The broad-spectrum adaptations of hominins in the later period of Late Pleistocene of China—Perspectives from the zooarchaeological studies

ZHANG ShuangQuan[*], ZHANG Yue, LI JingShu & GAO Xing

Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

Abstract   During the climatic fluctuations in the late Late Pleistocene, hominins in China had experienced some significant changes and adaptations in terms of subsistence strategies. Based on the zooarchaeological analyses of the faunal remains from the Shuidougou site of North China and the Ma'anshan site of South China, the present study demonstratively indicates that the broad-spectrum diet and its closely-related resource intensification for hominins were already at their places roughly at 33–35 cal ka BP. Compared to hominins of earlier period, who would have preferentially exploited large and medium-sized ungulates, hunter-gathers at later period had otherwise incorporated more small-sized animals (especially the quick ones, such as birds and hares) into their diet. Meanwhile, hominins of the later time had also greatly accelerated extractions and exploitations of the nutritional yields from the large and medium-sized animals. However, it seems clear from the current study that there was significant difference regarding the potential mechanisms for the broad-spectrum adaptations of hominins in the late Late Pleistocene of China.

Keywords   Late Late Pleistocene, Paleolithic, Taphonomy, Zooarchaeology, Broad-spectrum revolution, Resource intensification

1.   Introduction

The late Late Pleistocene (40–10 ka before present) is characterized by a high frequency of climatic and environmental oscillations in the geological history of earth. A series of millenium scale paleoclimatic flunctations, such as the Dansgaard-Oeschger cycles (DO 1–DO 8), Heinrich events and the Younger Dyras were documented in the glacial and deep sea sediments from the North Atlantic, Greenland and adjacent regions (Bond et al., 1993; Bond and Lotti, 1995). And the climatic records from the eolian loess in China (Porter and An, 1995; Guo et al., 1996), the high-resolution stalagmites from the southern China (Wang et al., 2001, 2008) and the deep sea sediments from the Japan Sea (Tada et al., 1999; Li et al., 2001) confirmed, on the one hand, the widespread occurrence of these events in the Eastern Asia and indicated, on the other hand that the climatic instability during the later period of Late Pleistocene was not a regional phenomenon, but rather a global or sub-global trend (Hemming, 2004).

Paleoclimatic fluctuations might have profound effects on cultural adaptations and subsistence strategies of the Paleolithic hunter-gathers, as the spatial distribution and

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

availabilities of basic food resources for humans' survival should, to a large extent, be determined by the interactive changes of climate, topgraphy and environment of the local area. Particularly for hominins in the Late Pleistocene of Eurasia, population influxes and the forthcoming competitions and interactions between the newcomers and the aboriginals may have also triggered the evolutionary adaptations of humans on this continent. Conditioned by local ecological parameters and cultural variations (including technological traditions), humans may have taken a range of measures, for example, increasing dietary breadth, intensifying resource extractions, enhancing mobilities and/or technological innovations and manipulating institutional protocols to cope with the extreme environmental changes characteristic of the Late Pleistocene (Barton et al., 2007; Zhang and Chen, 2013).

At the turn of the century, archaeologists from America and Europe found that the subsistence strategies of Pleistocene hominins in Southern France and the Mediterranean basin had some singnificant changes (Grayson and Delpech, 1998, 2002, 2003; Stiner et al., 1999, 2000; Stiner, 2001). Based on the zooarchaeological analyses of the faunal remains from a series of sites of Italy, Israel and Turkey, spanning roughly 200–10 ka before present, Stiner et al. (Stiner et al., 1999, 2000; Stiner, 2001; Stiner and Munro, 2002) proposed a new prey ranking system. Since the traditional Linnean taxonomic system failed to discern the possible shift in dietary breadth of Paleolithic hominins, an alternative measure of prey diversity from the archaeological sites should be specified. In consideration of the body size and defense mechanisms (or more precisely, work of capture), prey animals from the sites were categorized into large game, small slow game and small quick game, respectively; and a clear trend in human subsistence strategies was recognized by employing this system. Meanwhile, these studies strongly indicated that the fact that more and more small quick animals were incorporated into the diet of honimins during this process could neither be easily explained by environmental or climatic changes, nor it was an outcome of hominins' technological innovations. On the contrary, population growth pulses occurring in the Levant at the Late Pleistocene should be the major cause for the expanding of human diet breadth (Stiner et al., 1999, 2000; Stiner, 2001; Stiner and Munro, 2002).

Adopting the new prey-ranking system to archafaunal studies in other parts of the world like Greece and Portugal, had lent further support on a major subsistence shift of hominins from a large animal dominanted diet to a diet with more and more small quick animals included (Bicho, 1994; Starkovich, 2011, 2012; Stiner and Munro, 2011; Stiner et al., 2012). And in the process towards a broad-spectrum diet in Pleistocene, prehistoric hominins might have also intensified extractions of the nutritional yields from the animal resources (Zeder, 2012), which was again indicated in the archaeological records from the Levant (Munro,

2004; Munro and Bar-Oz, 2005).

In contrast to the Levant, archaeological studies concerning the broad-spectrum diet of hominins in the late Late Pleistocene of China are still largely lacking, although scholars have recently begun to touch on this important issue (Chen, 1995; Cui, 2011; Pan and Chen, 2011; Guan et al., 2012; Zhang et al., 2013).

2. Materials and methods

Archaeological studies based on direct and/or indirect evidences from the Pleistocene sites have demonstrated that plants should have been an integral part of the Pleistocene humans diet, along with animals (Pryor, 2008; Elston et al., 2011; Guan et al., 2012). In terms of broad-spectrum diet, the majority of scholars have even focused on the significance of plant exploitation at the terminal Pleistocene (Binford, 1968; Flannery, 1969; Unger-Hamilton, 1989; Bar-Yosef and Meadow, 1995; Kennett and Winterhalder, 2006). However, ethnographic data indicated that compared to the animal resources, plant species appear contribute less (and even to a negligible exent, roughly 1–5% on some occasions) to the diets of modern hunter-gathers (Cordain et al., 2002). Paleoenvironmental reconstructions have also argued against the major contributions of plants, as it seems quite likely that edible plants would have been largely unavailable for hominins during the long cold seasons of the late Late Pleistocene (Barron et al., 2003). Another line of evidence negating the major role of plants in hominins diets lies in isotopic analyses, which demonstrated that Neandertals and early modern humans were mainly subsisted on animal foods, rather than on the plant species (Richards et al., 2000, 2001; Lee-Thorp, 2008; Richards, 2009). In short, compared to the meagre input of plants to prehistoric diets, animal remains should bear more significance for the investigations of human dietary expansions, at least for the time period at the boundary of the Middle Paleolithic and the Upper Paleolithic (Morin, 2012).

In this study, we therefore center only on animal finds from the Shuidougou site of North China and the Ma'anshan site of South China. Based on detailed investigations of changes of prey species abundance and the differential exploitations of bone elements and varying extent of human-induced modifications at the differnt time periods, we may accordingly find some evidence for human diet expansions in the late Late Pleistocene of China. One of the notable advantages of these archaeological sites are the high quality of recovery and documentation as fine-screening or techniques alike were practiced uniformly in the course of excavation; and skeletal remains of samll animals were therefore retrieved with a large extent of confidence. Another advantage for the current sample lies, however, on systematic studies of the taphonomic attributes

of the faunal remains during the recent years, which have suggested that animals from the sites were not introduced into the sites by taphonomic agents other than Paleolithic humans. Some Paleolithic sites in China, for example, Salawusu from the Inner Mongilia Region and Siyu from the Shanxi Province both yielded a large number of animal bones. However, for the absence of detailed taphonomic analyses of the faunal remains, it is difficult to conclude presently that bones from either sites were primarily accumulated and modified by humans. Consequently, faunal remains from sites of this kind are not included in the current study.

3. Results

3.1 The Shuidonggou site

The Shuidonggou site (38°17′52″N, 106°30′21″E; 1205 m a.s.l.) is located on the southwestern edge of the Ordos Desert, approximately 28 km southeast of Yinchuan city, Ningxia Hui Autonomous Region of China (Figure 1). Since the beginning of twentieth Century when the French scientist discovered Shuidonggou (SDG) Locality 1, more and more Upper Paleolithic sites have been uncovered, of which SDG 7 and SDG12 yielded large numbers of vertebrate fossils (Gao et al., 2013a, 2013b).

During the field-seasons of 2003–2005, ten thousands of stone artifacts, animal bones and several pieces of ornaments were unearthed from SDG7, which was recently dated by OSL to 27–25 ka (Gao et al., 2013b; Pei et al., 2014). The SDG7 fauna of is dominated by *Equus hemionus, Procapra przewalskii, Bubalus* sp. and *Coelodonta antiquitatis*. Based on its taphonomic characteristics, the faunal remains from SDG7 is proposed to be essentially preserved in a primary context to some extent and only slightly disturbed by flowing water; and the seemingly small number of cut-marked bones from SDG7, however, does not negate the dominant role played by humans in the accumulation of the bones (Zhang et al., 2014). The SDG12, dated to 12.2–11 cal ka BP by AMS techniques, were found in 2005 and systematically excavated in 2007, and a large number of stone artifacts, bone tools and fragmented animal bones were unearthed. Stone artifacts therefrom include microlithic cores, microblades, scrapers, millstones, grinding rods, stone pestles and some partially polished stone tools (Gao et al., 2013b); and the bone tools from the site comprise awls, needles and a composite bone knife (Gao et al., 2009; Yi et al., 2013). In addition to these technological components,
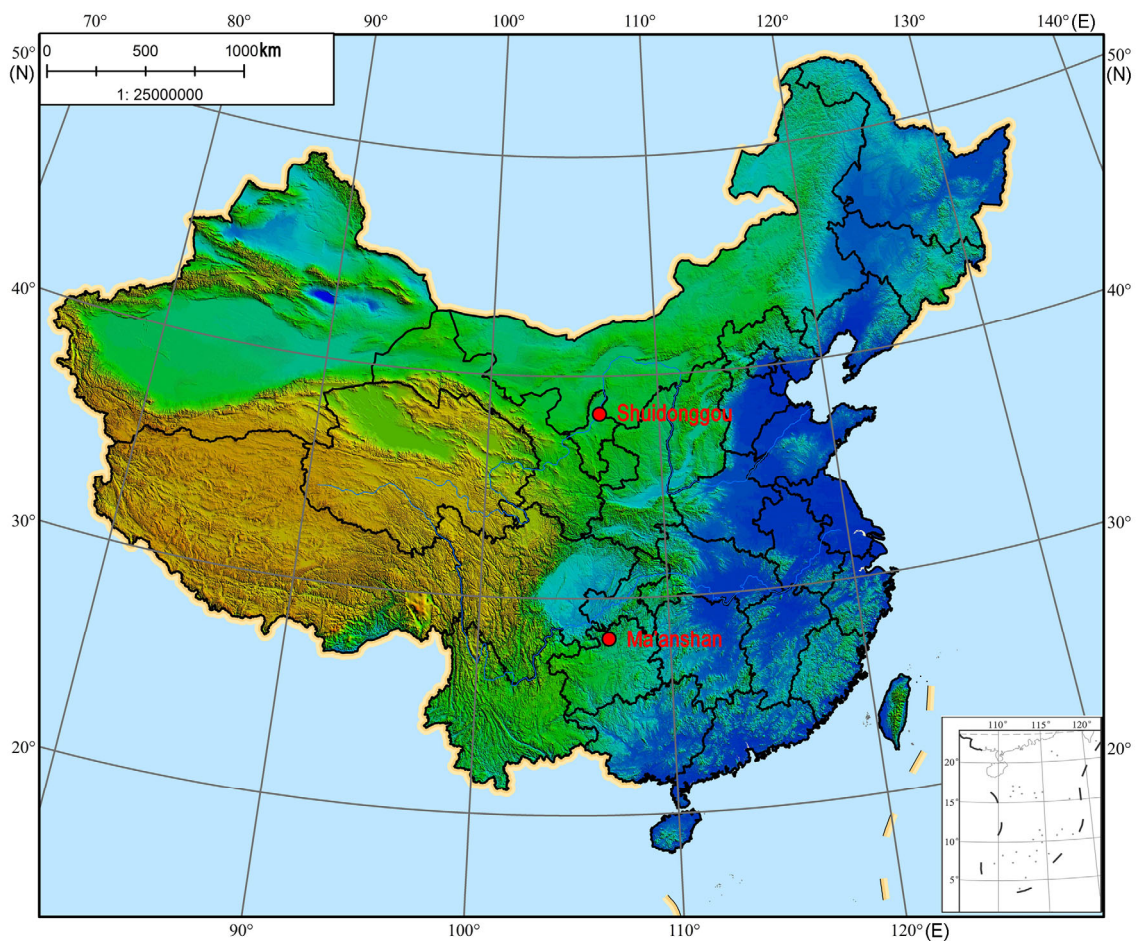
Figure 1 Geographic locations of the Shuidonggou site and the Ma'anshan site.

more than 10000 pieces of animal fossils were unearthed that can be taxonomically identified to hare (*Lepus* sp.), badger (*Meles meles*), wildcat (*Felis microtus*), deer (Cervidae), gazelle (*Procapra przewalskyi*), boar (*Sus* sp.), horse (*Equus przewalskyi*), buffalo (*Bubalus* sp.), bird (Aves), reptile (Reptilia) and rodent (Rodentia), respectively. The taphonomic study of the bones from the site shows that this assemblage was primarily accumulated by hominins other than natural agents (Zhang et al., 2013).

3.1.1 Comparison of the species abundance of the SDG7 and SDG12

Diet breath expansions in prehistoric records do not necessarily mean new species were added to the diet, but rather a higher proportion of low-ranked animals was included (Stephens and Krebs, 1986; Kelly, 1995; Starkovich and Stiner, 2010). Statistically speaking, two large animal species, *Equus hemionus* and *Procapra przewalskii* dominated the SDG7 fauna, which it is strikingly different from the thing at SDG12 in that small animals, such as *Lepus* sp., constituted the majority of the assemblage and the large species decreases in number correspondingly; meanwhile, there are also a comparatively larger number of birds and small carnivores from the SDG12 fauna (Figure 2).

When the animals from the two sites are tabulated to the new prey ranking system proposed by Stiner (Stiner et al., 1999, 2000; Stiner, 2001; Stiner and Munro, 2002), it becomes even more clearer that there is virtually absent of slow small games such as tortoises and shellfish at SDG12,

but fast-moving small animals, such as rabbits and birds are dominant and account for about 61.07% of the fauna. This constitutes a sharp contrast with that of the SDG7, of which quick small animals is proportionately lower (approximately 15% of the assemblage).

In conclusion, either based on Linnean taxonomy or the new prey ranking system, it appears that compared to SDG7, hominins at SDG12 largely expanded their dietary breadth by adding more low-ranked quick small animals into their diet.

3.1.2 Surface modifications on animal bones from the SDG7 and SDG12

In terms of the broad diet of prehistoric periods, the extent of the intensification of their extraction of animal resources will provide us with another tool to look into hominins subsistence adaptations (Munro and Bar-Oz, 2005; Bar-Oz and Munro, 2007; Munro, 2009; Prendergast et al., 2009).

(i) Cut marks. Only thirteen bones from SDG7 (10.92%) bear cut marks, of which eight (23.3%) are long bones of *Equus hemionu* and two (6.45%) others belong to a smaller animal species, *Procapra przewalskii*. On the contrary, a much higher percentage of bones of *Procapra przewalskii* from SDG12 were cut marked; and in terms of their distributions, cut marks on bones from SDG12 are actually noticed on a wide array of elements, including those of low nutritional values, such as metapodials and phalanges (Table 1). It could be argued therefore that hominins at SDG12 processed their games in a more intense manner.
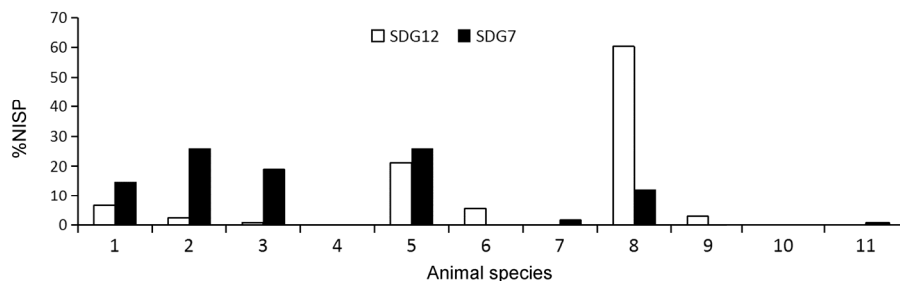
Figure 2 Comparison of the %NISP counts on animal species from SDG7 and SDG12. 1, *Bubalus* sp.; 2, *Equus hemionus*; 3, Cervidae; 4, *Sus scrofa*; 5, *Procapra przewalskyi*; 6, *Meles meles*; 7, *Vulpes vulgaris*; 8, *Lepus* sp.; 9, Aves; 10, Reptilia; 11, Mollusca.

Table 1 Cut-marked bone counts on elements from the SDG12

Elements	*Procapra przewalskyi*			*Lepus* sp.			*Meles meles*		
	Cut-marked NISP	Total NISP	Percentage (%)	Cut-marked NISP	Total NISP	Percentage (%)	Cut-marked NISP	Total NISP	Percentage (%)
Mandible	3	23	13.04	0	41	0	0	4	0
Rib	5	81	6.17	2	201	1	0	18	0
Scapula	0	12	0	0	65	0	1	2	50
Vertebrate	2	25	8	0	9	0	0	4	0
Humerus	5	19	26.32	4	80	5	0	3	0
Pelvis	0	0	0	1	33	3.03	0	0	0
Radius	5	29	17.24	1	42	2.38	4	8	50
Femur	3	12	25	0	54	0	0	4	0
Tibia	4	24	16.67	1	50	2	0	5	0
Carpal/tarsal	2	44	4.55	0	82	0	0	1	0
Metapodial	13	66	19.7	0	269	0	1	37	2.7
Phalange	5	26	19.23	0	60	0	0	13	0

Cut marks are also observed on bone elements of *Lepus* sp. (Table 1) in SDG12. It is noticeable that cut mark frequencies of this species are considerably lower than those of *Procapra przewalskii* from the SDG12. However, this phenomenon has been recorded in several archaeological sites from the Levant as well; and it could be argued that due to the small pack of meat of this animal, there will has a narrow chance for a stone artifact contacting the bone surfaces during processing of the carcass of this species. In addition, it has been observed that cut marks on *Lepus* sp. from SDG12 are extradinarily incised deep into the cortical, which provides strong evidence against the argument that these marks were derived from skinning when butchers preferred to acquire fur and/or pelt instead of meat, since in the former case, marks on the bones should be pretty much superficial.

Only few bones of small carnivores were unearthed from SDG12, but proportions of cut marked specimens for these animals are considerably high. For example, frequency of cut-marked scapula of *Meles meles*, which is of course an element of high nutritious yields, comes to 50%; it is also the case for radius/ulna of this animal (Figure 3a, Table 1). It hence implies that hominins at SDG12 mainly aimed at the extracting of nutrients, rather than fur and/or pelt during their processing of this carnivore species.

(ii) Burning marks. Few burned bones were unearthed

Figure 3 Human-induced bone modifications. (a) Cut-marked radius of a small carnivore (SDG12); (b) burned bone from SDG12; (c) burned bone from the Upper Cultural Layer of Ma'anshan site. Note: scales in (a1) and (c) are 1 cm; scale in (a2) is 1 mm; scale in (b) is 0.5 cm; (a2) is a microscopic view of the squared part in (a1).
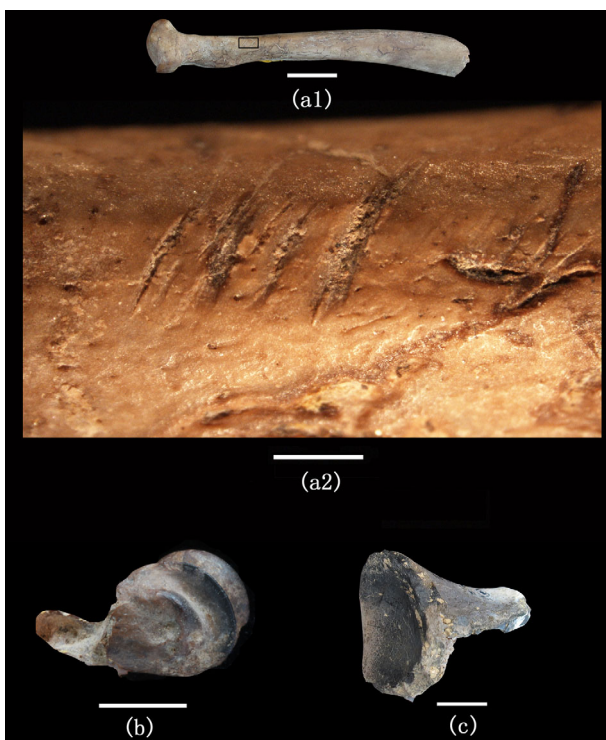
from the SDG7; and in SDG12, while the proportion of burned specimens is low, marks from this modification have noticeably been observed on most bone elements of *Procapra przewalskii*. Besides, the majority of the burned long bone specimens are epiphyses rather than mid-shafts, which should strongly indicates that these marks was most probably induced by cultural modifications rather than natural fire, since marks derived from the latter would usually distribute evenly on epiphyses and mid-shafts of the bones.

The proportions of burning-marked metapodials and phalanges of *Procapra przewalskii* from the SDG12 are much higher than that of the elements of high yields (Table 2). Bearing in mind the extreme difficulties in processing the metapodials and phalanges of a prey animal without the aid of fire, it appears that compared to hominins at SDG7, inhabitants at SDG12 have more intensively extracted the nutritional content of the extremities of the animals they had brought down.

Burning marks are also observed on almost every element of *Lepus* sp. from SDG12, which again may signifies a high extent of extraction of nutrients from this animal species. Similar to that of *Procapra przewalskii*, the burned specimens of *Lepus* sp. are uniformly of epiphyseal kinds (Figure 3b), not a single mid-shaft of this animal bearing evidence of burning.

3.2 The Ma'anshan site

The Ma'anshan site (106°49′37″E, 28°07′18″N，960 m a.s.l.) is located in Tongzi County, Guizhou Province (Figure 1). It was systematically excavated in 1986 and 1990, and an area of 48 m^2 was excavated to a depth of ca. 2 m. From the top to the bottom, eight stratigraphic layers were identified successively. Based on the differential characteristics of the stone artifacts and animal bones from the site, two culture layers were finally distinguished: the Upper Cultural Layer (hereafter "UCL", Stratum 3–6) and the Lower Cultural Layer (hereafter "LCL", Stratum 7–8). Most of the stone artifacts from the UCL are less than 40 mm in length, while those from the LCL are normally longer than this dimension. Apart from this evidence, no other difference could be discerned from the lithic assemblages of the two units (Zhang, 1988). In addition, no formal bone tools were unearthed from the LCL, while bone awls, spears and a bone rod with grooves were found from the UCL. The AMS dates for the UCL roughly fall within the range of 18–35 cal ka BP, and a single U-series date for LCL is around 53 ka (Zhang, 2008; Zhang et al., 2010; Zhang et al., 2016). To be addressed, most of the animal bones of UCL come from strata 5–6 (33–35 cal ka BP) and the taphonomic study shows that faunal remains from both stratigraphic units were primarily accumulated by hominins subsistence activities, such as hunting, transporting, dismembering and defleshing, etc. (Zhang, 2008; Zhang et al., 2010).

Table 2 Burned bone counts on elements from the SDG12

Elements	*Procapra przewalskyi*			*Lepus* sp.		
	Burned NISP	Total NISP	Percentage (%)	Burned NISP	Total NISP	Percentage (%)
Vertebrate	2	25	8	1	9	11.11
Scapula	0	12	0	2	65	3.08
Rib	1	81	1.23	3	201	1.49
Humerus	1	19	5.26	13	80	16.25
Radius	1	29	3.45	4	42	9.52
Femur	1	12	8.33	5	54	9.26
Metapodial	15	66	22.73	13	269	4.83
Carpal/Tarsal	1	44	2.27	5	82	6.1
Phalange	4	26	15.38	5	58	8.62

3.2.1 Comparison of the species abundance of the UCL and LCL

In the process towards broad diet, on the one hand, new species of animal or plant would be continuously added into hominins diet, and on the other, proportions of small-sized animals, which are generally lower-ranked in terms of their return rates, might be increased with time (Stephens and Krebs, 1986; Kelly, 1995; Starkovich and Stiner, 2010). Following Brain (1981), animal species from the Ma'anshan site was categorized into four classes: Class I (10–50 kg live weight, and including *Muntiacus* sp., and *Capricornis* sp.); Class II (100–200 kg live weight, and including *Cervus unicolor*, and *Sus* sp.); Class III (300–1000 kg live weight, and principally *Bubalus* sp.); and Class IV (1000–3000 kg live weight, notably *Rhinoceros sinensis and Stegodon orientalis* (Zhang et al., 2010). Zooarchaeological studies demonstrates that larger-sized animals of Class III dominated the fauna of LCL (63.78%), while the ratio of somewhat smaller animals of Class II is much higher (76.35%) in the UCL. It may implies that hominins of UCL began to hunt more smaller animals than they did in the LCL (Zhang et al., 2010). Another line of evidence for the diet breath expanding in this time period probably lies in the comparatively large number of small animals, especially the bamboo rats (*Rhyzomys* sp.) from the UCL, which had principally dominated the micro-mammal assemblage (79%) (Zhang et al., 2010).

3.2.2 Representation of the distal limb bones of the large and medium-sized animals from the UCL and LCL

When facing choice of transport, hunter-gathers would have to make some decisions based on nutritional differences of the bone elements of a large animal (Binford, 1978; Metcalfe and Jones, 1988; Bartram, 1993). In the LCL at Ma'anshan site, hominins preferentially transported the upper and middle limb bones (humerus, femur, radius and tibia, ect.) of class II and class III animals, which obviously have more meat and marrow attached; meanwhile they usually abandoned the lower limbs (metapodial), carpal/tarsal and phalanges, which are certainly elements of low nutritional values, at the kill-butchery sites out of the cave. For hominins from the UCL, they had not only transported the carcass parts of high nutritional contents, but also brought back those of low yields (Zhang et al., 2010).

3.2.3 Surface modifications on animal bones from the UCL and LCL

(i) Cut marks. The extent of hominins exploitation of bone elements of low nutritional values of an animal will provide extra clues to the study of resource intensifications in prehistory (Munro and Bar-Oz, 2005; Bar-Oz and Munro, 2007; Munro, 2009; Prendergast et al., 2009). Taphonomic studies demonstrate that cut-marked frequency on the low yields phalanges from the UCL of the Ma'anshan site is 11.94% and no cut marks were observed on bones of these elements from the LCL. It thus strongly suggests that hominins in the UCL had probably taken more efforts than their counterparts in the LCL in extraction of the meager content of nutrients from the distal limbs of the prey animals.

(ii) Percussion notch and bone completeness indexes. When in a condition of ample resources, hominins usually would not bother to process bones of low yields, such as calcaneus, astragalus and phalange, as which are notoriously known to hold little or no marrow at all and generally have less meat attached. On the contrary, when in a period of short of food, hominins would rather spend more time and take great pains to utilize bone elements of low nutritional values and therefore they would definitely fragment these bones in much higher rates (and proportions of bone fragments with complete circumference would thus be dramatically decreased) (Munro and Bar-Oz, 2005; Munro, 2009). Zooarchaeological studies shows that the completeness indexes of the bone elements of low yields from the UCL is much lower than that of LCL, which should indicate to some extent that hominins at the time of LCL were less likely to utilize animal parts of the lower nutritional contents than they did in the UCL (Zhang, 2008). Furthermore, ratios of bones bearing percussion marks are lower in LCL than that in the UCL, which again support the argument that hominins in the UCL had substantially extracted nutrients (especially marrow) from the carcass. However, bearing in mind the small sample of the percussion-notched specimens from this assemblage, this argument is currently by no means conclusive.

(iii) Burning marks. Studies on the distributional patterns of burning marks on bones from the archaeological sites could, to some extent, provide evidence on hominins intensification of animal resources (Morin, 2012). In the UCL of the Ma'anshan site, burning marks are recognized from most bone elements (except pelvis) of the class II animals (Table 3, Figure 3c). On the contrary, in the LCL of the site, burning marks are not as common as that in the UCL, and they are observed mainly on the bone elements of high nutritional values, such as the mandible, rib and humerus of the class II animals (Table 3). It may suggest therefore that hominins at the time of UCL were more likely to extract nutritional yields from animal carcass with the aid of fire than they did in the LCL.

4. Discussion

So far, several episodes of expanding of dietary breadth of prehistoric hominins have been documented from a couple of geographic regions of the world, although they still have distinct characteristics in terms of the timing, intensity and the driving forces behind them (Villaverde et al., 1996; Hockett and Haws, 2002; Speth and Tchernov, 2002; Speth, 2004; Starkovich, 2011, 2012; Stiner and Munro, 2011; Stiner et al., 2012).

In the Paleolithic records of China, an early example of possible increase of human dietary breadth was evidenced by isotopic studies from the Tianyuan cave of North China, roughly at 40 ka before present (Hu et al., 2009). Archaeobotanical studies based on materials from the North-Western China also provided insight on the increasing importance of broad diet for the Pleistocene hominins (Guan et al., 2012). Specifically in the field of zooarchaeology, Prendergast et al. (2009) has presented an example of resource intensification of the prehistoric humans at the terminal of Pleistocene from the Yuchanyan site of the Hunan Province; an analysis of the evenness indexes of the prey animals from different localities of the Shuidonggou site has also indicated a great potential of this site for the studies of Paleolithic dietary expansions (Zhang et al., 2013).

Based on differences of the prey animal abundance and the differential incidences of the cultural modifications on animal bones from SDG7 and SDG12, the current study indicates an occurrence of broad-spectrum diet at the later period of the Late Pleistocene. Compared to the hominins of earlier age at SDG7, inhabitants at SDG12 mainly exploited the quick small animals of the site, such as hare and badger, which were generally ranked low in terms of their nutritional yields. Beside, hominins at SDG12 also greatly enhanced their efforts in extraction of the small pack of content from distal limbs of comparatively large animal species at the

Table 3 Burned bone counts on elements from the Ma'anshan site

Elements	Layers	Total NISP	Burned NISP	Percentage (%)
Cranium	UCL	7	1	14.29
	LCL	4	0	0
Mandible	UCL	56	8	14.29
	LCL	8	1	12.5
Vertebrate	UCL	93	4	4.3
	LCL	11	0	0
Scapula	UCL	15	1	6.67
	LCL	1	0	0
Pelvis	UCL	4	0	0
	LCL	2	0	0
Rib	UCL	276	18	6.52
	LCL	43	5	11.63
Humerus	UCL	123	12	9.76
	LCL	26	1	3.85
Femur	UCL	59	5	8.47
	LCL	19	0	0
Radius/Ulna	UCL	144	10	6.09
	LCL	53	0	0
Tibia	UCL	75	5	6.67
	LCL	38	0	0
Carpal/Tarsal	UCL	190	7	3.68
	LCL	13	0	0
Metapodial	UCL	457	47	10.28
	LCL	62	7	11.29
Phalange	UCL	298	9	3.02
	LCL	30	0	0

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site, for example, *Procapra przewalskyi*.

It could be argued that an increase of the abundance of small-sized animals in the archaeofauna could possibly be the outcome of technological innovations (Lupo and Schmitt, 2005). Compared to SDG7, the appearance of the microlithic implements and bone needles from SDG12 might have signified an important upgrade of technological capabilities of hominins at the site. Although these new cultural elements might have promoted to some extent the efficiencies of searching and hunting of the small animals, especially the agile ones, such as hare, badge and bird, they could not, however, explain away the intensified extraction of the high-ranked animals at SDG12. It is worth noting that the large-scale exploitation of the quick small animals in Levant had been demonstrated to have appeared somewhat earlier than technological improvements at the same area, which strongly indicated that hominins' exploitation of agile animals should not have been restricted by technological equipments (Stiner et al., 1999, 2000; Stiner, 2001; Stiner and Munro, 2002). For hominins at SDG12, it's therefore quite clear that technological elements should not have been the main driving force for their adoption of the broad diet.

When calibrated against the GISP2 oxygen isotope curve (Grootes and Stuiver, 1997), it seems that compared to SDG12 (12.2–11 cal ka BP), climate at the formation of the cultural deposits of SDG7 (25–27 ka) was a little colder (Figure 4). Paleoenvironmental analyses conducted at SDG7 also indicated the sparsely-covered vegetation in a dry and cold environment (Liu et al., 2009). Hominins in such period of time of potential food shortage, nonetheless,

mainly hunted the large and medium-sized animals and rarely preyed on small ones; besides, they were also less intensified in extraction of yields of the extremities of the prey animals. On the contrary, in a comparatively warm and humid environment (Liu et al., 2008), when food resources should be plentiful, hominins at SDG12 adversely mainly took the quick small animals for their diet. As a whole, the sharp contrast presented here indicates that hominins adoption of a broad diet at the Shuidonggou site should not have close relations with climatic fluctuations in the area.

In addition to the technological and climatic hypotheses, an imbalance between human populations and the resources available was also proposed as potential candidate accounting for the occurrence of great diversification of prehistoric human diet (Binford, 1968; Flannery, 1969; Stiner et al., 1999; Stiner and Munro, 2002). Specifically for the Shuidonggou site, when the carrying capacity of the local environment could not sustain the increasingly expanding of human populations, inhabitants at SDG12 might have to add new species to their diet to relieve the constrains imposed by the demographic pulses. Consequently, the dominated high-ranked animal species at SDG7, such as wild ass, deer and gazelle were replaced by low-ranked small animals, for example, hare at SDG12; inhabitants at SDG12 also intensified their use of the high-ranked animals and took more efforts to extract the potential foodstuffs of these animals and had therefore induced much higher incidences of cultural modifications on bone surfaces.

A couple of techniques, such as genetics, archaeological site numbers, density and size have been attempted to ac-
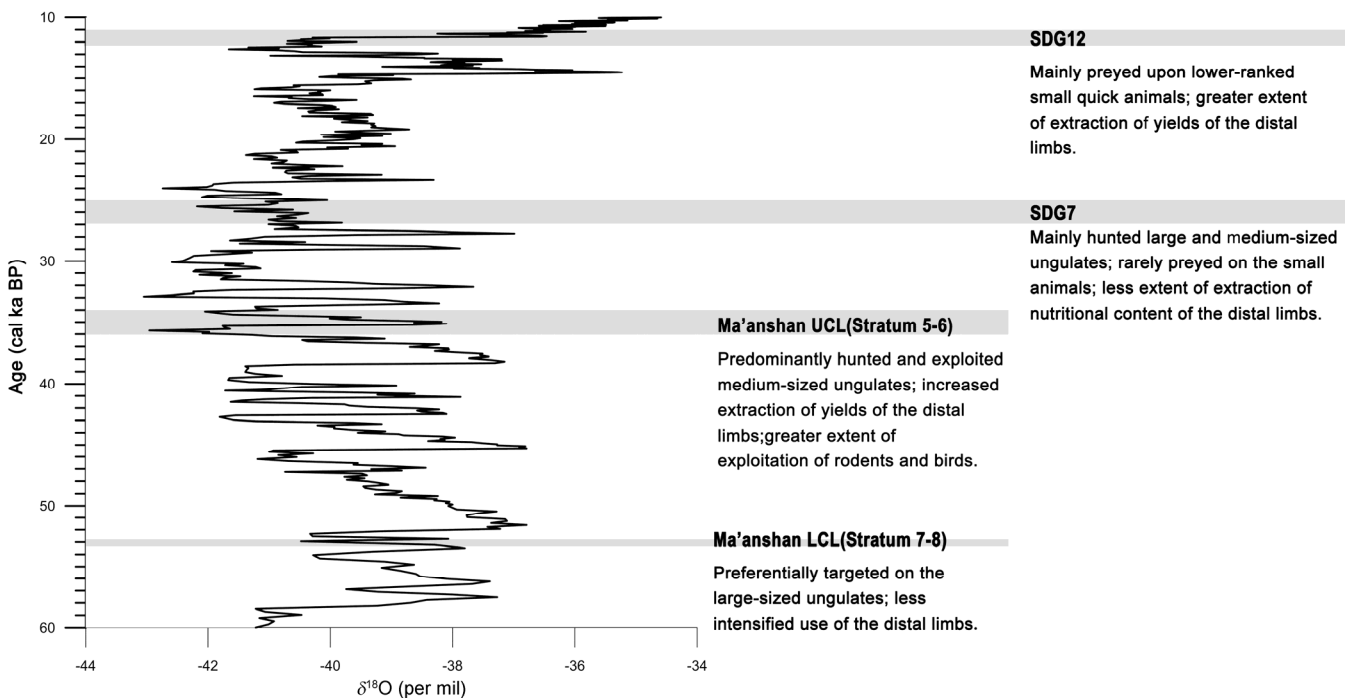
Figure 4 Changes on human diets at the Shuidonggou site and the Ma'anshan site (calibrated against the GISP2 oxygen isotope curve of 60–10 ka before present).

cess information on past population fluctuations. However, it seems clear that most works in this regard are proved to be effective only in reconstruction of population trends of comparatively recent times (Tarasov et al., 2006; Li et al., 2009; Zheng et al., 2011; Wagner et al., 2013) and there is, in fact, not a highly reliable way to help interpret the demographic dynamics of the Paleolithic periods, although some scholar have recently investigated this matter by probing into the radiocarbon data of the Paleolithic sites (Shennan and Edinborough, 2007; Wang et al., 2014). Therefore, zooarchaeological results from the Shuidonggou site may shed new light on this issue, at least to some extent.

Quite similar to that of the Shuidonggou site, there are also distinct differences between the relative abundance of the prey species from the two stratigraphic units of the Ma'anshan site. The first unit (LCL) was dominated by the large-sized animals, for example, buffalos; and the second (UCL), on the other hand, dominated by comparatively smaller animals, such as the sambar deer. This could indicate that compared to the hominins from the LCL, inhabitants from the UCL had increasingly incorporated more smaller animals into their diet; the appearance of large numbers of small animals, such as the bamboo rats and birds might also signify certain extent of broad diet for hominins of the UCL (Zhang et al., 2010). Besides, during the formation of UCL, hominins have intensified their use of the foodstuffs from the animal species, which was clearly reflected in the greater extent of their transport of the lower limb bones and the higher incidences of human-induced modifications on bone surfaces of these games.

Spore and pollen analyses have already suggested generally uniform paleoenvironmental conditions for the two stratigraphic units of the Ma'anshan site (Zhang, 2008; Zhang et al., 2010). But when calibrated against the GISP2 oxygen isotope curve (Grootes and Stuiver, 1997), it seems that compared to the LCL (53 ka BP), climate at the formation of the main deposits of UCL (33–35 cal ka BP) was somewhat colder (Figure 4). This change alone might have affected local vegetation and animal populations. A warm and humid climate would have beneficially affected plants and animals therein and this would in turn facilitate hominins to catch animals with less difficulty since the encounter rate with these animals would significantly increase when the animals were in a favorite environment. In this case, hominins in LCL preferentially hunted the large animals and less thoroughly processed the carcasses of these animals. And when the climate went worse at UCL, large animals originally lived in this area were largely gone to extinction or were forced to migrate to other places of lower-elevations and this would have inevitably dwindled the population size of these high-ranked animals around the site. In the end, hominins at UCL were accordingly adjusted their subsistence strategies and began to included smaller animals in the diet; and at the same time, they might also have largely increased efforts in extraction of the yields

from their games. In short, regarding the mechanism for the broad-spectrum adaptations at the UCL of Ma'anshan site, it appears that climatic fluctuations should constitute the most parsimonious explanation for its occurrence, which is quite different from the situations at SDG12 where demographic pluses should have most plausibly triggered expansions of human diet.

5.　Conclusion

Zooarchaeological analyses of the faunal remains from the Shuidougou site and the Ma'anshan site indicate that Paleolithic hominins at SDG12 and the Upper Cultural Layer of Ma'anshan site had significantly intensified extractions of nutritious yields from the large animals at the sites; meanwhile they had also incorporated a large number of agile small animals, such as hare, bamboo rat and birds into their diet. This line of evidence shows that hominins in the Late Paleolithic record of China, roughly at 33–35 cal ka BP (the UCL of the Ma'anshan site) at the latest, were already on their way shifting to a subsistence strategy of broad diet. Later, especially at the terminal Pleistocene, hominins' broad diet adaptation were documented from a much higher number of archaeological sites of wide geographic distributions, among which the most notable ones are the Shuidonggou, the Upper cave and the Yuchanyan cave (Norton, 2005; Prendergast et al., 2009; Elston et al., 2011; Guan et al., 2012).

However, it appears quite certain from the current study that there was significant difference regarding the potential mechanisms for hominins transition to broad-spectrum diets at SDG12 and the UCL of the Ma'anshan site. For humans at the former site, a rapid population growth during this period might have been responsible for their exploitations of quick small games and intensifications of animal resources; for the latter group of people, on the contrary, the most parsimonious explanation for their subsistence shift probably lies in the climate-driven environmental changes.

It's needless to say that in the absence of taphonomic studies on most archaeofaunas of the Pleistocene China and again in deficiency of fine-screening techniques in the recovery of bones of old-fashioned excavations, any information derived currently from discussions of the broad diet adaptations of prehistoric humans in China are largely fragmentary and biased. Future studies from various arrays of academic fields will definitely shed more light on this important issue.

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