Quaternary International xxx (2016) 1–8

Contents lists available at ScienceDirect

Quaternary International

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

Human-environment interactions within the West Liao River Basin in Northeastern China during the Holocene Optimum

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A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
43°30′N
Pollen
Flotation
Millet
Holocene Optimum
Neolithic

A B S T R A C T

Cultural studies of Neolithic China have focused on the social aspects and the human–environment interactions associated with those cultures. However, the uneven spatial distribution of Neolithic sites in Northeastern China has not yet been explored. This study traces the relationship between human settlement patterns and the agro-ecological environment during the Holocene Optimum, based on the spatial distribution of 4184 Neolithic sites, together with optically stimulated luminescence (OSL) dating and pollen analysis of five profiles and 22 plant flotation samples from 10 of the archaeological sites in the West Liao River Basin, the hub of Neolithic Cultures in Northeastern China. The overwhelming majority (~96.7%) of the Neolithic sites are located south of 43°30′N latitude in the West Liao River Basin on the southern fringe of the Horqin Dunefield. The dunefield, which has been commonly hypothesized as vegetated during the Holocene Optimum, was a typical steppe at that time and not suitable for growing millet, the primary staple crop of Neolithic Cultures. Our results and other archaeological site records reveal that the 43°30′N latitude was a remarkable barrier for the dispersal of human settlements in Northeastern China during the Neolithic Age. The barrier was probably formed by the low frost tolerance of millet and the temperature gradient associated with the latitude, making large-scale agricultural production impossible in the regions north of this latitude at the time. Our findings provide evidence for the natural northern limit of Neolithic Cultures in Northeastern China during the Holocene Optimum.

1. Introduction

The emergence of grassland is considered as an important facilitating factor for the evolutionary divergence of apes and humans about 5–10 million years ago (Retallack et al., 1990). Alternating cycles of humid and arid climate led to early modern human population expansion into and out of tropical Africa after 70 kyr ago (Scholz et al., 2007). Fossils and DNA records demonstrate that humans crossed mountains and rivers to reach East Asia (Stringer and Andrews, 1988; Ke et al., 2001; Demeter et al., 2012). Large-scale population increase in ancient China was attributed to conditions in the Holocene Optimum (Chen et al., 2005, 2015; Li et al., 2006, 2009), and a large number of archaeological sites are found near the Yellow and Yangtze Rivers (Chen et al., 2005, 2015). Meanwhile, there was also a notable increase of human population in Northeastern China, and Neolithic Cultures flourished in the West Liao River Basin and its surrounding regions, including the Xiaohexi, Xinglongwa, Zhaobaogou, Hongshan and Xiaoheyan Cultures. The above findings indicate that population migration and the dispersal of human settlements of pre-historic societies were closely related to environment changes.

Neolithic cultures represent an early stage of human civilization in China. Many studies focus on their social aspects (Robert and Christian, 2006; Shelach et al., 2011; Liu and Chen, 2012), and on

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http://dx.doi.org/10.1016/j.quaint.2016.01.011
1040-6182/

the human–environment interactions associated with these cultures (Chen et al., 2005, 2015; Li et al., 2006, 2009). In the rubric of the human–environment interaction pertinent to various cultures, there is an interesting and yet insufficiently-explored phenomenon: the uneven distribution of Neolithic settlements in Northeastern China. It is observed that most settlements were clustered in the regions south of the southern fringe of the Horqin Dunefield, while only a few Neolithic sites are found within or in the regions north of the northern fringe of the Horqin Dunefield (Bureau of National Cultural Relics, 2003). This dunefield basically disappeared during the Holocene Optimum, as it was stabilized by vegetation (Lu et al., 2013). In theory, the "vegetated" dunefield should have been ideal for human settlements in the Neolithic Age. But in reality, only a few Neolithic sites can be found there, as well as in the regions north of the dunefield. Our main research questions then are: How did the observed spatial distribution of Neolithic sites in Northeastern China arise? And, in what ways is the spatial distribution mediated by regional geographic and environmental settings during the time?

Global environmental changes and their possible ecological consequences have attracted the attention of both scientists and the lay public (Mann et al., 2008; Ding et al., 2010; IPCC, 2013). It is important to understand the relationship between environmental evolution and its impact on pre-historic human settlements during extreme climatic periods (e.g., the warm and humid Holocene Optimum). Such understanding may provide insights about how people can adapt to global warming in the future. In the present study, we sought to map out the distribution of Neolithic settlements in Northeastern China and also reveal the region's environment history. Then, based on this information we further traced the human–environment interaction of the region's Neolithic cultures (i.e., relationship between the spatial distribution of human settlements and the agro-ecological environment) during the Holocene Optimum.

2. Study area

Our study area is the West Liao River Basin and its surrounding regions (41°17′–45°41′N, 116°21′–123°43′E) in Northeastern China. These cover an area of ~13 × 10^4 km^2 (Fig. 1). This is also the transition zone between the Inner Mongolia Plateau and Songliao Plain. The West Liao River originates in the southwest of Keshiketeng County, Chifeng, Inner Mongolia, and joins the branches of the Xar Moron, Baicha, Shaolang and Laoha Rivers and then feeds into the Liao River and eventually to the Bohai Sea (Fig. 1). Due to the uplift of Great Khingan Mountain, the western part of the West Liao River Basin is higher than in its eastern part. The average elevation falls from 2833 m a.s.l. in the west to 280 m a.s.l. in the east, with mountains gradually replaced by hills and plains. The Greater Khingan Mountain and the Yanshan Mountain dominate the western part of the study area. Loess hills are located in the southern region, and the Horqin Dunefield lies in the northeastern region.

The study area lies in the present-day's northern fringe of the Asian Summer Monsoon in China, which is a transitional zone between semi-humid and arid climates, with mean annual precipitation between 250 and 500 mm. It is sensitive to environmental change. Land cover in this region consists of woodland and forest steppe in the western mountains, meadow steppe on the western plateau, steppe on the central low hills and plains, drifting and semi-drifting sand in the northeastern Horqin Dunefield; the sporadic occurrence of croplands is possible in the northern loess area.

Culturally, our study area is the birth-place of rain-fed agriculture in Northern China (Zhao, 2005, 2011 and, 2014; Jones and Liu, 2009) and also the hub of the Neolithic cultures in Northeastern China (Robert and Christian, 2006; Lawler, 2009; Christian et al., 2010). Given the cultural significance of the region, it has received much scholarly attention and interest in recent years (e.g., Xia et al., 2000; Xu et al., 2002; Li et al., 2006; Jia et al., 2016a and 2016; Yang et al., 2015).

3. Materials and methods

3.1. Spatial distribution of Neolithic sites

The locational information of the Neolithic sites in the West Liao River Basin and its surrounding regions was obtained from the *Atlas of Chinese Cultural Relics*: *Inner Mongolia Autonomous Region* (Bureau of National Cultural Relics, 2003), which was compiled according to the second nation-wide archaeological surveys of 1981–1985. The maps of Neolithic sites in the atlas were digitized. Standard Universal Transverse Mercator projection was used as the base with some obvious control points [e.g., (44ºN, 118ºE), (44ºN, 120ºE), (44ºN, 122ºE), etc.]. County administrative boundaries were also employed as reference points for determining the X–Y coordinates of the Neolithic sites. The resultant spatial distribution of archaeological sites was plotted on a relied map (Fig. 2).

3.2. Optically stimulated luminescence (OSL) dating and plant remains analysis

Five typical loess sections were sampled along the West Liao River for OSL dating and pollen analysis, including WFD (118°4′4.3″N, 43°14′31.2″E), WNTE (119°10′29.8″N, 43°0′21.9″E), HLDK (119°30′16.4″N, 42°21′11.8″E), KL (121°17′24.0″N, 43°49′12.0″E) and TY-A (123°1′12.0″N, 44°47′24.0″E) (Fig. 1). All of the loess sections contain both sandy and paleosol layers, and are presented in Fig. 3.

The stratigraphic frameworks were established according to the 29 OSL results obtained from the sediment samples taken from the five loess sections, including 4 dates from WFD, 10 from WNTE, 7 from HLDK, 4 from KL and 4 dates from TY-A (Yi et al., 2013). Once the Neolithic soil layer of each loess section had been identified, the soil layer was further sub-sampled for pollen analysis. The sampling positions of each of the loess sections is shown in Fig. 2, with 171 g soil taken from WFD, 148 g from WNTE, 111 g from HLDK, 132 g from KL and 108 g from TY-A. Those soil samples were prepared according to standard laboratory procedures, including hydrochloric acid, potassium hydroxide, hydrofluoric acid and flotation with heavy liquid (specific gravity of 2.1). In order to calculate the pollen concentration and influx, one tablet containing a known number of *Lycopodium* spores (mean of ca. 27,637) was added to each soil sample at the beginning of preparation. All of the palynomorphs were identified and counted under a Nikon light microscope at 400× magnification with reference to a published pollen atlas for the arid and semi-arid areas of China (Xi and Ning, 1994; Wang et al., 1995). In order to ensure a statistically significant sample size, a minimum of 150 grains of terrestrial pollen and spores were counted for each soil sample. Scanning electron microscopy was employed to identify pollen types of special interest. The OSL dating and the pollen analysis were conducted in the Laboratory of Geomorphologic Processes and Environment, School of Geographic and Oceanographic Sciences, Nanjing University.

We also collected twenty-two flotation samples from 10 Neolithic sites in our study area by wash-over flotation in a bucket (Fig. 1). In the Xiaoheyan archaeological site, two flotation samples were collected. Five flotation samples were collected from each of