

## Zooarchaeological perspectives on the Chinese Early and Late Paleolithic from the Ma'anshan site (Guizhou, South China)

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### ABSTRACT

Ma'anshan is a Paleolithic cave site in the Guizhou province of southern China. The total area of the excavations is ca. 48 m<sup>2</sup>, and the cultural deposit is divided into two layers representing the Chinese Late Paleolithic and the later part of the Early Paleolithic. The upper layer dates between 19,295 BP and 31,155 BP by AMS technique, and the lower layer is dated to around 53,000 BP by U-Series technique. Thousands of bone fragments were recovered from the two layers. Species abundance, bone surface modifications, skeletal element representation, and mortality patterns were studied in an investigation of assemblage formation history and patterns of prey selection and meat consumption by hominins. Interpretations of the faunal data are strengthened by reference to experimental studies and ethnoarchaeological data. The zooarchaeological data indicate that the later occupants of Ma'anshan Cave hunted mainly medium and small game animals, while the earlier occupants tended to prey upon larger animals. In the later period, hominins also made fuller use of the carcasses. The breadth of the meat diet increased with time, due to the inclusion of quick small animals (bamboo rats and birds) in the later period. The differences between the two faunal assemblages are consistent with the chronologic boundary currently drawn between the Chinese Early and Late Paleolithic ca. 30–27 ka BP, based on technological and other evidence.

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### 1. Introduction

The Chinese Paleolithic has been divided into two cultural stages, the Early and Late Paleolithic. This terminology contrasts with those commonly used in western Eurasia and Africa. The boundary between these periods in China conventionally is drawn at about 30–27 ka BP, based on the appearance in the latter of blade and microblade technology, formal bone tools, ornaments (Gao and Norton, 2002), or a combination of these. This study examines whether differences in the faunal assemblages from Ma'anshan Cave differ between the Chinese Early and Late Paleolithic as determined by the artifactual record. Zooarchaeological and taphonomic studies of Chinese Paleolithic sites are still few in number (e.g., Norton and Gao, 2008; Prendergast et al., 2009). Usually, only a species list is provided for the faunal assemblages, and there is

little or no information on relative species abundance, frequencies of skeletal parts, prey mortality patterns or bone surface modification (e.g., Pei, 1940; Zhang, 1988). It has been almost impossible to distinguish between the Chinese early and late Paleolithic game use from such limited criteria.

Some of the Pleistocene bone collections for which species lists are available are housed in the Institute of Vertebrate Palaeontology and Paleoanthropology (IVPP) in Beijing. Of these, the Ma'anshan collections are very suitable for re-examination because of the recovery of all specimens, including microfauna and long bone mid-shaft fragments of large animals. The cave of Ma'anshan yielded thousands of bone fragments (the ratio of NISP to non-identified specimens is 4358/40,000) and artifacts. The ages of the assemblages range from 15 to 53 ka BP (Zhang, 1988, 2001; Long, 1992). Though excavated under conditions that would not be considered optimal today, these collections nonetheless provide an important opportunity to examine whether differences exist between the faunal assemblages of the Chinese late Early Paleolithic and the Late Paleolithic at one location.

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## 2. Background

Ma'anshan Cave is located 2 km southeast of Tongzi County, northwest Guizhou Province (Fig. 1). The cave lies at an altitude of 960 m above modern sea level, and 40 m above the nearby Tianmen River. Its interior is 24 m long and narrows towards the back. The entrance faces northeast and is the widest part of the cave at 21 m across (Fig. 2).

Ma'anshan Cave was systematically excavated in 1986 and 1990 by the IVPP under the direction of Professor Zhang Senshui and Long Fengxiang. An area of 25 m<sup>2</sup> was excavated in 1986 in the east part of the cave. The trench was a 7 m trapezium, 4 m wide on the western edge and 3 m wide on the eastern edge. Two pits, A and B, were divided at the middle point of the trapezium's longitudinal axis. In 1990, 23 contiguous 1 m squares were excavated in the middle part of the cave (Fig. 2). Sieving was not performed during the excavations, but much effort was made to collect all of the lithic and faunal fragments from the excavated sediments. In fact, the excavation records document careful retrieval of bone specimens; although sieving was not performed, the excavators used another method called *pating collection*. Because the clay was very sticky, dry sieving was impossible, as was water sieving because of a lack of water in the vicinity. In addition to collecting all obvious bone during the excavation of each unit, the sediments were taken to a processing area where they were poured onto a surface and the clayey chunks were patted into very small pieces or powder. All of the bones and artifacts were removed manually in this way, including all micro-mammal and bird bones, bone tools, and thousands of long bone

shaft fragments, hence the high NISP and non-identified specimen ratio (4358/40,000).

Nine stratigraphic layers were identified in the Ma'anshan deposits in 1986 by Zhang (1987), and fifteen layers were identified in the 1990 excavation by Long (1992). According to the field records, these two stratigraphic profiles do not correspond. Re-examination of the stratigraphic profile in 2006 by Zhang Senshui and colleagues revealed that some of the sediments originally labeled as separate strata could not be separated unambiguously, and that only eight strata (as opposed to 15) are clearly present, as shown in Fig. 3. Bedrock occurs below the lowest sedimentary layer. Stone artifacts and animal bones were recovered from all eight strata. Ceramic artifacts were unearthed only from the most recent strata 1 and 2, and material from these layers is not included in this study. A brief stratigraphic description is as follows:

Stratum 3, Grey, black, brownish, yellow and red clay mixed together, ca. 30 cm thick, containing thin layers of ash, small breccias (commonly 2–3 cm or 5 cm long), stone artifacts and animal bones.

Stratum 4, Yellow clay, consolidated, ca. 25 cm thick, containing some small breccias, a few animal bones and stone artifacts.

Stratum 5, Dark brownish clay, 25–40 cm thick, containing thin layers of ash, a few breccias, a small amount of gravel (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, 10% coarse sands in the upper sub-layer;

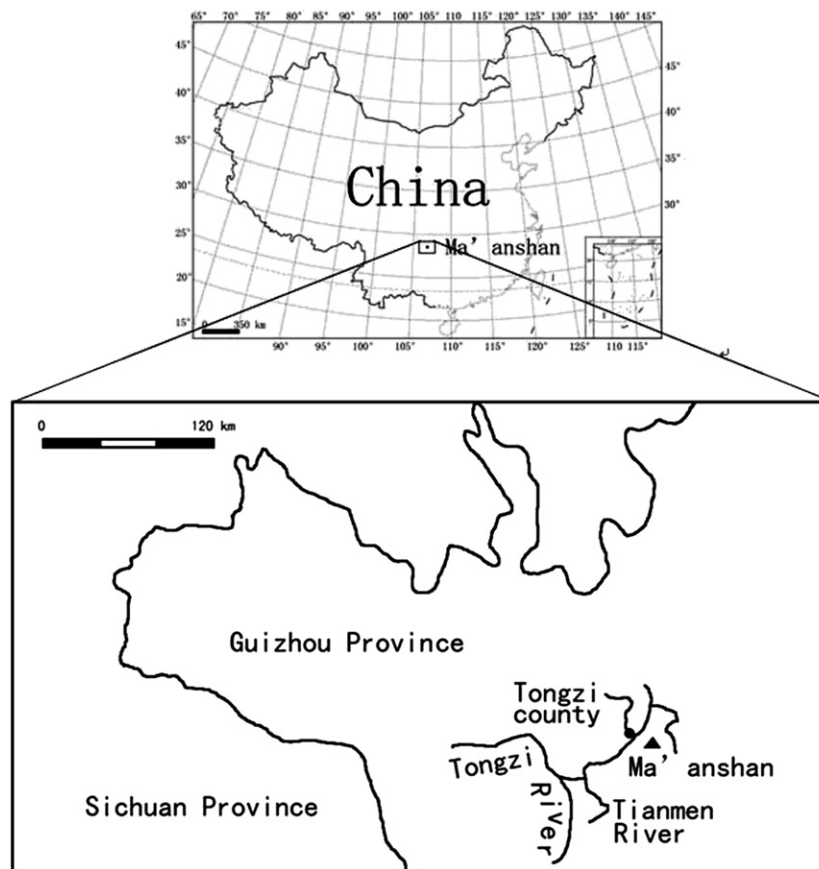


Fig. 1. Location of the Ma'anshan site.

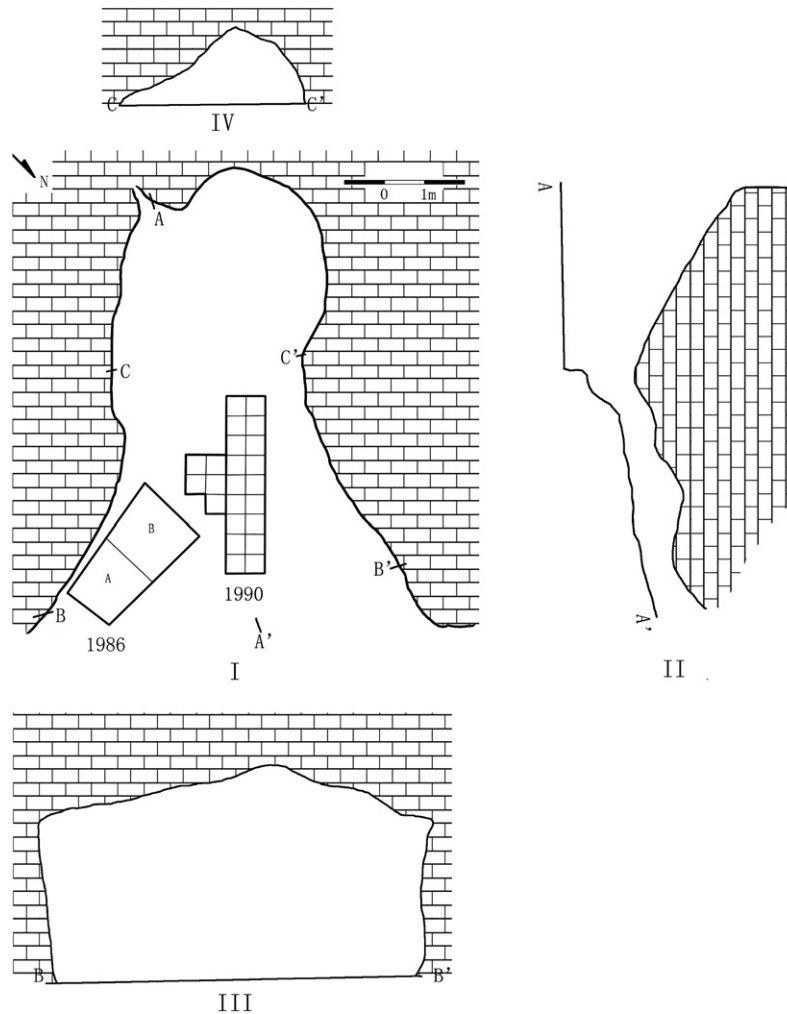


Fig. 2. (I) Plan of Ma'anshan site; (II) vertical section of AA'; (III) cross section of BB'; (IV) cross section of CC'.

in the lower layer, the number of yellow capped breccias increases, containing a few gravels, and many animal bones and stone artifacts.

Stratum 8, Yellow brownish clay mixed with many large breccias (commonly around 20 cm long, but the biggest is 52 cm × 40 cm × 32 cm), ca. 25 cm thick, containing a few animal bones and stone artifacts.

Stratum 9, Green weathered shale, no artifacts and bones.

Two chronometric ages for Ma'anshan stratum 3 were obtained in 1988. One was a  $^{14}\text{C}$  date on a bone fragment that yielded an age of  $15.1 \pm 1.5$  ka. The other was a Uranium-series date on a *Cervus unicolor* tooth that suggested a slightly older age of  $18 \pm 1$  ka. Uranium-series dating on *C. unicolor* teeth from stratum 8 yielded a much older age of 53 ka. To obtain a more precisely dated sequence, bone samples from strata 3–8 were submitted to the AMS dating laboratory of Peiking University in 2007. The ages obtained for strata 7 and 8 are younger than those of strata 3–6 (Table 1); these two somewhat more recent dates may be the result of contamination, a common problem with radiocarbon determinations as they approach or exceed the limits of the technique. Alternatively, the samples may be intrusive from overlying layers.

The U-series date of stratum 8 is around 53 ka BP, and is believed to be more reliable, because the age is beyond the range of AMS

dating but within the effective range of U-series dating. The AMS dates for strata 3 through 6 all fall within the range of 15,000–32,000 ka BP and these dates are well within the effective range of AMS technique. Moreover, the U-series result of 1988 for stratum 3 is very similar to the  $^{14}\text{C}$  date. The considerably older U-series date of stratum 8 at 53 ka is assumed to represent the true (approximate) age of that layer. The age of stratum 7 has not yet been determined, but according to the stratigraphic sequence, it cannot be younger than 31 ka BP or older than 53 ka BP.

Though the stratigraphic profiles of the 1986 and 1990 excavation trenches do not correspond, an erosional surface was observed in both trenches that divides the sediment column into two parts. Argillaceous clay with scattered breccias occurs in the upper part (Fig. 3, strata 1–6). Very densely distributed breccias distinguish the lower part of the sequence, strata 7–8, where bones are highly fossilized and stained by black manganese oxides. The bones from strata 3–6 are much less altered.

There are also major differences between the artifact assemblages of the two parts of the stratigraphic sequence, and it is on these grounds that we refer to two major cultural layers or components. In the upper cultural layer (strata group 3–6), most of the stone artifacts are shorter than 40 mm in length, and sixteen formal bone tools are present. In the lower cultural layer (strata group 7–8), stone artifacts are larger, usually longer than 40 mm,



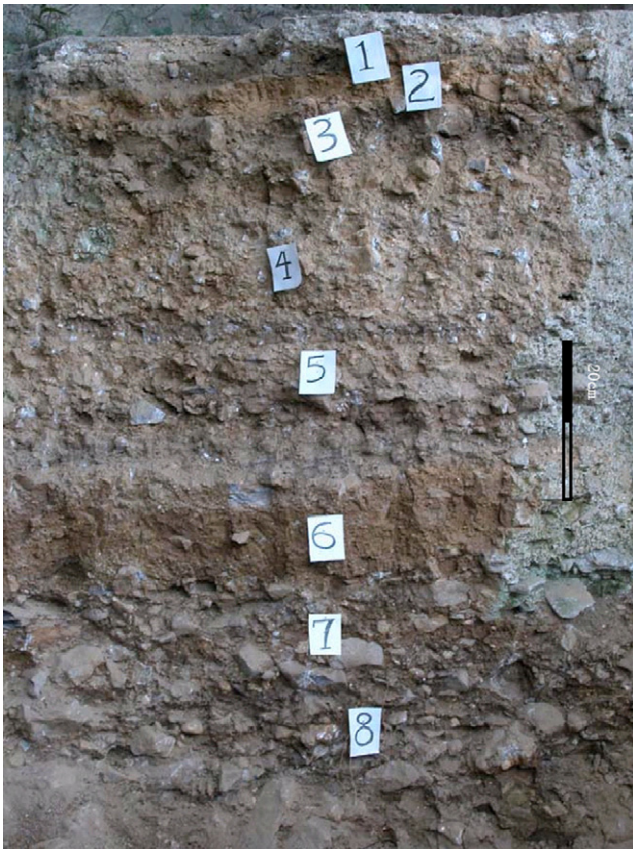


Fig. 3. Stratigraphy of the Ma'anshan site.

and no formal bone tools were found (Zhang, 1987). The two cultural layers are examined separately in the zooarchaeological analyses below.

### 3. Materials and methods

The Ma'anshan faunal assemblage contains roughly 40,000 faunal specimens. Only those specimens that could be identified to species and/or skeletal element are included in this study. Of the total macromammal NISP (4358), 2892 specimens are from the upper cultural layer and 1466 from the lower layer. About 17% of the identifiable remains from the upper layer are dental specimens (NISP 487), and 13% are dental specimens in the lower layer (NISP 189).

Four groups of observations were recorded for non-dental specimens and are important to the analytical sections presented below: (1) taxon, skeletal element and portion, side, sex, and ontogenetic age if applicable; (2) fragmentation characteristics, including specimen length and width, fracture angle and form; (3)

portion-of-element data analysis based on anatomical landmarks in relation to independent standards of skeletal bulk density; (4) bone surface modification, including weathering, cut marks, percussion marks, gnawing, burning damage and intensity, abrasion, rodent gnawing, and root etching damage (Fisher, 1995). The bone surfaces were examined under strong incandescent light, and surface damage was further observed with the aid of a 16× hand lens.

### 4. Taphonomy and assemblage formation history

In the Ma'anshan site, the surfaces of some bones were destroyed by biological erosion, manganese or weathering. Most of the bone specimens have biological erosion marks (93.76% in the upper layer, 89.82% in the lower layer), with a dendritic pattern indicative of root action (Andrews and Cook, 1985; Binford, 1981). The marks are unevenly distributed among specimens, ranging from mild to severe. Heavy root damage is more common in the upper layer (80%) than in the lower layer (64%).

About 95% of the bone specimens were stained black by manganese in the lower layer, but there is none of this kind of damage in the upper layer. One third of the bones from the lower layer are so stained that their black surfaces are very rough and seem to be dissolved.

Weathering damage (Behrensmeyer, 1978) to the Ma'anshan bone assemblage is divided into 4 classes. The surfaces of bones that were weathered to classes 3 and 4 (about 13%) have some exfoliation present or are coarsely fibrous and rough in texture, potentially obscuring any tool marks that may have been present.

Only five specimens with carnivore tooth marks were identified at Ma'anshan. Two of the specimens, an epiphysis of a metapodial and an astragalus, are from the upper layer. The other three gnawed specimens are from the lower layer: a humeral epiphysis, a tibia epiphysis, and a mid-shaft fragment of a humerus. Some experimental studies indicate that, if carnivores have primary access to a carcass, the percentage of mid-shaft fragments with tooth marks will be very high (63–88%), but very low if hominins have primary access to a carcass (7–15%) (e.g., Blumenshine, 1988, 1995; Marean and Spencer, 1991; Selvaggio, 1998; Capaldo, 1997). These models are directed mainly to studies of very early culture periods, but since the foraging practices of the Ma'anshan hominins are not known, it is useful to exclude the possibility of scavenging from carnivore kills at the outset. Since there are no gnawed mid-shaft specimens in the upper layer of Ma'anshan, and gnawed midshafts are very rare (0.27%) in the lower layer, it is very unlikely that hominins obtained the most or any of the carcasses by scavenging carnivore kills. Four of the five examples of gnawing traces occur on the surfaces of spongy bone parts, possibly made after the medullary marrow had been removed by the hominin occupants. Carnivore traces at this site are minimal in any case.

Rodent gnawing damage is only slightly more common than carnivore damage at Ma'anshan. Twenty bone specimens from the upper layer (0.8%) and thirty four (2.7%) from the lower layer were gnawed by porcupine-sized rodents. However, these gnawing rates are far below what has been observed in porcupine lairs (from 22% to 100%; Brain, 1981). Small rodent gnawing rates also can be high in situations where bones lie undisturbed on the surface in caves for long periods (Stiner et al., 1996). The very low rates of rodent gnawing in Ma'anshan indicate that the rodents were neither bone collectors nor significant bone modifiers at this site, even though the majority of the bones were exposed to the atmosphere for some time before burial.

Finally, there was no evidence of any fluvial action on the bones. No water polished specimens were found, and lighter and heavier bones co-occur in the same units.

Table 1  
Chronometric dates of the Ma'anshan deposits.

Stratum	<sup>14</sup> C (BP) dates	U-series dates
3	19,295 ± 65 15,100 ± 1500*	18,000 ± 1000*
4	29,170 ± 110	
5	29,480 ± 135	
6	31,155 ± 140	
7	19,260 ± 90	
8	25,310 ± 125	53,000**

(\*) from Zhang (1988); (\*\*) Zhang (2001).

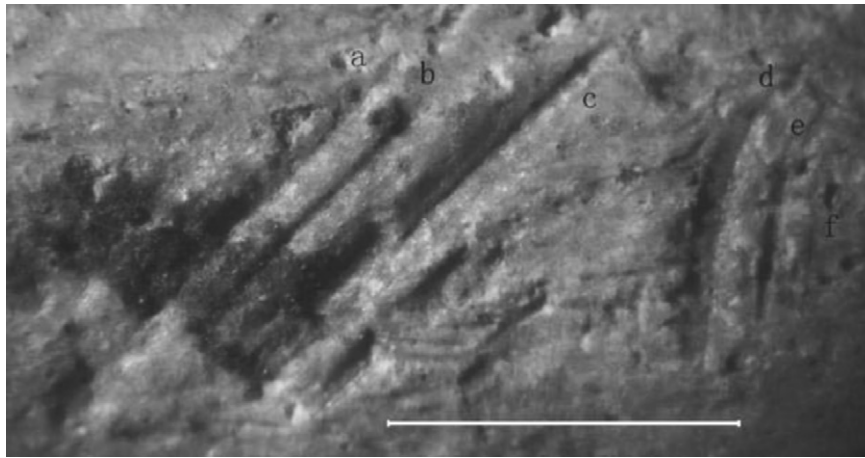


Fig. 4. Cut marks (a–e) on the surface of a bone at Ma'anshan (the scale is 2000  $\mu\text{m}$ ).

Having excluded carnivores, rodents and fluvial action as major bone modifying agents at Ma'anshan, we conclude that hominins were the primary agents of bone collection and modification at the site.

Cut marks on the Ma'anshan bones were identified using the criteria set forth by Blumenshine et al. (1996; see also Potts and Shipman, 1981): (1) a V-shaped cross section; (2) micro-striations often occurring inside the marks (Fig. 4c); (3) grouped cut marks often parallel to each other (see Fig. 4, a–c). In this research, only those whose surfaces were not badly damaged by weathering, biological and/or mineral staining were sampled for the cut mark analysis. The cut mark analysis is confined to the limb, rib and foot

bones because these elements are well represented in the faunal assemblages; other types of bones with well preserved surfaces from the upper or lower layers are too few to compare (Tables 2 and 3). Further, only the bones of class II and class III-sized animals (animal classification is seen in *Prey species abundance*) are considered, because the sample of class I and IV animals is too small (Tables 2 and 3).

The main focus of this analysis is evidence for hominin defleshing behavior. The surface of a long bone therefore is subdivided into epiphysis, near-epiphysis and mid-shaft areas of the element (Selvaggio, 1994). Carcass disarticulation often produces cut marks on the epiphyses, if the legs are segmented at the joints.

Table 2

Cut mark counts for long bones by element and portion of element from the upper and lower layers of the Ma'anshan site.

Bone element	Cultural layer	Long bone portion	Cut-marked NISP/total NISP (% cutmarked)		
			Class I	Class II	Class III
Humerus	Upper layer	Midshaft	1/5 (20)	3/20 (15)	2/9 (22.2)
		Epiphysis	1/7 (14.29)	0/3 (0)	0/1 (0)
		Near epiphysis	0/5 (0)	0/5 (0)	0/0 (–)
	Lower layer	Midshaft	0/4 (0)	9/12 (75)	26/71 (36.6)
		Epiphysis	0/0 (–)	0/2 (0)	8/16 (50)
		Near epiphysis	0/0 (–)	0/1 (0)	6/12 (50)
Femur	Upper layer	Midshaft	2/8 (25)	4/26 (15.4)	0/5 (0)
		Epiphysis	0/5 (0)	0/4 (0)	0/4 (0)
		Near epiphysis	2/2 (100)	0/2 (0)	0/1 (0)
	Lower layer	Midshaft	1/6 (16.67)	5/9 (55.5)	14/26 (53.8)
		Epiphysis	0/1 (0)	0/5 (0)	1/4 (25)
		Near epiphysis	0/0 (–)	0/2 (0)	0/2 (0)
Radius/Ulna	Upper layer	Midshaft	1/2 (50)	0/39 (0)	1/9 (11.1)
		Epiphysis	0/3 (0)	0/8 (0)	0/2 (0)
		Near epiphysis	0/3 (0)	0/10 (0)	0/1 (0)
	Lower layer	Midshaft	2/5 (40)	7/24 (29.2)	14/70 (20)
		Epiphysis	0/0 (–)	0/0 (–)	1/8 (12.5)
		Near epiphysis	0/0 (–)	0/2 (0)	1/9 (11.1)
Tibia	Upper layer	Midshaft	0/0 (–)	5/19 (26.3)	2/8 (25)
		Epiphysis	0/0 (–)	1/5 (20)	0/3 (0)
		Near epiphysis	0/0 (–)	0/4 (0)	0/0 (–)
	Lower layer	Midshaft	0/1 (0)	9/22 (40.9)	28/52 (53.8)
		Epiphysis	0/0 (–)	0/2 (0)	3/5 (60)
		Near epiphysis	0/0 (–)	0/0 (–)	4/7 (57.1)
Metapodial	Upper layer	Midshaft	0/3 (0)	7/111 (6.3)	0/5 (0)
		Epiphysis	0/4 (0)	9/68 (13.2)	2/17 (11.7)
		Near epiphysis	0/4 (0)	9/37 (24.3)	0/7 (0)
	Lower layer	Midshaft	0/0 (–)	7/28 (25)	5/33 (15.1)
		Epiphysis	0/0 (–)	0/5 (0)	3/20 (15)
		Near epiphysis	0/0 (–)	0/2 (0)	3/12 (25)

Note: Only those specimens whose surfaces were not badly damaged by weathering, biological and/or mineral staining were included in the cut mark analysis.

**Table 3**

Cut mark counts on elements other than long bones from upper and lower layers of the Ma'anshan site.

Bone element	Cultural layer	Cut-marked NISP/total NISP (% cutmarked)			
		Class I	Class II	Class III	Class IV
Rib	Upper layer	1/9 (11.1)	39/123 (31.7)	8/25 (32)	1/1 (100)
	Lower layer	0/0 (–)	6/22 (27.3)	6/39 (15.4)	3/13 (23.1)
Phalange	Upper layer	3/22 (13.6)	16/134 (11.9)	3/30 (10)	1/14 (7.1)
	Lower layer	0/2 (0)	0/11 (0)	2/7 (28.6)	0/1 (0)
Podial	Upper layer	1/2 (50)	2/121 (1.6)	1/9 (11.1)	0/3 (0)
	Lower layer	0/0 (–)	2/3 (66.7)	3/18 (16.7)	0/2 (0)
Cranium	Upper layer	0/2 (0)	2/6 (33.3)	0/0 (–)	0/0 (–)
	Lower layer	0/0 (–)	1/1 (100)	0/0 (–)	0/0 (–)
Mandible	Upper layer	1/1 (100)	3/14 (21.4)	1/4 (25)	0/0 (–)
	Lower layer	1/1 (100)	1/6 (16.7)	8/20 (40)	0/4 (0)
Vertebra	Upper layer	1/13 (7.7)	5/40 (12.5)	1/5 (20)	0/0 (–)
	Lower layer	0/0 (–)	2/7 (28.6)	2/6 (33.3)	0/2 (0)
Scapula	Upper layer	1/3 (33.3)	0/5 (0)	0/1 (0)	0/0 (–)
	Lower layer	0/1 (0)	0/1 (0)	1/2 (50)	0/0 (–)
Pelvis	Upper layer	1/1 (100)	0/2 (0)	0/0 (–)	0/0 (–)
	Lower layer	0/1 (0)	0/1 (0)	1/5 (20)	0/0 (–)

Since the near-epiphysis area of the bone surface is transitional between the epiphysis and the midshaft, Capaldo (1997) proposed that only unskilled butchers would leave cut marks here. Binford (1981), based mainly on his ethnoarchaeological work with Nunamiut butchers (Binford, 1978), found that cut marks on the near-epiphysis areas of some long bones likely represent defleshing activities, because large muscles are attached. It is widely agreed that cut marks found on the midshafts of upper long bones reflect defleshing, because they tend to be covered by meat (e.g., Binford, 1978, 1981; Domínguez-Rodrigo, 1997a; Domínguez-Rodrigo and Barba, 2005; Capaldo, 1997; reviewed by Lyman, 1994). Metapodials are covered mainly with skin and tendons, so cut marks on these elements tend to be from skinning, sinew removal or disarticulation, but not defleshing.

Domínguez-Rodrigo (1997b) hired Maasai and Mwalangulu people (south-eastern Kenyan herders, formerly hunters) to butcher and completely deflesh zebra and wildebeest (200 kg live weight), animals that are generally similar in size to *C. unicolor*, using stone tools. Fig. 5 compares the cut mark frequencies of the long bone midshafts of class II sized animals in the Ma'anshan site with those from Domínguez-Rodrigo's "hominid first or hominid only" defleshing experiment. The values for the lower layer of Ma'anshan are relatively high and fall within Domínguez-Rodrigo's 95% confidence intervals. Most of the data for the upper layer fall well below. For the class III-sized animals, the cut mark percentages for long bone midshafts from the lower layer are also higher (Fig. 6). It is thus possible that the earlier hominins at Ma'anshan defleshed upper and middle limbs more completely than did the later occupants, but we note that the tools were also much larger and perhaps more likely to leave traces on the bones.

Rib shafts also have significant amounts of meat attached to them. A comparison of cut mark frequencies on ribs and meaty limb bones may indicate whether the hominins defleshed them to different extents. In the upper layer, the cut mark percentages for the ribs of class II and III-sized animals (32% and 32% of NISP, respectively) are a little higher than the highest cut mark frequencies (26% and 25%) for the upper and middle limbs. Cut mark frequencies for ribs of class II and III-sized animals in the lower layer (27% and 15%) are much lower than the highest value of the upper and middle limbs (75% and 54%). The later hominins defleshed limbs and ribs with nearly equal completeness, whereas the earlier hominins defleshed limbs more completely than ribs. These results indicate that differently sized stone tools do not explain the differing cut mark frequencies on the limb bones.

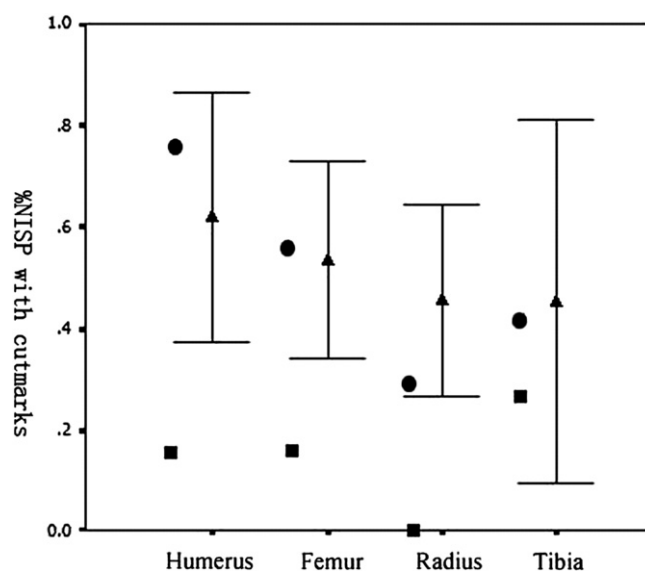


Fig. 5. The comparison of cut mark percentages of the long bone midshafts of class II sized animals from Ma'anshan with those from the experimental data (shown by triangles within confidence intervals) of Domínguez-Rodrigo (1997b). Filled circles represent the cut mark percentages of the lower layer; filled square represent the cut mark percentages of the upper layer.

From the ethnographic analogues, Gifford-Gonzalez (1989) found that bones covered by meat during roasting generally do not get burned but those no longer covered by flesh will be burned. Buikstra and Swegle (1989) reached a similar conclusion via experiment, and that the partially burned bones (PBB) tend to result from roasting. In Ma'anshan, there are 6.3% and 2.1% burned bones of the NISP in the two layers, respectively. In the upper layer, the PBB percentage is 35.96% of all the burned bones, which is higher than 14.81% PBB in the lower layer. The PBB percentage of the upper and middle limbs of class II and III-sized animals is 2.49% and 4.08% in the upper layer. In the lower layer, the corresponding data are lower at 0 and 0.56%. It therefore is assumed that more animal limbs were cooked during the formation of the upper layer than in the lower layer. It is easier to remove cooked meat from bones than raw meat with stone tools, hands or teeth. Roasting practices may reduce the incidence of the cut marks. So the lower cut mark frequencies for the limbs in the upper layer may indicate that the later hominins were more likely to roast the limbs of large prey.

Cut marks also occur on the ungulate phalanges. The frequencies of cut marks on the first and second phalanges of all body size classes range between 7 and 17% of NISP in the upper layer. There is little meat on phalanges, so the cut marks on these elements could

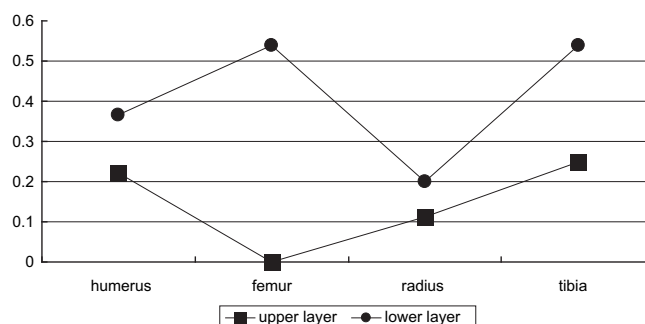


Fig. 6. The cut mark percentages of the long bone midshafts of class III-sized animals.



**Table 4**  
Macromammal bone counts in the upper and lower layers of the Ma'anshan site.

Vertical unit Taxon/body size class	English names	UL				LL			
		NISP	NISP %	MNI	MNI %	NISP	NISP %	MNI	MNI %
<i>Macaca</i> sp.	Monkey	23	0.89	6	12	6	0.46	3	9.38
<i>Stegodon orientalis</i>		9	0.35	2	4	18	1.39	7	21.88
<i>Viverra</i> sp.	Civet	1	0.04	1	2				
<i>Meles</i> sp.	Badger	2	0.08	1	2				
<i>Felis microtus</i>	Wild cat	1	0.04	1	2				
<i>Canis</i> sp.	Wolf	5	0.19	3	6	1	0.08	1	3.13
<i>Ursus</i> sp.	Bear	92	3.54	2	4	1	0.08	1	3.13
<i>Ailuropoda</i> sp.	Panda	14	0.54	1	2	5	0.39	1	3.13
<i>Muntiacus</i> sp.	Muntjac	41	1.58	3	6	2	0.15	2	6.25
<i>Cervus unicolor</i>	Sambar	2010	77.43	19	38	325	25.14	3	9.38
<i>Capricornis</i> sp.	Serow	5	0.19	1	2				
<i>Bubalus</i> sp.	Water buffalo	325	12.52	5	10	830	64.19	6	18.75
<i>Sus</i> sp.	Pig	5	0.19	1	2	2	0.15	1	3.13
<i>Rhinoceros sinensis</i>	Chinese rhino	49	1.89	3	6	98	7.58	5	15.63
<i>Megatapirus augustus</i>	Giant tapir	14	0.54	1	2	5	0.39	2	6.25
Class I sized macromammal		156				36			
Class II sized macromammal		87				8			
Class III-sized macromammal		51				100			
Class IV sized macromammal		2				29			
Total:		2892				1466			

Note: (UL) Upper layer; (LL) Lower layer. NISP counts by taxon-specific and body size classes are combined; MNI, MNI% and NISP% counts are for taxon-specific identifications only.

be related to skinning and sinew removal, and perhaps also in connection with marrow processing (Binford, 1981). In the lower strata, cut marks are present only on the first phalanges of Class III-sized animals, and the frequency is higher at around 29%. The apparent bias to first phalanges is an artifact of transport patterns in this case, as there were very few phalanges in the lower layer of Ma'anshan (see below). Those that were carried to the cave were processed in a manner similar to that observed for the later assemblage.

## 5. Prey species abundance

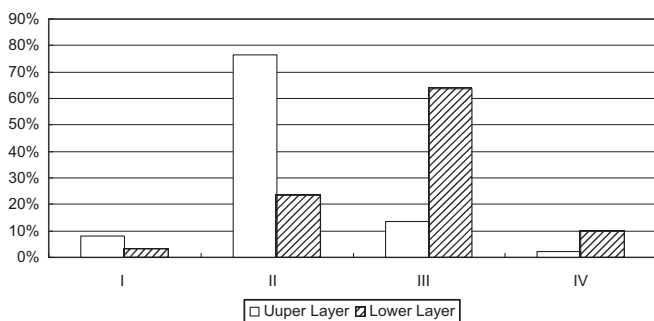
Fifteen large mammal genera (>10 kg) were identified, mainly from diagnostic teeth and antler specimens (Table 4). *C. unicolor* is the most common mammal in the upper layer. This species is also present in the lower cultural layer, but the much larger ungulate, *Bubalus* sp., dominates the assemblage. There therefore is a significant decrease in the mean body size of the mammals from the earlier to the later cultural period.

To explore differences in the relative importance of large, medium-sized, and small prey animals in the upper and lower layers, the Ma'anshan faunal remains were divided according to body size classes as defined by Brain (1981). At Ma'anshan, Class I (10–50 kg) includes *Macaca* sp., *Viverra* sp., *Meles* sp., *Felis microtus*,

*Canis* sp., *Muntiacus* sp., and *Capricornis* sp.; Class II (100–200 kg) includes *Ursus* sp., *Ailuropoda* sp., *C. unicolor*, and *Sus* sp.; Class III (300–1000 kg) is principally *Bubalus* sp. and *Megatapirus augustus*; Class IV (1000–3000 kg) includes *Rhinoceros sinensis* and *Stegodon orientalis*. This approach increased the sample size for each assemblage, since bones that could be identified to skeletal element and size class, but not to species, could be included in the comparison.

Small and medium-sized animals are much more common in the upper layer (Fig. 7). The percentage of Class II animals in the upper layer is 76% of NISP, of which 69.5% is *C. unicolor*, while the percentage of classes III is only 13.49%. In the lower layer, the percentage of Class III animals is 64% of NISP, and *C. unicolor* constitutes only 22% of the faunal assemblage.

Another contrast in prey selection between the upper and lower cultural layers concerns the exploitation of small game animals. There is no evidence for small game hunting in the lower layer of Ma'anshan, but 334 small or micro-mammal and bird bone specimens were unearthed from the upper layer. These remains represented nine species/genus of small mammals and birds and thirty four individuals (Table 5). Of the small prey animals, 79% of NISP and 50% of MNI belonged to the bamboo rat (*Rhyzomys* sp.). Averaging 2 kg in live weight, the bamboo rat is nearly as productive as lagomorphs, because females may give birth to three to five infants



**Fig. 7.** The NISP profile of the I-IV sized animals in the upper and lower layers of the Ma'anshan site.

**Table 5**  
Bird and micro-mammal bone counts for the Ma'anshan site.

Animal group	NISP	Latin name	NISP (tooth)	NISP (post cranial)	MNI
Micro-mammal	313	<i>Rhyzomys</i> sp.	114	151	17
		<i>Anourosorex squamipes</i>	1	2	2
		<i>Hystrix</i> cf. <i>subcristata</i>	15	0	2
		<i>Petaurista sulcatus</i>	1		1
		<i>Trogopterus xanthipes</i>	1		1
		Unidentified rodent	28		3
Aves	21	<i>Anser</i> sp.		2	1
		<i>Crossoptilon mantchuricum</i>		4	1
		<i>Phasianus colchicus</i>		1	1
		<i>Sturnus</i> sp.		1	1
		Unidentified bird		13	4
Total	334				34

1–2 times per year and these infants develop rapidly. This animal is still eaten in some areas of south China and is considered to be very good meat. Bamboo rats could represent a reliable alternative meat source. Yuchanyan, though apparently younger (>10ka BP, Prendergast et al., 2009) than Ma'anshan, is a broadly comparable site in South China (around 550 km southeast of Ma'anshan site) in that it also contains the remains of bamboo rat, along with a wide array of birds and other small animals. The micro-mammals and birds indicate considerable broadening of the diet after 30 ka at the Ma'anshan site and could indicate an early beginning for the Broad Spectrum Revolution (cf. Flannery, 1969; Stiner, 2001; Stiner et al., 1999) in South China.

## 6. Skeletal element representation

In order to compare the patterns of skeletal element representation among mammal body size classes in the two layers, bone elements are classified according to minimum anatomical units (MAU) and standardized as percentages of the most common element (Table 6, Fig. 8) following Binford (1978; see also review by Lyman, 1994). There are both similarities and differences between the skeletal element profiles of the upper and the lower layers. First, teeth generally are more common in both layers, and in some cases much more common, than expected relative to most but not all bone elements.

Focusing only on the relative representation of bone elements (i. e., excluding dental elements), the assemblages from the upper and lower cultural layers are similar with respect to the poor representation of vertebrae, ribs, scapulas and pelvises (Table 3), and no atlas and axis vertebrae were found. This could reflect hominin

transport decisions (e.g., Perkins and Daly, 1968; Binford, 1978; Lupo, 2001) or a bias caused by density-mediated bone destruction, since many parts of the poorly represented elements include soft spongy structures (Lyman, 1984). Another similarity between the upper and lower layer assemblages concerns the Class IV mammals, for which there are cranial, carpal/tarsal, metapodial and phalangeal elements, to the near exclusion of other skeletal parts. This may be because the bones of rhinos and elephants are exceptionally heavy, and hominins defleshed parts of the animals at the death site and took only some of the soft tissues back to the cave. It seems unlikely that these parts would be of nutritional interest to the hominins if they also had access to massive muscles of such large animals. Hence it is possible that these body parts were remnants of the carcasses, still available at the time of encounter and still containing some food value. Because the head and foot parts are structurally complex, it is difficult to obtain all the nutrition from them in a short time (Madrigal and Holt, 2002), so the hunters may have chosen to take them back to camp for processing.

A wider range of body parts are represented for the Class I-III mammals. The anatomical biases to the major limb bones (humerus, radius, femur, tibia) are especially pronounced in the lower layer, where MAU values for Class III animals are even higher for some limb bones than for head parts, even when head parts are calculated from teeth rather than bone (Fig. 8). The MAU percentages for metapodials, carpals/tarsals and phalanges in the lower layer are much lower than those for the upper and middle limbs, while in the upper layer the values of foot bones are equal to or higher than those of the upper or middle limbs, and for the class II sized animals, the carpal/tarsal percentages are even equal to that

**Table 6**

Skeletal element data (NISP, MAU and MAU%) for animals by body size class from the upper and lower layers of Ma'anshan site.

Upper layer	Class I			Class II			Class III			Class IV		
	NISP	MAU	MAU%	NISP	MAU	MAU%	NISP	MAU	MAU%	NISP	MAU	MAU%
Cranium (tooth)	34	16	100	373	21	100	66	6	100	14	5	100
Cranium (mandible)	5	0.55	3.44	56	6.95	33.1	7	1	16.67	0	0.1	2
Vertebra	21	1	6.25	85	3.14	14.95	12	0.33	5.5	0	0	0
Rib	20	0.12	0.75	276	1.304	6.2	51	0.32	5.33	2	0.02	0.32
Scapula	5	2.5	15.63	15	5.5	26.2	2	0.55	9.17	0	0	0
Humerus	37	2.6	16.25	123	6.25	29.76	32	1.5	25	0	0	0
Radius/Ulna	13	3.25	20.31	144	10	47.62	29	2	33.33	0	0	0
Pelvis	2	0.75	4.69	4	0.65	3.1	2	0.5	8.33	0	0	0
Femur	32	2.3	14.38	59	4.85	23.1	13	1	16.67	0	0	0
Tibia	2	0.5	3.13	75	6.5	31	24	3	50	0	0	0
Carpal/tarsal	2	1	6.25	190	21	100	18	3	50	8	2	40
Metapodial	18	1.6	10	475	15.67	74.62	48	2.2	36.67	3	0.18	3.5
Phalange	37	1.75	10.94	298	10.83	51.57	70	2.31	38.5	31	1.63	32.6
Cranial (fragment)	4			7			0			2		
Sesamoid	2			28			16			0		
	234			2208			390			60		
Lower layer												
Cranium (tooth)	4	4	100	15	7	100	80	8	48.34	90	12	100
Cranium (mandible)	1	0.1	2.5	8	0.5	7.14	33	4	24.17	10	0.7	5.83
Vertebra	0	0	0	12	0.429	6.13	10	0.4	2.42	1	0.1	0.83
Rib	0	0	0	43	0.183	2.61	81	0.44	2.66	29	0.09	0.73
Scapula	1	0.5	12.5	1	0.5	7.14	3	0.25	1.51	0	0	0
Humerus	5	0.5	12.5	26	1.4	20	187	11.7	70.69	0	0	0
Radius/Ulna	12	1	25	53	4	57.14	184	16.6	100	0	0	0
Pelvis	1	0.5	12.5	2	0.5	7.14	7	1.5	9.06	0	0	0
Femur	11	1.25	31.25	19	1.25	17.86	58	5.9	35.65	0	0	0
Tibia	2	0.4	10	38	2	28.57	107	7.43	44.89	0	0	0
Podial	0	0	0	13	2	28.57	28	6	36.25	5	2	16.67
Metapodial	2	0.1	2.5	62	2.9	41.43	92	3.69	22.3	2	0.03	0.21
Phalange	2	0.155	3.88	30	1.05	15	24	0.69	4.15	7	0.5	4.17
Cranial (fragment)	2			4			1			1		
Sesamoid	2			15			40			0		
	45			341			935			145		



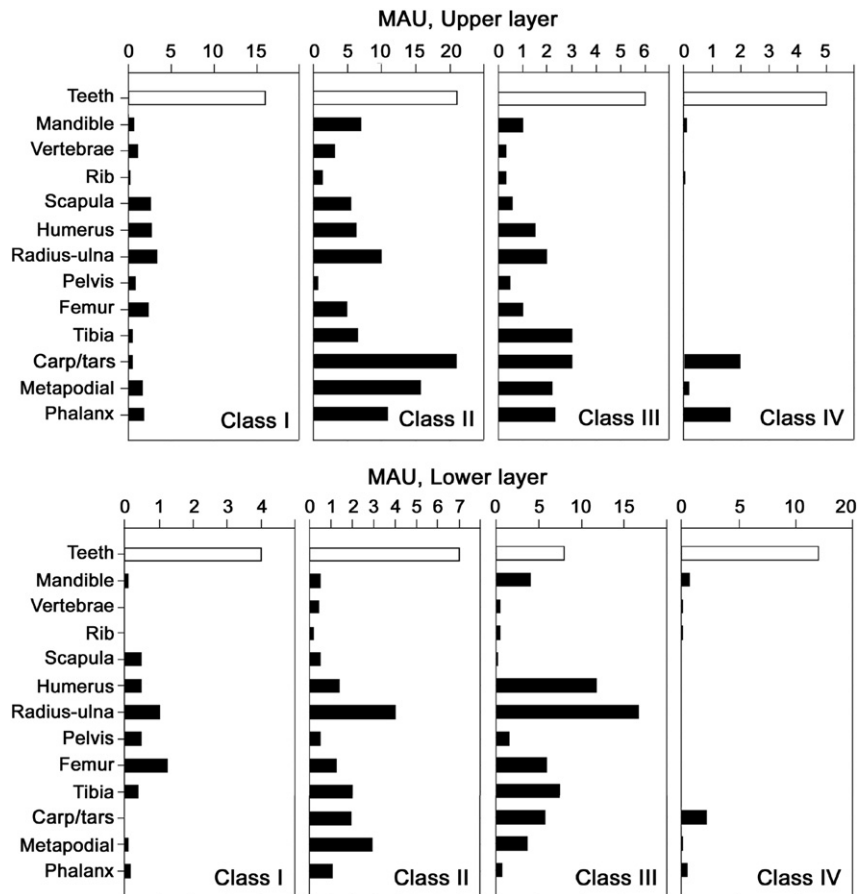


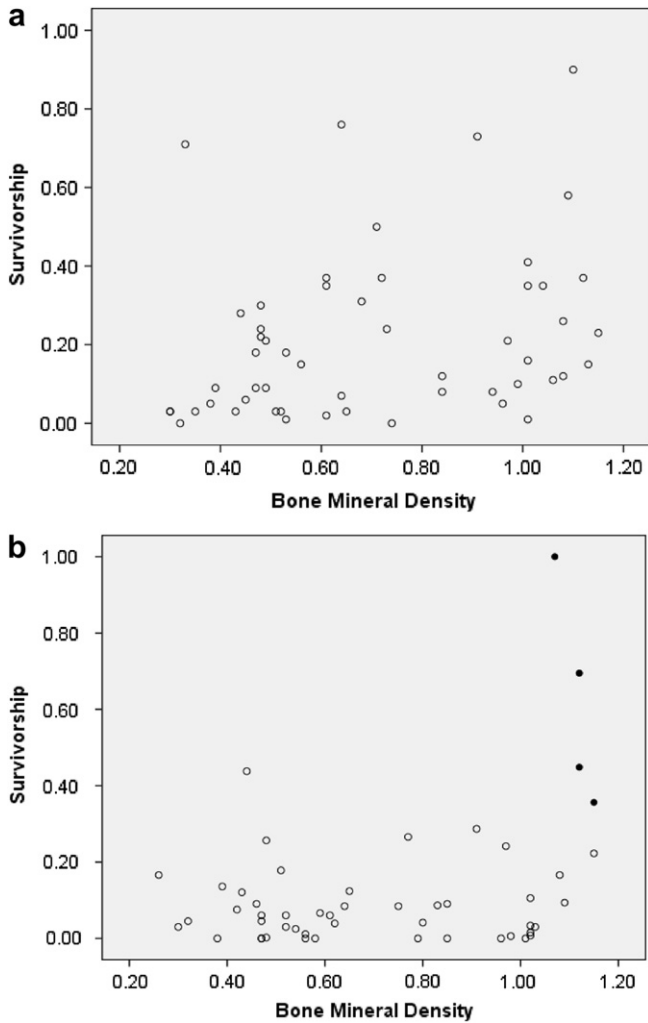
Fig. 8. The skeletal element profiles of the upper and lower layers at Ma'anshan, with bone-based and tooth-based cranial MAU values shown separately.

for cranial parts as determined from teeth. The metapodials of Class I–III mammals have bulk densities similar to those of the long bone midshafts (Lam et al., 1999; Lyman, 1994), and the densities of some portions of the phalange or carpal/tarsal are only somewhat lower. Furthermore, while the density of tooth elements generally is much higher (Lyman, 1994), the observed MAU percentages for the teeth of Class III-sized animals at Ma'anshan are much lower than those for the major limb bones. When plotting the values of the survivorship frequencies of *Cervus unicornar* in the upper layer and *Bubalus* in the lower layer (the two assemblages were chosen because they are the largest samples of the either layer) and the bone densities of the deer and the bovid (Lam et al., 1999; when  $BMD_2$  was available, standards that are adjusted to account for external and internal bone cavity shape, it is used;  $BMD_1$  is used in all other instances), the difference in the representation of these body parts in Ma'anshan greatly exceeds what would be predicted from differences in structural density. The scatterplot of the two variables for the *Cervus unicornar* bones in the upper layer suggests that the correlation coefficient is significant, but there is a moderately weak relation based on the  $r^2$  values (Pearson  $r = 0.28$   $p = 0.042$ , Spearman's rho or  $r_s = 0.36$   $p = 0.008$ , Fig. 9a, Table 7). A reasonable conclusion would be that the structural density of the skeletal parts exerted, at most, only a minor influence on the frequencies of skeletal parts. For the *Bubalus* bone assemblage in the lower layer, there is weak correlation between the two variables based on the Pearson  $r$  ( $r = 0.35$   $p = 0.01$ ), while the  $r_s$  indicates an insignificant relationship ( $r_s = 0.232$   $p = 0.095$ ). Fig. 9b shows that there are four outliers (filled circles); when these are excluded, there is no significant correlation between the two variables

( $r = 0.031$   $p = 0.834$ ;  $r_s = 0.034$   $p = 0.814$ , Table 7). All the four points belong to the upper and middle limbs, the humerus (HU3), the femur (FE4), the radius (RA3) and the tibia (TI3), which not only are quite high densities according to Lam et al.'s (1999)  $BMD_2$  standard (HU3 = 1.12, FE4 = 1.15, RA3 = 1.01, TI3 = 1.12), but also associate with higher general utility or marrow index values. These results collectively indicate that density-mediated attrition could not have had a significant influence on the skeletal element profiles.

No significant relations was found between the food utility index (FUI, Metcalfe and Jones, 1988; Emerson, 1990) and element representation (in the upper layer for *Cervus*:  $r = -0.269$   $p = 0.314$ ;  $r_s = -0.272$   $p = 0.308$ ; in the lower layer for *Bubalus*:  $r = 0.135$   $p = 0.618$ ;  $r_s = -0.062$   $p = 0.819$ ). On the other hand, marrow utility does seem to explain some of the variation in ungulate body part representation in the lower layer. Body part representation for *Bubalus* is very significantly correlated to an index of marrow utility (Binford, 1978;  $r = 0.699$   $p = 0.003$ ;  $r_s = 0.820$   $p = 0.000$ ). This is not the case for *Cervus* in the upper layer, for which the relation is non-existent ( $r = 0.428$   $p = 0.098$ ) or very weak ( $r_s = 0.587$   $p = 0.017$ ).

We conclude, therefore, that the higher percentages of upper and middle limbs in the lower layer are not explained by differential preservation, but instead reflect a situation of selective transport by the hominins. While the body part profiles by prey size class are not extremely different between the two layers, the earlier occupants of Ma'anshan site were more likely to carry back marrow-rich limb bones preferentially, and they tended to abandon foot bones at kill sites.



**Fig. 9.** Scatterplot of survivorship against bone mineral density values. a. Values of *Cervus unicolor* skeletal parts from the lower layer of Ma'anshan; b. Values of *Bubalus* skeletal parts from the lower layer of Ma'anshan.

### 7. Mortality patterns

The most common technique for estimating a mammal's age at death uses eruption and wear observations for deciduous and permanent teeth. In this study, occlusal wear is measured as the crown height, corrected for individual differences in tooth breadth, and by following standard wear stages (Brown and Chapman, 1991; Grimsdell, 1973; Hillman-Smith et al., 1986; Haynes, 1987, 1991; reviewed by Hillson, 1986:205–256). Unfortunately, all the teeth from Ma'anshan are isolated from the jaws. This analysis is confined to the teeth of *C. unicolor* (NISP 325 from the upper layer, 14 from the lower layer), *Bubalus* sp. (44, 74), *R. sinensis* (12, 75), *Stegodon orientalis* (2, 16), and *Macaca* sp. (20, 3). The very small samples available for *C. unicolor* and *Macaca* sp. in the lower layer, and *R. sinensis* and *S. orientalis* in the upper layer (Table 8), could not be included in the mortality analysis (a detailed analysis is presented in Zhang et al., 2009).

The age cohort data for the larger dental samples were converted to percentages (juveniles, prime adults and old adults) and plotted on a tripolar graph in relation to established mortality models (Stiner, 1990) (Fig. 10). The mortality profiles of *C. unicolor*, *Bubalus* sp., and *R. sinensis* all show a pattern of non-selective mortality that generally resembles the expected living structure of

**Table 7**

Body part representation data according to scan sites (following Lam et al., 1999) for *Cervus unicolor* from the upper layer and for *Bubalus* from the lower layer of Ma'anshan site.

<i>Cervus unicolor</i>	MNE	MAU% <sup>a</sup>	BMD	<i>Bubalus</i>	MNE	MAU% <sup>a</sup>	BMD
AC1	2.3	0.068	0.64	AC1	2.8	0.085	0.64
Astragalus*	26	0.765	0.67	Astragalus*	8.8	0.266	0.72
Calcaneum*	12	0.353	0.61	Calcaneum*	2.8	0.085	0.73
CE1-CE2*	5.5	0.065	0.44	CE1-CE2*	1	0.060	0.495
DN1	1	0.029	0.65	DN1	0	0.000	0.52
DN2-DN5*	3.65	0.107	1.06	DN2-DN5*	3.1	0.094	1.05
DN6	2.8	0.082	0.84	DN6	0	0.000	0.85
DN7	13.9	0.409	1.01	DN7	8	0.242	0.97
DN8	3.55	0.104	0.99	DN8	1	0.030	1.03
FE1	3	0.088	0.39	FE1	4.5	0.136	0.41
FE2	1	0.029	0.52	FE2	1	0.030	0.51
FE3	0	0.000	0.74	FE3	1	0.030	0.92
FE4	7.8	0.229	1.15	FE4	11.8	0.356	1.16
FE5	0.8	0.024	0.61	FE5	2	0.060	0.66
FE6	0	0.000	0.32	FE6	1.5	0.045	0.38
FE7	1	0.029	0.3	FE7	1	0.030	0.31
HU1	1	0.029	0.26	HU1	5.5	0.166	0.32
HU2	9.5	0.279	0.44	HU2	14.5	0.438	0.49
HU3	12.5	0.368	1.12	HU3	23	0.695	1.10
HU4	4	0.118	1.08	HU4	5.5	0.166	1.03
HU5	8	0.235	0.48	HU5	8.5	0.257	0.51
IL1	1	0.029	0.43	IL1	4	0.121	0.39
LU1-LU2*	22	0.185	0.47	LU1-LU2*	0	0.000	0.55
LU3	3.5	0.029	0.51	LU3	0	0.000	0.56
MR1+MC1*	24.68	0.896	0.91	MR1+MC1*	5.75	0.087	0.775
MR3+MC3*	60.95	0.726	1.09	MR3+MC3*	14.75	0.223	1.145
MR6+MC6*	42.45	0.312	0.635	MR6+MC6*	8.2	0.124	0.635
NC1-NC3*	24	0.706	0.576	NC1-NC3*	1.3	0.039	0.61
P11	41.2	0.303	0.48	P11	3.3	0.025	0.54
P12	20.9	0.154	0.92	P12	1	0.008	1.02
P13	68.55	0.504	0.71	P13	5.5	0.042	0.8
P21	49.7	0.365	0.61	P21	6	0.045	0.47
P22	50.8	0.374	0.72	P22	1.5	0.011	0.56
P31	30.3	0.223	0.48	P31	0	0.000	0.53
RA1	6.2	0.182	0.53	RA1	5.9	0.178	0.51
RA2	8.8	0.259	1.08	RA2	3.5	0.106	1.02
RA3	19.8	0.582	1.09	RA3	33.1	1.000	1.07
RA4	7	0.206	0.97	RA4	0	0.000	0.96
RA5	7	0.206	0.49	RA5	0	0.000	0.47
RI1	38.5	0.087	0.47	RI1	1	0.002	0.48
RI3	21.5	0.049	0.96	RI3	1	0.002	1.02
RI4-RI5*	35.77	0.081	0.67	RI4-RI5*	14.5	0.034	0.695
SP1	12	0.353	1.01	SP1	0.5	0.015	1.02
SP2	12	0.353	1.04	SP2	0	0.000	1.01
SP4	0.2	0.006	1.01	SP4	0.2	0.006	0.98
TH1	10.5	0.048	0.38	TH1	0	0.000	0.38
TH2	2.5	0.011	0.53	TH2	0	0.000	0.47
TI1	1	0.029	0.35	TI1	2.5	0.076	0.42
TI2	5.6	0.165	1.01	TI2	9.5	0.287	0.91
TI3	5.1	0.150	1.13	TI3	14.85	0.449	1.12
TI5	8	0.235	0.73	TI5	2.2	0.066	0.59
UL1	3	0.088	0.49	UL1	3	0.091	0.46
UL2	4	0.118	0.84	UL2	3	0.091	0.85

Notes: (\*) We averaged the BMD values for these portions. <sup>a</sup> *Cervus* MAU% based on MAU for teeth (17), *Bubalus* MAU% based on MAU for the radius (33.1).

the prey populations. Ambush hunting by the hominins could explain this mortality age profile, including the use of landscape trapping strategies. Though the mortality data are limited by small samples, there is no very obvious difference in the prey age selection for the herbivores in the earlier and later periods of Ma'anshan, and there is no apparent bias to prime-aged adults in these species.

The mortality age profile of *Macaca* sp. is biased to prime adult individuals. Ethnographic studies show that Piro and Machiguenga foragers tend to hunt prime-age adult monkeys (82% and 73%), even though juveniles are more common in the living monkey population (61%) in the Manu Natural Park (Michael and Hillard, 1991), because adult monkeys have a higher fat content.

**Table 8**

The mortality age profiles of larger mammals from the upper and lower layers of the Ma'anshan site based on dental remains.

Species	Cultural layer	Tooth count	MNI	Juvenile		Prime adult		Old adult	
				% MNI	% MNI	% MNI	% MNI		
<i>Cervus unicolor</i>	Upper layer	325	17	29.4	5	47.1	8	23.5	4
	Lower layer	14	2	50	1	50	1	0	0
<i>Bubalus sp.</i>	Upper layer	44	5	20	1	60	3	20	1
	Lower layer	74	6	16.7	1	66.7	4	16.7	1
<i>Rhinoceros sinensis</i>	Upper layer	12	3	33.3	1	66.7	2	0	0
	Lower layer	75	5	20	1	60	3	20	1
<i>Stegodon orientalis</i>	Upper layer	2	2	100	2	0	0	0	0
	Lower layer	16	7	85.7	6	14.3	1	0	0
<i>Macaca sp.</i>	Upper layer	30	6	0	0	83.3	5	16.7	1
	Lower layer	3	3	0	0	100	3	0	0

Note: The MNI calculation is based on the number of certain teeth, qualified by wear data. For *Cervus unicolor* and *Bubalus sp.*,  $M_3$  and  $dp_4$  are counted; the MNI of *Rhinoceros sinensis* is calculated from the number of  $M^3$  and deciduous teeth; most *Macaca sp.* teeth are upper molars, and the MNI is based on counts of the  $M^1$  and  $M^2$ . As for *Stegodon orientalis*, only one or two teeth can be in wear per quadrant at the same time, so the MNI calculation uses the morphology and wear condition of all the teeth (see Zhang et al., 2009).

The prime dominant age profile of *Macaca sp.* in Ma'anshan upper layer may also be explained by the hominins' need for dietary fat.

The mortality age profile of *S. orientalis* in the upper layer is also distinct from the patterns for the other large mammals. Juveniles were preferred, possibly because adults were too dangerous to hunt. One ethnoarchaeological study reports that the Liangula hunters in east Kenya, who hunted elephant for meat (not for tusks), preferred to prey upon juveniles because their meat tasted better (Holman, 1967). However, adult elephant meat is consumed by a variety of African groups today (e.g., Taylor, 1962; Schapera and Goodwin, 1937; Bailey, 1991; Janmart, 1952), so "taste" is not sufficient to explain the difference in prey age selection. Hominins at Ma'anshan probably preyed on juvenile *S. orientalis* because the calves were easier to kill, particularly if already stranded or separated from the mother or maternal herd.

It is interesting that a number of *R. sinensis* teeth from the lower layer were from prime adult individuals, which implied that the

hominids had no age bias on rhino huntings. This contrast, as well as the contrasting *Stegodon* mortality patterns between the upper and lower layers is intriguing. The samples available for comparison are quite small, however, and more data are needed to fully evaluate the implications of the observed differences in the Ma'anshan site.

## 8. Concluding discussion

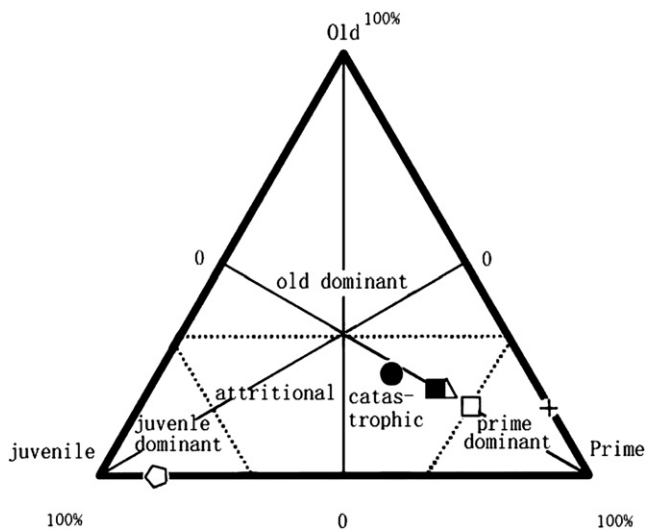
The analyses of species abundance, skeletal element representation, cut marks, and mortality patterns indicate that the occupants of the upper layer in Ma'anshan Cave hunted mainly medium-sized ungulate prey. The hunters brought meaty parts of their prey back to a base camp, where they defleshed both limbs and ribs with equal energy, and probably were more likely to roast these parts than the earlier hominids. To the extent that ribs are present in the lower layer, defleshing efforts were directed mainly to limb bones and much less to ribs.

Mortality patterns indicate a non-selective pattern for most of the herbivores, but the later occupants also hunted juvenile *Stegodon orientalis*, perhaps because of its edibility or, more likely, because the hunters were ill-equipped to attack adults. By contrast, adult *Stegodon* remains do occur in the lower layer, and this raises the question of whether these animals were obtained mainly by hunting or scavenging. Adult *Stegodon* was exceptionally large animals and represented one extreme in the prey body size range of animals consumed by the hominins at the cave. The occupants of Ma'anshan also hunted terrestrial monkeys. The strong preference for prime adult monkeys likely was a response to their higher fat yield.

Later hominins at Ma'anshan Cave appear to have made fuller use of herbivore carcasses on site than did the earlier occupants, and the prey spectrum suggests that they had somewhat broader diets as well. Hominin hunting may have played a part in restructuring of prey communities as the ratio of hunters to prey increased. It is also possible it is due to the environmental change, although the sporopollen analysis showed that there were few differences between the plants and the paleoenvironment of the earlier and later periods of the Ma'anshan site (Zhang, 2008). According to the dating results, the lower layer belongs to the interstadial period MIS 3 of the Last Glacial. In South China, MIS 3 was warm and wet (Huang and Zhang, 2006), and extensive broad-leaved forests would have supported large herbivores such as *Bubalus sp.* Environmental conditions became colder and drier after 30 ka (Huang and Zhang, 2006), and it is possible that some of the larger herbivores became scarcer in the environment.

A decline in the availability of the most profitable types of prey would force hunters to turn of less profitable types (Stephens and Krebs, 1986). If this condition is sustained for long periods, human populations must either shrink or evolve a new and more efficient adaptation. The new type of tools (including formal bone tools) and broadening of the meat diet imply that hominids had developed a new adaptation in the later period at Ma'anshan. There is no evidence of small game hunting in the lower layer of Ma'anshan, but a significant amount of small mammal and bird remains occur in the upper layer, and nearly 80% of these remains are from the bamboo rat. The zooarchaeological data show that smaller, more productive animals were being exploited in the later period (i.e., small mammals, birds and smaller ungulates, Table 5), and that large mammal carcasses were being processed more thoroughly (for general discussions, see Stiner, 2001; Stiner and Kuhn, 2006; Stiner and Munro, 2000).

The bone assemblages from the upper and lower layers of the Ma'anshan site provide zooarchaeological support for distinguishing the Chinese Early and Late Paleolithic. These and other data also



**Fig. 10.** Triangular graph of mortality age of Ma'anshan site. □ *Stegodon orientalis* (lower layer); ■ *Bubalus sp.* (upper layer); ▲ *Rhinoceros sinensis* (lower layer); ● *Cervus unicolor* (lower layer); □ *Bubalus sp.* (lower layer); + *Macaca sp.* (upper layer).

generally support a temporal boundary at roughly 30–27 ka BP, especially if combined with information on the broader chronology of technological changes in China. The bone assemblage from the upper layer, dated to ca. 15–31 ka, also indicates some differences in hominin economic behaviors in comparison to the earlier occupation at ca. 53 ka. As intensive zooarchaeological studies of Paleolithic faunal assemblages are still very few in China, a full evaluation of this conclusion will require study of other archaeofaunal collections in this part of the world.

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