

# Cut marks and terminal Pleistocene hominids in the Ma'anshan site: Evidence for meat-eating

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**In this paper, cut marks on the long bones of class II sized animals in the Ma'anshan site are studied. Based on the location and frequencies of the long bone cut marks, the distribution characteristics are analyzed as follows: (1) cut mark frequencies in the lower layer (LL) are much higher than those of the upper; (2) in the LL cut mark frequency of the upper limbs is the highest, and that of the middle and lower limbs is lower and the lowest; (3) In the upper layer (UL) the cut mark frequency, does not spread as orderly as in the LL. The data are compared to those of the experiment and it is demonstrated that values of the LL all fall into the experimental 95% confidence intervals, and the cut mark frequencies of the upper, middle and lower limbs coincide with those of the experiment; while the values of the UL are much lower, of which, those of the humerus, femur and radius are out of the intervals, and the frequencies of the upper, middle and lower limbs are far more different from those of the experiment. It implies that the earlier hominids (of the LL) defleshed the limbs of the class II sized animals with stone tools more completely than the later hominids. With the evidence of burning marks, it is suggested that the difference on the roasting behaviors derived the cut mark difference of the Ma'anshan UL and LL.**

cut marks, long bones, Ma'anshan site, Terminal Pleistocene, zooarchaeology

According to the archaeological and ethnological records, the Paleolithic hunters would disarticulate, deflesh the carcasses and percuss the bones for marrow when scavenging or after hunting. During the process, the tools hominids used probably would touch the animal bones, whereas cut marks or percussion marks occur. Since cut marks are quite different from the other marks<sup>[1,2]</sup>, especially from those produced by the non-hominid agency, it can be firmly used as the evidence of ancient hominids utilizing the animal sources.

Cut marks were first identified as the butcher marks by European archaeologists in the 19th century<sup>[3]</sup>, while not until the 1960s–1970s the cut mark study was systematically applied to reconstructing the hominid behaviors<sup>[4–6]</sup>. Before the 1980s it was commonly believed that animal bones and stone artifacts unearthed from the Plio-Pleistocene site in Africa were due to the meat and marrow eating of the earlier hominids<sup>[7,8]</sup>. However,

more and more archaeologists realized that not only one taphonomical agency can lead to the aggregation and modification of the bones<sup>[2,9,10]</sup>. According to the distribution of the tooth marks and cut marks on the bones, Binford<sup>[11]</sup> concluded that the early hominids in Olduvai were not hunters but scavengers. In the late 1980s and 1990s Blumenschine and his colleagues did two experiments and found that, if carnivores first and hominids second process the carcasses, the percentage of the tooth marks on the bone midshaft is high, while if hominids first and carnivore second, the percentage is much lower<sup>[12–15]</sup>.

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The comparison of the archaeological and experimental data supports Binford's point of view, while Dominguez-Rodrigo found that when the competition among the carnivores is very intense, even if the hominids first and carnivores second process the animals, the percentage of the tooth marks on the long bone midshaft is high. Through experiments he testified that cut mark study can resolve this problem. The experimental data show that the cut mark percentage has a positive relation to the amount of meat on the bones. In the Olduvai site, the cut mark percentage of the upper limbs, upon which much meat attaches, is very high, so Dominguez-Rodrigo inferred that early hominids were not scavengers but hunters<sup>[16]</sup>. These discussions extremely promoted the development of bone surface modification study, which thereafter has become a mature and effective method for reconstructing the early hominids behaviors. However, in China the study of the bone surface modification is still dominant by the description and identification of the marks, and the quantitative elements are very few. It, therefore, has not turned into a successful method for exploring hominids behaviors in China yet.

The Ma'anshan site was systematically and scientifically excavated, with bones being completely collected, including the difficult-to-identify long bone midshaft fragments and micromammal bones, so this assemblage is ideal for the taphonomical study. The paper will focus on the cut marks of the long bones to reconstruct the meat-eating behaviors of the Ma'anshan hominids.

## 1 Materials and method

### 1.1 Background of Ma'anshan site

Located in Tongzi County, Guizhou Province in Southwest China, the Ma'anshan cave is a Paleolithic site that was excavated twice in 1986 and 1990. The total area of the cave is about 48 m<sup>2</sup>, and the cultural deposit is 2 m deep, which was divided into two cultural layers (the UL includes strata 3–6; the LL includes strata 7–8) by the differences on the composition of the sediments, the petrification of the bones, the staining conditions of the bones by black manganese oxides, and the fauna as well as the stone artifacts assemblages. The age of the UL is between 19295 BP to 31155 BP (AMS), while that of the LL is dated to around 53000 BP (U-Series). There are 1118 pieces of long bones unearthed from the UL, of which 858 pieces belong to the class II sized animals, and the percentage is 76.74%. In the LL, 895 pieces of

long bones yielded, of which 198 pieces are class II sized, and the percentage is 22.12%<sup>[17–19]</sup>. Western zooarchaeologists commonly make their cut mark experiments on the long bone midshaft of the medium sized herbivores (whose living weight is around 100–200 kg, belonging to the class II sized animals) because (1) long bones contain most of the yellow marrow of the body, which is an important fat source of the ancient hominids, and therefore were usually taken back to the base camp; (2) long bone midshaft is much denser than the other bones and easier to be preserved; and (3) long bones are attached much meat, and are connected by joints, therefore, cut marks yielded by behaviors of defleshing and disarticulating limbs occur on the long bones. Since there are more systematical and actualistical data to be compared with, the class II sized long bones are chosen to study the cut marks in the Ma'anshan site.

### 1.2 Identification of cut marks

Cut marks typically have the following characteristics: (1) a V-shaped cross section; (2) the small ratio of width and depth; (3) micro-striations often occurring inside the marks; and (4) if cut marks occur in groups, they are often parallel to each other (probably because hominids repeated one action). Cut marks on the Ma'anshan long bones were identified under the criteria above<sup>[1,2,10,11]</sup>.

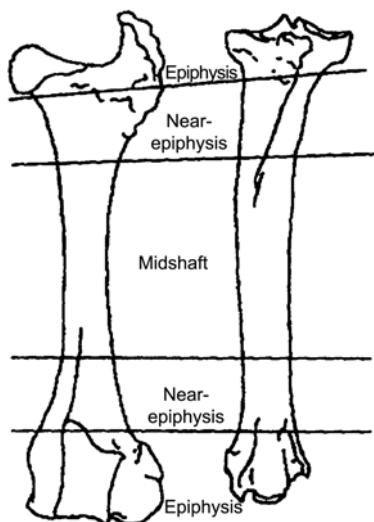
The identification steps are (1) observe the bone surface with eyes and fix the part that could have marks; (2) focus the part with magnifier and confirm whether there are cut marks; and (3) observe the bone surface again and confirm no other cut marks on the specimen. The magnification of the magnifier is 10–20 times, and the identification should be conducted in the incandescent lamp of 60–100 watt<sup>[9,20,21]</sup>.

Before the identification of the Ma'anshan bone assemblage, the authors have disarticulated and defleshed four goats with stone flakes, making cut-marked specimens which have been observed carefully; when identifying, the published morphological and contextual criteria were applied; and cut marks were observed under incident light of 60 W from different angles with a 16 power hand lens to record shapes of the sections, ratios of width to depth and the microstriations in the marks. Therefore, the identification of the cut marks on the Ma'anshan bone assemblage reaches the requirements of the low-power magnification techniques on surface modification<sup>[1]</sup>.

### 1.3 Cut mark location of the long bone

Animal bones unearthed from the paleolithic sites are usually very fragmental. Many long bone midshafts have no anatomical landmarks, whereas cannot be identified to bone elements, so it is difficult to locate cut marks. Blumenschine<sup>[13]</sup>, Capaldo<sup>[14]</sup>, and Selvaggio<sup>[15]</sup> grouped long bones into one class, because long bone midshafts are very different from the flat bones (ribs and scapulars), compact bones (carpals and tarsals), irregular bones (vertebrates and cranials), and short bones (phalanges). While Bunn<sup>[20]</sup> and Dominguez-Rodrigo<sup>[16]</sup> consider cut-mark percentages are related to the amount of flesh extracted from the bones, the more amount of flesh, and the higher cut-mark percentage. The relations will be obliterated if long bones are not classified into elements, so Dominguez-Rodrigo categorizes the long bones into upper limb bones (humerus and femurs), middle limb bones (radius and tibias) and lower limb bones (metapodials). The category is also taken as the classification system in this paper.

Different scholars have different locating methods of the long bone cut marks. Blumenschine and Capaldo classified a long bone into proximal epiphysis, near-epiphysis, midshaft and distal epiphysis<sup>[13,14]</sup>, based on which Selvaggio incorporated the proximal epiphysis and distal epiphysis into epiphysis<sup>[15]</sup>. Bunn and Dominguez-Rodrigo's division is including the proximal shaft, shaft and distal shaft<sup>[16,20]</sup>. Selvaggio's method is taken in this paper because (1) epiphysis is the part that connects joints of meat, and cut marks caused by disarticulating behaviors are commonly located here; and (2)



**Figure 1** The different sections in which long bones were divided (modified after Dominguez-Rodrigo, 1997<sup>[16]</sup>).

epiphysis is the spongy part of the long bones, having low density and containing red marrow, which is easy to be modified by carnivores and difficult to be kept in sites, and combining proximal and distal epiphysis will increase the sample size.

Since near epiphysis is the transitional spongy part of the epiphysis and the midshaft, and there are tendons attached, it is considered that unskilled butchers would leave cut marks here when disarticulating<sup>[14]</sup>. Also much meat is attached to the near epiphysis, so cut marks on this region would probably derive from the defleshing behavior.

As for the midshaft, it is commonly agreed that cut marks found here can be related to defleshing, because the long bone midshaft is very meaty and since it is distant from the epiphysis even the unskilled butchers would not leave disarticulating marks here.

### 1.4 The counting method of cut marks

The basic recording unit for the long bone cut marks is the epiphysis, near epiphysis or midshaft of the humerus, femur, radius, tibia, or metapodial. If one cut mark or a group of cut marks appear(s) on the surface of the basic unit, a record of cut marks will be added. For example, if cut marks are observed on the distal near-epiphysis and midshaft surface of a humerus specimen, a record will then be added to the humerus near epiphysis list and the midshaft list separately.

When counting the cut mark frequency, divide the number of the cut-marked basic units by the number of this kind of basic units. For example, the cut mark frequency of the humerus near-epiphysis will be got by dividing the number of the humerus near epiphysis with cut marks by the number of the humerus near epiphysis. Here, the near epiphyses not only include the one belongs to a near-epiphysis specimen but also the one belongs to any long bone specimen that has near-epiphysis part. Therefore, the sum of the basic units of epiphysis, near epiphysis or midshaft will be higher than the number of identified long bones, because some specimen could have more than one basic unit.

## 2 Long bone cut marks of the class II sized animals in the Ma'anshan site

### 2.1 The data

There are two culture layers in the Ma'anshan site. Bones of the LL mainly belong to the big ungulates, such as *Bubalus* sp., *Rhinoceros sinensis* and *Stegodon*

*orientalis*; while bones of the UL mainly belong to medium and small animals, such as *Cervus unicolor* and *Macaca* sp.<sup>[17-19,22]</sup>. Except for the difference on the species abundance, this research will tell whether there are differences on the bone surface modifications between the two assemblages by comparing the long bone cut mark distributions of the class II sized animals in the UL and the LL, which will also provide important information on the hominid meat-eating in the earlier and later period of the Ma'anshan site.

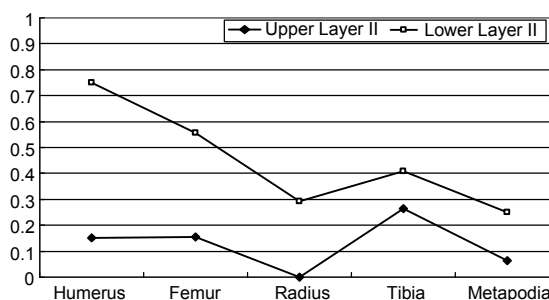
In the Ma'anshan site, most of the bone specimens have biological erosion marks (93.76% in the upper layer, 89.82% in the lower layer), which are dendritic patterned and usually covering most of the bone surface. They were formed after bones were abandoned, or even buried<sup>[23]</sup>, thus, some cut marks probably were covered by the densely spreading biological erosion marks. In the LL, except the biological erosion the bone surfaces were stained black by manganese and/or iron oxides. Some of them were so stained that the surfaces are seemed to be dissolved and cut marks would be covered. The weathering condition of the Ma'anshan bone assemblage is divided into four classes. Less than 13% specimens were weathered to stage 3-4<sup>[24]</sup>, and on these bones some exfoliation present or the surface is coarsely fibrous and rough in texture, so cut marks would disappear with the bone surfaces being destroyed.

In this research, the bones whose surface condition is good enough to identify cut marks are studied, because cut marks are very small and they will not increase or decrease the probabilities of a bone to be modified, that is, the cut-marked specimen has the same chance as the others to be destroyed by weathering, biological erosion or manganese. Therefore, the cut-mark frequency of the bones whose surfaces are undestroyed (the number of cut-marked bones/ the number of undestroyed bones), in some degree, can represent the cut marked probability of the bones before being destroyed.

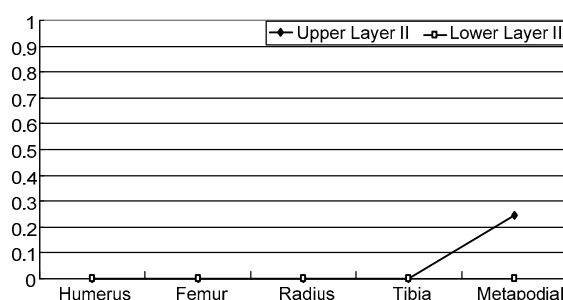
As shown in Figure 2, the characteristic of the cut mark frequencies of the long bone midshaft in the UL and the LL is (1) the cut mark frequency in the LL is much higher than in the UL; (2) in the LL, cut mark frequencies of the upper limbs (humerus and femur) are the highest, those of the middle (radius and tibia) and lower limbs (metapodial) are lower and the lowest; and (3) the profile of the cut mark frequencies in the UL is not as regular as that in the LL: cut mark frequency of the tibia is higher than those of the humerus and femur,

while that of the radius is lower than the metapodial's.

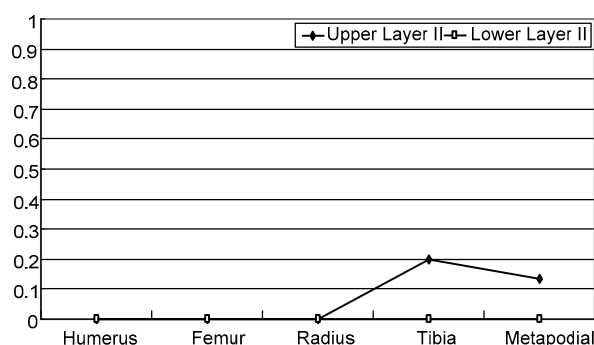
As demonstrated in Figure 3, only on the metapodial near epiphyses in the UL there find cut marks. For the epiphyses, in the LL there are no cut marks, and in the UL there are cut marks only on the tibias and metapodials (Figure 4). Comparison of the data to those of the experiments would provide some implications on how these characteristic formed.



**Figure 2** The cut mark frequencies of the long bone midshafts in the upper and lower layers.



**Figure 3** The cut mark frequencies of the long bone near epiphyses in the upper and lower layers.



**Figure 4** The cut mark frequencies of the long bone epiphyses in the upper and lower layers.

## 2.2 The analysis

Two groups of data from the actualistic studies have the same recording system as ours: (1) Dominguez-Rodrigo's experiment of hominids first modifying animals<sup>[16]</sup>, and (2) Lupo's study on the bone assemblages of Hadza

who killed, processed and consumed the preys<sup>[25]</sup>. While the latter mixed bones of the middle (Zebra & Alcelaphus, living weight 120–200 kg) and little herbivores (Impala, living weight 50 kg) when the cut mark frequency was counted. Experiments have proved that the size of animals will influence the cut mark frequencies, so Lupo's method probably will blur the difference on the middle and small sized animals' long bone cut mark frequencies. In Dominguez-Rodrigo's experiment there were only middle sized animals—Zebra & Alcelaphus, whose living weight is around 200 kg similar to Ma'anshan class II sized animals' 180 kg, thus, his data is picked as the comparative sample.

Dominguez-Rodrigo<sup>[26]</sup> considered three elements will influence cut mark frequencies of the long bones: (1) the butcher's skills: the more skilled the less cut marks<sup>[27]</sup>; (2) the prey's size: the bigger sized the less cut marks<sup>[28]</sup>, for example, Haynes<sup>[29]</sup> found that there were nearly no cut marks on the bones when defleshing elephants, because there was too much flesh to obtain the chips which are difficult and undeserving to cut off from the bones; and (3) the degree of defleshing completeness: if only cut big chunk of meat but leave the chips on the bones, which is called regular butchery, cut mark frequency will be much lower than that of the complete butchery<sup>[16,28,29]</sup>.

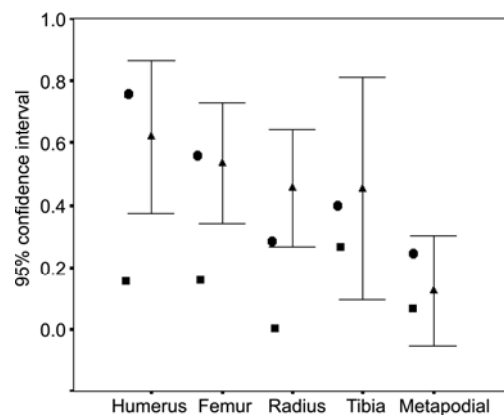
First, the Ma'anshan hominids should be skilled butchers. The archaeological evidences imply that hunting is one of the most important subsistence of the hominids in late Paleolithic. Through ten thousands of year practice Ma'anshan hunter's butchery skills would be as good as or even better than the Maasai and Mwalangulu herders employed by Dominguez-Rodrigo. The experienced people were employed to Dominguez-Rodrigo's experiment, and the data were compared to the archaeological one, which infer that he also believes that Paleolithic hominids were skilled butchers<sup>[26]</sup>.

Second, the animals used in Dominguez-Rodrigo's experiment are middle sized herbivores, which weight nearly the same as Ma'anshan's class II sized animals.

Third, in Dominguez-Rodrigo's experiment the method of complete butchery was conducted, but whether the Ma'anshan hominids took the same strategy only through the comparison could be presumed.

From the above, among the three elements that influence cut mark frequencies of the long bones, two are nearly the same in the two samples, so only if the third

one is identical too, the cut mark frequencies of Ma'anshan sample will fall into the experimental confidence intervals. Figure 5 shows that the values of the LL are much higher than those of the UL: the former fall into Dominguez-Rodrigo's 95% confidence intervals, while the values of humerus, femur and radius in the UL fall outside the intervals. Therefore, it is assumed that the Ma'anshan earlier hominids took the complete butchery method by stone tools, while the later hominids did not.



**Figure 5** The comparison on cut mark percentages of the long bone midshafts of class II sized animals to those from the experiment.

■ The filled circles represent the cut mark percentages of the LL; ● the filled squares represent the cut mark percentages of the UL.

Binford assumed that since there was much meat attached on the epiphysis, cut mark frequency should be high here after being defleshed<sup>[30]</sup>. It is then conferred that cut mark frequency of the class II sized animals' epiphyses should be high in the Ma'anshan LL, because it is shown above the limbs were completely defleshed. However, the sample is too small (the number of humerus, femur, radius and tibia is only 0, 1, 2, and 2, Table 1) to estimate whether the limbs were completely defleshed.

The numbers of specimens attached near-epiphysis whose surface were not badly damaged in the UL are 5, 2, 10, 4, 37 (Table 1) which are bigger than in the LL, and the cut mark frequency is 0. It is probably because of the defleshing incompleteness of the limbs by stone tools, which decreased the chances of stone tools touching bones, while it can not be precluded that the sample is too small to derive this conclusion.

The numbers of epiphysis with undamaged surface in the LL are 0, 5, 0, 3, 5 (Table 1), and the cut mark frequency is 0. In the UL, the numbers are 5, 4, 8, 5 and 64, cut marks are only found on the tibia and metapodial

**Table 1** Cut mark counts on the long bones of the class II sized animals

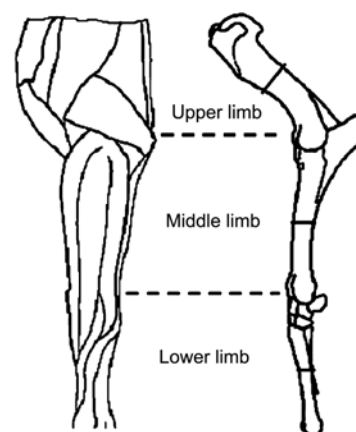
Bone element	Culture layer	Specimen (N)	Cut marked specimen (N and %)	Basic unit	Cut marked basic unit (N)	Basic unit (N)	Cut marked basic unit (%)
Humerus	Upper Layer	123	27 (21.95)	Midshaft	3	20	15
				Epiphysis	0	3	0
				N-epiphysis	0	5	0
	Lower Layer	26	12 (46.15)	Midshaft	9	12	75
				Epiphysis	0	2	0
				N-epiphysis	0	1	0
Femur	Upper Layer	59	31 (52.54)	Midshaft	4	26	15.38
				Epiphysis	0	4	0
				N-epiphysis	0	2	0
	Lower Layer	19	13 (68.42)	Midshaft	5	9	55.55
				Epiphysis	0	5	0
				N-epiphysis	0	2	0
Radius	Upper Layer	144	49 (34.02)	Midshaft	0	39	0
				Epiphysis	0	8	0
				N-epiphysis	0	10	0
	Lower Layer	53	25 (47.17)	Midshaft	7	24	29.16
				Epiphysis	0	0	0
				N-epiphysis	0	2	0
Tibia	Upper Layer	75	24 (32)	Midshaft	5	19	26.31
				Epiphysis	1	5	20
				N-epiphysis	0	4	0
	Lower Layer	38	24 (63.15)	Midshaft	9	22	40.91
				Epiphysis	0	2	0
				N-epiphysis	0	0	0
Meta-podial	Upper Layer	457	165 (36.11)	Midshaft	7	111	6.31
				Epiphysis	9	68	13.23
				N-epiphysis	9	37	24.32
	Lower Layer	62	34 (54.84)	Midshaft	7	28	25
				Epiphysis	0	5	0
				N-epiphysis	0	2	0

The sum of the three basic units of a long bone is commonly bigger than the number of the long bone specimens

epiphyses, and the frequencies are 20% and 13.23%. Since Dominguez-Rodrigo was only interested in cut marks resulting from defleshing, not disarticulation, the bones were disarticulated by metal knives on the joints of the epiphyses, and the cut marks that resulted were not counted, plus the other comparative data of the epiphysis cut marks have not been provided yet, so we cannot conclude on these data till now.

Dominguez-Rodrigo's experiment shows that cut mark frequencies are related to the distribution of edible tissues. Figure 6 demonstrates, the upper limbs have more meat than the middle limbs, and the lower limbs have the least amount of meat, which correspond to the cut mark frequencies from Dominguez-Rodrigo's experiment, about 60% of the upper, 30% of the middle and less than 10% of the lower limbs<sup>[16]</sup>. In the Ma'anshan UL, cut mark frequencies of the upper, middle and lower limbs are 15.22%, 8.62% and 6.31%, which are much lower than those from Dominguez-Rodrigo's experiment.

The experimental data is based on the method of complete butchery, while in the UL the bones were not defleshed completely by stone tools, so the two samples are different on cut mark frequencies. However, in the LL



**Figure 6** Differential distribution of edible tissues across the length of an ungulate limb (modified after Pickering, 2008<sup>[31]</sup>).

the cut mark frequencies of the upper, middle and lower limbs are 66.7%, 34.78% and 25%, which are very similar to the experimental data. It is again proved that the earlier hominids defleshed the class II sized animals with stone tools more completely than the later hominid.

### 3 Discussion

The age of the lower layer is around 50,000 BP, which belongs to the interstadial period OIS 3 of the Last Glacial Period. In south China, OIS 3 was warm and wet, with extensive broad-leafed forest<sup>[32]</sup> that could support large herbivores such as *Bubalus* sp., *Rhinoceros sinensis* and *Stegodon orientalis*. Because the climate deteriorated and became colder and drier after 30000 aBP<sup>[33]</sup>, these herbivores would have become scarcer. But why it seemed the hominids made less use of the preys when the food resources decreased? The study of burning marks implies that it is probably because of the hominids' roasting behaviors.

From the ethnographic analogues, it is found that when roasting, bones covered by meat will not get burned and those outside the flesh will. Through experiments Buikstra and Swegle reached the similar conclusion that the partially burned bone (PBB) can be derived from the roasting behaviors<sup>[34,35]</sup>.

In the UL, the PBB percentage is 35.96% of all the burned bones, which is much higher than 14.81% in the

LL. And the PBB percentage of the class II sized long bones is  $(1+1+3+5+12) \div (123+59+144+75+457) = 2.56\%$  in the UL, and 0 in the LL. So it is considered that later hominids were more likely to roast the limbs than the earlier hominids.

The cooked meat will lose water, thereafter the muscle fibre's elasticity decreases; it is then easy to cut meat off by stone tools or just deflesh the bones by teeth or hands. To strip the cooked meat from the bone will cut down the incidence of the cut-mark occurrence, therefore, the lower cut mark frequencies of the limbs in the UL than in the LL are probably because the later hominids were more likely to roast the limbs.

From all above, the study of cut marks, in some degree, could reconstruct hominid meat-eating behaviors, while it is just one side of the hominids behaviors, only with the researches of species of abundance, mortality age profiles, and skeletal element profiles, the hunting subsistence of Ma'anshan hominids would be systematically reflected, and therefore, the causes of behavioral differences between the later and earlier hominids will be deeply detected<sup>[17-19]</sup>.

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- Blumenschine R J, Marean C W, Capaldo S D. Blind tests of inter-analyst correspondence and accuracy in the identification of cut marks, percussion marks, and carnivore tooth marks on bone surfaces. *J Archaeol Sci*, 1996, 23: 493–5075
- Shipman P, Jennie R. Early hominid hunting, butchering, and carcass-processing behaviors: Approaches to the fossil record. *J Archaeol Sci*, 1983, 2: 57–98
- Lartet E, Christy H. *Reliquiae Aquitanicae: being contributions to the archaeology and paleontology of perigord and adjoining provinces of southern France*. London: Williams and Norgate, 1965–1975
- Guilday J E, Parmalee P, Tanner D. Aboriginal butchering techniques at the Eschelma site, Lancaster County. *Pennsylvania Archaeologist*, 1962, 32: 59–93
- Wheat J B. The Olsen-Chubbuck site: a Paleo-Indian bison kill. *Memoirs of the Society for American Archaeology, Antiq*, 1972, 37: 10–959,
- Frison G C. *Prehistoric Hunters of the High Plain*. New York: Academic Press, 1978
- Isaac G L. The diet of early man: Aspects of archaeological evidence from Lower and Middle Pleistocene sites in East Africa. *World Archaeol*, 1971, 2: 279–298
- Leakey M D. *Olduvai Gorge. Vol.3. Excavations in Beds I and II, 1960-1963*. Cambridge: Cambridge University Press, 1971
- Bunn H T. Archaeological evidence for meat-eating by Plio-pleistocene hominids from Koobi Fora and Olduvai Gorge. *Nature*, 1981, 291: 547–577
- Potts R B, Shipman P. Cutmarks made by stone tools on bones from Olduvai Gorge, Tanzania. *Nature*, 1981, 291: 577–580
- Binford L R. *Faunal Remains From Klasies River Mouth*. New York: Academic Press, 1984.
- Blumenschine R J. 1988. An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. *J Archaeol Sci*, 15: 483–502
- Blumenschine, R J, Marean C W. A carnivore's view of archaeological bone assemblages. In J. Hudson eds. *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Southern Illinois University: Center for Archaeological Investigations, 1993, 273–300
- Capaldo S D. Experimental determinations of carcass processing by Plio-Pleistocene hominids and carnivores at FLK 22 (*Zinjanthropus*), Olduvai Gorge, Tanzania. *J Hum Evol*, 1997, 33: 555–598
- Selvaggio M M. Carnivore tooth marks and stone tool butchery marks on scavenged bones: archaeological implications. *J Hum Evol*,

- 1994, 27: 215–228
- 16 Dominguez-Rodrigo M. Testing meat-eating in early hominids: analysis of cut-marking processes on defleshed carcasses. *Hum evol*, 1997, 12: 169–182
  - 17 Zhang Y, Norton C J, Zhang S Q, et al. Applications of Zooarchaeological Counting Units to Ma'anshan Faunal assemblage (in Chinese). *Acta Anthropol Sin*, 2008, 27: 79–90
  - 18 Zhang Y, Wang C X, Zhang S Q, et al. A Zooarchaeological study of bone assemblages from the Ma'anshan paleolithic site. *Sci China Ser D-Earth Sci*, 2009, doi: 10.1007/s11430-009-0153-5
  - 19 Zhang Y, Wang C X, Zhang S Q, et al. The mortality age of the fauna from Ma'anshan Site (in Chinese). *Acta Anthropol Sin*, 2009, 28: 306–318
  - 20 Bunn H T. Archaeological evidence for meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. *Nature*, 1981, 591: 574–577
  - 21 Bunn H T. Archaeological evidence for meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. *Nature*, 1981, 591: 574–577
  - 22 Zhang S S. Ma'anshan paleolithic site (in Chinese). *Ann Rev Chin Archaeol*, 1987, 242–243
  - 23 Lyman R L. *Vertebrate Taphonomy*. London: Cambridge University Press, 1994
  - 24 Behrensmeier A K. Taphonomic and ecologic information from bone weathering. *Paleobiology* 8, 1978, 211–227
  - 25 Lupo, K D, O'Connell J F. Cut and tooth mark distributions on large animal bones: Ethnoarchaeological data from the Hadza and their implications for current ideas about early human carnivory. *J Archaeol Sci*, 2002, 29: 85–109
  - 26 Dominguez-Rodrigo M. Meat-eating by early hominids at the FLK 22 Zinj anthropossite, Olduvai Gorge (Tanzania): an experimental approach using cut-mark data. *J Hum Evol*, 1997, 33: 669–690
  - 27 Crader D. Recent single-carass bone scatters and the problem of butchery sites in the archaeological record. In: Clutton-Brock J, Grigson C, eds. *Animals and Archaeology: Hunters and Their Prey*. Oxford: BAR International Series, 1983, 163: 107–126
  - 28 Haynes G. *Mammoths, Mastodons and Elephants: Biology, Behavior and the Fossil Record*. Cambridge: Cambridge University Press, 1991
  - 29 Bunn H T. *Meat-eating and Human Evolution: Studies on the Diet and Substance patterns of Plio-Pleistocene Hominids in East Africa*. Dissertation for the Doctoral Degree. Berkeley: University of California, 1982
  - 30 Binford L R. *Bones: Ancient Men and Modern Myths*. New York: Academic Press, 1981
  - 31 Pickering T R, Egeland C P, Dominguez-Rodrigo M, et al. Testing the “shift in the balance of power” hypothesis at Swartkrans, South Africa: Hominid cave use and subsistence behavior in the Early Pleistocene. *J Archaeol Sci*, 2008, 27: 30–45
  - 32 Xia Z K, Liu D C, Wang Y P, et al. Environmental background of human activities during MIS3 stage record in the Zhijidong cave site, Zhengzhou (in Chinese). *Quat Sci*, 2008, 28: 96–102
  - 33 Huang Z G, Zhang W Q. The Quaternary faunas and climatic fluctuation in tropical China (in Chinese). *Tropical Geogr*, 2006, 26: 6–11
  - 34 Gifford-Gonzalez D P. Ethnographic analogues for interpreting modified bones: some cases from East African. In: Bonnicksen R, Sorg M H, eds. *Bone Modification*. Orono: University of Maine Center for the Study of the First Americans, 1989. 179–246
  - 35 Buikstra J E, Swegle M. Bone modification due to burning: experimental evidence. In: Bonnicksen R, Sorg M H, eds. *Bone Modification*. Orono: University of Maine Center for the Study of the First Americans, 1989, 247–258