Late Pleistocene changes in vegetation and the associated human activity at Beiyao Site, Central China

Zihua Tang [a,b], Shuisheng Du [c,*], Fuliang Liu [d]

[a] K L C c G E , I G G c , C Ac c c , B 100029, C
[b] CA C E c c P E c c , C
[c] c H , B N , B 100875, C
[d] G A c R c I , H P c , G 451200, C

A R T I C L E I N F O

A c :
Received 12 January 2017
Accepted 10 April 2017
Available online 19 April 2017

K :
Vegetation
Climate change
Loessic Paleolithic
Modern human dispersal
Beiyao site

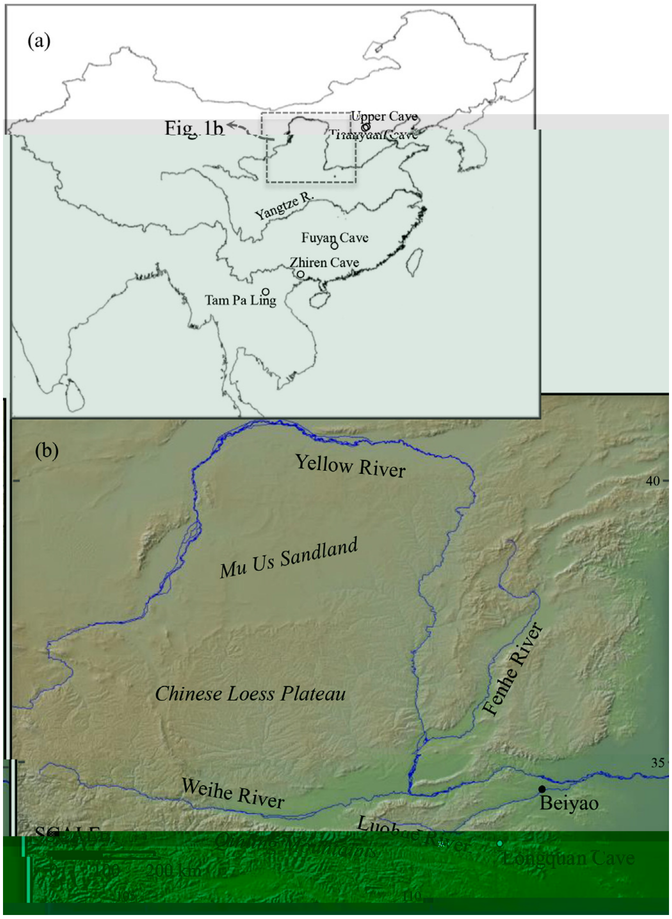
A B S T R A C T

The hypothesis that climate change paced modern human dispersal is complicated by newly found fossil evidence from East Asia. Here we conduct a palynological analysis to a loessic Paleolithic site in Central China, spanning past 240 ka, to investigate the vegetation history and assess the impact of climate change to human activity intensity. Our results show that steppe was dominant during glacial periods and local forest was recovered during interglacial periods, pretty correlative to the quantity of stone artifacts. This correlation would suggest a coupling between human activity intensity and climate fluctuation in the study area. In addition, few stone artifacts continuously occurred in the later Last Glacial period, being tentatively attributed to improved adaption of local habitants or immigration of modern human.

© 2017 Elsevier B.V. All rights reserved.

1. I c

Modern humans are broadly thought to expand to all continents except to Antarctica and Americas and to replace or assimilate archaic human species essentially by the Last Glacial Maximum (~20 ka BP). Evidenced by both biogeographic scenarios of *H* and numerical modeling of human dispersal (



F . 1. (a) Sketched East Asia map with some late Paleolithic sites mentioned in the text; (b) locations of the study site. The black dot indicates the Beiyao site, and the circle represents the Longquan Cave site.

Mountains, deciduous *Q c* forest dominates the elevation from 500 to 2600 m a.s.l. with increasing *B* and *P* , montane *A* /*P c* forests up to 3300 m a.s.l., and subalpine meadows the mountain top (Wu, 1995). The common arboreal species include *Q c* , *Q c* , *P* , *P* spp., spp., and *A* - , and herbs are dominated by Poaceae, *A* spp., *A* spp., and *c* spp.

The Beiyao site is located on a terrace of a tributary of the Luohe River (Fig. 1b). On the northern slope of the Qinling Mountains, the terrace as well as surrounding hills is covered by thick eolian loess. A paleolithic survey in 1998 unearthed 771 stone artifacts and the lowest cultural layer was primarily estimated more than 200 ka BP (Liu and Du, 2011). A systematic excavation was completed during 2007–2008. Four squares were designedly excavated and consequently exposed a 16-meter-thick outcrop. The upper part of the outcrop is a well-preserved loess–paleosol sequence, consisting of three paleosol and two loess units, S0, L1, S1, L2 and S2 from top to bottom. On the base of lithological features and OSL dating results these strata have been correlated to the Marine Isotope Stage (MIS) 1–MIS 7. The loess deposit reaches to ca. 14 m thick. The basal part is reworked by fluvial processes.

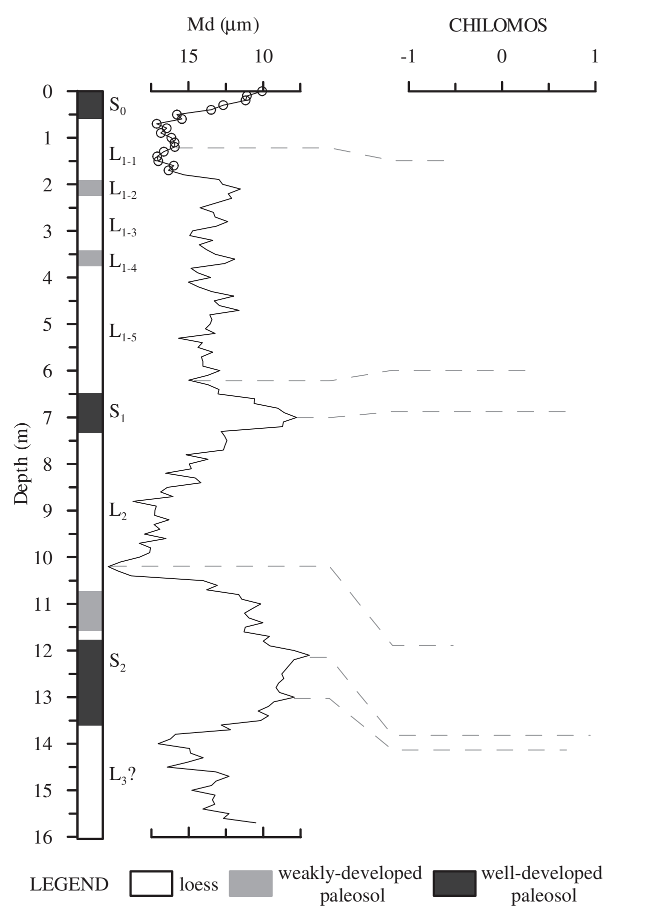
During the archeological seasons, a total of 719 paleolithics were collected mainly from S2 and L1, including 49 cores, 180 flakes, 3 tools and 487 pieces of knapping debris. Although the lithics recovered from various layers, the simple core–flake technology sufficed throughout the various cultural layers in the Beiyao site (Du and Liu, 2014). Alongside the archeological squares a loess section was logged and sampled at the interval of 10 cm. These samples were subjected to grain size and palynological analyses.

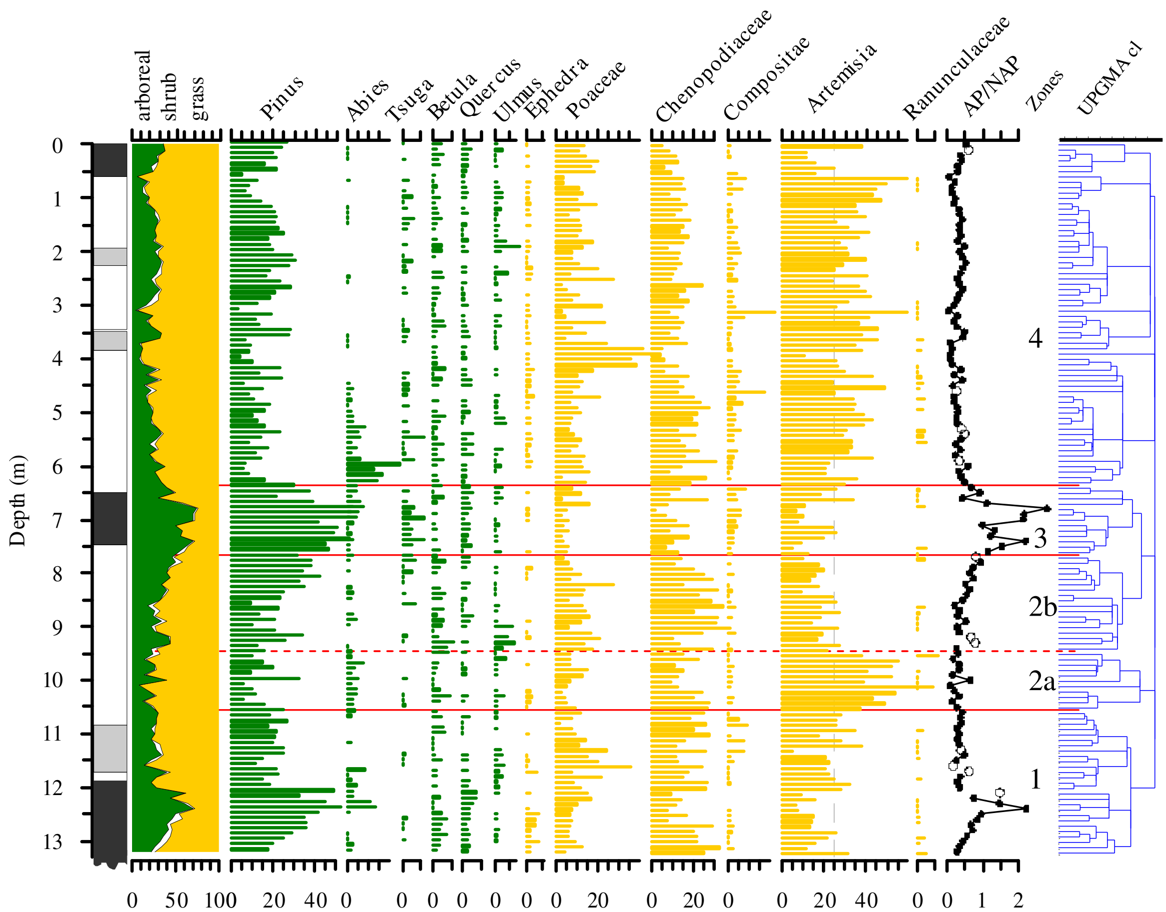
3. C fi

As mentioned earlier, lithological features demonstrated that the section consisted of the loess (L)–soil (S) sequence S_0, L_1, S_1, L_2, and S_2. The stratigraphy was confirmed by five OSL samples from the upper part of the section (Du et al., 2011) and by correlating magnetic susceptibility to benthic $\delta^{18}O$ record for the lower part (Du and Liu, 2014). Accordingly, the Beiyao section was loosely constrained to the last two glacial–interglacial cycles.

To refine the chronology of the study section, we measured here its grain size and correlated the grain size sequence to the Chinese Loess Millennial-scale Oscillation Stack (CHILOMOS, Yang and Ding, 2014). The CHILOMOS is a stacked grain size record based on 12,330 samples from eight loess sections across the Chinese Loess Plateau, whose chronology was correlated to the precisely dated Chinese stalagmite $\delta^{18}O$ record (Cheng et al., 2009; Wang et al., 2008). It is the very first millennial scale stack for the past glacial cycles in northern China.

A total of 156 samples were collected at 10 cm intervals, yielding a mean temporal resolution of 200–300 years. The loess units are clearly expressed by peak–trough alternations in the median grain size (Md) curve (Fig. 2), with peaks indicating stadials and troughs indicating interstadials. The great similarity between the Md curve and the CHILOMOS provides age constraints to refine the time scale for the study section. Taking the ages of maximum glacial/interglacial stages as time controls and then using the linear interpolation via the program AnalySeries 2.0 (Paillard et al., 1996), we established a refined time scale for the Beiyao section.





and S_2. A possible explanation for this difference is human impacts since the Neolithic period. The Luohe Valley, where the study site located, is one of the agriculture origin centers in East Asia, and extensively utilized at least during the past 8000 years. It is estimated quantitatively that, during the middle Holocene, agricultural activities expanded from gentle slopes along the river to hinterlands in middle and lower parts of the valley, occupying 2–9% land area (Yu et al., 2012). These processes would impact the regional vegetation components.

5.2. P c c c c

To the underlying strata, the excavators have noticed that paleosol and loess greatly differ from the number of their bearing artifacts (Du and Liu, 2014). More than 95% lithics (691/720) are from S_2 and S_1, which corresponds to MIS 7 and MIS 5 (Lisiecki and Raymo, 2005), respectively. By contrast, only nine and four lithics are from L_2 and L_{1-5}, which corresponds to the MIS 6 and MIS 4, and few artifacts are sporadically but continuously presented from L_{1-2} to L_{1-1}, correspondent to the late Last Glacial period, the MIS 3 to MIS 2.

Placing the artifacts quantity into the associated paleoenvironmental context will assist us to understand their interactions (Fig. 4). The paleosol layers bearing abundant artifacts are generally of finer grain size, higher magnetic susceptibility, and greater AP/NAP value than those of loess layers with few artifacts. All these proxies lead to a well-established paleoclimatic scenario in Chinese Loess Plateau. Grain size of eolian loess at a specific location is dominated by the proximity of desert (Ding et al., 1999) that is essentially controlled by the strength of East Asian summer monsoon (Yang and Ding, 2008), i.e. during warmer interglacial periods stronger summer monsoon retreats the desert–loess boundary northward, resulting in finer dust deposited on the loess plateau, and vice versa. Magnetic susceptibility is overwhelmingly dominated by the concentration of magnetite. In the loess plateau, it peaks in paleosols for the pedogenic origin of nano-sized magnetite, which is enhanced by stronger summer monsoon (Liu et al., 2007; Maher and Thompson, 1991; Zhou et al., 1990). As discussed earlier, the increasing AP/NAP values would indicate the recovery of local forest that, again, benefits from more summer monsoonal precipitation.

Assumed the frequency of Paleolithic being an indicator of human activity intensity, it appears that humans intended to live around the study area during warm periods instead of cold periods. Considering the climatic contexts of the study area, warm periods host at least two advantages for living during the Paleolithic period. First of all, the local ecosystem in a warmer period has a more diverse ecosystem (Yang et al., 2017; Zhao and Ding, 2014) and greater biomass (Yang et al., 2015), offering ancient humans a stable ecosystem and diverse foods. Moreover, it may be easier to survive winters during interglacial periods than glacial periods.

A plausible mechanism has been tentatively proposed to explain the human activity intensity in the study area: environmental pressures redistribute ancient inhabitants. During an interglacial period, East Asia summer monsoon brought plentiful moisture to the study area, as well as the Loess Plateau, feeding the terrestrial ecosystems and finally allowing human to survive in acceptable circumstances. Conversely, during a glacial period, weakened summer monsoon deteriorated local environments, exerting great pressures over daily life of local habitants. As a result, the human activities constrained and moved southward.

If valid, it is rational to expect more sites of glacial periods from the region to the south. South China and Southeast Asia, however, are notable for their scanty of fossil evidence. The most recent fossils also came from relatively warm periods, such as the Daoxian human fossil teeth from the Fuyan cave, Hunan Province, dated to 80–120 ka BP (MIS 5. Liu et al., 2015), and a human cranium from Tam Pa Ling, Laos, by ~46 ka BP (MIS 3. Demeter et al., 2012). Before convincing and concluding evidence comes, the relationship between modern human evolution and environmental changes in East Asia will be open to continuous debate.

One more issue worthy of further consideration is the sparse but continuous occurrence of artifacts during the MIS 3–2 periods. These artifacts are of a simple core–flake technology, just as the artifacts below did. The excavators argued that these indicated increases in human activity intensity in hush glacial conditions, showing some improved adaptations of local habitants (Du and Liu, 2014). Most recently, a contemporary Longquan Cave with radiocarbon dates of 40–30 ka BP was found nearby. The Longquan Cave is featured by a polished bone awl and structured space utilization (Du et al., 2016), both of which are closely associated with modern human behaviors (Mellars, 2005). Although conclusive fossil evidence is still absent, it is highly possible that modern human dispersed to the study area by the last glacial period.

6. C c

The pollen data of the Beiyao section, spanning the past 240 ka, shows that the vegetation sequences were paced by glacial/interglacial cycles. *A* –Chenopodiaceae steppe dominates the glacial periods, whereas local forests some recovered during the interglacial periods. This pattern might be closely related to zonal vegetation migration in response to summer monsoon.

Paleolithic was mainly presented in warm periods including MIS 7 and MIS 5, and continuously occurred within the last glacial stage, MIS 3–2, without marked technological innovations. Considering nearby contemporary Longquan Cave, which featured by modern human behaviors, it might be associated with modern human immigration to the study area.

The systematical investigation into the loess Paleolithic site at Beiyao provides a valg(4(emp(n)-8(e/ep)147(nt)M)17(9(in)186()24(sl)9304(u5(ao(

Luonan Basin, Central China. Quat. Res. 76:142–147. http://dx.doi.org/10.1016/j.yqres.2011.04.001.
Maher, B.A., Thompson, R., 1991. Mineral magnetic record of the Chinese loess and paleosols. Geology 19, 3–6.
Mellars, P., 2005. The impossible coincidence. A single-species model for the origins of modern human behavior in Europe. Evol. Anthropol. 14:12–27. http://dx.doi.org/10.1002/evan.20037.
Ni, J., Yu, G., Harrison, S.P., Prentice, I.C., 2010. Palaeovegetation in China during the late Quaternary: biome reconstructions based on a global scheme of plant functional types. Palaeogeogr. Palaeoclimatol. Palaeoecol. 289:44–61. http://dx.doi.org/10.1016/j.palaeo.2010.02.008.
Paillard, D., Labeyrie, L., Yiou, P., 1996. Macintosh program performs time-series analysis. EOS Trans. Am. Geophys. Union 77, 379.
Shang, H., Tong, H., Zhang, S., Chen, F., Trinkaus, E., 2007. An early modern human from Tianyuan Cave, Zhoukoudian, China. Proc. Natl. Acad. Sci. 104, 6573–6578.
Sun, N., Li, X., 2012. The quantitative reconstruction of the palaeoclimate between 5200 and 4300 cal yr BP in the Tianshui Basin, NW China. Clim. Past 8:625–636. http://dx.doi.org/10.5194/cp-8-625-2012.
Timmermann, A., Friedrich, T., 2016. Late Pleistocene climate drivers of early human migration. Nature 538:92–95. http://dx.doi.org/10.1038/nature19365.
Wang, S., Shen, C., Hu, S., Zhang, X., Wang, C., Cosgrove, R., 2005. Lithic artefacts collected from open-air sites during 1995-1999 investigations in Luonan Basin, China. Acta Anthropol. Sin. 24, 87–103.
Wang, Y., Cheng, H., Edwards, R.L., Kong, X., Shao, X., Chen, S., Wu, J., Jiang, X., Wang, X., An, Z., 2008. Millennial- and orbital-scale changes in the East Asian monsoon over the past 224,000 years. Nature 451, 1090–1093.
Wu, Z.Y., 1995. Vegetation of China. Science Press, Beijing, p. 1144.
Wu, X., Xu, X., 2016. The origin of modern humans in China: viewed from the Paleolithic data and Daoxian Hunan fossils. Acta Anthropol. Sin. 35, 1–13.
Xia, Z., Zheng, G., Chen, F., Liu, F., Guo, Y., 1998. Discovery of the Late Paleolithic site form the loess profiles at Beiyao, Luoyang, Henan Province. (in Chinese with English abstract). Quat. Sci. 19, 286.
Xu, Q.-H., Li, Y.-C., Tian, F., Cao, X.-y., Yang, X.-l., 2009. Pollen assemblages of tauber traps and surface soil samples in steppe areas of China and their relationships with vegetation and climate. Rev121TPalaeob..Palynta153:8ev16Tf25.9 [illegible]