

## Diet breadth and mortality patterns from Laoya Cave: A primary profile of MIS 3/2 hunting strategies in the Yunnan-Guizhou Plateau, southwest China

WANG XiaoMin<sup>1,2,3</sup>, GUAN Ying<sup>1</sup>, CAI HuiYang<sup>4</sup>, Sandrine COSTAMAGNO<sup>3</sup>,  
ZHANG LiMin<sup>1</sup>, XU ChunHua<sup>1</sup> & GAO Xing<sup>1\*</sup>

<sup>1</sup> Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China;

<sup>2</sup> University of Chinese Academy of Sciences, Beijing 100049, China;

<sup>3</sup> TRACES, CNRS, Toulouse 31058, France;

<sup>4</sup> Guizhou Provincial Museum, Guiyang 550001, China

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**Abstract** Laoya Cave is a long-term occupation site of Late Paleolithic humans in the Yunnan-Guizhou Plateau, southwest China, where abundant lithic, bone materials were recovered. Dating by the AMS technique showed a significant depositional process during marine isotope stage (MIS) 3/2. In this study, the species spectrum was presented from the perspective of zooarchaeology and the mortality profile of large Cervidae was examined to help increase our understanding of the subsistence strategy of local people dealing with climate and environmental changes. The main part of the diet was focused on large Cervidae, and the dominance of Ungulates indicates effective management of the cave and local fauna. On the other hand, the mortality profiles of large Cervidae varied correspondingly with climate change. The evidence indicates a specialized hunting strategy that was also flexible, depending on the prevailing climate and environment.

**Keywords** Cervidae, Late Paleolithic, Southwest China, MIS 3, Zooarchaeology, Survival strategy

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### 1. Introduction

For decades, archaeofaunal research on Late Paleolithic (about 30–10 ka BP; Gao and Norton, 2002) sites in China has been biased methodologically toward paleontology (e.g. Li, 1981; Zhang et al., 1997; Dong and Li, 2008) and regionally toward North China (Norton and Gao, 2008a, 2008b; Zhang et al., 2011, 2014; Zhang et al., 2013). This may be due to the karst processes in most of the caves in

South China, which reduced the amount of information from zooarchaeology by limiting the number of bone fragments that were recovered, and making their identification difficult. However, in recent years, taphonomic and zooarchaeological efforts have shown the possibility of investigating human subsistence in the Yunnan-Guizhou Plateau, southwest China, such as the consumption of *Rhinoceros* in the Early Paleolithic (Schepartz and Miller-Antonio, 2010), the differences in faunal assemblages between the Early and Late Paleolithic (Zhang, et al., 2010, 2009a, 2009b), and the resource intensification in the Early Neolithic (Jin, 2010).

Previous paleontological studies showed that the *Stego-*

\*Corresponding author (email: gaoping@ivpp.ac.cn)

*don orientalis*, *Aliuropoda melanoleuca*, *Cervus unicolor* and *Bubalus bubalus*, which usually lived in relatively warm, moist environments, lasted through-out almost all the Late Paleolithic in south China (Li, 1981; Ji, 1982). As a result, Late Paleolithic subsistence in southwest China was generally considered to be adapted to these stable food resources (Huang and Zhang, 2003; Xia et al., 2008). Accordingly, there were many sites reported during this period, in which fossil bones associated with artifacts and hearths are common (see the review in Li et al., 2014). In contrast, in the view of the stalagmite (Zhao and Wang, 2011) and pollen (Xue et al., 2015) records, the climate oscillations represented by the weaker summer monsoon occurred in this area during 12000–11000, 18000–15000, 25000–22500, 33000–30500 and 39000–37000 cal a BP, but there has been no significant evidence about whether and how these climate changes affected the consumption strategies of humans.

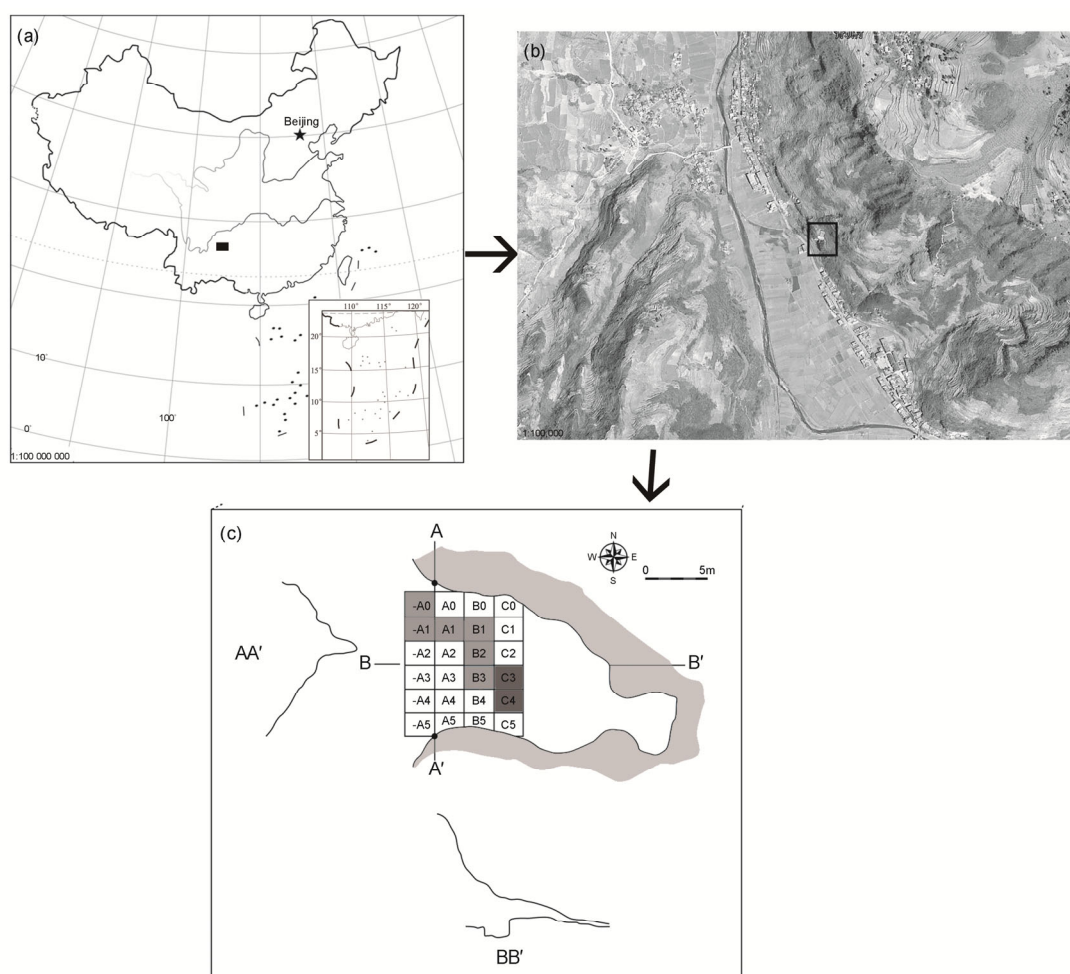
In this paper, we present a primary faunal analysis of a cave site on the Yunnan-Guizhou Plateau based on a small-scale but systematic excavation, which provides clear

sediment sequences and evidence of flaked stone tool manufacture. Although the information about bone surface modification was not obvious because of the effects of calcareous concretions that are hard to remove, this study examined the prey abundance and mortality profile in the faunal assemblages from Laoya Cave. The primary results show that animal exploitation seems to be sustained and variable during Late Paleolithic.

## 2. Background and methodology

### 2.1 Site and excavation

Laoya Cave is located in the town of Qingchang, west of Bijie County, in northwestern Guizhou Province (27°21'12.57"N, 105°1'8.46"E); this is the southwest portion of the Yunnan-Guizhou Plateau. The site lies at an altitude of 1468.58 m and faces northwest. The entrance is the widest part of the cave at 15 m across; it narrows toward the back. The cave's interior is only 20 m long, making it seem more like a shelter (Figure 1).



**Figure 1** Location ((a), (b)) of Laoya Cave and its plan and section (c). (a), (b) Modified from a topographic map on Google Earth: a darker tone of gray, and a higher gray scale indicates higher elevation. (c) Modified after Guan et al. (2015).

Laoya Cave was discovered in 1983 by a local museum investigating the presence of Quaternary fossils (Xu, 1986). An excavation was carried out in 1985 over a 24 m<sup>2</sup> area, but sieving was not performed at the time. After decades with no progress in research, IVPP recently restarted investigations in this region, with a new focus on geology, paleoenvironmental studies and archaeology (Guan et al., 2015). An area of 8 m<sup>2</sup> was excavated in 2013 and comprehensive records of all the recovered artifacts and identifiable fossils were collected. All the remains were systematically collected using a grid of 50 cm squares. The clay was sticky and there is no easy access to water at the site, but careful digging and sieving were performed during the later excavation even though some bones of micro-mammals, fishes, and birds were damaged because of the hard calcareous concretions at the site.

The depth of the Late Paleolithic deposits in Laoya Cave is ca. 2 m and 11 stratigraphic layers were identified. Stone artifacts and animal bones were found in all 11 layers; layers 2 to 6 are significant due to the presence of extensive deposits of ashes and confirmed hearths. The absolute ages of units in the sequences are based on AMS radiocarbon dating. Sediment details and dating results were carefully discussed in a previous paper (Guan et al., 2015) and briefly presented in Table 1.

By comparing the dating results with marine isotope stages (MIS), we determined that the stratigraphic sequence of Laoya Cave was formed during MIS 3/2 (Table 1). The lower part of the sequence almost matches the beginning of MIS 3, which also represents the initial Late Paleolithic in China, while the top falls into the period of the Last Glacial Maximum (LGM). The latest stalagmite record of Qixing Cave in the same area shows a gradual chill-off trend with significant fluctuation during 40 to 16 ka (Peng et al., 2002; Zhang et al., 2003), which indicates a relatively cold climate in the Yunnan-Guizhou Plateau at the time.

## 2.2 Methods of faunal identification and dental analysis

The zooarchaeological information on specimens at the Laoya Cave site was collected via excavation grids and stratigraphic units. During the excavation, the initial identifications were carried out based on osteological catalogs (Hillson, 1999, 2005). The final results of assemblages' classifications were based on comparisons with the extant specimen collections of IVPP. In brief, we calculated the number of identified specimens (NISP) and the minimum number of individuals (MNI) (following Grayson, 1984; Klein and Cruz-Urbe, 1984) and presented a paleontological review on the identification of border-line taxa among the confusing range of ungulates (see details in Guan et al., 2015). In this study, any skeletal elements that could not be assigned to species were grouped according to relative body size. Unfortunately, the karstic process results in hard deposits of calcareous cement on fossils, especially on bones. So the skeletal element profile, bone breaking pattern and bone surface modification are hard to be evaluated. As one of the most important clues of exploring the relationships between ancient humans and the animals they exploited, the mortality pattern would be documented from the information preserved by teeth in Laoya Cave.

The eruption and the wear stages of deciduous and permanent teeth are the most common indicators for the age at death of mammals. Both crown height and wear patterns can be used to distinguish the age at death of ungulates (Stiner, 1990). Recently, mortality work based on findings from Okinawa Island, Japan has offered a way to estimate the age of deer based on information gleaned from the third molar, such as crown height and incremental annuli (Kubo et al., 2011). This study concluded by offering age estimation equations for deer, and then examined these results with both living and fossil specimens. In reality, the results

**Table 1** Summary of chronostratigraphy and paleoclimate characteristics<sup>a)</sup>

Layer	Dating methods	Material	Age (uncal a BP)	Age (cal a BP)	MIS stage	Overall climate
1		Bone	12270±50	14285–14065	MIS 2	Colder
2		Bone	17670±60	21550–21205	MIS 2	Colder
		Bone	17530±60	21360–20995	MIS 2	Colder
3		Chacoal	17640±60	21510–21150	MIS 2	Colder
		Bone	19460±70	23605–23295	MIS 2	Colder
		Bone	19760±60	23940–23650	MIS 2	Colder
4	AMS-SD (Beta analysis)	Bone	19890±70	24085–23790	MIS 2	Cold
		Bone	20150±70	24370–24065	MIS 2	Cold
5		Bone	22140±80	26525–26140	MIS 3-2	Cold
		Bone	22910±90	27405–27130	MIS 3-2	Cold
6		Bone	23460±90	27740–27525	MIS 3	Cool
7		Bone	25480±110	29795–29340	MIS 3	Cool
8		Bone	26000±120	30630–29875	MIS 3	Cool
		Bone	32640±220	37060–36130	MIS 3	Cool

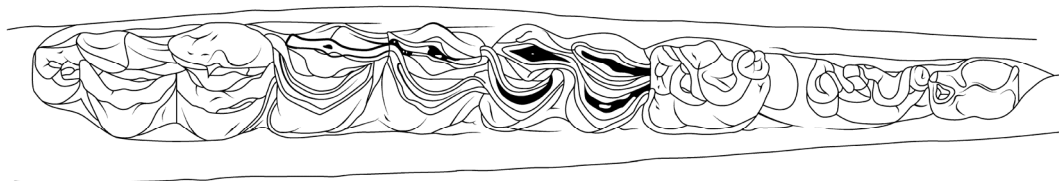
a) References are from Guan et al. (2015), Zhang et al. (2003).

show no major deviation from the work based on using teeth eruption and wear patterns, but the upper limit of living age and the wear rate in the later stage of the third molar could be affected by the inhabited environment and by the sex of the animal, thus changing the observed patterns and skewing conclusions. However, under human predation, some small overestimation of the third molar age will not affect the understanding of age stages, because a heavily worn third molar will always represent a relatively old age group. Therefore, in this study, the estimation of age at death was based on the study of eruption and attrition in living deer (Brown and Chapman, 1991, reviewed by Hillson, 2005).

Most investigations of animal mortality build upon a selective sample because the taphonomic conditions present at many sites destroyed the ideal complete dentition that could offer the precise age at death of animals. Therefore, previous work has often adjusted the study samples based on their bone assemblages, for instance, choosing only dp4, p4, m1, and m3 to comprise the sample (e.g., Klein, 1982; Morrison and Whitridge, 1997; Stiner, 1990, 1994), and divided the estimated age into age groups like nine- and thirteen-age groups (represented by Morrison and Whitridge, 1997;

Speth, 1991). These selections face two main problems: one is that all of these selections depend on a large sample size and the number of the chosen teeth should represent the MNI of corresponding animals. In other words, if the number of dp4, p4, and m3 specimens is lower than the MNI of the samples, the age profiles of the chosen teeth will not give us the best possible age structures of the whole prey situation. The other problem is that deciduous teeth are more likely to be consumed during taphonomic processes, so if the MNI depends on the deciduous teeth (like dp4), the final results may not be reliable. On the other hand, more elaborate age groups require a large MNI (usually >30) and complete dentitions. Only Stiner's (1990, 1994) three-age groups of death age distribution are suitable for all kinds of age determination.

Here we considered a way to enlarge the sample size to reduce the selection bias while attempting to account for all the identifiable teeth in the study. On a single dentition from an animal of a particular age, each tooth has a special wear pattern, which implies that the wear patterns of different teeth have their own significance to indicate their age (as in Figure 2). The characteristics of tooth eruption, use wear pattern and relative ages are described in Tables 2 and 3



**Figure 2** Different wear stages of teeth present in a single living specimen at its 27-month age stage, modified from Brown and Chapman (1991).

**Table 2** Tooth eruption and use wear pattern of different age groups of red deer<sup>a)</sup>

Tooth eruption	Use wear	Ages	Age cohorts
dp2, dp3, dp4, m1	m1 is fresh	4–5 months	Juvenile (a)
dp2, dp3, dp4, m1	m1 slightly used	10 months	Juvenile (a)
dp2, dp3, dp4, m1, m2	m1 slightly used, m2 is fresh	18 months	Juvenile (a)
dp2, dp3, dp4, m1, m2, m3	m1 moderately used, m2 slightly used, m3 is fresh	26 months	Juvenile (a)
p2, p3, p4, m1, m2, m3	m1 moderately used, m2 slightly used, m3 slightly used, p2–4 is fresh	27 months	Prime adult (b)
p2, p3, p4, m1, m2, m3	m1, m2 moderately used, m3 slightly used, p2–4 begin to be used	50 months	Prime adult (b)
p2, p3, p4, m1, m2, m3	m1, m2 well used, other teeth moderately used	138 months	Prime adult (b)
p2, p3, p4, m1, m2, m3	All teeth flattened	>138	Old adult (c)

a) Code a stands for juvenile, b stands for prime adult and c stands for old adult. References are from Brown and Chapman (1991), Nowak (1999), Payne (1985).

**Table 3** Correspondence of wear stages and age cohorts for particular teeth<sup>a)</sup>

	P2	P3	P4	M1	M2	M3	p2	p3	p4	m1	m2	m3	Deciduous teeth
Stage 1	b	b	b	a	a	a	b	b	b	a	a	a	
Stage 2	b	b	b	a	b	b	b	b	b	a	b	b	a
Stage 3	b	b	b	b	b	b	b	b	b	b	b	b	
Stage 4	c	c	c	c	c	c	c	c	c	c	c	c	

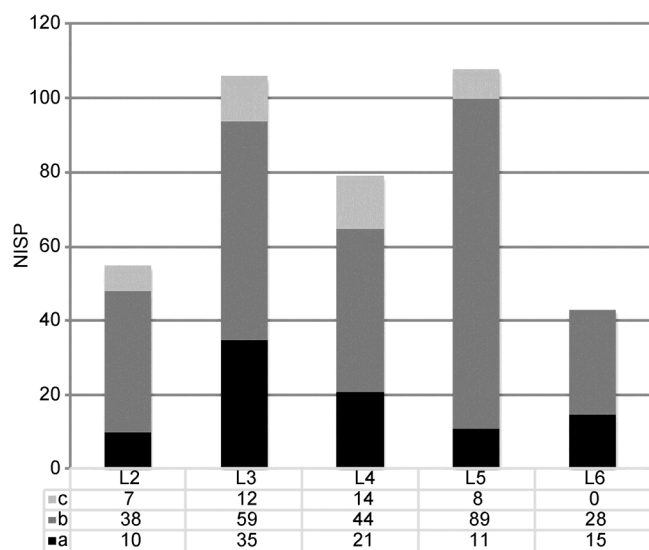
a) Stage 1: Fresh; the tooth cusps have not worn yet. Stage 2: The teeth begin to show use. The cusps and crests are slightly worn, and the dentine is not overly exposed. The outermost enamel has not linked to a "B" or "D". The fosset is large. Stage 3: The teeth are moderately used. The cusps of anterior lobe and posterior lobe have not linked up. The dentine is significantly exposed and the chewing face has become flat. The fosset is smaller. Stage 4: The teeth are well used. All the cusps have become well-rounded and the dentine is greatly exposed. The fosset has begun to close. The outermost enamel links to a "B" or "D." Code a stands for juvenile, b stands for prime adult and c stands for old adult. Wear stages were summarized from the living specimens present in Brown and Chapman (1991).



**Table 5** Statistics of large Cervidae teeth by anatomical portion and stratigraphic layer for mortality profile<sup>a)</sup>

Tooth type		L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
DP2	L	–	–	1	–	–	–	–	–	–	–	–
dp2	L	–	–	1	–	–	–	–	–	–	–	–
dp3	L	–	–	1	–	–	–	–	–	–	–	–
	R	–	1	–	–	–	–	–	–	–	–	–
dp4	L	–	1	1	1	2	–	–	1	–	–	–
	R	–	2	1	1	3	1	–	–	–	–	–
P2	L	–	1	1	–	2	1	–	–	–	–	–
	R	1	2	4	4	2	–	–	–	–	–	–
P3	L	–	–	2	3	5	2	1	–	–	–	1
	R	–	3	4	2	2	–	–	–	–	–	–
P4	L	–	1	3	4	1	1	–	1	–	–	–
	R	–	5	3	–	6	1	–	2	–	–	–
P	–	3	2	8	4	8	5	1	–	–	–	2
M1	L	–	–	2	1	2	–	–	–	–	–	–
	R	–	4	2	–	2	1	1	–	–	–	–
M2	L	–	–	1	1	1	–	–	–	–	–	–
	R	–	3	2	1	1	1	1	–	–	–	–
M3	L	–	–	1	1	1	–	–	–	–	–	–
	R	–	–	1	–	–	–	–	–	–	–	–
M	–	2	17	27	17	16	5	2	2	–	–	2
p2	L	–	–	3	1	1	2	–	–	–	–	–
	R	–	4	2	6	5	–	–	–	–	–	3
p3	L	–	4	6	4	5	–	–	–	–	–	1
	R	–	2	5	4	5	2	–	–	–	–	1
p4	L	–	3	5	1	5	2	–	–	–	–	1
	R	–	2	2	4	4	4	–	–	–	–	3
p	–	–	1	4	3	1	5	–	–	–	–	–
m1	L	–	1	1	2	4	6	–	–	–	–	2
	R	–	1	1	1	3	3	–	–	–	–	1
m2	L	–	1	–	2	3	6	–	–	–	–	1
	R	–	1	–	1	–	2	–	–	–	–	1
m3	L	–	–	8	4	3	3	–	–	–	–	1
	R	1	5	5	6	5	5	–	–	–	–	–
m	–	2	8	17	13	33	10	–	1	–	–	1
Others	–	2	12	19	7	12	3	–	–	–	–	1
Total	–	13	87	144	99	143	71	6	7	–	–	22

a) L: left; R: right.

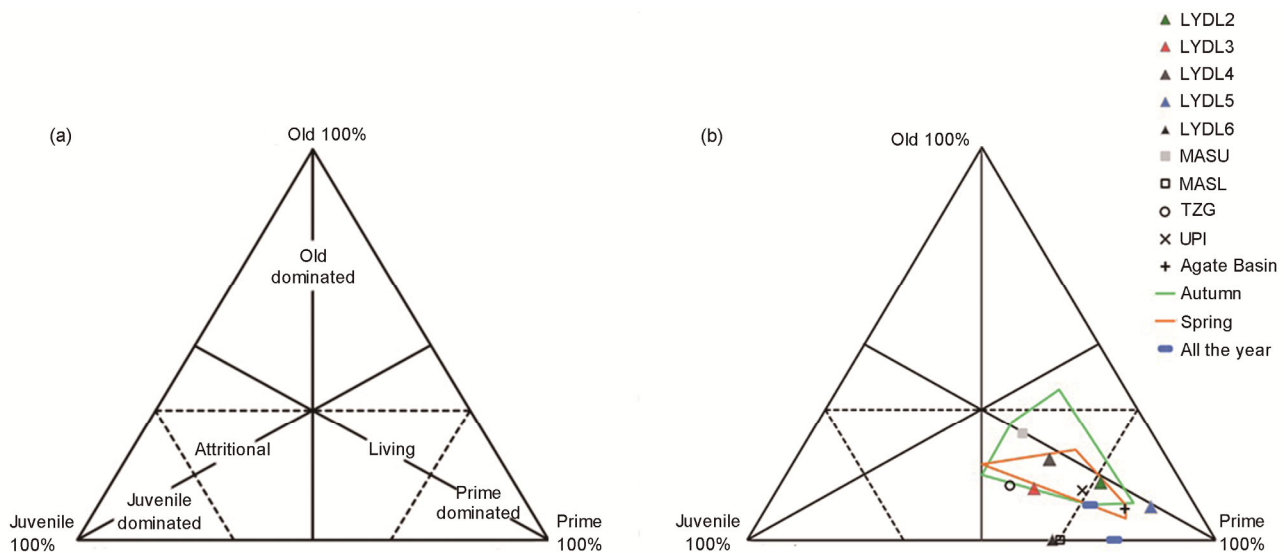
**Figure 4** Age profile of large Cervidae from Layers 2–6 in Laoya Cave. Code a, juvenile; b, prime adult; c, old adult.

deer. And also, the mortality profiles of ungulates from Europe and North America during the Middle and Late Pleistocene are presented in the ternary plots for comparison (Figure 5).

## 4. Discussion and conclusion

### 4.1 Long-term occupation and Cervidae preference at Laoya Cave

In general, a statistical analysis of bone modifications and breaking patterns should be presented as the main evidence for distinguishing between human processing and natural processes and for indicating the pre- and post-depositional destruction of skeletal material at a site presenting multiple animal deaths. However, in Laoya Cave, the calcareous concretion process led to a very ambiguous situation, one that would not allow a convincing observation of those two preferred characteristics. Fortunately, assemblages of stone



**Figure 5** Ternary plots of mortality patterns of large Cervidae from Laoya Cave by layers and the relative sites. (a) The model from Stiner (1990); (b) LYDL 2-6 stand for Layers 2–6 of Laoya Cave; MASU/L stand for upper and lower portions of Ma'anshan Site, from Zhang et al. (2010); TZG stands for Tangzigou Site, from Jin (2010); UPI and Agate Basin from Stiner (1994); the Autumn, Spring and All the year scopes represent the seasonal occupations based on selective hunting of ungulates of European Middle and Late Pleistocene sites, from Blasco (2014).

artifacts and hearths are contemporaneous with the faunal assemblage at this site, which could indicate secondary evidence of human occupation of this cave for quite a long time (Guan et al., 2015). This type of living structure might be considered as evidence for long-term encampment; indeed, it might even be considered as a possibility for a base camp (Costamagno et al., 2006).

During MIS 3/2, which gradually became relatively colder than earlier times, humans in Laoya Cave showed a good ability of controlling their habitation. Because the cave is located in the southwest of China, there was little change in the local biogeography and fauna (Ji, 1982; Huang and Zhang, 2003). The remains of ungulates, especially the large Cervidae, dominate the faunal assemblage at the site. Moreover, when different layers were distinguished and the deposition within the cave was not considered to be a one-off consumption event by ancient humans, we still observed a concentration on a specific diet. This kind of bias to Cervidae has never been previously reported in south China, even when most of the sites were dominated by ungulates. On the other hand, the significant low portion of carnivores in Laoya Cave indicates an effective defense by humans from possible hunting competitors. The site also includes a large quantity of fish bones and several micro-fauna remains, especially in Layers 2 and 3. Although these are hard to identify and some cannot be properly recovered, a consistent survival of resource utilization is thinly veiled.

Unlike other Late Pleistocene cave sites in south China, Bovidae are not common in Laoya Cave. Although the specimens are quite fragmented, Cervidae fossil teeth are far more prevalent than those of other species; thus, we conclude that Cervidae were the most important animal resource for the Laoya Cave occupants. Despite the large

number of teeth present, skull bones are surprisingly scarce, including a significant lack of antlers. This may be related to selective behavior, which gathered antlers for further use; or the bone mineral density, which caused fragile skull parts to become unrecognizable fragments during burial; or it may simply be limited by the excavation areas. However, the leg bones uncovered are also quite fragmented, which led us to consider the possibility that the human occupants of Laoya Cave made best use of their game. Another remarkable phenomenon is that, even though we did not recognize many intact Cervidae skull and limb parts, we noticed a possible special processing of metapodials beside the hearth in Layer 2: The proximal and distal parts were removed and the shaft of the metapodial was kept (Figure 6).



**Figure 6** Absence of proximal and distal parts of metapodial of large Cervidae in Laoya Cave.



Environmental and climate change and population pressure during the Late Pleistocene were considered to spur the development of small game exploitation, which has been observed at sites in the Mediterranean Basin and were recently reported in North China (e.g., Stiner and Munro, 2002; Zhang et al., 2013). Small game exploitation is quite important at South China cave sites based on the abundant deposits of microfauna and fish remains. But due to the cemented formation process, the naturally and artificially fragmented specimens became indistinct during burial and excavation is difficult, making it a challenge to identify these remains and include them in the statistical record. As a result, details regarding large game use are quite important to uncover information about diet breadth and selective behavior in the period.

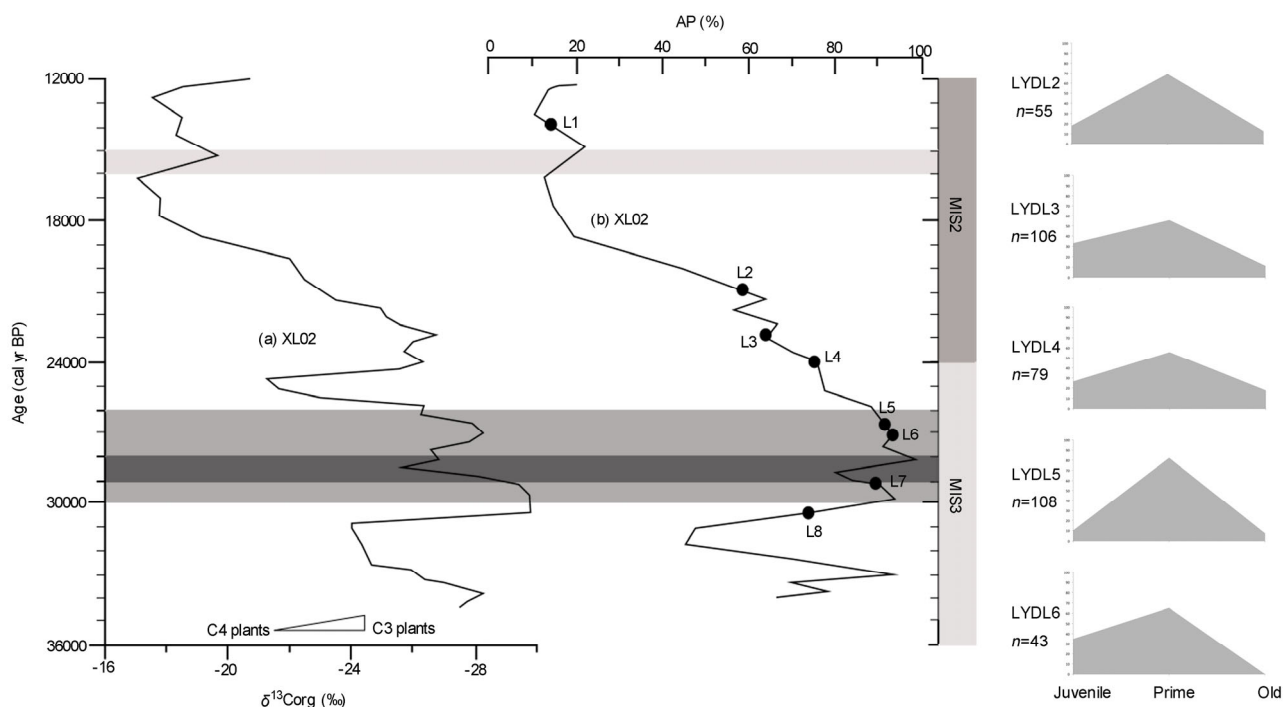
#### 4.2 Variable but prime-age dominated mortality profile of large Cervidae

Age data on the main prey in Laoya Cave present a challenging methodological problem, as the materials are too scanty to present an exhaustive profile. Nevertheless, by focusing on the dominating isolated teeth of large Cervidae, we are still able to generate a profile of the most important game used at the Laoya Cave site, which reveals the dominance of primary adults but changes by layers. The prime-dominated trend is familiar from Eurasia during the Upper Paleolithic and Mesolithic (Stiner, 1994; Adler et al., 2006; Bar-Oz et al., 2007) and linked to the high nutritive

value of prime adults (Stiner, 1990).

According to the dating results, the people of Laoya Cave were living in a time of notable climate change, when targeting the most productive age stage in a herd could have been a survival strategy (Figure 7). Another clue to the climate, environment, and survival needs of the time is the lack of large mammals like *Bos*, *Rhinoceros*, and *Stegodon*, which might not have been ideal prey for the people of Laoya Cave due to possible transport waste. This pattern is quite common in Europe, indicating a selective exploitation of the most available elements of the environment. Notably, despite the several separated layers in the cave, the game dominance shows no significant change, but the age structure of large deer varied, which could indicate a variable choice based on environment change. L5 and L6 landed in a significant warm period, the prime-dominated trends of Large Cervidae are quite obvious. As with the abundance of fishes mentioned above, L3 and L4 shows reduction of this preference and a rising in juveniles maybe caused by falling temperatures, which could mean that humans exploited the resource more intensively (juvenile% > 30%) (Munro, 2004). However, L2 presents a revival of prime-dominated animals but the proportion of old individuals also increases, which could indicate either local intensification of resource caused by environmental change or shortages caused by a larger human population (Prendergast et al., 2009).

David and Enloe (1993) assumed the characteristics of specialized hunting based on the Upper Paleolithic assem-



**Figure 7** Comparison of climate curves of Xialu peatland, southwest China and age profiles by layers of Laoya Cave. The climate curves are the  $\delta^{13}\text{C}_{\text{org}}$  record and AP percentage modified from Xue et al. (2015). Just before L1, there was a rapid warming indicated by the light grey bar. L5–7 falls to a warm and wet climate showed by the grey bar. The dark grey bar is a weaker summer monsoon event. The age profiles were presented by layers and the grey area shows the percentage of each groups, 100% in total.



blages in France. The preference for specific game would result in the fossil assemblages demonstrating an emphasis on specific types and age of game, a catastrophic mortality profile, seasonal slaughter, and possible selective transport of the richest elements. Such hunting strategies are considered to be part of planned procurement, which would indicate active communication and cooperation among humans of the time (Morgan, 1980; Rendu et al., 2012). Although we cannot reasonably determine information on seasonal hunting in Laoya Cave, the abundance of bones, the preference of Large Cervidae, the gathering of teeth and post-cranial fragments, and the primary profile of the limited excavation show a significant match with signs of specialized hunting. When environmental and social pressure occurred, the focus shifted from a preference on prime animals to a wider range of age groups and resources, and then to the integration of maintaining both stability and high nutrition. Combined with the remains of plants (Guan et al., 2015) found in Layers 2 and 3, this indicates an intensive subsistence strategy that was well adapted to the climate and environmental changes through time. Even more, this adaptation may have led to the origin of animal and plant management systems.

## 5. Problems and future research

This is just the beginning for this discussion. Due to the limited excavation and distinctive karst conditions of the region, no arbitrary conclusion should be made before more sites experience a comprehensive zooarchaeological examination. More effective fossil examinations and comprehensive zooarchaeological work are expected to be done at sites in the Yunnan-Guizhou plateau, especially concentrating on the Late Paleolithic and associated climatic fluctuations. As is the case with lithic variability, the features of lifestyle in the Late Paleolithic in southwest China could be made clearer with further accumulation of zooarchaeological evidence.

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