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ORIGINAL PAPER

Intensive exploitation of animal resources during Deglacial times in North China: a case study from the Yujiagou site

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Abstract

Archeological evidence of intensive human foraging behavior during the Deglacial period (ca. 16,000–8000 cal. BP) from the perspectives of artifact manufacturing technologies and the use of plant resources has been widely reported in China. However, the zooarchaeological perspective has contributed less, especially with respect to animal remains from open-air sites in North China. In this paper, we present taphonomic and zooarchaeological data from layers 3 and 4 at the Yujiagou site regarding the formation processes of faunal assemblages as well as the hunting, processing, and consumption behaviors of the site's occupants. These data enable the reconstruction of how animal resources were obtained, illuminating the lifestyles of hunter-gatherers who used a micro-blade technology in North China. Results indicate that the Yujiagou hunters preferred juvenile gazelles and horses, and that bone marrow was a significant source of energy for humans. Taking into account climate changes that occurred during the Late Pleistocene and Early Holocene, we hypothesize that exploitation of animal resources intensified at this time. This pattern differs from that of the broad-spectrum diet exploitation widely reported in Europe and Southwest Asia.

Keywords Yujiagou site · Nihewan Basin · North China · Deglacial · Zooarchaeology · Subsistence · Intensification

Introduction

Resource intensification during the terminal of Late Pleistocene is concerned to be the dynamics of the agriculture origins and other fundamental behavioral changes of the hunter-gatherer groups (e.g., Bar-Yosef 2017; Yeshurun et al. 2014; Zeder 2012; Elston et al. 2011; Barton et al. 2007; Munro 2001). Evidences of intensification were revealed widely over the world, especially in Mediterranean region and Africa, focusing on three major topics: (1) how to identify the intensification, (2) how to assess the degrees of intensification, and (3) how to explain the cause of intensification (e.g., Morgan 2015; Elston et al. 2011; Munro and Atici 2009; Jones 2009; Grayson et al. 2001). For the former two questions, diet breadth, prey size, and further processing of carcass were investigated to underline the strategies of intense exploitations of the environment by human. For example, a series of studies of Epipaleolithic sites around the Mediterranean Basin suggested increasing diet breadth, targeting young individuals, decreasing prey body size, and extracting within bone nutrition, showing the pursuit of more energy gain by greater efforts (Stutz et al. 2009). Climate fluctuation and population density were considered to be the main causes of the resource intensification while the innovations of technologies were thought to be the specific strategies to increase the efficiency of resource procurement (Munro 2004; Stiner et al. 1999, 2000).

During the Deglacial period (roughly 16,000–8000 cal. BP), the global climate changed rapidly and frequently, and diverse technological complexes evolved in North China including micro-blades, grinding tools, and ceramics (Elston and Brantingham 2002; Barton et al. 2007; Yi et al. 2013, 2015). These three technologies were thought to signal subsistence

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intensification strategies necessitated by the harsh environment of the Younger Dryas and/or by increased population, which may have affected human food procurement strategies in ways that led to the development of wild resource (both plants and animals) management or, further, to the origin of agriculture (Elston et al. 2011; Bar-Yosef 2017; Yang et al. 2018).

Knowledge of the expansion of human dietary breadth to include plants, facilitated by breakthroughs in paleoethnobotany, especially the analysis of macro-remains such as carbonized seeds and micro-remains including starch and phytoliths, has been greatly expanded in China (Liu et al. 2011, 2013a, 2013b; Bestel et al. 2014; Guan et al. 2014). Subsistence processes including intensive collection, use, and even cultivation of wild plants were identified, and the concept of a plant-oriented broad-spectrum revolution (BSR) was internalized (Cohen 2011; Bestel et al. 2018). Evidence of early plant domestication has been found at several sites in China, including rice remains from southern China (e.g., the Yuchanyan site, 17.7–13.8 ka cal BP; Prendergast et al. 2009; and the Zengpiyan, Xianrendong and Diaotonghuan sites, all ca. 18/16–11 ka cal BP; Zhang and Hung 2008) and millet remains from northern China (e.g., the Cishan site, 1.03–0.87 ka BP; Lu et al. 2009).

To the contrary, although there are abundant faunal remains known from sites dating to the Deglacial, zooarchaeological studies that focus on intensification and/or the BSR are rare. Faunal remains from only three sites have been subjected to systematic study to elucidate taphonomic processes and evidence of intensive animal exploitation. Prendergast et al. (2009) and Jin (2010) investigated the extent to which carcasses were processed for within-bone nutrients at the Yuchanyan and Tangzigou sites in South China. In addition, increased hunting of small, fleet animals such as rabbits/hares was observed at Shuidonggou Locality 12, in northwest China, suggesting the BSR effect in animal procurement (Zhang et al. 2013). Prendergast et al. (2009) contributed a zooarchaeological perspective on intensification in two ways: one is the spectrum of game hunted, and the second is the degree to which a single carcass was processed for nutrients. While the former conclusion could have been reached from the perspective of BSR, intensification should be a more comprehensive concept to investigate the exploitation of animals. Studies from the southern Levant show that juvenile individuals increased in faunal assemblages during the Epipaleolithic due to human hunting pressure, which could be detected as changes in the prey spectrum age groups (Munro 2001, 2004, 2009).

On the other hand, general interpretations based on the comparative portions of Stiner's high- and low-ranked game argue the expansion of animal diet to include small-bodied taxa throughout most of the region where zooarchaeological studies were conducted (e.g., Stiner et al. 1999, 2000; Rillardon and Brugal 2014; Blasco and Peresani 2016; Starkovich 2017; Munro et al. 2018). However, during the Deglacial, and even during the Late Pleistocene, no remains of rabbits/hares and tortoises, and few remains of rodents and birds have been reported from archeological sites in North China. So, how was the prey spectrum composed in central North China? How did ancient hunters process their prey? Is there any evidence of intensive animal exploitation during the Deglacial in central North China?

In this paper, we provide an overview of faunal remains from Yujiagou, part of the Hutouliang Site Complex in the Nihewan Basin, and present zooarchaeological evidence for human subsistence during the Deglacial period, exploring the possibility that intensification occurred from paleoeconomic and paleoenvironmental perspectives. Indeed, given the scarcity of zooarchaeological studies that have been conducted in North China dealing with this significant period, it is hoped that our study will enable the elucidation of comparable subsistence strategies in future work as well as from parallel research conducted at related sites.

The Yujiagou site, Nihewan Basin

Geographical setting

The Nihewan Basin is an intermontane depression surrounded by the Xiong'er Mountains in the north and an extension of the Heng Mountains in the south, covering an area of roughly 1849 km^2 (~ 40°05′-40°20′N, ~ 114°25′–114°44′E; Fig. 1a). It includes a large number of Paleolithic localities, most of which are open-air sites in the eastern part of the basin, contained in lacustrine sediments or alluvial deposits of the Sanggan River terraces (Liu et al. 2013a, 2013b). More than 30 Upper Paleolithic sites have been found in this area, located on the second terrace of the Sanggan River and its tributary, the Huliu River. During Paleolithic investigations along the left blank of the Sanggan River in 1973, the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences (IVPP, CAS) found more than ten micro-blade sites in the vicinity of Hutouliang village, a cluster of localities subsequently referred to as the Hutouliang Site Complex (Fig. 1b; Gai and Wei 1977; Xie 2006).

The Yujiagou site (40°09′49″N, 114°28′47″E, ca. 865 m above sea level) is located in a small valley about 500 m northeast of Hutouliang ridge (Fig. 1c). The site was identified as locality 65039 in the Hutouliang Site Complex during former investigations. From 1995 to 1997, the Hebei Province Cultural Relics Bureau and Peking University conducted systematic excavations of a 120-m^2 area (Fig. 1d). Although a total station was not used during the excavations, the investigators employed a meter-square grid and dug in 5 cm spits to maintain provenience control. Sediments were dry- and wet-screened to retrieve microfauna and smaller artifacts.

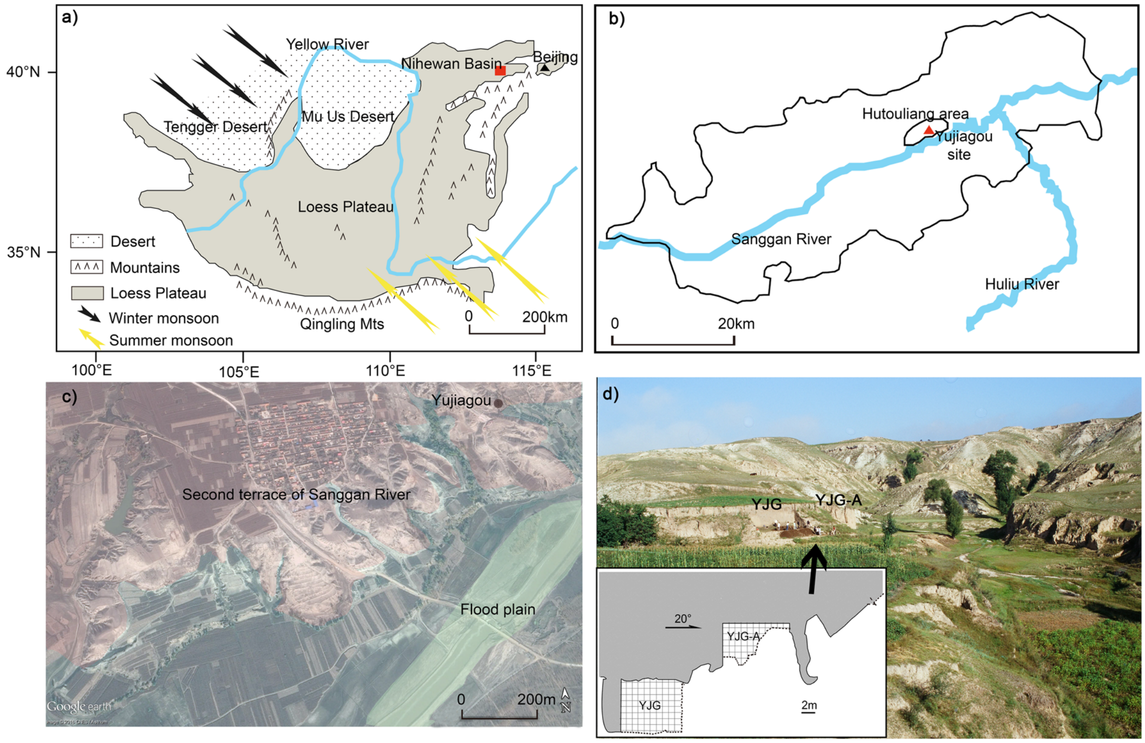

Fig. 1 Geographic location of the Yujiagou site (**a** Nihewan Basin in North China, modified from Ao et al. 2013; **b** Hutouliang Site Complex and Sanggan River; **c** the Yujiagou site in the Hutouliang area on the second terrace of the Sanggan River; **d** excavation of the Yujiagou site in 1995–1997)

Stratigraphy and dating

Fieldwork conducted at Yujiagou revealed a stratigraphic section with total depth of approximately 8 m, comprising seven archeological layers numbered layer 1 to 7 from the top to the bottom. The sequence consists mainly of loess silt in layers 1–4. A thick river gravel bed in layer 7 underlies sandy sediments in layers 5 and 6 (Fig. 2). Detailed information of sedimentation were introduced by Mei (2007) based on the north profile of YJG and were summarized as follows: Layer 1 (~ 0.3 m thick), the surface layer, brown-yellow loess silt, vertical joints growth; layer 2 (~ 1.3 m thick), gray-black clayey silt, soft, and organic rich; layer 3a (~ 1.5 m thick), dark brown loess silt, soft, with small-sized pebble; layer 3b (~

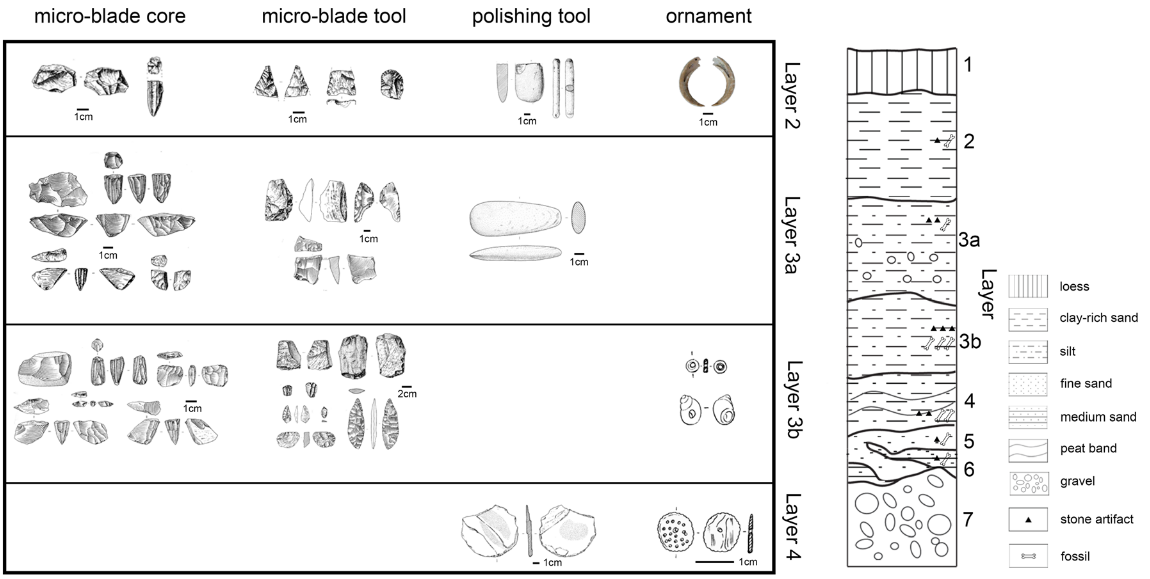

Fig. 2 Stratigraphic profile of the Yujiagou site depicting typical artifacts from layers 2 to 4 (artifact illustrations were modified from Mei 2007)

1.3 m thick), light brown clayey silt with compact texture; layer 4 (~ 0.6 m thick), brown-gray loess silt, dense texture, with rust-like sediments; layer 5 (~ 0.8 m thick), brown clayey silt with calcareous concretion; layer 6 (~ 0.3 m thick), brown-gray or celadon calcareous silt with coarse brown sand; and layer 7 (> 0.4 m thick), gravel bed, consist of mainly limestones in high psephicity.

Thermoluminescence (TL), optical stimulated luminescence (OSL) and accelerator mass spectrometry (AMS^{14}C) were carried out to present the ages of different layers of Yujiagou (Table 1, Xia et al. 2001; Tsuneto et al. 2009; Lin et al. 2018; Rui et al. 2019). In order to obtain more accurate dating of fauna, we sent eight bone samples to beta analytic and got radiocarbon dates of faunal assemblages from layers 2–5 (Table 1). The new dates could be divided into two ranges, while layers 2 and 3a were dated from ca. 10,373 to 8406 cal BP and layers 3b, 4 and 5 were dated from ca. 16,023 to 13,855 cal BP. Here, we rely exclusively on the radiocarbon dates of bones because (1) the TL sample of Xia et al. (2001) did not distinguish the sub-layers within layer 3; (2) the margin of error of the TL method is approximately ± 10%, which is too great to be useful for our purposes; (3) the OSL results of Tsuneto et al. (2009) and Rui et al. (2019) concentrated on the layers 6, 3a and 2, in which the bones were not as abundant as those in layers 3b and 4; and (4) the specific layers of AMS ^{14}C samples of Lin et al. (2018) are obscure.

There is an obvious hiatus from 12.9 to 11.5 cal ka BP between layers 3a and 3b, which may suggest that mobile hunter-gatherer groups left this area or abandoned this site during the harsh Younger Dryas interval.

Archeology and environment

The lithic assemblage recovered from layers 3b and 4 (typical artifacts are presented in Fig. 2) at Yujiagou has been classified as a micro-blade industry characterized by the presence of wedged-shaped micro-blade cores, which may have entered the Nihewan Basin from Northeast Asia during ca. 20–14 ka BP (Wang 2018). The geographical distribution of wedged-shaped micro-blade cores is quite limited in northern China, and Hutouliang seems to be the southernmost area that contains this technology during the Upper Paleolithic. This technology was then replaced by a conical micro-blade core technology between ca. 14–9 ka BP, while partially ground stone tools and ceramics were common in the Hutouliang region around 11 ka BP, developing rapidly from about 9 ka BP onwards (Mei 2007). The ornaments follow a pattern similar to that of the lithic artifacts. Ostrich egg shell beads disappear in layer 3a while they dominate the ornament assemblages from layers 3b and 4.

The ^{14}C results attribute the age of the Yujiagou site to MIS 2, while layers 4 and 3b fall within the transition of the last glacial maximum (LGM) to the Bølling-Ållerød stage (B/A), while layer 3a is post-Younger Dryas in age. The Yujiagou site was occupied mostly during relatively warm climatic stages. Sporopollen analyses were undertaken to elucidate local climatic conditions (Fig. 3). Transitions from dry and cold bushveld conditions in layers 7 to 5 to continuously warm and dry steppe and bushveld ecologies in layers 4-3b, to warm and humid forest steppe in layers 3a-2, and finally to relatively warm and humid forest steppe (layer 1) suggests the environment changed rapidly and frequently in this valley along the Sanggan River, even during periods of overall temperature increases (Xia et al. 2001; Xie 2006).

Material and methods

Over 30,000 specimens were unearthed during the 1995–1997 excavations, including fossils, lithic artifacts, bone and antler tools, ceramics, and ornaments (Table 2). Layers 3b and 4 yielded 90% of the specimens recovered from all seven layers, and the assemblages of artifacts from those layers are distinctive.

A total of 19,686 bone specimens was recovered from seven layers, including 12,382 from layer 3b and 4439 from layer 4. Bone tools and ornaments are not included in these totals. In this paper, we focus on layers 3b and 4, due to the large sample sizes of specimens, the distinctive artifact assemblage, and the well-documented climate stages.

We carried out taphonomic and zooarchaeological analyses in order to explore the attrition of the bone assemblages, hunting preferences, transferred decisions, and consumption strategies. All bone fragments were examined against comparative materials stored in the IVPP for anatomical and taxonomic identification. Identifiable bones and tooth fragments were assigned to the most discriminating taxonomic level possible. Values for the number of specimens (NSP), the number of identified specimens (NISP, following Lyman 1994), minimum number of individuals (MIN, following Lyman 1994), minimum number of elements (MNE, following Stiner 1994), and minimum animal units (MAU, following Binford 1984) were calculated. Bones that could not be assigned to species were grouped into body-size classes (Table 3) relative to the estimated body weight of individuals. Subsequently, %MAU for different body sizes was summarized and applied in bivariate tests of standard food utility index ((S)FUI, Metcalfe and Jones 1988), unsaturated marrow index (UMI, Morin 2007), general utility index (GUI, Emerson 1993), food utility index (AVGFUI, Emerson 1993), bone fat index (BFI, Emerson 1993), standardized average of marrow fat (AVGMAR, Emerson 1993), and meat drying index (MDI, Friesen 2001).

To assess in situ attrition, tooth- and cranial-based MNI (Stiner 1994), completeness index (Marean 1991), and correlation of %MAU and bone mineral density (BMD, Lyman 1984; Lam et al. 1999) were applied.

Table 1 Dating results of different layers from the Yujiagou site (calibrated using OxCal online version 4.3)

Layer	Field no.	Lab No.	Material	Dating method	Age			Reference
					Uncalibrated/BP	Calibrated/BP (95%)	ka	
Layer 2	95YJG(2): 165	Beta-439276	Bone	AMS^{14}C	7670 ± 30	8539–8406	–	Reported here
Layer 3a	95YJG(3): 5	Beta-439277	Bone	AMS^{14}C	9110 ± 30	10,373–10,206	–	Reported here
Layer 3b	95YJG(3): 891	Beta-439278	Bone	AMS^{14}C	12,360 ± 40	14,690–14,132	–	Reported here
Layer 3b	97YJG(3): 2874	Beta-439280	Bone	AMS^{14}C	12,520 ± 50	15,100–14,385	–	Reported here
Layer 3b	97YJG(3): 3261	Beta-439281	Bone	AMS^{14}C	12,170 ± 50	14,205–13,855	–	Reported here
Layer 4	96YJG(4): 120	Beta-439282	Bone	AMS^{14}C	13,180 ± 40	16,023–15,675	–	Reported here
Layer 4	97YJG(4): 1282	Beta-439283	Bone	AMS^{14}C	12,850 ± 40	15,545–15,160	–	Reported here
Layer 5	97YJG(5): 99	Beta-439284	Bone	AMS^{14}C	13,020 ± 40	15,780–15,348	–	Reported here
Layer 1	YJG-01	YJG-01	K-feldspar grains	OSL	–	–	1.6 ± 0.1	Rui et al. (2019)
Layer 2	YJG-02	YJG-02	K-feldspar grains	OSL	–	–	2.7 ± 0.6	Rui et al. (2019)
Layer 2	YJG-03	YJG-03	K-feldspar grains	OSL	–	–	9.8 ± 0.6	Rui et al. (2019)
Layer 3a	YJG-04	YJG-04	K-feldspar grains	OSL	–	–	9.7 ± 0.7	Rui et al. (2019)
Layer 3a	YJG-05	YJG-05	K-feldspar grains	OSL	–	–	11.4 ± 0.7	Rui et al. (2019)
Layer 3a	YJG-06	YJG-06	K-feldspar grains	OSL	–	–	13.4 ± 0.8	Rui et al. (2019)
Layer 3a	YJG-07	YJG-07	K-feldspar grains	OSL	–	–	12.2 ± 0.7	Rui et al. (2019)
Layer 3b	YJG-08	YJG-08	K-feldspar grains	OSL	–	–	12.8 ± 0.7	Rui et al. (2019)
Layer 4	YJG-09	YJG-09	K-feldspar grains	OSL	–	–	13.5 ± 0.9	Rui et al. (2019)
Layer 5	YJG-10	YJG-10	K-feldspar grains	OSL	–	–	13.5 ± 0.8	Rui et al. (2019)
Tan clayey silt (80 cm)	–	XA10889	Sediment	AMS^{14}C	5028 ± 37	5895–5661	–	Lin et al. (2018)
Tan clayey silt (110 cm)	–	XA10888	Sediment	AMS^{14}C	7163 ± 36	8036–7932	–	Lin et al. (2018)
Yellow silty sand (140 cm)	–	XA10887	Sediment	AMS^{14}C	8844 ± 46	10,159–9710	–	Lin et al. (2018)
Yellow silty sand (170 cm)	–	XA10886	Sediment	AMS^{14}C	9729 ± 49	11,243–10,877	–	Lin et al. (2018)
Yellow silty sand (200 cm)	–	XA10885	Sediment	AMS^{14}C	10,460 ± 39	12,549–12,131	–	Lin et al. (2018)
Yellow silty sand (250 cm)	–	XA10884	Sediment	AMS^{14}C	11,421 ± 40	13,360–13,145	–	Lin et al. (2018)
Yellow silty sand (275 cm)	–	XA10883	Sediment	AMS^{14}C	11,330 ± 47	13,277–13,085	–	Lin et al. (2018)

Table 1 (continued)

Layer	Field no.	Lab No.	Material	Dating method	Age			Reference
					Uncalibrated/BP	Calibrated/BP (95%)	ka	
Yellow silty sand (300 cm)	–	XA10882	Sediment	AMS^{14}C	14,356 ± 71	17,721–17,225	–	Lin et al. (2018)
Yellow silty sand (325 cm)	–	XA10881	Sediment	AMS^{14}C	12,220 ± 66	14,440–13,860	–	Lin et al. (2018)
Yellow silty sand (350 cm)	–	XA10880	Sediment	AMS^{14}C	12,499 ± 48	15,059–14,327	–	Lin et al. (2018)
Yellow silty sand (400 cm)	–	XA10879	Sediment	AMS^{14}C	13,454 ± 49	16,385–15,990	–	Lin et al. (2018)
Yellow fine-grained sand containing gravel (450 cm)	–	XA10878	Sediment	AMS^{14}C	21,509 ± 72	25,975–25,651	–	Lin et al. (2018)
Caesious silt (500 cm)	–	XA10877	Sediment	AMS^{14}C	22,238 ± 89	26,807–26,142	–	Lin et al. (2018)
Caesious silt (550 cm)	–	XA10876	Sediment	AMS^{14}C	23,781 ± 97	28,049–27,645	–	Lin et al. (2018)
Upper Layer 6	–	–	Ploymineral	OSL	–	–	9.2 ± 1.4	Tsuneto et al. (2009)
Lower Layer 6	–	–	Ploymineral	OSL	–	–	9.0 ± 1.3	Tsuneto et al. (2009)
					–	–		
Layer 3a	–	–	Ceramic	TL	–	–	11.7	Mei (2007)
Layer 2	–	–	Quartz	TL	–	–	2.1 ± 0.3	Xia et al. (2001)
Layer 2	–	–	Quartz	TL	–	–	6.1 ± 1.1	Xia et al. (2001)
Layer 3	–	–	Quartz	TL	–	–	7.0 ± 0.8	Xia et al. (2001)
Layer 3	–	–	Quartz	TL	–	–	11.1 ± 0.9	Xia et al. (2001)
Layer 6	–	–	Quartz	TL	–	–	12.2 ± 1.0	Xia et al. (2001)

To determine the age-at-death and season-of-death of the animals in our sample, dental wear was recorded and tooth eruption sequences were compared with living species (Hillson 2005; Munro et al. 2009). This approach yielded three age classes and results were summarized in a ternary diagram, as suggested by Stiner (1994). For small bovids, such as gazelle, the juvenile category ends when all deciduous teeth are replaced by permanent teeth (about 18 months), while the limit of adult dentition falls around 58 months. For large ungulates, such as the horse, life spans are longer, while the age class of adult individuals ranges from 4 to 17 years old.

Long-bone fractures were also observed to investigate whether bones were broken when fresh (green) or old (dry). The morphology of the fracture angle, fracture outline, and fracture edge were recorded following Villa and Mahieu (1991), and the FFI values (suggested by Outram et al. 2005) based on the morphologies of bone fractures were calculated. The degree of completeness of long-bone shaft circumference (i.e., C1, less than half complete; C2, more than half complete; C3, complete), and the remains of each long bone (i.e., L1, less than one quarter; L2, one quarter to one half; L3, one half to three quarters; L4, more than three quarters complete) were also recorded as indicators of bone marrow exploitation strategies. Bone types (i.e., diaphysis, epiphysis, and axial) and bone size were recorded to explore the possibility of marrow and grease consumption (following Karr 2015; Outram et al. 2005). Furthermore, in order to test marrow extraction, the correlation between fragment indices (NISP:MNE, Wolverton 2002) and UMI was evaluated (following Munro and Bar-oz 2005).

A × 40 magnifier was used to observe bone surfaces in order to preliminarily classify modifications made by non-

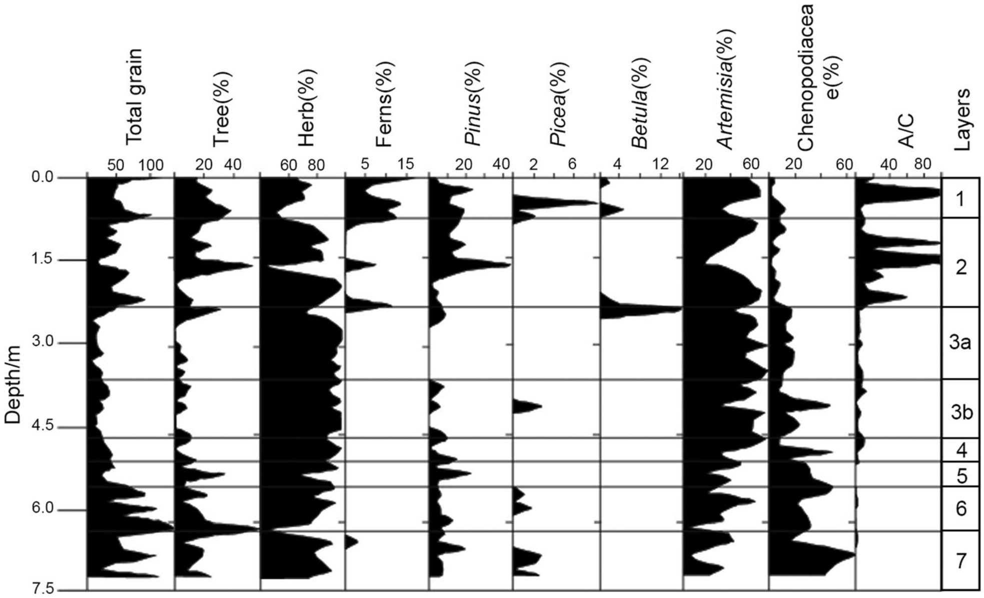

Fig. 3 Diagram of main sporopollen percentages from the Yujiagou section (modified from Xia et al. 2001)

human and human agents, including weathering (Behrensmeyer 1978), cut marks, percussion marks, and carnivore tooth marks (following Blumenschine et al. 1996; Dominguez-Solera and Dominguez-Rodrigo 2009). A higher-power digital microscope (Keyence VHX-600EOS, × 20–× 5000) was employed for more detailed specimen examinations.

Results and data interpretation

Taphonomy and attrition assessment

Zooarchaeological studies in northern China are rare, mainly due to poor bone preservation, especially in open-air sites. Most archeological sites are affected by attritional processes; thus, the taphonomic assessment of slow destruction is an essential aspect of generating more accurate interpretations of past human behavior.

In Yujiagou layer 3b, 382 specimens were identifiable to taxa (i.e., identification index 3.1%, Table 4). However, for layer 4, the identification index is extremely low (only 1.82%), resulting mainly from the highly fragmented character of the assemblage. The fragmentation analysis results presented here are of great significance. The bulk of the faunal remains (11,697 in total) in both layers are less than 30 mm in maximum length; specifically, 68.87% for layer 3b, and 72.06% for layer 4 (Fig. 4). In layer 3b, specimens ranging in size from 40 to 50 mm and 80–100 mm are more numerous than in layer 4. Moreover, in layer 3b, there are 77 specimens whose length are over 100 cm, and there are 199 specimens that can be identified to anatomical parts. Therefore, the identification index of layer 3b would be higher to a certain extent.

To evaluate the relative representation of elements with different structural densities, tooth- to cranial-based MNIs

Table 2 Distribution of artifacts at the Yujiagou site

Layer	Animal remains	Chipped stone tools	Polished stone tools	Polished bone tools	Ceramics	Ornaments			
						Shell beads	Bone beads	Stone rings	OES beads
2	177	389	11	7	27	2	1	–	–
3a	483	292	1	–	2	2	–	–	–
3b	12,382	3689	–	1	8	7	1	7	4
4	4439	6793	1	–	3	1	–	10	–
5	905	408	–	–	–	–	–	2	–
6	410	107	–	–	–	–	–	–	–
7	933	291	–	–	–	–	–	1	–
Total	19,686	11,969	13	8	40	12	2	20	4

OES ostrich egg shell

Table 3 Animal size classes used in this study

Size class	Species	Ungulate size	Weight (kg)	
Class 1	Shellfish, zokor, civet			< 23 kg
Class 2	Gazelle, topi, ostrich, boar, fox			23–84 kg
		Small cervid	< 50 kg	
		Small bovid	< 60 kg	
Class 3	Horse, donkey, red deer, hyena	Equid	> 250 kg	84–296 kg
		Large cervid	> 150 kg	
Class 4	*Bos* sp.			296–1000 kg
		Large bovid	> 600 kg	
Class 5	*Coelodonta*	Rhinocerotidae		> 1000 kg

(Stiner 1994) were tested in this study. In both stratigraphic layers, the rates of tooth/cranial-based MNIs are higher than 0.4, which suggests relatively high preservation (Table 5), especially for gazelle remains from layer 3b where this rate is higher than 0.8, indicating minimal loss of identifiable bones by decomposition and/or advanced fragmentation.

Similar results were obtained using Marean's (1991) completeness index which quantifies the quality of preservation of high-density elements such as phalanges and tarsal bones. The percentage of completeness ranges from 70% to 100% in layers 3b and 4 (Table 6), suggesting attrition was not significant during the burial of these assemblages. For the tarsal of gazelle, the completeness index in layer 3b is significantly higher than that in layer 4, which accord with the fragmentation analysis. Furthermore, the test of Spearman's correlation of BMD and %MAU for ungulate remains shows no significant relationship between bone preservation and their density (Table 7). Overall, the post-depositional processes of in situ attrition played only a minor role in the formation of the assemblages from layers 3b and 4.

More than 50% of the bones in layers 3b and 4 were weathered to class 0–2 (Fig. 5) in which only 2% and 5% of bone surfaces were assignable to class 0, indicating short term of exposure before deposition. In this case, the weathering damage did not compromise taxonomic identification or the observation of bone surface modification. None of the specimens display rounding of their broken surfaces, and no evidence of water polishing was found. Due to the co-occurrence of bones of different sizes in the same units, especially those smaller than 20 mm (46.97% in layer 3b and 52.01% in layer 4), we conclude that fluvial transport was insignificant at the site.

Damage caused by rodent gnawing and the chewing and digestion of carnivores is not common in either layer (Fig. 5). Only 19 specimens in layer 3b and 11 specimens in layer 4 were found to be modified by carnivores. The low rates (less than 10% in both layers) of rodent and carnivore activities indicate that those animal agents were neither bone collectors nor significant modifiers of these assemblages. However, root damage with dendritic patterns is more common in the Yujiagou collections. In fact, the preserved dry roots of reeds

Table 4 NISP and MNI results from layers 3b and 4 at the Yujiagou site

Taxonomic name		Layer 3b				Layer 4			
Common	Latin	NISP	%NISP	MNI	%MNI	NISP	%NISP	MNI	%MNI
Shell	–	3	0.79%	3	5.66%	0	0	0	0
Zokor	*Myospalax* sp.	11	2.88%	4	7.54%	0	0	0	0
Ostrich	*Struthio anderssoni*	51	13.35%	1	1.89%	6	7.40%	1	4.76%
Civet	*Viverra* cf. *zibetha*	1	0.26%	1	1.89%	0	0	0	0
Fox	*Vulpes* sp.	1	0.26%	1	1.89%	0	0	0	0
Gazelle	*Procapra przewalskii*	223	58.38%	27	50.94%	31	38.28%	11	52.38%
Topis	*Spiroceros* sp.	1	0.26%	1	1.89%	0	0	0	0
Red deer	*Cervus elaphus*	0	0	0	0	3	3.70%	1	4.76%
Wild horse	*Equus przewalskii*	78	20.42%	12	22.64%	40	49.39%	7	33.34%
Wild ass	*Equus hemionus*	6	1.57%	2	3.77%	0	0	0	0
Woolly rhinoceros	*Coelodonta antiquitatis*	7	1.83%	1	1.89%	1	1.23%	1	4.76%
Total		382	100%	53	100%	81	100%	21	100%
NSP		12,339				4439			
NISP/NSP		3.1%				1.82%			

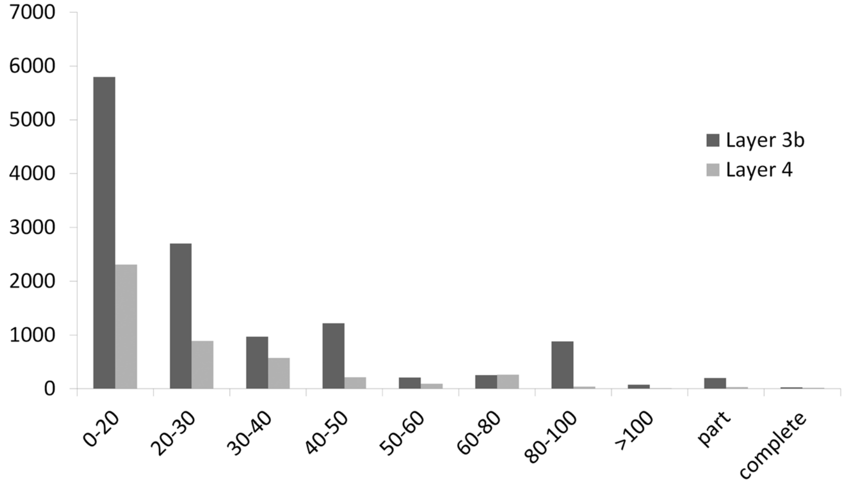

Fig. 4 Size distribution of bones from Yujiagou, layers 3b and 4

were recovered during excavations. Such erosion might obscure other types of modification which may have been present on the bone surfaces; the percentages are still low (7.9% in layer 3b, 5.1% in layer 4), after all.

In sum, non-human biotic agents had a low impact on the formation history of the faunal assemblages from Yujiagou. Post-depositional forces were *not* the major cause of bone breakage and fragmentation. We conclude that humans were the primary agents of the accumulation and modification of the bone assemblages from layers 3b to 4.

Prey abundance

Ten animal genera were identified from layer 3b, including freshwater shellfish, birds, rodents, small carnivores, and ungulates. Five genera were present in layer 4, where there are no signs of shells, rodents, or carnivores. Ungulates are the most abundant taxon in these assemblages. Small carnivores (e.g., civet and fox) are sporadically present in the sample, concentrated in the upper layer. It is important to note also that traces of small prey species, such as tortoises, rabbits/hares, and small birds, are absent from the site although ostrich eggshells (OES) were collected from layers 3 to 4, suggesting their intended use as a raw material in the manufacture of ornaments.

In terms of total NISP of taxa, the most common species in layer 3b is *Procapra przewalskii* (58.38% of total NISP), followed by *Equus przewalskii* (20.42% of total NISP). These two species also dominate layer 4, but their percentages change to 38.28% for gazelle and 49.39% for wild horse, which makes *E. przewalskii* more common in this assemblage. The MNI values in layer 3b reflect a pattern similar to the NISPs in that the gazelle (*P. przewalskii*) is most abundant, followed by horse (*E. przewalskii*). Although the NISP of horse exceeds that of gazelle in layer 4, the MNI suggests that gazelle was always the most abundant game species. The changes of %MNI of gazelle and horses from layer 4 to 3b are not as significant as that of %NISP. The %MNI values of both gazelle and horse show a decreased proportion, and the taxon composition was generally consistent from layer 4 to 3b. It could be the result of high level of fragmentation of bones, corresponding with the attrition assessments.

Since some bones could be assigned to anatomical level and size class, but not to species, broader taxonomic groups based on body sizes were used for classification (Fig. 6). This approach increased the sample size of both assemblages. Classes 2 and 3 ungulates are much more common in layer 3b. The percentage of class 2 ungulates (mostly small bovids and cervids) in layer 3b is 66.85% of NISP, while the percentage of classes 3 ungulates (mostly equid and large cervid) is only 22.93%. In layer 4, the percentage of classes 3 ungulates increases to 37.45% of NISP, while class 2 ungulates constitute 51.79% of the faunal assemblage. In this aspect, the prey size seems decreased from layer 4 to layer 3b. However, the decreasing ratio is not significant.

Table 5 Tooth- and cranial-based MNIs of gazelle and horse

Layer	Species	Cranial-MNI	Tooth-MNI	Cranial-MNI/Tooth-MNI
3b	Gazelle	22	27	0.815
	Horse	3	7	0.429
4	Gazelle	3	5	0.6
	Horse	2	4	0.5

Ungulate mortality profiles

The preservation of long bones at the Yujiagou site is not sufficient to reconstruct survivorship curves based on epiphyseal fusion. Instead, the age at death of dominant ungulates was estimated based on isolated teeth and mandibles. The eruption sequence and wear patterns of gazelle teeth in different age stages were used according to the study of related

Table 6 Completeness index of ungulates from Layers 3b and 4

Layer	Species	First phalanx	Second phalanx	Third phalanx	Astragalus	Calcaneus	Central tarsal
3b	Gazelle	100%	100%	–	98%	90%	100%
	Horse	100%	100%	–	100%	–	–
	Rhinoceros	–	–	–	–	70%	–
4	Gazelle	–	–	100%	73%	70%	94%
	Horse	–	100%	100%	98%	–	–
	Rhinoceros	100%	–	–	–	–	–

living species (Munro et al. 2009). For horses, crown heights were measured and the equation of linear regression of Fernandez and Legendre (2003) was used to calculate ages. Mortality profiles (juveniles, prime adults, and old adults) are presented as percentages (Fig. 7) and illustrated in ternary plots following Stiner (1994).

Mortality results of gazelles and horses from Yujiagou Layers 3b and 4 are biased toward juvenile individuals. In layer 3b, there are 49 specimens (63.64%) belonging to the juvenile individuals of gazelles, while 17 (65.38%) of those belong to horses. In layer 4, the juvenile gazelles account for 70.9%, while the juvenile horses account for 51.28%. Obviously, the percentages of juveniles increased in layer 3b over layer 4 in the case of horses while decreased in the case of gazelle.

Transport and processing of prey animals

The MNE, MAU, and %MAU of different ungulates from layers 3b to 4 were calculated (detailed number are presented in supplementary Table 1). The relative proportions (%MAU) of small ungulates (i.e., gazelles), medium ungulates (i.e., horses and red deer), and large ungulates (i.e., large bovids) from layers 3b to 4 are presented in Fig. 8. In Layer 4, the most commonly collected anatomical parts (%MAU > 75) of gazelles were front limbs such as scapulae and ulnae, followed by skulls and metatarsals. Most of the body parts of gazelles are present, except for the pelvis. As for medium ungulates, distal limb bones and skulls are the most common. Although horse scapulae were not found in this layer, all other body parts were recovered. The front limbs and ribs were the most commonly encountered anatomical parts for large bovids. In layer 3b, mandibles comprise the most represented parts of gazelles, followed by skulls and ulnae while the fore limbs are more frequently represented than are the hind limbs. All body parts of small ungulates are present in this layer. For medium-sized horses, skulls and limbs, especially front proximal limbs, are the most commonly represented. However, their pelvises are missing. Among large bovids, limbs were more frequently represented than axial bones. The antlers of red deer and the horn cores of large bovids were the most frequently represented elements, perhaps indicating their presence in the site for non-edible purposes.

Table 7 Spearman's correlation of %MAU and BMD on ungulates from layers 3b and 4

Layer		Small cervid	Small bovid	Large bovid	Equid
3b	r_s	− 0.229	− 0.223	− 0.083	− 0.016
	p	0.362	0.373	0.743	0.949
4	r_s	− 0.256	0.511	0.093	− 0.383
	p	0.306	0.030	0.714	0.117

In these two layers, the distribution of %MAU of gazelles and horses is nearly equal, suggesting their carcasses may have been transported back to the site as complete packages. The skulls of those two ungulates are more frequently represented than most limb bones, which does not correspond with their relative density. On the one hand, the horn cores of gazelle and the petrosum of horses have a higher probability of taphonomic survival and, on the other hand, undiagnosed fragmentary limb elements, due to the consumption of marrow, could lower the proportional count of represented limb bones.

Of the identifiable remains, 10.84% in layer 3b bear cut marks while 8.19% bear percussion marks. The percentage of cut marks in layer 4 is 28.1%, and that of percussion is 7.71%. Although all the main ungulate species were processed in some way, butchery marks in gazelles and horses account for more than 88.75% of the total striations present. Among gazelles, anthropogenic bone modifications concentrated on the limbs in both layers, especially on the joints of long bones, suggesting dismembering and the harvesting of tendons (Fig. 9). The hind limbs bear more cut marks than the fore limbs. Considering the intumescent head of the ulna in ungulates, it is more convenient to locate the joints of the humerus and radius-ulna than those of the femur and tibia. In layer 3b, cut marks appear on mandibles and the ends of ribs while in layer 4, cut marks were found only on mandibles and limb elements. Moreover, cut marks parallel to the bone's long axis were observed on metacarpal shafts, indicating skinning or butchery behavior. Percussion marks on gazelle bones in both layers are concentrated on long-bone epiphyses.

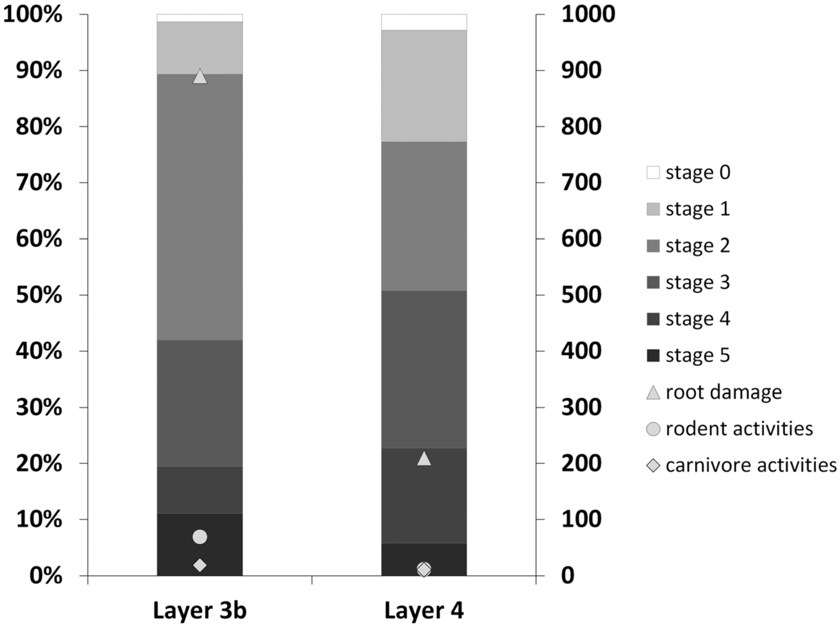

Fig. 5 Weathering stages and non-human modification frequencies in Yujiagou, layers 3b and 4

A different pattern was observed on equid remains from layer 3b. Here, cut marks are fewer while percussion marks increase, and all such modifications occurred on limb bones. Percussion marks appear mostly on the posterior limbs, notably, focusing on the proximal ends of metapodials. Similarly, cut marks appear only on hind limbs. In layer 4, no typical percussion marks were identified, but cut marks were more frequent than inl 3b, being found mostly on the distal limbs. With respect to the butchery process, signs of skinning, dismembering, and harvesting tendons, periosteum, flesh, and marrow were detected on gazelles in both layers. However, among horses, breaking long bones for marrow extraction seems to have been more important than other processes, especially in layer 3b.

Further analyses were undertaken to evaluate strategies for obtaining bone marrow. Spearman's bivariate analysis results show that there is no significant correlation between %MAU and the utility indexes (FUI, UMI, GUI, AVGFUI, BFI, and AVGMAR indices were used; Table 8) among all taxa. This lack of correlation between %MAU and the utility indices does not reflect a particular utility or transport strategy.

Significant positive correlation between fragment indices and marrow index was detected in long bone fragments of small bovids and horses in layers 3b and 4 (Table 9). Unlike other results, *p* value of small bovids from layer 3b is higher than 0.05, indicating the diaphysis bones might be less fragmental.

The quantitative distributions of bones of different size groups are similar in both layers that the sizes of most specimens are in 0–20 mm and 20–30 mm (Fig. 5). Nevertheless, in layer 3b, bones in the 40–50 mm and 80–100 mm size groups are also quite numerous. In layer 3b, cancellous bones account for 80% of the total specimens in the 0–20 mm size group, and 50% in the 20–50 mm size group (Fig. 10). With increasing bone size, the number of cancellous elements that could be assigned to anatomical portion also increased, especially

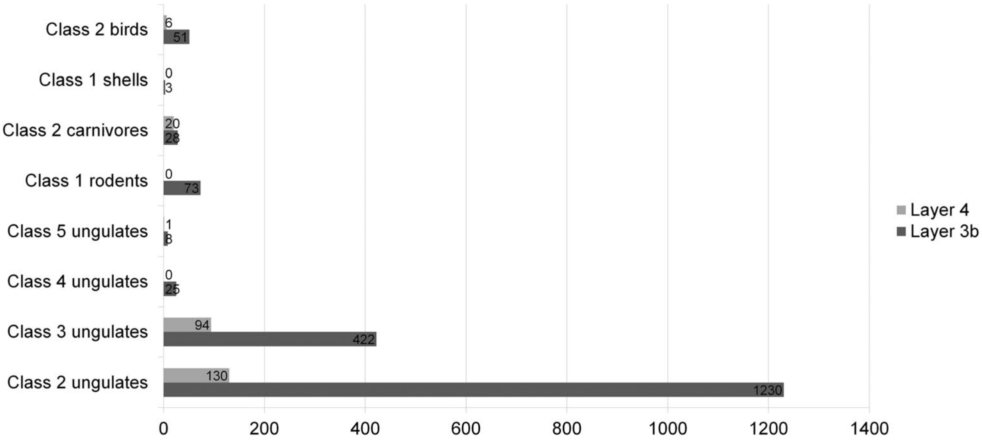

Fig. 6 Numbers of animals of various size classes from Yujiagou, layers 3b and 4

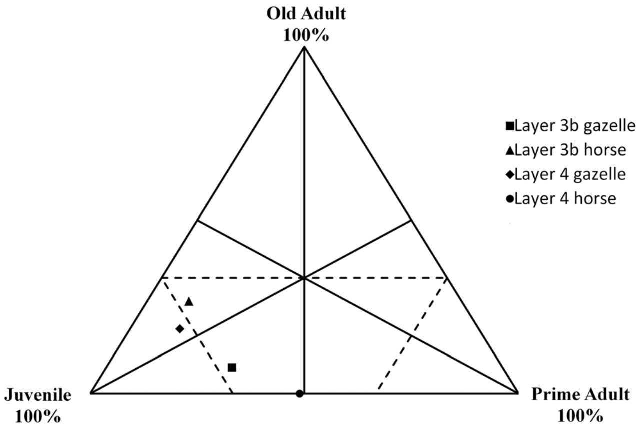

Fig. 7 Ternary diagram for gazelle and horse age classes

cancellous axial bones. Diaphyseal bones also increased with size, but fragments larger than 100 mm are rare. In another words, cancellous bones account for a large number of smaller fragments, and the smaller the bone is, the harder it is to be taxonomically identified. Correspondingly, in the larger size groups, diaphyseal bones account for a higher proportion of the total. The distribution of bone types of different sizes in layer 4 differs significantly from that in layer 3b. Cancellous bones comprise more than 50% of all size groups, but there is no significant relationship between the number and size of diaphyseal bones. Based upon ethnographic data (Binford 1978), smashing long bones randomly (i.e., struck at any point, mostly the middle of the diaphysis) produces more diaphysis fragments than removing the epiphyses first.

Comparison of length and circumference of long-bone fragments was undertaken to test the possibility of different reduction strategies. In layer 3b, long-bone shafts with circumferences less than one-third and lengths less than one-half of their original dimensions are fewer than those in layer 4 (Fig. 11). Meanwhile, in layer 4, most of the shafts are in C1 and L2 levels. It is most likely that the marrow extraction strategy reflected in layer 3b was more focused; epiphyses were removed to poke the marrow out. Moreover, in the earlier level, the reduction processes were more extensive.

The patterns of FFIs show further differences in the approaches to obtaining bone marrow between the two strata (Fig. 12). In layer 4, over 50% of the fractures of long bones fall within FFI0. With the improved FFI level, the number of bones decreased sharply, indicating that the long bones from this layer were mostly broken when they were fresh. FFIs in layer 3b are more concentrated in FFI1 and FFI2, although there are still some specimens in FFI0, suggesting that while many specimens were broken fresh, most long bones experienced a short period of exposure before cracking, leading to some dehydration of the bones.

Discussion

Variations in the agents and processes that acted on the Yujiagou assemblage are clear indicators of the mechanisms of bone accumulation, including non-anthropogenic processes (i.e., weathering, carnivore, and rodent gnawing and root activity) as well as human modifications. The weathering profiles of bones from two successive layers at the Yujiagou site suggest that most specimens are relatively little-weathered. Furthermore, rodent and carnivore gnawing marks are significant but have not affected or over-written evidence of human modification, including cut marks and impact damage. Although a high proportion of root marks are also present, carbonate casts dominate as opposed to root damage, indicating that plants developed in a relatively moist environment and decomposed quickly after death, probably later than the cessation of human occupation at the site. We therefore

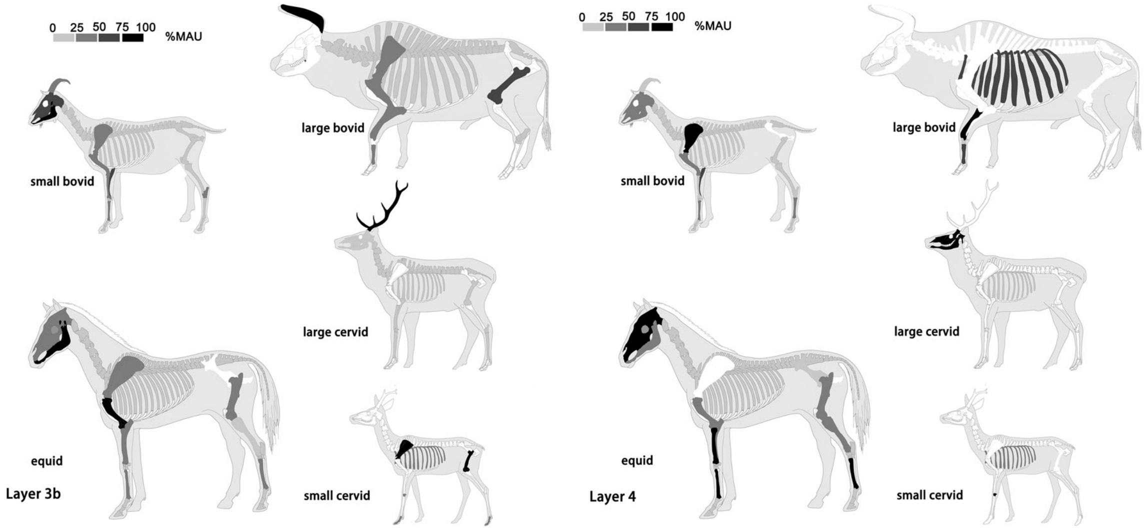

Fig. 8 %MAU distribution of ungulates

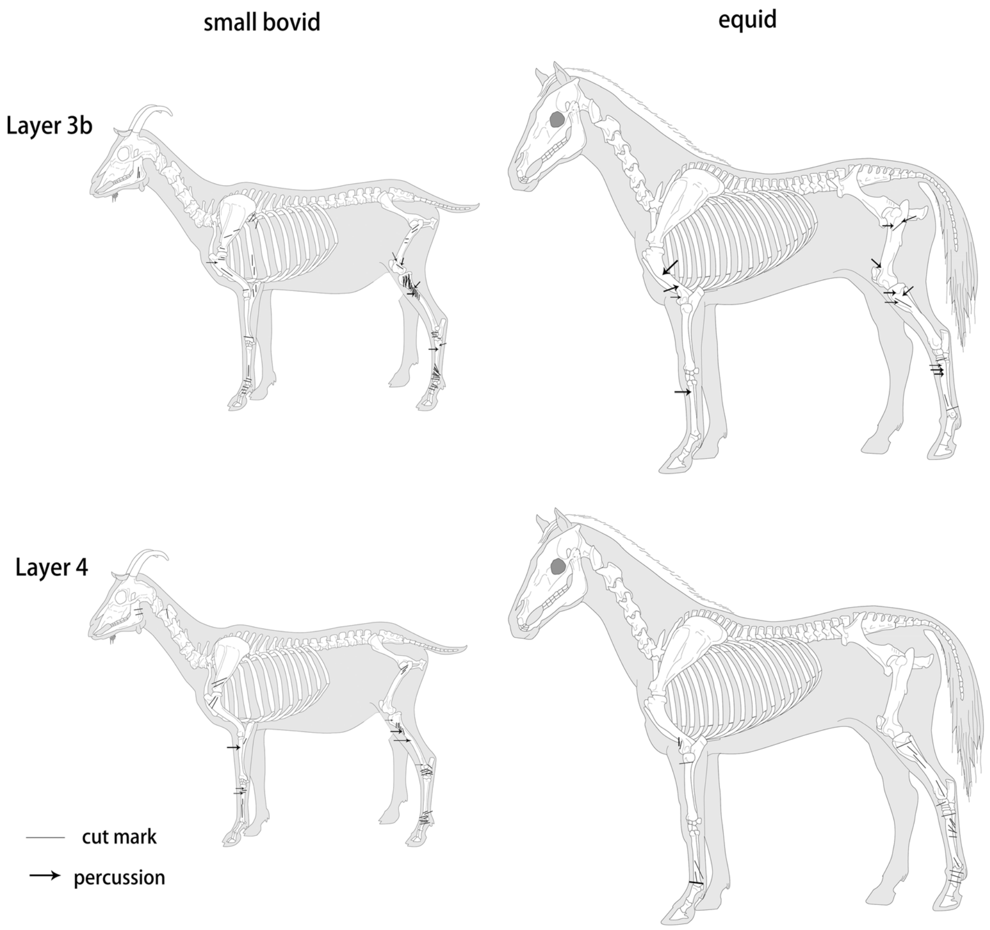

Fig. 9 Anatomical locations of anthropogenic modifications of gazelle and horse bones

conclude that the actions of non-anthropogenic agents played a secondary role in taphonomic processes, and that, primarily, the Yujiagou layers 3b and 4 assemblages were the result of human activities.

Table 8 Spearman's correlation of %MAU and multiple utility index among ungulates

		(S)FUI	UMI	GUI	AVGFUI	BFI	AVGMAR	MDI
Layer 3b								
Small cervid	r_s	0.173	− 0.003	0.150	0.134	0.202	− 0.006	0.356
	p	0.493	0.990	0.551	0.595	0.421	0.982	0.147
Large cervid	r_s	− 0.188	− 0.066	− 0.198	− 0.155	− 0.311	− 0.072	− 0.493
	p	0.456	0.794	0.430	0.538	0.209	0.782	0.038
Small bovid	r_s	0.832	− 0.229	− 0.140	− 0.075	− 0.222	0.063	− 0.329
	p	0.054	0.361	0.580	0.769	0.375	0.809	0.183
Large bovid	r_s	0.631	− 0.047	0.187	0.260	0.093	0.078	− 0.220
	p	0.121	0.852	0.457	0.298	0.712	0.766	0.379
Equid	r_s	0.081	0.127	− 0.201	− 0.191	− 0.207	0.255	− 0.159
	p	0.748	0.616	0.425	0.447	0.411	0.324	0.528
Layer 4								
Small cervid	r_s	0.083	− 0.219	0.188	0.152	0.220	− 0.093	0.004
	p	0.742	0.382	0.456	0.548	0.379	0.722	0.988
Large cervid	r_s	0.263	− 0.386	− 0.028	− 0.028	0.022	− 0.310	0.328
	p	0.291	0.114	0.911	0.911	0.931	0.226	0.184
Small bovid	r_s	0.082	− 0.083	− 0.087	− 0.079	− 0.082	0.160	− 0.190
	p	0.746	0.742	0.731	0.755	0.745	0.541	0.449
Large bovid	r_s	−0.095	0.081	0.077	0.026	0.128	0.057	− 0.036
	p	0.707	0.749	0.762	0.920	0.612	0.829	0.889
Equid	r_s	−0.185	0.348	− 0.176	− 0.170	− 0.237	0.099	− 0.344
	p	0.463	0.158	0.484	0.500	0.345	0.706	0.162

Table 9 Spearman's correlation of NISP:MNE and marrow index in Layers 3b and 4

		Layer 3b	Layer 4
Small bovid	r_s	0.89	0.74
	p	0.097	0.041
Equid	r_s	0.54	0.67
	p	0.032	0.02

Animal exploitation strategies at Yujiagou

The taxonomy of the recovered animal remains varies little throughout the site's stratigraphic levels with regard to the fact that most of the ungulates represented are steppe animals, although the presence of *Coelodonta* suggests a relatively cold and dry climate. As indicated by an earlier sporopollen analysis, the Yujiagou site vicinity was dominated by a savanna ecosystem during the Deglacial in which the climate slowly became warmer and wetter from layer 4 to layer 3b (Xia et al. 2001).

According to calculations of species abundance, skeletal element representation, butchery patterns, mortality profiles, and bone breakage patterns, the hunting and processing strategies of the Yujiagou occupants have been revealed.

Horses (class 3 ungulates) and gazelles (class 2 ungulates) dominate the two assemblages. From the lower (layer 4) to the upper (layer 3b) horizon, the proportion of gazelles increased, while the share of horses declined, but gazelles always dominated these assemblages. This might suggest that hunters increasingly targeted smaller ungulates through time. Alternatively, this pattern could be the consequence of a warmer climate, as the equids, especially Przewalski's horse, were better adapted to a cold and dry environment. Despite slight variation in the composition of game species represented in these two layers, the associated micro-blade toolkit was suitable for hunting both horses and gazelle. Equids have strong running ability, but their range of daily activities is relatively fixed, and they often scatter when frightened (Jiang 2004a). By employing compound tools such as spears, hunters could have herded horses into a trap and/or attacked them by surprise. Gazelles are skittish and alert with a discriminating sense of smell (Jiang 2004b). Hidden hunters who position themselves downwind of gazelle can often effectively shoot them from long distances with bows and arrows. Moreover, animal behavioral studies (Jiang 2004b) suggest that in late autumn, groups of gazelle converge for purposes of reproduction and migration; thus, larger herds could have

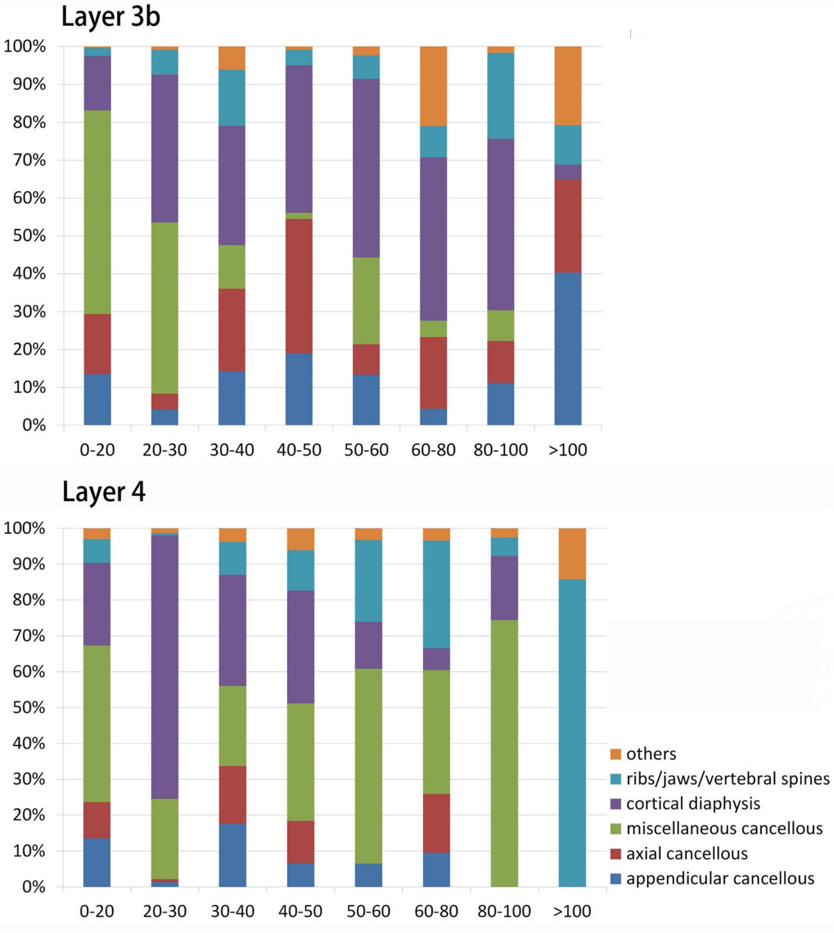

Fig. 10 Proportions of different bone types by sizes

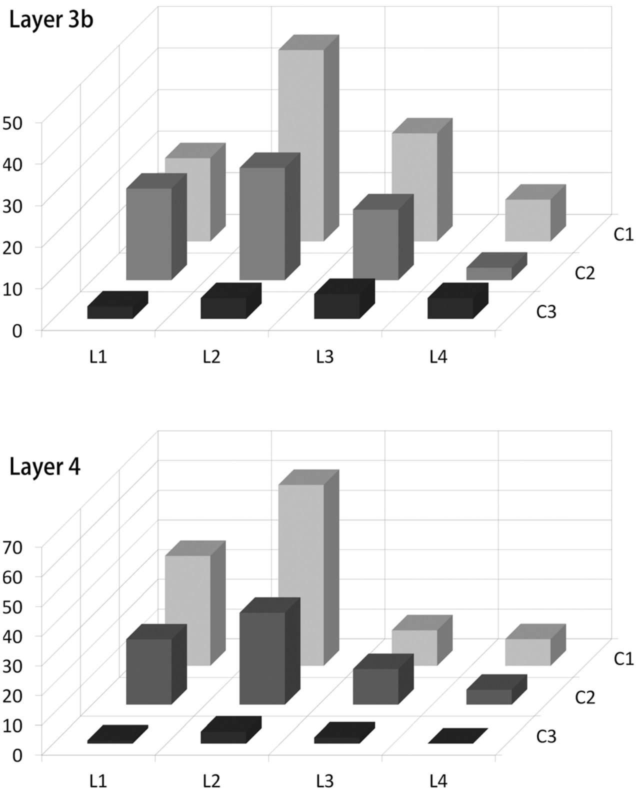

Fig. 11 Relative frequencies of shaft length by shaft circumference

improved the possibility of mass kills. In this way, Yujiagou hunters obviously had sufficient knowledge of their prey, especially their ecology and ethology, efficient and portable tools, and advanced planning and cooperative hunting behaviors.

From the perspective of the selective transport of prey species, Yujiagou hunters employed different handling strategies for animals of various sizes. Analysis of the spatial distribution of bone units shows that all osseous elements of small bovids were present in both layers, indicating that hunters transported whole carcasses back to the site. Among the larger game animals, large bovids contributed only partial skeletons to the site, but equid skeletons were rarely missing. It is possible that early hunters dispatched equids near the site by taking advantage of known regularly used routes to watering places, and transported them, essentially whole, back to Yujiagou. This decision may have been related to the need for enhanced exploitation of bone marrow. This aim seems more obviously documented in the upper layer, where elements of the upper limbs of equids, such as the humerus, were more frequent than in the lower strata.

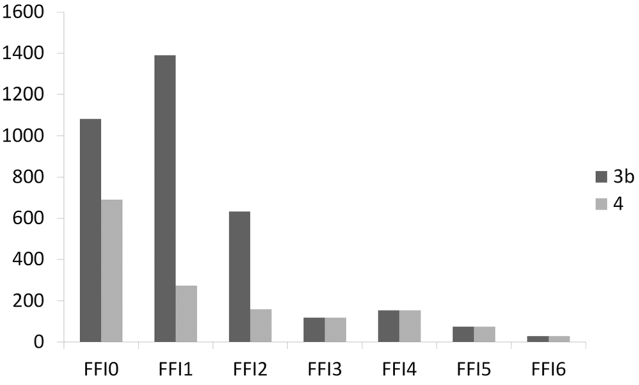

Fig. 12 FFI distribution of long bones

Although there were no significant differences in the hunting and transport strategies in the two layers, approaches to the butchery of carcasses display some variability. Cut and percussion marks were detected on bones from both layers, suggesting dismembering and cutting to obtain meat and cracking bones for marrow. The frequency of percussion signs in layer 3b is slightly higher than in layer 4, indicating that the pursuit of bone fat grew through time. The breakage pattern of long bones also indicates that the human occupants responsible for layer 4 exploited bone marrow immediately after butchery, while those in layer 3b may have accumulated bones stripped of meat for a short time. Overall, short-term storage of raw material and improvements in the strategy for obtaining bone marrow in layer 3b are noticeable at Yujiagou; thus, the exploitation of bone marrow seems to have been organized in this way, indicating group planned behavior.

In general, the exploitation strategies of Yujiagou's occupants were geographically local and conformed with environmental changes. That is to say, in acquiring animal resources, humans adapted to changes in resource status brought about by climatic and environmental fluctuations and met their demand for food by exploiting the most abundant resource types. At the same time, they were not limited to a single food type and the comprehensive development of meat, oil, and even eggs enriched their nutritional structure.

Intensification or not?

Micro-blade technology, polished stone technology, and ceramics appeared simultaneously in layer 4 at Yujiagou. Although pottery and grinding tools appeared only sporadically, they still demonstrate that innovation in the manufacturing of artifacts was taking place, and the ability of humans to obtain energy from a particular environment was increasing. In this way, the technological foundation of the intensification of resource exploitation was built. Research suggests that lithic raw material was sourced on Nanshan Mountain, which is located nearly 10 km south of Yujiagou, across the Sanggan River (Mei 2007). This suggests that although people lived on the north bank of the river, their range included the river's south bank, and they were well aware of nearby resources and exploitable environmental niches.

Zooarchaeological analysis reveals three aspects of intensified strategies of exploitation of faunal resources at Yujiagou.

1. Small bovids were always the most important vertebrate resources utilized at the site. In layer 3b, as artifacts became more numerous (in number and in types), the proportion of small bovids in the faunal assemblage increased while the share of horses decreased, indicating that hunters began to focus more on smaller ungulates and that their procurement strategies were more specialized. As mentioned above, the local environment got wetter and warmer from layer 4 to layer 3b. The decreasing diversification and increasing specification of Yujiagou hunter could be the adaptation of environment changes, while the small bovids survive better in the relatively warm climate. On the other hand, the seasonal information of gazelle from layer 3b indicated that the hunting began at the time when the herd formed the largest (autumn, during mating and migration), which made the hunting more efficient in terms of time and area.
2. Our data indicate that juvenile ungulates were preferentially hunted by humans at the Yujiagou site in both layers analyzed. This result is in marked contrast to records from other Upper Pleistocene sites (mostly in southern China) where fully grown adult animals were usually preferentially selected as prey (Prendergast et al. 2009; Jin 2010; Zhang et al. 2010; Wang et al. 2016). Indeed, the significantly higher proportion of juveniles at Yujiagou is similar to profiles reported from late Natufian contexts where young animals often comprise more than 30% of faunal samples (Munro 2004). Juvenile ungulates offer less energy returns than do adults, making them lower-ranked game for hunters to pursue. We therefore assume that hunting pressure had become manifest even if there are no traces of small game in the site's faunal assemblage. In addition, the predominance of juveniles could be a result of short-term free-ranging young individuals whose behavior resulted in a low possibility of escape and the higher mobility of juveniles predisposes them to be, essentially, storable products acquired through large-scale round-up hunting.
3. Organized extraction of bone marrow is a much more time-consuming and laborious task than simply obtaining meat. Based upon ethnographic evidence, this arduous and protracted work is clearly worth the effort since, on the one hand, bone marrow can provide high-quality nutrition while, on the other hand, its production can also be carried out by community members who are not involved in hunting or gathering. Although we have not found clear evidence of bone grease production at Yujiagou, the polished tools and ceramics could be considered aspects of the processing and boiling process, especially when the absence of plant remains at the site is taken into account. According to the bone fragments analysis, two different strategies to obtain within bone nutrition were assumed. During the colder period (layer 4), as soon as the flesh were consumed, humans broke the long bones immediately to obtain the marrow. When the climate became better, while the massive kill of gazelle occurred, it seems that the long bones were kept transitorily, and then were processed intensively.

Once the intensification was revealed, the causes of the strategies should be addressed. In general, the climate fluctuated during the occupation of Yujiagou, the occupants exploited the local resources as concentrated as they can. However, the concentration was suggested by the monospecific prey rather than the diachronic compare. Because no comparable zooarchaeological study has yet been undertaken in North China, it is impossible to determine the full range of subsistence strategies employed by humans in this region during this time. Moreover, in the smaller time scale, while the environment got warmer and wetter during B/A, the exploitation strategies seem to be more intensive, which could perhaps be explained by the increasing population (indicated by the increasing density of artifacts in Layer 3b).

Nevertheless, the primary zooarchaeological data from Yujiagou presented here demonstrate repeated occupation of the site as well as intensification of exploitation of faunal resources, which is different from reports of broad-spectrum exploitation of lower-ranked prey in northwestern China (Shuidonggou Locality 12), Europe, and Southwest Asia. At present, although few remains of hares, birds, or aquatic preys were reported in archeological sites in North China, to consider the lack of these animals in the local environment is unreasonable. Besides that, few zooarchaeological perspectives were undertaken in North China, and the strategies of Yujiagou could be an individual case.

Conclusion

The zooarchaeological approaches applied on the faunal remains from layers 3b and 4 at Yujiagou site improved our understanding of subsistence behaviors in North China during the deglacial. Within the information of chronology, we defined the occupants of both layers survived in this region during the transition from the end of LGM to B/A (ca. 15,950 to 13,855 cal. BP). The taphonomy analysis suggests that the accumulation of bones did not mainly result from the natural processes. Most of the bone surface modifications were caused by butchery activities. Thus, the bone assemblages are supposed to be able to represent comprehensive and actual human activities. Comparing with the natural faunas, the prey composition in Yujiagou is remarkably differed. The gazelle and horse, especially the juvenile individual, were the preferred prey of hunters. Even more, the Yujiagou hunter might have already acquired the mating and migratory habits of gazelle, and explored them during fall, which suggested the specification in the planned hunting. In addition to the intensive hunting, the foragers tended to pursuit the within bone fat that long bones were broken for marrow by different procedures in layers 3b and 4.

The present studies show that, at Yujiagou, no small lower-ranked prey was explored. Unlike other contemporaneous sites around Mediterranean Basin, Yujiagou, in North China reveal different intensification strategies. Similar results were mentioned in the studies of Epipaleolithic faunal in Levant (Munro and Atici 2009). However, the pattern brought out by Munro and Atici were built upon zooarchaeological data from 11 sites. Therefore, additional zooarchaeological studies should be applied in this area to improve our understanding of intensification activities and human relationships with local environments.

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