First Discovery of *Dicerorhinus sumatrensis* from Yanjinggou Provides Insights into the Pleistocene Rhinocerotidae of South China

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Abstract: The Rhinocerotidae is one of the most common and important families in the Pleistocene mammalian fauna of South China. Since the last century, most of the Pleistocene rhinocerotid fossils were prematurely assigned to *Rhinoceros sinensis*, which has resulted in confusion of taxonomy for decades, especially in South China. The Yanjinggou area in Chongqing Municipality of China, where the neotype of *R. sinensis* came from, has yielded abundant rhinocerotid fossils and is a key area to solve this problem. A recently discovered juvenile skull from a karstic fissure in this area can be referred to *Dicerorhinus sumatrensis* (Fischer, 1814), which is the first confirmed non-*Rhinoceros* rhinocerotid from the area. This new finding indicates that non-*Rhinoceros* fossils might have been mixed in AMNH collection from Yanjinggou and thus the diagnosis of *Rhinoceros sinensis* needs reformation. On the other hand, *Stephanorhinus* ?*kirchbergensis* is also detected in Granger's collection based on our reobservation. The coexistence of *Rhinoceros*, *Dicerorhinus* and *Stephanorhinus* shows the higher diversity of Pleistocene rhinocerotids in South China.

Key words: Pleistocene, *Dicerorhinus sumatrensis*, *Rhinoceros sinensis*, Yanjinggou, South China

1 Introduction

The Yanjinggou area in Wanzhou District of Chongqing Municipality, China, encompasses a range of high-altitude NE–SW-striking karstic trough valleys on the anticline of Fangdou Mountain, represented by Pingba Valley (Chen et al., 2013). Since American paleontologist Walter Granger discovered a great number of well-preserved Quaternary mammalian fossils from this area in the 1920s, the so-called "Wanhsien fauna" or "Yenchingkou (= Yanjinggou) fauna" has been named and known as the typical Pleistocene mammalian fauna of South China (Colbert and Hooijer, 1953). Fossils from the Yanjinggou area have been firmly entrenched in the study of Asian rhinocerotids, one of the most common taxa in the Pleistocene mammalian faunas of South China and Southeast Asia. These rhinocerotid fossils were first identified as *Rhinoceros sinensis* (Matthew and Granger, 1923; Colbert and Hooijer, 1953) and used as a benchmark for comparison, but the large range in variation and lack of detailed description have caused considerable controversy for a long time (Chen et al., 2012; Yan et al., 2014). On the other hand, the Rhinocerotidae is one of the

most important groups in the Asian Pleistocene mammalian faunas. Accurate identification and study of this group is very helpful in our understanding of the natural variability and evolution of past ecosystems and climates (Asperen and Kahlke, 2015; Pan and Zhu, 2019).

Recently, a juvenile skull, referred here to *Dicerorhinus sumatrensis* (Fischer, 1814), was excavated from a karstic fissure called Dayakou in the Yanjinggou area (Fig. 1a). This specimen will provide insights into the taxonomy and supply a new clue for a holistical understanding of the Pleistocene rhinocerotids in South China.

2 Materials and Methods

The studied material was unearthed from level 2 of the Dayakou locality, and includes a juvenile cranium and its articulated mandible. The Dayakou locality is a karstic fissure infilled with breccia and clays (Fig. 1b, c). According to the lithological characters and the occurrence, the deposits can be divided into three layers (Chen et al., 2013), from bottom to top: (1) grayish-black huge breccia; (2) gray breccia, where the majority of the mammalian fossils were found; and (3) brownish-red clay. Chen et al. (2013) revised the biochronology of the mammalian faunas in the Yanjinggou area and correlated
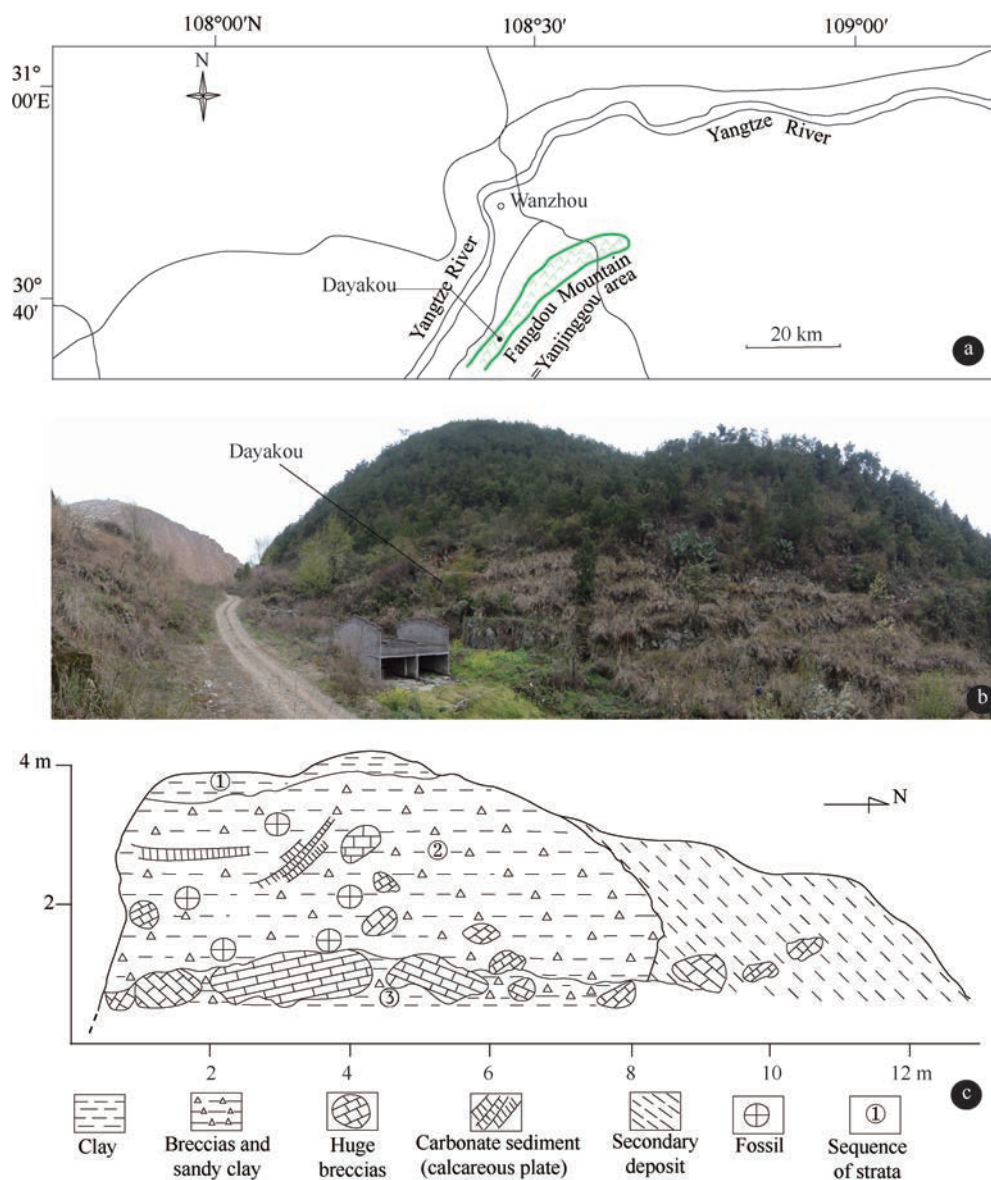
Fig. 1. Location (a), landscape (b) and stratigraphic section (c) of the Dayakou locality, Yanjinggou area, Chongqing, S. China.

the Dayakou locality to the middle Early Pleistocene; the fauna from this locality includes: *Rhizomys troglodytes*, Muridae gen. et sp. indet., *Homotherium* sp., *Panthera pardus*, Felidae gen. et sp. indet., *Stegodon orientalis*, *Hesperotherium sinense*, *Sus* sp., *Cervavitus fenqii*, *Cervus* sp., *Muntiacus* sp., and the *Dicerorhinus sumatrensis* described herein.

For morphological comparison, Pleistocene rhinocerotid fossils from South China stored in the IVPP were checked, as well as specimens from Yanjinggou stored in the AMNH. Juvenile skulls of extant *Rhinoceros unicornis* (IVPP OV 1046) and *Dicerorhinus sumatrensis* (AMNH 173576) stored in IVPP and AMNH were also observed.

Institutional abbreviations: AMNH, American Museum of Natural History, New York, USA; CPV, Three Gorges Institute of Paleoanthropology, China Three Gorges Museum, China; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, China.

The dental terminology used is modified from Guérin (1980), Deng (2004) and Qiu and Wang (2007), as shown in Fig. 2. All measurements were taken according to Guérin (1980) using manual calipers accurate to 0.1 mm and given in millimeters (Table 1 and 2).

3 Systematic Paleontology

Class Mammalia Linnaeus, 1758
  Order Perissodactyla Owen, 1848
    Family Rhinocerotidae Owen, 1840
      Genus *Dicerorhinus* Gloger, 1841

Species *Dicerorhinus sumatrensis* (Fischer, 1814)
(Figs. 3–4; Tables 1–2)

Referred material: CPV 90, a juvenile skull (cranium and the articulated mandible). The incisors were lost; the basioccipital bone and the left ascending ramus were broken.

Locality and Horizon: Dayakou fissure, Yanjinggou area, Wanzhou District, Chongqing Municipality, South China; middle Early Pleistocene.

Diagnosis (based on skull and teeth, emended from Pocock, 1945a, b; Groves and Kurt, 1974; Antoine, 2002; Tong and Guérin, 2009): smallest in the living rhinoceros; cranium dolichocephalic; nasal horn boss weak, frontal horn boss very weak or invisible; nasal notch and anterior border of orbit moved backward; postglenoid process not fused with posttympanic process; sagittal crest absent; occipital plane subvertical, occipital outline trapezoidal; orbitonasal length surpassing orbitoaural length; occipitonasal and condylonasal lengths subequal; I2 and i1 absent, I1 and i2 reduced; crown of cheek teeth lowest in the living rhinoceros; anterior hypocone constriction present.

3.1 Cranium

The cranium is dolichocephalic (Fig. 3, Table 1). According to the burial condition and preservation, it is compressed from side to side and the roof is shifted towards the left. The occipital plane is nearly vertical, though its basioccipital is lost. The roof is slender and rhombic in dorsal view, and its outline is slightly concave in lateral view.

The nasals are long and narrow, with a width of ca. 95 mm at the nasal base and a length of ca. 175 mm from the tip of the nasal to the base; they become slightly narrower from the base to the tip, with a constriction at the midpoint part. The tip of the nasals is downward, convex and rough,

indicating the presence of a nasal horn, although the horn might have been smaller than that of adult individuals. The
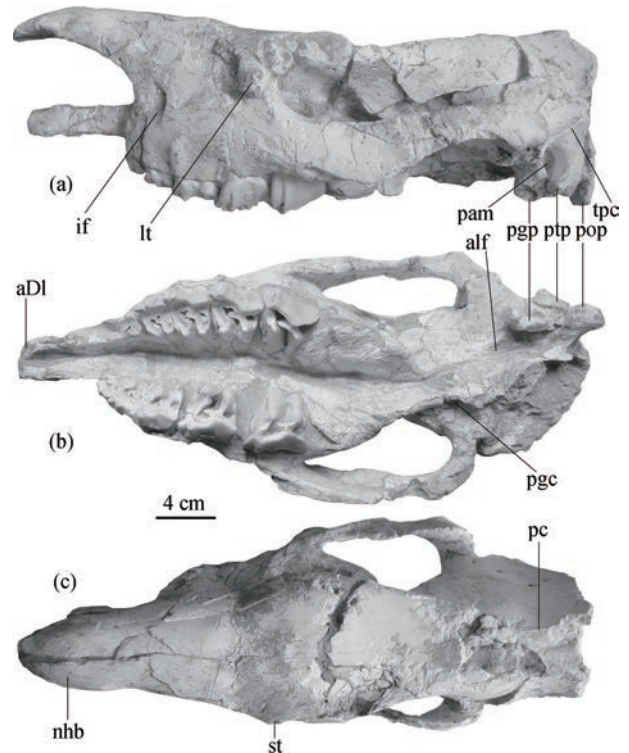

Fig. 3. Cranium of *Dicerorhinus sumatrensis* (CPV 90) from Dayakou, Yanjinggou area, Chongqing, S. China.

(a) Lateral view; (b) ventral view; (c) dorsal view. aDI, alveolus of upper deciduous incisor; alf, anterior lacerate foramen; if, infraorbital foramen; lt, lacrimal tubercle; nhb, nasal horn boss; pm, pseudoauditory meatus; pc, parietal crest; pgc, pterygoid canal; pgp, postglenoid process; pop, paroccipital process; 1ptp, posttympanic process; st, supraorbital tubercle; tpc, temporal crest.
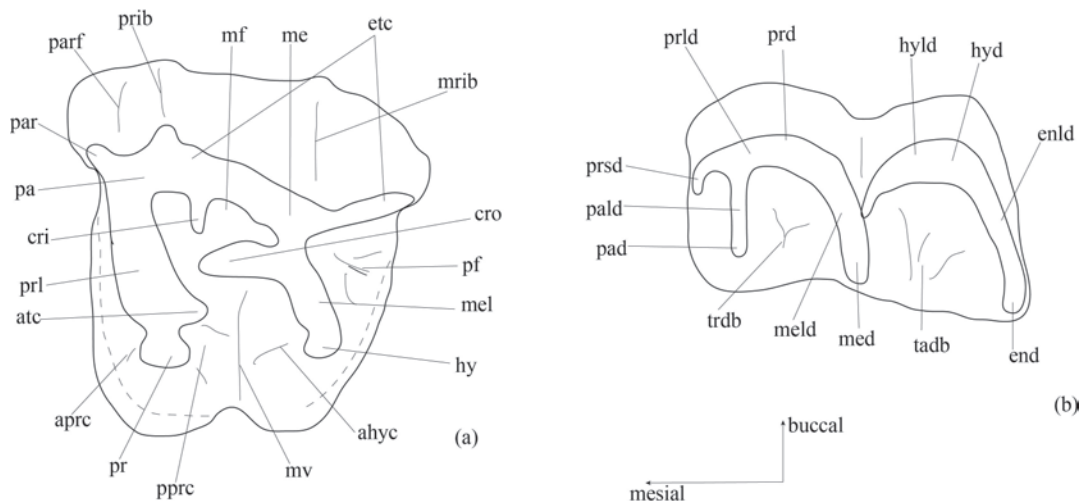

Fig. 2. Terminology of rhinoceros cheek teeth, modified from Guérin (1980), Deng (2004) and Qiu and Wang (2007).

(a) Upper cheek tooth; (b) lower cheek tooth. ahyc, anterior hypocone constriction; aprc, anterior protocone constriction; atc, antecrochet; cro, crochet; cri, crista; ect, ectoloph; efd, extoflexid; end, entoconid; enld, entolophid; hyd, hypoconid; hyld, hypolophid; hy, hypocone; me, metacone; med, metaconid; meld, metalophid; mf, medifossette; mel, metaloph; mrib, metacone rib; mv, median valley; pa, paracone; pad, paraconid; pald, paralophid; par, parastyle; parf, paracone fold; pf, posterior fossette; pprc, posterior protocone constriction; pr, protocone; prd, protoconid; prib, paracone rib; prl, protoloph; prld, protolophid; prsd, protostylid; tadb, talonid basin; trdb, trigonid basin.

central suture is not fused in dorsal view. The nasal septum is absent, and the posterior portion of the nasal is like a "roll tile". The nasal–frontal suture is at the level of the boundary of DP3/DP4.

The premaxilla is short, beginning at the one-third point of the nasal notch posteriorly. The tip of the premaxilla approaches the anteroposterior position of the tip of the nasal bone anteriorly, and the single alveolus of DI1 is preserved. The nasal notch is narrow and angularly V-shaped, and its bottom is situated at the level of anterior margin of DP1. There is a large single infraorbital foramen behind the bottom of the nasal notch, at the level of the middle of DP3. The maxilla is somewhat convex laterally, and its surface is smooth. The lacrimal is almost round at the face. The nasal–lacrimal suture is relatively wide.

Table 1 Measurements of the skull of *Dicerorhinus sumatrensis* from Dayakou

Dimensions	CPV 90
Distance between nasal tip and occipital crest	ca.480
Distance between nasal tip and bottom of nasal notch	120.2
Minimal width of braincase	95.8
Distance between occipital crest and supraorbital tubercle	ca.266
Distance between nasal notch and orbit	114.1
Distance between nasal tip and orbit	227.3
Width of occipital crest	125.9
Minimal width between parietal crests	46
Width between postorbital processes	135.2
Width between supraorbital tubercles	ca.140
Width between lacrimal tubercles	149.3
Maximal width between zygomatic arches	220.4
Height of occipital surface	ca.115
Cranial height in front of DP2	ca.140
Cranial height in front of M1	ca.141
Length of mandible	ca.390
Height of horizontal ramus in front of dp2	56
Height of horizontal ramus in front of m1	65
Length of symphysis	58.7
Antero-posterior diameter of ascending ramus	111.8
Height of jaw in condyle	170.9

The lacrimal tubercle is well developed. The supraorbital tubercle is less developed than the lacrimal tubercle. The anterior margin of the orbit is situated at the level of the boundary between DP4 and M1, slightly behind the anterior margin of the zygomatic arch. The latter is positioned low and has a very weak postorbital process. The upper margin of the zygomatic arch goes upward posteriorly, and the lower margin is curved. The posterior portion of the arch or the zygomatic process of the temporal is expanded laterally. The temporal crest is thin.

The postglenoid process is relatively weak and contacts but does not fuse with the tip of the posttympanic process to form a pseudoauditory meatus. The posttympanic process is strong and separated from the paroccipital process by a vertical furrow. The paroccipital process is wide and thin. The tympanic bulla is broken. The anterior lacerate foramen is large, and the pterygoid canal is relatively small. The pterygoid process of the sphenoid is thick but broken at the tip. The choanal is long and thin, with its anterior margin at the level of the boundary of DP4/M1.

The frontal is flat and narrows posteriorly. No frontal horn boss can be confirmed, which may be because of sexual dimorphism (Pocock, 1945a; Thein et al., 2008) or due to the young ontogenetic stage. The braincase is moderately wide and swollen. The parietal crests are broadly separated. The interparietal cannot be observed.

The occipital surface is probably trapezoid-shaped, with its basal part broader than the top. The occipital crest forms a curved top edge and turns downward and forward to fuse into the temporal crest.

3.2 Mandible

The mandible (Fig. 4) was articulated to the cranium. In top view, the mandibular symphysis constricts slightly at the middle part. Its posterior margin is located at the level of dp2/dp3 boundary. In lateral view, the symphysis is

Table 2 Measurements of the deciduous teeth of *Dicerorhinus sumatrensis* from Dayakou, and comparisons with related species

		CPV 90 Left	CPV 90 Right	*D. sumatrensis* AMNH 173576	*S. kirchbergensis* Yangtze River[a]	*R. sinensis* Longgudong Cave[b]	*R. unicornis* South Asia[c]
DP1	L	21.5	20.9	22.5–23.3	26.0–32.9	19.5–26.0	22–28
	W	16.4	16.8	20.6–21.2	23.7–28.0	19.0–22.0	23–25
DP2	L	26.6	26.9	28.2	38.0–47.3	28.8–36.0	31
	W	29.8	29	31.0	39.9–47.9	28.4–37.4	38
DP3	L	36.9	37	35.9–37.1	47.0–55.8	36.5–40.0	36–39
	W	35.1	36.6	40.0–41.3	45.3–52.0	33.3–41.4	46
DP4	L	41.5	42.5	43.7–43.9	48.0–60.0	43.3–53.2	38–45
	W	37.1	39.7	41.4–44.0	49.6–54.5	42.5–50.0	49–56
DP1–DP4	L	118.2			172.8–183.0		
dp1	L	15.4	14.7		17.1–25.9	31.0–36.8	19–21
	W	8.1	8.2		9.8–13.0	15.0–18.3	11
dp2	L		20.1	23.1–23.7	27.5–38.8	28.0–31.0	31–33
	W	12.2	12.9	13.2–13.9	15.8–20.0	15.0–15.6	18–19
dp3	L	35.6	36.9	35.0–35.4	41.1–50.8	37.3–40.0	42–46
	W	20.3		19.0–20.2	20.4–25.5	17.4–21.5	23–24
dp4	L	35.9	37.7	37.0–37.2	44.3–52.0	41.1–49.8	43–45
	W	22.3		19.9–21.5	21.7–27.6	21.0–26.0	23–25
dp1–dp4	L	ca. 118	ca. 115		182.0–201.0		

L, length; W, Width; [a], data based on Tong and Wu (2010), Chen et al. (2012), Young and Liu (1950), and Fang and Dong (2007); [b], data based on Zheng and Yang (2004); [c], data based on Colbert and Hooijer (1953).

slender and curves forward and upward. A pair of small alveoli of di2 can be observed but there is no evidence of lower canine. The horizontal ramus is shallow. The mandibular angle is rounded and smooth. There is a long distance between the ascending ramus and last cheek tooth. The ascending ramus is broad and thick. The coronoid process is very low with its tip broken and likely was curved backward. The condyloid process is quite wide transversely.

3.3 Upper cheek teeth

Only DP1–DP4 and M1 can be observed (Fig. 3, Table 2). DP1 is heavily worn and double-rooted; its outline is roughly triangular and longer than wide; the protoloph and crista are absent; the protocone connects with the hypocone in advanced wear stages on the lingual side.

The crown morphology of posterior deciduous teeth is similar. They are roughly square in outline. The ectoloph is wide and relative smooth; the protoloph and the metaloph are backwardly inclined, which makes the crown irregular π-shaped. The parastyle is well developed, and decreases successively from DP2 to DP4. The parastyle fold is weak, except on DP2. The metastyle is not developed. The paracone is slightly larger than the metacone. The paracone rib is well developed, and the metacone rib is obvious but much weaker. The protocone is constricted and connects with the hypocone at the base. The anterior and posterior protocone constrictions are both clear, while only an anterior constriction on hypocone is present. The crochet is well-developed. The crista is strong on DP2 and forms a medifossette with the crochet. The antecrochet is absent on DP2, but present on DP3 and DP4. The median valley is narrow and deep, and the posterior fossette is V-shaped and shallower. The lingual cingulum is very weak and discontinuous. The anterior and posterior cingula are moderately developed.

M1 is very similar to DP4, except for its higher crown and weaker metacone rib. This tooth is not erupted completely.

3.4 Lower cheek teeth

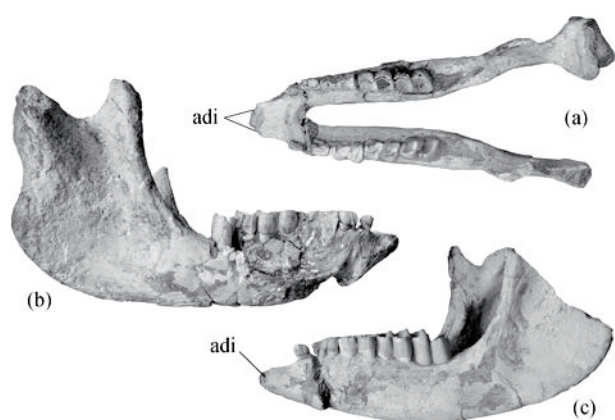Only dp1–dp4 and m1 can be observed (Fig. 4, Table 2).

Fig. 4. Mandible of *Dicerorhinus sumatrensis* (CPV 90) from Dayakou, Yanjinggou area, Chongqing, S. China.
(a) Crown view; (b) right lateral view; (c) left lateral view; adi, alveolus of lower deciduous incisor.

The dp1 is small and simply constructed; its valley is not prominent and has only one lobe. The dp2s at both sides are heavily worn and their anterior portions are broken. They appear to be U+L-shaped, and the trigonid is wider than the talonid. The metaconid elongates backward to lean against the entoconid and the entolophid, making the talonid basin very narrow. The dp3 is the longest among the lower deciduous cheek teeth. The paralophid turns backward slightly on the buccal side, and the protolophid extends parallel to the row; these two lophids form a right angle. The metalophid extends posteriolingually. The trigonid basin is narrower than the talonid basin. The ectoflexid is almost upright. No evident cingulum is present. The dp4 and m1 are similar to dp3. Their trigonids are shorter than dp3, but wider.

4 Identification and Comparison

Tong and Moigne (2000) and Chen et al. (2012) reviewed the Pleistocene rhinocerotid fossils from South China. Though there is always much more to explore, it is no longer in dispute that at least three genera, *Rhinoceros*, *Stephanorhinus* and *Dicerorhinus*, were contemporaneous in the Pleistocene of South China.

4.1 Comparison of skulls

The material studied here belongs to a juvenile individual. Its nasal horn boss is weak and the frontal horn boss cannot be observed. At this point, it is hard to discriminate the species based on the skull among *Rhinoceros*, *Stephanorhinus* and *Dicerorhinus*. However, this new skull is relatively complete, giving more information for the further comparison.

The one-horned genus *Rhinoceros* includes two extant species, *R. unicornis* and *R. sondaicus* and two extinct species, *R. sinensis* and *R. fusuiensis* in the Quaternary of South China. *Rhinoceros* fossils are abundant but no comparable skull has been reported. According to adult specimens of the extant species, the skull of this genus is short, with the occipital plane inclined forward, which makes the dorsal profile strongly concave; the auditory meatus (= pseudoauditory meatus) is closed inferiorly by fusion of the postglenoid and posttympanic processes (Guérin, 1980; Pocock, 1945b). Examination of a juvenile skull (IVPP OV 1046) of *R. unicornis* shows that it also exhibits the typical characters of *Rhinoceros*. Clearly, the Dayakou specimens are different from *Rhinoceros* taxa with its dolichocephalic skull, vertical occipital plane and unfused postglenoid and posttympanic processes.

Tong (2012) summarized up the non-*Coelodonta* dicerorhines in China and revised most of them to *Stephanorhinus*. Tong and Wu (2010) described a juvenile skull of *Stephanorhinus* from Shennongjia, Hubei Province. The skull is dolichocephalic and its horn bosses are also unclear, the same as the specimens from Dayakou. The tip of its nasal is straight, whereas curving downward and convex on the Dayakou skull. Additionally, a prominent ossified septum is developed in the nasal of adult *Stephanorhinus* species from Shennongjia, but the preservation condition leads to the septum being unclear on the juvenile skull. By observing an unpublished

juvenile skull stored in Chongqing Laboratory of Geoheritage Protection and Research, the ossified septum is present at the tip of the nasal of *Stephanorhinus*, but there is no trace on the Dayakou skull.

Dicerorhinus sumatrensis is the smallest and the most primitive species of the living rhinos (Strien, 1974). In South China, *D. sumatrensis* fossils have only been described from Liucheng *Gigantopithecus* Cave, Guangxi (Tong and Guérin, 2009) and *D.* cf. *sumatrensis* from Yunxian Man Site, Hubei (Echassoux et al., 2008; Tong, 2012). The Yunxian Man Site *D.* cf. *sumatrensis* is just slightly larger than the extant *D. sumatrensis*. Thein et al. (2008) established *D. gwebinensis* from the Plio-Pleistocene deposits of Irrawaddy sediments in Myanmar. The holotype of *D. gwebinensis*, a skull lacking the premaxillary bone and basioccipital portion, might foster the illusion that the skull has a more concave dorsal profile and more elevated occiput than *D. sumatrensis*. Therefore, both *D.* cf. *sumatrensis* from Yunxian and *D. gwebinensis* from Irrawaddy cannot be separated from the extant species because the minor differences and only *D. sumatrensis* is a valid name for this taxon during the Quaternary in South China and Southeast Asia. Despite the young age, the Dayakou skull shows a strong similarity to *D. sumatrensis*, such as the dolichocephalic skull, the vertical or subvertical occipital plane, the broadly separated parietal crests, the unfused postglenoid and posttympanic processes, and the ventrally deflected nasal tip. Compared with a modern juvenile skull of *D. sumatrensis* (AMNH 173576), the profile and almost every morphological character of CPV 90 resembles it, except for a somewhat larger lacrimal tubercle. Furthermore, the morphological similarity of *D. sumatrensis* specimens from different geological times probably shows the evolutionarily conservation of this species.

4.2 Comparison of teeth

Deciduous cheek teeth of *Stephanorhinus kirchbergensis* have been reported from several localities along the Yangtze River (Fang and Dong, 2007; Tong and Wu, 2010; Chen et al., 2012). The teeth of this species have an apparent larger size (Table 2), higher crowns, more crista, higher molarized dp1 and a more developed protostylid than that on the Dayakou specimens.

Among the Quaternary Rhinocerotidae, *Rhinoceros fusuiensis* is more similar to *R. sondaicus* than other Quaternary rhinocerotids and is considered to be the potential ancestor of *R. sondaicus* (Yan et al., 2014). Their upper cheek teeth are very easy to identify. As Hooijer (1946) mentioned, the anterior protocone constriction ("the vertical depression in the anterior surface of the protoloph" in the original paper, p.11) is not present in *R. sondaicus* but defined in *Dicerorhinus sumatrensis*; the anterior hypocone constriction ("vertical depression in the anterior surface of the metaloph" in the original paper, p.11) is developed in *D. sumatrensis* but cannot be observed in *R. sondaicus*. Actually, these derived characters can be used to distinguish *R. fusuiensis* and *R. sondaicus* from all the other known Quaternary rhinocerotids. The specimen CPV 90 is clearly different.

Rhinoceros sinensis is now considered a "wastebasket"

or a junior synonym of *R. unicornis*. The understanding of *R. sinensis* is mainly based on the materials from Yanjinggou, but any comparison with them is meaningless, as will be discussed below. We take the fossils of *R. sinensis* from Longgudong Cave, Hubei Province (Zheng and Yang, 2004) for comparison. A modern juvenile specimen of *R. unicornis*, IVPP OV 1046, was also checked. CPV 90 is smaller than *R. sinensis* and *R. unicornis* (Table 2); the paracone and metacone ribs of DP1–DP4 are weaker; the posterior protocone constriction and the anterior hypocone constriction are present in CPV 90, but absent in *R. sinensis* and *R. unicornis*.

Dicerorhinus sumatrensis is the smallest among the Pleistocene rhinocerotids in South China (Table 2). The cheek teeth of AMNH 173576, a modern juvenile specimen of *D. sumatrensis*, was checked and its crown height is lower than in *Rhinoceros* and *Stephanorhinus*. The crochet and antecrochet are usually well developed, and the crista is absent. The paracone and metacone ribs are stronger than *Stephanorhinus*, but weaker than *Rhinoceros*. The anterior protocone constriction, the posterior protocone constriction and the anterior hypocone constriction are more developed than *Rhinoceros* and *Stephanorhinus*. On the basis of these features, CPV 90 resembles *D. sumatrensis*.

Morphological comparison of lower deciduous teeth is usually difficult. In the studied specimens, dp1s show considerable intrapopulation variation among the different rhinocerotids, and dp2–dp4s are always similar except for the size variation. The size of CPV 90 is closest to *Dicerorhinus sumatrensis*. Additionally, the development of the incisors is one of the most important distinguishing features among Quaternary *Rhinoceros*, *Stephanorhinus* and *Dicerorhinus*: *Stephanorhinus* has no incisors; *Rhinoceros* has both upper and lower incisors; and the number of incisors of *Dicerorhinus* is the same as *Rhinoceros*, but much smaller.

Taken together, the Dayakou specimens should be identified as *Dicerorhinus sumatrensis*.

5 Discussion

The Dayakou skull of *Dicerorhinus sumatrensis* is the first confirmed non-*Rhinoceros* rhinocerotid from the Yanjinggou area, which supplies an incredible opportunity for us to get a clearer understanding of the Pleistocene rhinos in South China.

As one of the most common and most important taxa, rhinocerotids can be detected in almost every Pleistocene paleontological and paleoanthropological site in South China and Southeast Asia. Although abundant, their materials are mostly isolated teeth; identifiable tooth rows are mainly immature. Guérin (1980) compared many extant rhinocerotid specimens and took the profile of the ectoloph as an important feature, but, from our observation, it seems always unstable in different wear stages. Hooijer (1946), Filoux and Suteethon (2018), Suraprasit et al. (2016) and Bacon et al. (2018) described some rhinocerotid fossils from the Malay Archipelago, Thailand, and India, and Antoine (2012) summarized the Pleistocene and Holocene rhinos of Southeast Asia from

the systematic, biochronological and biogeographical perspectives, but it is a pity that all of them had no chance to go through the abundant rhinocerotid fossils from South China. Actually, given the region's rich fossil record, we consider the study of rhinocerotid fossils from South China to be fundamental, representing key information in the understanding of the group as a whole.

Owen (1870) first named *Rhinoceros sinensis* based on several isolated teeth from Chongqing ("near the city of Chung-king-foo" in the original paper, p.421). Koken (1885) and Matsumoto (1915) also identified some isolated rhinocerotid fossils of unknown origin as this species. Granger first discovered many wonderful fossils from the Yanjinggou area in Chongqing (Matthew and Granger, 1923). Colbert and Hooijer (1953) studied this collection and took all rhinocerotid fossils from Yanjinggou as a whole to compare with the extant Asiatic *Rhinoceros* and correlated them with *R. sinensis*. They deduced that the teeth of *R. sinensis* have high variability, and thought that all the known Pleistocene rhinocerotid fossils from South China should belong to this species. Since then in the last century, most of the Pleistocene rhinocerotid fossils from South China were assigned to *R. sinensis* (Tong, 2001; Chen et al., 2012), which has made this species a "wastebasket" and caused taxonomic confusion.

During the past two decades, more and more Pleistocene rhinocerotid fossils from the Yangtze River Valley were correlated to *Stephanorhinus* (Zheng and Huang, 2001; Huang et al., 2002; Tong, 2002; Tong and Wu, 2010; Chen et al., 2012), and *Dicerorhinus* fossils were also identified in South China (Tong and Guérin, 2009; Tong, 2012). Additionally, recent fieldwork in the Yanjinggou area shows that the classical Yanjinggou fauna is a mixed assemblage lacking an unambiguous record of locality or layer (Chen et al., 2013). The newly discovered Dayakou skull indicates that a "roublemaker" might be mixed in Granger's collection. Thus, as the benchmark for morphological comparison in South China, the rhinocerotid fossils from the Yanjinggou area need to be reevaluated.

On the other hand, we have checked partial rhinocerotid fossils collected by Granger from Yanjinggou stored in the AMNH. A detailed redescription will be done after more observation and consideration, however, we are sure that in Granger's collection, *Rhinoceros sinensis* and *Stephanorhinus* ?*kirchbergensis* can be detected. AMNH 18628 (Matthew and Granger, 1923, fig. 1), a badly crashed skull, was proposed as the neotype of *R. sinensis*, but Ringström (1927) and Teilhard de Chardin and Leroy (1942) suggested that it belonged to an entirely different species. Here, we agree with Matthew and Granger (1923) because the molars of AMNH 18628 have a clear anterior protocone constriction and lack the posterior protocone constriction and anterior hypocone constriction. However, the knowledge of this species was mainly obtained from a better-preserved skull AMNH 18626 (Matthew and Granger (1923, fig. 2; Colbert and Hooijer, 1953), which, however, in our opinion, may not be a real *Rhinoceros*. Specimen AMNH 18782 (Colbert and Hooijer 1953, fig. 39B), having relatively larger

size and more developed crista than *Rhinoceros*, is apparently *Stephanorhinus* ? *kirchbergensis*.

So, what is *Rhinoceros sinensis*? Colbert (1942) and Colbert and Hooijer (1953) proposed that *R. sinensis* was an intermediate form between *R. sondaicus* and *R. unicornis*. Antoine (2012) and Filoux and Suteethon (2018) considered it as a junior synonym of *R. unicornis.* The identification of *Dicerorhinus sumatrensis* and *Stephanorhinus* ?*kirchbergensis* from Yanjinggou fauna indicates not only a high diversity of rhinocerotids in South China, but also taxonomic confusion regarding *R. sinensis*. The diagnosis of *R. sinensis* needs to be reformed, but at present it is not easy to distinguish the true "*R. sinensis*" in most cases. To clarify the taxonomic problem, more detailed comparisons are needed and our research is still in progress.

6 Conclusions

The well-preserved rhinocerotid skull from the Dayakou locality in the Yanjinggou area is referred to *Dicerorhinus sumatrensis* (Fischer, 1814) based on its dolichocephalic skull, the vertical or subvertical occipital plane, broadly separated parietal crests, the unfused postglenoid and posttympanic processes, the downward curving nasal tip, and the presence of incisors.

This skull is the first confirmed non-*Rhinoceros* rhinocerotid from the Yanjinggou area, which supplies a new clue for our understanding of the Pleistocene rhinocerotids in South China. Taxa of at least three genera, *Rhinoceros*, *Dicerorhinus* and *Stephanorhinus*, coexisted in the Yanjinggou area showing a rather high diversity of rhinocerotids in this area.

Given the serious taxonomic complexity, the diagnosis of *Rhinoceros sinensis* should be readdressed.

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