Social development and living environment changes in the Northeast Tibetan Plateau and contiguous regions during the late prehistoric period

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Social development and living environment changes in the Northeast Tibetan Plateau and contiguous regions during the late prehistoric period

Huihui Cao, Guanghui Dong

A R T I C L E   I N F O

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A B S T R A C T

The relationship between the evolution of human societies and their living environments has been discussed intensively in recent decades. It is important to understand the patterns and mechanisms of human–environment interaction and evolution in order to cope with rapidly changing environments in the modern world. We reviewed the results of dating, archaeobotanical, and zooarchaeological studies from 139 prehistoric sites in the Northeast Tibetan Plateau (NETP) and contiguous regions (NETP-CR: i.e., the Hexi Corridor and western margin of the Chinese Loess Plateau) and compared them with paleoenvironmental records to study variations in spatiotemporal patterns of social development in the area and their relationships with climate and vegetation changes. Our results show that hunter-gatherer groups occupied vast areas of the NETP at low intensities during ~15,000–5500 BP (years before present). This was directly related to forest cover and climate change. An increase in temperature and precipitation turnover of vegetation from desert steppe to alpine meadow/subalpine shrub, and recovery of animal population on the Tibetan Plateau created more food resources and space for hunter-gatherers. Millet farmers settled extensively below 2500 m a.s.l. (meters above sea level) in the NETP-CR between ~5500 and 3600 BP, and might have coexisted with hunting groups above 2500 m a.s.l. via subsistence exchange. The distribution of human settlements during that period was affected by climate change, with the relatively warm and wet climate promoting the expansion of millet agriculture to the NETP-CR during 5500–4500 BP, while climate deterioration caused humans to retreat to lower altitudes. During 3600–2200 BP, a range of livelihoods emerged in different regions of the NETP-CR. This was promoted by early trans-Eurasian exchange and the development of an agro-pastoral economy that utilized cold-tolerant crops and livestock. This eventually promoted the expansion of permanent human settlements to high-altitude areas in the NETP. This study found that human societies adopted various strategies to adapt to the changing living environment throughout late prehistoric times in the NETP-CR. The results provide a long-term perspective on the trajectory of regional socio-environmental co-evolution.
1. Introduction

How human societies adapt to fast-changing environments caused by global warming is an issue of broad interest. The study of social evolution and its relation to past environmental changes helps us to understand the patterns and mechanisms of human–land relationship changes and provides lessons that help us to cope with the challenge of living environment variations in the modern world (Samuels, 2016; Chen et al., 2019a). Previous studies have suggested that the patterns and major influencing factors of human-environment interaction have varied across the stages of human evolution and across spatial scales (Dong et al., 2017, 2020; Revelles et al., 2018). However, there has been little reported research that has focused on the relationship between social evolution and living environment changes during the Paleolithic, Neolithic, and Bronze Age periods on a regional scale.

The history and driving forces of the peopling of the Tibetan Plateau (TP) have been discussed intensively over the past ten years (Aldenderfer, 2011; Brantingham et al., 2013; Chen et al., 2015; d’Alpoim Guedes et al., 2015; Meyer et al., 2017). Recent research has revealed that the first occupation of Denisovans on the TP can be traced back to ~160,000 BP (years before present) (Chen et al., 2019b). Modern humans have occasionally occupied the hinterlands of the TP during 40,000–30,000 BP (Zhang et al., 2018). Hunter-gatherers dominated the TP, especially the Northeast Tibetan Plateau (NETP), more intensively from ~15,000 BP (Madsen et al., 2006; Zhang et al., 2016) until the arrival of farming groups from the nearby Chinese Loess Plateau (CLP). The latter began to settle extensively below 2500 m a.s.l. (meters above sea level) in the NETP and contiguous regions (NETP-CP: i.e., the Hexi Corridor and western margin of the CLP) between ~5500 and 3600 BP (Dong et al., 2013a; Li et al., 2019).

Humans expanded upward and settled year-round above 3000 m a.s.l. on the NETP in ~3600 BP. This was facilitated by the utilization of frost-tolerant barley and sheep, which were introduced into the area around 4000 BP (Chen et al., 2015; Dong et al., 2018). However, humans adapted via lifestyle differences in regions of the NETP with different altitudes (Zhang and Dong, 2017) between ~3600 and 2300 BP. The same pattern appeared in the Hexi Corridor during ~2900–2100 BP (Yang et al., 2019a, b). Although the timeline of human occupation in the NETP is clear, the spatiotemporal patterns of human societies in the NETP-CR have not been reconstructed in detail.

Previous studies have detected differences in human subsistence strategies in different regions of the NETP-CR during the Bronze Age (Zhang and Dong, 2017; Yang et al., 2019a). These were closely related to the onset and intensification of trans-Eurasian exchange (Ma et al., 2016; Dong et al., 2018). The NETP-CR living environment also varied substantially between ~15,000 and 2000 BP (Shen et al., 2005; Qiang et al., 2017; Zhang et al., 2018). This is thought to be an important driver of cultural evolution in the area (Dong et al., 2012; J. Z. Hou et al., 2016). We systematically reviewed and analyzed archaeobotanical and zooarchaeological data, as well as dating results from Paleolithic, Neolithic, and Bronze Age sites in the NETP-CR. We compared the resulting data with paleoclimate records to explore how human societies interacted with their living environments during various phases of the late prehistoric period.

2. Methods

2.1. Data sources

A total of 492 chronological data points (485 radiocarbon dates and seven optically stimulated luminescence (OSL) dates) were collected from 139 Paleolithic, Neolithic, and Bronze Age sites in the NETP-CR. All conventional ages from $^{14}$C dates were calibrated to
Human occupation in the NETP-CR during different periods is well documented. The intensity of human occupation varied significantly during the different periods, as indicated by the distribution of prehistoric sites (Fig. 1). Prehistoric humans occupied the Qinghai Lake Basin for a long time during 15,000–5500 BP, and then spread to the surrounding area during 12,000–9000 BP and 9000–5500 BP, with different intensities. During the Neolithic and Bronze Age periods, the number of archaeological sites increased, and the range and intensity of human activity expanded. Humans tended to migrate to higher-altitude areas during 5500–4500 BP, and then retreated to lower altitudes during 4500–3600 BP, before once again expanding to higher elevations during 3600–2200 BP (Fig. 1).

Animal and plant remains indicate that prehistoric human subsistence changed significantly in the Paleolithic, Neolithic, and Bronze Age periods. Humans fed on wild animals during 15,000–5500 BP. During 5500–4000 BP, millet (*Setaria italica* and *Panicum miliaceum*) agriculture appeared in the NETP-CR, domestic animals appeared in lower-altitude areas, and wildlife still dominated at higher elevations. During 4000–2200 BP, barley (*Hordeum vulgare*)-based agriculture and shepherding were the dominant subsistence activities in higher-altitude areas, while millet, barley, and wheat (*Triticum aestivum*) became the major subsistence crops in lower-altitude areas.

### 2.2. Data analysis

Archaeological sites distribution and dating results (including radiocarbon and OSL dates) indicate that the range and density of human activity in the NETP-CR varied significantly in different prehistoric periods (Fig. 1). Prehistoric humans occupied the Qinghai Lake Basin for a long time during 15,000–5500 BP, and then spread to the surrounding area during 12,000–9000 BP and 9000–5500 BP, with different intensities. During the Neolithic and Bronze Age periods, the number of archaeological sites increased, and the range and intensity of human activity have further expanded. Humans tended to migrate to higher-altitude areas during 5500–4500 BP, and then retreated to lower altitudes during 4500–3600 BP, before once again expanding to higher elevations during 3600–2200 BP (Fig. 1).

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### 3. Results and discussion

#### 3.1. The trajectory of prehistoric human occupation in the NETP-CR

To explore the history of human occupation in the NETP-CR more accurately, we reconstructed the spatiotemporal patterns of human societies in the area primarily based on the distribution of well-dated prehistoric sites (Fig. 1). The results of the second national archaeological survey in Gansu Province and Qinghai Province (*Bureau of National Cultural Relics, 1996, 2011*) were also considered.

Some researchers have suggested that hunter-gatherer groups might have occupied the NETP-CR before 30,000 BP (*Huang et al., 1987; Brantingham et al., 2007*). However, the chronologies of a few Paleolithic sites attributed to that period are debatable due to the absence of reliable dates (*Sun et al., 2010; Zhang et al., 2016*). The quartz OSL date of the archaeological layer in the Xiao Qaidam Basin Paleoolithic site indicated that it is younger than 11,000 BP, rather than 30,000 BP (*Sun et al., 2010*). Foragers occupied the Qinghai Lake Basin in the NETP-CR starting in ~15,000 BP (*Madsen et al., 2006; Wang et al., 2020*) and remained dominant until ~5500 BP. The intensity and scope of human occupation varied during the different periods of 15,000–5500 BP.

Humans were engaged in hunting and gathering activities between 15,000 and 12,000 BP in the Qinghai Lake Basin of the NETP-CR. Some of the campsites from that period include the Yaowuyao, Jiangxigou, Heimahe, Hudongzhongyangchang, and Shihuotang sites between 5500 and 2200 BP.

To analyse spatial variations in animal and plant remain compositions, we chose zooarchaeological and archaeobotanical data from 15 excavated sites, and added three zooarchaeological and seven archaeobotanical data between 4000 and 2200 BP to provide comprehensive comparative data. We also collected zooarchaeological data from 18 prehistoric sites between 15,000 and 2200 BP and archaeobotanical data from 107 prehistoric sites between 5500 and 2200 BP.

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Hunting groups continued to occupy the Qinghai Lake Basin (*Rhode et al., 2014*), although the centre of their occupation shifted to the Gonghe Basin above 2600 m a.s.l. in the upper portion of Yellow River Valley, where an indigenous culture (the Zongri) developed between approximately 5500 and 4000 BP (*Chen et al., 1998*). A total of 51 Zongri cultural sites were found in the eastern Gonghe Basin (*Chen et al., 1998*). Hunting game provided a livelihood for the Zongri (*An and Chen, 2010; Ren et al., 2020*). During the same period, the late Yangshao (5500–5000 BP) and Majiayao (5300–4000 BP) farming groups expanded to the NETP-CR from the western CLP (*Bureau of National Cultural Relics, 1996; Dong et al., 2018*) and settled extensively below 2500 m a.s.l. (*Chen et al., 2015*). Although an abundance of Majiayao pottery fragments has been found in contemporaneous sites above 2500 m a.s.l. (e.g., Zongri sites) (*Bureau of National Cultural Relics, 1996*), these relics were probably brought to these sites via trans-regional exchange in the NETP-CR rather than being produced locally (*Hong et al., 2012; Cui et al., 2020*). The centre of the Majiayao groups in the NETP-CR shifted from the upper Yellow River Valley between 5500 and 4500 BP to the lower Huangshui River Valley and Hexi Corridor between 4500 and 4000 BP (*Dong et al., 2013b*). This pattern is shown in Fig. 1 and lasted until ~3600 BP.

The scope of the human habitats was remarkably enlarged during 3600–2200 BP in the NETP-CR (Fig. 1). Humans settled permanently at a large scale above 2500 m a.s.l. in the NETP (*Chen et al., 2015*) and the settled area in the Hexi Corridor also reached an unprecedented level (Fig. 1) (*Bureau of National Cultural Relics, 2011*). This contrasts with the Neolithic period, when the dominant cultures including the Majiayao and Qijia (~4300–3600 BP) developed broadly in Gansu Province and Qinghai Province. Various cultures emerged and coexisted in different regions of the NETP-CR (Fig. 1) (*Xie, 2002*), such as the Kayue (3600–2600 BP), Nuomuhong
3.2. Spatiotemporal patterns of subsistence strategies in the NETP-CR during the late prehistoric period

The characteristics of assemblages of animal and plant remains, as well as tools, unearthed from archaeological sites, have been included in a fundamental dataset used to understand past human subsistence strategies. To explore the variation in subsistence...
strategies in the NETP-CR during the late prehistoric period, we calculated the percentage number of identified specimens (NISP) for various fauna, including wild animals, domestic omnivores (pigs (*Sus domesticus*) and dogs (*Canis familiaris*)), and domestic herbivores (cattle (*Bos taurus*), sheep/goat (*Ovis aries/Capra hircus*), horse (*Equus caballus*), etc.). We also calculated the proportions of various plant remains (foxtail/common millet, wheat, barley, and weeds) at each site, as well as the total number from various periods. The spatial and temporal patterns of animal and plant subsistence utilization are shown in Figs. 2 and 3.

The artefacts unearthed from sites dated between 15,000 and 5500 BP were overwhelmingly stone tools (*Gai and Wang, 1983; Rhode et al., 2007; Tang et al., 2013*), which were used primarily to hunt game. Although a few pottery shards were identified occasionally from culture layers that dated to ~7000–5000 BP at the Jiangxigou site in the Qinghai Lake Basin (*Rhode et al., 2007; Hou et al., 2013*), these shards were likely brought to the region via cultural exchanges. The age of the shards coincided with the expansion of the Yangshao Culture to this location. Contemporaneous shards discovered in the Qinghai Lake Basin were identified as Majiayao painted pottery (*Hou et al., 2013*). Only wildlife remains were identified from sites dated to 15,000–5500 BP in the NETP-CR (Figs. 2a and 3f), further indicating that humans relied primarily on hunting game during this period. The assemblage of prey varied over time. For example, humans in the Qinghai Lake Basin mainly hunted large and medium-sized mammals such as wild horses or wild donkeys (*Equus* sp.) during ~15,000–12,000 BP, but there was a shift to small and medium-sized wildlife, such as hare (*Ochotona* sp.), gerbil (*Meriones* sp.), and marmot (*Marmota himalayana robusta*) during ~9000–5500 BP (*Gai and Wang, 1983; Madsen et al., 2006; Wang et al., 2020*).

The spatial patterns of human livelihoods transformed notably with the arrival of Neolithic groups in the NETP-CR, starting in approximately 5500 BP when coloured pottery was commonly used in the upper Yellow River Valley, especially in areas below 2500 m a.s.l. (*Bureau of National Cultural Relics, 1996; Dong et al., 2013a*). Carbonized grains of common and foxtail millet were identified

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**Fig. 3.** Assemblages of plant and animal remains unearthed from prehistoric sites and the number of dated sites in the NETP and NETP-CR compared to climate records. (a), pollen-based mean July temperature reconstruction from Xingyun Lake (*Wu et al., 2018*); (b), δ¹⁸O record of the Asian monsoon strength from Dongge Cave stalagmites (*Dykoski et al., 2005*); (c), total charcoal concentrations (CC) from the Gonghe Basin (*Miao et al., 2017*); (d), tree pollen percentage in the Qinghai Lake (*Shen et al., 2005*); (e), the number of dated sites every 500 yr in the NETP-CR during 15,000–2000 BP; (f), assemblages of animal and plant remains identified from prehistoric sites below and above 2500 m a.s.l. in the NETP-CR. The total number identified is marked at the top of each pie chart, N/A (not available) means there is only composition ratio and no specific number in the original literature.
frequently in late Yangshao and Majiayao sites in the NETP-CR (Zhang, 2012; Chen et al., 2015; Yang et al., 2019a), revealing that millet cultivation was an important subsistence strategy in areas lower than 2500 m a.s.l. Isotopic evidence suggests that Zongri groups above 2500 m a.s.l. consumed C₄ foodstuffs (Cui et al., 2006). Recent studies have revealed the unique combination of a high percentage of millet in plant remains (>96%) and wildlife in animal remains (>98%) at Zongri sites created during 4600–4000 BP (Fig. 3d) (Ren et al., 2020). This evidence implies that Zongri groups continued to hunt game as their primary strategy but also exchanged millet crops with surrounding Majiayao societies (Ren et al., 2020). This also explains the high proportion of wildlife remains in the Andaqiai site (>90%; Fig. 2b) (Wang, 2017). A similar millet agriculture mixed with hunting economic existed in Karuo groups, an alternative and equally plausible hypothesis suggests the inhabitants in Karuo were not farmers, but foragers who obtained cultivated crops by trade (d’Alpoim Guedes, 2015, 2018). Humans in Andaqiai (~2059 m a.s.l.) engaged in millet cultivation and raised domestic pigs and dogs during 5000–4500 BP in the Quanke–Jianzha Basin of the upper Yellow River Valley (Chen et al., 2015; Wang, 2017). The archaeobotanical and zooarchaeological evidence suggests that they might also have hunted wild animals or acquired them via cultural exchanges with contemporaneous Zongri groups (Ren, 2017; Ren et al., 2020). In the Hexi Corridor, Machang groups adopted rain-fed agriculture as their major source of livelihood during 4300–4000 BP (Yang et al., 2019a). The percentage NISP of domesticated omnivores (pigs and dogs) and herbivores (sheep and cattle) identified in the Mozuizi site were 57% and 39%, respectively (Figs. 2b and 3f) (Institute of Archaeology, Chinese Academy of Social Sciences, 2011). This suggests that livestock production became an important subsistence strategy in the Hexi Corridor during this period.

The spatial patterns of human subsistence strategies in the NETP-CR during the Bronze Age clearly changed. These changes were triggered by the introduction of new cultural elements into the area, such as copper smelting, wheat, barley, sheep, cattle, and horse (Dong et al., 2018). These techniques and food sources were rapidly integrated into human livelihoods when they were introduced in the Hexi Corridor, respectively (Zhou et al., 2016; Yang et al., 2019a). The area was one of the earliest copper-smelting centers in China (Li, 2005). Barley and sheep became the most important sources of subsistence in the NETP-CR during ~3600–2200 BP, especially in high-altitude areas of the NETP (Fig. 2c). The percentages of herbivorous livestock and weeds in the NETP-CR during 3600–2200 BP were much higher than those during previous periods (Fig. 3f), which suggests the development of an animal husbandry economy in the area during the Bronze Age. However, primary subsistence strategies varied by region and phase in the NETP-CR during the Bronze Age (Fig. 2c) (Zhang and Dong, 2017; Yang et al., 2019a). The same spatial pattern was found in other areas of North China during the same period (Cheung et al., 2017; Li et al., 2020).

3.3. Interactions between social development and living environment changes in the NETP-CR during the late prehistoric period

The evolution of human societies is intricately linked to living environment changes during the prehistoric period (Dong, 2018). Human hunting and gathering activities were restricted by the abundance of edible wild animals and plants during the Paleolithic period. This was further affected by environmental changes (Elston et al., 2011; Tallavaara et al., 2018). The adaptability of human societies to climate change has clearly increased since Neolithic times, when farmers began to proactively produce foodstuffs and altered their living environments to facilitate sedentary lifestyles (Fiorentino et al., 2013; Zhuang and Kidder, 2014; Cheng et al., 2018). Social resilience to living environment changes was further strengthened during the 5th and 4th millennium BP when transcontinental exchange emerged and intensified, profoundly influencing human livelihoods in various areas of the Old World (Spengler et al., 2014; Liu et al., 2019). The impact of human activity on living environments also clearly increased during this period (Marinova and Atanassova, 2006; Marshall et al., 2018).

Hunter-gatherer groups migrated seasonally between high-altitude areas of the NETP (such as the Qinghai Lake Basin and foothills of the Kunlun Mountains) and low-altitude areas of the NETP-CR during ~15,000–5500 BP (Zhang et al., 2016). The scope and intensity of human occupation in the NETP-CR have changed substantially over time (Fig. 1). The intensity of human occupation fluctuated roughly synchronously with the percentage of tree pollen in sediments from the Qinghai Lake Basin (Fig. 3), which was the centre of human occupation in the NETP-CR between 15,000 and 12,000 BP. This suggests that surrounding tree cover might have synchronously with the percentage of tree pollen in sediments from the Qinghai Lake Basin (Fig. 3), which was the centre of human occupation in the NETP-CR during ~15,000–12,000 BP. This suggests that surrounding tree cover might have synchronously with the percentage of tree pollen in sediments from the Qinghai Lake Basin (Fig. 3), which was the centre of human occupation in the NETP-CR during ~15,000–12,000 BP. This suggests that surrounding tree cover might have synchronously with the percentage of tree pollen in sediments from the Qinghai Lake Basin (Fig. 3).
was triggered by climate deterioration (Dong et al., 2012, 2013b). Zongri groups were the last foragers and hunters in the NETP to subsist on wild animals and millet, with the millet obtained by exchanges with Majiayao groups in the lower-altitude areas (Ren et al., 2020).

Barley, wheat, sheep, and cattle were introduced into the Hexi Corridor around ~4000 BP (Dodson et al., 2013; Dong et al., 2018) and then spread rapidly to other regions of the NETP-CR. These innovations had significant impacts on social development and relationships with the living environment. The introduction of new cold-tolerant crops and livestock combined with declines in temperature and precipitation (Fig. 3a and b) to induce rapid changes in human primary livelihoods in the Hexi Corridor (Zhou et al., 2012; Yang et al., 2019a) and NETP (Ma et al., 2016), as well as the development of agro-pastoral production, which facilitated extensive, permanent human occupation of the higher altitude areas of the NETP after 3600 BP (Chen et al., 2015). The evident improvements in social resilience with respect to the living environment facilitated continued human settlement growth in the NETP-CR during 3600–2200 BP (Fig. 3) (Bureau of National Cultural Relics, 1996, 2011), when the climate was relatively cold and dry in comparison to 15,000–3600 BP. Humans altered their living environments in the Hexi Corridor during 3600–2200 BP (Zhou et al., 2012; Yang et al., 2017; Zhang et al., 2017). The fir frequency and Stellera flower content of lake sediment in the NETP increased substantially during this period (Fig. 3c) (Huang et al., 2017). Tree cover was low in the NETP during 3600–2200 BP (Fig. 3d). This was likely due to the impact of human activities and climate change. Additionally, an open landscape aids in the development of herding activities, which were among the major subsistence methods in the Hexi Corridor (Yang et al., 2019a) and Qaidam Basin (Dong et al., 2016). This pattern can also be detected from increases in the weights of weeds in plant remains and herbivorous livestock in animal remains (Fig. 3f).

4. Conclusions

Based on a comprehensive analysis of archaeobotanical and zooarchaeological evidence, as well as radiocarbon and OSL dates from Paleolithic, Neolithic, and Bronze Age sites in the NETP-CR, we reconstructed the spatiotemporal patterns of social development in the area for the period between ~15,000 and 2200 BP. Foragers were the primary occupants of the Qinghai Lake Basin in the NETP during ~15,000–12,000 BP. The intensity of their occupation declined from 12,000 to 9000 BP but increased from 9000 to 5500 BP as their living area expanded. Hunting groups continued to colonize the Gonghe Basin above 2500 m a.s.l. during ~5500–4000 BP, when millet farmers settled in large numbers below this altitude in the NETP-CR. The centers of human settlement shifted between ~5500 and 4500 BP and ~4500–3600 BP. The scope of the human permanent settlement expanded significantly in comparison to previous periods, especially in high-altitude areas during ~3600–2000 BP. Humans adopted various subsistence strategies in different areas of the NETP-CR during this period. The primary factors that influenced social development in the NETP-CR varied throughout the late prehistoric period, with forest vegetation changes having a major influence on hunter-gatherer groups during ~15,000–5500 BP, while cultural exchanges facilitated the coexistence of millet farming and hunting groups during ~5500–4000 BP. Cold-tolerant barley and sheep were introduced into the NETP-CR around 4000 BP. They had been adopted as important sources of subsistence in the early 4th millennium BP. This led to the development of agro-pastoral production and diversified livelihoods, as well as an enhanced social resilience to living environment changes and extensive expansion of human habitats in the NETP-CR, especially in high-altitude areas of the NETP. Studies of prehistoric human activity and living environmental changes provide a long-term perspective on the trajectory of regional socio-environmental co-evolution.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.regsus.2020.09.001.

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