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STABLE ISOTOPIC DETECTION OF MANUAL INTERVENTION AMONG THE FAUNAL ASSEMBLAGE FROM A MAJIAYAO SITE IN NW CHINA

Weimiao Dong[1] • Cheng-Bang An[1*] • Wenjie Fan[1] • Hu Li[1] • Xueye Zhao[2]

[1]Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, Lanzhou 730000, China.
[2]Institute of Cultural Relics and Archaeology of Gansu Province, Lanzhou 830011, China.

ABSTRACT. Faunal remains from Shannashuzha in Minxian County, Gansu Province, China were isotopically analyzed to understand animal husbandry, and thus human subsistence strategy, during the Majiayao culture (5200–4800 cal yr BP) period. Stable carbon isotopic results reveal that only two pig samples clearly show a C_4-dominated diet with a mean $\delta^{13}C$ value of –8.5‰, which possibly indicated controlled feeding practices by human beings. No other significant manual intervention can be observed among the remaining samples, suggesting that both wild and domesticated meat sources were used at Shannashuzha. Statistically, *Bos* are indistinguishable from Cervidae based solely on isotopic results, suggesting that *Bos* may have remained in wild form during the Majiayao culture period. The presence of hare/rabbit, bamboo rat, and badger reflects the diversified food exploitation behavior.

KEYWORDS: Majiayao culture, stable isotopes, animal husbandry, subsistence strategy.

INTRODUCTION

As one of the agricultural origination centers of the world (Vavilov 1951; Diamond 2002), the first domesticated millet was found over 10,000 yr ago in northern China (Lu et al. 2009; Yang et al. 2012) and a widespread millet agriculture developed in the following millennia (e.g. Bettinger et al. 2007, 2010; Crawford 2009; Jones and Liu 2009; Liu 2015). Other than plants, livestock as well as other animals were another important aspect of the life of the ancient culture. Some animals were raised as meat and other byproducts, including pigs (*Sus scrofa domestica*), sheep (*Ovis aries*), goats (*Capra aegagrus*), and cattle (*Bos taurus*), while others were used for transportation (horse, *Equus ferus*) or for hunting (dog, *Canis lupus*, and cat, *Felis catus*) (Diamond 1999). It is likely that pig domestication occurred during the early Holocene independently in different parts of the world (Larson et al. 2005), with China as one of the centers (Yuan and Flad 2002; Flad et al. 2007; Yuan 2010). However, cattle domestication in China can only be traced back to ~4500 years ago (Yuan 2010). Chinese scholars (Su and Yin 1981; Chang 1986; Yan 1992) agree that Neolithic north China consisted of several agricultural culture sequences that included the Hongshan culture (~6000–5000 cal yr BP) colonizing the Liao River, the Dawenkou culture (~6300–4500 cal yr BP) in the lower Yellow River, the Yangshao culture (~6800–4900 cal yr BP) in the middle Yellow River, and the Majiayao culture (~5200–4800 cal yr BP) in the upper reaches of the Yellow River, each with prominent achievements. The peak of the cultural sequence was reached during the Yangshao culture in the mid-Holocene in central China (Yan 2009).

Previous studies have revealed that the Yangshao people were sedentary agriculturalists who lived in villages with specific structure patterns and had significant gender divisions of labor. Yangshao inhabitants grew millet and raised pigs as primary food sources, but also hunted game, fished, and gathered wild food as supplementary sources (Institute of Archaeology, Chinese Academy of Social Sciences 2010). Stable isotopic results verified that a large proportion of their diet came from cultivated plants, primarily millet (Wang 2004; Pechenkina et al. 2005; Barton et al. 2009; Fu et al. 2010; Ling et al. 2010; Guo et al. 2011; Hu et al. 2014).

The Majiayao culture was distributed throughout northwest China in the second half of the Holocene and later branched into several other cultures (Xie 2002), the emergence of which

*Corresponding author. Email: cban@lzu.edu.cn.

overlapped the later phase of Yangshao culture. It is debatable whether the Majiayao culture originated independently in northwest China culturally parallel to the Yangshao culture in central China or developed as a western successor of the latter (Yan 1989; An 1999; Xie 2002). What is explicit is that the Majiayao culture is primarily known by its exclusively marvelous and numerous painted red ceramics with figure patterns (An 1999). Results from archaeobotanical studies (Jia et al. 2013) indicate that rain-fed millet agriculture was fully developed during the Majiayao culture period. Hu (2015) came to the same conclusion, based on a flotation extraction of seeds at the Majiayao cultural site of Shannashuzha, where millet seeds were found to be the largest proportion of crop remains. Combined with the agriculturally oriented stone tools found at this site, it is believed that the occupants of the Majiayao culture site practiced a millet-based agriculture (Hu 2015). Dong et al. (2013) hypothesized that agriculture played different roles in different regions during the Majiayao period based on the types of tools found. Liu et al. (2010) thought the Majiayao was a farming culture dependent on the mercy of a suitable climate. However, no research on Majiayao lifestyle has ever directly taken the use of animal sources into consideration. Did Majiayao people raise pigs and grow millet like their eastern neighboring Yangshao farmers (Wang 2004; Guo et al. 2011) or did they pasture animals such as sheep and goats as well as grow crops similar to their higher-elevated Tibetan Plateau shepherd neighbors (d'Alpoim Guedes et al. 2014; Chen et al. 2015)?

Stable carbon and nitrogen isotopes of bone collagen are indicative of animal diet (DeNiro and Epstein 1978, 1981) and this technology has been widely applied (e.g. Ambrose 1990; Richards et al. 2000). In addition, isotope information can also reveal social status due to different diet (e.g. White et al. 1993; Price et al. 2010), explore subsistence strategies (e.g. Wang 2004; Bocherens et al. 2005), unveil migration patterns (e.g. White et al. 2009; Eggers et al. 2011), or differentiate domesticated fauna from wild fauna (e.g. Fornander et al. 2008; Hu et al. 2009).

This study examines the faunal dietary distribution at the Majiayao culture site of Shannashuzha, in order to distinguish domesticated animals from wild animals and to analyze the role of animals and animal management practices in people's lifeways at Shannashuzha using stable isotope analysis.

STUDY AREA

Archaeological Context

Majiayao is the last of the early to middle Neolithic cultures that were widely distributed in Gansu Province and eastern Qinghai Province (Ganqing region), which is geographically located in the valley of the upper Yellow River (Dong et al. 2013). Chronologically, the Majiayao culture can be placed during 5200–4800 cal yr BP, relative to the Dadiwan culture (7800–7350 cal yr BP), the Yangshao culture (6800–4900 cal yr BP), the Qijia culture (4300–3500 cal yr BP), and the Xindian and Siwa cultures (3600–2500 cal yr BP) (Shui 2001; Xie 2002).

Geographical Setting

The material for this study derives from a residential site of Shannashuzha (34°29′34.06″N, 104°4′24.54″E), which is located on the margin of the Tibetan Plateau in Minxian County, Gansu Province (Figure 1). The site is close to the river bank of the Tao, which is a tributary of the Yellow River, and is surrounded by high mountains to the northeast and southwest, with an

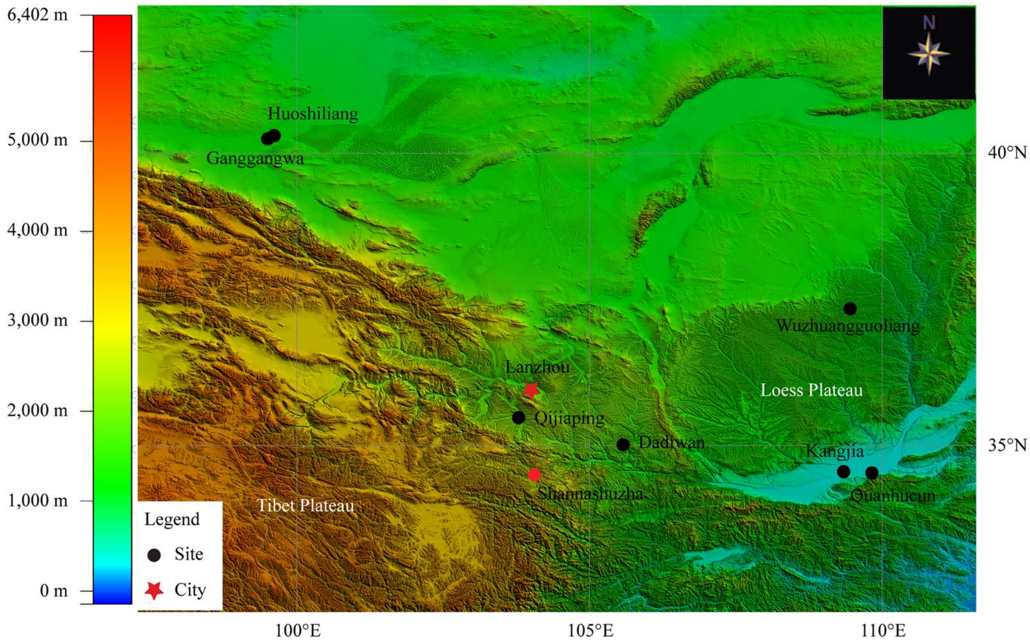

Figure 1 Study area and sites studied. At Huoshiliang site, two pigs, six Cervidae, two cattle as well as two Caprinae samples were tested (Atahan et al. 2011); at Ganggangwa site, two pigs, two Cervidae, four cattle and two Caprinae bones were tested (Atahan et al. 2011); at Qijiaping site, nine pigs and six cattle samples were tested (Ma et al. 2014); at Dadiwan site, 32 pigs, seven Cervidae and two cattle bones were tested (Barton et al. 2009); at Wuzhuangguoliang site, five pigs and three hares bones were tested (Guan et al. 2008); at Kangjia site, three pigs, one Cervidae, two cattle and one Caprinae samples were tested (Pechenkina et al. 2005); at Quanhucun site, 10 pigs, one hare and six cattle bones were tested (Hu et al. 2014).

annual temperature of 5.7°C and annual precipitation of 597 mm. Because of the high altitude of 2323 m (asl), the site is mainly dominated by a moist and cold climate year-round.

Material

The main cultural type of this site is the Majiayao culture, with mid- to late Yangshao cultural relic units sporadically found. All the material here listed was collected from Majiayao cultural relic units. The Shannashuzha site is rich in faunal remains, including domesticated animals, which are mainly pigs and dogs, as well as many wild species including gazelles, monkeys, and bears. The faunal remains for this study were collected from pits and cultural strata during the excavation in 2012 (unpublished results).

Conifers and herbaceous plants compose the main natural vegetation coverage here. Based on the charcoal analysis results of this site, more humid-oriented plants such as bamboo were not unusual back to the Majiayao period. Generally, more diversified vegetation should be expected during the time of occupation (unpublished results).

METHODS

Sample Selection

Thirty animal bones in total were collected for carbon and nitrogen isotope analyses. Of these bones, 24 specimens were classified into 10 species that included rabbits (*Lepus capensis*), bamboo rats (*Rhizomys pruinosus*), Siberian roe deer (*Capreolus pygargus*), barking deer

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(*Muntiacus muntjak*), red deer (*Cervus elaphus*), sika deer (*Cervus nippon*), cattle (*Bos taurus*), badgers (*Meles meles*), pigs (*Sus scrofa domestica*), and Chinese goral (*Naemorhedus goral*). Four samples were identified as Cervidae, and two herbivore animal samples remained unidentified. Of the faunal samples analyzed, only badgers and pigs are omnivores, with the others all herbivores.

Extraction of Bone Collagen

Bone collagen extraction followed the procedure described herein. All the visible contaminants were mechanically removed from both inner and outer bone surfaces until only fresh surfaces were exposed using an electric Dremel® grinder. Approximately 2 g of dense bone was selected from cut sections and washed thoroughly with deionized water in an ultrasonic bath. Bone samples were then oven-dried to a constant weight at 70°C. After drying, the weights of the samples were recorded utilizing an EL204-IC analytical balance. Bone samples were subsequently demineralized by soaking them in a 0.5N solution of hydrochloric acid (HCl) at 4°C and refreshing the solution every 2 days for about 3 weeks, until the bone samples were soft and no bubbles were produced. After demineralization, the resulting sample material was washed repeatedly with deionized water to neutrality. The samples were then immersed in a 0.125N solution of sodium hydroxide (NaOH) at 4°C for 20 hr to remove remaining lipids and other acids. After lipid removal, samples were washed with deionized water to neutrality and dissolved in a 0.001N HCl solution at 70°C in the oven for 2 days to gelatinize. The samples were filtered with a filter paper and deionized water. The gelatinized collagen samples were lyophilized using a Labconco* FreeZone lypholizer at –50°C, weighed, and sealed in tin capsules for analysis.

Isotope Analysis

The stable carbon and nitrogen isotope analyses were performed using a continuous-flow isotope ratio mass spectrometer (IRMS), combined with a Conflo interface device, Thermo Finnigan DeltaPlus at the Key Laboratory of Western China's Environmental Systems, Ministry of Education (MOE), Lanzhou University. An elemental analyzer (EA), vario EL *Cube* (State Key Laboratory of Applied Organic Chemistry, Lanzhou University) was used to determine the atomic C/N ratios. A C/N ratio between 2.9 and 3.6 indicates retention of *in vivo* isotopic signature of the collagen sample (Ambrose 1990).

The isotopic results are expressed as delta (δ) values in parts per mil (‰) notation, $\delta^{13}C = 1000 \times [(R_{sample}/R_{standard}) - 1]$, where R_{sample} and $R_{standard}$ are the $^{13}C/^{12}C$ ratios of the sample and standard, respectively, and the same for $\delta^{15}N$. For carbon, the result is relative to the international VPDB (Vienna PeeDee Belemnite limestone) standard, while for nitrogen the standard is AIR. The long-term standard deviation of the machine is ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. Reference standards used for $\delta^{13}C$ and $\delta^{15}N$ calibrations were GLY ($\delta^{13}C$ = –33.3‰, $\delta^{15}N$ = 10‰), PUGE ($\delta^{13}C$ = –12.6‰, $\delta^{15}N$ = 5.6‰), and collagen ($\delta^{13}C$ = –9‰, $\delta^{15}N$ = 7.6‰).

AMS Dating

Two bamboo samples were selected for accelerators mass spectrometry (AMS) radiocarbon dating (Table 1) as bamboo has a relatively short lifetime. The pretreatment of the samples followed the procedure of Manning and Reid (1977) and Vogel et al. (1984) at the Key Laboratory of Western China's Environmental Systems, Ministry of Education (MOE), Lanzhou University, and the ^{14}C analysis was conducted at the Laboratory of Quaternary Geology and Archaeological Chronology of Peking University, Beijing. The data were

Table 1 AMS dates of Shannashuzha.

Laboratory code	Provenience	Material	^{14}C age (BP)	Calibrated range 1σ (68.2%)
LZU1564	T0309H113	Bamboo	4460 ± 25	5270–4979 cal BP
LZU1565	T0110H17	Bamboo	4400 ± 25	5035–4881 cal BP

calibrated using the program CALIB v 7.02 and the IntCal13 curve (Stuiver and Reimer 1993; Reimer et al. 2013).

RESULTS

Isotopic results, collagen yields, C/N ratios, and other detailed information on the samples are shown in Table 2 and Figure 2. As can be seen in Table 2, the atomic C/N ratios of 30 collagen samples ranged from 3.2 to 3.3, with collagen yields ranging from 1.1% to 11.8%, indicating that all samples could be characterized as unaltered collagen (Ambrose 1990). The mean $\delta^{13}C$ value of the 27 herbivore samples was –21.2 ± 0.3‰ with a range from –17.8 to –23.4‰, indicating a mainly C_3-based diet; we discuss the ^{13}C-enriched *Lepus capensis* sample later in the text. The mean $\delta^{15}N$ value for herbivores was 3.5 ± 0.3‰, with a range of –0.2 to 7.1‰, suggesting a low protein diet. The omnivore samples were isotopically distinguished from the herbivore ones, having a mean $\delta^{15}N$ value of 7.6 ± 0.3‰ (n = 3), ranging from 7 to 8.1‰, indicating some proportion of an enriched protein-food source intake. The $\delta^{13}C$ values are distinct from the herbivores; the two pigs had $\delta^{13}C$ values of –8.1‰ and –8.8‰, respectively, suggesting a diet with a C_4 food source component. The one badger sample had a $\delta^{13}C$ value of –18.9‰, suggesting a C_3-based diet.

DISCUSSION

Herbivores

Cattle

In our study, the cattle have a mean $\delta^{13}C$ value of –22.0 ± 0.5‰ (n = 7), ranging from –23.4 to –20.0‰, slightly depleted compared to deer whose mean $\delta^{13}C$ value is –21.1 ± 0.3‰ (n = 15). The cattle have mean $\delta^{15}N$ value of 4.1 ± 0.4‰ (n = 7) with a range from 3.2 to 5.7‰. Deer have a mean $\delta^{15}N$ value of 3.7 ± 0.3‰ (n = 15) ranging from 3.4 to 7.1‰, although these variations in $\delta^{15}N$ are statistically insignificant (nonparametric Mann-Whitney U test, Tables 3, 4), making cattle indistinguishable from deer merely using isotope results. Compared to the older Bovidae samples from Kangjia (Yangshao culture) (Pechenkina et al. 2005), Dadiwan (Dadiwan culture phase 2) (Barton et al. 2009) and later Huoshiliang, Ganggangwa (Bronze Age) (Atahan et al. 2011), and Qijiaping (Qijia culture) (Ma et al. 2014) sites from this large area, the cattle at Shannashuzha have mean $\delta^{13}C$ and $\delta^{15}N$ values that are depleted by 4.7‰ and 3.1‰, respectively (nonparametric Mann-Whitney U test, Figures 1, 3; Table 3, 4). Taking a closer look, two Kangjia samples represent the most ^{13}C-enriched cattle (–15.1‰ and –14.2‰, respectively). At least one of them was identified to be *Bubalus*, which explained the enrichment of ^{13}C signal (Pechenkina et al. 2005). Of the remaining 14, only one from Qijiaping site was interpreted as a C_3-C_4-mixed source (Ma et al. 2014). Further proof of grazing in natural pastures can be suggested since cattle from Shannashuzha have a both ^{13}C- and ^{15}N-depleted diet similar to the range of the Chinese goral's (Table 2).

Cattle can provide meat, milk, and animal skins, as well as being used as transportation and cultivation tools in the agricultural societies. Unlike sheep and goats, cattle husbandry also

Table 2 Bone collagen stable carbon and nitrogen isotopic results of Shannashuzha.

Sample nr	Species/families	Skeletal element	Collagen wt%	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	C wt%	N wt%	C:N
T0205H6γ	?	Rib	7.7	–19.8	2.9	44.8	16.3	3.2
T0205H4α	?	Lumbar vertebrae	6.1	–20.0	2.2	44.8	16.3	3.2
T0205H6β	*Lepus capensis*	Tibia	11.8	–17.8	–0.2	44.2	16.1	3.2
T0204H5	*Rhizomys pruinosus*	Jaw	2.5	–23.2	2.1	43.5	15.7	3.2
T0204H5	*Capreolus pygargus*	Femur	9.2	–20.0	0.8	45.7	16.7	3.2
T0205H4α	*Capreolus pygargus*	Jaw	2.1	–20.8	3.7	44.1	15.5	3.3
T0205H6β	*Capreolus pygargus*	Pelvis	7.5	–22.1	2.5	44.3	16.3	3.2
T0205β	*Muntiacus muntjak*	Metatarsus	6.3	–21.4	2.9	45.3	16.6	3.2
T0204H5	Cervidae	Tibia	4.5	–22.4	4.3	45.1	16.4	3.2
T0205H4β	Cervidae	Jaw	2.8	–20.5	3.8	43.7	15.5	3.3
T0205H6γ	Cervidae	Tibia	9.3	–21.1	3.4	45.2	16.5	3.2
T0205β	Cervidae	Talus	2.9	–23.2	7.1	44.2	16.2	3.2
T0204β	*Cervus elaphus*	Tarsal	6.7	–20.1	3.8	45.2	16.5	3.2
T0205β	*Cervus elaphus*	Maxilla	8.8	–23.1	3.2	44.7	16.4	3.2
T0205H6β	*Cervus elaphus*	Femur	7.5	–20.5	3.2	44.4	16.2	3.2
T0204β	*Cervus nippon*	Maxilla	1.1	–22.0	4.2	40.8	14.7	3.2
T0205H4α	*Cervus nippon*	Femur	7.9	–20.6	3.8	45.1	16.2	3.2
T0205β	*Cervus nippon*	Tibia	5.4	–19.8	3.8	44.2	16.1	3.2
T0205β	*Cervus nippon*	Axis	5.6	–18.2	4.6	44.1	16.1	3.2
T0204H5	*Bos taurus*	Atlas	3.8	–21.8	3.2	46.0	16.7	3.2
T0205H4α	*Bos taurus*	Rib	3.0	–22.6	3.7	45.3	16.4	3.2
T0205H4β	*Bos taurus*	Phalanges	8.6	–23.2	3.5	44.5	16.3	3.2
T0205H4β	*Bos taurus*	Cervical vertebra	2.1	–22.6	5.1	44.4	16.2	3.2
T0205β	*Bos taurus*	Phalanges	3.5	–23.4	3.9	44.4	16.0	3.2
T0205β	*Bos taurus*	Talus	6.0	–20.5	5.7	45.2	16.6	3.2
T0205β	*Bos taurus*	Femur	4.5	–20.0	4.0	43.4	15.9	3.2
T0205H6β	*Naemorhedus goral*	Humerus	9.4	–20.6	2.4	44.3	16.2	3.2
T0205H6γ	*Meles meles*	Skull	11.1	–18.9	7.0	45.0	16.3	3.2
T0108β	*Sus scrofa domestica*	Jaw	3.5	–8.1	8.1	45.0	16.2	3.2
T0204H5	*Sus scrofa domestica*	Jaw	4.2	–8.8	7.8	45.9	16.2	3.3

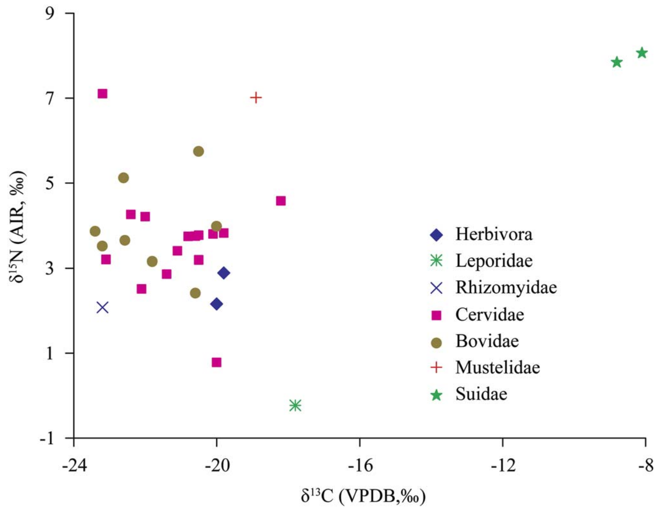

Figure 2 Isotopic results of faunal remains at Shannashuzha

Table 3 Statistical results of stable isotopes for cattle and deer from both Shannashuzha and the other sites.

		$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)		
	# of samples	mean	SD (σ)	mean	SD (σ)	References
Cattle (this study)	7	–22	0.5	4.1	0.4	This study
Cattle (other sites)	16	–17.3	0.6	7.2	0.3	Pechenkina et al. 2005; Barton et al. 2009; Atahan et al. 2011; Ma et al. 2014
Deer (this study)	15	–21.1	0.3	3.7	0.3	This study
Deer (other sites)	22	–19.6	0.4	5.7	0.3	Pechenkina et al. 2005; Barton et al. 2009; Atahan et al. 2011; Hu et al. 2014

Table 4 Mann-Whitney U test results of different groups of the samples.

	Cattle vs. deer (this study)		Cattle (this study) vs. cattle (other sites)		Deer (this study) vs. deer (other sites)	
	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
U	32	40	3	3	95	42
W	60	160	31	31	215	162
Z	–1.448	–0.881	–3.542	–3.543	–2.167	–3.806
Asymp	0.148	0.378	0	0	0.03	0
Preci	0.162	0.407	0	0	0.03	0

requires that there is a plentiful water supply, and apparently, the Shannashuzha site is an ideal place for cattle to live. Unfortunately, manual intervention on the basis of isotopic results does not indicate if they are domesticated or not.

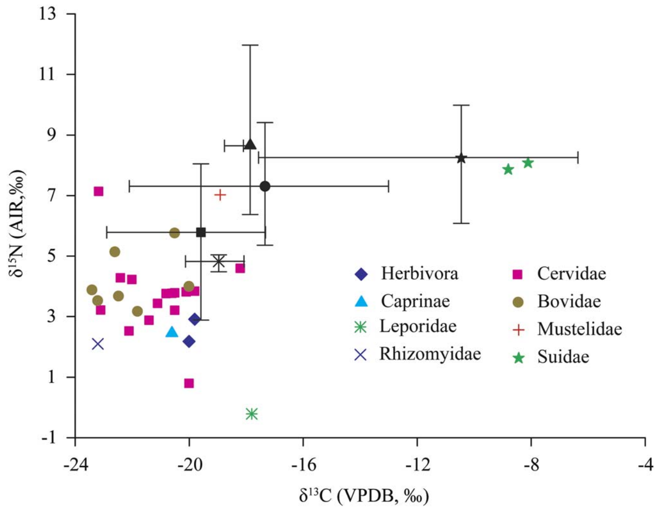

Figure 3 Comparison between the isotopic distribution of Shannashuzha and results from other nearby sites (Pechenkina et al. 2005; Guan et al. 2008; Barton et al. 2009; Atahan et al. 2011; Hu et al. 2014; Ma et al. 2014). Colored symbols represent the samples from Shannashuzha and corresponding black ones are the comparable results from other sites.

Deer

Different from cattle, deer are browsers with a tendency to choose food that is easy to digest, such as tender leaves and fresh grass. Three bone segments identified as Siberian roe deer, one barking deer, three red deer, four sika deer, and four samples only identified to be deer make Cervidae the largest family in the faunal assemblage at Shannashuzha.

Different variety of deer share similar isotopic compositions and have $\delta^{13}C$ values ranging from –23.2‰ to –18.2‰, $\delta^{15}N$ values distributed from 0.8‰ to 7.1‰, indicating a C_3-based food consumption (Figure 2). Compared to other contemporary samples from spatially neighboring sites (Pechenkina et al. 2005; Barton et al. 2009; Atahan et al. 2011; Hu et al. 2014), deer from Shannashuzha have significantly lower $\delta^{13}C$ and $\delta^{15}N$ values (nonparametric Mann-Whitney U test, Tables 3, 4; Figure 3).

Rabbit and Bamboo Rat

The sample of *Lepus capensis* has an extremely depleted $\delta^{15}N$ value of –0.2‰, much lower than the mean of its other herbivore counterparts [3.6 ± 0.2‰ (1σ, $n = 26$)], as well as that of Leporinae remains found at other contemporary neighboring sites (Guan et al. 2008; Hu et al. 2014; Figure 3), even 2.3‰ lower than that of its rodent relative bamboo rat's (Table 2, Figure 2), illustrating that ^{15}N-depleted plants composed most of its food. The value of –17.8‰ represents the most enriched ^{13}C signature of the herbivore samples, which have a mean $\delta^{13}C$ value of –21.2 ± 0.3‰ (1σ, $n = 27$) that is significantly different from the –23.2‰ of bamboo rat. Millet was pervasively found among all the units of this site and believed to be the staple of this community (Hu 2015); the C_4 plant has a mean $\delta^{13}C$ value of –10‰ (An et al. 2015). The isotopic composition suggests a high possibility that the *Lepus capensis* ate some millet related food, which provides a hint of the near-site activity of this hare/rabbit.

Omnivores

It is very likely that pigs were domesticated locally in China (Yuan and Flad 2002; Larson et al. 2005; Flad et al. 2007). The presence of pigs at an archaeological site can indicate a sedentary society. The earliest occurrence of domesticated pigs appeared at the nearby Dadiwan site ~7000 yr ago, which indicated the emergence of settled agriculture in this region (Barton et al. 2009). Pigs are omnivores and have a very broad food spectrum, usually as cleansers eating leftovers of humans, making them isotopically similar to human beings, but pigs can also consume grass, insects, and other animals. Badgers are also omnivores that consume reptiles and insects, as well as plants.

Two pig samples in this site have similar isotopic compositions (Figure 2; Table 2), and exhibit an explicitly C_4-plant based diet with a mean $\delta^{13}C$ value of -8 ± 0.1‰, which can be easily discriminated from the other C_3-based-food consumers whose mean $\delta^{13}C$ value is -21.1 ± 0.3‰ (1σ, $n = 28$). The pigs in this study also have enriched $\delta^{15}N$ values (8.0 ± 0.1‰) compared to the herbivores (3.5 ± 0.3‰, 1σ, $n = 27$) indicating consumption of animal protein, assuming a 3–6‰ "trophic effect" between the food source and consumer (Bocherens and Drucker 2003; Hedges and Reynard 2007; O'Connell et al. 2012). Since millet agriculture has long colonized this region by the Majiayao period (Barton et al. 2009; Jia et al. 2013), and millet was also the most common agricultural product at this site (Hu 2015), assuming a stable carbon isotope value of –10‰ for millet (An et al. 2015), it is reasonable to think that pigs at Shannashuzha were fed human-related food such as leftovers and by-products of millet. The badger at the same site mainly consumed a C_3-based diet.

CONCLUSIONS

Based on the stable isotope evidence presented in this study, animal husbandry of pigs was practiced among the Shannashuzha residents. The population at the Shannashuzha site was comprised of farmers, who developed diversified economic strategies, i.e. practiced agriculture with mainly millet as a staple, raised pigs in captivity and fed them mainly with a C_4-based diet, likely including human food waste. Isotope values of the *Lepus capensis* sample suggest that it lived near the site. Residents at Shannashuzha site also captured cattle, deer, goral, badgers, and even bamboo rats as supplementary food sources. They appear to have had two meat sources, including pig domestication and wild animal hunting.

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