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The significance of Shuidonggou Locality 12 to studies of hunter-gatherer adaptive strategies in North China during the Late Pleistocene

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A B S T R A C T

The effect of rapid climate change during the Late Upper Paleolithic on hunter-gatherers is attested by a variety of signals in the archaeological record. One of these, the spread of the microblade technology in North China, shows a particularly close relationship with climate change. The appearance of microblades and functionally related bone and ground stone technology at SDG12 is particularly revealing of this Late Pleistocene adaptive diversification in North China. SDG12 and other records suggest that microblade technology flourished in harsh environments that demanded high residential mobility. That in addition to their use in hunting weaponry, microblades were used in manufacturing the sophisticated cold weather clothing required for winter mobility, is shown by the presence of bone needles and a bone knife handle slotted to accept microblades. The SDG12 fauna and ground stone indicate an attendant shift from a more large game dominated, to a more plant and small game dominated diet that included net hunting and demanded a variety of production tasks that included net-making (spinning) and extensive stone boiling to maximize nutrient returns and as a step in manufacturing. We suspect these changes are the root cause of subsequent changes in social structure.

1. Introduction

Late Pleistocene global climate change profoundly affected hunter-gatherers. In particular, the two dry-cold events of this stage, i.e. the Last Glacial Maximum (LGM; ca. 24,500–18,300 a BP) and Younger Dryas (YD; ca 12,900–11,600 a BP), significantly challenged human survival abilities. Microblade technologies, one signal of resource intensification in North China (Elston et al., 2011), were principally responsible for successful human occupation of this area during these times.

While it is well known that microblade technology spread rapidly and broadly throughout Northeast Asia during the Late Pleistocene, the function of microblades is still under discussion (e.g., Elston and Brantingham, 2002; Chen, 2004, 2011; Elston et al., 2011; Yi et al., 2013). Some scholars argue for their function primarily as hunting weaponry used by highly mobile foragers (e.g. Lu, 1998; Elston and Brantingham, 2002; Goebel, 2002; Obata, 2002; Bazaliiskii, 2010; Elston et al., 2011); in contrast, others argue that craft and processing functions were more important, especially in cold climates, again by highly mobile hunter-gatherers (Dixon, 2010; Yi et al., 2013). It is clear in any case that microblades served multiple purposes (Obata, 2002), possibly different ones in different environments, preventing a clear "either or" settlement of the issue. Consequently, our time is better spent attending to the role of microblade technology in relation to broader adaptive strategies, i.e., what adaptive problems microblade technology solved, and the specific connections between the lithic technology, paleoenvironmental change, hunter-gatherer mobility, and social organization. The number of microblade archaeological sites reported in northern China has continued to increase (e.g., Zhao, 2006; Mei, 2007; Yin and Wang, 2007; Bettinger et al., 2010; Shi and Song, 2010; Zhang et al., 2011a,b), as have detailed environmental records, and precise regional chronologies, permitting synthetic discussion of microblade technology in relation to

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environment and technology in general. Shuidonggou Locality 12 (SDG12), which produced tens of thousands of microblade technological products as well as polished stone tools and bone tools, is especially informative in this regard.

In this paper, based on the analysis of findings from SDG12, as well as the summarization of relevant microblade sites in North China and the paleoclimate changes between 30 and 10 ka BP, we argue that 1) human adaptations displayed a remarkable diversity during the Late Upper Paleolithic (LUP) in this region, and 2) microblade technology, whose appearance and spread was synchronous with the climatic deterioration during this interval, played a decisive role in the more successful of these adaptations. Throughout this paper, all radiocarbon dates are calibrated unless otherwise specified.

2. Environment

Climate fluctuations during the last glacial period are globally revealed by several complexes, for instance, the records from the Guliya ice core (Thompson et al., 1997), Greenland ice cores (Dansgaard et al., 1993; Grootes et al., 1993), the Hulu Cave stalagmites (Wang et al., 2001), and the Chinese Loess Plateau (Xiao et al., 1995) (Fig. 1). The Greenland ice cores demonstrate that the rapid climate instability included over 20 warm episodes in the last glacial cycle, and some happened within only a few decades with a temperature change of 5–6 °C (Dansgaard et al., 1993). The extreme climatic variations during 30–10 ka BP can be termed as four phases in general, namely, "Marine Isotope Stage 3 (MIS3)", "Last Glacial Maximum (LGM)", "Bølling-Allerød (B/A)", and "Younger Dryas (YD)", dating as shown in Fig. 1.

MIS3 was a generally warm/wet phase. The Guliya ice core indicated strong climate variability on a centennial time scale (Thompson et al., 1997), and studies from northern China are relatively similar (e.g. Liu et al., 2000). Research on the Yuanbao section, Linxia in the western part of the Loess Plateau, showed that the climate between 31 and 25 ka BP was moderately warm and humid (Chen et al., 2004). A high-resolution pollen record from the Suancigou section in Gansu Province also revealed temperate and humid climatic conditions during the interval of 44–25 ka BP, when the vegetation was dominated by coniferous forest, consisting mainly of *Picea* and *Pinus* (Li et al., 2006). At Shuidonggou, the warm and moist environmental conditions during 30–24 ka BP allowed the growth of broad-leaf trees and sparse forest vegetation (Gao et al., 2008). High paleolake levels in the Tengger Desert of Northwest China were established from 35 ka uncal (uncalibrated, hereinafter) BP until 22 ka uncal BP, implying that the regional precipitation increased significantly (Zhang et al., 2002). Such conditions would have led to the formation of rich patches where plants and herbivorous animals flourished, facilitating human occupation of these areas.

A weakened summer monsoon and an intensified winter monsoon characterized the LGM of North China, causing reductions in temperature and moisture (e.g. An et al., 1991; Wünnemann et al., 2007). Pollen records from the Qilian Mountains (Herzschuh, 2006) and the Loess Plateau (Sun et al., 1997; Li et al., 2006) showed high frequencies of alpine and/or alpine desert vegetation, suggesting both dry and cold climatic conditions. These results are consistent with the evidence for lake levels. The paleolakes in the Tengger Desert shrank during the LGM, and completely disappeared around 18 ka uncal BP (Zhang et al., 2002). Meanwhile, deserts expanded to the south and east, and the strong winter winds led to deposition of the thick Malan Loess (Chen et al., 1997; Ding et al., 1999; Zhou et al., 2002). Compared to stages before and after the LGM, archaeological remains in northern China of this period are fairly rare (Barton et al., 2007), indicating that the environment deterioration adversely affected human subsistence.

The post-LGM oxygen isotope ($\delta^{18}O$) archive from the Hulu cave speleothems suggests a hemispheric increase in precipitation (Wang et al., 2001), and the $\delta^{18}O$ archive from Guliya ice core documents the enhanced temperature (Thompson et al., 1997) corresponding to the B/A warm phase. The summer monsoon intensity brought about the raise of lake levels, although these slight oscillations had only a minor impact on the water budget and did not recover the negative trend of the LGM (Wünnemann et al., 2007). During this time, a gradually warmer and wetter climate is documented by the increased woody plant component in the

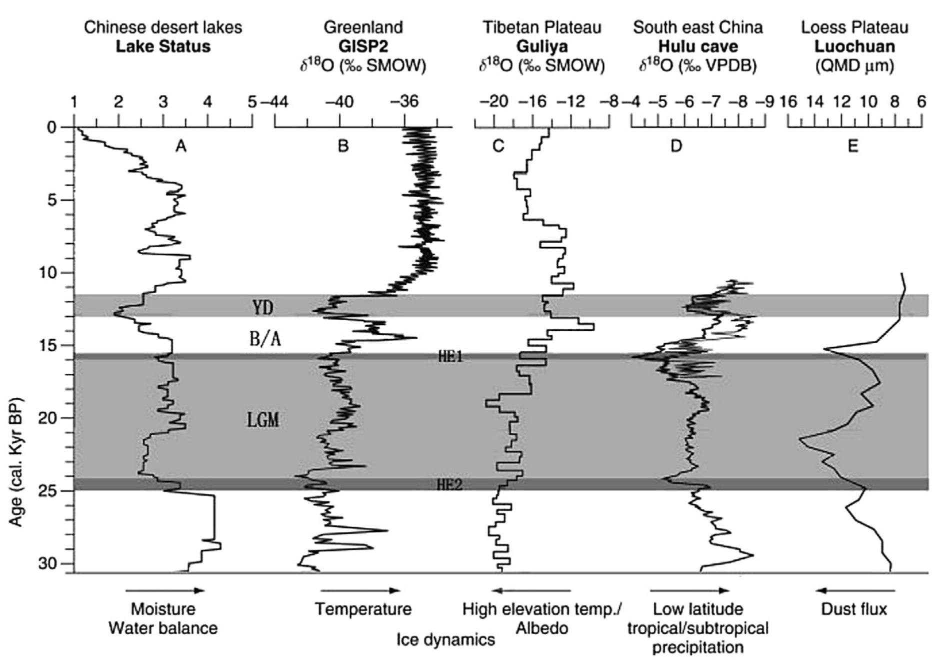

Fig. 1. Comparison of paleoclimate records. Adapted from Wünnemann et al. (2007), Barton (2009).

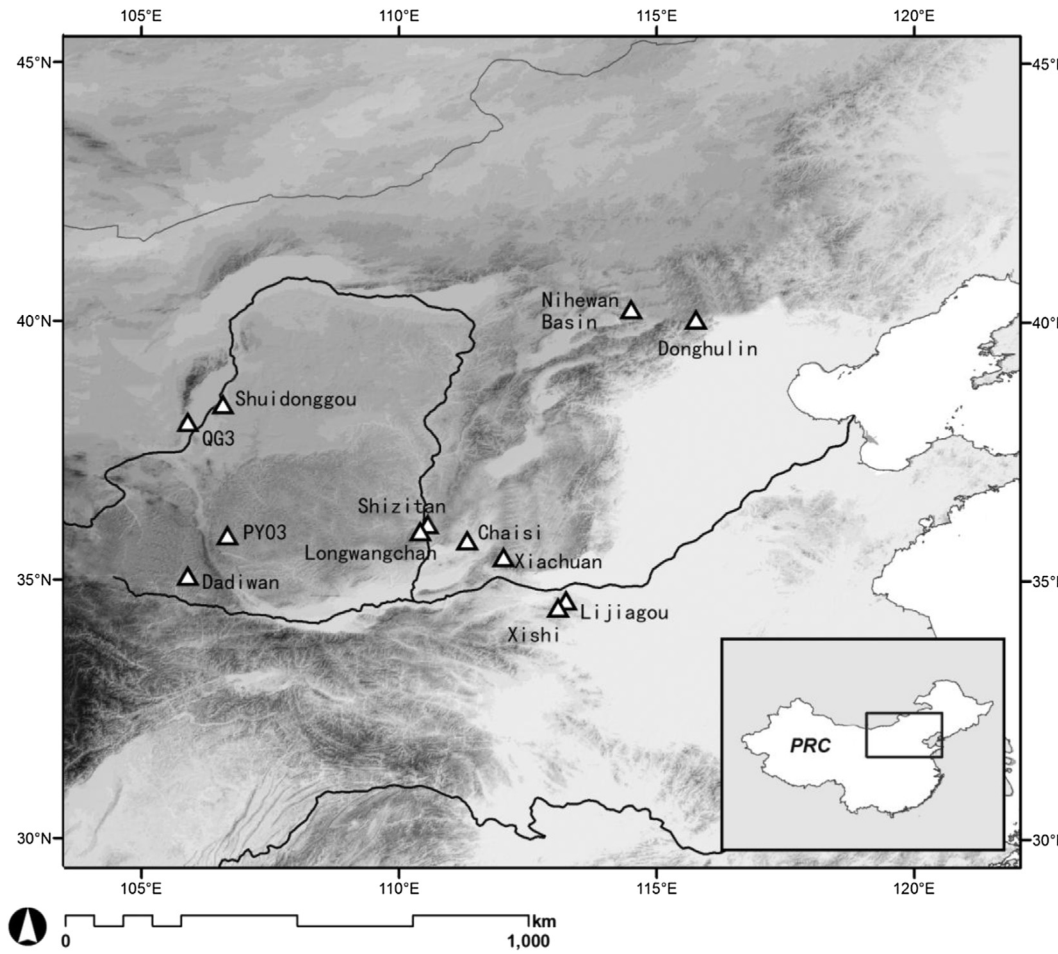

Fig. 2. Sites with unearthed microlithics discussed in this paper.

vegetation from the Suancigou section (Li et al., 2006), as well as the development of a second aeolian sand deposit with an incipient paleosol at site QG3 (Madsen et al., 1998). However, these short term developments were abruptly destroyed by the following YD event which was dominated by the winter monsoon and was notable for its drier, colder conditions along with increased seasonality mirrored in various records from China (e.g. Thompson et al., 1997; Wang et al., 2001; Wünnemann et al., 2007). Pollen analysis of the Haiyuan section in the Loess Plateau revealed that the landscape deteriorated into steppe and desert steppe from 11 to 9.8 ka uncal BP (Sun et al., 2007). The correspondent condition was also marked at site QG3, where aeolian sand formed, dating to 13.5–11.6 ka BP (Madsen et al., 1998). Granting local differences in its dating, the harsh YD appears to have begun and terminated abruptly.

3. Expansion of microblade technology in North China

It is clear that ancient environments profoundly affected prehistoric human subsistence-settlement systems, and as a consequence technology (including lithic technology) and social organization. Changes in lithic technology, however, are perhaps the best archaeological indicators of prehistoric subsistence-settlement patterns and change. Perhaps the most profound of these changes, at least in the Upper Paleolithic, is the advent of microblade technology. A brief summary of the expansion of this technology in China follows.

3.1. Early microblade technology in North China

Many Chinese Paleolithic sites have been reported in recent years, but well defined and dated microblade sites are still rare. In the 1970s, Jia et al. (1972) hypothesized that two major parallel traditions persisted from the Lower to Upper Paleolithic in North China: one is the Large Triangular Point and Chopper–Chopping Tool tradition (also called the Large Tool tradition); the other is the End Scraper and Burin tradition (or the Small Tool tradition). In the Small Tool tradition, lithic tool assemblages in northern China show a trend of size diminishing from early to late, producing the rudiment of microblade technological productions at first, and finally typical microblades. Actually, the technique for making long, narrow flakes was distinct from the one for producing microblades, but the misused definition profoundly impacted on Chinese scholars. One such antecedent site was Chaisi (also called Dingcun 77:01). Two dissimilar dating sets of 26,400 ± 800 uncal BP with shell (Shekeyuankaogusuo, 1980), and >40,000 uncal BP with charcoal (Li et al., 1980), makes this site questionable. Moreover, its stratigraphy is also challenged by scholars (e.g. An, 1983). So-called microblades from the Xiaonanhai site (charcoal from layer 6 resulted in a date of 24,100 ± 500 uncal BP, Shekeyuankaogusuo, 1980), the lower layer of Shuidonggou Locality 1 (Fig. 2), and the Shiyu site, dating to 28,945 ± 1370 uncal BP (Zhongkeyuankaogusuo [=Institute of Archaeology, Chinese Academy of Sciences], 1977), were also incorrectly classified as microblades but were in fact long and narrow flakes. After re-analyzing the lithics, Chen et al. (2010) indicated that the Xiaonanhai industry did not involve a microblade technology. Furthermore, Peng's (2012) reexamination of lithics from Shuidonggou Locality 1 concluded that there were no microlithics in the lower layer.

In addition to the above-mentioned sites, Xiachuan is cited frequently as an early microblade location. However, while microblade technology was certainly present, problems in dating (with dates ranging from 23,900 ± 1000 uncal BP to 16,400 ± 900 uncal BP; Shekeyuankaogusuo, 1978) and the lack of a clear association between these dates and a microblade technology, limit its reliability.

A more probable antecedent than any of the above is the Xishi Site, Dengfeng City, Henan Province, excavated in 2010, which produced three microcores and 82 microblades among the 8557 stone artifacts from its lower cultural layer, dated (on charcoal) to around 22 ka uncal BP (Gao, 2011). Equally convincing, and certainly one the earliest true microblade sites in China, is Shizitan locality S29 in Shanxi Province. Microblade technology is present in all seven of its cultural layers. While layer 7 has yet to be dated, layer 6 directly above dates to ca. 20,500 ± 100–ca. 18,090 ± 70 uncal BP (on charcoal and bone from hearths; Song, 2011). Longwangchan site is another of these early microblade sites. While there are discrepancies between its radiocarbon and optically stimulated luminescence (OSL) dates, with the two ranging from 29 to 21 ka BP, a reasonable estimate would be 25–27 ka BP (Zhang et al., 2011a). Younger than this is PY03, Ningxia, which yielded one microcore and two microblades, dated to 18,350 ± 70 uncal BP (Ji et al., 2005). Together these sites demonstrate quite convincingly that microblade technology was in use by the hunter-gatherers of northern China both before and during LGM, but neither widely nor intensively. Further, the spread of microblade technology immediately after LGM was relatively slow.

Relatively few North China microblade sites have been dated to the interval between LGM and YD, but enough to suggest at least in a general way why the technology was adopted and subsequently spread. The site of Dadiwan was occupied from MIS3, firstly by foragers with flake technology. Microblade technology appears in Component 4, dated 20–13 ka BP, and increases in frequency in the Component 5 immediately above, dated 13–7 ka BP (Bettinger et al., 2010). At QG3 site, microblade technology is present but accounts for only 21% of the lithic assemblage in Lower Sand I, dated 15–13.5 ka BP, then increases to 68% in the late-YD Sand II assemblage, dated 12.0–11.6 ka BP (Elston et al., 1997). Erdaoliang site, radiocarbon dated to 18,085 ± 235 BP, is the only true microblade site of this age in the Nihewan Basin (Xie et al., 2006), where a flake technology is much more common, as shown by such sites as Meigou, Weidipo and Xibaimaying (Xie and Yu, 1989; Mei, 2006). Altogether, these data suggest that microblade and flake technologies coexisted in the interval between LGM and YD, but that flake technology dominated. This relationship reversed at the very end of the Upper Paleolithic when microblade technology became the more dominant.

Microblade sites dating to the latest Paleolithic are widespread across the whole of northern China, including, for example, the Hutouliang site cluster, Jijitan (Xie et al., 2006), Songshan (An, 1978), the Paleolithic layer of the Lijiagou site (Zhang et al., 2011b), Donghulin (Zhao, 2006), and many others. Perhaps equally interesting is that as microblade technology increases, the flake technology synchronously disappeared. In addition to this, LUP hunter-gatherer adaptations became more intensive and diversified, as shown by the appearance of polished adzes and axes (presumably for wood working), grinding stones for plant processing, bone awls and needles for baskets and clothing, suggesting an increase in overall subsistence intensity and the increasing use of low-ranked resources. There are hints of these here and there in earlier sites, but not nearly in the amounts and frequencies observed in the LUP. However, for every large, well-stratified, and intensively occupied YD site there are many more with limited, essentially surficial assemblages. For example, numerous archaeological sites have been reported recently from the margins of the Tibetan Plateau (see Madsen et al., 2006; Yi et al., 2011), some with sparse buried assemblages, chiefly microblades or cores, but mostly surficial hearths and microblade/core surface scatters that analysis has shown were occupied during the LUP. Such remains are common throughout North China and while the bulk of these are undated, it seems fairly clear that, as the Tibetan Plateau examples, most were occupied during LUP.

The lingering question, then, is why did microblade technology replace simple flake technology in the terminal Pleistocene? To answer this requires analysis of those rare sites that provide more or less complete evidence regarding seasonal variation in regional subsistence-settlement patterns, SDG12 being one of these.

4. Shuidonggou (SDG) Locality 12

Located on the Biangou River, Ningxia Hui Autonomous Region, SDG12 is a deeply stratified site with 9 m of deposit, subdivided into four strata, Strata 3 containing Paleolithic remains (see Fig. 3) (Liu et al., 2008) dated by radiocarbon and OSL to 12.2–11.0 ka BP (Liu et al., 2008).

The excavation of SDG12 in 2007 covered an area of 12 m^2 and produced an extensive cultural assemblage, including roughly 9000 pieces of chipped and ground stone, more than 13,000 fragments of burnt rocks, more than 10,000 pieces of animal bone, and multiple bone tools including needles, awls, and one knife handle (Gao et al., 2009, 2013; Yi, 2013; Yi et al., 2013; Zhang et al., 2013)(see Fig. 4 and 5). While microblades and microblade cores make of only 18.3% of the lithic assemblage, most of the polyhedral cores and the chipping waste (75% of all chipped stone) are likely the byproducts of microblade production. Retouched flake tools are also present, but irregular rather than formal (Yi, 2013; Yi et al., 2013). The ground stone assemblage is small ($n = 22$) but well-made and functionally diverse and includes a whetstone, pestle, milling stone, and ground axe fragment (see Figs. 48, 51, 52 and 76 in Gao et al., 2013), suggesting plant processing, wood working, and tool refurbishing. Microblade technology, however, was clearly more dominant than any of these at SDG12.

As noted earlier, use as hunting weaponry is the most generally accepted function of microblade technology on the basis of plentiful remains of inset organic arrowheads and points from Northeast Asia. The discovery of a bone knife handle at SDG12, however, provides much stronger evidence for microblade use in connection with butchering, craftwork, or material processing. Slotted for microblades, the SDG12 bone knife handle shows exactly how the microblades were used, probably for fine cutting, and in combination with small-eyed bone needles, suggests that sewing, and more broadly the manufacture of specialized winter clothing to match the severely cold YD environment, was one of the central SDG12 activities (Yi et al., 2013).

In addition to the items (e.g., sewing needles) that suggest clothing manufacture, a large-eyed bone needle attests to weaving, perhaps for cordage intended for snares, hunting nets, and possibly, again, clothing. According to the paleoenvironmetal study of SDG12, *Typha* and *Acorus* were identified from the pollen record (Liu et al., 2008). Such plants are still used for spinning nets today, and might also have been used by ancient people.

Perhaps also connected with manufacturing is the vast quantity of fire-cracked rock documenting the earliest evidence for stone-boiling, possibly with skin containers (Gao et al., 2009), which may have been a step in hide- or wood-working, or simply a way of

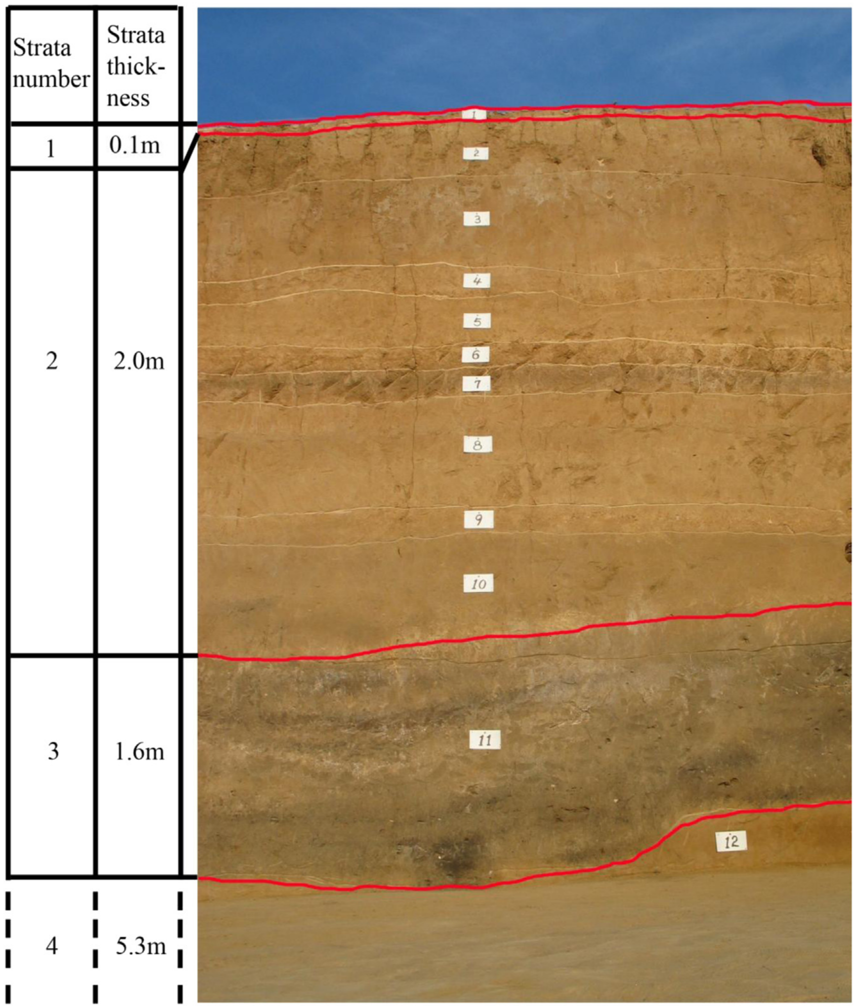

Fig. 3. Stratigraphic profile of SDG12.

extracting extra nutrients from plants and animals, i.e., a sign of intensification and expanded diet breadth.

That foragers at SDG12 expanded their diet breadth is shown not only by the presence of ground stone tools implying the exploitation of plants, but also by faunal remains, which unlike those from earlier sites in the area are relatively well preserved and predominantly hare (*Lepus* sp.; 57.4%) and Przewalsky's gazelle (*Procapra przewalskii*; 22.2%), the overwhelming numbers of the former in particular attesting to quite low marginal rates of return (Zhang et al., 2013).

It is surely significant that hunter-gatherers, who largely abandoned northern China during the LGM, did not do so during the comparably cold–dry YD, presumably because they had developed new behaviors and perfected new technologies more suited to such harsh conditions. The change is clearly shown by the repeated, intensive occupation of SDG12, which while not fully representative of human adaptation in North China during the YD attests in at least a general way to this successful adaptive change and the central role that microblade technology played in these developments.

5. Discussion and conclusion

Mobility strategy was briefly described by Kelly (1983) as "the way in which hunter-gatherers move about a landscape over the course of a year", characterized as a positioning strategy which may be most responsive to the structural properties of the surroundings (Binford, 1980). Hunter-gatherers move for many purposes, including collecting information on resources, establishing exchange and mating networks (Chen, 2004), but mainly for foraging food, that is to say, mobility is largely a food acquisition strategy. Whether hunter-gatherers employ residential or logistical mobility is affected by the structure of resources in their environment. Food availability differs as situations in specific environments are dissimilar, e.g., patchy versus homogenous resources, a seasonal versus seasonal climates, which means that foragers would have adopted different mobility strategies in distinct circumstances, and the pattern would alter when the climate changed in a region. Because residential mobility tends to increase when environmental productivity falls (Binford, 1980; Kelly, 1983, 1995), hunter-gatherers switched to a higher mobile strategy to successfully subsist in the harsh environments of LGM and YD.

Ethnographic evidence shows that technology is affected by settlement mobility of forager societies (Shott, 1986). In Binford's forager-collector model, curated technologies are correlated with logistical mobility, while the expedient ones relate to residential mobility (Binford, 1980). The climate of the Late Pleistocene was fluctuating considerably, making the availability of resources unstable, and accordingly encouraged a technological transformation.

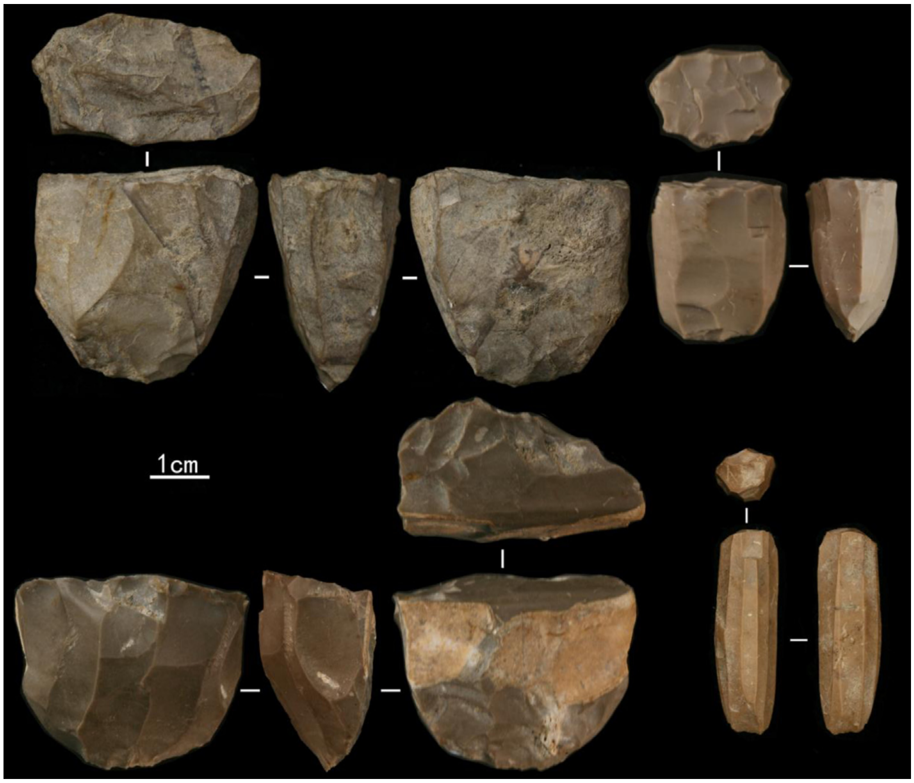

Fig. 4. Microcores unearthed from SDG12.

The above-mentioned archaeological phenomena reveal that the diffusion of microblade technology in North China was closely related to these environmental changes. Though the suggestion is controversial, microblade technology may have originated in Siberia before 35 ka BP (Kuzmin, 2007), and then spread to Mongolia, China, Korea, and Japan. As we showed above, a microblade technology emerged in China after 29 ka BP, and slowly dispersed in the following 15,000 years along with a flake technology. During the cold YD, microblade remains were widespread in the whole of North China, but chronologically secure flake remains are almost absent. These phenomena indicate that the dispersal of microblade technology in North China during the Late Pleistocene was a sign of mobility change which might have been more appropriate for cold conditions.

The diffusion of microblade technology presented a slow tendency before and during LGM, which was shown by its scarce remains. The LGM in North China was fairly severe. We might therefore ask why a microblade technology did it not widely spread during LGM if, as we suggested, it was suitable for high mobile hunter-gatherers surviving in cold weather.

We would argue that the slow transmission was mainly because the technology was too newly invented, and the time was too tight after its invention for foragers to adopt during LGM on a large scale. The harsh LGM resulted in instability and scarcity of resources and an inhospitable environment in which to live. To deal with these situations, some foragers changed their mobility strategies by becoming more mobile, as well as intensifying the exploitation of patches and including all the high/low-ranked game/plant resources. Even

Fig. 5. The bone handle and needle unearthed from SDG12.

though some hunter-gatherer groups switched their mobility patterns, the quantity and the effect were not sufficient for a microblade technology to disperse extensively. For the groups that had not mastered the new technologies, the sudden LGM was too challenging for human survival and cultural transmission, and it caused the reduction in settlement, though not the complete abandonment of northern China. In this phase, the ones who successfully survived with a microblade technology accumulated positive experiences mainly marked by the advantage of microblades and higher mobility to be able to subsist in the severe environment.

The climatic amelioration after LGM produced warmer temperatures and much more abundant food resources in northern China, which offered hunter-gatherers an opportunity to recolonize the area on a larger scale. Forager groups that abandoned North China came back once again synchronizing with a traditionally lower mobility and flake technology. Simultaneously, groups with microblade technology retained their subsistence practices in the region. Their total mobility was relatively low and the advantages of microblade was not urgently needed in these gentler conditions, so the technology did not have a good chance to spread in the population migrations and cultural exchanges between different groups, but developed with flake technology in parallel and even secondarily.

High living risk was produced by the environmental deterioration of the YD, and its influence was especially pronounced in middle and high latitudes. Due to the sharp decline of temperature and precipitation, resource patches degenerated, and some of them even disappeared, which made foragers spend more time on searching for food and other necessities. Torrence (2001) indicated that strategies for the procurement, manufacture, design and use of tools and techniques were strongly influenced by the severity of the risk defined by the probability of failure. Highly structured tools will be used to reduce the frequently encountered foraging risks (Wiessner, 1982). During the YD, the failure of hunting would have been lethal, and thus curated tools were required to ensure the success in hunting. In North China, high quality stone is extraordinary rare and diminutive, as Gao and Pei (2006) summarized that quartz, quartzite, and igneous rocks were major lithic materials, which were not mechanically appropriate for manufacturing formalized lithic tools (Andrefsky, 1994). In order to save time for seeking stone with good quality, saving the raw material was another major issue. For mobile hunter-gatherers, particularly the ones living in LUP who faced a special subsistence pressure, the time saved from finding raw materials could be used to get more food. Furthermore, the production of sophisticated clothing to maintain high mobility in the cold weather was also important. Wales (2012) proposed that Neanderthals in the coldest regions would have covered 70–80% of the body during the winter, and Upper Paleolithic modern human wear was probably more sophisticated in comparison with Neanderthals. In China, this prediction is supported by the archaeological finding of SDG12. The bone handle from SDG12 to inset edges indicates that lithics with narrow and parallel edges were necessary. Compared with the long-lasting flake technology, the microblade technology satisfied all these demands, and consequently the successful experiences accumulated in the LGM made the microblade technology widely popular in North China with the human migrations and cultural exchanges between different forager groups.

The diversity of the adaptations was another extrusive character in the LUP archaeological record. Accompanying the change of social organization and microblade technology, polished stones, grinding stones, bone tools were involved, as well as the broadened spectrum of food resources. The great quantity of archaeological sites tells us that these diversified skills helped foragers to fight against the severe environment, and to get enough resources, especially food. Bar-Yosef (2002) assumed a change in social structure among the Late Natufian people in Israel occurred because of the alternative food acquisition strategies, such as increased mobility. In Late Holocene central Alaska, with the decrease of large mammal populations, humans shifted to a broader-spectrum diet, focused more on seasonally abundant resources like caribou and fish instead of multi-seasonal hunting focused on bison. This shift finally resulted in settlement storage and logistical mobility geared to the seasonally overabundant resources (Potter, 2008). The YD in North China was likely a time of similar changes in settlement, subsistence, technology, and organization. As many large animals became extinct, the hunter-gatherers of North China responded by changing their tactics and tool kits, developing a broad range of adaptations all centered around microblade technology. The social progress in the Middle East and Alaska probably happened subsequently in North China as well.

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