasicum Antoine, 2002, p. 43–45
Elasmotherium caucasicum Deng and Zheng, 2005, p. 110–121
Elasmotherium peii Tong et al., 2014, p. 369–388

Material: A right mandibular fragment with m2–3 (IVPP V 27428) from Siyangou at Xinyaozi Ravine.

Description: Specimen V 27428 (Fig. 1) is a right adult mandibular fragment preserving m2–3. The mandibular body is massive, deep (high) but not very thick. The portion anterior to the fracture, just below the anterior border of m2, is broken away. The lingual side of the body is slightly convex, while the buccal side is somewhat concave. The ventral margin on the buccal side forms a protrusion resembling a horizontal torus. The depth (height) from the alveolar margin to the ventral margin measures 141.18 mm on the buccal side and 153.38 mm on the lingual side at m2, and 154.46 mm and 159.92 mm respectively at m3. The mandibular ramus is partially preserved. The masseteric tuberosity is well developed and protrudes laterally (Fig. 1B–C), indicating powerful masticatory musculature. The masseteric fossa is large and moderately deep, extending to the posterior lobe of m3. The pterygoid fossa is also deep but smaller, extending only to the posterior border of m3. The coronoid process, condylar process, angular process, and mandibular angle are all missing. The specimen is heavily mineralized and resistant to X-ray CT scanning, resulting in unclear slices.

The m2 is large and hypsodont, lacking any cingulid. Exposed and total crown heights estimated from CT images are given in Table 1. The crown is worn, but the occlusal structure remains clearly visible. The anterior lobe is distinctly shorter than the posterior lobe. The paraconid, protoconid, and metaconid are well developed. The paralophid, protolophid, and metalophid are thick and interconnect to form a "U"shape. The trigonid basin (anterior valley) is moderate and opens lingually. The anterior enamel wall of the trigonid basin is smooth, while the buccal and posterior walls are folded with numerous enamel wrinkles. An enamel fold extending from the paraconid and another from the protoconid fuse within the trigonid basin to form a small vertical shaft. The buccal enamel layer of the protolophid is also vertically folded. The hypoconid and entoconid of the posterior lobe are well developed, and the hypolophid and entolophid are similarly thick, connecting to form a flipped "L" shape. The anterior crest of the hypoconid (anterior part of the hypolophid) fuses with the protoconid, linking the anterior and posterior lobes to create a continuous enamel structure in occlusal view. The talonid basin (posterior valley) is surrounded anteriorly by the metalophid, buccally by the hypolophid, and posteriorly by the entolophid. It is well developed and widely open lingually. The anterior and buccal enamel walls of the talonid basin are strongly folded, while the posterior enamel wall is only mildly undulated. The buccal enamel layer of the hypolophid is vertically folded. Both anterior and posterior valleys are filled with cement. The buccal and lingual sides of the crown are cement-covered, though the cement layer on the buccal wall of the ectoloph is broken away with only some residue preserved.

The m3 is also large but longer and narrower than m2 in occlusal view. Its morphological structure generally resembles that of m2, though the trigonid basin is larger and lacks fused enamel folds forming a shaft. The talonid basin is longer than in m2, with less folded enamel walls. The entoconid is less developed than in m2. The total crown height of m3 estimated from CT images is substantially greater than that of m2 (Table 1).

Comparison and Determination: Specimen V 27428 is clearly a large rhinocerotid. The hypsodont crown and strongly folded enamel layers in the anterior and posterior valleys (trigonid and talonid basins) identify it as *Elasmotherium*.

Compared with *Elasmotherium peii* from Shanshenmiaozhui in the Nihewan Basin (Tong et al., 2014), the Xinyaozi specimen closely matches in several features: the anterior lobe is shorter than the posterior lobe; the trigonid basin (anterior valley) of lower molars is much smaller than the talonid basin (posterior valley); enamel folds in both basins and on the buccal side are well developed; and crown dimensions are similar (Table 1).

Compared with specimens from Xihoudu (Hsihoutu) identified as *Elasmotherium* cf. *inexpectatum* by Chia and Wang (1978) and reassigned to *E. peii* by Tong et al. (2014), the comparable m2 material shows close morphological similarity and similar crown dimensions (Table 1). However, the trigonid basin is larger in the Xihoudu specimen, with less developed enamel folds. Enamel folds on the anterior wall of the talonid basin are more developed in the Xihoudu specimen than in the Xinyaozi specimen, while those on the buccal wall show the opposite pattern. These differences likely reflect varying degrees of crown abrasion with age, with the Xinyaozi specimen being younger.

Compared with *Elasmotherium* cf. *E. peii* from Salcia, Moldova (David and Eremeico, 2003), the Xinyaozi specimen is similar to counterpart specimen 52-563 from Salcia in its developed enamel folds in both anterior and posterior valleys of lower molars, the distinctly shorter anterior lobe relative to the posterior lobe, and similar dental dimensions (Table 1). However, the metaconid, paraconid, and paralophid are more developed in the Xinyaozi specimen, and the trigonid basin (anterior valley) is smaller.

Relative to other *Elasmotherium* species, the dental measurements of *E. peii* from Xinyaozi fall within the ranges of both *E. caucasicum* from Taman and *E. sibiricum* from Stavropol Krai (Table 1). The Xinyaozi specimen differs from Taman specimens (Borissiak, 1914) in its greater m3 length relative to m2, fewer enamel folds in the trigonid and talonid basins, and smaller trigonid basin in m2. It differs from *E. sibiricum* (Antoine, 2002) in having fewer enamel folds on the posterior side of the paralophid and anterior side of the entolophid in m2.

The first *Elasmotherium* from the Nihewan Basin was reported as limb bone fragments (radius, semilunar, metacarpus, and metatarsus) without dental material, limiting taxonomic determination to the generic level as *Elasmotherium* sp. (Teilhard de Chardin and Piveteau, 1930). Additional material from the same locality was later noted as "Elasmotherium sp." by Teilhard de Chardin and Leroy (1942), including a molar fragment identified as a posterior buccal fragment of a left M2 (Chow, 1958). Deng and Zheng (2005) described limb bone material from the Nihewan Basin at the Tianjin Natural History Museum and assigned it to *E. caucasicum* following Antoine (2002). Tong et al. (2014) described elasmothere material from Shanshenmiaozhui in the Nihewan Basin and assigned it to *E. peii*, a species erected by Chow (1958) for elasmothere specimens from Shanxi Province together with another new species, *E. inexpectatum.* While Chinese specimens were all regrouped into *E. caucasicum* by Antoine (2002), Tong et al. (2014) compared Chinese and Russian material and concluded that *E. peii* differs clearly from both *E. caucasicum* and *E. sibiricum*, recommending retention of its taxonomic status. Based on the present work on *E. peii* from Xinyaozi and related comparisons, we agree that *E. peii* should be maintained as a valid taxon. Elasmotheres are very large rhinos with reasonably limited taxonomic diversity constrained by their size and food requirements. While it may be true that all *Elasmotherium* species represent a single genetically valid species, in paleontology it is reasonable to classify fossil specimens according to their morphology with geographic considerations.

Tribe Dicerorhinini Loose, 1975
Genus *Stephanorhinus* Kretzoi, 1942
Species *Stephanorhinus* cf. *S. kirchbergensis* (Jäeger, 1839) (Figs. 2-6; Tables 2-4)

Material: A right juvenile maxillary fragment (IVPP V 27429.1) from Xinyaozi Ravine; a pair of broken mandibles (V 27429.2) from Taijiaping at Xinyaozi Ravine; three broken left mandibles (V 27429.3-5) from Xinyaozi Ravine.

Description: The right juvenile maxillary fragment (V 27429.1) preserves complete DP1-3 and broken DP4 (Fig. 2 [Figure 2: see original paper]), with dental measurements listed in Table 2 .

The DP1 comprises four main cusps: paracone, protocone, metacone, and hypocone. The metacone is the largest cusp, with its anterior crest fusing with the posterior crest of the paracone to form the ectoloph. The parastyle is located anteriorly on the crown, with its posterior crest fusing with the anterior crest of the paracone so that the buccal side of the crown is formed by a consecutive chain of parastyle, paracone, ectoloph, and metacone. The protocone is moderate in size and obliquely oriented in occlusal view, with its anterior crest extending buccally to fuse with the anterior crest of the parastyle, forming the protoloph. A posterior crest connects the metacone and hypocone, forming the metaloph. A medisinus separates the protocone from the hypocone. A large medifossette is encircled by the protocone, protoloph, parastyle, paracone, ectoloph, metacone, metaloph, and hypocone. The crochet is absent, so the medifossette connects directly to the medisinus. A postfossette is located posterior to the metaloph between the hypocone and metacone and is much smaller than the medifossette. The precingulum is present but very weak, while the postcingulum is present and moderate.

The DP2 is well molarized and “π” -shaped in occlusal view, composed of four main cusps and three main lophs. Both parastyle and precingulum are developed. The crista protruding from the paracone is present but weak, dividing the central depression between the protoloph and metaloph into prefossette (anterior fossette) and medifossette. The crochet extending from the anterior side of the metaconule is developed and positioned between the medifossette and medisinus, but does not reach the crista, leaving the medifossette widely open. Antecrochet and metastyle are absent. The ectoloph is much higher than the protoloph and metaloph. The postfossette and postcingulum are developed, and the entocingulum is present and moderate.

The DP3 resembles DP2 but is much larger, with relatively small prefossette and medifossette and a much larger medisinus.

The DP4 is poorly preserved. The anterior lingual portion of the crown, including the protocone, protoloph, and precingulum, was broken and incorrectly reattached in a lying position during preparation. Nevertheless, its general morphology is observable and similar to DP3 but with larger dimensions.

The enamel layers of all upper deciduous cheek teeth are generally smooth, the crowns relatively hypsodont and quite ectolophodont.

Specimens V 27429.3-5 are three left mandibular fragments with deciduous cheek dentitions (Figs. 3-4). Specimen V 27429.3 is relatively well preserved, retaining much of the mandibular body, a small portion of the mandibular ramus, and the complete deciduous dentition (Fig. 3 [Figure 3: see original paper]). The body is thick in occlusal view, deep (high) posteriorly but shallow (low) anteriorly in lateral view. The dp4 is located just behind the symphysis. Specimens V 27429.4-5 are more fragmentary, preserving dp2-4 and dp3-4 respectively (Fig. 4 [Figure 4: see original paper]). The enamel and dentine layers of the lower deciduous cheek teeth are thin, while the cavities are large (Fig. 4F). Lower deciduous dental measurements are listed in Table 3 .

The dp1 is relatively small, composed of a main cusp (protoconid) and minor cusps such as metaconid and hypoconid. The talonid basin (posterior valley) is present but weak, and the ectoflexid is absent.

The dp2 comprises five main cusps and three lophids. The protoconid and hypoconid are relatively large, the parastylid is developed, the entolophid is wider than the metalophid, and the paralophid is the shortest. The metalophid is obliquely oriented at an angle less than 45° to the mandibular body. The talonid basin is larger than the trigonid basin, and cingulid and ectoflexid are not evident.

The dp3 also comprises five main cusps and three lophids, but the paralophid and metalophid are much wider than in dp2. The parastylid is well developed. The metalophid is obliquely oriented at an angle greater than 45° to the mandibular body. The posterior lobe of dp3 is somewhat selenodont in occlusal view. The metalophid is evidently higher than the hypolophid, and the ectoflexid is developed.

The dp4 resembles dp3 but lacks a parastylid and has a larger trigonid basin than dp3.

Specimen V 27429.2 is a pair of broken mandibles with complete permanent cheek dentitions (Fig. 5 [Figure 5: see original paper]). The anterior part of the symphysis is missing, with the posterior end located below p3. The lower portion of the mandibular body is poorly preserved, and most of the mandibular ramus is lost. The preserved portions indicate a robust mandibular body that curves slightly downward in lateral view and slightly medially in occlusal view. Lower cheek tooth measurements are listed in Table 4 .

The lower cheek teeth are heavily worn. The p2 comprises two lobes, with the posterior lobe larger than the anterior lobe and the anterior part of the posterior lobe largely fused with the posterior part of the anterior lobe. The anterior and posterior lobes are separated by a moderately sized ectoflexid. The p2 differs from p3 and p4 in possessing a parastylid. The p3 and p4 are both molarized, formed by anterior and posterior lobes, with p4 larger than p3. The m1-3 are also composed of anterior and posterior lobes, with the talonid basin larger than the trigonid basin and the ectoflexid well developed. A weak precingulid is present on the lingual base of the paralophid in p3-m3, though most cingulids are generally absent. The enamel layer of cheek teeth is smooth, and the paraconid rib is absent in all cheek teeth. Despite heavy wear, the angle formed by the protolophid and metalophid on p4 and m3 appears close to a right angle.

Comparison and Determination: The morphology of V 27429.1 (Fig. 2) resembles *Stephanorhinus kirchbergensis* in its generally smooth enamel layers, relatively hypsodont crown, ectolophodont upper cheek teeth (buccal lophs and cusps markedly higher than lingual ones), and absence of antecrochet and metastyle from upper cheek teeth. It is very similar to juvenile maxillary fragments Nos. 246 and 256 from Rhino Cave in Shennongjia (Tong and Wu, 2010). However, the dimensions of V 27429.1 are smaller than those from Rhino Cave, slightly smaller than those from Huludong and Zhoukoudian Localities 1 & 13, and close to the lower range limit of West European specimens (Table 2).

Compared with *S. kirchbergensis* from other localities, the morphology and dental dimensions of V 27429.3-5 (Figs. 3-4) are close to those from Zhoukoudian Locality 13 and Rhino Cave in Shennongjia, sharing features such as smooth enamel surfaces, well-developed parastylid, and absence of paraconid rib on dp2 and dp3. Their dental dimensions are also close to West European specimens (Table 3).

The morphology of V 27429.2 (Fig. 5) is similar to VM.670 from Zhoukoudian Locality 1 (Chow, 1979), TNP00315 from Daheigou and SGT2:1 from Shigou in the Nihewan Basin (Tong et al., 2014), and two mandible specimens from Rhino Cave in Shennongjia (Tong and Wu, 2010). However, the dental dimensions of V 27429.2 are generally smaller than those from other localities such as Anping (Zhang et al., 1980; Xu, 1986) and West Europe (Guérin, 1980) (Table 4).

Figure 6 [Figure 6: see original paper] illustrates that the Xinyaozi specimen is closer to *Coelodonta* than to *S. kirchbergensis*, but the smooth enamel surface in both upper and lower dentitions and absence of paraconid rib in lower cheek teeth distinguish it from *Coelodonta*.

Compared with "Rhinoceros sinensis (?)" from Xiashagou (Teilhard de Chardin and Piveteau, 1930), the upper deciduous dentitions from both Xinyaozi and Xiashagou share characters such as smooth buccal enamel, convex ectoloph, and developed crochet, though the crista is more developed and dimensions slightly larger in Xiashagou specimens (Table 2).

Overall, these comparisons indicate that the upper and lower deciduous dentitions are morphologically and metrically close to *S. kirchbergensis* from related localities, while the adult lower cheek teeth are morphologically similar to *S.*

kirchbergensis from related localities but metrically smaller. Although *S. kirchbergensis* is considered primarily a Middle Pleistocene species with some survivors to the Last Glaciation (Guérin, 1980; Fortelius et al., 1993), its discovery at Shigou in the Nihewan Basin extended its earliest appearance to the late Early Pleistocene (Tong et al., 2014). The Xinyaozi deposits are dated as contemporaneous with the Xiashagou fauna, i.e., early Early Pleistocene (Qiu, 2002; Qiu et al., 2002), making the appearance of *S. kirchbergensis* at this age questionable. If the Xinyaozi specimens can be confirmed as true *S. kirchbergensis*, it would extend its earliest appearance to the early Early Pleistocene. The Xinyaozi specimens are morphologically similar but metrically smaller than typical *S. kirchbergensis*. We therefore provisionally assign them to conformis species of *S. kirchbergensis* pending discovery of more complete material, although the juvenile specimens are quite certainly attributable to *S. kirchbergensis*.

Genus *Coelodonta* Bronn, 1831
Species *Coelodonta nihowanensis* Kahlke, 1969 (Figs. 7-9; Tables 5-6)

Synonymy:
Rhinoceros cf. *tichorhinus* Teilhard de Chardin and Piveteau, 1930, p. 17-19
Coelodonta nihowanensis Kahlke, 1969, p. 701-702
Coelodonta nihowanensis Chow, 1978, p. 48
Coelodonta antiquitatis Li, 1984, p. 64-65
Coelodonta antiquitatis Wei et al., 1985, p. 227
Coelodonta antiquitatis Tang et al., 1995, p. 79
Coelodonta nihowanensis Qiu et al., 2004, p. 119-125; p. 186-187
Coelodonta nihowanensis Tong and Wang, 2014, p. 710-724

Material: A maxillary fragment (IVPP V 27430.1) with left and right deciduous cheek teeth from Taijiaping at Xinyaozi Ravine; an isolated right dp3 (V 27430.2) and an isolated right dp4 (V 27430.3) from Xinyaozi Ravine.

Description: The maxillary fragment (V 27430.1) preserves left DP1-4 and right DP1-3 (Fig. 7 [Figure 7: see original paper]; Table 5). The palate is flat, with a width of 29.2 mm between the lingual edges of DP1s and 30.9 mm between those of DP3s.

The DP1 is roughly triangular in occlusal view, composed of four main cusps with the protocone the smallest. The protocone is developed, with its postprotocrista extending posteriorly and tending to close the medisinus. The parastyle is well developed and fuses with the paracone and metacone to form the ectoloph. The paracrista from the paracone extends lingually, dividing the trigon basin into prefossette and medifossette. The crochet from the metaconule is developed and extends forward, nearly closing the medifossette. Antecrochet is absent. The metaloph is evidently wider than the protoloph. The postcingulum is very developed, forming the posterior wall of the postfossette.

The DP2 is well molarized, composed of four main cusps and three main lophs. The parastyle and precingulum are well developed. The crista from the paracone protrudes forward and meets the crochet from the metaconule, completely closing the medifossette. The prefossette is short but very wide and opens to the medisinus. The postfossette is developed, and the postcingulum is moderate.

The DP3 resembles DP2 but with larger dimensions.

The DP4 resembles DP3 but is larger, with a relatively low crista.

The lower dentition is represented only by dp3 and dp4, with measurements listed in Table 6 .

The dp3 (V 27430.2) comprises anterior and posterior lobes. The parastylid is not evident, and the paraconid rib is absent or very weak. The protoconid rib is present and moderate. The protolophid is concave in buccal view. The trigonid and talonid basins are well developed and widely open, and the ectoflexid is well developed. The angle between the protolophid and metalophid is clearly obtuse, as is that between the hypolophid and entolophid. The dp4 (V 27430.3) is morphologically similar to dp3 (Fig. 8 [Figure 8: see original paper]) but with much larger dimensions (Table 6).

Comparison and Determination: Specimen V 27430.1 with DP1–4 is characterized by undulating ectoloph, closed medifossette, well-developed crochet, crista, paracone rib, metacone rib, parastyle, and metastyle. The lower deciduous cheek teeth V 27430.2–3 are distinguished by the presence of protoconid rib and undulation of the protolophid and hypolophid. These traits differentiate them from *S. kirchbergensis* and match those from Shanshenmiaozhui, conforming to the diagnosis of *Coelodonta* revised by Qiu et al. (2004). V 27430.1 closely resembles the specimen reassigned to *C. nihowanensis* by Tong and Wang (2014) and that figured in Plate II, fig. 3 of Teilhard de Chardin and Piveteau (1930), sharing features such as undulating buccal enamel of the ectoloph, closed medifossette, and absence of antecrochet. Its dental dimensions are close to those of *C. nihowanensis* from Xiashagou (Teilhard de Chardin and Piveteau, 1930), Shanshenmiaozhui (Tong and Wang, 2014), and Longdan (Qiu et al., 2004), but slightly differ from those of *C. antiquitatis* from Dingcun (Pei, 1958) and West Europe (Guérin, 1980), and somewhat differ from those of *S. kirchbergensis* from Xinyaozi and Zhoukoudian Localities 1 and 13 (Table 5; Fig. 9 [Figure 9: see original paper]).

Both upper and lower dental dimensions of the Xinyaozi specimens (Tables 5–6) are larger than those of *C. tologoijensis* from Transbaikalia (Beliajeva, 1966). A logarithmic comparison of upper deciduous cheek tooth dimensions (Fig. 9) shows that V 27430.1 is closest to *C. nihowanensis* from Longdan, then Xiashagou, then Shanshenmiaozhui. Those of *C. antiquitatis* from Dingcun and *S. kirchbergensis* from Xinyaozi (V 27429.1) are also similar, while those of *C. antiquitatis* from West Europe are slightly smaller and those of *S. kirchbergensis* from Zhoukoudian Localities 1 and 13 are slightly larger.

3. Discussion and Conclusion

Xinyaozi Ravine is located in the western part of the generalized Nihewan Basin (sensu lato), adjacent to the west side of the classical Nihewan Basin (sensu stricto). The Xinyaozi deposits yielding mammalian fossils correlate with those of Xiashagou described by Teilhard de Chardin and Piveteau (1930), i.e., Early Pleistocene (Qiu et al., 2002; Qiu, 2002). The first description of rhinos from the basin was published by Teilhard de Chardin and Piveteau (1930) based on fossils collected in the 1920s. Rhino remains from Xiashagou and surrounding areas were abundant but consisted mostly of limb bones with some fragmentary dentition and no complete cranial material, making taxonomic determination difficult. Teilhard de Chardin and Piveteau (1930) assigned rhino specimens to three taxa: *Rhinoceros sinensis* (?), *Rhinoceros* cf. *tichorhinus*, and *Elasmotherium* sp. The presence of *Elasmotherium* in the Nihewan Basin was subsequently confirmed by Deng and Zheng (2005) and Tong et al. (2014), with the rhino now precisely assigned to *Elasmotherium peii* (Tong et al., 2014). The elasmothere specimens are so characteristic—massive mandible and dentitions, strongly folded enamel layers, etc.—that they can be clearly distinguished from other rhinos, further confirming their presence in the Early Pleistocene deposits of the basin. Elasmothere taxa are not numerous in China, mostly ranging from the Late Miocene to Early Pleistocene and distributed in northwestern and northern China (Teilhard de Chardin and Piveteau, 1930; Deng, 2003, 2005, 2008; Deng and Zheng, 2005; Deng et al., 2013; Tong et al., 2014).

The "Rhinoceros cf. tichorhinus" from the basin was reassigned to *Coelodonta nihowanensis*, named by Kahlke (1969) and Chow (1978) independently as a new Early Pleistocene species of *Coelodonta*, together with specimens from Gonghe, Lingyi, and Zhoukoudian. The Gonghe specimens were later excluded from *C. nihowanensis* by Zheng et al. (1985), an approach accepted by subsequent authors (e.g., Qiu et al., 2004; Tong and Wang, 2014). Additionally, specimens from Danangou (Li, 1984) and Donggutuo (Wei et al., 1985) were reassigned from *Coelodonta antiquitatis* to *C. nihowanensis* by Tong and Wang (2014). The Xinyaozi specimens can clearly be included in *C. nihowanensis*, adding a new locality for this species in the basin besides Xiashagou, Danangou, Donggutuo, and Shanshenmiaozhui.

The famous woolly rhino (*Coelodonta*), widespread across northern Eurasia in the Late Pleistocene (Boule et al., 1928; Qi, 1975; Jiang, 1977; Tang et al., 1983; Prothero et al., 1986; Pei, 2001; Kahlke and Lacombat, 2008; Tong et al., 2011; Hou et al., 2013; Zhang et al., 2016), had an Early Pleistocene ancestor with a large population in the generalized Nihewan Basin. Its earlier ancestry can be traced back to the Middle Pliocene (Deng, 2002; Deng et al., 2011).

The *Rhinoceros sinensis* (?) specimens described by Teilhard de Chardin and Piveteau (1930) are problematic. They assigned maxillary fragments with deciduous or permanent cheek teeth and some fragmentary lower cheek teeth from Xiashagou to "R. sinensis (?)," but labeled them "R. cf. sinensis" in figure and plate captions. They noted that Xiashagou specimens differed from *R. sinensis* from Sichuan, central China (Colbert and Hooijer, 1953), in having smooth enamel on the ectoloph of premolars and a different P2 pattern. They also considered Xiashagou specimens distinct from *Rhinoceros etruscus* (*Stephanorhinus etruscus*) and *Rhinoceros mercki* (*S. kirchbergensis*), though differences from *S. kirchbergensis* were slight. *R. sinensis* was not clearly defined when named and long served as a "waste basket" taxon for most Pleistocene rhino specimens from southern China (Tong and Moigne, 2000; Yan et al., 2014), explaining why Teilhard de Chardin and Piveteau (1930) included Xiashagou specimens in this taxon with a question mark.

Yan et al. (2014) redefined the diagnosis of *R. sinensis*. Xiashagou specimens conform to this diagnosis in some characters—well-developed crochet, absence of crista and antecrochet in adults, moderately developed postfossette—but lack distinct protocone constriction on upper molars and do not show protoloph extension to the median valley as in typical *R. sinensis*. Conversely, Xiashagou specimens share some characters with *S. kirchbergensis*: highly molarized premolars, absence of antecrochet and metastyle, smooth enamel surface, and ectolophodont upper cheek teeth. They likely represent a variety of *S. kirchbergensis*. *R. sinensis* ranges from the Middle Pleistocene (Colbert and Hooijer, 1953; Tong and Moigne, 2000; Tong, 2002; Yan et al., 2014) and is distributed mainly in central and southern China. If its presence in the Nihewan Basin can be further confirmed, it would represent the earliest and northernmost record of the species.

Although the *Stephanorhinus* cf. *S. kirchbergensis* specimens from Xinyaozi are morphometrically somewhat similar to *Coelodonta nihowanensis* and Xiashagou "R. sinensis (?)," they are most similar to *S. kirchbergensis* as discussed above. Due to specimen incompleteness, available morphometric information is insufficient for precise determination before more complete material is discovered.

In conclusion, at least two rhino forms are present at Xinyaozi Ravine: *Elasmotherium peii* and *Coelodonta nihowanensis*, with a probable third form tentatively assigned to *S.* cf. *S. kirchbergensis*. If its taxonomic status can be confirmed, it would represent the earliest record of *S. kirchbergensis*, though it could also be a variety of *C. nihowanensis*. Early Pleistocene rhinos in the generalized Nihewan Basin thus include two confirmed taxa (*E. peii* and *C. nihowanensis*) and two uncertain taxa (*R. sinensis* (?) and *S.* cf. *S. kirchbergensis*), which may represent varieties of *C. nihowanensis* or *S. kirchbergensis*, or both.

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References

Antoine P-O, 2002. Phylogénie et évolution des Elasmotheriina (Mammalia, Rhinocerotidae). *Mém Mus Natl Hist Nat*, 188: 1-350.

Antoine P-O, Downing K F, Crochet J-Y et al., 2010. A revision of *Aceratherium blanfordi* Lydekker, 1884 (Mammalia: Rhinocerotidae) from the Early Miocene of Pakistan: postcranials as a key. *Zool J Linn Soc*, 160: 139-194.

Bai W P, Dong W, Zhang L M et al., 2019. New material of the Early Pleistocene spiral-horned antelope *Spirocerus* (Artiodactyla, Mammalia) from North China and discussion on its evolution. *Quatern Int*, 522: 94-102.

Belayeva (Beliajeva) E I, 1966. Rhinocerotidae. In: Vangengeim E A et al. eds. *Eopleistocene Mammals of Western Transbaikalia.* Moscow: NAUKA. 92-143.

Borissiak (Borissjak) A, 1914. Sur la dentition d' *Elasmotherium caucasicum* n. sp. *Bull Acad Imp Sci St-Pétersbourg*, Sér 6, 8(9): 555-558.

Boule M, Breuil H, Licent E et al., 1928. *Le Paléolithique de la Chine.* Arch Inst Paléont Hum, Mém, 4: 1-136.

Chia L P, Wang J, 1978. *Hsihoutu—a Culture Site of Early Pleistocene in Shansi Province.* Beijing: Cultural Relics Publishing House. 1-85.

Chow B S, 1978. The distribution of the woolly rhinoceros and woolly mammoth. *Vert PalAsiat*, 16(1): 47-59.

Chow B S, 1979. The fossil rhinocerotids of locality 1, Choukoutien. *Vert PalAsiat*, 17(3): 236-258.

Chow M C, 1958. New elasmotherine rhinoceroses from Shansi. *Vert PalAsiat*, 2(2-3): 131-142.

Colbert E H, Hooijer D A, 1953. Pleistocene mammals from the limestone fissures of Szechwan, China. *Bull Am Mus Nat Hist*, 102: 1-134.

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: Petculescu A, Ştiucă E eds. *Advances in Vertebrate Paleontology* "*Hen to Panta*" . Bucuresti: Institute of Speleology, Romanian Academy & "E. Racovita" . 17-24.

Deng T, 2002. The earliest known woolly rhino discovered in the Linxia Basin, Gansu Province, China. *Geol Bull China*, 21: 489-493.

Deng T, 2003. New material of *Hispanotherium matritense* (Rhinocerotidae, Perissodactyla) from Laogou of Hezheng County (Gansu, China), with special reference to the Chinese Middle Miocene elasmotheres. *Geobios*, 36: 141-156.

Deng T, 2004. A new species of the rhinoceros *Alicornops* from the Middle Miocene of the Linxia Basin, Gansu, China. *Palaeontology*, 47(6): 1427-1439.

Deng T, 2005. New discovery of *Iranotherium morgani* (Perissodactyla, Rhinocerotidae) from the Late Miocene of the Linxia Basin in Gansu, China and its sexual dimorphism. *J Vert Paleont*, 25: 442-450.

Deng T, 2008. A new elasmothere (Perissodactyla, Rhinocerotidae) from the Late Miocene of the Linxia Basin in Gansu, China. *Geobios*, 41: 719-728.

Deng T, Zheng M, 2005. Limb bones of *Elasmotherium* (Rhinocerotidae, Perissodactyla) from Nihewan (Hebei, China). *Vert PalAsiat*, 43(2): 110-121.

Deng T, Wang X M, Fortelius M et al., 2011. Out of Tibet: Pliocene woolly rhino suggests high-plateau origin of Ice Age megaherbivores. *Science*, 333: 1285-1288.

Deng T, Wang S Q, Hou S K, 2013. A bizarre tandem-horned elasmothere rhino from the Late Miocene of northwestern China and origin of the true elasmothere. *Chinese Sci Bull*, 58(15): 1811-1817.

Dong W, Wei Q, Bai W P et al., 2019. New material of the Early Pleistocene *Elaphurus* (Artiodactyla, Mammalia) from North China and discussion on taxonomy of *Elaphurus*. *Quatern Int*, 519: 113-121.

Dong W, Bai W P, Pan Y et al., 2020. New material of Cervidae (Artiodactyla, Mammalia) from Xinyaozi Ravine in Shanxi, North China. *Vert PalAsiat*, 58(3): 221-248.

Fortelius M, Mazza P, Sala B, 1993. *Stephanorhinus* (Mammalia: Rhinocerotidae) of the western Europe Pleistocene, with a revision of *S. etruscus* (Falconer, 1868). *Palaeontogr Ital*, 80: 1-16.

Guérin C, 1980. Les rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur en Europe occidentale. *Doc Lab Géol Lyon*, 79(1-3): 1-1185.

Hou Y M, Yang S X, Dong W et al, 2013. Late Pleistocene representative sites in North China and their indication of evolutionary human behavior. *Quatern Int*, 295: 183-190.

Jiang P, 1977. A new subspecies of *Coelodonta antiquitatis*. *Vert PalAsiat*, 15(3): 207-210.

Kahlke H-D, 1969. Die Rhinocerotiden-Reste aus den Kiesen von Süßenborn bei Weimar. *Paläont Abh A*, 3: 667-709.

Kahlke R D, Lacombat F, 2008. The earliest immigration of woolly rhinoceros (*Coelodonta tologoijensis*, Rhinocerotidae, Mammalia) into Europe and its adaptive evolution in Palaearctic cold stage mammal faunas. *Quat Sci Rev*, 27: 1951-1961.

Li Y, 1984. The Early Pleistocene mammalian fossils of Danangou, Yuxian, Hebei. *Vert PalAsiat*, 22(1): 60-68.

Liu P, Deng C L, Li S H et al., 2012. Magnetostratigraphic dating of the Xiashagou Fauna and implication for sequencing the mammalian faunas in the Nihewan Basin, North China. *Palaeogeogr Palaeoclimat Palaeoecol*, 315(5): 75-85.

Pei S W, 2001. Discovery of *Coelodonta antiquitatis* from Hutouliang in Nihewan Basin. *Vert PalAsiat*, 39(1): 72-75.

Pei W C, 1958. Description of mammalian fossils. In: Pei W C ed. *Report on the Excavation of Palaeolithic Sites at Tingtsun, Hsiangfenhsien, Shansi Province, China. Mem Inst Vert Paleont Paleoanthrop, Acad Sin* (2). Beijing: Science Press. 21-74.

Prothero D R, Manning E, Hanson C B, 1986. The phylogeny of the Rhinocerotoidea (Mammalia, Perissodactyla). *Zool J Linn Soc*, 87: 341-366.

Qi G Q, 1975. Quaternary mammalian fossils from Salawusu River District, Nei Mongol. *Vert PalAsiat*, 13(4): 239-248.

Qiu Z X, 2002. *Hesperotherium* -a new genus of the last Chalicotheres. *Vert PalAsiat*, 40(4): 317-325.

Qiu Z X, Wang B Y, 2007. Paracerathere fossils of China. *Palaeont Sin New Ser C*, 29: 1-396.

Qiu Z X, Wei Q, Pei S W et al., 2002. Preliminary report on *Postschizotherium* (Mammalia: Hyarcoidea) material from Tianzhen, Shanxi, China. *Vert PalAsiat*, 40(2): 146-160.

Qiu Z X, Deng T, Wang B Y, 2004. Early Pleistocene mammalian fauna from Longdan, Dongxiang, Gansu, China. *Palaeont Sin, New Ser C*, 27: 1-198.

Shvyreva A K, 1995. *History of the rhinoceros Elasmotherium.* Stavropol: G. N. Prozriteleva & G. K. Prave. 1-104.

Tang Y J, Zong G F, Xu Q Q, 1983. Mammalian fossils and stratigraphy of Linyi, Shanxi. *Vert PalAsiat*, 21(1): 77-86.

Tang Y J, Li Y, Chen W Y, 1995. Mammalian fossils and the age of Xiaochangliang Paleolithic Site of Yangyuan, Hebei. *Vert PalAsiat*, 33(1): 74-83.

Teilhard de Chardin P, 1936. Fossil mammals from locality 9 of Choukoutien. *Palaeont Sin, Ser C*, 7(4): 1-61.

Teilhard de Chardin P, Leroy P, 1942. Chinese fossil mammals. *Inst Géo-Biol*, 8: 1-142.

Teilhard de Chardin P, Pei W C, 1941. The fossil mammals from Locality 13 of Choukoutien. *Palaeont Sin, New Ser C*, 11: 1-26.

Teilhard de Chardin P, Piveteau J, 1930. Les mammifères fossils de Nihowan (Chine). *Ann Paléont*, 19: 1-134.

Tong H W, 2002. *Dicerorhinus mercki* (Jager). In: Wu R K et al. eds. *Homo erectus from Nanjing.* Nanjing: Jiangsu Science and Technology Publishing House. 111-120.

Tong H W, Moigne A M, 2000. Quaternary rhinoceros of China. *Acta Anthrop Sin*, 19(supp): 257-263.

Tong H W, Wang X M, 2014. Juvenile skulls and other postcranial bones of *Coelodonta nihowanensis* from Shanshenmiaozui, Nihewan Basin, China. *J Vert Paleont*, 34(3): 710-724.

Tong H W, Wu X Z, 2010. *Stephanorhinus kirchbergensis* (Rhinocerotidae, Mammalia) from the Rhino Cave in Shennongjia, Hubei. *Chinese Sci Bull*, 55: 1157-1168.

Tong H W, Tang Y J, Yuan B Y, 2011. Biostratigraphy division of vertebrate fossils. In: Yuan B Y, Xia Z K, Niu P S eds. *Nihewan Rift and Ancient Human.* Beijing: Geological Publishing House. 47-60.

Tong H W, Wang F G, Zheng M et al., 2014. New fossils of *Stephanorhinus kirchbergensis* and *Elasmotherium peii* from the Nihewan Basin. *Acta Anthrop Sin*, 33(3): 369-388.

Wei Q, 1997. The framework of archaeological geology of the Nihewan Basin. In: Tong Y S, Zhang Y Y, Wu W Y et al. eds. *Evidence for Evolution–Essays in Honor of Prof. Chungchien Young on the Hundredth Anniversary of His Birth.* Beijing: China Ocean Press. 193-207.

Wei Q, Meng H, Cheng S Q, 1985. New Palaeolithic site from the Nihewan (Nihowan) beds. *Acta Anthrop Sin*, 4(3): 223-231.

Xu X F, 1986. *Dicerorhinus kirchbergensis* (Jager, 1839) from the late Middle Pleistocene mammalian fauna of Anping, Liaoning. *Vert PalAsiat*, 24(3): 229-241.

Yan Y L, Wang Y, Jin C Z et al., 2014. New remains of *Rhinoceros* (Rhinocerotidae, Perissodactyla, Mammalia) associated with *Gigantopithecus blacki* from the Early Pleistocene Yanliang Cave, Fusui, South China. *Quatern Int*, 354: 110-116.

Zhang L M, Griggo C, Dong W et al., 2016. Preliminary taphonomic analyses on the mammalian remains from Wulanmulan Paleolithic Site, Nei Mongol, China. *Quatern Int*, 400: 158-165.

Zhang Z H, Zou B K, Zhang L K, 1980. The discovery of fossil mammals at Anping, Liaoyang. *Vert PalAsiat*, 18(2): 154-157.

Zheng S H, Wu W Y, Li Y et al., 1985. Late Cenozoic mammalian faunas of Guide and Gonghe Basins, Qinghai Province. *Vert PalAsiat*, 23(1): 89-134.

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