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Technology diffusion and population migration reflected in blade technologies in northern China in the Late Pleistocene

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Abstract In recent years, the origin and evolution of modern human behaviors have become a common topic of research in Paleolithic archaeology. One important part of modern human behavior, blade technology, was once thought to be unique to modern humans. Recent studies have suggested that variations in blade technology do not fully correspond to modern populations. However, the standardization, diversity, discontinuity in terms of time distribution, and differences in spatial distribution of blade technology give it an important role in discussions of modes of adaptation, diffusion of technology, and population migration of hominins. By categorizing the major blade assemblages in China, we show that there were two blade reduction methods in northern China: the Levallois method and the prismatic method. Dating back 30000–40000 years, the Levallois and prismatic blade method combined to form the characteristics of the early stage of the Upper Paleolithic. Artifacts bearing such characteristics are located in Northwest China, Northeast China, and the Qinghai-Tibet Plateau. The unearthed blades are similar in technological organization and are connected geographically with those discovered in Siberia and Mongolia, which also indicates a distinct border from those discovered in northern China. This fact is suggestive of population immigration. About 25000–29000 years ago, a combination of prismatic blades and microblades was developed in the hinterland of China; however whether it can be regarded as the representative of population migration or only a technological adaption remains undetermined. We suggest that the system of production of different blades should be distinguished in the study of blade assemblages and that different blade methods should not be integrated into a single technical system to discuss technology diffusion and population dispersal.

Keywords North China, Late Pleistocene, Blade technology, Technology diffusion, Human migration

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1. Introduction

The evolution of *Homo sapiens sapiens* and its behavior is currently a common research topic in the paleoanthropology and archaeology of the Paleolithic (Gao et al., 2010). Human fossils are relatively rare, while preserving abundant scientific information held in artifact remains from the Paleolithic plays an increasingly important role in the study of modern human evolution (Gao, 2014). Particularly in the discussion of the evolution of the modern human behavior,

stone tools, bone tools, ornaments, and animal fossils, have served as a foundation for our understanding of human behavior and adaption in relation to the evolution of *Homo sapiens*, and a large number of relevant research results have been reported (Aubert et al., 2014; Brown et al., 2009;

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Conard, 2009; Conard et al., 2009; Gao et al., 2003; Guan et al., 2012; Henshilwood et al., 2002, 2004; Li et al., 2014a; Peng et al., 2012; Vanhaeren et al., 2006; Zhou et al., 2013). Blade technique is an important feature of modern human behavior, regarded by some researchers as unique to modern human (Schick and Toth, 1993; Foley and Larh, 1997; Sherratt, 1997). However, it should be noted that with increasing depth of research, the temporal and spatial distribution of blades have been extensively expanded from the original concepts. Blades have been discovered from Middle Paleolithic and even at the end stage of Lower Paleolithic. Human fossils discovered with blades are also diversified beyond merely those of *Homo sapiens sapiens* (Bar-Yosef and Kuhn, 1999; Conard, 1990; Delagnes, 2000; Delagnes and Meignen, 2006; Kozlowski, 2001; Johnson and McBrearty, 2010; Meignen, 2000; McBrearty and Brooks, 2000; Shimelmitz et al., 2011; Wilkins and Chazan, 2012). Although they had a relatively higher degree of standardization in the Paleolithic period than other objects did, blades can be made using different methods. Its existence can be dated back to East Africa and South Africa over 500 thousand years ago. Later it can be traced in West Asia, Europe, and Africa, without, however, a broad distribution. Blade creation was not a common behavior for hominins in Africa, Europe, West Asia, Central Asia, or Northeast Asia until the Upper Paleolithic, beginning around 40–50 ka BP. In China, Australia, and America, blades did not develop into a common tool or even exist 10–40 ka BP.

Although many scholars no longer believe that the existence of blades marks the existence of modern humans, and it has been recognized that blade as a pattern of human behavior lacks one-to-one correspondence with particular species of hominin (Bar-Yosef and Kuhn, 1999; Conard, 1990), the standardization, diversity, discontinuity in terms of time distribution, and differences in spatial distribution of blade technology make it of potential significance in discussions of adaptation modes, technology diffusion, and population migration of hominins. China has fewer blade assemblages from the Paleolithic than other regions do, which makes it more idiosyncratic than those of the same period in western Eurasia, Siberia, or Mongolia. In this article, we discuss the main blade assemblages in China, based on which we reflect on the role of blade technology in human behavioral evolution in China and their archeological significance.

2. Blades and blade technology

A blade is defined as a flake detached from a stone core with parallel or nearly parallel sides, and a length double its width or longer (Bordaz, 1970; Bordes, 1968). Such a definition, emphasizing dimensions, may expand the scope of blades, considering that similar objects can be produced using different flaking methods (Li, 2012). For example, some objects with discoid cores (3.7%) share morphological similarity with blades (Eren et al., 2008). However these elongated flakes have a completely different technological meaning than a systematic production of blades. Therefore, a blade should be defined additionally by technological attributes. In this article, we defined a blade as a flake detached from a prepared core with parallel or nearly parallel sides and straight ridges on the dorsal side; the length doubles the width at least and usually longer, and the width exceeds 12 mm (Li, 2012). Even after adding technological attributes to its definition, some long flakes with similar outlook are easily misjudged to be blades. Therefore the accuracy of blade distinction should be further enhanced by comprehensively considering other lithic objects discovered in the assemblages.

A flaking technology is a system consisting of multiple procedures, usually divided by scholars into “technique” and “method” (Inizan et al., 1999; Inizan, 2012; Pelegrin, 1995; Tixier, 1967). “Technique” includes external conditions associated with flaking, including the texture of hammer (hard or soft), posture (direct percussion, indirect flaking, pressure applied etc.). “Method” denotes the well-organized plan in the mind of knappers, expressing the idea of the expected product, including preparation of the core shape, platform, and flaking faces. Various technological systems have been discovered for producing blades, and each corresponds to a distinct temporal and spatial distribution.

For now three flaking methods have been summarized (Boëda, 1988, 1995), including the Levallois method, the prismatic method and the Hummalian method. The first two methods were more commonly seen and were developed into multiple variant methods, while the third method is relatively limited. A hard hammer was frequently used in the Levallois method, with which the flake was detached from a flat-faceted core using a recurrent method. Such method mainly existed during the transition of the Middle and Upper Paleolithic as well as during the early stage of the Upper Paleolithic (Figure 1a). In the prismatic method, a longitudinal ridge was first prepared bifacially and then flaked along the ridge to produce the first blade, known as the crested blade, followed by more blades detached along the ridges produced by former blades on the core (Figure 1b). This flaking method is connected with multiple techniques, including hard hammer percussion, soft hammer percussion, indirect flaking, and pressure flaking. It is also a long-lasting method, occurring from nearly 500 ka BP to the Holocene.

3. Paleolithic sites with blades in China

Discoveries of blades are not rare in Paleolithic sites in China. Apart from the typical blades unearthed in sites of late stages of the Late Pleistocene (Boëda et al., 2013; Chen and Zhang, 2004; Chen Q J et al., 2006, 2009, 2010; Gao et al., 2013a, 2013b; Li, 1993; Jia et al., 1974; Ningxia Mu

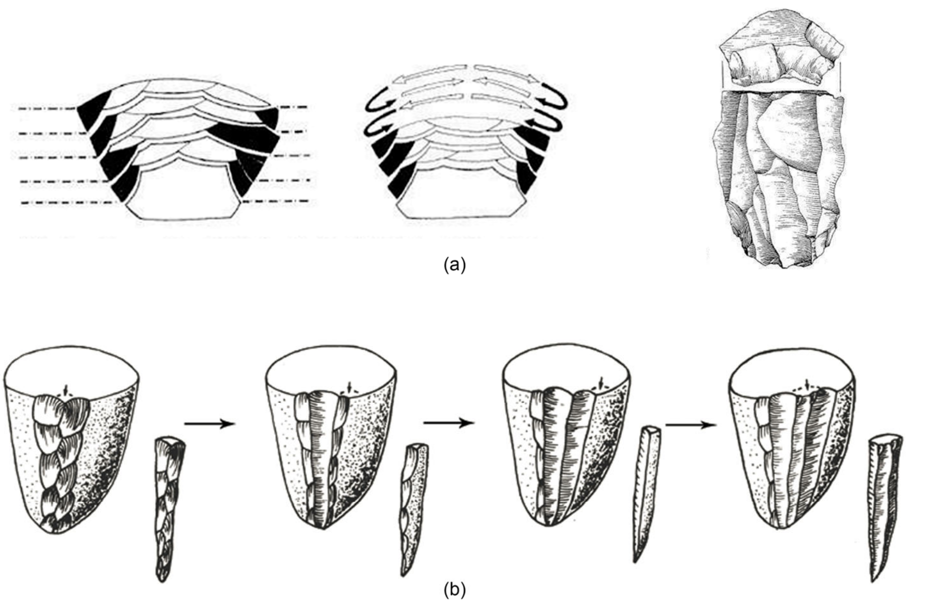

Figure 1 Illustration of different methods for blade productions. (a) Levallois flaking pattern and Levallois blade-cores (Boëda, 1988); (b) sequence diagram of prismatic blade flaking (modified after Bordaz, 1970).

seum et al., 1987; Ningxia Provincial Institute of cultural relics andArchaeology, 2003; Zhang et al., 2006), blades have been reported in some early Pleistocene sites (e.g., the Xiaochangliang site) (Huang, 1985; Chen et al., 1999). However it should be noted that the so-called blades excavated from the Xiaochangliang site are few and of an irregular shape (Li, 1999); diagnostic products of blade technology (e.g., crested blades) remained undiscovered. Based on the strict definition of blades and blade technology, the findings believed to be blades are not products of blade reduction but rather by-products of other flaking methods and are thus excluded from the discussion of this article. We will focus on the types of blade technology existing in the late stage of the Late Pleistocene, their temporal and spatial distribution, and their archaeological significance.

Blades are mainly distributed in the North China and the Qinghai-Tibet Plateau, and up to the present time, no reliable discoveries of blades in South China have been reported (Figure 2). The temporal distribution of those sites mainly corresponds to Marine Isotope Stage 3 (24–59 ka, MIS 3). Blades were produced with the Levallois and prismatic methods, and the techniques used to produce the blade including striking with a hard hammer, indirect flaking, and pressuring; flaking with a soft hammer was probably also performed. Blades discovered in assemblage levels usually indicated a combination of multiple flaking methods for blades and non-blade products. These assemblages can be divided into two groups, namely those with blades produced with the Levallois method and the prismatic method, and those with blades produced with the prismatic method and the microblade method. Some blade samples were also collected on the surface; however due to their small numbers, only a single flaking method could be identified.

3.1 Initial Upper Paleolithic (IUP) sites

Assemblages representing IUP are featured with a combination of the Levallois method and the prismatic method. Stone tools include the most common types of the Upper Paleolithic, such as end scraper and burins (Kuhn, 2003; Kuhn and Zwyns, 2014). A typical representative of this stage is the Shuidonggou site (Locality 1 and 9), alongside the Humashibazhan site in Heilongjiang Province and the Luotuoshi site in Xinjiang.

3.1.1 Shuidonggou site

Twelve Paleolithic localities in the Shuidonggou basin have been studied. Blades were discovered in the lower cultural layer at Locality 1, the cultural Layers 5a and 7 at Locality 2, and Locality 9 (Chen et al., 2012; Gao et al., 2013b), dated to 33–43 ka BP (Gao et al., 2013b; Li et al., 2013a).

The early excavation of Locality 1 may have caused unreliable correspondence between the age of the cultural layer and the archaeological materials (Gao et al., 2008a; Li et al., 2013a). The age of the Paleolithic cultural layer was narrowed to 33–43 ka BP through a series of chronology studies (Liu et al., 2009; Morgan et al., 2014; Nian et al., 2014a). Blanks were mainly produced with the method of direct hard hammer flaking through several methods including Levallois flake method, prismatic method, Levallois blade method, and simple core-flake and bipolar methods (Figure 3a, f) (Brantingham et al., 2001; Peng, 2012; Peng et al., 2014). The stone tools are mainly scrapers and end scrapers and burins were also discovered. A new study focusing on the 2078 lithic artifacts from the excavation of Locality 1 in the 1980’s, show 54 blade cores made using the Levallois blade method, and 10 made using the prismatic method, accounting for 49.1% and 9.1% of the total cores,

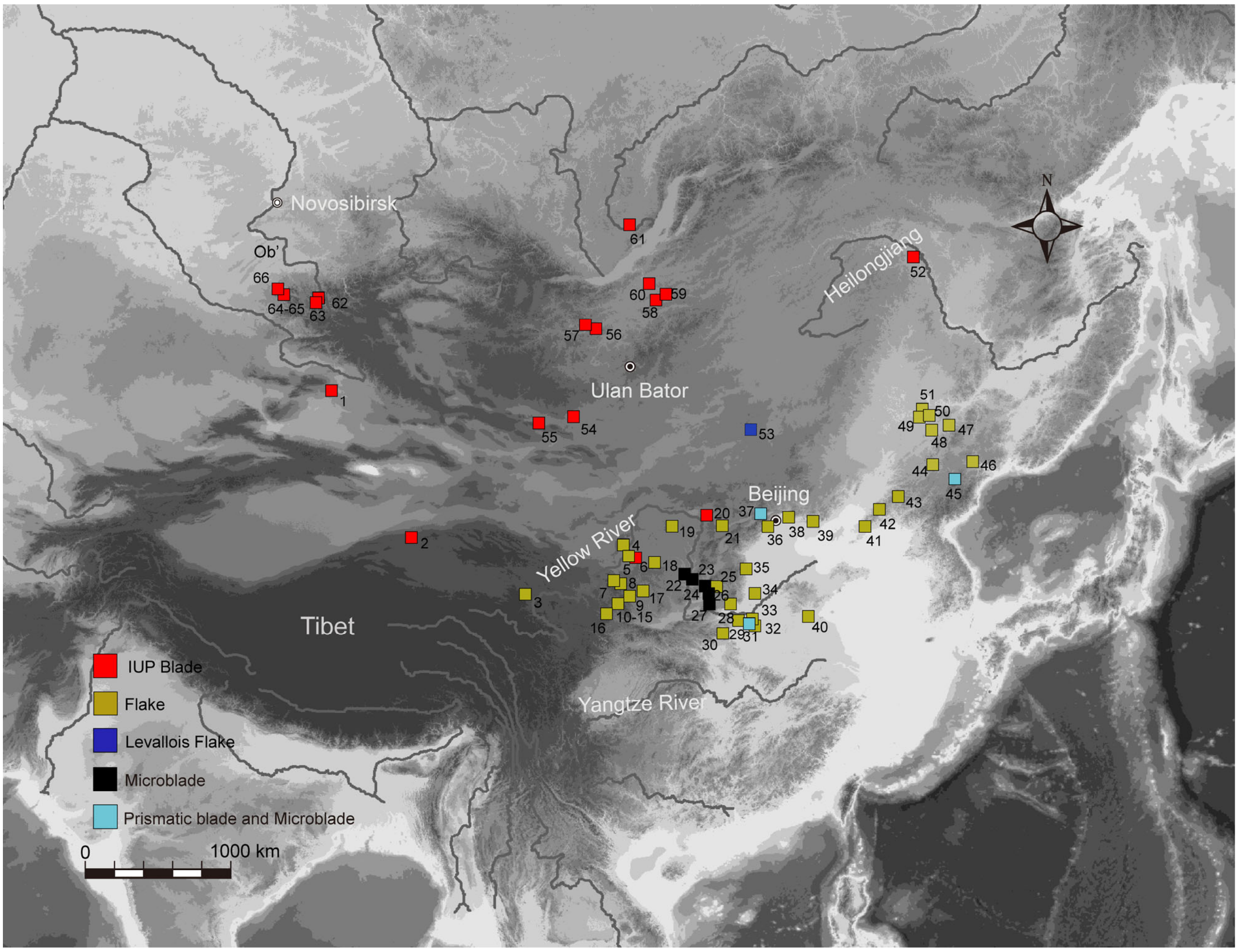

Figure 2 Major Paleolithic sites in North China and surrounding areas dated into MIS3 (~59–24 ka). 1, Luotuoshi; 2, Lenghu 1; 3, Heimahe1; 4, Pigeon Montain 1; 5, Shuidonggou locality 2, 7; 6, Shuidonggou locality 1, 9; 7, TX08; 8, TX03; 9, GY03; 10, Shuangbuzi; 11, Changweigou; 12, Xujiacheng; 13, ZS08; 14, ZL05; 15, Shixiakou 2; 16, Gutougou; 17, Liujiacha; 18, Sala Wusu; 19, Wulanmulun; 20, Yushuwan; 21, Shiyu; 22, Longwangchan; 23, Shizitan 29; 24, Dingcun (7701); 25, Licunxigou; 26, Dingcun (Chaisi); 27, Xiachuan; 28, Tashuihe; 29, Beiyao; 30, Longquandong; 31, Xishi; 32, Huangdikou; 33, Laonainaimiao; 34, Xiaonanhai; 35, Dangcheng; 36, The Upper Cave; 37, Youfang; 38, Wangfujing; 39, Zhuancun; 40, Heilongtan; 41, Gulongshan; 42, Xiaogushan; 43, Miaohoushan; 44, Xianrendong; 45, Shirengou; 46, Shimenshan; 47, Xuetian; 48, Zhoujia Youfang; 49, Yanjiagang; 50, Guxiangtun; 51, Huangshan; 52, Shibazhan; 53, Jinsitai; 54, Tsagaan Agui; 55, Chikhen Agui; 56, Orkhon 1 & 7; 57, Tolbor 4; 58, Kandabaevo; 59, Tolbaga; 60, Varvarina Gora; 61, Makarovo 4; 62, Kara Bom; 63, Kara-Tenesh; 64, Ust-Karakol 1; 65, Denisova cave; 66, Anui 2.

respectively. It also includes 130 standard blades and 424 elongated flakes, accounting for 7% and 22.7% of the total flakes, respectively (Peng et al., 2014).

For Locality 2, blade cores were only discovered in cultural Layers 7 and 5a, which were determined to be a Levallois flat-faced core and a semi-prismatic core, respectively. The stratigraphic relationships between these two cores clearly show that they can be dated back to around 32–41 ka BP, with comprehensive stratigraphic correlation and AMS^{14}C age determination (Li et al., 2013b).

The flaking method used to produce the stone artifacts unearthed from Locality 9 resembles that of Locality 1. Among the 417 lithic artifacts, 1 blade core made using the Levallois method and 2 made using the prismatic or semi-prismatic method were determined, representing 11.1% and 22.2% of the total cores, respectively. There were 45 intact blades and 104 fragments, accounting for 7% and 38.1%, respectively (Peng et al., 2013). The age of remains dated with an optically stimulated luminescence technique (OSL) was around 27–42 ka BP (Pei and Liu, 2013). This result was only of reference value, considering that the cultural layer was located close to the surface and that there was poor consistency between the OSL dating results and the depth of stratum.

Discovery of blades was also reported at Localities 7 and 12 in Shuidonggou (Pei et al., 2012; Wang et al., 2013). The extremely low proportion of the alleged "blade" in Locality 7, accounting for only 0.2% of total unearthed stone artifacts, indicated the possibility that these may be unexpected products of simple flaking. The remains at Locality 12 were mainly microblades, with no blade cores or products bearing technological features of blades (Yi et al., 2015), which

Figure 3 Blades and cores of different technical types unearthed in IUP remains in northern China. (a)–(e) Levallois blade-core; (f)–(h) prismatic blade-core. (a), (f) Shuidonggou Locality 1; (b) (c) Yushuwan; (d), (h) Luotuoshi; (e), (g) Shibazhan.

indicated that these blades may be by-products produced from a prepared stage of the reduction of microblades.

3.1.2 Shibazhan site

The Shibazhan site has been repeatedly excavated; however, the detailed report on locality 75075, explored in 2005, is the only study that has been detailed published (Wei and Gan, 1981; Zhang et al., 2006). Twenty-four stone artifacts were excavated from undisturbed Layer C, including 1 semi-prismatic blade core (4.2%), 4 intact blades (16.7%), and 3 blade fragments (12.5%). The age of the layer, dated by OSL, was around 24.7±1.7 ka BP (Zhang et al., 2006).

Preliminary observation of lithic materials in 1975 and 1976 showed that not only prismatic blade cores but also Levallois flat-faced blade core existed in the assemblage (Figure 3e, g). However, due to the large number of localities at the site, the specific corresponding relationship between the layer and the archaeological materials requires further determination.

3.1.3 Luotuoshi site

All stone artifacts discovered at this site were collected on the surface and shared the technological style of those discovered at Shuidonggou Locality 1, including Levallois blade core, prismatic blade core (*N*=7, 8.3%), blade (*N*=116, 22.7%) and end scraper (*N*=8, 5.2%) (Figure 3f, h). Despite the difficulty of achieving absolute chronological data, it can still be understood by technological features that stone artifacts here were products of the Initial Upper Paleolithic, when large blades were mainly produced (Derevianko et al., 2012; Peng, 2012).

3.1.4 Jinsitai Cave site

During the 2000 and 2001 excavations, this site was believed to contain three cultural layers, namely upper, middle, and lower. The lower layer was supposed to feature small flake tool industry, and the middle layer inherited the flake tool industry while also containing large numbers of pebble tools and certain products with Levallois features. The upper layer was represented by microblade industry (Wang, 2006; Wang et al., 2010). The corrected ages for the lower and middle cultural layer by AMS ^{14}C were 41414±223 a (BA04480) and 27888±314 a (BA04479), respectively (Wang et al., 2010). Our observation of some of the stone artifacts excavated in 2000 and 2001 resulted in the discovery that the lower cultural layer did not correspond to small flake tool industry and some of them featured clear Levalloisian characteristics. The stone artifacts from the middle layer did not only include three Levallois flakes and blades as had been believed by scholars but also a true Levallois core existed (Figure 4), which was supported by the conclusions of other researchers (Deng, 2012). The samples newly excavated during 2012 and 2013 included Levallois cores and Levallois points, which were discovered from the lower layer of the sequence. Blades were rarely found. Few end scrapers (*N*=0) and burins (*N*=1), which were common in Upper Paleolithic, were found in middle and lower layers at Jinsitai, indicating significant difference from the lithic assemblage discovered at Shuidonggou Locality 1.

The Jinsitai site and Shuidonggou Locality 1 served as representative sites containing large blades, based on which the distribution and dispersal of blade techniques in North China were discussed (Gao et al., 2013a). Further technological assessment is required for stone artifacts discovered in Jinsitai Cave; however, based on currently available materials, there is still quite a remarkable difference from stone artifacts from Shuidonggou Locality 1. The lithic assemblage from Jinsitai cave does not belong to flaking system with blade as its major products, and the retouched tools are a middle Paleolithic toolset mainly based on side scrapers. Therefore we prefer here to categorize the non-microblade layers of the Jinsitai cave site as middle Paleolithic assemblages with intensive Levallois technological features, rather than being one from the Initial Upper Paleolithic.

3.1.5 Other related findings

Some assemblages containing blades have been discovered in North China and the Qinghai-Tibet Plateau. Due to the small number of stone artifacts and lack of reported information, we opt not to describe them in detail here. These findings, however, do provide clues for discussing the distribution and diffusion of different blade techniques.

The Yushuwan site is located in the Yushuwan area in Junggar Banner of Inner Mongolia. The stone artifacts were collected at the surface, and two confirmed Levallois blade cores were discovered at this site (Zhang, 1959, 1960)

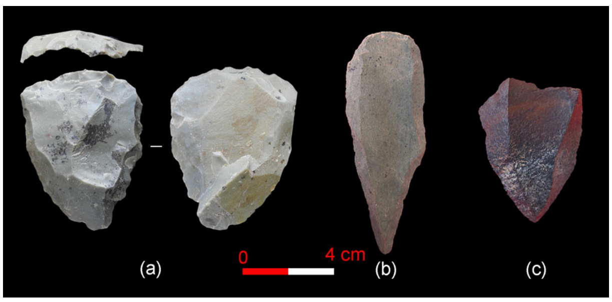

Figure 4 Some stone artifacts unearthed from the Jinsitai Cave. (a) Levallois cores; (b), (c) Levallois points (Wang et al., 2010).

(Figure 3b, c). Lenghu Locality 1 is located in Lenghu village of the Haixi Mongolia Tibetan Autonomous Prefecture of Qinghai Province. Stone artifacts were collected at the surface, including 2 cores and 1 blade, all shared features of Levallois blade technique. According to age of the ice wedge, these stone artifacts were estimated to have been formed 36396±958 a ago (Brantingham and Gao, 2006; Brantingham et al., 2007; Gao et al., 2008b).

3.2 Microblade sites containing blades

The remains of microblades are one of the important characteristics of the Late Paleolithic in Northeast Asia. Theoretically two sources contributed to the "blades" discovered in microblade assemblages: those produced as by-products from preparation of microblade reduction and those produced by systematic blade production. The flaking methods for microblades are similar to those of blades in that a ridge is first created to guide the striking force so as to generate long and thin flakes; therefore it is not difficult to obtain a long flake of a size similar to a blade during microblade core preparation. However, such products lack diagnostic features of blade technology, such as the blade core and crested blade, which can be distinguished in blades produced with a systematic system. Blades as by-products are mostly found in microblade assemblages, for example, Shuidonggou Locality 12, while intended blade production is relatively rare. Such remains may include the Youfang site in Nihewan Basin in Hebei Province, the Xishi site in Dengfeng in Henan Province, and some of the Paleolithic localities in the east of Jilin Province.

3.2.1 Youfang site

A total of 695 stone artifacts were unearthed in 1986, including 6 stone hammers, 72 cores, 475 stone flakes, 11 microblade cores, 92 microblades, and 39 stone tools (Xie and Cheng, 1989; Xie et al., 2006). Although blade cores and blades were not proposed by original researchers, their existence can be presumed based on the description in the excavation report. Among cores with a single platform, 9 were cone-shaped or flat-cone-shaped. The platform was trimmed and flake scars were found around the core body. The flake scars were 8–15 mm wide and 40–60 mm long. According to the description above, at least some of the cores fit the features of prismatic blade cores. Moreover, 287 long flakes were found, accounting for 41.3% of the total stone artifacts. The definition of such flakes used by researchers at the time included the following: "the length is more than twice the width," "most items have nearly parallel sides," and "items have one or two longitudinal ridges on the dorsal side" (Xie and Cheng, 1989). Therefore we can be sure that most of the long flakes were standard blades. Most of the blanks of end scrapers explored in the site can also be categorized as blades (Xie and Cheng, 1989). In 2014, observations on some of the newly excavated samples and communication with Dr. Mei Huijie, the principal responsible excavator, also confirmed the existence of a certain percentage of prismatic blade cores and blades. The types of retouched tools include side scrapers (*N*=12, 30.8%), points (*N*=7, 17.9%), end scrapers (*N*=8, 20.5%), burins (*N*=3, 7.7%), and backed knives (*N*=2, 5.1%).

OSL with IRSL showed that the cultural layer of the Youfang site dated to 14–16 ka BP (Nagatomo et al., 2009). Considering that the abnormal decay of the feldspar signal will lead to an underestimation of the age of the sample with IRSL, quartz multiple aliquot regenerative-dose protocol was applied to re-test, which placed the OSL age of the cultural layer to 26.6–29.2 ka BP (Nian et al., 2014b).

3.2.2 Xishi site

Over 8500 stone artifacts were excavated, including stone hammers, blade cores, flakes, blades, microblade cores, microblades, and retouched tools (Wang and Qu, 2014; Wang and Wang, 2014); 62 blade-cores (82.7% of the total cores), 127 intact blades (10.5%), 25 crested blades (2.1%), 3 microcores (4%), and 82 microblades (6.8%) were classified (Gao, 2011). Technological analysis of the blade products indicated that most were made with classical blade techniques based on the prismatic method. The retouched tools of the site included end scrapers, side scrapers, burins, and points, mainly end scrapers (Gao, 2011; Wang and Qu, 2014). Calibrated AMS^{14}C dating traced the layer containing blades back to around 25 ka BP, similar to the results of OSL dating (Wang and Wang, 2014).

3.2.3 Shirengou site and surrounding localities in Helong

A total of 1331 stone artifacts were unearthed in the Shirengou site, including flake cores, blade cores, microblade cores, flakes, blades, microblades, and stone tools (Chen Q J et al., 2006, 2010). Two blade cores showed clear features of prismatic blade cores; in particular, one piece of blade core fragment (Chen Q J, et al., 2010) showed renewed flaking surface and overshot flake with regular blade scars on the dorsal face, expressing features of the pressuring method or the indirect flaking method. Twenty-one blades were unearthed, among which 4 were crested blades. The retouched tools included 67 scrapers (63.2%), 5 backed knives (4.7%) and 2 drills (1.9%) (Chen Q J et al., 2006, 2010).

The Dadong site in Helong County, the Beishan site in Huichun County, and the Xishan site in Fusong County all contained both blades and microblades (Chen and Zhang, 2004; Chen et al., 2009; Chen and Wang, 2008; Li, 2008). One blade core from at the Xishan site bears significant features of prismatic blade cores with its platform faceted and parallel blade scars left on the flaking surface, which may be suggestive of the indirect or pressuring flaking method (Chen Q J et al., 2010).

Few of the Paleolithic localities in eastern Jilin Province have been excavated, and the stone artifacts there are mostly collected on ground with no absolute dating. Based on geomorphological estimation, the lithic industrial features, and the absence of pottery or polished stone tools on the ground, these remains are suggested to date to the late Paleolithic or transitional period of Paleolithic and Neolithic (Chen and Wang, 2008). However any analysis of the remains performed without previous absolute dating data is to be considered incomplete, and the accuracy of the discussion of the distribution and dispersal of blade techniques may be affected. Nevertheless, these assemblages have their particularity in the sequence of lithic technology evolution, which may provide clues for the discussion of the diffusion of lithic technology.

3.3 Suspected sites with blades

It is believed by many scholars that remains of blades are contained in many Late Pleistocene sites in northern China. The Shiyu site in Shanxi and the Xiaonanhai site in Henan are among those on the list of highly suspected sites (An, 2006; Du, 2005; Kato, 2006).

Over 15 thousand stone artifacts have been unearthed from the Shiyu site, and only part of the “small long flakes” were described by the researchers, who did not note whether blades were discovered, but suggested that “such small long flakes may be produced by the indirect flaking method” (Jia et al., 1972). Later these small long flakes were categorized as blades, and one multifaceted core as a blade core by some scholars (Du, 2005; Kato, 2006). However, it should be noted that, without detailed technological analysis, the definition of blade merely by its appearance and size is prone to deviation. Moreover, it can also be seen from the originally published sketch that the scar pattern left on the core of these so-called “blade cores” is irregular and remarkably different from the pattern on a classic blade core. The original author did not disclose the number and proportion of such “small long flakes”; however it is not surprising to find a small number of long flakes with an appearance similar to blades out of 15 thousand stone artifacts. Furthermore, it has been reported that most retouched tools are manufactured on irregular flakes (Jia et al., 1972), which is distinguished from the classic blade assemblage containing mainly blade blanks. The small long flakes discovered at the site are considered products of indirect flaking technique; however, this conclusion lacks support from either experimental or statistical data (Du, 2005; Kato, 2006).

Over 8 thousand stone artifacts were unearthed from the Xiaonanhai site (An et al., 1965; Chen et al., 2010). Columnar cores, rectangular flakes, and narrow small flakes were described by the original researchers, whose samples were later confirmed by scholars as products associated with blade technology (An, 2006; Du, 2005; Kato, 2006). However, Chen et al. studied 944 artifacts unearthed in 1978 and reported that no blade cores existed in this site: most of the products were bipolar cores (Chen C, et al., 2010). Three “blades” were identified, accounting for only 0.3% of the total sample. No diagnostic technological items such as crested blades, were identified. Furthermore, contrary to the viewpoint of previous scholars (Jia, 1978), the researchers pointed out that the lithic assemblage discovered at the Xiaonanhai site had nothing to do with the microblade technology.

From the above analysis, we know that scholars tended to expand the definition of blade when evaluating lithic assemblages containing few “blades” discovered in the Late Pleistocene in northern China. Due to the low proportion and irregular pattern of the so-called “blades” and the lack of diagnostic products, in this article we prefer to exclude them from blade remains but regard them as simple core-flake assemblages commonly discovered in Northern China.

4. Distribution of Northern Chinese blade technology and its significance

Two blade reduction methods have been reported in Northern China, namely the Levallois method and the prismatic method, which feature a distinct temporal and spatial distribution. However, the isolated presence of certain methods is rarely observed in archaeological sites. The co-existence of the Levallois method featuring the use of the hard hammer and prismatic method for producing blade was common, which is regarded as a major technical feature of Initial Upper Paleolithic remains. However, the co-existence of the semi-prismatic/prismatic methods and the microblade method is seen as significant feature for earlier microblade remains.

4.1 Dispersal of IUP technological system and potentially reflected expansion of population

IUP assemblages, featuring the co-existence of Levallois method and prismatic or semi-prismatic method, mainly distribute in China’s northwest and northern regions, including Xinjiang, Qinghai, Ningxia, Inner Mongolia, and Heilongjiang Province (Figure 2). Technologically, these assemblages resemble the IUP discovered in Siberia and Mongolia and are differentiated by the simple core-flake assemblages common in northern China (Li et al., 2014b). Temporally, the dates of IUP in northwest China concentrated on 30 to 40 ka BP, after which no trace has been left of similar technological system. The discovery of IUP in the Siberian Altai area, the Baikal region, and northern Mongolia were earlier than similar discoveries in China, and also indicated their connection with the transition from the Middle to the Upper Paleolithic period (Derevianko, 2011; Gladyshev et al., 2010, 2012). Therefore, most scholars agree that the blade technology seen in Chinese IUP remains was introduced from Siberia or Mongolia (Boëda et al., 2013; Brantingham et al., 2001; Derevianko, 2011; Gao et al., 2002; 2013a; Li et al., 2013b; Madsen et al., 2001).

IUP sites have been found in various ecological regions, such as Siberian mountains, the desert of northwest China, Mongolian mountains, and the Gobi desert, which indicate that such technology was strong in environmental adaptability. Despite of the lack of inter-regional statistics and comparison of technological characteristics, there is a resemblance between the flaking method and the general features of stone artifacts found in IUP in northern China with those discovered in Siberia and Mongolia. This indicates a dispersal of an overall package of the technology rather than partial technique elements. As a result, this resemblance may represent the distribution of a technique bearing a strong environmental adaptability to southern and eastern areas. Spatially, a distinct boundary is observed between Chinese IUP remains associated with Siberian and Mongolian IUP sites and the remains of simple core-flake technology in the east of northern China (Figure 2), which roughly overlaps with the isohyet line of 400 mm (Li et al., 2014b). Here we have to answer the question: what stopped a technique adaptive to various biological zones from continuing to spread further to the southeast? One explanation may be the population density that constructed the distribution pattern of IUP remains in eastern Eurasia. From Figure 2, we can see that the remains of simple core-flake technology had a great time duration in northeast China, with a relatively high density, which implies a continuously residence with high concentration. Sites dated over 40 thousand years ago are rare in northwest China, reflecting the relatively lower population density in this region. The diffusion of IUP from east to south benefitted from the low population distribution and was impeded by the relatively high population density in northeast China (Li et al., 2014b). IUP only had a short history in north China, which was then replaced by a core-flake technology of long duration, such as the Shuidonggou site (Chen et al., 2012; Gao et al., 2013a, 2013b; Li et al., 2013a, 2013b, 2014b). Thus, we speculate that the diffusion of this technology was not only a diffusion of the specific survival adaptation, but more likely to be related to specific population migration.

Until the present, human fossils have not been found in any IUP site in China, and multiple types of human groups existed in Siberia, one of the birthplaces of this technology (Krause et al., 2010; Reich et al., 2010), making it difficult to determine the biological attributes of the immigration or whether the IUP assemblages discovered in Northern China remained within the same population. Research on blade technology of the western Eurasian continent indicates that there is a lack of one-to-one correspondence between techniques with certain hominin species (Bar-Yosef and Kuhn, 1999; Conard, 1990). Against such a background, it is not advisable to map the blade technology to a specific human group. Alternatively the attention of study should be on how to explain what causes specific cultural and geographical areas of such technology distribution: the migration of populations carrying the whole technological system, the communication of information focused on technical learning and imitation, or the result of the independent development of isolated regions. Meanwhile, attention also needs to be paid to the adaptability of the technology caused by changing a regional environment within the same cultural and geographical area.

If the dates of IUP sites in Northern China are reliable, the temporal distribution of these sites reflects the general direction and mode of the diffusion of the technology (Figure 5). Findings in the Jinsitai site clearly share features of the Levallois technology, which produced Levallois flakes and points. The lithic assemblage shows characteristics of the Middle Paleolithic in the western regions of Eurasia. In the technological evolution sequence, it is located earlier than Levallois blade technology, while chronologically its existence was later than IUP technology discovered in Shuidonggou area. The Shibazhan site, where IUP remains were also discovered, is significantly more recent than the Shuidonggou site. Based on chronological evidence, it is safe to speculate that the IUP technology in Northeast Asia experienced an eastward and southward diffusion. This technology reached southern areas around 30–40 ka BP, including Shuidonggou, without evidence of spreading further south. The eastward diffusion of the IUP reached areas including the Shibazhan site around 25 ka BP, which may have expanded further to cover Far East region of Russia (Brantingham and Kuhn, 2001; Derevianko et al., 1998).

4.2 Early microblade remains with blades and their diffusion model

The flaking method of blades discovered in microblade assemblages in north China belongs to the prismatic blade core method, but currently the detailed flaking techniques are difficult to determine. The early prismatic method usually relates to striking with a hard hammer, and the later dealt more with soft hammer techniques, or indirect or pressuring techniques. Flaking experiments for blades and microblades have been conducted by some Chinese scholars (Liu, 1991; Zhao, 2011); however, due to the lack of

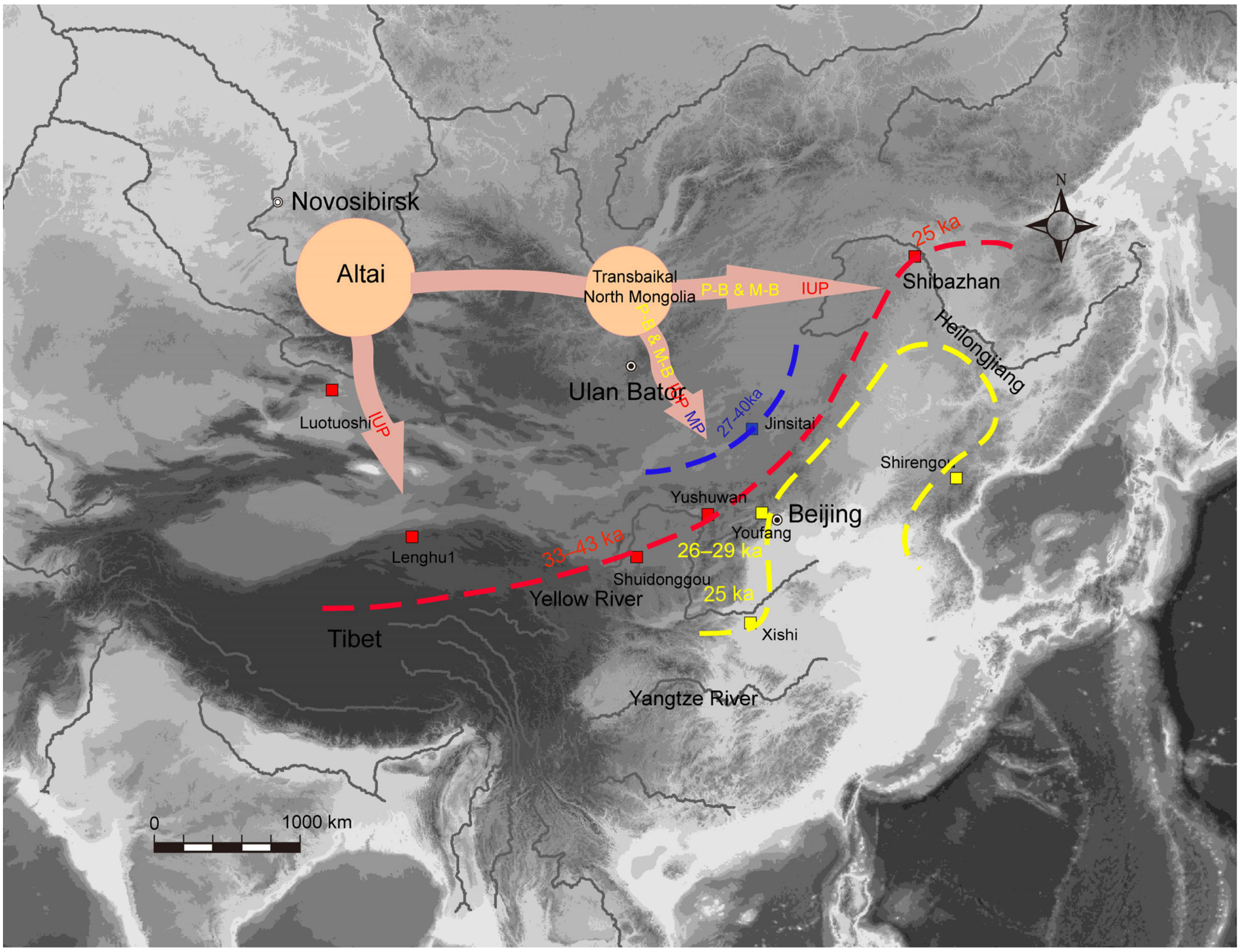

Figure 5 Temporal and spatial distribution and dispersal directions of different blade technology in China. MP, Levallois flaking method; IUP, Levallois and prismatic blade methods; P-B & MB, Prismatic blade-core and microblade technology. The blue, red and yellow dotted lines represent the borders of MP, IUP and P-B & MB, respectively.

comparative study with archaeological materials, consensus cannot readily be achieved based on the visual experience of scholars alone. Regular blade scars with features of systematic flaking left on the blade core discovered in some remains in east Jilin Province resemble those of blade cores produced with indirect percussion or pressuring techniques.

There is still controversy about the origin of the microblade technology (Chen, 2013; Gai, 1991; Li, 1993; Yi et al., 2016; Zhang, 1990). It should be noted that the proportion of microblade products in microblade-based assemblages in northern China is low; for example, the proportion of microblade cores and microblades at the Xishi site in Henan Province accounted for only 4% and 6.8%, respectively, of the total unearthed lithic artifacts (Gao, 2011), and cores and blanks associated with the prismatic method are rare in terminal Pleistocene microblade-based assemblages. The co-existence of blades and microblades and the domination of blades at the beginning indicate that the origin of microblade technology may be related to prismatic blade technology instead of an independent flaking system.

Controversy remains about areas and time of origin of microblade technology. Some scholars suggest that microblade-based remains in Mongolia and Siberia were formed around the last glacial maximum (Chen, 2013; Goebel, 1999, 2002; Graf, 2009), while others date its origin as early as 35 ka BP, taken the Ust-Karakol 1 in Altai area (Layer 10, Layer 9C) and Anui 2 remains for examples (Derevianko et al., 2003; Keates, 2007; Kuzmin, 2007a, 2007b). Early microblades are usually connected with prismatic blade assemblages, regardless of dating. The dating results show microblade technology in China emerged later than similar remains in Mongolia and Siberia, and the emergence of such technology in Southern and Eastern China tended to be later than in Northern and Western China, which indicates a general direction of spread from north to south and from west to east (Figure 5). Despite the lack of absolute chronological data for similar remains in northeast regions, two possible routes of diffusion have been proposed based on a distribution pattern concentrated in eastern Jilin Province, one along Heilongjiang and Wusuli River Valley, and the other from the Korean Peninsula. The former route is better supported considering the absence of characteristic artifacts discovered in similar remains in Korean Peninsula, such as tanged point (Bae, 2010; Seong, 2009), in remains in east Jilin Province.

Few microblade-based remains with blades have been found in northern China; these showed significantly different distribution patterns than Levallois blade assemblages. No similar remains have ever been found in northwest China, but its presence has been reported in the northern hinterland of China: for example, the Xishi site in Henan Province. Such facts indicate that different diffusion routes may be followed by microblades and Levallois blades; the former may be derived from northern Mongolia. Nevertheless, based on the available materials, whether the presence of microblade-based remains in the northern hinterland represents the migration of populations from Mongolia, or merely a rapid diffusion of behavioral adaptation, remains a question.

5. Discussions and conclusions

The definition of "blades" as a special flaking product may be easy to be extended if based merely on the size and appearance. The technology of producing blades includes a series of interrelated procedures, which requires the co-existence of multiple stone artifacts, such as blade-cores, blades, core tablets, and flakes for renewing the flaking surface to ensure its presence. The small amount of "blades" discovered in assemblages without support of stone artifacts indicating the existence of blade technology raises the reasonable possibility that these so-called "blades" may be by-products of other flaking technology. Furthermore, blades may be the result of various methods, such as the Levallois method and the prismatic blade method, and the same method can be connected with diversified flaking techniques using a hard hammer, soft hammer, indirect flaking, or pressuring. Therefore, the discussion of blades should be case-specific, based on detailed discussion of the method and technique, based on which different blade technology can be concluded upon and confusion can be avoided.

Temporal and spatial distribution characteristics of blade technology in Northern China showed wave type diffusion mode (Figure 5). From technological evolution sequence, we see a successive relationship in eastern Eurasia from Levallois flake technology, Levallois blade technology, prismatic blade technology, to the microblade technology; from the temporal and spatial relationship, the diffusion of the latecomer may exceed the predecessor before the complete demise of the predecessor. Currently, there is still a lack of agreement whether the Levallois blade technology in eastern Eurasia can be traced to a single origin or the convergence of the similar technique on both sides of the old world (Derevianko, 2011; Kuhn and Zwyns, 2014). However if we focus on the eastern part of the Eurasian continent, the Altai region has the earliest record of such technology. The prismatic blade technology may be traced with multiple independent periods and regions contributing to its origin (Johnson and McBrearty, 2010; Wilkins and Chazan, 2012), yet the earliest record of such a technology in eastern Eurasia during the Upper Paleolithic is also traced to the Altai area. The origin of the microblade is controversial; still, the earliest reports indicate the Altai area as major candidate (Yi et al., 2016). Therefore it is not difficult to see that the Altai area in eastern Eurasia played a critical role in technology diffusion in the Upper Paleolithic in Northeast Asia, during which time new lithic technology was spread from the origin to different regions of East and Northeast Asia. In the process of technology diffusion, it takes longer for technology to influence places further away from a central area, and the affected zone of older technology tends to be exceeded by its updated successor.

Logically, we expect that the arrival of new technology tends to occur later in areas that are farther away from its origin; however this leads us to contemplate further why the influence of an updated technology always exceeds its predecessor but still is not subjected to unrestricted diffusion. New technology is often accompanied by an accumulation of knowledge and a stimulation of environmental fluctuation. With a better ability to adapt to environments, it is often easier for a new technique to break through limitations to expand its influence over an older technology. However, the superiority of the new technology is not universal, having a certain adaptive range, which may encounter obstacles during the diffusion process. These obstacles may be composed of two aspects. One is the resistance of native adaptation against newly imported technology. The reason the Levallois blade technology did not deeply affect the eastern part of Northern China may be the resistance of the effective adaptive ability of the local simple core-flake technology. The second aspect of the obstacle may come from resistance of different environments. The microblade technology may not be as advantageous in the environment of southern China as in northern China and Northeast Asia, which may explain why the microblade technology was not introduced in southern China, but expended to northern China and Northeast Asia broadly.

Technology is a sequence of operations that needs to be acquired by social learning. The diffusion of technology reflects the spread of people, information, or both (Lyman and O'Brien, 1998; Shennan, 2008; Tostevin, 2007). At the same time, it is a reflection of a way of living and adaptation, which provide a solution for hominins faced with a certain environment (Bird and O'Connell, 2006; Kuhn, 1995, 2004). Therefore, study focusing on stone artifacts is expected to solve two major academic issues: to discuss the spread and exchange of groups of hominins or information that they share based on human behaviors such as lithic technology; and to study how hominins faced with emerging problems as well as their evolution through technological learning and innovation. Although blade technology, which is a type of lithic technology important to the Paleolithic, cannot reflect the detailed migration of hominin species, it can still be used as supportive evidence when discussing the spread and interaction of different cultural groups in the Late Pleistocene and the coping ability of different types of technology in different environments.

In this article, we described the distribution of Late Pleistocene remains of blades and microblades in Northern China and the reflected routes, patterns, and possible causes of human and technology diffusion. However more academic questions remain to be answered in the future: for example, how did simple core-flake technology in Northern China last from the early Pleistocene to the Late Pleistocene, how can we explain the common spreading tread of blade technology from the north to south and from west to east, why did the simple core-flake technology in northern China experience an extensive recession around 30000 years ago, after the appearance of microblade technology, why did the distribution of microblades not extend to Southern China, and what made Northern China the critical center of agricultural origin, playing the role of a pioneer of new technology during the early Holocene while acting as a technology receiver during the Late Pleistocene?

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