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Contents lists available at SciVerse ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

Microblade technology and the rise of serial specialists in north-central China

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ARTICLE INFO

Article history:

Received 14 August 2012

Revision received 1 February 2013

Keywords:

Microblade technology

Serial specialist

Winter mobility

Younger Dryas

Clothing

ABSTRACT

Though present before the Last Glacial Maximum, microblade technology is uncommon in the lithic assemblages of north-central China until the onset of the Younger Dryas (12,900–11,600 calBP). While it is clear that microblades here and elsewhere were connected with mobile adaptations organized around hunting, the attendant assumption that they served primarily in hunting weaponry is not. The archaeological record of north-central China, including excavations at Pigeon Mountain (QG3) and Shuidonggou Locality 12 (SDG 12) in Ningxia Autonomous Region, and Dadiwan in Gansu Province, and a handful of bone/antler tools slotted for microblade inserts, indicate a more direct linkage to mobility. These data suggest the rise of microblade technology in Younger Dryas north-central China was mainly the result of microblades used as inserts in composite knives needed for production of sophisticated cold weather clothing needed for a winter mobile hunting adaptation akin to the residentially mobile pattern Binford termed “serial specialist.” Limited time and opportunities compressed this production into a very narrow seasonal window, putting a premium on highly streamlined routines to which microblade technology was especially well-suited.

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Introduction

The late Pleistocene featured two severe, cold-dry climatic downturns, the Last Glacial Maximum (LGM; ca. 24,500–18,300 calBP) and Younger Dryas (YD; ca. 12,900–11,600 calBP) that profoundly affected human adaptation in North China. During the LGM archaeological evidence for human occupation of northern China is scant (Barton et al., 2007) and North China's earliest blade-based lithic industry, the Early Upper Paleolithic (EUP) flat-faced core-and-blade technology best known from Shuidonggou Locality 1 (SDG1) on the upper Yellow River (Brantingham et al., 2004), was replaced by a bipolar percussion technology better suited to lower quality but more readily available raw material (Barton et al., 2007). The YD was shorter than the LGM, but nearly as severe (Herzschuh and Liu, 2007; Wunneman et al., 2007), and

as during the LGM both sites and radiocarbon dates are rare. However, locations abandoned during the LGM, including Shuidonggou on the upper Yellow River and Dadiwan in the western Loess Plateau (Bettinger et al., 2010a), remained in use during the YD; and lithic technology, rather than becoming less complex as it did in the LGM, became more complex, shifting to a more technically demanding microblade technology, suited to a much narrower range of much higher quality raw material than had been needed for freehand and bipolar percussion or even EUP flat-faced core-and-blade technology. In the minority in pre-YD lithic assemblages, microblades and microcores come to dominate the YD and post YD lithic assemblages of northern China, declining only after ca. 8000 calBP, even where the requisite raw material is locally scarce or absent.

The preceding suggests that the behavioral response to the YD by hunter-gatherers living between the upper Yellow River and adjacent sandy deserts in the north, and the upper Wei River in the Loess Plateau in the south (Lu, 1998: Fig. 1), was different and more successful than that of the LGM. It also suggests that microblades were central to this difference. Following the lead of many others (various authors in Elston and Kuhn (2002), Goebel

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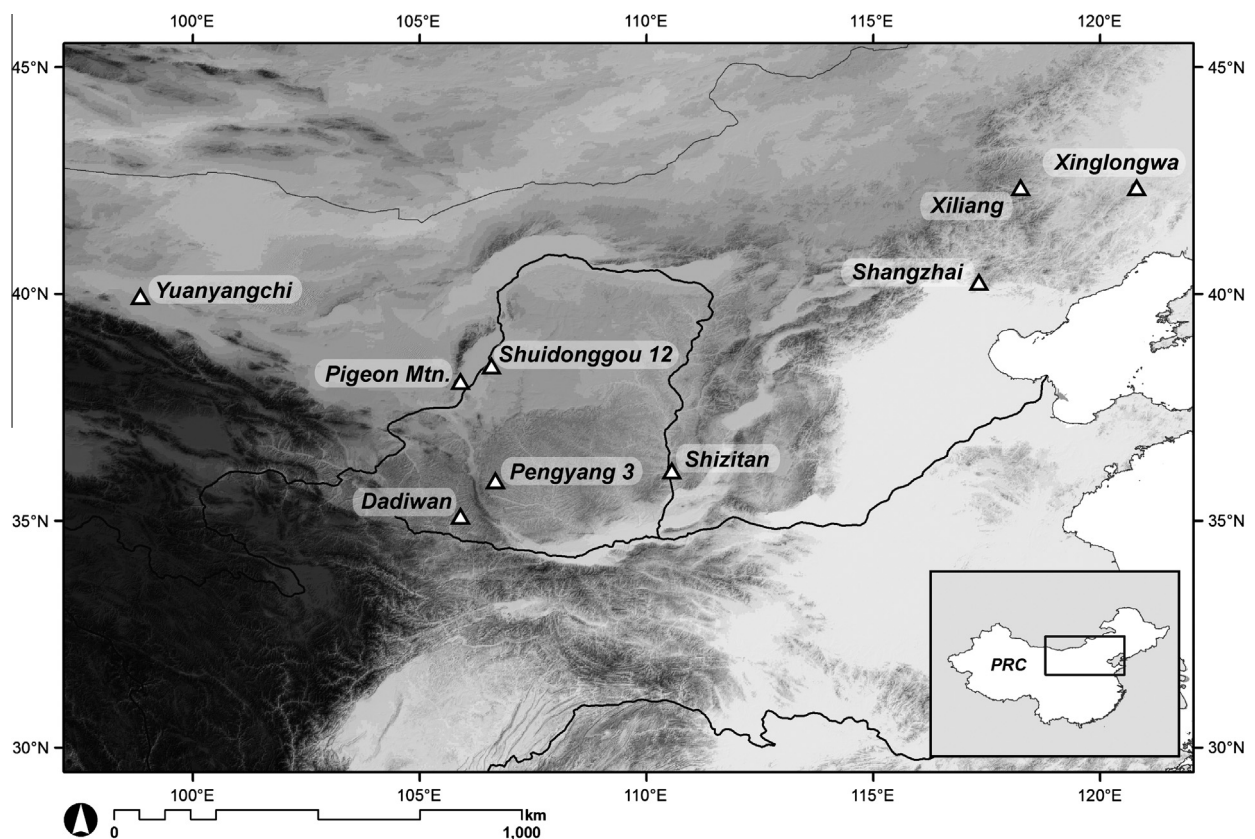


Fig. 1. Study region with sites mentioned in text. Note: “Shuidonggou 12” is abbreviated in the text as “SDG12”.

(2002), Neeley (2002) and Shott (1986)), we suggest the difference was chiefly in mobility, specifically that microblade technology facilitated increased YD mobility. In key respects our argument is reminiscent of Goebel's (2002: 123) for a “microblade adaptation” characterized by greater residential mobility and successive, short-term targeting of single, large game prey species – the strategy Binford (1980: 17) termed *serial specialist*, and which Goebel sees as permitting the post-LGM recolonization of Siberia and its subsequent occupation throughout the YD. Perhaps more than Goebel, however, we see the settlement difference being greatest in terms of winter mobility. We argue that: (1) YD hunter-gatherers of north-central China were serial specialists, more winter mobile than their LGM predecessors; (2) that this was because LGM hunter-gatherers lacked the gear needed for frequent winter residential mobility, winter clothing in particular; and (3) that microblade or microlithic technology (An, 1978; Lu, 1998) was central to the production of this gear and thus to the emergence and viability of serial specialists in North China. Along with general climatic amelioration associated with the Holocene, increasing sedentism after 8 kya diminished the importance of winter travel and the microlithic technology needed for the manufacture of fitted clothing (cf. Lu, 1998). We outline this argument below in sections dealing with the origins, antiquity, and function of microblade technology by reviewing the archaeology of three sites with YD microlithic components indicating hunter-gatherer adaptation to cold environments. We offer this as a theoretically-informed hypothesis about the evolution of hunter-gatherer behavior that explains the archaeological data of northern China (and perhaps elsewhere) better than any alternative. To this end, we follow our discussion with suggestions for additional research necessary to evaluate and refine the hypothesis.

The Younger Dryas

Greenland ice records suggest a hemispheric return to glacial age temperatures ca. 12,900–11,600 calBP (Alley, 2000; Alley et al., 1993; Meese et al., 1997; Rasmussen et al., 2006) while the Kulishu speleothem record of northern China points to a YD defined by a weakened Asian Monsoon, $12,850 \pm 40$ – $11,510 \pm 40$ calBP (Ma et al., 2012). Precision dating of the Last Glacial termination is elusive, particular for localized paleoenvironmental archives, due in part to limitations of the radiocarbon calibration curve (Muscheler et al., 2008). What matters most to the current analysis is broad correspondence between archaeological patterns and the proxy records of environmental change.

Detailed accounts of the environmental and ecological context of the Bølling Allerød–Younger Dryas–Holocene oscillation pattern (wet–dry–wet and/or warm–cold–warm) in China can be found elsewhere (Elston et al., 2011), and are beyond the scope of this paper. In summary, proxy records from lake sediments (Liu X. et al., 2008c, 2002; Shen et al., 2005), loess deposits (An et al., 1993; Chen et al., 1997; Madsen et al., 1998; Wang et al., 1999); high-elevation ice cores (Thompson et al., 1997; Yao et al., 1997), and speleothem records in southern (Wang et al., 2001; Yuan et al., 2004), central (Liu D. et al., 2008b), and northern China (Ma et al., 2012) reveal abrupt changes in patterns of precipitation and/or temperature at the termination of the Last Glacial. Similar patterns are visible throughout Central and Northeast Asia (Herzschuh, 2006; Wright and Janz, 2012).

While it is important to note disparities in the resolution, dating, proxies, and conclusions derived from each of these studies, it is clear that paleoenvironmental archives throughout the region reflect environmental change characteristic of the YD elsewhere,

and that the timing of this anomaly is approximately the same in China as it is throughout the northern hemisphere. What is less clear is the extent to which the anomalies in the proxy data reflect changes in temperature, precipitation, or the complex interactions between them (see [Peterse et al., 2011](#)).

In the end, both temperature and precipitation affect primary productivity, which clearly affects hunter-gatherer resource acquisition (see [Binford, 2001](#)). Furthermore, few would disagree that YD climate above 30° Latitude was significantly colder than it is today, and today outdoor winter work in those areas requires substantial clothing. We do not argue that the YD climate was unique for its capacity to push foraging groups into novel innovations in technology or behavior. We merely argue that it was cold and difficult in northern latitudes at that time, and during that time people solved the problem of winter-time resource acquisition in a way that they had not during the Last Glacial Maximum.

Microblade origins

The origin and antiquity of microlithic technology in China remain controversial ([Lu, 1998](#); [Chen, 2004](#)), in large part because there are very few well-dated, stratified sites. Candidates for the earliest Chinese microlithic site include Chaisi (Dingcun Locality, Locality, 77:01), Shanxi Province, dated at 30,600 calBP; Xiachuan, Shanxi Province, dated from 28,000 to 19,300 calBP; PY03, Ningxia Hui Autonomous Region, dated at 22,100 calBP; and perhaps Dadiwan, Component 4, Gansu Province, dated from 20,000 to 13,000 calBP ([IA-CASS, 1983](#); [Huang and Hou, 1998](#); [Kuzmin et al., 2007](#); [Barton et al., 2007](#); [Bettinger et al., 2010a,b](#); [Elston et al., 2011](#)). All four are problematic owing to stratigraphy, context, or sample size ([An, 1983](#); [Kuzmin et al., 2007](#); [Elston et al., 2011](#)). Dadiwan Component 4, for example, shows clear evidence of stratigraphic mixing; the PY03 microlithic assemblage is exactly one microblade core.

[Barton et al. \(2007\)](#) speculate that microblade technology developed out of the bipolar or so-called flake-and-shatter technology that replaced EUP flat-faced core-and-blade technology during the LGM, which would place its development after ca. 24,500 calBP; this is consistent with evidence that microblades are found throughout northern Asia (i.e., in Siberia, Mongolia, Japan and Korea) shortly after the LGM ([Bleed, 2002](#); [Elston and Brantingham, 2002](#); [Goebel, 2002](#); [Kuzmin et al., 2007](#)), as well as in Central China, Northeast China, Northwest China and Qinghai-Tibetan Plateau ([Chen, 2007](#); [Gao et al., 2008a](#); [Yi et al., 2011](#)). While microliths constitute a minority of the early lithic assemblages ([Lu, 1998](#); 88), they become increasingly common by 15,000 BP ([Chen, 2004](#)).

Within this context, this paper presents evidence that the initial rise in microblade use in North China occurs after 13,000 calBP, during the YD, from three key sites in west-central northern China: Dadiwan, Pigeon Mountain and Shuidonggou Locality 12 (SDG 12) ([Fig. 1](#)). The area is generally arid and centrally-located in modern China, bracketed on the north by the Tengger Desert, on the south by the Wei River, on the east by the Ordos Plateau and Liupan Mountains and on the west by the Qilian Mountains. The Yellow River transects the region, flowing roughly northeast; Pigeon Mountain and Shuidonggou are within the Yellow River corridor. Dadiwan is to the southwest, on the deeply incised landscapes of the Western Loess Plateau. The region is characterized by a long archaeological record and research history, extending well into the Lower Paleolithic and to Chardin's work at the first EUP localities discovered at Shuidonggou, in 1923 ([Licent and Chardin, 1925](#)). Subsequent work includes substantial excavations focusing on the Neolithic components at Dadiwan 1978–1984 ([GSWKY, 2006](#)), abundant work on the diverse Late Pleistocene deposits at Shuidonggou ([Gao et al., 2008b](#); [Guan et al., 2011](#); [Liu et al.,](#)

2009; [Ningxia Museum, 1987](#); [Pei et al., 2012](#)), survey and excavation focused on identifying Late Pleistocene and Early Holocene adaptations in the Tengger Desert and Yellow River Corridor ([Bettinger et al., 1994](#); [Elston et al., 1997, 2011](#); [Madsen et al., 1996, 1998](#)), and extensive survey and excavation work by our team on the Western Loess Plateau, including re-excavation of Dadiwan, from 2004 to 2009 ([Barton, 2009](#); [Bettinger et al., 2010a,b](#); [Morgan et al., 2011](#); [Zhang et al., 2010](#)).

The microlithic at Dadiwan

[Bettinger et al. \(2010a,b\)](#) report a six component cultural sequence for the Dadiwan site in Gansu (see also [Barton, 2009](#); [Zhang et al., 2010](#)). The cultural deposit here is 10 m deep and contained in a series of sedimentary loess and loessic paleosols that document human occupation of the site from before 80,000 calBP to the middle Holocene ([Table 1](#)). The assemblages dating before the LGM are characterized exclusively by large quartz flakes and shatter and by small quantities of large mammal bone. Relevant to the current discussion are: LGM Component 3 (33,000–20,000 calBP), during which the site was largely abandoned; Component 4 (20,000–13,000 calBP), in which microliths first appear in a lithic assemblage dominated by a hard-hammer, flake-and-shatter (macrolithic) technology using locally abundant massive quartz; and Component 5 (13,000–7000 calBP), in parts of which microliths briefly dominate before largely disappearing in Component 6 (7000–5700 calBP) ([Bettinger et al., 2010a](#); [Fig. 3](#)).

The Dadiwan microliths are extremely small; microblades average only 9 mm in length, and microblade cores are less than half the size of ones reported elsewhere in North China ([Bettinger et al., 2010b](#)), suggesting that the fine-grained cryptocrystallines from which they were made were locally scarce, possibly even absent, within the Loess Plateau. This would seem to make Dadiwan, and the western Loess Plateau in general, an unlikely place for the origin of microblade technology, the necessary raw material being so scarce. The likely source for the technology, the raw material, and the peoples connecting the two is 330 km to the north on the upper Yellow River and adjacent deserts, where the requisite raw material is more readily available and microlithic technology (unrepresented in the SDG1 and SDG2 EUP assemblages) appears sometime after the LGM but clearly before the YD, as shown at Pigeon Mountain (see [Elston et al., 1997](#)) (see [Table 2](#)).

The microlithic at Pigeon Mountain

QG3 (also called the Four Springs Site) is located in Pigeon Mountain Basin, Ningxia Hui Autonomous Region, flanked to the east by the upper Yellow River and west by the Tengger Desert/Shamo ([Elston et al., 1997, 2011](#); [Madsen et al., 1998](#)). QG3 is stratified, permitting [Elston et al. \(1997\)](#) and [Madsen et al. \(1998\)](#) to divide the assemblage into two components: Sand I dating from 14,977 to 13,480 calBP, and Sand II dating from 11,948 to 11,641 calBP. The temporal gap is the result of erosion reflecting the severely cold-dry YD, not necessarily an occupational hiatus. Two quite different lithic technologies are present. What is called “macrolithic technology” consists of percussion flaked cores, bifacial and unifacial tools made on metamorphic greenstone, quartzite and fine-grained sandstone stream pebbles and cobbles. The microlithic technology includes microblades, microblade cores, and microlithic tools mostly made on cryptocrystallines. Groundstone celts and milling equipment are few, and the milling equipment is tentatively associated with Sand I. Evidence for a major shift to microlithic technology is unequivocal ([Table 2](#)). Whereas the products of microlithic technology are in the minority in the earlier Sand I assemblage before the YD erosional episode (21%), they dominate the Sand II late-YD assemblage (68%).

Table 1

Frequency distribution of lithics and ceramics by component at Dadiwan, western Loess Plateau, Gansu (Bettinger et al., 2010a: Table 1). Note: LGM (Component 3) densities (specimens per m³) are lowest in sequence, suggesting the site was essentially abandoned. Microlithic tools, cores, and debitage dominate some but not all Component 5 lithic assemblages. Component 5 corresponds to Dadiwan I (Laoguantai culture), Component 6 to Dadiwan II (Late Banpo) in the published Dadiwan site report (GSWKY, 2006).

Component	1	2	3	4	5	6	All
Approximate age kcal BP	60.0–42.0	42.0–33.0	33.0–20.0	20.0–13.0	13.0–7.0	7.0–5.7	
Late Yangshao Sherds	*	*	*	*	*	*	.07
Late Banpo Sherds	*	*	*	.02 ^a	.02	.18	.19
Dadiwan Sherds	*	*	*	.02 ^a	.11	.12	.09
Microlithic tools, cores, and debitage	*	*	.12 ^a	.16	.38	.02	.20
Macrolithic tools, cores, and debitage	1.00	1.00	.88	.80	.48	.17	.46
Total (accommodating rounding errors)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Specimens (#)	31	72	25	261	756	624	1769
Specimens (# per m ³)	10.2	36.2	8.1	54.9	124.3	273.7	

^a Stratigraphically out of place; see Bettinger et al., 2010a.

* <.01.

Table 2

Frequency distribution of lithics by component at Four Springs (QG3), Pigeon Mountain Basin, Upper Yellow River, Ningxia (Elston et al., 1997: Table 1).

	Sand I 15.0–13.5 calBP	Sand I/II	Sand II 12.0–11.6 calBP	Total
Microcores	.02	.02	.02	.02
Microblades	.05	.02	.35	.22
Microlithic debitage	.14	.03	.31	.22
Macrolithic debitage	.79	.93	.32	.53
Total (accommodating rounding errors)	1.00	1.00	1.00	1.00
Specimens (#)	199	98	425	722

Table 3

Preliminary analysis of SDG12 lithic assemblage.

Category/type	Stratigraphic level					Total
	1	2	3	4	5	
<i>Chipped stone (freq.)</i>						
Used/retouched flake	.09	.05	.05	.04	.04	.05
Microblade core	.03	.00	.02	.01	.01	.01
Microblade	.20	.04	.14	.18	.23	.18
Polyhedral core	.00	.00	.01	.01	.01	.01
Debitage	.68	.89	.76	.73	.69	.73
Bipolar cores and flakes	<.01	.01	.02	.02	.02	.02
Total (accommodating rounding errors)	1.00	1.00	1.00	1.00	1.00	1.00
Specimens (#)	90	230	1960	2897	2098	7275
<i>Ground stone (#)</i>						
Axe/celt			1			1
Milling stone					1	1
Pestle					1	1
Whetstone				1	2	3
Unidentified fragments	1		2	3	4	10
Specimens (#)	1		3	4	8	16
<i>Miscellaneous stone (#)</i>						
Hammerstone			7	2	3	12
Manuport				13	10	23
Perforated disk				1		1
Specimens (#)			7	16	13	36

The microlithic at Shuidonggou 12 (SDG12)

SDG12 was discovered in 2005 as a locally oxidized band of ashy, charcoal-rich midden, approximately 50 m long and a meter thick (maximum thickness = 1.6 m), exposed in a cutbank in the second terrace (T2) floodplain deposit of the Biangou River, Ningxia Hui Autonomous Region (Liu D.C. et al., 2008a). The site is about 60 km northeast across the Yellow River from QG3, and like QG3 is flanked by the Yellow River on one side (in this case the west)

and by desert (in this case the Mu Us) on the other. Radiocarbon and OSL dating place the SDG12 occupation between 12,200 and 11,000 calBP (Liu D.C. et al., 2008a; Pei et al., 2012).¹ Excavation of 12 m² of the deposit produced more than 7000 pieces of chipped and ground stone (Table 3) that investigators divided into horizontal

¹ Pei et al. (2012) report the lone radiocarbon date from SDG12 incorrectly. Liu et al., 2008 provide a conventional age of 9797 ± 91 rcybp, based on the 5568 half life; Pei et al. present the calibrated age as uncalibrated and then calibrate that.

levels 1 (youngest) through 5 (oldest), which show only minor differences in composition. While the age span reflects differences between the two dating methods, the large instrumental error inherent to OSL, and the radiocarbon calibration offset for the Terminal Pleistocene, SDG12 is essentially a single YD component. Preliminary analysis of the lithics, and more detailed treatments in preparation, in press, or published by other scholars permit the following brief summary.

The SDG12 assemblage

The assemblage is indisputably microlithic; chipped stone accounts for more than 99% of the cultural assemblage, microblades and microblade cores for nearly 20% of that (Fig. 2, Table 3). At least some of the larger microblades are unilaterally backed, resembling the microblade inset in the knife from the Shangzhai site. The bulk of the remaining chipped stone includes small, angular cores (1%) and chipping waste (73%) that are likely byproducts of microblade manufacture. Raw materials are the same and the non-microblade cores are of roughly the right size and display multiple abortive attempts to produce the platform-core face configuration necessary for microblade production; however, these and the bipolar cores may have also been used to generate expedient flake tools, lightly used or retouched examples of which make up about 5% of all lithics.

There are no formal (i.e., extensively shaped or retouched) chipped stone tools. In contrast, the much smaller groundstone assemblage ($n = 16$) includes formal plant processing and wood-working tools (Table 3). Like the ground stone assemblage, the worked bone assemblage, while not extensive, includes more formal tools than the much larger chipped stone assemblage, including large- and small-eyed bone needles (indicating use as sewing implements [Hoffecker, 2011]) and at least one tabular knife han-

dle unilaterally slotted to accept microblades, similar in morphology to an example from Xiliang and in both morphology and decoration to examples from Dadiwan discussed below (Figs. 3 and 4). Not shown in Table 3 are more than 13,000 pieces of fire-cracked rock attesting to significant levels of stone boiling (Gao et al., 2009), possibly with skin containers. The faunal assemblage (Zhang et al., n.d.) is dominated by hare (*Lepus* sp., 57.4%) and Przewalsky's gazelle (*Procapra przewalskii*, 22.2%), with much smaller numbers of buffalo (*Bubalus* sp., 6.8%), badger (*Meles meles* (5.7%), horse (*Equus przewalskii*, 2.9%), cervids (*Cervidae*, 1.0%), pig (*Sus* sp., .03%), and unidentified birds (2.9%). This distinctive faunal assemblage furnishes important clues about the function of SDG12 and the role of microblade technology in the subsistence-settlement system of which it was a part.

Activity at SDG12

The dominance of hare in the SDG12 assemblage has parallels in the Siberian “microblade adaptation” (Goebel, 2002: 126), but anatomical and behavioral similarities between the SDG12 leporids and the North American black-tailed jackrabbit (*Lepus californicus*), and between Przewalsky's gazelle and the North American pronghorn (*Antilocapra americana*), suggest a more specific resemblance between SDG12 and North American Great Basin sites used for late prehistoric–ethnographic communal game procurement (e.g., Arkush, 1995; Frison, 1971; Lubinski, 1999, 2000).

L. californicus was the single most important source of skins used in Great Basin clothing (Steward, 1938: 38), the chief purpose for their procurement, (Steward, 1940:220), which was necessarily communal, typically with nets, both to obtain the requisite numbers and because the species neither burrows nor keeps to set trails, making trapping ineffective. The Tolai Hare (*Lepus tolai*) in the Shuidonggou area today shares key characteristics with *L. californicus* (e.g., non-burrowing, Smith et al., 2008: 291–292), and it is reasonable to assume they, too, would have been most effectively taken by communal drives, possibly with nets.

Important for meat as well as hides, the North American pronghorn was likewise more effectively taken communally. Staying to open ground made it difficult to approach, and its tendency to run rather than hide, and unwillingness to jump even low fences, made it susceptible to communal drives using v-shaped wing traps leading to low-fenced corrals (Steward, 1940: 218–220). Nearly identical in size, and in Przewalsky's own words, “marvelously swift,” Przewalsky's gazelle displays the pronghorn's preference for open ground, for running to avoid predators (Leslie et al., 2010: 133), and hesitation to jump fences much over 1 m high, which would have made it susceptible to communal drives into brush or log corrals or perhaps into the Biangou River itself. Mass (and presumably communal) capture of similar animals (*Gazella subgutturosa*) in the Near Eastern steppe zone (Bar-Oz et al., 2011) provides a sound prehistoric analog for the strategies visible at SDG12.

Implications of the SDG12 assemblage

What is perhaps most interesting about SDG12 is the connection between its chipped stone and faunal assemblages, which suggests that the major function of microblades in YD north-central China was less in weaponry than in butchering and craftwork – the manufacture of clothing specifically. To see this, note first that the bulk (80%) of the SDG12 faunal assemblage is hare and gazelle, whose procurement would not have required sophisticated weaponry. Hare were likely taken in nets, dispatched with sticks or clubs. Gazelle may have been killed with clubs, spears, darts, or arrows, but if corrals or pounds were used, or the Biangou River as a water barrier, any shooting would have been point blank at animals having almost no possibility of escape, so even primitive versions would have sufficed. Sophisticated and costly composite

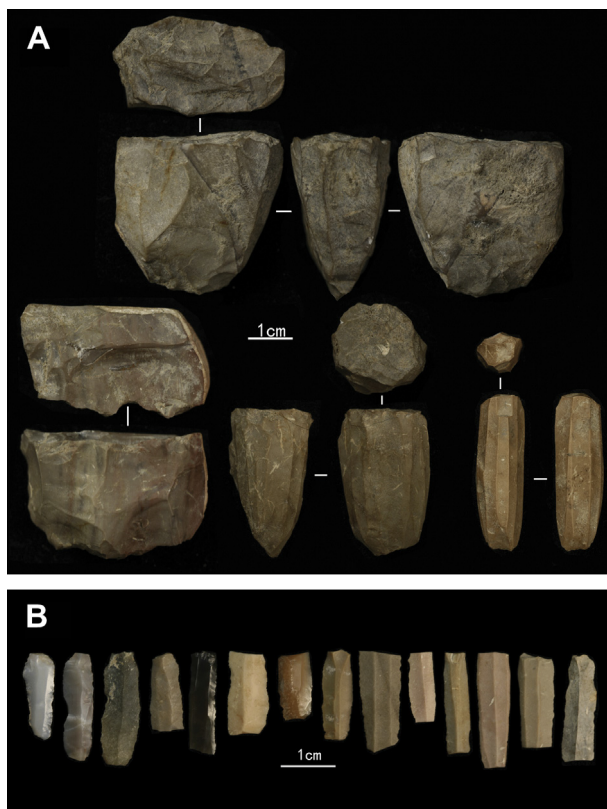


Fig. 2. Microblade cores and preforms (A), and microblades (B) from Shuidonggou 12.

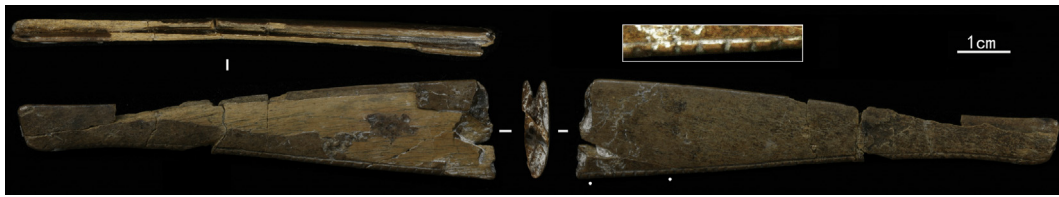


Fig. 3. Decorated bone knife handle slotted to accept microblades from Shuidonggou 12. Specimen is similar in shape, and presumably function, to those found elsewhere in northern China, during and after the Younger Dryas, and similar in decoration to slotted knives from Dadiwan (Fig. 6). Inset on upper right magnifies a section (indicated by the two white dots) of the carefully incised decoration running both faces along the back margin of the knife.



Fig. 4. Bone needles and stitching awl from Shuidonggou 12.

projectiles fitted with microblade insets would not have been required, nor are any represented in the (admittedly small) worked bone assemblage. Despite this, the chipped stone assemblage is almost entirely microblades, microblade cores, and byproducts of microblade manufacture. Note further that more than half the faunal assemblage is a species (hare) likely more important for its skin than its notoriously lean meat (Speth and Spielmann, 1983), and that the only SDG12 implement unequivocally connected with microblade use is a knife type perfectly suited to butchering and hide-cutting. That eyed needles are present, along with immense quantities of boiling stones (Gao et al., 2009) as would be needed were the inhabitants rendering grease not only for food but for tanning (Hatt, 1969: 14–15), completes the case that the principal activity at SDG12 was the production of sophisticated, fitted clothing from scratch in a location where groups could converge to obtain both the necessary skins and the stone suitable for making the microblades needed to fashion those skins into clothing.

While the absence of features (other than ill-defined charcoal concentrations perhaps representing fires) suggests the SDG12 occupation was short-term, probably seasonal, it was no minor undertaking. The heavily altered SDG12 cultural deposit and density of tools and debris demonstrate significant investment in producing what was presumably winter clothing, which we speculate was central to a YD adaptation akin to what Binford (1980: 16–17) called “serial specialist” – groups relying on mobility rather than

storage to solve the overwintering problem in cold, highly seasonal, fuel-poor environments.

Microblade function

That microlithic technology develops on the upper Yellow River during the YD suggests a functional response, microlithic technology solving some problem (or exploiting some opportunity) that arose with the cold-dry YD deterioration of the north-central China environment (Herzschuh and Liu, 2007; Wunneman et al., 2007). This, along with the northern distribution of microblade technology in China (Gai, 1985: Fig. 12.3; Lu, 1998: Fig. 1) and eastern Eurasia more generally (Hoffecker, 2005: 111), suggests the connection has to do with adaptation to cold, arid environments. The nature of this connection, however, is as problematic as those of microblade origins and chronology.

Microblades obviously served multiple purposes (Dixon, 2010; Elston and Kuhn, 2002). However, that so many microblade-users depended so much on hunting has magnified the perception that the main function of microblades was in hunting weapons – as spear, dart, and arrow point side- and end-blade insets (e.g., Elston and Brantingham, 2002: 104; Elston et al., 2011), and the companion perception that Dixon's (2010: 79) “exacto” knife functions – for butchering, hide cutting and trimming, and other delicate craftwork (e.g., Maxwell, 1984: 365), were “add-ons” insufficiently important individually or collectively to warrant investing in microblade technology. While the case for use as weaponry insets is clear – especially from Siberia (e.g., Bazaliiskii, 2010: Fig. 3.6), that the weaponry function was universally dominant is not, at least in part because many northeast Eurasian microlithic assemblages (e.g., Dyuktai) contain chipped stone projectile points, suggesting that while microblade-inset weapons may have been superior, stone-only points offered a reasonable, probably cheaper alternative (Yi and Clark, 1985).

Chinese examples of composite, microblade-edged weapons are almost exclusively from the northeast, mainly from the Xinglongwa site. These are mainly bone harpoons, commonly with three or more barbs carved on one side and a groove on the opposite to accept microblade insets, presumably for fishing (ZSKYNGM, 1985, 1997). One unusual example is bilaterally barbed on the lower section and bilaterally grooved for microblades above that (Guo, 1995). The Xinglongwa composite tool assemblage includes at least a one bilaterally grooved spear point, presumably for terrestrial game (ZSKYNGM, 1997). This slotted-bone assemblage dates broadly to 8300–7200 calBP (based on a recalibration of charcoal dates printed in Shelach, 2000:371).

Functional evidence of microblade use in craftwork, at least in northeast China, is shown by a bone knife unilaterally grooved to accept microblades from the Xiliang site, Xiaohexi culture, a Xinglongwa progenitor, ca. 8500 calBP (Liu, 2007: 40). A similar unilaterally slotted knife, but fitted with one complete, rather large microblade (not with microblade segments), one edge backed by bifacial retouch, is attested at the somewhat later Shangzhai site

in Pinggu, Beijing, ca. 7600–6600 calBP (Cui et al., 2010: Fig. 1). In north-central China this craftwork function is the only one represented, by tabular bone knife handles from the early and middle Neolithic levels at Dadiwan (approximately 7900–6000 calBP), decorated and unilaterally slotted to accept microblade segments (GSWKY, 2006: 236, 237), and the similarly decorated and slotted specimen from the YD site of SDG12. Slightly younger (~4500 calBP) and more elaborate are two examples from the Yuanyangchi site in Gansu: composite knives with flat bone blades with microblade insets attached to separate bone handles (GSBWG, 1974).

While the Dadiwan composite microblade knives could have had many uses, that eyed sewing needles are among the earliest Dadiwan bone implements (Dadiwan I or Laoguantai Phase, ca. 7900–7200 calBP) (GSWKY, 2006: 59), suggests that fitted clothing played a critical role in that likely very mobile and hunting-oriented early Neolithic adaptation (Barton, 2009; Barton et al., 2009) as well, raising the possibility this sort of craftwork was the key function of Dadiwan's composite microblade knives, indeed Dadiwan microblade technology in general, there being no evidence for microblade use in other capacities, such as edging weapons. The results of excavations conducted in 2007 at SDG12 on the upper Yellow River, roughly 370 km north of Dadiwan, add credence to the hypothesis that the main function of YD microblade technology in north-central China was in the production of sophisticated winter clothing.

Serial specialists

Serial specialists play almost no role in most discussions of the “forager–collector continuum”, in large part because the serial specialists of ethnography defy the otherwise positive correlations between latitude (i.e., temperature, ET) and hunter–gatherer storage and sedentism (Fig. 5A and B), the otherwise negative correlation between latitude and residential mobility (Fig. 5C), and between residential mobility and technological sophistication and tool curation. Low latitude (<30°, i.e., warm environment) foragers tend to be highly mobile, using year-round residential mobility to counter resource shortages that are primarily spatial, moving as needed to resources available throughout the year. Low resource demand and relatively steady (i.e., year round) resource supply favor simple, generalized, and often expedient, forager technology. In contrast, mid-latitude foragers (30° > latitude > 60°) tend to be more winter-sedentary. They use logistical mobility and storage to counter resource shortages that are more seasonal than spatial; collectors employ sophisticated technology to acquire and store in bulk warm season resources for use in winter, when few are available. High latitude (latitude > 60°, i.e., cold environment) hunter–gatherers face this same “overwintering problem” in much more extreme form, but solve it not by storing warm season resources (to which they would then be tethered), but with specialized technology and winter residential mobility, repositioning themselves to exploit prey that have themselves solved the overwintering problem.

At most places above 60° latitude it is evidently either impossible or uneconomical to acquire and store enough warm season resources to support sedentary winter settlements, leaving as the only alternative a pattern of winter mobility in pursuit of large, fat-rich prey – for inland folk chiefly large-bodied ungulates. On this view, serial specialists combine the mobility of Binford's foragers and the technological sophistication of Binford's collectors. Serial specialization places significant demands on subsistence technology (e.g., weaponry) to counter winter subsistence risk, but even greater demands on technologies (including clothing) connected with mobility, which is even more critical than subsistence technology in countering winter subsistence risk. As low latitude foragers show, it is more expedient to solve spatial resource

incongruities (i.e., local resource shortfalls) by residential mobility than by technological intensification: it is easier to find a better place to hunt than a better weapon to hunt with. Steegman et al. (1983: 349) make this point for the Northern Algonkians – that their entire boreal forest adaptation hinged on mobility, which hinged in turn on key technologies: toboggans, snowshoes, tents, and clothing (Steegman, 1983: 257; Steegman et al., 1983: 324–328).

Discussion

It has been clear for some time (e.g. Elston et al., 1997) that while microblades may have been around in north-central China since at least the LGM, they become prominent (i.e., chipped stone technology becomes “microlithic”) only much later, with the YD. This sequence suggests a stronger connection between microblades and mobility than between microblades and hunting. If microblades were only (or mainly) for edging weapons, their rise to YD dominance would suggest an equally dramatic rise in hunting, making it difficult to understand why a much more demanding microblade technology would develop to facilitate the much less important pre-YD hunting. In any event, the SDG12 assemblage is at odds with the idea of a hunting shift. No more or less abundant than in pre-YD assemblages (e.g., QG3), formal plant processing tools suggest a continued dietary importance of YD plants, and there is no evidence for hunting of a sort that would require microblade production (i.e., of weaponry insets) on anything like the scale in which they occur. A shift to serial specialist provides a better explanation.

Like low latitude foragers, serial specialists are frequently on the move, which limits both the amount of gear they can carry and the time they can invest in making it. Unlike low latitude foragers, however, serial specialists require a variety of sophisticated technological adaptations. In this respect they more closely resemble mid-latitude collectors, but moving more often and being less centrally tethered, they generally cannot devote whole seasons of “downtime” to craft production as collectors do. Instead, serial specialists are frequently forced to accomplish significant amounts of craftwork in relatively short periods of time. Microblade technology is admirably suited to such streamlined mass-production, and this is exactly what the SDG12 record indicates. The intensity with which SDG12 was used and the emphasis on communal procurement suggests a fairly short-term occupation by groups that probably operated independently during the rest of the year, almost certainly during the winter. SDG12 was most likely occupied immediately before that in connection with a seasonal “gearing up” for winter, perhaps equivalent to the ethnographically recorded “sewing camps” of the Copper Inuit (Damas, 1972: 13, 25, 26) and Netsilik Inuit (Balicki, 1970: 54–55).

Suggestions for future work

Terminal Pleistocene, early Holocene hunter–gatherer research in China is still in its infancy: very few surveys have been conducted, few stratified sites have been recorded and even fewer have been excavated, dated, or studied extensively. Shortcomings in the data likely reflect the limited nature of the sample. We hope the following outline will help to guide future research regarding chronology, tool function, and settlement patterns.

Chronology

Over the whole of northern China perhaps a dozen cultural sites have radiocarbon age estimates that fall within the YD (see Barton et al., 2007; Elston et al., 2011); perhaps a dozen more (including Dadiwan) might be attributed to that range based on other chrono-

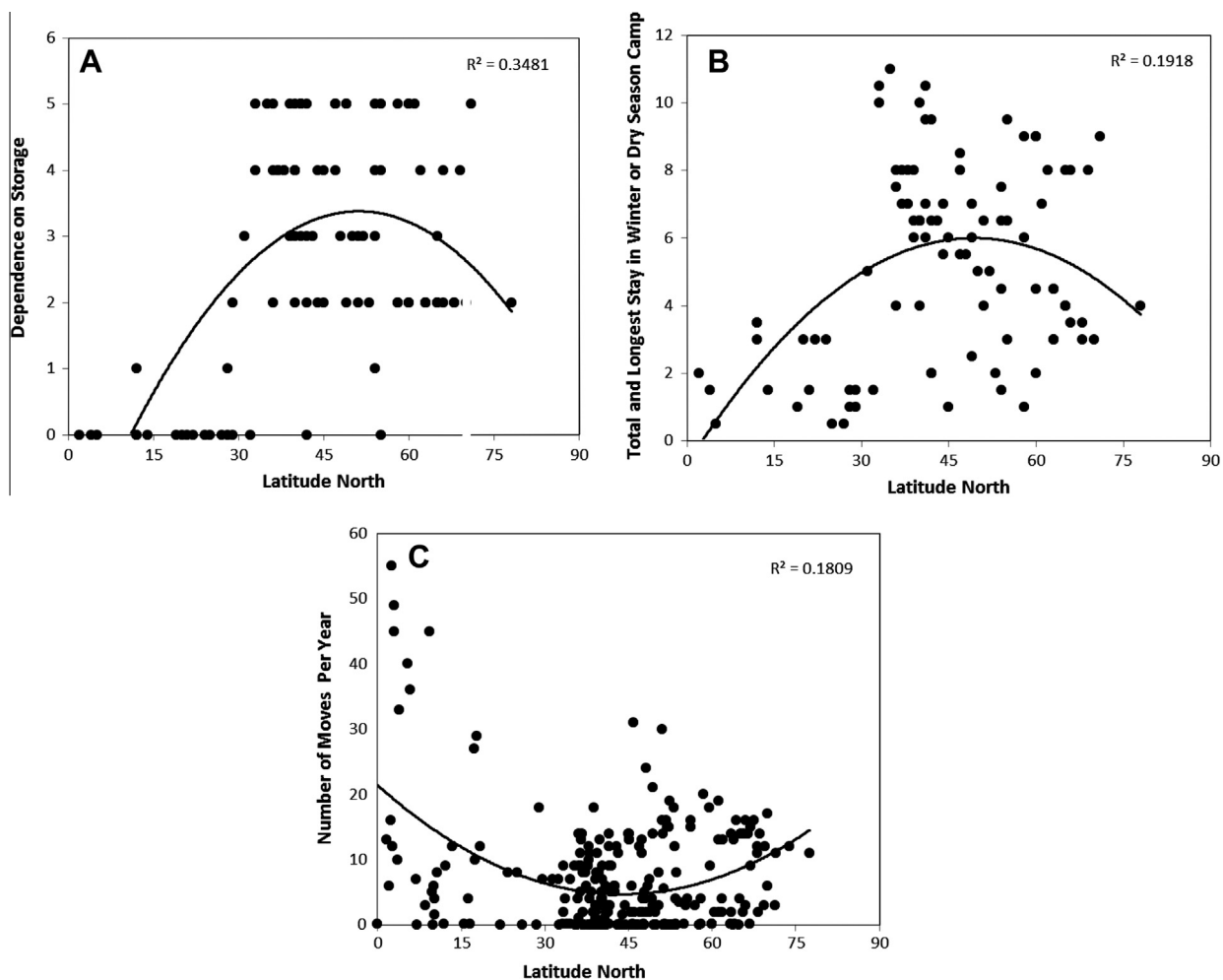


Fig. 5. (A) High latitude hunter-gatherers are less storage dependent than mid-latitude hunter-gatherers. Dependence on storage first increases, then decreases, with latitude. Data provided by Keeley's (1995) sample of 96 hunter-gather groups as measured by Keeley's variable STOR: a six-level categorical scale of storage dependence, ranging from 0 (no storage) to 5 (storage of staples in surplus). Trend line is second order polynomial. (B) High latitude hunter-gatherers are less sedentary than mid-latitude hunter-gatherers. Sedentism first increases, then decreases, with latitude. Data provided by Keeley's (1995) sample of 96 hunter-gatherers as measured by Keeley's variable STAY: a measure of sedentism, expressed as the total and longest stay (in months) in a winter or dry season camp or village. Trend line is second order polynomial. (C) High latitude hunter-gatherers are more residentially mobile than mid-latitude hunter-gatherers. Number of residential moves per year as a function of latitude in 254 Northern Hemisphere hunter-gatherers (Binford, 2001). Mobility first decreases, then increases with latitude. Trend line is second order polynomial.

stratigraphic methods. More than anything, the paucity of evidence reflects a lack of interest in terminal Pleistocene, early Holocene archaeology and not, as some would have it (e.g. Kennett et al., 2008) a reduction in human populations during the YD. Indeed, if summed probability distributions of calibrated radiocarbon age estimates suggest anything about the probability of finding archaeological sites, whether by human demography or archaeological visibility, the YD is better represented than the preceding Bølling–Allerød warm phase, and about as well represented as the succeeding early Holocene (see Barton et al., 2007: Fig. 3). Still, the small sample size, and the lack of precision age estimates for them, makes it impossible to evaluate the early YD extirpation hypothesis proposed for North America (Kennett et al., 2008), or any other finely-tuned argument about the correlation between human culture and environmental change. More surveys, more sites, more excavations, and more dates are necessary to create the sample required to do so. This echoes conclusions made previously for Northeast Asia as a whole (Wright and Janz, 2012).

Tool function

Though recent studies have employed use-wear analysis to reveal the function of chipped-stone tools from YD components in

China (Zhang et al., 2009), to date we lack direct evidence for the use of microlithic tools in hunting, processing, manufacturing, or any other tasks. If the current hypothesis is correct, use-wear analysis should reveal patterns of butchery, skinning, cutting of tanned hides (shaping; cutting eye holes for needles), cutting of sinew and other cordage, and preparation of other (namely bone) tools such as needles, awls, and hafts necessary to the manufacturing enterprise. At site types other than the pre-winter “sewing camp,” these and other activities, including the use of microblades for hunting, should also be visible in use-wear patterns, the relative frequency of which should index the function of the site, and in concert with other data, the season of its use (see below).

The current hypothesis contends that microblade technology was well-suited to most of these tasks, which is precisely what made it so valuable: a limited number of raw material blanks could serve a maximal number of functions. It enables a wide range of application with limited raw materials, and therefore limited baggage. Use-wear patterns, for example, should further reveal microblades hafted in slotted bone or antler handles, exposing only a few millimeters depth of cutting surface – indeed, if the average microblade from Dadiwan (see Bettinger, et al., in press) were slotted into one of the many handles found at the site, roughly 1.5–

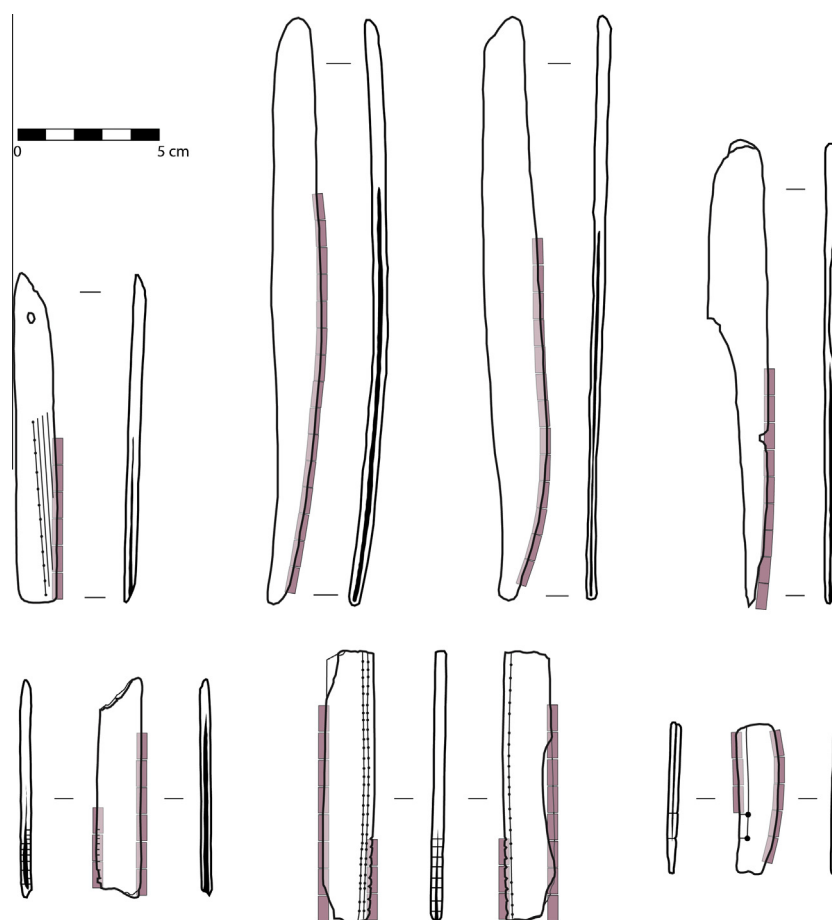


Fig. 6. Slotted bone handles from Dadiwan (redrawn from [GSWKY, 2006](#)), fitted with microblades based on the average dimensions of 27 microblades found at the site ([Bettinger et al., in press](#)): 9.13 mm in length (std = 1.56 mm), 3.64 mm in width (std = .55 mm), 0.94 mm in thickness (std = .34 mm). Note: marginal decoration on specimens illustrated on the upper left, lower right, and lower middle, similar to slotted knife from SDG12 ([Fig. 3](#)).

2.0 mm of edge would be exposed ([Fig. 6](#)). This is sufficient for cutting thin hides from deer or rabbit; thicker hides could be cut with multiple passes of the knife. Hafting blades in a protective handle leaving only millimeters exposed would maintain a sharp cutting edge while minimizing breakage. This further suggests that such tools were used for cutting hides or sinew strips, which are characteristically thin, rather than for butchering meat, which is much thicker.

Settlement patterns

Much of this hypothesis is about seasonal variation in human activity. Currently, archaeological data are too thin to evaluate settlement patterns during the termination of the Last Glaciation quantitatively. Known sites in our study area may reflect different phases of the settlement system. Though we do expect the pre-winter aggregation camps (e.g. SDG12) to be more visible, better preserved, and marked by deeper, denser anthropogenic debris than mobile short-term winter or summer camps, the latter may still appear. Indeed, we suggest that Dadiwan's terminal Pleistocene, early Holocene component may be an example of this. If so, use-wear on the Dadiwan microblades should reveal a higher proportion of hunting, butchering, and/or food processing activities than at SDG12. The faunal assemblage should reflect seasonal access to migratory game (namely cervids and bovines), and possibly local suids. Anthropogenic deposits should be thin in testament to the mobile pattern of residency. If the depositional context permits, isotopic analysis of dental increments (e.g. [Koch et al., 1989](#); [Stutz, 2002](#)) should reveal homogenous patterns of capture: we suspect winter or late spring. Finally, as additional stratified sites

become available, we expect the patterns of animal exploitation to reveal different phases of a highly scheduled settlement-subsistence system finely tuned to regional variations in resource abundance conditioned primarily by the movements of animals.

Conclusion

Evidence suggests that the connection between microblades and the YD hunting adaptation in north-central China is less about weaponry than the production of sophisticated clothing needed to make winter mobility and hunting feasible. Winter sedentism does not entirely eliminate, but substantially relaxes, clothing requirements; fires and well-built and well-positioned shelters provide sufficient protection. Tethered to their cold-season stores, the winter-sedentary Great Basin Shoshone used as their chief piece of clothing a simple rabbit skin blanket ([Steward, 1938: 38](#); [Yoder et al., 2004](#)). In contrast, the winter-mobile Cree-Ojibwa fashioned hare into parkas, hoods, mittens, and leggings ([Rogers, 1963: 70, 71–72](#)). The Fuegoan example shows it is possible for well-conditioned adults to move short distances in extreme cold without fitted clothing, but longer trips would have been extremely difficult (and likely impossible) for children ([Steegman et al., 1983: 323, 332–335](#)). Pre-LGM peoples of north-central China may have been winter-sedentary, as [Goebel \(2002: 123\)](#) hints for pre-LGM Siberians, and for this reason unable to weather LGM climatic deterioration. Alternatively, they may have been winter-mobile but lacked the technology needed to bring this off during the more severe LGM winters, this capability arising only with the development

of sophisticated winter clothing and the microblade technology essential to its production.

It is important in closing to make our argument very clear. We do not argue that microblades were not used as weapon insets (clearly they were), or that microblade technology did not originally develop for this purpose (clearly it might have). We merely argue that the YD ascendance of microblade technology in north-central China is the result of its importance in craftwork essential to a highly mobile, serial specialist lifeway, the production of clothing in particular. While microblades were multifunctional, this much is certain: of the very few microblade-edged tools known from north-central China all are knives, none are points. If microblades were mainly for weapons it should be the other way around.

Acknowledgments

This work could not have been done without the aid of F.H. Chen, H. Wang, D.J. Zhang, C. Wang, Z. Zhou, F. Peng, N. Ma and support by grants from the Strategic Priority Research Program of the Chinese Academy of Sciences (XDA05130302), National Basic Research Program of China (973 Program, 2010CB950203), the National Science Foundation (#SBR-941092323, #SBR-9729929, #BCS-0222742), by the National Geographic Society, the Leakey Foundation, the University of California – Davis, the University of California Pacific Rim Research Program, and Utah State University.

References

- Alley, R.B., 2000. The Younger Dryas cold interval as viewed from central Greenland. *Quaternary Science Reviews* 19, 213–226.
- Alley, R.B., Meese, D.A., Shuman, C.A., Gow, A.J., Taylor, K.C., Grootes, P.M., White, J.W.C., Ram, M., Waddington, E.D., Mayewski, P.A., Zielinski, G.A., 1993. Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event. *Nature* 362 (6420), 527–529.
- An, Z.M., 1978. Hai La'er de Zhongshiqi Shidai Yichun-Jianlun Xishiqi de Qiyuan he Chuantong (The Mesolithic remains in Haila'er-A note on the origin and tradition of microblade). *Kaogu Xuebao* (Acta Archaeologica Sinica) 3, 289–316.
- An, Z.M., 1983. Zhongguo Wanqi Jiushiqi de 14C Duandai he Wenti (Problems with 14C dating of the Chinese Upper Paleolithic). *Renleixue Xuebao* (Acta Anthropologica Sinica) 2 (4), 342–351.
- An, Z.S., Porter, S.C., Zhou, W., Lu, Y., Donahue, D.J., Head, M.J., Wu, X., Ren, J., Zheng, H., 1993. Episode of strengthened summer monsoon climate of Younger Dryas age on the loess plateau of Central China. *Quaternary Research* 39, 45–54.
- Arkush, B.S., 1995. The Archaeology of CA-MNO-2122: A Study of Pre-Contact and Post-Contact Lifeways among the Mono Basin Paiute. UC Publications in Anthropological Records. University of California Press.
- Balicki, A., 1970. The Netsilik Eskimo. Natural History Press, New York.
- Bar-Oz, G., Zeder, M., Hole, F., 2011. Role of mass-kill hunting strategies in the extirpation of Persian gazelle (*Gazella subgutturosa*) in the northern Levant. *Proceedings of the National Academy of Sciences of the United States of America* 108 (18), 7345–7350.
- Barton, L., 2009. Early Food Production in China's Western Loess Plateau. Ph.D. Dissertation, Department of Anthropology, University of California, Davis, CA.
- Barton, L., Brantingham, P.J., Ji, D.X., 2007. Late Pleistocene climate change and Paleolithic cultural evolution in northern China: implications from the Last Glacial Maximum. In: Madsen, D.B., Gao, X., Chen, F.H. (Eds.), *Late Quaternary Climate Change and Human Adaptation in Arid China*. Developments in Quaternary Science, vol. 9. Elsevier, Amsterdam, pp. 105–128.
- Barton, L., Newsome, S.D., Chen, F.-H., Wang, H., Guilderson, T.P., Bettinger, R.L., 2009. Agricultural origins and the isotopic identity of domestication in northern China. *Proceedings of the National Academy of Sciences of the United States of America* 106, 5523–5528.
- Bazaliiskii, V., 2010. Mesolithic and Neolithic mortuary complexes in the Baikal region. In: Weber, A.W., Katzenberg, M.A., Schurr, T.G. (Eds.), *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*. University of Pennsylvania Museum of Archaeology and Anthropology Press, Philadelphia, pp. 51–86.
- Bettinger, R.L., Madsen, D.B., Elston, R.G., 1994. Prehistoric settlement categories and settlement systems in the Alashan Desert of Inner Mongolia, PRC. *Journal of Anthropological Archaeology* 13, 74–101.
- Bettinger, R.L., Barton, L., Morgan, C.T., Chen, F., Wang, H., Guilderson, T.P., Ji, D., Zhang, D., 2010a. The transition to agriculture at Dadiwan, People's Republic of China. *Current Anthropology* 51 (5), 703–714.
- Bettinger, R.L., Barton, L., Morgan, C.T., 2010b. The origins of food production in North China: a different kind of agricultural revolution. *Evolutionary Anthropology* 19, 9–21.
- Bettinger, R.L., Morgan, C., Barton, L. (in press). The North China Nanolithic. In: Goodale, N., Andrefsky, W. (Eds.), *Lithic Technological Systems and Human Evolution*. Cambridge University Press, Cambridge.
- Binford, L.R., 1980. Willow smoke and dog's tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45, 4–20.
- Binford, L.R., 2001. *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. University of California Press, Berkeley.
- Bleed, Peter, 2002. Cheap, regular, and reliable: implications of design variation in Late Pleistocene Japanese microblade technology. In: Elston, R.G., Khun, S. (Eds.), *Thinking Small: Global Perspectives on Microlithization*, Archaeological Papers of the American Anthropological Association, vol. 12. American Anthropological Association, Washington, DC, pp. 95–102.
- Brantingham, P.J., Li, J., Madsen, D.B., Gao, X., Bettinger, R.L., Elston, R.G., 2004. The Initial Upper Paleolithic at Shuidonggou, Northwest China. In: Brantingham, P.J., Kuhn, S.L., Kerry, K.W. (Eds.), *The Early Upper Paleolithic beyond Western Europe*. University of California Press, Berkeley, pp. 223–241.
- Chen, S.Q., 2004. Adaptive changes of prehistoric hunter-gatherers during the Pleistocene–Holocene transition in China. Ph.D. Dissertation, Dedman College Southern Methodist University, 2004.
- Chen, C., 2007. Techno-typological comparison of microblade cores from east Asia and North America. In: Kuzmin, Y.V., Keates, S.G., Shen, C. (Eds.), *Origin and Spread of Microblade Technology in Northern Asia and North America*. Archaeology Press, Simon Fraser University, Burnaby, BC, pp. 7–38.
- Chen, F.H., Bloemendal, J., Wang, J.M., Li, J.J., Oldfield, F., 1997. High-resolution multi-proxy climate records from Chinese loess: evidence for rapid climatic changes over the last 75 kyr. *Palaeogeography, Palaeoclimatology, Palaeoecology* 130, 323–335.
- Cui, T.X., Yang, Q., Yu, J.C., Zhou, S.L., Zhao, C.H., 2010. Microwear analysis of a bone-handled microblade excavated at Shangzhai Site in Beijing: evidences from ESEM. *Science China: Earth Science* 53 (9), 1335–1342.
- Damas, D., 1972. The Copper Eskimo. In: Bicchieri, M.G. (Ed.), *Hunters and Gatherers Today*. Holt, Reinhart, and Winston, New York, pp. 3–50.
- Dixon, E.J., 2010. A reappraisal of circumpolar microblade technology. In: Westerdahl, C. (Ed.), *A Circumpolar Reappraisal: The Legacy of Gutorm Gjessing (1906–1979)*. BAR International Series Archaeo Press, Oxford, UK, pp. 77–85.
- Elston, R.G., Brantingham, P.J., 2002. Microlithic technology in Northeast Asia: a risk minimizing strategy of the Late Pleistocene and Early Holocene. In: Elston, R.G., Khun, S. (Eds.), *Thinking Small: Global Perspectives on Microlithization*, Archaeological Papers of the American Anthropological Association, vol. 12. American Anthropological Association, Washington, DC, pp. 103–116.
- Elston, R.G., Kuhn, S.L. (Eds.), 2002. *Thinking Small: Global Perspectives on Microlithization*, vol. 12. American Anthropological Association, Arlington, Virginia.
- Elston, R.G., Xu, C., Madsen, D.B., Zhong, K., Bettinger, R.L., Li, J., Brantingham, P.J., Wang, H., Yu, J., 1997. New dates for the North China Mesolithic. *Antiquity* 71 (274), 985–993.
- Elston, R.G., Dong, G.H., Zhang, D.J., 2011. Late Pleistocene intensification technologies in Northern China. *Quaternary International* 242 (2), 401–415.
- Frison, G.C., 1971. Shoshonean antelope procurement in the Upper Green River Basin, Wyoming. *Plains Anthropologist* 16, 258–284.
- Gai, P., 1985. Microlithic industries in China. In: Wu, R., Olsen, J.W. (Eds.), *Paleoanthropology and Paleolithic Archaeology in the People's Republic of China*. Academic Press, New York, pp. 225–241.
- Gao, X., Yuan, B., Pei, S., Wang, H., Chen, F., Feng, X., 2008a. Analysis of sedimentary-geomorphological variation and the living environment of hominids at the Shuidonggou Paleolithic site. *Chinese Science Bulletin* 53 (13), 2025–2032.
- Gao, X., Zhou, Z.Y., Guan, Y., 2008b. Qingzang Gaoyuan Bianyuan Diqu Wangengxinshi Renlei Yicun yu Shengcun Moshi (Human Cultural remains and adaptation strategies in the Tibetan Plateau margin region in the late Pleistocene). *Disiji Yanjiu* (Quaternary Sciences) 28 (6), 969–977.
- Gao, X., Wang, H.M., Liu, D.C., Pei, S.W., Chen, F.Y., Zhang, X.L., Zhang, Y., 2009. Shuidonggou 12 Didian Gurenlei Yonghu Yanjiu (A study of freize activities at Shuidonggou locality 12). *Acta Anthropologica Sinica* 28 (4), 329–336.
- Goebel, T., 2002. The “microblade adaptation” and recolonization of Siberia during the Late Upper Pleistocene. In: Elston, R.G., Kuhn, S.L. (Eds.), *Thinking Small: Global Perspectives on Microlithization*, Archaeological Papers of the American Anthropological Association, vol. 12. American Anthropological Association, Arlington, Virginia, pp. 117–131.
- GSBWG – Gansu Sheng Bowuguan Wenwu Gongzuodui (Gansu Provincial Museum Cultural Relics Workgroup), 1974. Yongchang Yuanyangchi Xishiqi Shidai Mudi de Fajue (The Neolithic tombs of Yuanyangchi in Yongchang). *Kaogu* (Archaeology) 5, 299–308.
- GSWKY – Gansu Sheng Wenwu Kaogu Yanjiusuo (Gansu Province Institute of Cultural Relics and Archaeology), 2006. Qin'an Dadiwan xishiqi shi dai yizhi fa jue baogao (Dadiwan in Qin'an: Report on Excavations at a Neolithic site). Cultural Relics Publishing House, Beijing.
- Guan, Y., Gao, X., Wang, H., Chen, F., Pei, S., Zhang, X., Zhou, Z., 2011. Spatial analysis of intra-site use at a Late Paleolithic site at Shuidonggou, Northwest China.. *Chinese Science Bulletin* 56 (32), 3457–3463.
- Guo, D.S., 1995. Hongshan and related cultures. In: Nelson, S.M. (Ed.), *The Archaeology of Northeast China: Beyond the Great Wall*. Routledge, New York, pp. 21–64.
- Hatt, G., 1969. Arctic skin clothing in Eurasia and America: an ethnographic study. *Arctic Anthropology* 5 (2), 3–132.

- Herzschuh, U., 2006. Paleo-moisture evolution in monsoonal Central Asia during the last 50,000 years. *Quaternary Science Reviews* 25, 163–178.
- Herzschuh, U., Liu, X., 2007. Vegetation evolution in arid China during Marine Isotope Stages 3 and 2 (~65–11 ka). In: Madsen, D.B., Chen, F., Gao, X. (Eds.), *Late Quaternary Climate Change and Human Adaptation in Arid China*, Developments in Quaternary Science, vol. 9. Elsevier, Amsterdam, pp. 41–49.
- Hoffecker, J.F., 2005. A Prehistory of the North: Human Settlement of the Higher Latitudes. Rutgers University Press, New Brunswick, New Jersey.
- Hoffecker, J.F., 2011. The early upper Paleolithic of eastern Europe reconsidered. *Evolutionary Anthropology* 20, 24–39.
- Huang, W.W., Hou, Y.M., 1998. A perspective on the archaeology of the Pleistocene–Holocene transition in North China and the Qinghai–Tibetan Plateau. *Quaternary International* 49/50, 117–127.
- IA-CASS (Institute of Archaeology, Chinese Academy of Social Sciences), 1983. *Collection of Radiocarbon Dates of Chinese Archaeology*. Wenwu Press, Beijing.
- Keeley, L.H., 1995. Proto-agricultural practices by hunter-gatherers. In: Price, T.D., Gerbrauer, A. (Eds.), *Last Hunters, First Farmers*. School of American Research Press, Santa Fe, pp. 95–126.
- Kennett, D.J., Kennett, J.P., West, G.J., Erlandson, J.M., Johnson, J.R., Hendy, I.L., West, A., Culleton, B.J., Jones, T.L., Stafford, T.W., 2008. Wildfire and abrupt ecosystem disruption on California's Northern Channel Islands at the Allerød–Younger Dryas boundary (13.0–12.9 ka). *Quaternary Science Reviews* 27, 2528–2543.
- Koch, P.L., Fisher, D.C., Dettman, D., 1989. Oxygen isotope variations in the tusks of extinct proboscideans: a measure of season of death and seasonality. *Geology* 17, 515–519.
- Kuzmin, Y.V., Keates, S.G., Chen, S., (Eds.), 2007. *Origin and Spread of Microblade Technology in Northern Asia and North America*. Archaeology Press, Simon Fraser University, Burnaby, BC.
- Leslie, D.M.J., Groves, C.P., Abramov, A., 2010. *Procapra przewalskyi* (Artiodactyla: Bovidae). *Mammalian Species* 42 (124–127).
- Licent, E., Chardin, P.T.d., 1925. Le Paléolithique de la Chine. *L'Anthropologie* 35, 201–234.
- Liu, G., 2007. The Xinglongwa culture in relation to other cultures. In: Hu, Y. (Ed.), *The Origins of Jades in East Asia: Jades of the Xinglongwa Culture*. The Center for Chinese Archaeology and Art at the Chinese University of Hong Kong, Hong Kong, pp. 40–51.
- Liu, X., Shen, J., Wang, S., Yang, X., Tong, G., Zhang, E., 2002. A 16,000-year pollen record of Qinghai Lake and its paleoclimate and paleoenvironment. *Chinese Science Bulletin* 47, 1931–1937.
- Liu, D.C., Chen, F.Y., Zhang, X.L., Pei, S.W., Gao, X., Xia, Z.K., 2008a. Shuidonggou 12 Didian de Guhuanjing Yanjiu (Preliminary comments on the paleoenvironment of the Shuidonggou Locality 12). *Renleixue Xuebao (Acta Anthropologica Sinica)* 27 (4), 295–303.
- Liu, D., Wang, Y., Cheng, H., Edwards, R.L., Kong, X., Wang, X., Wu, J., Chen, S., 2008b. A detailed comparison of Asian Monsoon intensity and Greenland temperature during the Allerød and Younger Dryas events. *Earth and Planetary Science Letters* 272, 691–697.
- Liu, X., Dong, H., Rech, J.A., Matsumoto, R., Yang, B., Wang, Y., 2008c. Evolution of Chaka Salt Lake in NW China in response to climatic change during the latest Pleistocene–Holocene. *Quaternary Science Reviews* 27, 867–879.
- Liu, D.C., Wang, X., Gao, X., Xia, Z., Pei, S., Chen, F., Wang, H., 2009. Progress in the stratigraphy and geochronology of the Shuidonggou Site, Ningxia, North China. *Chinese Science Bulletin* 54, 3880–3886.
- Lu, L.D., 1998. The microblade tradition in China: regional chronologies and significance in the transition to Neolithic. *Asian Perspectives* 37 (1), 84–112.
- Lubinski, P.M., 1999. The communal pronghorn hunt: a review of the ethnographic and archaeological evidence. *Journal of California and Great Basin Anthropology* 21 (2), 158–181.
- Lubinski, P.M., 2000. Of Bison and lesser mammals: prehistoric hunting patterns in the Wyoming Basin. *University of Utah Anthropological Papers* 122, 176–188.
- Ma, Z.-B., Cheng, H., Tan, M., Edwards, R.L., Li, H.-C., You, C.-F., Duan, W.-H., Wang, X., Kelly, M.J., 2012. Timing and structure of the Younger Dryas event in northern China. *Quaternary Science Reviews* 41, 83–93.
- Madsen, D.B., Elston, R.G., Bettinger, R.L., Xu, C., Zhong, K., 1996. Settlement patterns reflected in assemblages from the Pleistocene/Holocene transition of North Central China. *Journal of Archaeological Science* 23 (2), 217–231.
- Madsen, D.B., Li, J.Z., Elston, R.G., Xu, C., Bettinger, R.L., Geng, K., Brantingham, P.J., Zhong, K., 1998. The Loess/Paleosol record and the nature of the Younger Dryas climate in Central China. *Geoarchaeology: An International Journal* 13 (8), 847–869.
- Maxwell, M.S., 1984. Pre-Dorset and Dorset prehistory of Canada. In: Sturms, D. (Ed.), *Handbook of North American Indians*, vol. 5: Arctic, W.C. Sturtevant, General editor, Smithsonian Institution, Washington, DC, pp. 359–368.
- Meese, D.A., Gow, A.J., Alley, R.B., Zielinski, G.A., Grotes, P.M., Ram, M., Taylor, K.C., Mayewski, P.A., Bolzan, J.F., 1997. The Greenland Ice Sheet Project 2 depth-age scale: methods and results. *Journal of Geophysical Research* 102 (C12), 26411–26423.
- Morgan, C., Barton, L., Bettinger, R.L., Chen, F.H., Zhang, D.J., 2011. Glacial cycles and Palaeolithic adaptive variability on China's Western Loess Plateau. *Antiquity* 85 (328), 365–379.
- Muscheler, R., Kromer, B., Björck, S., Svensson, A., Friedrich, M., Kaiser, K.F., Southon, J.R., 2008. Tree rings and ice cores reveal 14C uncertainties during the Younger Dryas. *Nature Geoscience* 1, 264–267.
- Museum, Ningxia., 1987. A report on the 1980 excavations at Shuidonggou. *Kaogu* 10, 439–449 (in Chinese).
- Neeley, M.P., 2002. Going microlithic: a Levantine perspective on the adoption of microlithic technologies. In: Elston, R.G., Kuhn, S.L. (Eds.), *Thinking Small: Global Perspectives on Microlithization*, Archaeological Papers of the American Anthropological Association, vol. 12. American Anthropological Association, Arlington, Virginia, pp. 45–55.
- Peterse, F., Prins, M.A., Beets, C.J., Troelstra, S.R., Zheng, H., Gu, Z., Schouten, S., Sissinghe Damsté, J.S., 2011. Decoupled warming and monsoon precipitation in East Asia over the last deglaciation. *Earth and Planetary Science Letters* 301, 256–264.
- Rasmussen, S.O., Andersen, K.K., Svensson, A.M., Steffensen, J.P., Vinther, B.M., Clausen, H.B., Siggaard-Andersen, M.L., Johnsen, S.J., Larsen, L.B., Dahl-Jensen, D., Bigler, M., Röthlisberger, R., Fischer, H., Goto-Azuma, K., Hansson, M.E., Ruth, U., 2006. A new Greenland ice core chronology for the last glacial termination. *Journal of Geophysical Research* 111, D06102.
- Rogers, E.S., 1963. Changing settlement patterns of the Cree–Ojibwa of northern Ontario. *Journal of Southwestern Anthropology* 19 (1), 64–88.
- Shelach, G., 2000. The earliest Neolithic cultures of Northeast China: recent discoveries and new perspectives on the beginning of agriculture. *Journal of World Prehistory* 14 (4), 363–413.
- Shen, J., Liu, X., Wang, S., Matsumoto, R., 2005. Palaeoclimatic changes in the Qinghai Lake area during the last 18,000 years. *Quaternary International* 136, 131–140.
- Shott, M.J., 1986. Technological organization and settlement mobility: an ethnographic examination. *Journal of Anthropological Research* 42 (1), 15–51.
- Smith, A.T., Xie, Y., Hoffmann, R.S., Lunde, D., MacKinnon, J., Wilson, D.E., Wozencraft, W.C. (Eds.), 2008. *A Guide to the Mammals of China*. Princeton University Press, Princeton, NJ.
- Speth, J., Spielmann, K., 1983. Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *Journal of Anthropological Archaeology* 2 (1), 1–31.
- Steegman Jr., A.T., 1983. Boreal forest hazards and adaptations: the past. In: Steegman, A.T., Jr. (Ed.), *Boreal Forest Adaptations: The Northern Algonkians*. Plenum, New York, pp. 243–267.
- Steegman Jr., A.T., Hurlich, M.G., Winterhalter, B.P., 1983. Coping with cold and other challenges of the Boreal Forest: an overview. In: Steegman, A.T., Jr. (Ed.), *Boreal Forest Adaptations: The Northern Algonkians*. Plenum, New York, pp. 317–351.
- Steward, J.H., 1938. Basin-Plateau Aboriginal Sociopolitical Groups. Bureau of American Ethnology Bulletin, vol. 120. Smithsonian Institution, Washington, DC.
- Steward, J.H., 1940. Native Cultures of the Intermontane (Great Basin) Area. Smithsonian Miscellaneous Collections, Washington, DC, pp. 445–502.
- Stutz, A.J., 2002. Polarizing microscopy identification of chemical diagenesis in archaeological cementum. *Journal of Archaeological Science* 29, 1327–1347.
- Thompson, L.G., Yao, T., Davis, M.E., Henderson, K.A., Mosley-Thompson, E., Lin, P.N., Beer, J., Synal, H.A., Cole-Dai, J., Bolzan, J.F., 1997. Tropical climate instability: the last glacial cycle from a Qinghai–Tibetan ice core. *Science* 276, 1821–1825.
- Wang, J., Shi, Q., Chen, F., Xia, D., 1999. Rapid oscillations of Chinese monsoon climate since the last deglaciation and its comparison with GISP2 record. *Chinese Science Bulletin* 44 (3), 284–285.
- Wang, Y.J., Cheng, H., Edwards, R.L., An, Z.S., Wu, J.Y., Shen, C.-C., Dorale, J.A., 2001. A high-resolution absolute-dated Late Pleistocene monsoon record from Hulu Cave, China. *Science* 294, 2345–2348.
- Wright, J., Janz, L., 2012. The Younger Dryas in arid Northeast Asia. In: Eren, M. (Ed.), *Hunter-Gatherer Behavior: Human Response during the Younger Dryas*. Left Coast Press, Walnut Grove, CA, pp. 231–247.
- Wunneman, B., Hartman, K., Janssen, M., Huai, C.Z., 2007. Responses of Chinese desert lakes to climatic instability during the last 45,000 years. In: Madsen, D.B., Chen, F., Gao, X. (Eds.), *Late Quaternary Climate Change and Human Adaptation in Arid China*, Developments in Quaternary Science, vol. 9. Elsevier, Amsterdam, pp. 11–24.
- Yao, T., Thompson, L.G., Shi, Y., Qin, D., Jiao, K., Yang, Z., Tian, L., Thompson, E.M., 1997. Climate variation since the Last Interglaciation recorded in the Guliya ice core. *Science in China (Series D)* 40 (6), 662–668.
- Yi, S., Clark, G., 1985. The “Dyuktai Culture” and new world origins. *Current Anthropology* 26 (1), 1–20.
- Yi, M.J., Gao, X., Zhang, X.L., Sun, Y.J., Brantingham, P.J., Madsen, D.B., Rhode, D., 2011. Qingzang Gaoyuan Bianyuan Diqu Shiqian Yizhi 2009 nian Diaocha Shijue Baogao (A Preliminary Report on Investigations in 2009 of Some Prehistoric Sites in the Tibetan Plateau Marginal Region). *Renleixue Xuebao (Acta Anthropologica Sinica)* (30), 124–136.
- Yoder, D.T., Blood, J., Mason, R., 2004. How warm were they? Thermal properties of rabbit skin robes and blankets. *Journal of California and Great Basin Anthropology* 25 (1), 55–68.
- Yuan, D., Cheng, H., Edwards, R.L., Dykoski, C.A., Kelly, M.J., Zhang, M., Qing, J., Lin, Y., Wang, Y., Wu, J., Dorale, J.A., An, Z., Cai, Y., 2004. Timing, duration, and transitions of the last interglacial Asian monsoon. *Science* 304, 575–578.
- Zhang, X.L., Shen, C., Gao, X., Chen, F.Y., Wane, C.X., 2009. Use-wear evidence confirms the earliest hafted chipped-stone adzes of Upper Palaeolithic in northern China. *Chinese Science Bulletin* 55, 268–275.
- Zhang, D.J., Chen, F.H., Bettinger, R.L., Barton, L., Ji, D.X., Morgan, C.T., Wang, H., Chen, X.Z., Dong, G.H., Guilderson, T.P., Zhao, H., 2010. Archaeological records of Dadiwan in the past 60 ka and the origin of millet agriculture. *Chinese Science Bulletin* 55 (16), 1636–1642.
- Zhang, Y., Zhang, S.Q., Liu, D.C., Wang, C.X., Xu, X., Pei, S.W., Wang, H.M., Gao, X., n.d. New perspective on the Broad Spectrum Revolution in the transitional period

- between Pleistocene and Holocene in China: zooarchaeological study of Shuidonggou Locality 12.
- ZSKYNNMG – Zhongguo Shehuikexueyuan Kaogu Yanjiusuo Neimenggu Gongzuodui (Chinese Academy of Social Sciences Institute of Archaeology, Inner Mongolia Workgroup), 1985. Neimenggu Aohanqi Xinglongwa Yizhi Fajue Jianbao (A preliminary report of the excavation of Xinglongwa site in Aohanqi, Inner Mongolia). *Kaogu* 10, 865–874.
- ZSKYNNMG – Zhongguo Shehuikexueyuan Kaogu Yanjiusuo Neimenggu Gongzuodui (Chinese Academy of Social Sciences Institute of Archaeology, Inner Mongolia Workgroup), 1997. Neimenggu Aohanqi Xinglongwa Juluo Yizhi 1992 Nian Fajue Jianbao (A preliminary report of the 1992 excavation at the Xinglongwa site, Aohan Banner, Inner Mongolia). *Kaogu (Archaeology)* 1, 1–26.