Journal of Archaeological Science 39 (2012) 3610–3626

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

The Shuidonggou site complex: new excavations and implications for the earliest Late Paleolithic in North China

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A R T I C L E I N F O

Article history:
Received 29 January 2012
Received in revised form
7 June 2012
Accepted 8 June 2012

Keywords:
Blades and microblades
Modern human behavior
Late Paleolithic
Shuidonggou
North China

A B S T R A C T

The initial Late Paleolithic, said to appear between 40 and 30 kya in eastern Asia, is defined by the appearance of many innovations. These archaeological indicators include the appearance of more refined stone tool making techniques (e.g., include the appearance of blade and microblade technology), complex hearth construction, use of pigments and personal ornamentation, as well as worked faunal implements such as bone and antler tools. We report here new findings from a multidisciplinary research project conducted at the Shuidonggou (Choei-tong-keou) site complex in northern China, a series of localities that date from the initial Late Paleolithic to the Neolithic.

Six new localities (SDG7–12) were discovered and five localities [SDG2 (previously identified) and SDG7–9 and 12] were excavated, yielding more than 50,000 stone artifacts, fauna, ostrich eggshell beads, and hearths. Dating results suggest that human occupation of the Shuidonggou area occurred during the Late Pleistocene to Middle Holocene (~32,000–6000 BP). Some sites are characterized by small, irregular flakes, casually retouched tools [modified or informally retouched tools (i.e., non-standardized tools with sporadic retouch which was not well controlled)], and small numbers of blades or no blades. Others lithic assemblages are dominated by blades and microblades. At two sites, higher quality or exotic raw materials were exploited, but at the majority of sites locally-available river cobbles were used. In addition to blades, microblades and hearths, more than 80 finely-perforated and polished ostrich egg-shell beads, mostly colored with red ochre, were recovered from three sites. Several worked bone needles and an awl were also uncovered from the youngest site, SDG12, in deposits dating to c. 13,000 cal BP. The implications for the initial appearance of the Late Paleolithic in China and movement of modern human populations into North China are discussed.

1. Introduction

Many behavioral and technological innovations appear in the archaeological record of Eurasia between c. 45,000 and 24,000 BP (Brantingham et al., 2001; Gao and Norton, 2002; Klein, 2008; Norton and Jin, 2009; Bae and Bae, in press). This period has been termed the 'initial Upper Paleolithic' (among others, Kuhn et al., 1999; Bar-Yosef, 2002, 2007) and is largely associated with movements of modern humans into that part of the world (Henshilwood and Marean, 2003; Klein, 2008; Norton and Jin, 2009) and/or the complex interplay between population movements and environmental, demographic and cultural influences (Kuhn et al., 2004). As a whole, the initial Upper Paleolithic in western Eurasia is characterized by the systematic production of blades with Levallois core reduction strategies, resulting in significant numbers of elongated Levallois points and faceted striking platforms (Kuhn et al., 1999, 2001, 2004). Retouched blades are also common, but there are regional differences in the proportions of other formal tool types (Andrefsky, 1994) generally considered characteristic of either Middle or Upper

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http://dx.doi.org/10.1016/j.jas.2012.06.028

Paleolithic industries. A variety of other advanced behavioral traits is also associated with the appearance of the Upper Paleolithic, such as worked bone, worked antler or ivory, body ornaments, long-distance movement of some materials, the structured use of space and hearths, and improved hunting techniques (Bar-Yosef, 2007).

Current evidence suggests that the initial Upper Paleolithic first appeared in western Asia in the Levant at 45,000–40,000 BP (Bar-Yosef, 2000; Kuhn et al., 1999). Dates for its first appearance eastwards are younger, suggesting population movements. In the Altai region of southern Siberia, it is present at Kara Bom around 43,000 BP (Goebel et al., 1993; Derevianko et al., 2000), and in the Mongolian Gobi at Chikhen Agui and Tsagaan Agui at 33,000 and 27,000 BP (Brantingham et al., 2001; Fig. 1a). In these eastern Asian sites, lithic assemblages include high-quality raw materials, the introduction of new or exotic lithic raw materials, and more refined tools made on blades and microblades (Brantingham et al., 2001), which persist in some areas until the terminal Pleistocene (Gao, 1999; Gao and Norton, 2002). However, stone tool assemblages from this time range in eastern Asia are rare. The best known site is Shuidonggou (c. 30,000–11,000 BP) (Lin, 1996; Bar-Yosef and Kuhn, 1999; Brantingham et al., 2001; Norton and Jin, 2009). Shuidonggou has traditionally been considered the type site for early blade technology in eastern Asia, due in part to the fact that it has been well known in prehistoric studies since its discovery in 1923 (Madsen et al., 2001). It should be noted however that an earlier date for the initial appearance of blade technology in eastern Asia has been suggested, with some evidence in Korea possibly dating as early as 38,000 BP (Norton and Jin, 2009; Bae and Kim, 2010; Bae and Bae, in press). Other sites exist in the Shuidonggou region

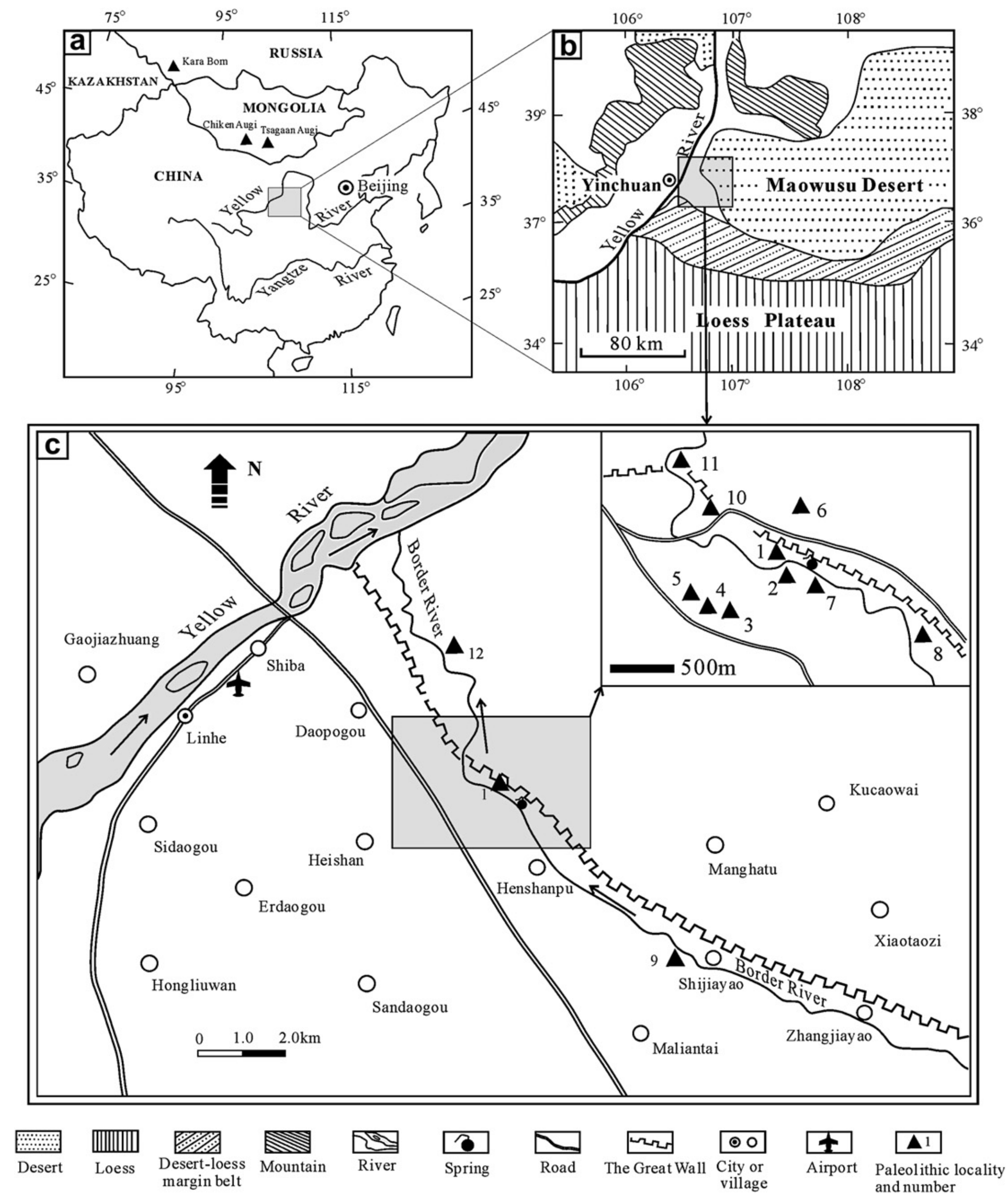

Fig. 1. The location of the Shuidonggou site and adjacent sites. a. The location of Shuidonggou and other Northeast Asian sites discussed here. b. The Shuidonggou study area in its geographic setting. c. Provides details of the Shuidonggou localities.

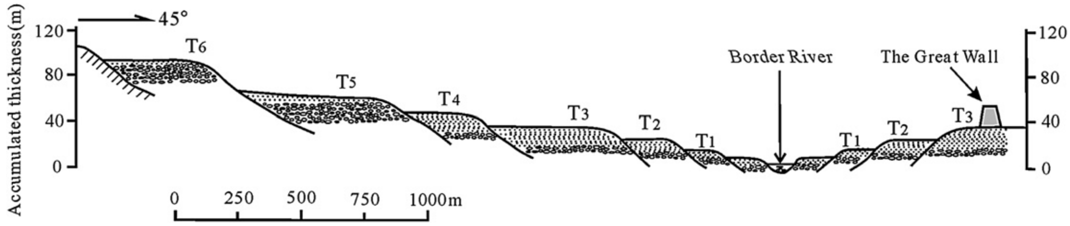

Fig. 2. Quaternary geomorphology of the Shuidonggou area, showing the six terraces of the Border River.

that appears to predate Shuidonggou but have Shuidonggou-like stone toolkits (Barton et al., 2007; Morgan et al., 2011; Zhang et al., 2011). Thus, although Shuidonggou may be considered the type site for the transition to blade tool industries in Northeast Asia, there is growing evidence that it is not the oldest site that displays this type of evidence in the region.

It is generally accepted that Paleolithic cultural developments in eastern Asia differed significantly from the western Old World

Table 1
Dating results from the Shuidonggou site complex. ¢ = archaeological layers; § = dated samples from current excavations (2003–2010).

	Locality and layer	Sample no.	Material	yr BP	Cal yr BP ± σ[a]	Method	Reference
¢	SDG1 4th layer	PV-330	Bone	5900 ± 70	6639–6825	^{14}C	Li et al., 1987
¢	SDG1 upper cultural layer	PV-316	Shell	8520 ± 150	9305–9690	^{14}C	Li et al., 1987
¢	Loc 1 upper cultural layer	S25	Soil	5940 ± 100	6657–6898	^{14}C	Sun and Zhao, 1991
¢	SDG1 upper cultural layer	S31	Ash	7436 ± 101	8175–8366	^{14}C	Sun and Zhao, 1991
¢	SDG1 upper cultural layer	S37	Diatoms	8190 ± 120	9007–9395	^{14}C	Sun and Zhao, 1991
	SDG1 1st layer §	S1-1	Fine sand and silt	4200 ± 200		OSL	Liu et al., 2009
	SDG1 1st layer §	S1-2	Fine sand and silt	9100 ± 1000		OSL	Liu et al., 2009
	SDG1 3rd layer §	S1-3	Fine sand and silt	28,700 ± 6000		OSL	Liu et al., 2009
	SDG1 4th layer §	S1-4	Fine sand and silt	29,300 ± 4100		OSL	Liu et al., 2009
	SDG1 4th layer §	S1-5	Fine sand and silt	32,800 ± 3000		OSL	Liu et al., 2009
	SDG1 5th layer §	S1-6	Fine sand and silt	15,800 ± 1100		OSL	Liu et al., 2009
¢	SDG1 6th layer	82042	Equus teeth	38,000 ± 2000		U-series	Chen et al., 1984
¢	SDG1 6th layer	82043	Equus teeth	34,000 ± 2000		U-series	Chen et al., 1984
¢	SDG1 6th layer	PV-317	Carbonate concretion	25,450 ± 800	29,546–30,910	^{14}C	Li et al., 1987
¢	SDG1 6th layer §	S1-7	Fine sand and silt	17,700 ± 900		OSL	Liu et al., 2009
¢	SDG1 6th layer §	S1-8	Fine sand and silt	34,800 ± 1500		OSL	Liu et al., 2009
¢	SDG1 6th layer §	S1-9	Fine sand and silt	35,700 ± 1600		OSL	Liu et al., 2009
¢	SDG1 upper part, 8th layer	PV-331	Bone	16,760 ± 210	19,584–20,170	^{14}C	Li et al., 1987
¢	SDG2 4th layer §	S2-1	Fine sand and silt	20,300 ± 1000		OSL	Liu et al., 2009
¢	SDG2 6th layer	Hearth1	Charcoal	26,350 ± 190	30,884–31,160	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth2	Charcoal	25,670 ± 140	30,326–30,646	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	n/a	Ostrich eggshell	26,930 ± 120	31,181–31,352	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth3	Charcoal	26,830 ± 200	31,123–31,336	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth4	Charcoal	25,650 ± 160	30,304–30,647	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth5	Charcoal	26,310 ± 170	30,869–31,137	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth7	Charcoal	29,520 ± 230	33,907–34,617	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer	Hearth10a	Charcoal	23,790 ± 180	28,275–28,856	AMS ^{14}C	Madsen et al., 2001
¢	SDG2 6th layer §	Beta 207935	Ostrich eggshell	28,420 ± 160	32,494–33,146	AMS ^{14}C	Unpublished
¢	SDG2 6th layer §	Beta 207936	Charcoal	28,330 ± 170	32,288–33,007	AMS ^{14}C	Unpublished
¢	SDG2 8th layer §	S2-2	Fine sand and silt	27,800 ± 1400		OSL	Liu et al., 2009
¢	SDG2 10th layer §	S2-3	Fine sand and silt	20,500 ± 1100		OSL	Liu et al., 2009
¢	SDG2 13th layer §	S2-4	Fine sand and silt	29,200 ± 2100		OSL	Liu et al., 2009
	SDG2 15th layer §	S2-5	Fine sand and silt	23,600 ± 2400		OSL	Liu et al., 2009
	SDG2 15th layer §	S2-6	Fine sand and silt	38,300 ± 3500		OSL	Liu et al., 2009
	SDG2 16th layer (upper part) §	S2-10	Peat	29,759 ± 245	34,415–34,768	AMS ^{14}C	Liu et al., 2009
	SDG2 16th layer (lower part) §	S2-11	Wood	36,329 ± 215	41,222–41,649	AMS ^{14}C	Liu et al., 2009
	SDG2 17th layer §	S2-7	Fine sand and silt	19,600 ± 2500		OSL	Liu et al., 2009
	SDG2 17th layer §	S2-8	Fine sand and silt	64,600 ± 3600		OSL	Liu et al., 2009
	SDG2 17th layer §	S2-9	Fine sand and silt	72,000 ± 4900		OSL	Liu et al., 2009
	SDG7 2nd layer §	S7-1	Fine sand and silt	18,900 ± 900		OSL	Liu et al., 2009
¢	SDG7 8th layer §	S7-2	Fine sand and silt	25,200 ± 1800		OSL	Liu et al., 2009
¢	SDG7 9th layer §	S7-3	Fine sand and silt	26,300 ± 2700		OSL	Liu et al., 2009
¢	SDG7 10th layer §	S7-4	Fine sand and silt	27,200 ± 1500		OSL	Liu et al., 2009
¢	SDG9 2nd layer §	SDG9-OSL-2	Fine sand and silt	27,400 ± 3600		OSL	Unpublished
¢	SDG9 2nd layer §	SDG9-OSL-2	Fine sand and silt	35,900 ± 6200		OSL	Unpublished
¢	SDG9 2nd layer §	G07-SDG9-1	Fine sand and silt	29,500 ± 2600		OSL	Unpublished
¢	SDG9 2nd layer §	G07-SDG9-2	Fine sand and silt	29,700 ± 5300		OSL	Unpublished
¢	SDG9 2nd layer §	G07-SDG9-3	Fine sand and silt	29,400 ± 6100		OSL	Unpublished
	SDG12 2nd layer §	CG1	Fine sand and silt	12,100 ± 1100		OSL	Liu et al., 2008
	SDG12 8th layer §	CG2	Fine sand and silt	33,100 ± 1700		OSL	Liu et al., 2008
¢	SDG12 11th layer §	CC1	Charcoal	11,271 ± 107	13,078–13,296	AMS ^{14}C	Liu et al., 2008
¢	SDG12 11th layer §	CG3	Fine sand and silt	11,600 ± 600		OSL	Liu et al., 2008
	SDG12 20th layer §	CG4	Fine sand and silt	47,200 ± 2400		OSL	Liu et al., 2008

[a] Calibrated using Calib Rev 6.1.0 (Stuiver and Reimer, 1993) and Intcal09 calibration dataset (Reimer et al., 2009).

(Ikawa-Smith, 1978; Gao and Norton, 2002; Norton et al., 2009; Bae and Bae, in press). In particular, the Chinese Paleolithic was dominated by simple core and flake tool industries, and Middle Paleolithic technologies (e.g., Levallois) were absent or appear very late in the record (Gao and Norton, 2002; Norton et al., 2009). Although some improvements in tool production did occur prior to 30,000 BP, they were gradual and relatively minor, leading Gao and Norton (2002) to conclude that only two distinct stages existed in China during the Pleistocene – the Early and the Late Paleolithic. In contrast with the western Old World, a distinct "Middle" Paleolithic has not yet been identified in China and broader eastern Asia (Gao, 2000; Norton, 2000; Gao and Norton, 2002; Norton et al., 2009; Norton and Jin, 2009; Bae and Bae, in press).

In China, major technological and cultural changes occur in the north c. 30,000–27,000 BP in the form of an 'initial Upper Paleolithic', which we here term the initial Late Paleolithic (Gao and Norton, 2002). However, these assemblages are extremely limited in number (Zhang, 1990; Lin, 1996; Gao, 1999). Apart from Shuidonggou, only a handful of sites include evidence of large blade technologies, and the blades are few in number or equivocal (Li, 1993). There does, however, appear to be a common technological trend that defines the existing sites as an initial Late Paleolithic, equivalent to the initial Upper Paleolithic in western Eurasia. This includes the exploitation of higher quality lithic raw materials, the introduction of new or exotic rock types, more refined core working methods in the form of blade and microblade technologies, and the use of Levallois core reduction strategies for blade production (Brantingham et al., 2001; Gao and Norton, 2002). Other archaeological indicators of more advanced behavior at this time are the appearance of complex hearth construction, the use of pigments, personal ornamentation, and tools in bone and antler (Zhang, 1985; Gao, 1999; Norton and Jin, 2009).

Shuidonggou is presently the most important site complex for the initial Late Paleolithic in northern China, particularly because it has been the subject of a large number of studies. This paper reports on a recent multidisciplinary research program which has now yielded the first personal ornaments from this site complex, including color-stained ostrich eggshell beads dated to c. 32,000 years. The purpose of this paper is to discuss the result of recent multidisciplinary research (dating, geomorphology, site surveys, excavation, etc.) conducted on the site complex. Although detailed analysis of the cultural remains is still in progress, we present lithic assemblage data relevant to the site formation processes at Shuidonggou.

2. Research history

Shuidonggou (38°17′55.2″N, 106°30′6.7″E; 1198 m a.s.l.) is located on the southwestern edge of the Ordos Desert in Ningxia Hui Autonomous Region of China (Fig. 1b and c). Since 1923, the site [In China, and other areas of eastern Asia (e.g., Korea), "site" usually represents an area and "locality" represents different areas within the site. For instance, the famous Dingcun site is actually comprised of at least fourteen localities] has long been recognized as critical to understanding the North Chinese Late Paleolithic (Licent and Teilhard de Chardin, 1925; Boule et al., 1928; Jia et al., 1964; Bordes, 1968; Li, 1993; Yamanaka, 1995). Early researchers classified the lithic industry from Shuidonggou Locality 1 (SDG1) as evolved Mousterian or emergent Aurignacian (Licent and Teilhard de Chardin, 1925; Boule et al., 1928; Zhou and Hu, 1988). In particular, it was noted that core forms from SDG1 closely resembled those from Eurasian Mousterian sites, while the retouched tools had some strong parallels with Eurasian Upper Paleolithic types. Bordes (1968: pp. 129–130) later confirmed that the impression given by the industry was that of a very evolved Mousterian in the

Table 2
Overview of the descriptive data for different localities and associated finds at the Shuidonggou site complex.

Locality name	Longitude/Latitude	Geomorphic location	Age (yr BP)	Dating methods	Date of discovery/ Date of excavation	Archaeological remains				
						Blades	Microblades	Fauna	Worked shell and bone	Hearth, charcoal, ash Layer
1	106°30′6.7″E/38°17′55.2″N	T2-T1, 1198 m a.s.l.	34,800 ± 1500–6732 ± 186	^{14}C, U-series, AMS ^{14}C cal, OSL	1923/1923, 1963, 1980	×		×		
2	106°30′9.6″E/38°17′51.8″N	T2, 1200 m a.s.l.	34,591 ± 177–20,300 ± 1000	AMS ^{14}C cal, OSL	1923/2003–2005	×		×	OESB	Hearth, charcoal fragment, and clay ash layer
3	106°29′46.7″E/38°17′44.3″N	T2-T1, 1200 m a.s.l.			1923/2004	×	×			
4	106°29′44.9″E/38°17′45.5″N	T2-T1, 1202 m a.s.l.			1923/2004	×	×			
5	106°29′38.7″E/38°17′50.3″N	T2-T1, 1201 m a.s.l.			1923/2004	×				
6		T2,			1963-9-13/no	×	×			
7	106°30′20.7″E/38°17′51.4″N	T2, 1205 m a.s.l.	27,200 ± 1500–25,200 ± 1800	OSL	2003-4-15/2003–2005	×		×	OESB	Charcoal fragment, and clay ash layer
8	106°31′03″E/38°17′29″N	T2, 1213 m a.s.l.		OSL	2003-4-20/2003			×	OESB	Charcoal fragment, and clay ash layer
9	106°32′34″E/38°15′39″N	T2, 1223 m a.s.l.	35,900 ± 6200–27,400 ± 3600	OSL	2003-4-20/2007	×				
10	106°29′34″E/38°18′21″N	T2, 1185 m a.s.l.			2003-4-15/no		×			
11	106°29′47″E/38°18′09″N	T2, 1179 m a.s.l.			2003-4-15/no		×			
12	106°29′49.0″E/38°19′40.0″N	T2, 1158 m a.s.l.	13,296–13,078	AMS ^{14}C cal	2005/2007, 2010	×	×	×	Bone needles and bone awls	Hearth, charcoal fragment, and clay ash layer

× – Presence.
OESB – Ostrich eggshell beads.

process of transition to the Upper Paleolithic, but with its own regional traits.

Chinese researchers, beginning with Pei (1937), have also noted typological connections between Shuidonggou and western Middle Paleolithic industries (e.g., Zhang, 1987; Gao et al., 2002). However, these studies placed emphasis on the Late Paleolithic components such as the abundance of blades and retouched blade tools in the SDG1 assemblage (Jia et al., 1964; Li, 1993; Lin, 1996). In 1980, the Institute of Archeology of Ningxia Hui Autonomous Region conducted an excavation at SDG1 (Ningxia Museum, 1987; Ningxia Museum and Ningxia Institute of Regional Geological Survey, 1987; Institute of Archeology of Ningxia Hui Autonomous Region, 2003). This excavation produced more than 5500 Paleolithic artifacts from the lower cultural layer dated (^{14}C) to 17,250 $\pm$ 210 (animal fossil) to 26,190 $\pm$ 800 (calcareous concretion) BP and more than 1200 Neolithic artifacts from the upper cultural layers which dated (^{14}C) to 5900 $\pm$ 70 to 8770 $\pm$ 150 BP. The published analysis of the Paleolithic artifacts shows that: 1) 48.3% of cores are classified as blade cores; 2) 60.2% of all flake products are blades; 3) the majority of formal tools is made on blade blanks; 4) there is a high number of truncated blades; and 5) 4.6% of the artifacts are small enough to be classified as microliths or small cores for producing flakes and bladelets. The smaller lithics are made on finer raw materials (quartz, flint and agate), and the blades, truncated blades and bladelets are considered strongly suggestive of hafting because of their more standardized form or small size. Middle Paleolithic traits are also present in the form of 14 unifacially retouched points on blades or triangular flakes, numerous facetted striking platforms, and core reduction strategies that are typically associated with Middle Paleolithic Levallois blade production.

Although the earlier studies published on Shuidonggou (e.g., Licent and Teilhard de Chardin, 1925; Boule et al., 1928; Jia et al., 1964; Ningxia Museum and Ningxia Institute of Regional Geological Survey, 1987) did not mention any evidence of pigment use, personal ornaments, and/or worked bone and antler tools, more recent research reported in Chinese journals has identified these items at the site complex (e.g., Gao et al., 2004; Wang et al., 2009). Thus the material culture of Shuidonggou fits well within the definition of the initial Upper/Late Paleolithic of western Eurasia and Northeast Asia (Bar-Yosef and Kuhn, 1999; Kuhn et al., 1999; Brantingham et al., 2001; Institute of Archeology of Ningxia Hui Autonomous Region, 2003).

Beginning in 2002 the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP of the Chinese Academy of Sciences) and the Institute of Archeology of Ningxia Hui Autonomous Region developed a joint research program that focused on geomorphology, excavation and optically stimulated luminescence (OSL) dating of the Shuidonggou site complex, covering an area of over 50 km^2 (Gao et al., 2004; Fig. 1b). Six new Paleolithic sites (designated SDG7–12) were discovered and more than 100 artifacts were surface collected. Large scale excavations were conducted at five of the sites [SDG2 (previously discovered), SDG7, SDG8, SDG9, and SDG12]. As a result of these recent excavations, new cultural horizons have been identified and more than 50,000 Paleolithic stone artifacts recovered. The assemblages include blades and microblades, large numbers of vertebrate fossils, some ostrich eggshell beads, hearths, pigments and bone tools.

3. Geomorphology and geochronology

3.1. Geomorphology

Shuidonggou is located 28 km southeast of Yinchuan and 10 km east of the Yellow River (Fig. 1). The area, occupying the western margin of the Maowusu Desert (the southwestern part of the Ordos Desert), lies in the transition zone between the desert and the Loess Plateau in North China (Bureau of Geology and Mineral Resources of Ningxia, 1983). The Border River, a tributary of the Yellow River which runs southeast to northwest (Fig. 1b), originates in Qingshuiying about 40 km to the southeast and runs northwest along the southern edge of the Great Wall (built along the southern

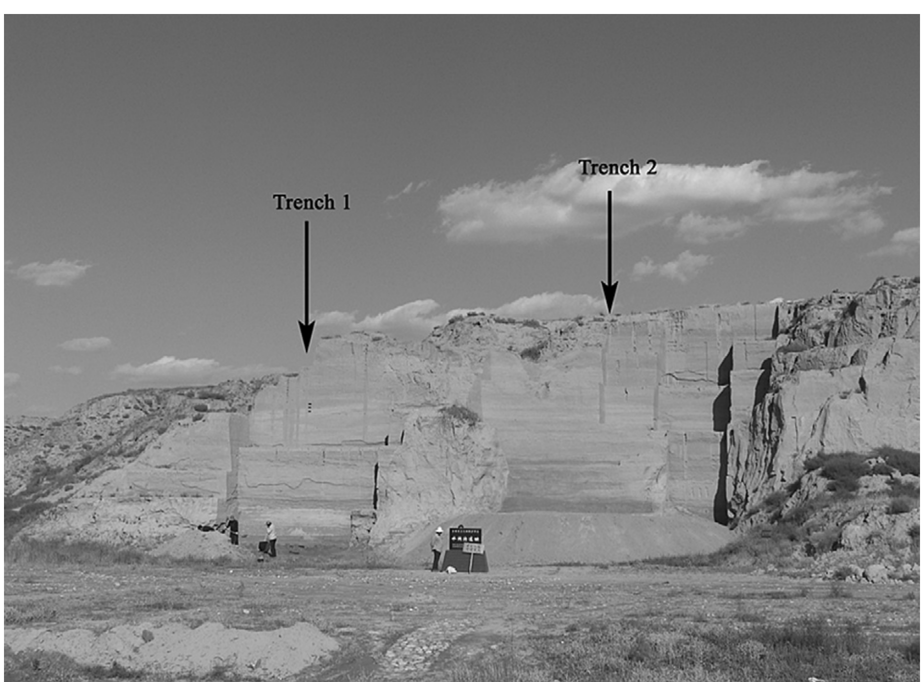

Fig. 3. Photo showing the stratigraphic profile of SDG2 (view from west).

Table 3
The stratigraphic sequence at SGD 2, (* a layer bearing archaeological remains).

Layer	Stratigraphic description	Depth (below surface)/m	Dates/yr BP
1–2	Grayish and brownish yellow silt, loose structure	0–1.16	
3	Grayish white silt, firm structure, horizontal bedding, interbedded with a few rubiginous mottles and granular charcoals	1.16–3.50	
*4	Light yellow silt	3.5–3.64	20,300 ± 1000
5	Light yellow silt, horizontal bedding, some gray calcareous silty clay aggregates	3.64–4.76	
*6	Light yellow silt	4.76–5.20	33,907–34,617 30,326–30,646
7	Grayish yellow silt, firm structure, horizontal bedding	5.20–5.76	
*8	Light yellow silt	5.76–5.86	27,800 ± 1400
9	Light Grayish yellow silt, firm structure, horizontal bedding, with a few rubiginous mottles	5.86–6.30	
*10	Light yellow silt	6.30–6.40	20,500 ± 1100
11–12	Light Grayish yellow silt, firm structure, horizontal bedding, with a few rubiginous mottles	6.40–7.40	
*13	Light yellow silt	7.40–7.70	29,200 ± 2100
14	Light Grayish yellow silt, horizontal bedding with a lot of rubiginous mottles	7.70–8.30	
15	Grayish green silt, horizontal and current bedding, with a lot of rubiginous mottles	8.30–10.50	23,600 ± 2400 38,300 ± 3500
16	Grayish black peat, rumpled, contained a lot of plant remnants and some of gastropod fossils	10.50–11.40	41,222–41,949 34,415–34,768
17	Grayish yellow silt and fine sand, horizontal bedding. Irregular boundaries contacted to upper and lower layers	11.40–11.80	19,600 ± 2500 64,600 ± 3600 72,000 ± 4900
18	Gravel layer, mainly limestone and quartzite.	11.80+	

margin of the desert during the Ming Dynasty). After crossing under the Great Wall, it becomes the Shuidonggou River, which eventually feeds into the Yellow River.

The site localities are distributed along both banks of the Border River. There are six terraces of the Border River, labeled T6 to T1 from oldest to youngest (Fig. 2). The oldest terrace dates perhaps to the Early Pleistocene and the youngest to the Holocene (Gao et al., 2008; Liu et al., 2009). These terraces have been formed by intermittent faulting and erosion caused by the Yellow River and its local tributaries. Terrace heights are at 100 m, 75 ~ 80 m, 60 m, and 40 m for T6 to T3 respectively above the current Border River level (Gao et al., 2008). T2 and T1 have heights of 13 m and 6 m. The archaeological localities discussed here are restricted to T2.

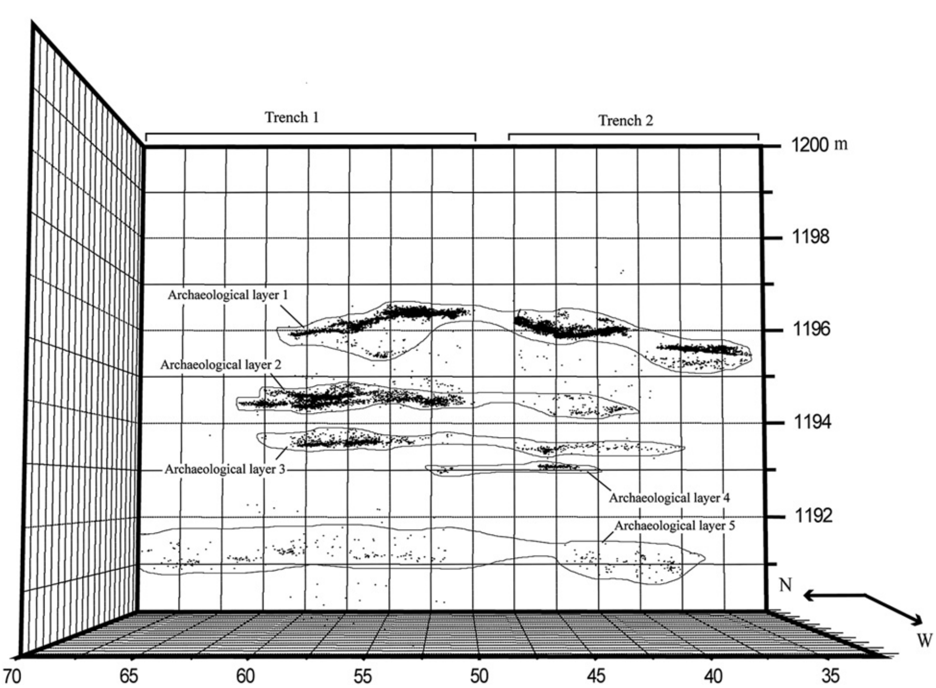

Fig. 4. The 3 dimension map showing the vertical distribution of the five discerned archaeological layers at SDG2 (view from west).

Table 4
The archaeological finds from SDG2. OESB = ostrich eggshell beads.

Stratigraphic layers	Archaeological remains								Total
	Lithic artifacts		Bones		OESB		Subtotals		
	Trench 1	Trench 2	Trench 1	Trench 2	Trench 1	Trench 2	Trench 1	Trench 2	
Layer 4	6052	5785	213	5	1	0	6266	5790	12,056
Layer 6	164	2390	14	871	0	74	178	3335	3513
Layer 8	266	828	102	13	0	1	368	842	1210
Layer 10	75	239	60	76	1	0	135	315	450
Layer 13	106	37	18	19	0	0	124	56	180
Total	6663	9279	407	984	1	75	7071	10,338	17,409
Combined total	15,942		1391		76				

Gravels blanketing the surfaces of T6 and T5 are approximately 5 m in thickness and contain many agate cobbles. Detailed study of the prehistoric raw material procurement patterns have not yet been done, but terrace gravels found (from 0.5 to 1.0 km from the sites) in the immediate region are the most likely sources. New OSL results obtained for the lowest levels of Terrace 2 provide dates from c. 72,000 ± 4900 BP, but these layers currently lack signs of human occupation. Cultural material is present in horizons dating from 34,618 cal BP to 13,296 cal BP, and thus far all archaeological remains have been limited to Terrace 2 (Liu et al., 2008, 2009). T2 and T1 have developed in two stages. The lower part of both terraces consists of sand-gravel, while the upper part is gray-yellow fine silt and loam. T4 and T3 are both composed of sand-gravel layers, sandy lenses and silts.

3.2. Geochronology

A systematic dating program using AMS ^{14}C and OSL was carried out following the most recent excavations by the IVPP and the Institute of Archeology of Ningxia Hui Autonomous Region (Liu et al., 2008, 2009). Due to the importance of the initial Late Paleolithic and technological comparisons between West and East, the dating of T1 and T2 has also received considerable attention in the past. Table 1 provides a comprehensive list of both the older and the more recent dating studies. The raw radiocarbon dates were calibrated using Calib Rev. 6.1.0 (Stuiver and Reimer, 1993) and Intcal09 (Reimer et al., 2009). Unless otherwise specified, we use the calibrated radiocarbon dates in the section below.

Since 1984, various chronometric methods have been applied to the Pleistocene deposits of T2. The first published dates of 38,000 and 34,000 BP are U-series results on faunal teeth (Chen et al., 1984) and appear to be too old. Two younger dates published later by the Ningxia Museum and Ningxia Institute of Regional Geological Survey (1987) indicate a Late Pleistocene age and probably sample the same two Pleistocene deposits that were analyzed by Li et al. (1987). Of the 13 dates in Table 1 for the SDG1 Pleistocene levels, the four results which range between c. 15–17,000 BP are probably too young due to contamination with younger carbon or mixing of sediments. Most researchers favor the older dates (Brantingham et al., 2001; Madsen et al., 2001; Gao et al., 2002). The bulk of the dates therefore suggests that SDG1 probably dates to at least 25,000 BP but could be several thousand years older. Based on the diversity of dates and error ranges, it is currently difficult to more narrowly bracket the age range of SDG1.

For SDG2, the topmost deposit, Layer 4, is c. 20,300 BP based on only one OSL date, and the four underlying archaeological layers have older dates. Madsen et al. (2001) published eight uncalibrated AMS ^{14}C dates from Layer 6 which cluster around 26,000 BP, which if calibrated to around 31,000 cal BP (Table 1). Two recent unpublished radiocarbon dates are in close agreement with each other and suggest Layer 6 is c. 33,000 cal BP to 32,000 cal BP. Layers 8 and 13 have one new OSL result each of 27,800 and 29,200 BP respectively, but both have large error margins (Liu et al., 2009). It is thought these layers have a minimum age of c. 28,000. Layer 10 has one anomalous OSL

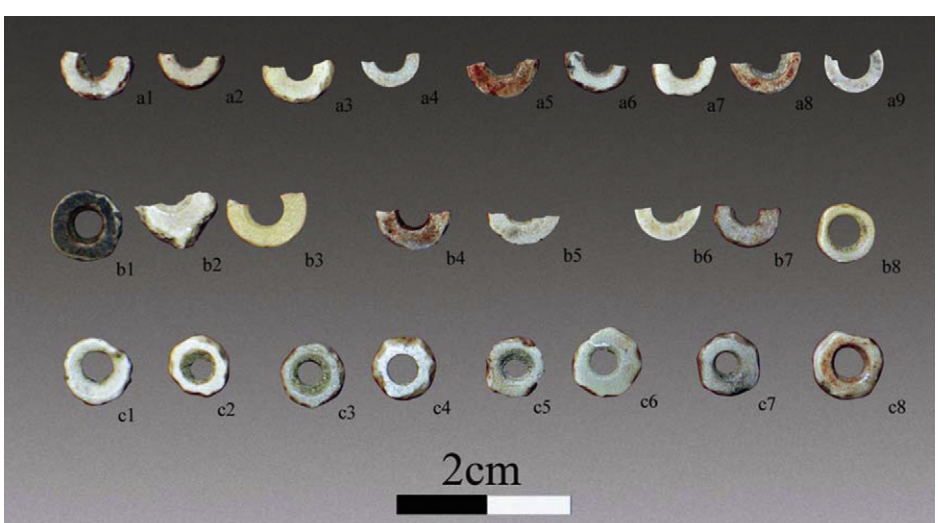

Fig. 5. Some Ostrich eggshell beads recovered from SDG2.

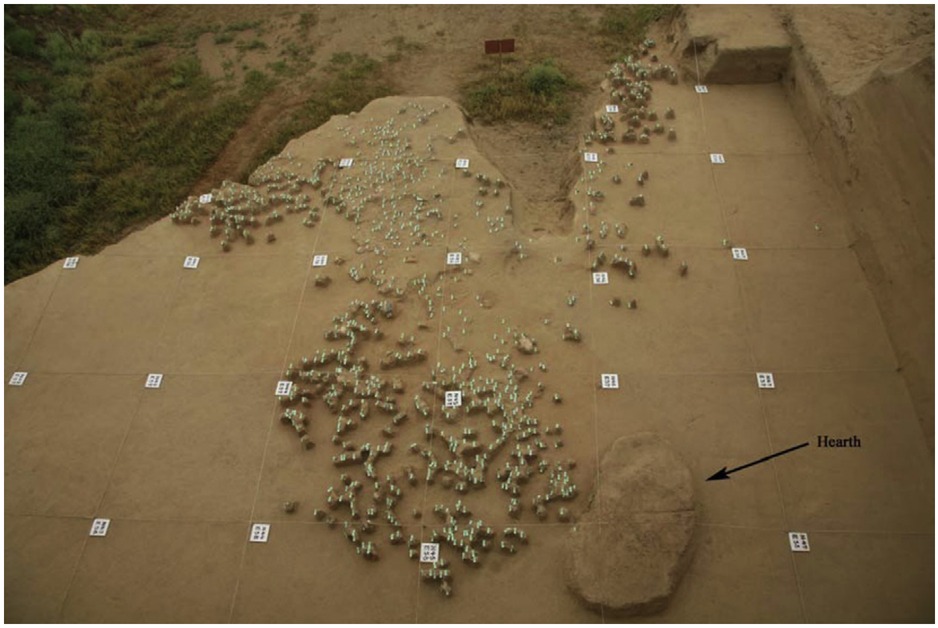

Fig. 6. Photo showing the an area of hearth layer of archeological layer 2 of SDG2.

result of 20,500 years which appears to be unreliable. Two radiocarbon dates from Layer 16 (a layer below the archaeological layers and absent of any archaeological remains) suggested that the layer was formed between or about 41,649 cal BP to 34,415 cal BP. Therefore we tentatively conclude that, with the exception of the younger Layer 4 deposit, the majority of the archaeological deposits of SDG2 probably formed c. 32,000 cal BP.

The OSL dates for the three archaeological layers at SDG7 (Layers 8–10) have rather large error margins, but they are stratigraphically consistent, ranging from c. 25,200 to 27,200 BP (Table 6).

SDG9 has produced five OSL dates for Layer 2, the only archaeological deposit. They range between c. 27,400 and 35,900 BP, and all dates have large error margins, which may be related to the shallow depth of the layer (10–60 cm below surface) (Table 1).

The single site with terminal Pleistocene deposits is SDG12. Layer 12 has yielded two consistent dates with both OSL and AMS ^{14}C methods of c. 13,000 cal BP and 11,600 BP, respectively (Liu et al., 2008). The youngest Shuidonggou deposits are from SDG1 (T1), and here the dates of c. 6657 to 9395 cal BP are generally accepted for the upper cultural layer which contains a diversity of Neolithic artifacts (Li et al., 1987; Sun and Zhao, 1991).

In sum, the archaeological deposits at Shuidonggou represent occupations at various times between c. 33,000 BP and c. 5000 years ago. The lower stratigraphic layers, without signs of occupation, are possibly as old as c. 72,000 BP, 64,600 BP, or 38,000 BP if the OSL dates are reliable. These results thus confirm and expand the presence of a long sequence of human behavioral development at the Shuidonggou site complex during the Late Pleistocene, the Terminal Pleistocene, and the mid-Holocene. There are also very significant gaps in occupation, which we discuss in the concluding section of this paper.

4. Archaeology

SDG1 was first discovered and excavated by Emile Licent and Pierre Teilhard de Chardin in 1923, while SDG2, SDG3, SDG4, and

Table 5
Technological composition of the lithic assemblages at SDG2. Apart from the Small Flaking Debris(SFD), all other material is ≥20 mm in maximum length. Percentages for SDF are calculated for each assemblage by layer. Percentages of blades are calculated only for the combined total of complete flakes and blades in each assemblage. See the text in the geochronology section for explanation of the dates provided in this table.

Artifact group	Artifact type	*N*					Total
		L4	L6	L8	L10	L13	
Small flaking debris <20 mm	Small flaking debris	6810 (57.5%)	1883 (73.7%)	841 (76.9%)	170 (54.1%)	75 (52.5%)	9779
Cores & core elements	Freehand cores	73	11	16	9	10	119
	Bipolar cores & core remains	755	32	11	5	5	808
Detached pieces	Blades	18 (14.3%)	6 (7.5%)	3 (21.4%)	1 (16.7%)	0	28 (12.2%)
	Flakes (complete)	108	74	11	6	2	201
	Flakes (broken and fragments)	579	255	62	24	4	924
	Chunks	3317	219	138	95	44	3813
Core tools	Core tools	6	2	3	1	0	12
Retouched flakes	Retouched flakes	171	72	9	3	3	258
Total		11,837	2554	1094	314	143	15,942
Estimated age		20,300?	28,000	28,000	?	28,000	

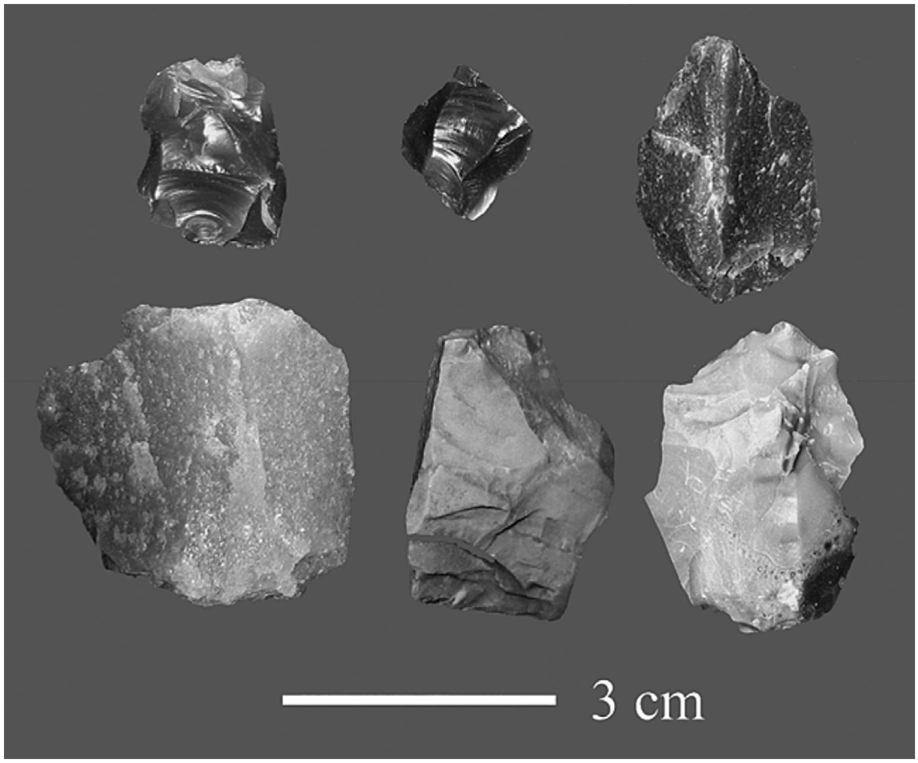

Fig. 7. Photo showing some bipolar and bipolar elements recovered from SDG2.

SDG5 were noted as secondary localities but never excavated (Licent and Teilhard de Chardin, 1925; Boule et al., 1928). In 1963, SDG6 was identified and a large number of artifacts, including microblades, were surface collected (Zhang, 1999a). From 2002 to 2010, six new sites were discovered (SDG7–12), with excavations conducted at five sites [SDG2 (previously identified), SDG7, SDG8, SDG9, and SDG12; Fig. 1c]. Table 2 outlines all of the major localities discovered to date and the associated finds since the 1920s.

Prior to excavations, systematic mapping and geomorphological study of the area was carried out, with key sections for stratigraphic profiles of the terraces identified along the river. Detailed sections were also recorded in areas yielding *in situ* artifacts and fauna, and new localities were designated only after confirmation from test excavations. All excavations were conducted in 2–5 cm increments, with larger spits used for sterile layers. Sediments were dry sieved with 4 mm mesh, and flotation was used during excavation of the hearth layer at SDG2. Materials

Table 6
SDG7 stratigraphy, (* a layer bearing archaeological remains).

Layer	Stratigraphic description	Depth (below surface)/m	Dates/yr BP
1	Light grayish black silt, loose structure	0–0.10	
2	Light grayish yellow fine sand, loose structure	0.10–1.20	18,900 ± 900
3	Greyish yellow and calcareous silt, firm structure, horizontal and current bedding	1.20–2.65	
4	Greyish yellow and calcareous silt, loose structure, horizontal and current bedding	2.65–3.00	
5	Light grayish yellow silt, interbedded with silty clay, firm structure, horizontal bedding	3.00–3.60	
6	Gray and grayish green clay silt, interbeded with some rubiginous mottles, with horizontal and current bedding in the upper part	3.60–6.95	
*7	Gray clay silt, firm structure, horizontal bedding	6.95–7.90	
*8	Light grayish yellow and green fine silt, firm, structure interbeded with some small calcareous concretions	7.90–8.85	25,200 ± 1800
*9	Gray and grayish green fine calcareous silt, loose structure, with a few rubiginous mottles and calcareous concretions	8.85–9.30	26,300 ± 2700
*10	Gray and grayish white silt, firm structure, with a few small concretions scattered in the layer	9.30–9.60	27,200 ± 1500
*11	Grayish-yellow and green clay silt, with a lot of rubiginous mottles	9.60–10.00	
12	Gravel layer, mainly limestone and quartzite.	10.00+	

Fig. 8. A photo showing view of the SDG7 excavations (view from north).

were three dimensionally point-plotted using a total station EDM. Specimens were entered into an electronic database after each layer was excavated, and systematic sampling for sedimentary analysis (particle size, magnetic susceptibility, etc.) and environmental study (pollen, organic carbon, and stable isotopes) was done. Although we have not yet worked on refitting, clusters of lithics of the same raw material type were noted during the excavation of different horizons at all sites. This suggests that assemblage integrity is very good and a search for refitting sets of artifacts may be highly productive. Results of the new excavations are described below for each locality.

4.1. Locality 2

SDG2 is only c. 150 m from Locality 1 but on the opposite bank of the river. Eighteen stratigraphic layers were identified, with a total thickness of more than 12 m (Fig. 3). The deposits are generally similar to SDG1, although there are some differences in the earliest and latest layers of the sequence. The stratigraphy is summarized in Table 3. The earliest layers are dated by OSL from c. 72,000 to 36,329 BP, but these levels lack cultural remains. Dating results for the five archaeological layers range from c. 34,617 cal BP to 20,300 BP, but the most reliable dates may be c. 32,000 years for at least three of the layers, as noted in the Geochronology section. The vertical distribution of unearthed specimens in SDG 2 is shown in Fig. 4. In the section Fig. 4 shows, the area of cultural remains density shows where the Layer 6 (archaeological layer 2) earth-pit hearths were recovered with thickness less than 50 cm, reflected in the high concentrations of human activities around the hearths. Although there was an unexcavated area between Trench 1 and Trench 2, a connection between the two trenches can be inferred based on the consistent profiles of the two excavation pits (Guan et al., 2011). Layer 6 (archaeological layer 2) could not be divided into sub-layers indicating that this layer was deposited during a continuous period.

A total of 15,942 stone artifacts, 1391 faunal specimens, and 77 ostrich eggshell beads were recovered during the excavations, with all but two of the beads found in Trench 1, and with 74 of the beads found in Layer 6 (Table 4, Fig. 5). Some were drilled from only one face of the shell (e.g., a1–9, b1, and b3–7 in Fig. 5) and others from both faces (e.g., c1–8). Some of the ostrich eggshells have been colored with red ochre. It should be noted that some beads (e.g., b2 in Fig. 5) were in the manufacturing stage, which suggests that the locality may have been a work place of making beads.

Layer 6 also contains discrete, well-preserved hearths, lithic artifacts associated with the hearths, faunal remains, and clusters of material near the hearths (Fig. 6), which represent short-term,

Table 7
Technological composition of the lithic assemblages at SDG7, all levels combined. Apart from the Small Flaking Debris (SFD), all other material is ≥20 mm in maximum length. The percentage for SFD is calculated for the total, and the percentage of blades is calculated of complete flakes and blades.

Artifact group	Artifact type	*N* All levels
Small flaking debris <20 mm	SFD	5834 (55.2%)
Cores & core fragments	Freehand	210
	Bipolar	56
Detached pieces	Blades	18 (2.1%)
	Flakes (complete)	851
	Flakes (broken flakes & flake fragments)	1691
	Chunks (angular fragments of blocky shape)	1781
Core tools	Core tools	14
Retouched flakes	Retouched flakes	102
Hammerstones	Hammerstones	8
Total		10,565

Table 8
SDG8 stratigraphy, (* a layer bearing archaeological remains).

Layer	Stratigraphic description	Depth (below surface)/m
1	Light grayish black silt, loose structure	0–0.10
*2	Grayish yellow silt, loose structure	0.10–4.15
3	Yellow sandy silt, firm structure	4.15–4.35
4	Greyish yellow silt, horizontal bedding	4.35+

Table 9
Technological composition of the lithic assemblage in Layer 2 at SDG8. Apart from the SFD, all other material is ≥20 mm in maximum length. The percentage for SFD is calculated for the total.

Artifact group	Artifact type	*N*
		All levels
Small flaking debris <20 mm	SFD	445 (55.5%)
Cores & core fragments	Freehand	12
	Bipolar	8
Detached pieces	Blades	0
	Flakes (complete)	209
	Flakes (broken flakes & flake fragments)	92
	Chunks (angular fragments of blocky shape)	22
Core tools	Core tools	1
Retouched flakes	Retouched flakes	10
Hammerstones	Hammerstones	3
Total		802

intermittent occupations of the location by small foraging parties. It also has a large assemblage with almost three-quarters of the material consisting of Small Flaking Debris (SFD-material <20 mm in maximum dimension; see Schick, 1987), which indicates excellent site integrity for this layer. Each of the five archaeological layers is separated by a sterile horizon. Based on the sizes of the associated lithic assemblages, Layers 4, 6, and 8 can be considered relatively major phases of occupation, while Layers 10 and 13 are minor (Table 5).

The two most common raw materials used are silicified limestone and quartzite, followed by chert, quartz, sandstone and chalcedony. The bipolar reduction strategy is well represented at SDG2 (Fig. 7, Table 5). All 258 retouched pieces from the five layers are made on flakes, and no retouched blades are present. However, blades comprise 7.5%–21.4% of the whole flake component from the four of layers, with an average of 12.2% for all five layers combined. It may be possible that some of the materials were moved post-depositionally. We are currently trying to investigate the extent of this movement through refitting studies of the bones and lithics.

4.2. Locality 7

SDG7 is c. 300 m southeast of SDG2. Excavations from 2003 to 2005 exposed over 25 m^2 and 12 stratigraphic layers with a total thickness more than 12 m (Table 6, Fig. 8). Archaeological remains are limited to the five lowest layers above the basal gravel layer. As noted earlier, the three middle layers of this group have yielded OSL dates of c. 25,200 to 27,200 BP. Because there were no sterile levels between these layers, the five lithic assemblages have been combined for technological analysis (Table 7). This was considered a more reliable approach, especially considering the large overlap in the three available dates. The combined lithic assemblage is 10,565 pieces. In addition, there are two ostrich eggshell beads and 326 vertebrate faunal specimens were unearthed from the site, identified species include *Lepus* sp., *Felis microtus*, *Vulpes* sp., *Canis* sp., Cervidae, *Gazella przewalskyi*, *Equus przewalskyi*, *Bubalus* sp., etc. Few gnaw marks made by carnivore were identified, and none gnaw marks made by rodents and water flows which indicate the animal assemblage were probably not accumulated by carnivore, rodents, and natural flow force. Therefore, it can de deduced from the evidence of cut-marked long bone fragment that early humans were most probably responsible for the accumulation of these animal remains.

Technologically, the SDG7 lithic assemblage is dominated by Small Flaking Debris (55.2%). However, the percentage is marginally lower than what is expected for a completely preserved collection of artifacts knapped on-site. Experiments by Schick (1987) show that 60–75% of SFD is expected to be recovered when a 4 mm sieve mesh is used. Freehand flaking is more prominent than the bipolar technique but both types of

Fig. 9. The SDG9 excavation and exposed artifacts (view from south).

Table 10
Technological composition of the lithic assemblage in Layer 2 at SDG9. Apart from the SFD, all other material is ≥20 mm in maximum length. The percentage for SFD is calculated for the total. The percentage of blades is calculated for the combined number of complete flakes, blades and Levallois flakes.

Artifact group	Artifact type	*N* All levels
Small flaking debris <20 mm	SFD	120 (28%)
Cores	Blade cores	2
	Radial cores	4
	Other freehand cores	7
Detached pieces	Blades	46 (30%)
	Levallois flakes	5
	Flakes (complete)	103
	Flakes (broken flakes & flake fragments)	85
	Chunks (angular fragments of blocky shape)	51
Retouched flakes	Retouched flakes	5
Total		428

cores occur in significant numbers. Only 2.1% of the complete flake and blade component has blade dimensions, and all retouched pieces are made on flakes. Most raw materials derive from local sources. Silicified limestone and quartzite dominate, while chert, chalcedony, sandstone and quartz are less common.

4.3. Locality 8

SDG8 is c. 2 km southeast of SDG1. In 2003, 16 m^2 of excavations revealed four stratigraphic layers and a total thickness of over 6 m (Table 8). No dating samples were taken as only Layer 2 contains archaeological remains, and the stratum is comparable to the archaeological layers at SDG7 and SDG2. One ostrich eggshell bead and 29 lithic artifacts were found during a small test excavation (1 m^2 exposed) before formal excavation in 2003. The completed excavation produced 802 stone artifacts, 18 vertebrate faunal specimens, and 7 ostrich eggshell beads. All of the shell beads were deeply colored with red ochre. It may be possible that some of the materials were moved post-depositionally. We are currently trying to investigate the extent of this movement through refitting studies of the bones and lithics.

Table 9 summarizes the small SDG8 lithic assemblage from both excavations. Small flaking debris (SFD) is dominant (55.5%). Both freehand and bipolar cores are present, with freehand flaking in the majority. There are no blades and all 10 retouched pieces are made on flakes.

4.4. Locality 9

SDG9 is c. 7 km southeast of SDG1. Excavations in 2007 exposed an area of 12 m^2 (Fig. 9). Three stratigraphic layers of sandy silt are present with a total thickness of only 1 m. Only Layer 2 has archaeological remains, uncovered from 10 to 60 cm below the surface. Five OSL dates for Layer 2 range between 35,900 ± 6200 and 27,400 ± 3600 BP, but three of the dates cluster more closely to c. 29,000 years and all error margins are large (see Table 1). A small test excavation conducted in 2003 produced nine lithic artifacts, while excavations in 2007 yielded 417 artifacts. SDG9 is, in essence, a small scatter of artifacts in a layer that was not deeply buried, which could explain the large error margin of the OSL dates, if the archaeological horizons were more vulnerable to disturbance.

The lithic assemblage, however, features a larger diversity of raw materials than the other localities. Fine-grained, high quality rocks are present, predominantly of silicified limestone, plus some chert and quartzite. Unlike the other localities, SDG9 indicates exploitation of high-quality raw material, transported either from a local source or from some exotic location. Technologically, the SFD component is minor (28.0%; Table 10). For the SFD, blades (Fig. 10), blade cores, and Levallois flakes are present in relatively significant numbers in this small assemblage. Blades also comprise 30% of the whole flake component. These are all features which make this small assemblage prominent in terms of an initial Late Paleolithic technology, and they are undoubtedly a reflection of the better quality of raw material overall at SDG9. The transport of better quality raw materials into this site could explain the lower percentage of SFD, if material was more heavily pre-flaked off-site.

4.5. Locality 12

SDG12 is c. 3 km northwest of SDG1. Excavations in 2007 and 2010 exposed an area of 220 m^2. Twenty stratigraphic layers were identified, with a total thickness of more than 9 m and dates ranging from c. 47,200 to 12,100 BP (Table 11). However, archaeological materials are restricted to the 11th layer (Fig. 11). An AMS ^{14}C date on charcoal excavated from Layer 11 indicates an age of 13,078–13296 cal BP, with an OSL date of 11,600 ± 600 BP, indicating close overlap.

SDG12 appears to consist of one major occupation in Layer 11. Hearths and associated lithic artifacts, faunal remains, and worked bone are also present in this layer. More than 30,000 microlithic-sized artifacts are present in the assemblage, which is still under analysis. Fig. 12 shows a selection of microblades and microblade cores. The lithics and large numbers of faunal bones are found in association with charcoal and a layer of ashy clay (see Fig. 11). More than 10,000 animal fossils were excavated from the site, identified

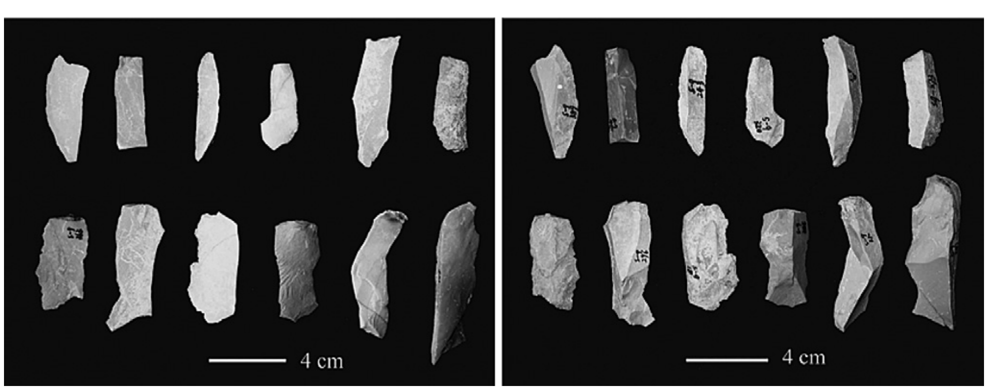

Fig. 10. Blades from SDG9 (ventral views are at left and dorsal views at right).

Table 11
SDG12 stratigraphy, (* a layer bearing archaeological remains).

Layer	Stratigraphic description	Depth (below surface)/m	Dates/yr BP
1	Light gray silt and fine sand, loose structure	0–0.10	
2	Grayish yellow silt, firm structure	0.10–0.50	12,100 ± 1100
3	Greyish yellow silt and fine sand, loose structure	0.50–0.90	
4	Maroon clay, firm structure	0.90–1.15	
5	Light grayish yellow silt	1.15–1.40	
6	Maroon clay, firm structure	1.40–1.50	
7	Grayish black clay	1.50–1.65	
8	Light grayish-yellow fine sand and silt, current bedding	1.65–2.25	33,100 ± 1700
9	Maroon clay	2.25–2.35	
10	Grayish white fine sand	2.35–2.75	
*11	Grayish black and black silt and fine sand, some part interbeded with small pebble and stone fragments	2.75–2.96	11,600 ± 600 13,0781–13,296
12	Grayish yellow and brownish yellow sand, horizontal bedding	2.96–4.30	
13	Gray clay silt, horizontal bedding	4.30–4.40	
14–16	Grayish yellow and gray fine sand and silt	4.40–5.30	
17	Gray clay	5.30–5.43	
18	Grayish yellow fine sand, with horizontal ceding in the upper part	5.43–5.93	
19	Gray clay, with high content of calcareous concretions	5.93–6.00	
20	Grayish yellow and brownish yellow sand, with horizontal bedding in the upper part and oblique bedding in the lower part.	6.00–8.00+	47,200 ± 2400

species include *Lepus* sp., *Meles meles*, *F. microtus*, Cervidae, *G. przewalskyi*, *Sus* sp., *E. przewalskyi*, *Bubalus* sp., and some rodents, birds, as well as reptiles. Preliminary zooarchaeological observation shows no obvious marks made by water flows and abrasions, while only two gnaw marked fossil fragments made by carnivore were identified. Evidence of the 5.1% of cut-marked bone fragments indicates that early human most probably responsible for the accumulation of the animal remains (Zhang et al., in press). The lithic raw materials feature an extraordinary diversity of fine-grained and highly siliceous rocks, mostly chert and silicified dolomite, indicating the exploitation of higher quality rocks and exotic materials. Fauna is present, as well as two bone needles, an awl and one bone tool for net weaving (Fig. 13). SDG12 is an assemblage more typical of China's Late Pleistocene microlithic industries.

5. Discussion

Many Chinese researchers have considered that the small flake toolkits and the blade and microblade technologies of the Late Pleistocene were a direct outgrowth of the small core-flake industry typical of China's Early Paleolithic (Jia et al., 1964, 1972; Jia, 1978; Gai, 1985; Li and Shi, 1985; Jia and Huang, 1985; Huang, 1989). These lithic assemblages dominated by small artifacts have been referred to as the "small tool tradition" (Jia et al., 1972; Jia and Huang, 1985; Huang, 1989) and the "Principal Paleolithic Industry

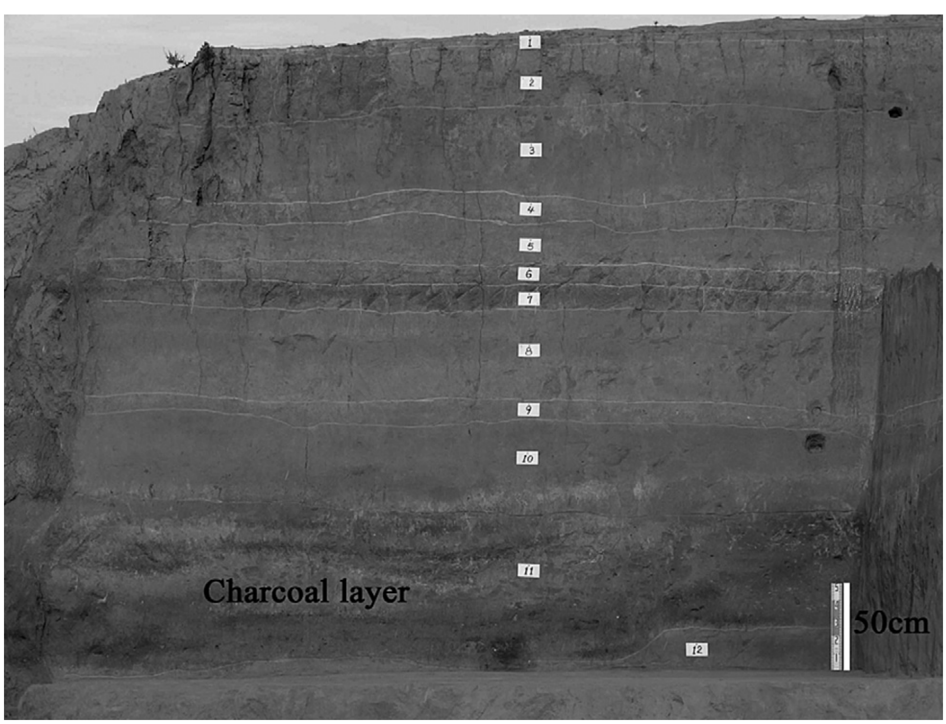

Fig. 11. The SDG12 stratigraphic sequence, with the AMS dated Layer 11 indicated toward the base of the strata (view from west).

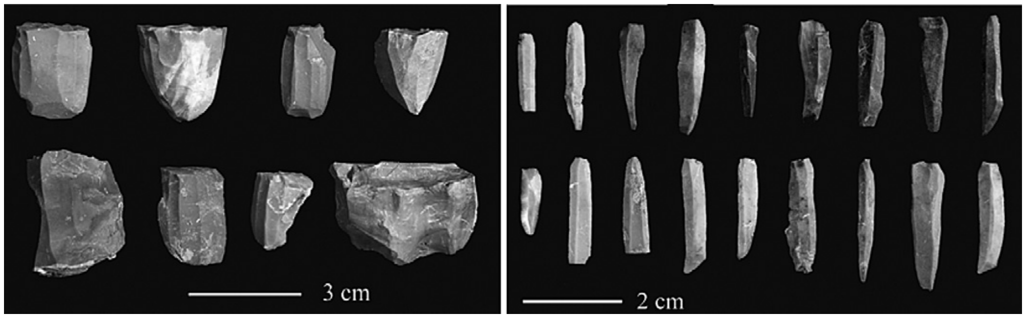

Fig. 12. Microblades cores (left) and microblades (right) from SDG12.

of North China" (Zhang, 1990, 1997, 1999b, 2002). Typical sites include Zhoukoudian Upper Cave, Shiyu, Salawusu, Xiaonanhai and Xiaogushan (Zhang, 1990, 1997; Miller-Antonio, 1992). In contrast, the "Principal Paleolithic Industry of South China" or the "Pebble Tool Tradition" is characterized by larger artifacts, distributed mainly in the low elevation areas of the Changjiang River System (Zhang, 1999b, 2002).

The Shuidonggou archaeological pattern is strikingly different from other Chinese Paleolithic assemblages, which continue to exhibit Mode 1 (or simple core and flake) technologies, lacking any regular production of blades, throughout much of the Pleistocene (Gao and Norton, 2002; Norton and Jin, 2009). Some of the Shuidonggou assemblages in this study are also characterized by small, irregular flakes, and casual retouch [informally retouched tools (i.e., non-standardized tools with sporadic retouch which was not well controlled)], which is characteristic of the Late Paleolithic sites belonging to the "small tool tradition" (Zhang, 1990; Gao and Norton, 2002). But other assemblages show a blade component, ranging from 2% of whole flakes at SDG7, to 12% at SDG2, to even 30% at SDG9 where finer quality raw materials are prominent – a pattern more resembling the original SDG1 material. The close proximity of the SDG localities in this study and their restricted time frame indicate that all of the assemblages belong to the Shuidonggou initial Late Paleolithic tradition. It may be possible that the variability is not significant and probably results from sampling bias and activity differences of the sites in time and space.

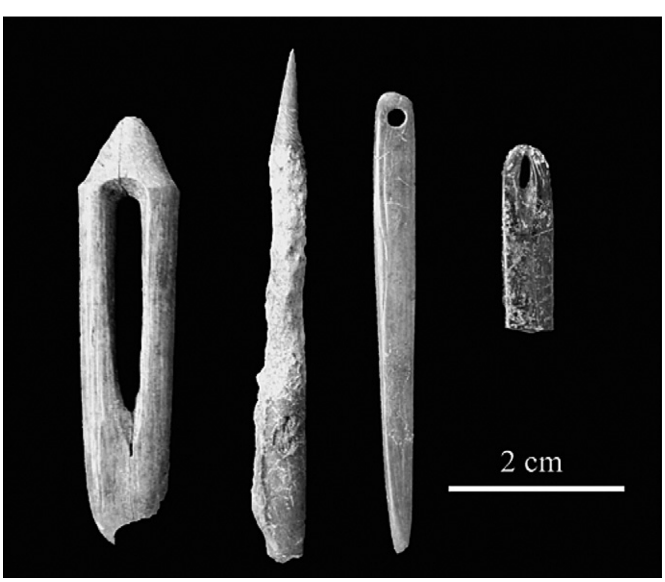

Fig. 13. Worked bone from SDG12: a tool for working fishing nets, an awl, and two needles.

Bipolar flaking technology, which is noted at SDG2, SDG7 and SDG8, is a general characteristic of the North Chinese Paleolithic (Zhang, 1989), used from the Early to the Middle Pleistocene in the Nihewan basin sites and at Zhoukoudian Locality 1. It also continued to play an important role in Late Pleistocene industries (Gao, 1999; Gao and Norton, 2002). However, bipolar flaking is an ancient technique useful for working pebbles and smaller cobbles of some raw materials (Patterson, 1976, 1990; Schick and Toth, 1993: p. 120). Its significance in the Late Paleolithic lies rather in the association with an increased use of fine grained raw materials and their transport from exotic sources. Bipolar percussion is commonly used in the initial stage of core working in industries with organized microblade production (Elston and Brantingham, 2002). It is possible that the bipolar pebble reduction strategy at Shuidonggou provided the foundation from which later microblade technologies in China developed. Such pebble-based microblade core technologies appeared sometime around the Last Glacial Maximum and came to dominate the Siberian, Mongolian, and north Chinese sequences by the Pleistocene–Holocene transition (Lü, 1998; Lin, 1996; Elston and Kuhn, 2002).

The presence of personal ornaments and the use of ochre pigment have long been associated with the emergence of modern human behavior in both the Western Old World Upper Paleolithic and the African Middle Stone Age (McBrearty and Brooks, 2000; Kuhn et al., 2001; d'Errico, 2003; Henshilwood and Marean, 2003; Zilhão, 2007; Klein, 2008; d'Errico et al., 2009; Henshilwood et al., 2011). Since the 1930s, the best-known evidence of Paleolithic art and symbolism in China has come from Zhoukoudian Upper Cave (Pei, 1934; Norton and Gao, 2008; Norton and Jin, 2009). The artifacts include seven perforated white calcareous stone beads, which were found near the Upper Cave 102 cranium. The majority of these ornaments were excavated from Layer 4, the source of human burials thought to date between 34,000 and 20,000 BP (Pei, 1934; Norton and Gao, 2008). In 1983, five teeth and one juvenile femur of modern *Homo sapiens*, as well as lithic and bone artifacts, were excavated from the Xiaogushan site in Liaoning Province, Northeast China (Zhang et al., 1985; Huang and Fu, 2009; Norton and Jin, 2009). The perforated carnivore and cervid teeth and three bone needles from Xiaogushan are similar to the osseous implements from Zhoukoudian Upper Cave. One of the most interesting aspects of the Xiaogushan materials is a finely crafted composite bone harpoon that displays similarities to those from the European Magdalenian cultures. The presence of extinct open-steppe taxa indicates a Late Pleistocene age for the deposits. The only reported ^{14}C date is ~40 kya (Wu, 2004). However, a newer set of OSL dates suggests that the bone artifacts, including a harpoon, pendants and a disc, were produced between 30 and 20 ka (Zhang et al., 2010), similar to the age of the Shuidonggou sites.

Given the age of occupation and the associated archaeology (e.g., worked ostrich eggshell beads, bone needles, and bone awl), the Shuidonggou foragers were likely modern humans moving into the region and not an indigenous archaic human population. We note that when analyzing the materials unearthed in the 1920's excavations at SDG1, Breuil observed some parallel incisions on the surface of siliceous pebbles and inferred that these incisions were made by burins (Boule et al., 1928). Unfortunately, he did not provide more details about those incised pebbles. The current laboratory research being conducted on materials from the 1980s excavations at SDG1 indicates an engraved stone object from a lower cultural layer was identified. An analysis using a 3D digital microscope shows that the incisions were made by an intentional behavior and were probably of a non-utilitarian character (Peng et al., 2012). There is worked bone from a large mammal reported by Madsen et al. (2001) associated with Hearth 4 dated to ~25.6 kya from SDG2. Furthermore, a polished bone unearthed from SDG2 and one polished bone stained with ochre pigment recovered from SDG7 are additional examples of modern human behavior during the Late Paleolithic of Northern China (Guan et al., 2012). The earliest human occupation at Shuidonggou is around 33–24 kya, which is substantially younger than the initial Upper Paleolithic from western Eurasia. Thus, it is quite plausible that modern humans migrated into northern China from western Eurasia during this time period (Wang, 1989; Zhang, 1990; Lin, 1996; Norton and Jin, 2009), though there appears to be growing evidence that modern humans were present in Northeast Asia well before the occupation of Shuidonggou (Shang et al., 2007; Norton and Jin, 2009; Morgan et al., 2011; Bae and Bae, in press).

6. Conclusions

The new discoveries and dates presented here indicate that modern humans are present at Shuidonggou close to 33,000 BP, while the youngest occupation occurs in the terminal Pleistocene about 13,000 BP. The Last Glacial Maximum is likely to have been too cold and dry for occupation in this part of northern China, and there is currently a paucity of sites at this time. The data suggests there were two peaks of occupation falling around 32–24,000 and 13–11,000 BP. Paleoenvironmental data should be investigated to determine if such clusters of occupation dates correspond with optimum climatic conditions for survival in North China, and if those other periods lacking cultural remains were cold, dry phases too harsh for occupation. The SDG9 site suggests an abrupt appearance of blade technology about 29,000 BP, likely coinciding with the eastward movement of modern human populations into the region. Overall, SDG9 and other sites (SDG 2, 7, 8 and 12) show the typical pattern of the initial Late Paleolithic. These characteristics include the production of blades with Levallois core reduction strategies, some use of small cores to produce bladelets, and some higher quality raw materials which may have been transported a distance. Other modern traits characteristic of the Late Paleolithic include finely perforated, polished and ochre-stained ostrich eggshell beads and worked bone tools such as needles and awls. Hearths are also not unusual.

The most important area for further research in North China is the question of why peak occupations at Shuidonggou occurs c. 32–24,000 and 13–11,000 BP. These dates are substantially younger than those for the initial Upper/Late Paleolithic in western Eurasia and northeastern Asia (Kuhn et al., 1999, 2004; Bar-Yosef, 2000, 2007; Brantingham et al., 2001; Bae and Bae, in press). The presence of people in some phases and their absence in others need to be investigated with proxies for climatic change in the Late Pleistocene of North China. If the pattern is confirmed, it would shed light on the origins of such technologies through population movements (Zhang, 1990; Lin, 1996; Madsen et al., 2001; Gao et al., 2002; Norton and Jin, 2009; Bae and Bae, in press). Although a terminal Pleistocene human parietal fossil was found near Shuidonggou Locality 1 (Wu et al., 2004), there is no human fossil evidence associated with the initial Late Paleolithic in North China. The earliest directly dated, unambiguous example of a modern human in China (and in East Asia) is a femur from layer III, Tianyuan Cave near Zhoukoudian, dated by AMS to 34,430 ± 510 BP (cal. 40,328 ± 816 BP) (Shang et al., 2007). It is clear that modern humans were responsible for the Shuidonggou initial Late Paleolithic in North China, but the pattern of more advanced small tool industries in the rest of China still remains to be explained.

Acknowledgments

The authors would like to thank Professors Kan Zhong, Xiaoling Ma, and Jianhua Che from Institute of Archeology of Ningxia Hui Autonomous Region, Professors Zhengkai Xia, Liping Zhou, and Jiafu Zhang from Peking University, Professors Baoyin Yuan from Institute of Geology and Geophysics, CAS, and Yuzhu You, Xingwu Feng, Shuangquan Zhang, Chunxue Wang, Zhenyu Zhou, Mingming Cao, Ning Ma, Feng Li, Mingjie Yi, Zhigang Luo and others from IVPP for their help in participating in the field excavations, discussions, opinions and suggestions. Thanks to Professor Kathy Schick and Nicholas Toth from the Stone Age Institute and Indiana University, USA, Dr. Mohamed Sahnouni and Sileshi Semaw from National Research Center on Human Evolution, Spain for instructive comments. This work was financially supported by the National Basic Research Program of China (973 Program) (2010CB950203), the Strategic Priority Research Program of the Chinese Academy of Sciences (XDA05130203), the International Cooperation Program of the Ministry of Science and Technology of China (2009DFB20580), and a fellowship for East and Southeast Asian Archaeology and Early History from the American Council of Learned Societies, with funding from Henry Luce Foundation (08/09). K. Kuman's participation in this research is funded by the Bilateral Program in Paleosciences between South Africa and China (Department of Science and Technology of South Africa and the Ministry of Science and Technology of China). C.J. Bae acknowledges the financial support for his research in China from the Wenner-Gren Foundation (ICRG #82) and the National Geographic Society (#8372-07). We thank two reviewers for comments on an earlier draft. We take full responsibility for any errors that may be present.

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