

Zhoukoudian Upper Cave Revisited

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As with many archaeofaunal assemblages that were excavated before the 1970s, the faunal collection from the Late Paleolithic site of Zhoukoudian Upper Cave suffers from excavation- and curation-related differential discard and loss of particular kinds of skeletal elements. Yet taphonomic analysis of the mortality profiles and bone surface modifications indicates (1) that the Lower Recess probably served as a natural trap and (2) that hunter-gatherers processed cervids on site. This study supports the hypotheses originally proposed by Wen-chung Pei.

Zhoukoudian (Dragon Bone Hill), located 50 km southwest of Beijing, China, is made up of a series of limestone cave sites that were discovered and excavated beginning in the early twentieth century (fig. 1). The best known of the Zhoukoudian sites is Locality 1, where remains of at least 40 *Homo erectus* individuals were excavated in the 1920s and 1930s (see Goldberg et al. 2001 and references therein) and where taphonomic studies have been conducted (e.g., Binford and Stone 1986; Boaz et al. 2004). Perhaps the second-most-recognized site is Zhoukoudian Upper Cave (ZKD UC), discovered in 1930 during fieldwork at Locality 1 and excavated in 1933 and 1934 (Pei 1934, 1939). ZKD UC is best known for the human fossils it contained; those remains purportedly were in cave sediments as a result of deliberate burial. The three human crania (UC 101, 102, and 103) have been used either to strengthen or to weaken the regional-continuity model in East Asia (e.g., Weidenreich 1939a, 1939b; Wolpoff, Wu, and Thorne 1984; Kamminga and Wright 1988; Kamminga 1992; Cunningham and Wescott 2002; Cunningham and Jantz 2003). Many artifactual and faunal remains were recovered from ZKD UC; analysis of the latter materials forms the foundation of this study.

Wen-chung Pei, considered by many to be the father of Zhoukoudian research, contributed many detailed taphonomic interpretations of the fauna from the Zhoukoudian localities, including ZKD UC (e.g., Pei 1934, 1938, 1940). Our taphonomic analysis of the ZKD UC fauna tests two hypoth-

eses originally proposed by Pei and other researchers: (1) that the Lower Recess served as a natural trap and (2) that hunter-gatherers contributed to the accumulation, modification, and deposition of faunal remains in the cave. We test these hypotheses by analyzing multiple lines of taphonomic evidence, including bone surface modification (e.g., cut marks, tooth marks, and burning) and mortality profiles.

Stratigraphy

Zhoukoudian Upper Cave is a north-south-facing cave situated directly above Locality 1 (fig. 1). The fill of the cave is made up of loose gray sediment distinct from the hard red breccia and stalagmitic layers of the underlying Zhoukoudian Formation. The deposits from ZKD UC were over 10 m thick and can be divided into an Entrance, an Upper Room, a Lower Room, and a Lower Recess (fig. 2). The Entrance is 4 m high and 5 m wide. It leads directly into the Upper Room, which runs another 8 m to the back of the cave. Sediments in the Lower Room are roughly 8 m thick and sit below the Upper Room. Sediments in the Lower Recess are about 3 m thick and are underlain by the Zhoukoudian Formation (Pei 1934, 1939).

Five cultural levels were distinguished by Pei: Layers 1–3 in the Entrance and Upper Room and Layers 4 and 5 in the Lower Room (fig. 2). From Layer 1, a few human bones, two flint tools, and a perforated tooth were recovered. In Layer 2, 28 perforated mammalian canines and a few human bone fragments were found. Ash, suggestive of human occupation, was discovered in Layer 3, though few artifactual materials were found. The three human crania, most of the human postcranial remains, and the majority of the artifacts were discovered in Layer 4, which was 5 m thick. From the excavation reports we had access to, it is not clear how many human remains and/or artifacts came from Layer 5. The Lower Recess primarily contained complete skeletons of terrestrial mammals but lacked cultural remains, which led some to postulate that that area had served as a natural trap (Pei 1934, 1939; Wu and Poirier 1995).

Chronometric Dating

Standard radiocarbon (^{14}C), thermoluminescence (TL), uranium-series (U-series), and accelerator mass spectrometry (AMS) methods were applied to derive a general chronological framework for site formation (table 1). Absolute dates for the primary cultural level (Layer 4) vary widely (between 34,000 and 10,000 BP). We are currently investigating the chronometric age of the deposits in more detail.

Cultural Materials

The cultural deposits fall within the East Asian Late Paleolithic (Norton 2000a; Gao and Norton 2002; Norton et al. 2006; Norton, Gao, and Feng n.d.). Artifacts from ZKD UC include

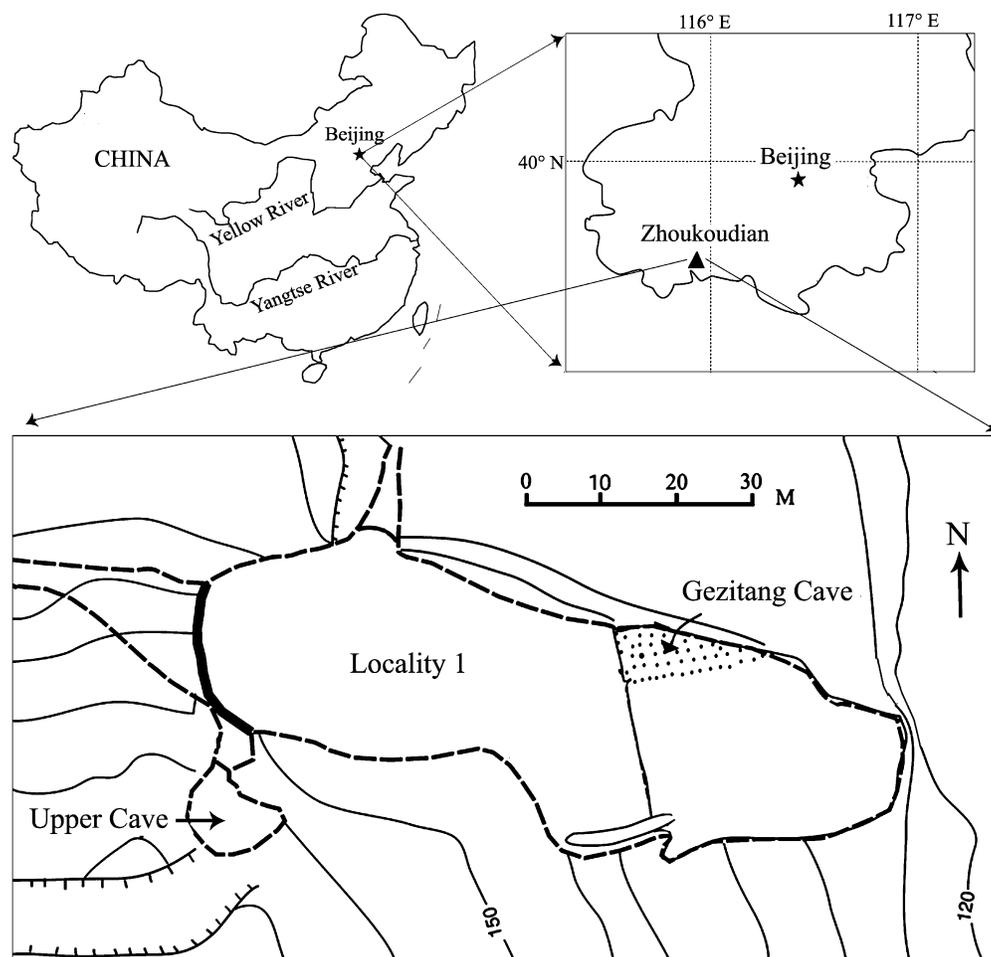


Figure 1. Location of Zhoukoudian Upper Cave (bottom map modified after Goldberg et al. 2001, fig. 2).

a flint concave side scraper, a flint end scraper, a chert flake without any retouch, a broken bone needle, a broken and polished mandible of a sika deer (*Cervus nippon*), and a polished red deer (*Cervus elaphus canadensis*) antler. Also recovered were 17 quartz tools, including a side scraper and a bipolar flake. Pieces of red hematite were found throughout the deposit. In addition, bits of red hematite were found in the sandy clay matrix that adhered to the human crania from Layer 4 (Pei 1934, 1938–39, 1939).

Perhaps the best-known artifacts are the perforated ornaments. Seven perforated white calcareous stone beads colored by red hematite were found near the UC 102 cranium; 125 perforated animal teeth were also recovered, of which 25 were colored by red hematite. The teeth are from deer, foxes, tigers, badgers, and weasels that were indigenous to the region during the time of occupation. The majority of the perforated animal teeth were recovered from Layer 4, with a few found in Layer 2. Three perforated *Arca* shells were recovered from Layer 4 near the perforated stone beads and teeth. It is thought that

the perforated shells, stone beads, and teeth formed at least one but probably more composite necklaces that were included in the three human burials (Pei 1934, 1938–39, 1939).

Four bone pendants were also found, with only one coming from a known stratigraphic context (Layer 2). The bone pendants are thought to be made from the long bones of birds. Twenty vertebrae of a moderately large fish (*Cyprinus carpio?*) and a supraorbital bone (*Ctenopharygodon iddellus*) were recovered, with the latter displaying signs of an attempt to perforate the edge. Traces of red hematite were found on the supraorbital bone (Pei 1934, 1938–39, 1939).

Faunal and Floral Assemblages

Forty-nine mammalian species were originally identified in the ZKD UC locality (Pei 1940), though only 20 taxa were identified in this study (table 2). The reason for the difference is probably the disappearance of specimens from the collection room of the Institute of Vertebrate Paleontology and

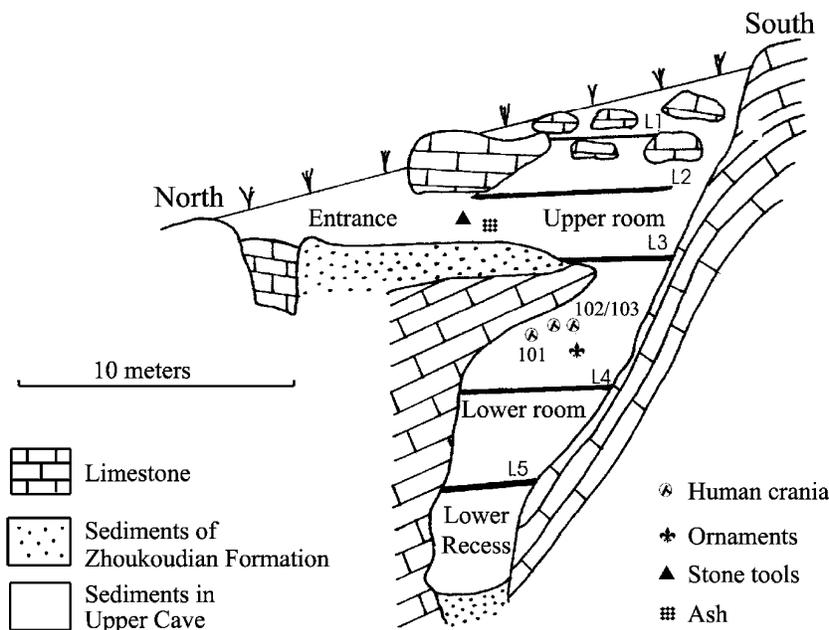


Figure 2. Stratigraphic profile of Zhoukoudian Upper Cave (redrawn after Pei 1939a, 330, figs. I–III).

Paleoanthropology (IVPP), Chinese Academy of Sciences. Nevertheless, the most abundant species in the original collection were still the best represented in the available assemblage. Faunal remains were found distributed throughout the deposit, with as many as 30 complete cervid skeletons in the Lower Recess (Pei 1934, 1939, 1940; Wu and Poirier 1995). The most abundant plant remains in ZKD UC were *Celtis* sp. seeds, found throughout the cultural levels but absent from the Lower Recess (Pei 1934).

Table 1. Chronometric Dates from Zhoukoudian Upper Cave Layer 4 and Lower Recess

Location and Date	Method	Reference
Layer 4:		
10,470 ± 3,600 BP	¹⁴ C	Li et al. 1985; Wu and Wang 1985
19,000 ± 1,000 BP	U-series	Chen, Yuan, and Gao 1984
23,150 ± 330 to 26,500 ± 450 BP	AMS	Hedges et al. 1988; Chen, Hedges, and Yuan 1989
29,000–34,000 BP	AMS	Chen, Hedges, and Yuan 1992
Lower Recess:		
18,340 ± 4,100 BP	¹⁴ C	Li et al. 1985; Wu and Wang 1985
21,000 ± 4,000 BP	U-series	Chen, Yuan, and Gao 1984
32,500–50,000 BP	TL	Pei 1985
32,600 ± 200 BP	AMS	Hedges et al. 1988; Chen, Hedges, and Yuan 1989
33,000–34,000 BP	AMS	Chen, Hedges, and Yuan 1992

Materials and Methods

The ZKD UC faunal assemblage consists of approximately 2,800 specimens currently stored in the IVPP, the Zhoukoudian Museum, and the Geological Sciences Museum. The majority of the collection is located in the IVPP.¹ We used modern comparative material from the IVPP collections department for identifications.

The macromammal faunal collection forms the foundation of this study and is characterized as follows (table 3): 716 macromammal specimens, primarily cervids (*Cervus nippon*, *Cervus elaphus canadensis*) and carnivores (*Panthera* sp., *Vulpes* sp.), dominated by cranial (skull, maxilla, and mandible) fragments (>550), and 226 isolated macromammal teeth, primarily from cervids. In addition, two fairly complete skeletons (*Ursus spelaeus*, *Panthera tigris*), on display in the Zhoukoudian Museum, are associated with ZKD UC.² The remainder of the assemblage is made up of birds and micromammals.

The taphonomic data collection and analysis follow methodology used in other studies (e.g., Norton, Kim, and Bae 1999; Norton 2000b; Norton et al. 2007; Norton and Gao 2008). Statistical tests were run in SPSS 11.5, with results considered significant if $P \leq 0.05$; χ^2 statistics were calculated on the count data and not the percentages, though we present both in the tables and figures.

1. We had access to only the specimens on display in the latter two locations.

2. Since these articulated skeletons are in display cases, we could not remove and closely examine each individual element. Accordingly, these specimens were not included in the quantitative section of this study.

Table 2. Mammalian Species Identified by Pei (1940)
Compared with the Available Faunal Assemblage

Order/Infraorder and Scientific Name	Common Name	Pei (1940)	Current
Primates:			
<i>Homo sapiens</i>	Humans	*	*
Insectivora:			
<i>Scaptochirus</i> sp.	Mole	*	
<i>Erinaceus</i> sp.	Hedgehog	*	*
Chiroptera:			
<i>Rhinolophus</i> sp.	Horseshoe bat	*	
<i>Myotis</i> sp. A (<i>Myotis pequinius</i> ?)	Myotis (larger form)	*	
<i>Myotis</i> sp. B (<i>Myotis chinensis</i> ?)	Myotis (smaller form)	*	
Carnivora:			
<i>Canis lupus</i>	Wolf	*	*
<i>Nyctereutes procyonoides</i>	Raccoon dog	*	*
<i>Vulpes vulgaris</i>	Fox (red)	*	*
<i>Vulpes corsac</i>	Fox	*	*
<i>Cuon alpinus</i>	Dhole	*	
<i>Ursus angustidens</i>	Bear	*	
<i>Ursus spelaeus</i>	Cave bear	*	*
<i>Ursus arctos</i>	Brown bear	*	*
<i>Meles leucurus</i>	Badger	*	*
<i>Mustela eversmannii</i>	Steppe polecat	*	*
<i>Mustela</i> cf. <i>altaica</i>	Mountain weasel	*	
<i>Paguma larvata</i>	Palm civet	*	
<i>Hyaena ultima</i>	Spotted hyaena	*	
<i>Panthera tigris</i>	Tiger	*	*
<i>Panthera pardus</i>	Leopard	*	
<i>Lynx lynx</i>	Lynx	*	*
<i>Felis</i> cf. <i>microtus</i>	Small cat	*	*
<i>Felis catus</i>	Domestic cat	*	
<i>Cynailurus</i> cf. <i>jubatus</i> (<i>Acinonyx jubatus</i>)	Cheetah	*	
Rodentia:			
<i>Sciurus</i> sp.	Tree squirrel	*	
<i>Petaurista sulcatus</i>	Flying squirrel	*	
<i>Cricetulus varians</i>	Hamster	*	
<i>Cricetulus obscurus</i>	Hamster	*	
<i>Apodemus sylvaticus</i>	Wood mouse	*	
<i>Epimys rattus</i> (<i>Rattus rattus</i>)	Rat	*	
<i>Gerbillus</i> sp.	Gerbil	*	
<i>Microtus epiratticeps</i> (<i>Microtus brandtioides</i>)	Meadow vole	*	
<i>Alticola</i> cf. <i>stracheyi</i>	Strachey's mountain vole	*	
<i>Siphneus armandi</i>	Tibetan zokor	*	*
Hystricognathi:			
<i>Hystrix</i> sp.	Porcupine	*	
Lagomorpha:			
<i>Lepus europaeus</i>	European hare	*	*
<i>Ochotona daurica</i>	Daurian pika	*	
Perissodactyla:			
<i>Rhinoceros</i> sp.	Rhinoceros	*	
<i>Equus hemionus</i>	Kulan	*	
Artiodactyla:			
<i>Sus</i> sp.	Pig	*	
<i>Capreolus manchuricus</i>	Roe deer	*	
<i>Cervus elaphus canadensis</i>	Red deer or wapiti	*	*
<i>Cervus nippon</i>	Sika deer	*	*
<i>Hydropotes</i> sp.	Water deer	*	*
<i>Gazella prjewalskyi</i>	Gazelle	*	*
<i>Ovis</i> sp.	Sheep	*	
<i>Bos</i> sp.	Bison	*	*
Proboscidea:			
<i>Elephas</i> sp.	Elephant	*	

Table 3. Number of Identified Specimens (NISP) of Macromammal Assemblage by Taxon and Element

Element	<i>Bos</i> sp.	<i>Gazella</i> sp.	<i>Cervus</i> sp.	<i>Felis</i> <i>lynx</i>	<i>Felis</i> <i>microtus</i>	<i>Felis</i> <i>tigris</i>	<i>Hyaena</i> sp.	<i>Canis</i> <i>lupus</i>	<i>Meles</i> sp.	<i>Mustela</i> sp.	<i>Ursus</i> <i>arctos</i>	<i>Ursus</i> <i>spelaeus</i>	<i>Vulpes</i> <i>corsac</i>	<i>Vulpes</i> <i>vulgaris</i>	Other ^a	NISP Total
Antler			11													11
Horn core		2	3													5
Skull			27		1	1		1	5	2		1	2	6	1	47
Maxilla	2		107	2	1	2		1	12	1		1	4	28		161
Mandible	2		219		15	3			49	8	1	3	8	40	3	351
Dentition			149	8		25	2		19				21		2	226
Atlas														9	6	15
Cervical vertebra			1												2	3
Thoracic vertebra			6													6
Lumbar vertebra			3													3
Sacral vertebra						2						1				3
Caudal vertebra			1													1
Rib			1													1
Innominate			1			9			2			2			5	19
Scapula			1												2	3
Humerus			5			3										8
Radius			3												1	4
Ulna			2												1	3
Astragalus			2													2
Calcaneum			1													1
Femur			1									1				2
Tibia			1													1
First phalange			6												14	20
Second phalange			6												3	9
Third phalange			5												2	7
Metapodial			16												6	22
Naviculo-cuboid			1													1
Tarsal			3												4	7
NISP Total	4	2	582	10	17	45		2	87	11	1	9	35	83	52	942

Note: Specimens that could not be assigned to a specific excavation season were excluded from the comparative analysis between the cultural layers (ZKD UC 1933) and the Lower Recess (ZKD UC 1934). Accordingly, these counts are higher than what is presented in the analysis section of this study.

^aThe majority of the elements in the "Other" category were carnivore specimens that could not be identified to taxon.

Cervids (*C. nippon* [sika deer] and *C. elaphus canadensis* [red deer]) are the most abundant macromammal taxa. Although mandibles are the most abundant skeletal element, juvenile, particularly neonate, sika deer and red deer mandibles are difficult to distinguish. Accordingly, for this study all sika deer and red deer remains were collapsed into one cervid group. Tigers (*P. tigris*), cave bears (*U. spelaeus*), foxes (*Vulpes vulgaris*), and badgers (*Meles leucurus*) are the most abundantly represented carnivores. In order to increase sample size, the carnivores were grouped together. There is no reason to believe that carnivore taxonomic presence would have differed between the stratigraphic units unless an external influence (e.g., presence of hunter-gatherers) presented itself.

Justification for Distinguishing the 1933 and 1934 Collections

Despite having access to all written Zhoukoudian accounts, we were unable to find the ZKD UC excavation reports that recorded the three-dimensional provenance of each individual bone and stone. In addition, the code written on each bone

provided only excavation year and day and occasionally the two-dimensional provenance. For instance, on one specimen, the code UC:34:87:G7 (fig. 3) meant that it was associated with ZKD UC, recovered on day 87 of the 1934 excavation season and found in pit G7. G7 (G = north-south; 7 = east-west) is only two dimensions, and we are unable to determine the depth and thus the stratigraphic level from which the specimen was derived. Accordingly, we developed a unique system to analyze intrasite variation.

Pei (1934, 1939) stated that ZKD UC was excavated in 1933 and 1934. He noted that the 1934 field season concentrated on the excavation of the Lower Recess area. Since it was proposed that the Lower Recess deposits accumulated as a result of a natural trap, the material recovered from the 1934 excavation season should represent a noncultural assemblage. In turn, the faunal remains recovered from the 1933 field season should either be entirely associated with materials from the cultural levels (Layers 1–5: Entrance, Upper Room, Lower Room) or be considered to represent a mixture of material from both the cultural levels and the Lower Recess.



Figure 3. Codes on the ZKD UC specimens.

Unless otherwise specified, only bone and teeth specimens that could be linked with a particular field season (1933 or 1934) were included in the analysis (fig. 3B, 3C). For instance, certain specimens were labeled only “UC” (fig. 3A), and because of their lack of context they could not be confidently assigned to an annual field season. Other specimens were labeled “1934,” but the Chinese character associated with those specimens indicated that they were from sieved deposits (fig. 3D). This excluded a small fraction of the assemblage (e.g., cervid mandibles total: 219; 1933: 86 [39.2%]; 1934: 107 [48.9%]; unknown: 26 [11.9%]).

Mortality

Cervid right mandibles, being most abundant, were used in the reconstruction of the mortality profiles. Mortality profiles were based on tooth eruption and crown height and wear reconstructions (Klein and Cruz-Urbe 1984; Stiner 1994; Hillson 2005). The cervid mandibles were sorted into three age groups: juvenile, prime, and old (Grant 1982; Brown and Chapman 1990, 1991; Stiner 1994; Chapman, Brown, and Rothery 2005). Juveniles retained their deciduous teeth and/or had permanent teeth still in the eruption stage. Prime and old individuals were distinguished on the basis of tooth-crown height and wear of the permanent first molar, which erupts first and wears the fastest (Chapman, Brown, and Rothery 2005). Prime-age cervids had the first molar fully erupted; tooth crowns were almost complete, and there was minimal

wear. Old cervids had fully erupted first molars, but the tooth-crown height was almost completely reduced or the root-crown boundary exposed. In addition, the occlusal surface was appreciably or completely worn, with the mesial and distal infundibula reduced to pinprick size (Chapman, Brown, and Rothery 2005).

A triangle graph was used to examine the ZKD UC 1933 and 1934 mortality profiles. In general, if the data point falls to the lower right of the center line in the triangle graph, it represents a catastrophic mortality profile suggestive of ambush hunters (efficient hunting humans and large cats). If the data point falls to the left, it represents an attritional mortality profile, which is associated with cursorial hunters (hyenas, wolves, or inefficient hunting humans [Stiner 1994, 2002a]). Because these data points alone are often difficult to interpret, the ZKD UC 1933 and 1934 data were run in a modified triangle-graph program that creates contour lines representing 95% confidence intervals (CIs) based on sample size. Any overlap between the contour lines indicates that the samples cannot be distinguished at a statistically significant level (Steele and Weaver 2002).

Bone Surface Modification

Butchering and tooth marks were identified following standard methodologies (e.g., Binford 1981; Brain 1981; Shipman 1981; Blumenschine and Selvaggio 1988; Capaldo and Blumenschine 1994; Blumenschine 1995; Fisher 1995). Initially,

presence/absence data for the taphonomic agent were recorded, followed by the location of the mark on the specimen and the confidence level of the interpretation. Only specimens that had marks we could identify with 100% confidence were included in that particular analysis. The bone surface was initially examined under a high-incident light with the naked eye, and potential marks were then studied utilizing a hand lens at 16× (Blumenschine, Marean, and Capaldo 1996). The specimen was examined at different angles to the light in order to maximize potential detection of micromorphological features (e.g., presence/absence of microstriations within or emitting from the depression).

When applicable, we compared our results with actualistic data (e.g., Capaldo 1997; Lupo and O'Connell 2002). Capaldo's (1997) hammerstone-to-carnivore comparisons, conducted in East Africa, were designed to reconstruct situations in which Plio-Pleistocene hominins had primary access to a carcass and completely processed it for the meat and marrow; in the case of the crania, they processed it for the brains and marrow. Ravaging carnivores were then allowed to scavenge what was left over. The ethnoarchaeology data are based on the Hadza from East Africa (O'Connell et al. 2002). Humans transported hunted carcasses to the Hadza base camp to be processed, and the carcasses were ravaged by carnivores after the site was abandoned (Lupo and O'Connell 2002). We chose Capaldo's (1997) and Lupo and O'Connell's (2002) data sets because they published cut-mark and tooth-mark data for the crania.

Burning data were collected (see Lyman 1994 for review). Although not all calcined specimens can be associated with cultural behavior, most of the evidence for fire in ZKD UC was probably from campfires. There is no reported evidence of naturally produced fire from bat guano at the site (Pei 1934, 1939, but see Goldberg et al. 2001 for their study of the Zhoukoudian Locality 1 sediments).

Results

A significant difference exists in the distribution of cervids and carnivores between ZKD UC 1933 and 1934 ($\chi^2 = 20.77$, $df = 1$, $P < 0.001$; table 4). Significantly more cervids are present in ZKD UC 1934 than would be expected.

Mortality Profiles

In ZKD UC 1933, young individuals make up 39.47% (15 of 38) of the sample, and prime individuals make up 52.63% (20 of 38). In ZKD UC 1934, 56.25% (27 of 48) of the cervids

Table 4. Number of Identified Cervid and Carnivore Specimens (All-Inclusive) by Excavation Season

Excavation Season	Cervid	Carnivore	Cervid : Carnivore Ratio
ZKD UC 1933	153	126	1.21
ZKD UC 1934	219	81	2.70

Table 5. Number of Identified Specimens and Percentage Data for Cervid Mortality Profiles

Age	ZKD UC 1933 ($N = 38$)	ZKD UC 1934 ($N = 48$)
Young	15 (39.47%)	27 (56.25%)
Prime	20 (52.63%)	20 (41.67%)
Old	3 (7.89%)	1 (2.08%)

Note: Based on the right mandibles.

are categorized as young, and 41.67% (20 of 48) are prime. When old individuals are included in the analysis, the variation between ZKD UC 1933 and 1934 is not significant ($\chi^2 = 3.31$, $df = 2$, $P = 0.191$; table 5).

On the triangle graph (fig. 4), the overlap between the 95% CIs for the 1933 and 1934 data sets indicates that the two mortality profiles cannot be distinguished. This is consistent with the χ^2 analysis. Despite the lack of statistically significant difference, figure 4 suggests that the 1933 data set represents catastrophic mortality while the 1934 sample represents a mortality pattern intermediate between catastrophic and attritional.

Skeletal Element Representation

Cervid axial, forelimb, and hindlimb sections divided by excavation season are represented by minimum animal unit (MAU; as defined by Binford 1984) counts of 1 (fig. 5a). However, in the 1933 assemblage, the cervid cranial section has an MAU of 24, and the 1934 collection had an MAU of 34. Although this pattern is not as marked among the carnivores, it is still fairly distinctive. Carnivore cranial MAU counts are more than three times higher than those for the next-highest region (axial) for both the 1933 and 1934 assemblages (fig. 5b).

A head-dominated or head-and-foot-dominated faunal assemblage is indicative of scavenging (see Bartram and Marean 1999; Marean and Assefa 1999 for review). Because ZKD UC is a head-dominated archaeofaunal collection, should it be considered an example of East Asian Late Paleolithic hunter-gatherer scavenging of large game, with the connotation that these humans still lacked the forward-planning ability to hunt successfully? Our answer is no.

What Explains the Head-Dominated Assemblage?

Differential discard/loss by archaeologists and curators of certain animal taxa and skeletal elements influences the composition of faunal assemblages. This is a problem that affects many archaeofaunal collections throughout the world. In some cases, archaeologists have chosen to minimize or discount this problem when interpreting their data sets (e.g., Binford 1984, 1985; Binford and Stone 1986; Stiner 1994, 2002b; see critiques by Marean and Kim 1998; Bartram and

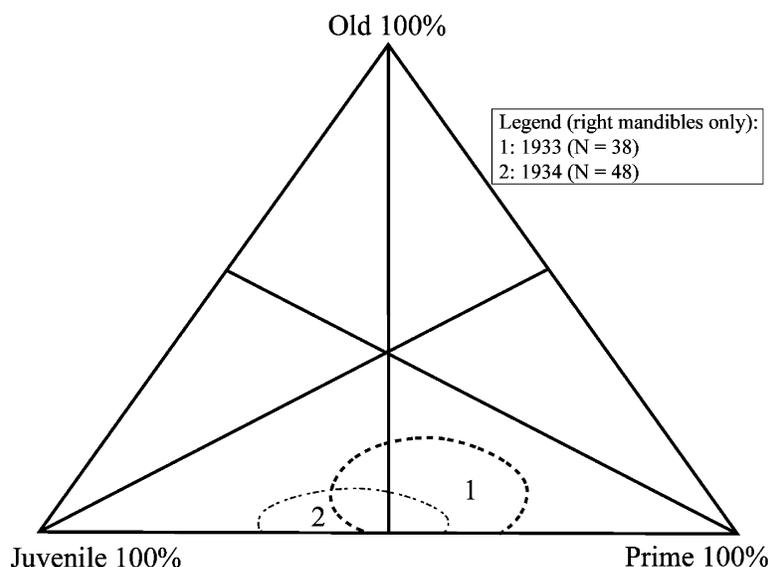


Figure 4. Cervid mortality profiles from ZKD UC 1933 (1) and ZKD UC 1934 (2) with 95% confidence intervals (Steele and Weaver 2002). ZKD UC 1933 falls in the ambush-hunting pattern; ZKD UC 1934 falls in the attritional-mortality-profile range (Stiner 2002a).

Marean 1999; Pickering, Marean, and Dominguez-Rodrigo 2003). In order to ascertain whether this is a problem with ZKD UC, we compare Pei's (1940) original faunal report with the specimens available for this analysis (table 6). Pei listed the number of elements present for a particular taxon and often used the word "numerous" rather than reporting the actual frequency of postcranial parts. For example, for the five most abundant macromammal species (*Vulpes vulgaris*, *Ursus spelaeus*, *Meles leucurus*, *Panthera tigris*, *Cervus nippon*) in the assemblage, Pei reported that numerous postcranial elements were present. However, there is a paucity of postcranial specimens in the collection we studied. Only 9 atlas vertebrae could be associated with *V. vulgaris*, 2 innominates with *M. leucurus*, 14 miscellaneous postcranial specimens with *P. tigris*, 66 miscellaneous postcranial elements with *C. nippon*, and 4 miscellaneous specimens for *U. spelaeus*.³ The most parsimonious explanation for the archaeofaunal assemblage's being head-dominated is that it is the result of preferential retention and curatorial loss of many postcranial elements over the past 70 years. Nevertheless, we believe the collection still warrants study.

Although analysis of skeletal-part profiles is important to Middle/Upper Paleolithic hominin subsistence studies (e.g., Bartram and Marean 1999; Assefa 2006), it is only one of three important taphonomic components in any reconstruction

3. Not including the complete *Ursus* skeleton that is currently on display in the ZKD Museum. It is accounted for in Pei's report and is considered to be in addition to numerous other postcranial specimens both in the original report and here.

tion of the interaction between humans and carnivores. The other two components are mortality profiles and bone surface modification. Because of the paucity of limb elements, we were unable to conduct analysis on bone breakage.

Variations in cut-mark and tooth-mark percentages depend not only on timing of access (primary or secondary) but also on what body parts were initially present (Blumenschine 1988, 1995). Many of these actualistic studies dealt with complete or nearly complete carcasses. This suggests that cranial-region bone surface modification data from actualistic studies can be compared with biased head-dominated faunal collections in order to identify timing of access in the zooarchaeological record.

Bone Surface Modification

Tooth marks (cervids). A significantly higher percentage of cervid cranial specimens recovered from ZKD UC 1934 (53 of 167 [31.74%]) display tooth marks compared with those recovered from ZKD UC 1933 (14 of 107 [13.01%]); $\chi^2 = 12.28$, $df = 1$, $P < 0.001$; fig. 6). The number of tooth-marked specimens from the Hadza base camp (10 of 158 [6.30%]) is lower than that for either data set from ZKD UC. When all three data sets are included, the variation in number of tooth-marked specimens is significant ($\chi^2 = 37.96$, $df = 2$, $P < 0.001$). However, when just comparing the Hadza base camp with ZKD UC 1933, the difference in number of tooth-marked bones is not significant ($\chi^2 = 3.53$, $df = 1$, $P = 0.06$). The Hadza base camp data are significantly different

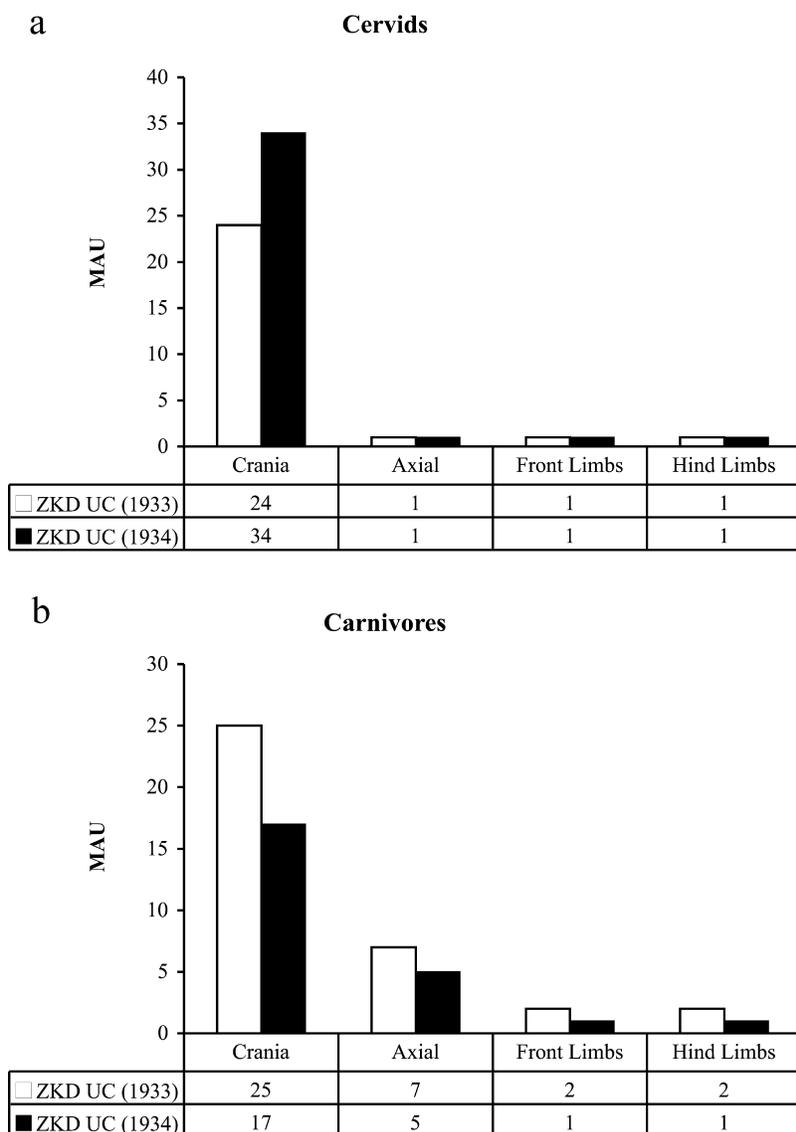


Figure 5. Cervid and carnivore minimal animal unit counts partitioned by anatomical region.

from those for ZKD UC 1934 ($\chi^2 = 33.54$, $df = 1$, $P < 0.001$).

Cut marks (cervids). Cut marks are found on a higher percentage of cervid cranial remains from ZKD UC 1933 (32 of 117 [27.35%]) than from ZKD UC 1934 (23 of 180 [12.78%]; fig. 7). This difference is statistically significant ($\chi^2 = 9.98$, $df = 1$, $P = 0.02$). Surprisingly, the number of cranial-region cut-marked bones from Capaldo's (1997) hammerstone-to-carnivore comparisons (3.68 of 16 [23%])⁴ and Lupo and

4. Capaldo (1997) published only average counts from his experiments. Accordingly, the percentages and average number of identifiable specimen counts are close approximations to what he published.

O'Connell's (2002) Hadza base-camp data (37 of 158 [23.40%]) are very similar to the data from ZKD UC 1933 (27.35%). In both actualistic studies, the cut-mark frequencies are almost twice as high as those from ZKD UC 1934.

Burning. Fifteen of 124 (12.1%) ZKD UC 1933 cervid cranial specimens are calcined, while only 8 of 185 (4.32%) ZKD UC 1934 cranial fragments display evidence of burning. The variation in burning between the cervid specimens from the 1933 and 1934 field seasons is significant ($\chi^2 = 6.51$, $df = 1$, $P = 0.01$).

Tooth marks and cut marks (carnivores). Twelve of the 80

Table 6. The Five Most Abundant Macromammals as Reported by Pei (1940) and as Observed in the Current Collections

Order and Scientific Name	Common Name	Skeletal Element Breakdown	
		Pei (1940)	Current
Carnivora:			
<i>Vulpes vulgaris</i> and <i>Vulpes corsac</i>	Fox (primarily red)	Several complete skeletons, several crania, many mandibles, and numerous fragmentary postcrania	8 cranial specimens, 32 maxillae, 47 mandibles, 21 loose teeth, and 9 atlas vertebrae
<i>Ursus spelaeus</i>	Cave bear	1 complete skeleton, 3 crania (2 adult, 1 juvenile), several complete mandibles, and numerous postcrania	1 complete skeleton (in ZKD Museum), 1 cranium, 1 maxilla, 1 mandible, 9 loose teeth, 1 sacral vertebra, 2 innominates, and 1 femur
<i>Meles leucurus</i>	Badger	Several complete skeletons, many crania and mandibles, and numerous fragmentary postcrania	5 crania, 12 maxillae, 49 mandibles, 19 loose teeth, and 2 innominates
<i>Panthera tigris</i>	Tiger	<i>1 complete skeleton, 3 crania (2 adult, 1 juvenile),^a several complete mandibles, and numerous postcrania</i>	1 cranium, 2 maxillae, 3 mandibles, 16 loose teeth, 3 humeri, 9 innominates, and 2 sacral vertebrae
Artiodactyla:			
<i>Cervus nippon/Cervus elaphus canadensis</i>	Sika deer/red deer	<i>30 complete skeletons from the Lower Recess,^a 3 complete skeletons, >20 crania, >100 mandibles, numerous isolated teeth, and numerous postcrania</i>	11 antlers, 3 horn cores, 27 crania, 107 maxillae, 219 mandibles, 149 loose teeth, and 66 postcranial remains

Note: Bolded text represents the most significant difference between Pei's report and what is available today. Italics indicate specimens that disappeared before Pei was able to complete his report.

^aSome of the better-preserved ZKD UC specimens were sent to Nanjing for safekeeping but were lost during the Japanese invasion at the beginning of World War II. Accordingly, the original faunal assemblage was much larger than what appeared in Pei's report.

(15%) carnivore cranial specimens from ZKD UC 1933 display evidence of tooth marks while 12 of the 52 (23.08%) ZKD UC 1934 fragments show signs of carnivore modification, a nonsignificant difference ($\chi^2 = 1.38$, $df = 1$, $P = 0.240$). Cut-mark data on the carnivore cranial elements (1933: 3 of 80 [3.75%]; 1934: 0 of 52 [0%]) are not significantly different (Fisher's exact test [two-sided sig.] = 0.278).

Discussion

Did the Lower Recess Serve as a Natural Trap?

If the Lower Recess served as a natural trap, very little human modification would be expected to be present on the faunal remains from ZKD UC 1934. On the other hand, if the Lower Recess was an area where hunter-gatherers resided or discarded their refuse, then we should expect to find similar levels of human and nonhuman modification between ZKD UC 1933 and 1934. Taphonomic analysis indicates that human modification is present on the ZKD UC 1934 materials, albeit at significantly lower levels than on those from ZKD UC 1933. Does this necessarily mean that we can discard the natural-trap hypothesis and consider the Lower Recess simply as a place where hunter-gatherers regularly deposited their refuse?

A closer examination of the original Zhoukoudian field journals shelved in the IVPP library reveals a more compli-

cated situation. According to the 1934 Zhoukoudian field journal, on May 19, 1934, several pieces of quartz and a piece of chert were discovered during the excavation of ZKD UC. This indicates that artifacts can be associated with the 1934 excavation season. This can be interpreted in two ways. First, instead of producing only material from the Lower Recess, the 1934 field season involved at least partial excavation of Layer 5. Second, the lithics and human-modified bone could have been secondarily deposited, having originated in the upper levels. Either way, at least some evidence of human modification might be expected to be present on the ZKD UC 1934 faunal remains. However, in order for the natural-trap hypothesis to hold true, we should expect to find the percentages of human-modified bone to be lower than that in the material from ZKD UC 1933. The results of the above analysis (e.g., burning, cut marks) support this.

Two additional lines of evidence substantiate the natural-trap hypothesis: (1) The presence of *Celtis* seeds throughout Locality 1 and the cultural levels in ZKD UC suggests hominin transport; the absence of *Celtis* seeds in the Lower Recess is evidence for little or no human presence there. (2) The presence of at least 30 articulated cervid skeletons in the Lower Recess is probably the reason why there are significantly more cervid remains than carnivore remains in that area of the cave (table 4). This evidence better supports the natural-trap hypothesis because if carnivores or humans were killing and

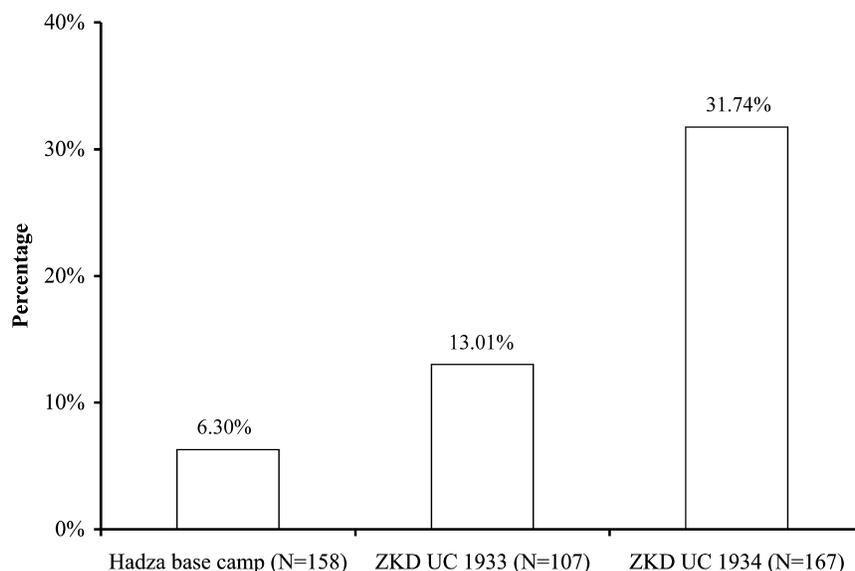


Figure 6. Number of tooth-marked cervid cranial specimens from ZKD UC and from ethnoarchaeological research (Hadza data from Lupo and O'Connell 2002).

transporting deer into the cave, then most of the carcasses would have become disarticulated during the consumption process (Blumenshine 1986).

East Asian Late Paleolithic Hunter-Gatherer Subsistence Strategies

Mortality patterns suggest that ambush hunters (e.g., big cats, humans) were the primary bone accumulators in the ZKD UC 1933 cervid assemblage. Hyenas and wolves are better known for producing an attritional mortality profile (Stiner 1994, 2002a). Because their remains were discovered in the cave, canids cannot be completely ruled out. However, many of the tooth marks on the cervid bones are small, implicating a small carnivore. In this case, the bone modifiers were probably scavenging foxes and small cats.

Cut-mark and tooth-mark data indicate that hunter-gatherers contributed many of the cervids in ZKD UC. We found nonsignificant variation in tooth-mark percentages on carnivore bones, suggesting similar levels of carnivore activity and the likelihood of similar carnivore interaction when humans were not present at the site. Therefore, the higher cut-mark and lower tooth-mark frequencies implicate hunter-gatherers in the accumulation of ZKD UC 1933. These frequencies correspond well with data derived from actualistic studies showing that hominins and modern hunter-gatherers were processing carcasses at their leisure and then later abandoning them to be ravaged by scavenging carnivores.

Conclusions

Because of the biased nature of the ZKD UC faunal assem-

blage, the taphonomic analysis we present here is limited. Future research at ZKD UC is critical in order to collect a more complete faunal assemblage. In addition, further fieldwork would allow for three-dimensional mapping of the faunal and artifactual materials in situ, facilitating more confident reconstructions of the human-carnivore interactions at the site. This is in addition to the possible presence of supplementary modern *Homo sapiens* fossils at ZKD UC.

Application of modern taphonomic approaches is critical to reconstructing Pleistocene hominin large-game procurement strategies in East Asia. This study (see also Norton et al. 2007; Norton and Gao 2008) serves to lay the foundation for additional taphonomic research in this region, where it has previously received minimal attention. These taphonomic studies will facilitate reconstructions of hominin-carnivore interactions over large game and shelter resources during the Plio-Pleistocene in East Asia.

Two primary conclusions drawn from this study are that the Lower Recess served as a natural trap and that the ZKD UC humans processed cervids in the cave. Because of the age of the site and the results of this taphonomic analysis, it is probable that the Late Paleolithic ZKD UC hunter-gatherers were proficient hunters of the local cervid population. However, because of the biased nature of the bone collection, this suggestion needs to be qualified. We were unable to determine whether the hunter-gatherers were transporting complete deer carcasses or only certain body parts to the cave. Irrespective of what large-game transport decisions were made, multiple lines of taphonomic evidence support the hypothesis that the ZKD UC hunter-gatherers were processing the cervids at the site.

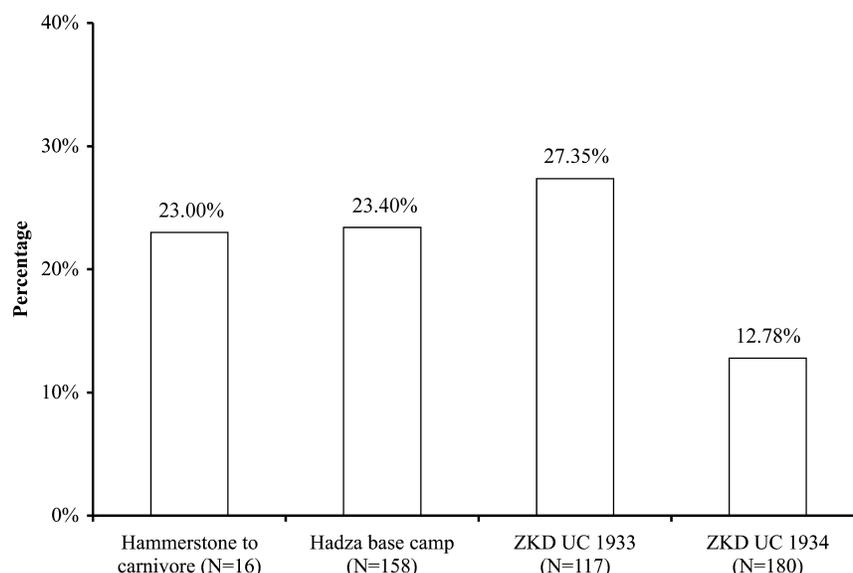


Figure 7. Number of cut-marked cervid cranial specimens (hammerstone to carnivore data from Capaldo 1997; Hadza base-camp data from Lupo and O'Connell 2002; in Capaldo's publication, only percentages and means were published).

As the results of this study suggest, ZKD UC can contribute more than just UC 101, 102, and 103 to resolving current questions in paleoanthropology. In particular, the archaeological and taphonomic records can contribute to debates (e.g., on the origins of modern human behavior) that have traditionally focused on the Western Old World human evolutionary record.

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