

A zooarchaeological study of bone assemblages from the Ma'anshan Paleolithic site

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Ten thousands of bone fragments were recovered from the Ma'anshan Paleolithic site, of which 4358 pieces can be identified to skeletal elements or species. In this research, the bone assemblages are quantified based on elements of MNI, MNE, and MAU. Then bone surface modifications and skeletal element profiles of the bone assemblages are studied to understand shlepping behaviors and reveal the technique of disarticulating and defleshing the animals' bodies, etc. Based on the analyses of bone assemblages and the comparative study with the ethnoarchaeological as well as experimental data, it is assumed that later hominids at the site made fuller use of the game animals than the earlier hominids. Incorporating the lines of evidence from chronological dating, paleoenvironment, and polished bone tools between the two cultural layers, here we propose three hypotheses suggesting that the changes of environment, the migrations of the hominids from the North, or the demographic pulses may cause such a behavioral difference. However, it is yet to be determined which hypothesis can better explain the changes.

Ma'anshan site, zooarchaeology, Paleolithic, hominid behavior

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In Paleolithic sites, artifacts are often unearthed along with the animal bones that contain much information, such as the meat diet of the ancient hominids, their hunting strategy, and the way they transferred and processed the preys. From the zooarchaeological study of these animal bones, human behaviors or even the scene of their life can be reconstructed. In China, for a long time the zooarchaeological study of the Paleolithic site was confined to the identification of species, which, dominant with qualitative analyses, led to the loss of much of the information that otherwise could have been extracted from the bones. In this paper, Ma'anshan bone assemblage is studied by quantitative method, especially on species abundance, surface modifica-

tion, and skeletal element profiles, based on which the changed behaviors, the living strategies, and the possible causes for the behavioral difference are hypothesized.

1 Site introduction

Ma'anshan site is located 2 km southeast of Tongzi County (106°49'37"E, 28°07'18"N), northwest Guizhou Province. It is a cave site that lies at an altitude of 960 m above sea level and 40 m higher above the nearby Tianmen River [1] (Figure 1).

It was systematically excavated twice in 1986 and 1990 covering 48 m² [2]. The deposit is 2 m deep and is divided into 9 stratigraphic layers (Figure 2). A brief stratigraphic

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description is as follows:

Stratum 1, grey and black clay, 5–10 cm thick, containing potteries, modern artifacts and small breccias (3–5 cm).

Stratum 2, brownish yellow clay, consolidated, ca. 20 cm thick, only present in the west part of the site, containing potteries, modern artifacts and few breccias.

Stratum 3, grey, black, brownish, yellow and red clay mixing together, ca. 30 cm thick, containing thin layers of ash, small breccias, stone artifacts and animal bones.

Stratum 4, yellow clay, consolidated, ca. 25 cm thick, containing many breccias (commonly 2–3 cm or 5 cm long), a few animal bones and stone artifacts.

Stratum 5, dark brownish clay, 25–40 cm thick, containing thin layers of ash, many breccias, a few gravels (ca. 10 cm long), numerous animal bones and stone artifacts.

Stratum 6, very fine brownish clay, consolidated, ca. 25 cm thick, containing very few breccias, many animal bones and stone artifacts.

Stratum 7, big and small breccias plus coarse sands mixed together, ca. 35 cm thick, in the upper sub-layer 10% coarse sands, in the lower the number of yellow capped breccias increasing, containing gravels, a large number of animal bones and stone artifacts.

Stratum 8, yellow brownish clay mixed with many breccias, ca. 25 cm thick, containing a few animal bones and stone artifacts. The breccias are very big, commonly around 20 cm long, and the biggest is 52 cm×40 cm×32 cm.

Stratum 9, green weathered shale.

Potteries and modern artifacts were unearthed from strata 1 and 2, so fauna from these two are not included in the Paleolithic study. An erosional surface was observed and was considered to divide the deposits into two parts. This division was made because of the major differences between the bone and artifact assemblages of the two parts. In the upper part, most of the stone artifacts are shorter than 40 mm; all the polished bone tools were found in this part; the bone fragments mainly belong to *Cervus unicolor*. In the lower part, stone artifacts are larger, most of them longer than 40 mm; no polished bone tools were found; and the bone fragments mainly belong to large animals, such as *Bubalus* sp., *Rhinoceros sinensis*, and *Stegodon orientalis*. Therefore, it is suggested that the two parts contain two different cultural layers—the upper layer (UL) and the lower layer (LL) [3].

Bone samples from strata 3–8 were sent to the AMS dating laboratory of Peking University in 2007. The results are shown in Table 1. The ages obtained for strata 7 and 8 are younger than those of strata 3–6, which means that inverted dates occur in the Ma'anshan deposits. The U-series date of stratum 8 is around 53 ka BP, which is beyond the range of AMS dating. Furthermore, bones from strata 7–8 were badly petrified and stained black by minerals. It is therefore probable that the AMS dates for strata 7–8 are not as reliable as those of strata 3–6 because all the dating results of strata 3–6 are confined to 15000–32000 ka BP. This is not beyond the AMS dating age range, and the dating materials

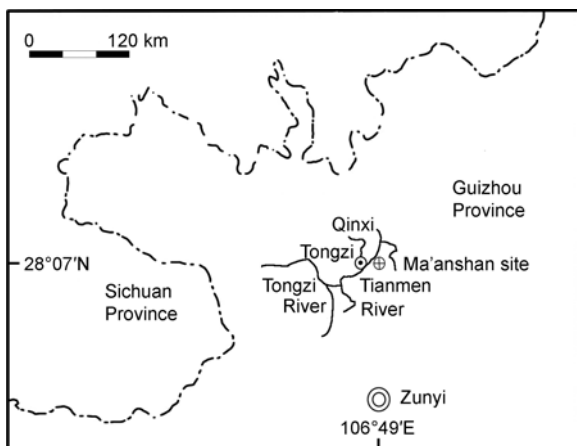


Figure 1 Location of the Ma'anshan site.



Figure 2 Stratigraphy of the Ma'anshan site.

Table 1 Chronometric dates of the Ma'anshan deposits

Stratum	¹⁴ C date (ka BP)	U-series date (ka BP)
3	19295±65 15100±1500 [1]	18000±1000 [1]
4	29170±110	
5	29480±135	
6	31155±140	
7	19260±90	
8	25310±125	53000 [3]

were not petrified or stained. Moreover, the U-series dating result of stratum 3 is very similar to the ^{14}C dates [1], which also verifies the credibility of the AMS dating results of strata 3–6. Thus, it is likely that the age of strata 3–6 is between 15–31 ka BP, and date of stratum 8 is 53 ka; a date for stratum 7 has not yet been obtained, but according to the stratigraphic sequence, it cannot be younger than 31 ka BP or older than 53 ka BP.

2 The hominids' preys

All the bones that could be identified to skeletal element were included in this study, of which the NISP of macro-mammals is 4358 (2892 in the UL and 1466 in the LL). Of all the identifiable bones, 676 (487 in the UL and 189 in the LL) are teeth, 3682 are cranial and postcranial bones (2405 in the UL and 1277 in the LL).

Fifteen genera of large mammals were identified from teeth and antler; these are listed in Table 2 with the MNIs following White [4]. As can be seen, *Cervus unicolor* was by far the most common mammal in the UL (38% of MNI's). In the LL, the MNI percentage of the largest animals, *Bubalus* sp., *Rhinoceros sinensis*, and *Stegodon orientalis*, was higher than 15%, while that of the other animals was lower than 10%. In order to know the percentages of MNI's of large, medium-sized, and small animals in the upper and lower layers, the Ma'anshan fauna was divided into four classes, following Brain [5]. These were Class I (10–50 kg live weight, including *Macaca* sp., *Viverra* sp., *Meles* sp., *Felis microtus*, *Canis* sp., *Muntiacus* sp., and *Capricornis* sp.); Class II (100–200 kg live weight, including *Ursus* sp., *Ailuropoda* sp., *Cervus unicolor*, and *Sus* sp.); Class III (300–1000 kg live weight, principally *Bubalus* sp. and *Megatapirus augustus*); and Class IV (1000–3000 kg

Table 2 The minimum number of individuals (MNI's) of mammals (excluding microfauna) in the UL and LL of Ma'anshan

Latin name	MNI's of	Percentage	MNI's of	Percentage
	UL	(%)	LL	(%)
<i>Macaca</i> sp.	6	12	3	9.38
<i>Stegodon orientalis</i>	2	4	7	21.88
<i>Viverra</i> sp.	1	2		
<i>Meles</i> sp.	1	2		
<i>Felis microtus</i>	1	2		
<i>Canis</i> sp.	3	6	1	3.13
<i>Ursus</i> sp.	2	4	1	3.13
<i>Ailuropoda</i> sp.	1	2	1	3.13
<i>Muntiacus</i> sp.	3	6	2	6.25
<i>Cervus unicolor</i>	19	38	3	9.38
<i>Capricornis</i> sp.	1	2		
<i>Bubalus</i> sp.	5	10	6	18.75
<i>Sus</i> sp.	1	2	1	3.13
<i>Rhinoceros sinensis</i>	3	6	5	15.63
<i>Megatapirus augustus</i>	1	2	2	6.25

live weight, notably *Rhinoceros sinensis* and *Stegodon orientalis*. This division not only classifies animals by size, but also increases the sample size because bones that could be identified to skeletal element and size class, but not to species, could be included.

There were major differences in species abundance between the UL and the LL. As shown in Figure 3, the MNI percentages of the small- and medium-sized animals in the UL are higher than those of the large and very large animals. The MNI percentage of class II sized animals in the UL is 46%, of which 38% were from *Cervus unicolor*; while the MNI percentages of classes III and IV combined were only 22%. In the LL, the sum of class III and IV sized animals' MNI percentage was 62.5%; but the percentage of *Cervus unicolor* was only 9.38%.

The study of bone surface modification shows 20 bone specimens were gnawed by rodents in the UL, and 34 in the LL. The percentages (0.8% in the UL and 2.7% in the LL) are much lower than those of the assemblages from porcupine lairs (22%–100%) [5]. It is therefore most unlikely that rodents modified or transported the bone assemblages at Ma'anshan. Five pieces of bones with carnivore tooth mark were identified at Ma'anshan, and the percentage is about 0.3%. It is much lower than 82% deriving from the experiment in which carnivores' primary access to a carcass is observed, and thus the bones here are most unlikely to be taken to the cave by the carnivores. No water-polished specimens were found at Ma'anshan; besides, lighter and heavier bones were mixed together. There was little sand in the sediment and ashes were distributed in concentration in every stratum of the Ma'anshan deposits, which implies fluvial action did not disturb the deposit and could be excluded as agent for transporting and modifying the bone assemblages. Hominids are therefore believed to have been the primary agents, because the bones were unearthed along with thousand of stone artifacts, burned remains, and on certain bones, there are cut marks and roast marks. Thus, the difference on the species abundance between the UL and the LL was probably derived from the changes on the meat diets of Ma'anshan occupants. It is assumed that in the

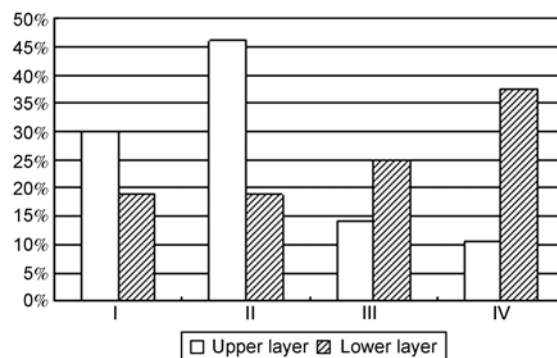


Figure 3 The MNI percentages of the four class sizes (I–IV) of animals in the upper and lower layers of the Ma'anshan site.

earlier period they tended to prey on the big animals, such as *Bubalus* sp., *Rhinoceros sinensis*, and *Stegodon orientalis*, whereas in the later period the *Cervus unicolor* and *Macaca* sp. became their favorites.

3 Skeletal element representation

It is considered that when the hominids could not take all the animal games to the base camp they would disarticulate them and choose to carry some parts back [6]. Therefore, the skeletal element profiles sometimes could demonstrate how the hominids selectively took the body parts of their preys to the base camp.

Usually one *Cervus unicolor* has twenty-eight ribs but only two humeri, so if only the number of ribs and humeri was compared in sites, the former is commonly higher than the latter. MAU (minimum anatomical units) is a quantita-

tive unit that can resolve the overestimating problem and display the skeletal element profiles [6, 7]. The counting method is to divide the total number of the body part by the number of times that it occurs in one complete skeleton. For example, with finding of nine humeri of deer, the MAU value (4.5) will be derived from dividing nine by two because one deer always has two humeri. MAU% is the norms of MAU by dividing the greatest MAU value in the assemblage [7]. For example, in Ma'anshan UL, the greatest MAU value (21) of the class II sized animals is from the carpal/tarsal, so its MAU% is $21 \div 21 = 100\%$; the radius' MAU value is 10, therefore its MAU% is $10 \div 21 = 47.62\%$.

Ma'anshan bone elements are represented by the MAU% as shown in Figure 4. There are both similarities and differences between the skeletal element profiles of the UL and the LL.

The similarities are as follows: (1) the number of vertebrae, ribs, scapulas, or pelvises is much lower, and no atlas

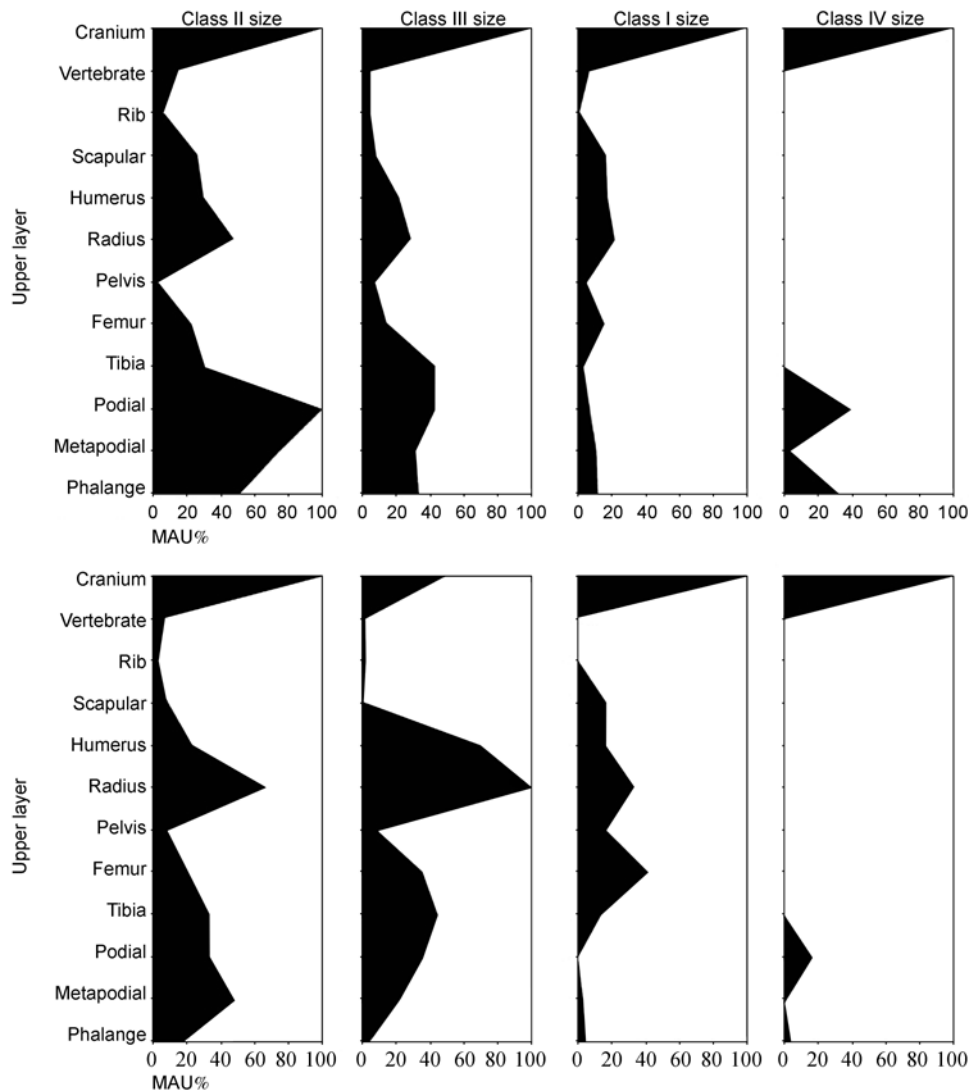


Figure 4 The skeletal element profiles of the upper and lower layers at Ma'anshan.

and axis were found. This could have been caused by hominids' selective transportation, or by their low bone density, because they are all spongy bones, which are more easily eroded than compact bones [8, 9]. (2) Of class IV sized animals, cranial or lower limb bones (including carpal/ tarsal, metapodial, and phalanges) are in the great majority, while there were nearly none of the other parts. This may be because the rhinos and elephants were so heavy that hominids defleshed them at the death-site and took only meat back to the cave. The foot bones probably were taken as the riders of preys' hides for meat transportation or for some other functions, such as getting sinews for sewing [10]. Because the anatomical structure of the head is very complicated, it is difficult to obtain all the nutrition from it in a short time [11], so the hunters may have chosen to take heads back and processed them in the base camp at leisure, which have resulted in the large number of cranial fragments. The higher number of the cranial items than foot bones could simply reflect the higher bone density of teeth [12].

The difference between the skeletal element profiles of the ULs and LLs is as follows: the MAU% predominance of the class I-III sized animals' upper and middle limbs (the upper limbs include the humeri and the femora, and the middle ones include the radii and the tibias) in the LL is more obvious than those in the UL. For class III sized animals from the LL in particular, the MAU% of the upper and middle limbs is even higher than the MAU% of head parts, as determined by teeth. Therefore, it is assumed that the earlier hominids were more likely than the later hominids to take the upper and middle limbs that contain more meat to the cave.

4 The defleshing behaviors

After hunting, the hominids would skin, disarticulate, and deflesh the animal bodies. In these procedures, the tools might touch the bone surface and cause the cut marks.

Cut marks typically have the following characteristics [13]: (1) a V-shaped cross section; (2) micro-striations often occur inside the marks (c in Figure 5); (3) if cut marks occur in groups, they are often parallel to each other (see a-c in Figure 5). Cut marks were identified under these criteria for the Ma'anshan bone assemblages.

The cut mark analysis in this paper is confined to the upper and middle limb bones and ribs because the NISPs of other skeletal elements whose surfaces are not damaged (by weathering, biological, and mineral staining influences) are so small that they have little statistical significance.

A long bone can be divided into its epiphysis, near epiphysis and midshaft. Carcass disarticulation by hominids is often associated with cut marks on the epiphysis, which is the part that connects joints of meat. Since the near epiphysis is the transitional part between the epiphysis and the

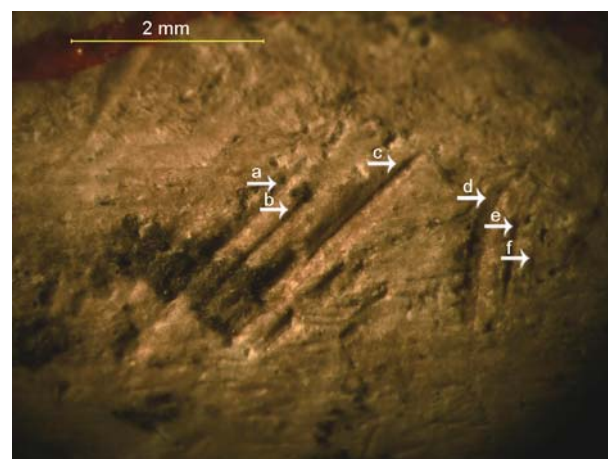


Figure 5 Cut marks on the surface of a bone at Ma'anshan.

midshaft, Capaldo considered that only unskilled butchers would leave cut marks here [14]. Binford believed that because much meat is attached to the epiphysis and near epiphysis, so the cut marks on these regions would be derived from defleshing behavior [15]. As for the midshaft, it is commonly agreed that cut marks found here can be related to defleshing because this part is very meaty, and it is more distant from the epiphysis than the near epiphysis so that even the unskilled butchers would not leave cut marks here.

The cut marks on the long bone midshaft will be focused upon in this analysis to discern hominid defleshing behavior at Ma'anshan site. However, this analysis includes only the specimens of classes II and III sized animals' upper and lower limbs, because the sample of classes I and IV sized animals is too small.

Experiments show that the more complete the limbs are processed by stone tools, the more cut marks are made [16, 17]. Domínguez-Rodrigo hired Maasai and Mwalangulu people (south-eastern Kenya herders, formerly hunters) who are accustomed to butchering carcasses and completely deflesh zebra and wildebeest (200 kg live weight), which are similar in size to *Cervus unicolor* [17]. Figure 6 shows the comparison of the cut mark frequencies of the long bone midshafts of class II sized animals at Ma'anshan and those of Domínguez-Rodrigo's experiment. As it demonstrates, the values of the LL are much higher than those of the upper: the former fall into Domínguez-Rodrigo's 95% confidence intervals, while most of the latter fall outside them. For the class III sized animals, the cut mark percentages of long bone midshaft of the LL are also higher than those of the upper (Figure 7). It is thus considered that the earlier hominids at Ma'anshan might have defleshed upper and middle limbs by stone tools more completely than the later ones. Here by stone tools are emphasized because hominids could deflesh the bones with teeth or hands, while these ways could not make obvious marks as tools did. So, it cannot be concluded whether the later hominids processed the limbs

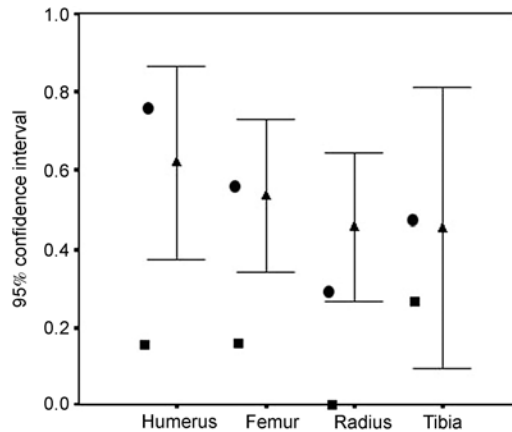


Figure 6 The comparison on cut mark percentages of the long bone midshafts of class II sized animals with those from the experiment. The filled circles represent the cut mark percentages of the LL; the filled squares represent the cut mark percentages of the UL.

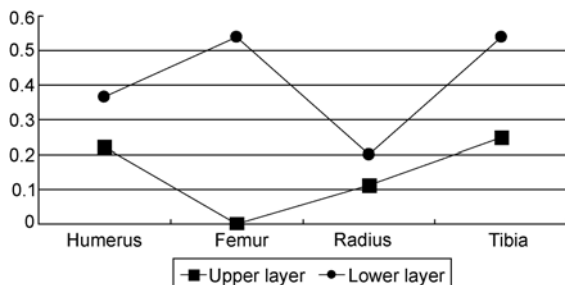


Figure 7 The cut mark percentages of the long bone midshafts of class III sized animals.

incompletely or not, because besides tools, they could get meat by other means.

Ribs are also attached with much meat as the upper and middle limbs. If we compare the cut mark frequency of these two meaty parts, we can discern whether the hominids defleshed them differently. In the UL, the cut mark percentages of the ribs of class II and III sized animals (31.70% and 32%) are slightly higher than the highest cut mark frequency (26.31% and 25%) of the upper and middle limbs; whereas in the LL the cut mark frequency of the ribs (27.27% and 15.38%) are much lower than the highest value of the upper and middle limbs (75% and 53.85%). Therefore, it is suggested that the later hominids defleshed limbs and ribs with nearly equal completeness. In contrast, earlier hominids defleshed limbs more completely than they did ribs.

5 The behavior of roasting

From the ethnographic analogues, Gifford found that when roasting, bones covered by meat will not get burned and those outside the flesh will [18]. Through experiments Buikstra and Swegle reached the similar conclusion that the



Figure 8 Specimen with roasting marks.

partially burned bone (PBB) (as those in Figure 8) can be derived from the roasting behaviors [19].

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 upper and middle limbs from the classes II and III sized animals is 2.49% and 4.08% in the UL. In the LL, there are no PBB of class II, and the PBB percentage of class III is 0.56%, which is lower than the UL's 4.08%. 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. That is to say, 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.

6 Discussion

The analyses of species abundance, skeletal element representation, surface modification, and mortality age imply that the occupants of the UL preferred to hunt medium- and small-sized animals, brought more parts of the prey back to base camp, defleshed both limbs and ribs in equal proportions with their stone tools, and might have roasted the meat with bones attached. However, occupants of the LL preferred to prey on large animals, were more likely to take meaty limbs of their prey back to the base camp, defleshed limbs more completely than they did ribs. Later hominids at the site appear to have made fuller use of the game animals than the earlier hominids. Why did these differences occur? Three hypotheses are raised to provide some explanations.

First hypothesis, the environmental change caused the differences. The age of the LL is around 53 ka, which belongs to the interstadial period OIS 3 of the Last Glacial Period [20]. In South China, OIS 3 was warm and wet [21], with extensive broad-leafed forest that could support large

herbivores such as *Bubalus* sp., *Rhinoceros sinensis*, and *Stegodon orientalis*. Because the climate deteriorated and became colder and drier after 30 ka, these herbivores would have become scarcer. Hominids therefore adapted by hunting small- and medium-sized animals, particularly *Cervus unicolor*. Because food was scarcer, they also made greater use of the entire carcass by defleshing a wider range of skeletal parts.

In Holocene, *Bubalus* sp. and *Rhinoceros sinensis* were extinct [22]. It is possible that in the late Pleistocene the number of these animals had begun to decrease. However, there were no MNI record of the fauna in this area, so it cannot be concluded that the meat diet change was due to the decreasing number of big animals by then.

Second hypothesis, different human groups caused these differences. When OIS3 was over, it was very dry and cold in North China, so some hominid groups may have moved south and occupied Ma'anshan cave. In North China, a few sites date to OIS3, e.g. the upper cultural strata of Zhijidong (50–35 ka BP) [23], Zhaocunqian'an (50–37 ka BP) [24], Shandingdong Upper Cave (34–27 ka BP) [25], Xiaogushan (40 ka BP) [26], Heshundangcheng (30 ka BP) [27], Shiyu (28 ka BP) [28], Tashuihe (26 ka BP) [29], and Liujiacha site (50–35 ka BP) [30]. The animal bones reported from these sites mainly belong to medium-sized animals, such as deer, gazelle and horse. It is therefore possible that some hominid groups transferred from North China to the south, but still preferred to hunt small- and medium-sized animals because they still kept their former hunting techniques. Additional evidence that humans migrated into South China from the north comes from the bone tools. None was found in the LL, but the upper one contained polished bone awls, arrowheads, and ornaments. These are the earliest polished bone tools in South China. One of them was from stratum 6, the age of which is around 31 ka. The others were unearthed from stratum 3, dated to ca. 15 ka. The tool types and drilled hole in one example are very similar to those from the Upper Cave and the Xiaogushan site in Liaoning Province, North China [31, 32]. These items therefore provide good evidence for the migration hypothesis. However, the stone tools from the Ma'shanshan site have not yet been systematically studied, so we cannot provide more quantitative information on the artefactual changes before and after 30 ka.

Third hypothesis, a broad-spectrum revolution caused these differences. It is possible that in the later period at Ma'anshan, human populations increased, and placed greater pressure on their resources. Consequently, later hominids extended the range of animal resources and exploited them more completely than the earlier hominids [33, 34]. Stiner considered that the increased number of small animals could be a good indicator of an expanding population, because some small animals are very productive and can provide a predictable food resource. Certain numbers of small animals' bones, such as bamboo rat, porcupine, and

bird bones were found in the upper strata of Ma'anshan site, while none in the lower strata. Since the micromammals and birds can widen the meat diet and are the reliable food resources, the small animals' bones found from the UL could be the evidence for a broad-spectrum revolution after 30 ka. However, the occurrence of certain kinds of hunting techniques, such as the net hunting and trapping, also could lead to the extension of the meat diet [35].

It is not possible at present to identify whether these changes were caused by palaeoenvironmental changes, hominid migrations, or by demographic pressure resulting from a population increase. Further studies are needed of other archaeofaunal collections in China to confirm the changes seen at Ma'anshan.

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