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Age Profiles of Rhino Fauna from the Middle Pleistocene Nanjing Man Site, South China—Explained by the Rhino Specimens of Living Species

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ABSTRACT A total of 60 pieces of rhino materials have been identified from the Nanjing Man site. Morphologically, they belong to the species *Dicerorhinus mercki*. Among the materials, 40 pieces are broken bones, and 20 are isolated teeth or jaw bones (totally comprising 41 tooth units). Among the teeth, 74% are deciduous, most of them attached to jaws. Other isolated teeth are not greatly worn, meaning they were not naturally replaced, so they represent juvenile animals. Because the skeletons are completely isolated and most of them are broken, their death can not be attributed to a natural trap. Therefore, it is very probable that hominid activities were associated with rhinos at this site. Copyright © 2001 John Wiley & Sons, Ltd.

Key words: rhinoceros; age profiles; Middle Pleistocene; Nanjing Man site

Introduction

Nanjing Man site is a newly discovered human site, it's geologic age is late Middle Pleistocene, with an absolute date of 0.5 Ma (Zhou *et al.*, 1999). The deposit is karst (cave) originally and the geographical location is at the suburb of Nanjing, 32°N, 119°E (Hua, 1996).

The fauna from the site is very similar to that of locality 1 at Zhoukoudian (Choukoutien), but no stone industries were found at Nanjing Man site up to now, so knowledge about the human activities for this site is very limited. It is hoped that analysis of rhino materials can provide some information.

Materials

The discoveries of rhino materials include 40 pieces of broken limb bones, 20 pieces of teeth and isolated teeth, comprising in total 41 tooth units; most of which were measured and described by Huang (1996), so here only the undescribed materials from the larger cave will be discussed.

1. N-D001. Broken skull only with tooth rows complete, with left DP^1–DP^4 and right DP^1–DP^3 preserved; other parts are absent; right DP^2–DP^3 and left P^3 are incomplete. DP^1 is moderately worn, with exposed dentine between cusps not completely joined; the protoloph is only slightly used. DP^2–DP^3 are moderately used, the only difference is that for DP^2, the medifossette is nearly closed, DP^4 is slightly worn, with exposed dentine between cusps not joined, so M1 is not erupted yet (Figure 1).

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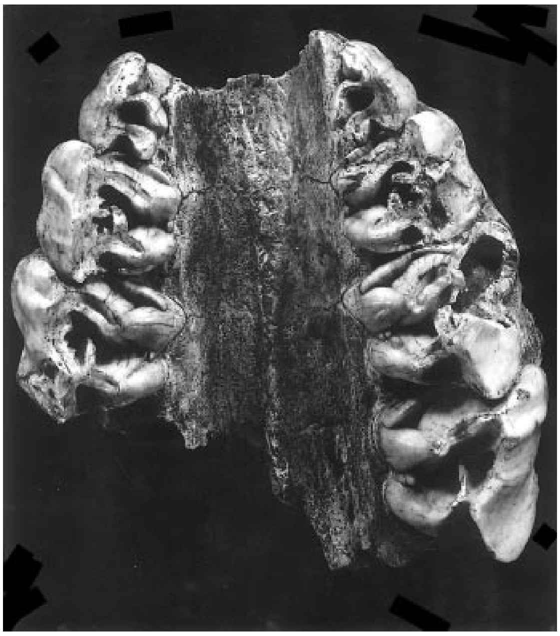

Figure 1. Incomplete skull of *Dicerorhinus mercki* (N-D001).

2. N-D002. Right upper tooth row (maxilla), with DP^1–DP^4, all the teeth are complete; DP^1–DP^3 moderately used, DP^4 slightly worn; for both DP^1 and DP^4, the exposed dentine between cusps is not joined yet; for DP^1, the protoloph is not used yet; for DP^2 the medifossette is completely closed; for DP^4, the exposed dentine between cusps is not joined (Figure 2).
3. N-D003. Right DP^4, very fresh, slightly worn, with exposed dentine between cusps not joined (Figure 3).
4. N-D004. Right DP_4, completely fresh, unused, with no dentne exposed (Figure 4).
5. N-D005. Left M_1, with paralophid and metalophid moderately used and hypolophid slightly used.
6. N-D006. Left DP_3, well used and flattened. Anterior and posterior valleys (infundibulum) have disappeared.
7. D. 053. Left maxilla with DP^1–DP^3, moderately worn.
8. D.0-164. Right P^3, well worn, postfossette isolated and medivallum absent, representing an adult.
9. D.0-165. Left P^4, well worn, postfossette almost isolated and medivallum almost absent, representing an adult.
10. D.0-167. Left DP^4, slightly used.
11. D.0-168. Left DP^3, just coming into use.

Other tooth materials listed by Huang (1996):

- X③ :189. Left maxilla with DP^3–M^1.
- X:01191. Right maxilla with DP^3–DP^4.
- X:0562. Left mandible with DP_2–DP_4.
- X③ :645. Left mandible with DP_3–DP_4.
- X:01621. Left P_2.
- X③ :648. Left P^3.
- X:01185. Right P^3.
- X③ 647. Right DP_3.
- X③ 646. Right M_2.
- X:01181. Right M^3.
- D:050. Right mandible with DP_2–M_1.

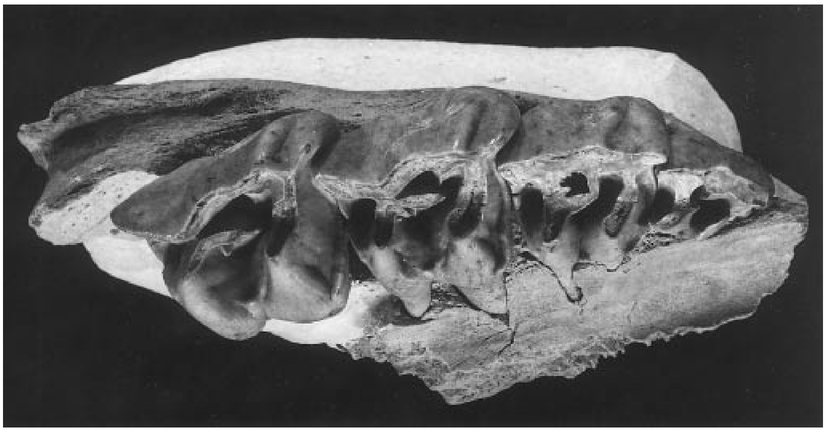

Figure 2. Right maxilla of *Dicerorhinus mercki* (N-D002).

Figure 3. Right DP^4 of *Dicerorhinus mercki* (N-D003).

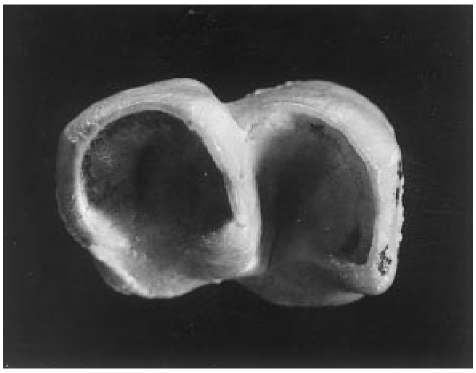

Figure 4. Right DP_4 of *Dicerorhinus mercki* (N-D004).

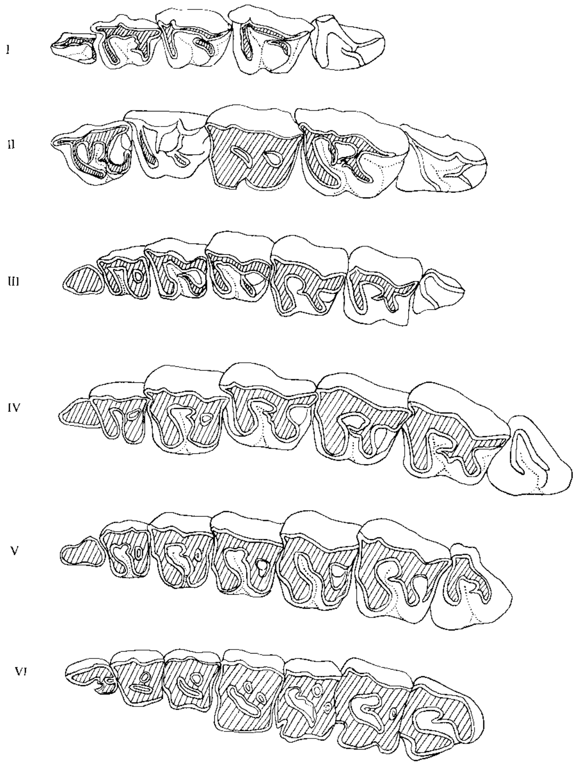

Figure 5. Examples of dental eruption and wear for different ontogenetic stages of rhinos. I. Neonate; II. Juvenile; III–IV. Sub-adult; V. Young adult; VI. Old adult. I. *Rh. sondaicus*, Muséum National d'Histoire Naturelle (MNHN) A7966, with only DP1–DP4 in use, M1 in erupting. II. *Coelodonta antiquitatis*, MNHN SJA 20, P2–P3, DP4, M1, M2 in erupting. III. *Rh. sondaicus*, MNHN A 2277, DP1, P2–M1, M3 in erupting. IV. *Diceros bicornis*, MNHN 1974–124, DP1, P2–M2, M3 fully erupted, but not used. V. *Rh. sondaicus*, MNHN A7971, DP1, P2–M3, M3 slightly used. VI. *Rh. unicornis*, MNHN 1960–59, P1–M3.

Age estimation of rhinos based on dental replacement and wear

Dental eruption, tooth replacement and dental wear can be reliable indicators for determing the age of animals (Wilson *et al.*, 1982). These methods can also be employed to estimate the age at death for fossil rhinos.

Although tooth eruption could be a little different for different species, the general pattern is usually very regular, as shown in Figure 5 and Table 1. Regarding the eruption sequence of milk teeth, normally it should occur from DP1 to DP4 (Borsuk-Bialynicka, 1973), but usually DP2 erupts first, DP3 second, DP1 third and finally DP4, although sometimes DP1 erupts last (Player & Feely, 1960). The permanent teeth erupt in the following order: M1, M2, P2, P3, P4, M3 (Groves, 1967; Borsuk-Bialynicka, 1973; Guérin, 1980). M1 erupts after all of the deciduous teeth, and before the replacement of milk teeth. The order of the replacement of milk teeth is usually DP2 first, then DP3, and finally DP4; this sequence is quite stable.

Among all the teeth, DP1 is the most varied both in eruption and loss, it may fall out even later than DP4, because it is not replaced by a permanent tooth (Player & Feely, 1960; Borsuk-Bialynicka, 1973; Hitchins, 1978). Apart from DP1, the eruption of M2 is not very regular either; normally it should occur shortly after M1 and before P2 and P3, but the author found an

Table 1. Dental eruption order and age classes of rhinoceros

Dental eruption stages						Significant teeth and their wear	Ontogenetic stage[a]	Age year[b]	ofSize[c]
DP1?						Only milk teeth are in use	Neonate	<1.5	<2/5 of adult
DP1?	DP2								
DP1	DP2	DP3							
DP1	DP2	DP3	DP4						
DP1	DP2	DP3	DP4	M1		DP4 not replaced yet	Juvenile	1.5–4	2/3 of adult
DP1	DP2	DP3	DP4	M1	M2				
DP1?	P2	DP3	DP4	M1	M2				
DP1?	P2	P3	DP4	M1	M2				
	P2	P3	P4	M1	M2	M3 fully erupted, but not used	Sub-adult	4–6	3/4 of adult
	P2	P3	P4	M1	M2	M3			
	P2	P3	P4	M1	M2	M3	M3 coming into use	Adult	≥6	1/1

[a] After Foster (1965).
[b] After Foster (1965), Anderson (1966) and Roth & Child (1968).
[c] After Bigalke *et al.* (1950), Schenkel & Schenkel-Hulliger (1969) and Hitchins (1970).

example which shows M2 erupted after P2 and before P3, but M2 always erupts before P4.

In conclusion, as the eruptions of M1, P4, M3 are very regular, it's reliable and practical to use them to signify the age phases of rhinos.

In practice, if the deciduous tooth is attached to the jaw bone, it means that death occurred at a young age (before the sub-adult stage). If the deciduous tooth is isolated, there exists two possibilities, one is that it was replaced by it's permanent counterpart naturally, the second is that the animal was dead before the replacement by it's permanent counterpart. Normally, these two situations are not very difficult to recognize. If the isolated milk tooth is well worn or flattened, it probably represents a natural replacement. If the isolated milk tooth is not very well worn, it can usually be used as evidence of death at a young age. Thus, the milk teeth are a very reliable indicator of age at death for rhinos.

Regarding the permanent teeth, dental wear is also an important index for estimating the age at death.

Based on the formulae shown in Table 1 and Figure 5, as well as the principles mentioned above, we can make some classification for the materials from the Nanjing Man site (see Table 2).

With regard to the milk teeth, if most of them are still attached to jaw bones and other isolated teeth are either fresh or only slightly used, they certainly also represent death at a young age; only two pieces (N-D006 and X③:647) of isolated milk teeth are open to question, and whether they were replaced naturally or died before replacement is not very clear.

It can be seen from Table 2 and Figures 6 and 7 that the majority of the tooth materials (74%) represent juveniles (see Figure 8 for comparison of upper and lower teeth).

Mortality profile analysis

Archaeologists generally conclude that the animal bones found in a site were accumulated by people when most or all of the following conditions are met: (1) associated artifacts or cultural remains (e.g. fireplaces or house ruins) are abundant; (2) the depositional context does not suggest that objects in the site were transported by flowing water or another physical agency; (3) the bones belong to animals that are unlikely to have lived in the site themselves; (4) the bones come from animals that are too large to have been taken by predatory birds; and (5) few, if any of the bones exhibit traces of ancient animal chewing or gnawing, while other evidence (especially coprolites) for animal occupation of the site is also sparse or lacking (Klein, 1982).

Table 2. Identification on the teeth materials from the Nanjing Man locality

	DP1	DP2	DP3	DP4	P2	P3	P4	M1	M2	M3
Upper										
Left	2	2	4	3		2				
Right	2	2	3	3	1	1				1
Lower										
Left		1	2	2	2			1		
Right		1	2	2				1	1	

At the Nanjing Man locality, where the fossils of rhinos were found in the cave deposits, it means that the animals were hunted by man and/or by carnivores, or at least they were moved by man and/or by carnivores after death, because normally rhinos inhabit an open-air habitat, not caves.

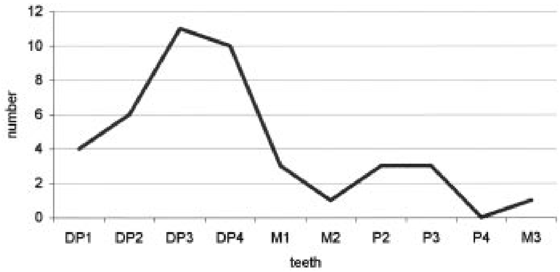

Figure 6. Distributional frequency of rhino teeth at the Nanjing Man locality.

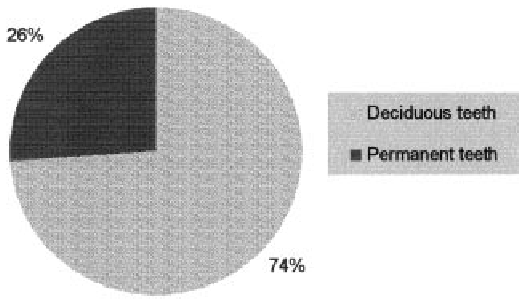

Figure 7. Percentage of deciduous teeth at the Nanjing Man locality.

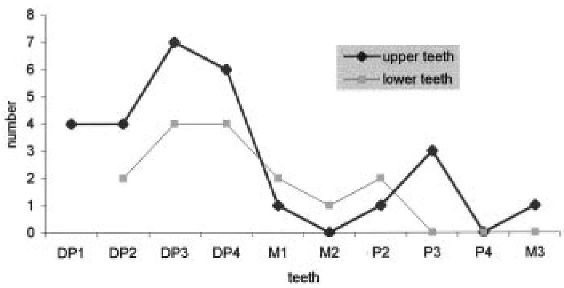

Figure 8. Comparison in numbers between upper and lower teeth at the Nanjing Man locality.

The rhino materials are very fragmented and there is no complete skeleton preserved. This means they were modified after death. On the other hand, it also indicates that the animals did not die in natural trap, but very probably died as a result of active hunting because, in a natural trap, the skeletons should be preserved completely and not disturbed, i.e. showing a catastrophic profile (Klein, 1982). Furthermore, among the fossil population in a natural trap, there is no age selection.

The percentage of milk teeth at the Nanjing Man locality is 74%. According to Klein (1982), a relatively high proportion of very young individuals suggests active hunting, so it seems that most of the rhinos died as a result of active hunting. As mentioned above, the bones are very fragmented, and there exist some gnawing traces left on the bones by carnivores, mainly by hyena, but no cut marks made by man were recognized (Jia, 1996).

Now, it's quite clear that most of the rhinos died from active hunting, but whether they were hunted by man or by hyena is not quite clear. Gamble (1979) proposed five herbivore size classes, mammoths and woolly rhinos form the top rank, and man is the only hunter of these giants. From this view point, it's easy to make the assumption that it's man who hunted the rhinos at the Nanjing Man locality. However, it might also be proposed that, as most of the rhinos died at young age, it's also possible that they were hunted by hyenas. It is, therefore, necessary to employ some research results on the size development of modern rhinos. This work was done by Bigalke *et al.* (1950), and their study revealed that even a juvenile rhino (1.5

years old) can reach a body weight of 500 kg, which is the same weight as an adult horse. It's a little difficult for hyena to capture such a large animal. In addition, the modern observed kills of carnivores in Africa show that among the composition of bone accumulations associated with *Hyaena brunnea* and *Crocuta crocuta*, there are no rhinos, and, similarly, among the prey of leopards, there are no rhinos either (Brain, 1981). Thus, it is very probable that man hunted the rhinos.

The Middle Pleistocene site of Aridos near Madrid provides clear evidence for organized exploitation by hominids (Villa, 1990), suggesting that the hominid activities of hunting large mammals was quite widespread in the Middle Pleistocene.

Among the human sites in China, most of them (> 78%) are associated with rhino fossils (Tong, in press), so it is very probable that rhinos were among the prey of man in prehistory. The Nanjing Man locality, is similar to the majority of other sites.

Conclusion

In conclusion, we can assume the following.

1. Most of the rhinos died at a juvenile stage.
2. A natural trap can be excluded as the cause of death.
3. The rhino materials were moved into the cave by man and/or by carnivores.
4. It is very probable that rhinos were among the prey of man at the Nanjing Man locality. At the least, the hominid activities at the site were closely associated with rhinos.

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