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Perspective

The temporal-spatial evolution of handaxe technology in China: Recent progress and future directions

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Handaxes are often regarded as the "tool-type-specimen" of the Acheulean techno-complex, not only because they are a very common artefact but because they contain rich technological, behavioral, and cognitive data that have been used to highlight trends in human evolution and lithic production strategies. To this end, the handaxe is the earliest tool possessing consistent morphological features, in particular, the appearance of a symmetrical concept in handaxe shape when compared with other Acheulean large shaping tools (e.g., cleavers), and their manufacture is widely regarded as a significant milestone in the evolution of lithic technology, indicating improvements in tool-making hominins' abilities for complex thought and cognition. According to current archaeological data, the handaxe emerged at ca. 1.76 Ma and disappeared gradually ca. 300–150 ka, persisting in some areas into the late Pleistocene [1]. In addition, handaxes as a tool-type occur in a range of regions, covering most parts of Africa and Eurasia; hence, their discovery and detailed study provide important data for understanding transcontinental early human migrations and diffusions, and the transmission of material culture.

However, the existence of handaxes in China was once a highly debated issue, and it stemmed from a hypothesis originally proposed in the 1940s by anthropologist Hallam Movius, from Harvard University. The hypothesis argued for a division in the Old World into eastern and western parts along a hypothetical "line" extending from the northwest to the southeast of the Indian subcontinent. It argued for significant technological and cognitive differences in contemporary early human groups living on either side of this line, where groups in East Asia and Southeast Asia to the east of the line were characterized by undeveloped cultures with an absence of handaxes and Acheulean technology coupled with the persistence of simple chopper-chopping tools; in contrast, areas west of the line contained a large number of handaxe sites, thus reflecting more advanced technologies [2]. Such a line was later formally termed the "Movius Line", and at the time, it was an adequate reflection of existing archaeological records and what was known across the Old World, historically biased given the limited work in regions on either side of the line. However, the influence of this line was far-reaching, for decades, triggering extensive discussions on whether there were handaxes in China and whether there were indeed developmental and cultural differences in the technology and cognition of early humans, between the East and the West [3].

Following the establishment of the People's Republic of China in the late 1940s, archaeology as a discipline has developed considerably. In the 1950s, the Dingcun Paleolithic site-complex, in Shanxi Province, was discovered and excavated, becoming the first region to bear handaxes and Acheulean technology in China, and for East Asia [4]. Since the 1970s, a series of discoveries from the Baise Basin in Guangxi, the Lishui River Valley in Hunan, the Shuiyangjiang River Valley in Anhui, the Danjiangkou Reservoir Region (DRR) in Hubei and Henan, and the Luonan Basin in Shaanxi have not only confirmed the existence of handaxes in China, they have significantly expanded the spatio-temporal range of this key stone tool type [5–8] (Fig. 1). These discoveries have also confirmed that China's handaxes reflect both homogeneity and variability in terms of shaping strategies and morphological characteristics [8]. We are now at a stage where academics around the world accept that handaxes exist in China, and that the "Movius Line" represents an antiquated way of thinking about regional technological developments and progressions that is no longer supported by current archaeological datasets [8,9]. Since these discoveries, we are now also able to explore a range of new scientific questions. Below, we summarize the most pertinent issues being discussed in Chinese palaeolithic studies.

The age and makers of Chinese handaxes The earliest handaxes come from the Baise Basin in the Guangxi Zhuang Autonomous Region, South China [5]. Through argon-argon ($^{40}Ar/^{39}Ar$) dating of tektites directly associated with handaxes, tektites formed ca. 0.8 Ma, providing an inferred age for the handaxes that places them at the transition between the Early and Middle Pleistocene. The favourable tektite-dating conditions that occur in the Baise

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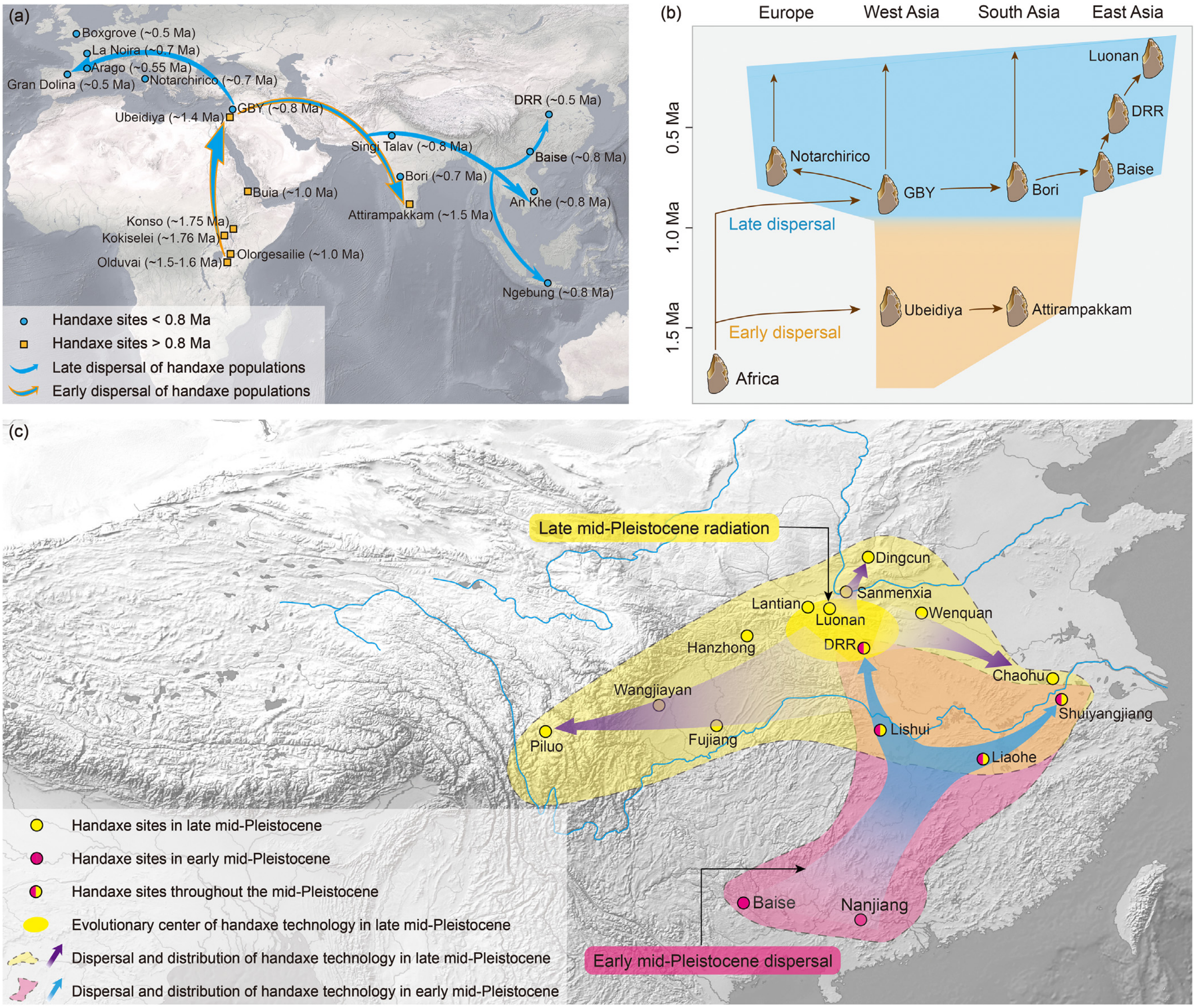

Fig. 1. The transcontinental dispersal of handaxe technology (a, b) and its distribution and dispersal in China (c).

Basin are rare for other handaxe-bearing regions across China, such that many sites have faced longstanding issues when trying to resolve chronology. Understandably, this has limited our ability to perform robust inter-site comparisons and to explore complex trends in lithic production through time. Dating difficulties are predominantly due to underlying sedimentological issues, particularly in South China where the strong acidity of the red soils has foiled sampling attempts for dating. As a result, the age of most South China handaxe sites is inferred, either by using stratigraphic indicators, or based on the location of sites within river terrace sequences, and therefore the age results on these sites are less reliable and need further test and dating efforts.

In contrast, in the Qinling Mountains region, located in the transition zone between the North and the South, a series of recent Optical Stimulated Luminescence (OSL) dating results show that handaxes occur here during the late Middle Pleistocene, ca. 250 ka, and they disappeared very late. For instance, handaxes in the DRR and Luonan Basin disappeared at about 100–50 ka, and handaxes in the Lantian region persisted until 50–30 ka [10]. Therefore, the handaxes from the Qinling Mountains region are currently some of the youngest recorded anywhere in the world.

Regarding who made handaxes in China, there is still some debate given the chronological issues highlighted above. For the Baise Basin, they were likely produced by *Homo erectus* populations living in the region ca. 0.8 Ma. Similarly, skull fossils attributed to *Homo erectus*, discovered at the Xuetangliangzi site in the DRR (Hubei Province), provide further evidence of which species was responsible for handaxe production, but there is still some controversy surrounding this assertion given the unclear stratigraphic relationship between the handaxes and fossils [8]. From at least the late Middle Pleistocene, we can be sure that handaxe producers would have been an important member of archaic hominin in China, but given the current lack of human fossils the exact taxonomic designation for who these people were has remained unclear. However, it is likely that China's handaxe populations evolved in parallel with other contemporary archaic humans (such as Denisovans, who may not have used handaxes; [11]), and this inference is complementary with the complex and diverse morphological features presented in the human fossil record in China during this key time period.

Spatial distribution and dispersal patterns of Chinese handaxe technology Handaxe-bearing sites are now widely distributed across the region given several decades' worth of field surveys and excavations by Chinese archaeologists, and based on current dating results the emergence of handaxes in southern China (especially the Lingnan Region) precedes that in northern China surrounding the Qinling Mountains, indicating a south to north diffusion of handaxe technology. To be specific, handaxe technology appeared first in the Baise Basin of the Guangxi Zhuang Autonomous Region and the Nanjiang River Basin of Guangdong Province, both of which are in the Lingnan Region. Thereafter, handaxe technology spread northward to the middle and lower reaches of the Yangtze River, which include the Lishui, Liaohe and Shuiyangjiang River Valleys. Following this diffusion, handaxe technology also reached the southern part of the Qinling Mountains at around 0.5 Ma, within the Danjiangkou Reservoir Region, based on the dating results from the Shuangshu site [8] (see Fig. 2 for handaxe examples from different regions).

From ca. 250 ka onwards, handaxe technology became popular in the areas surrounding the Qinling Mountains, with a proliferation of sites throughout the region and beyond. We suggest that this scenario was likely related to the remarkable growth of handaxe populations during this stage. To the north, handaxe technology reached the Xiangfen Basin (i.e., the Dingcun site complex) of the Fenhe River Valley in Shanxi Province; to the east, it reached the Wenquan site in Henan Province and the lower valley of the Yangtze River, e.g., with the discovery of large flake-based lithic assemblages at the Chaohu area of Anhui Province [12,13]; and, to the west, it entered the Fujiang River Valley, Sichuan Basin and even the eastern margin of the Tibetan Plateau along the Yangtze River and its tributaries [14,15] (Fig. 1c), which provide solid evidence for the westward spread of handaxe technology and the east–west diffusion along the Yangtze River. Furthermore, we can reasonably infer that handaxe populations may prefer to use the developed water system of the Yangtze River to facilitate their migration and dispersal.

The Piluo site (Daocheng County, Ganzi Prefecture) in the eastern Tibetan Plateau is a unique example given its geographical position at an elevation of ~3700 m (Fig. 1c), and its chronology. The site was discovered in 2020 during a field survey of Paleolithic sites on the Plateau, and when dozens of handaxes were collected on the surface researchers immediately conducted tests and formal excavations in multiple phases. According to the preliminary OSL dating results, the *in situ* handaxes here are >130 ka and as a result, they are now considered to be the highest-altitude Acheulean technological products in the world. Morphologically, some of the handaxes at Piluo retain the 'classic' teardrop shape and thin cross-sectional profile, which are commonly associated with the Middle Pleistocene handaxes from Europe, and they also reflect some of the most skillful handaxe knapping ever found in East Asia [15].

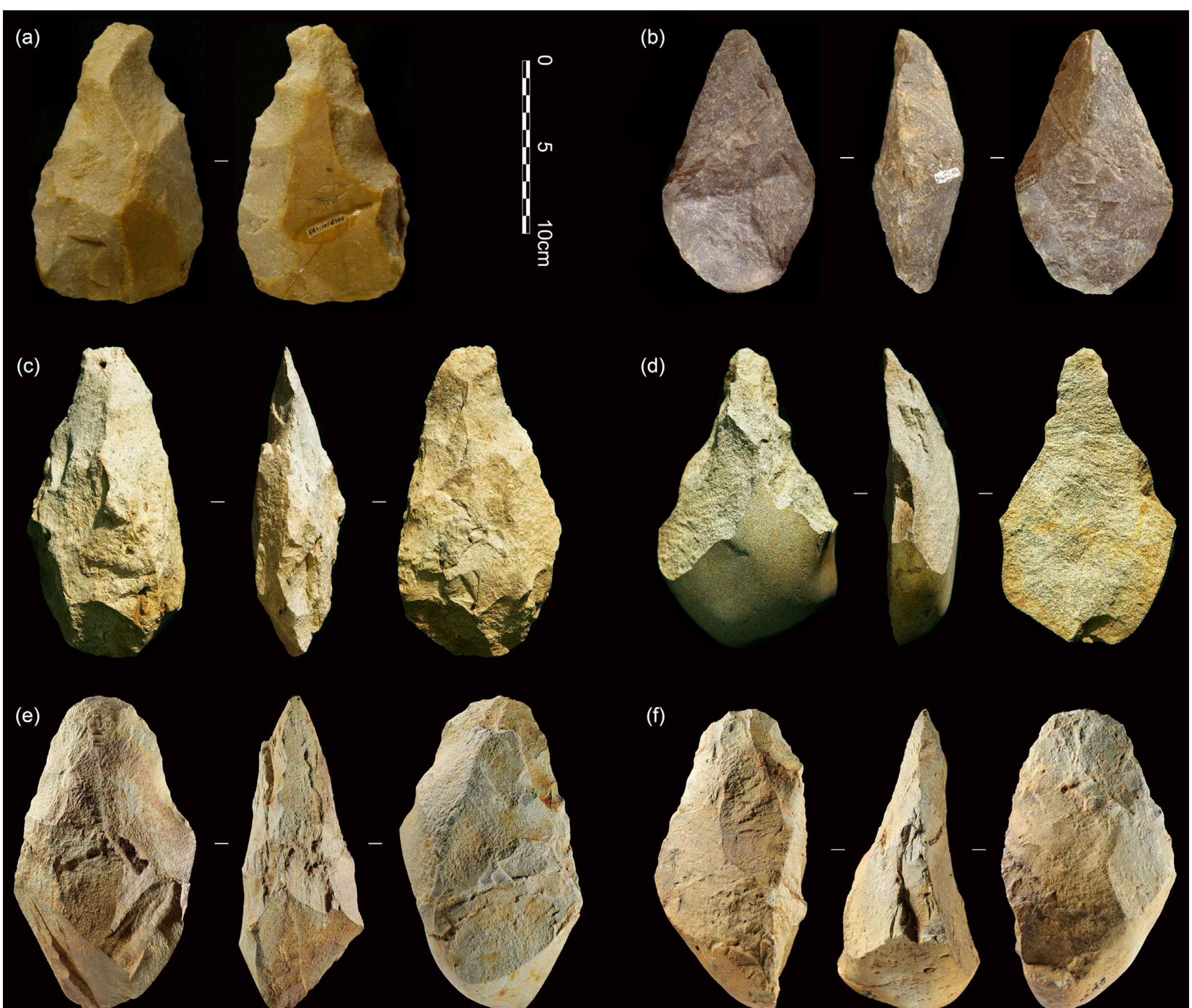

Fig. 2. Handaxes discovered in the different regions of China. Specimens (a) and (b) are from the Luonan Basin, (c) and (d) are from the Danjiangkou Reservoir Region (DRR), (e) and (f) are from the Baise Basin.

Such technological features are in consistent with the relatively younger age of handaxes at the Piluo site.

Based on current datasets, we believe that the earliest handaxe technology appeared in China at ca. 0.8 Ma, followed by continuous developments and a prosperous proliferation of the technology ca. 250 ka, centered around the Qinling Mountains region (exemplified by the high density of handaxe-bearing sites in the DRR and Luonan Basin) [6,8]. Along with an increase in population, handaxe technology began to spread from the central region laterally, forming another wave of diffusion following the early Middle Pleistocene diffusion from the Baise Basin to the middle and lower reaches of the Yangtze River. The spread of handaxe technology during this stage was more extensive, given that populations also explored and adapted to the Tibetan Plateau. We hereby propose a "Late Mid-Pleistocene Radiation Model of Handaxe Technology" for the evolution of handaxe-producing populations in China.

Global significance of Chinese handaxe technology Evidence from sites, such as Konso and Kokiselei, shows that handaxe technology first appeared in East Africa at about 1.7 Ma, contemporary with the emergence of *Homo erectus* in Africa indicating a possible relationship between these two events. At approximately 1.5 Ma, hominins with a handaxe technology first left Africa and spread into Eurasia. The extent of this initial early spread was very limited, as only a few handaxe sites bearing similar technological and morphological characteristics with African sites have been found dating to this period, such as Ubeidiya in Israel and Attirampakkam in India, dated to ca. 1.4 Ma and ca. 1.5 Ma, respectively (Fig. 1a, b). Since at least 0.8 Ma, handaxe groups with more sophisticated knapping ability in Africa began a second migration out of Africa. The $\sim$0.8 Ma Gesher Benot Ya'aqov (GBY) site in Israel has often been regarded as a key indicator of this later dispersal, which overall was far more extensive than the first migration beyond Africa and subsequently had a profound impact on the distribution of handaxe technology around the world [1].

Human groups entering Eurasia dispersed in two directions: One towards the east to the Indian Peninsula, Southeast Asia, and East Asia, with the other direction towards the west to Europe. Currently, several handaxe-bearing sites dating back to about 0.7 Ma in Europe, such as Notarchirico in Italy and La Noira in France, indicate this migration (Fig. 1a). The ca. 0.8 Ma Baise Basin handaxes demonstrate that China, located in the easternmost part of Eurasia, also formed an important part of this diffusion event, substantially expanding the distribution of handaxe technology, and providing vital evidence that deepens our understanding of transcontinental dispersal and exchange patterns of handaxe-producing populations (Fig. 1a, b). Post-dispersal, handaxe technology evolved along distinct trajectories in different regions of Eurasia, and its disappearance also happened at different times. Given the persistence of handaxe technology in China until the late Pleistocene ca. 100–50 ka, the Chinese sites represent the youngest expression of this global technology known from anywhere in the world today.

Understanding handaxe technology in China allows us to explore tool functionality, as well as how past populations adapted to changing environmental conditions. The ecological environments represented by the current cohort of Chinese handaxe sites are diverse, ranging from subtropical conditions in the Lingnan Region (e.g., the Baise Basin) and the middle and lower reaches of the Yangtze River, to warm-temperate conditions in the Luonan Basin and at Dingcun in the Yellow River Valley in northern China. And now, following the recent discovery of high-altitude sites in the Sichuan Province, this expands the living environment of handaxe populations to include cold and hypoxic regions of the Tibetan Plateau (Fig. 1c). Collectively, this wide ecological distribution documents the high behavioral plasticity and flexible environmental adaptability of handaxe-producing populations across China. Functionally, given the rare documentation (globally) of handaxes from tropical/subtropical rainforests, the handaxes from the Lingnan Region in the southernmost part of China were likely used as large chopping/digging tools to obtain rich plant resources, thus manifesting as a unique regional environmental adaptation for local populations.

Based on current archaeological datasets, we provide some thoughts and opinions on the evolution of Chinese handaxe technology. First, we suggest that the emergence of handaxe technology in China was likely related to the transcontinental migration of early humans, and that this technology subsequently followed its own unique trajectory in the region given a range of influencing site-scale, environmental and ecological variables that handaxe-producing populations were exposed to. We still only have limited knowledge about the true extent of handaxe technological variability, as well as what the actual function of handaxes was throughout the different regions, and these questions need to be studied in more detail in the future. Second, we propose the "Late Mid-Pleistocene Radiation Model of Handaxe Technology", which argues for the proliferation of handaxe technology in the Qinling Mountains region, followed by dispersal from this core area to other regions. However, given current dating difficulties, we acknowledge this as an important shortcoming but emphasize that it is one issue that needs to be prioritized; future research should focus on high-resolution dating work on more handaxe sites in different regions of China, that will with time inevitably test the robustness of our proposed radiation model. Lastly, although early human fossil evidence is scant, the technology of the handaxes themselves likely demonstrates that the handaxe-producing populations in China were different from contemporary groups without Acheulean technology, and this may be indicative of considerable diversity in hominins living in China since the late Mid-Pleistocene. In the future, investigation of ecological niches occupied by different groups of populations, as well as their subsistence strategies, will provide insights into our understanding of the behavioral differences and similarities among groups. In addition, sedimentary DNA studies should be implemented at handaxe sites with favourable preservation and context, and such studies may provide key evidence to identify the taxonomic status of handaxe populations in China.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

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