

Precipitation change and its effects on prehistorical human activities in the Gonghe Basin, Northeastern Qinghai-Tibet Plateau during middle and late Holocene

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Abstract. Northeastern Qinghai-tibet Plateau is considered as the ideal region for study of the climate change during the Holocene. Based on the meteorological data, the surface & fossil pollen data, this paper reconstructed the precipitation series of the region since middle Holocene with the GIS and MAT techniques, and discussed its relationship with prehistorical human activities. The results indicate that there are four major climatic phases: (I) Middle Holocene Humid Phase (6300-5000 aBP), with the primitive millet-farming first imported into the region; (II) Late Middle Holocene Sub-humid Phase (5000-3900 aBP), with the millet-farming spread rapidly within the region; (III) Late Holocene Fluctuation Phase (3900-2900 aBP), with the mean annual precipitation dropped down to lower than 240 mm, and a production mode-shift to a combination of cropping and husbandry; (IV) Late Holocene Stationary Phase (2900-0 aBP), with a precipitation alike the modern time, and a steady farming-pastoral economic pattern.

1. Introduction

Holocene is a time period accompanied by the rapid development of modern human civilization, during which the environmental impacts and constraints on human activities are huge influential. The various prehistoric cultures on the northeastern Qinghai-Tibet (hereafter QT) Plateau form a complete sequence, which includes Yangshao culture (7000-5300 aBP), Majiayao culture (5300-4000 aBP), Qijia culture (4100-3600 aBP), Kayue culture (3600-2500 aBP) and Xindian culture (3400-2600 aBP). The relationship between prehistoric culture evolution and environmental change received much attention from scholars at home and abroad [1,2]. Based on the data of pollen, charcoal grains, and stone implements, also related archaeological materials, studies had been mainly on the qualitative analysis of the environmental change during different development periods of prehistorical human civilization [3-5], whereas there were few studies focusing on the reconstruction of climate change series of this region in Holocene[6,7]. Based on the fossil pollen records from Genggahai Lake, Gonghe Basin, this paper attempts to reconstruct the precipitation series in middle Holocene with the GIS and MAT techniques, and to discuss the relationship between precipitation change and prehistorical human activities.



2. Regional setting

The northeastern QT Plateau primarily refers to Gonghe Basin and the Yellow and Huang rivers' valleys in Qinghai province, China. The region reveals a topographic feature of opposite arranged mountains and valleys. The mountains are mainly 2000-3500 m in altitude with east-west trending. The river valleys (altitude 1700-2600 m) are developed into broad floor ones. It has a plateau temperate semi-arid climate with the vegetation mostly covered by temperate steppe. Prehistoric civilization relics found are relatively concentrated on the northeastern QT Plateau, with the Neolithic age, Majiayao culture and Qijia culture (bronze-stone implements mixed period), engaged primarily in agriculture, and the Bronze age, Kayue and Xindian cultures, adjusted the cropping structure and mixed with husbandry.

The Gonghe Basin (Figure 1) is located in the northeastern margin of the QT Plateau, and at a convergence zone of Asian winter-summer monsoon and westerlies, it is a Mesozoic-Cenozoic fault basin, with an east-west length of around 160 km and 30-40 km of north-south, and an average elevation of more than 2900 m. With the distinct geographic position and a fragile eco-system, Gonghe Basin becomes an ideal region for studies on Holocene climatic change [5].

Genggahai (36°11'26"N, 100°06'15" E; altitude 2858 m) is a brackish water lake located in Gonghe Basin, with 1.8 m in depth and around 2 km² in size. It is a micro-size closed lake replenishing water from underground [8]. Located in the margin area of the monsoon climate region, it is a transition zone of semi-arid steppe and arid desert steppe [9], with an annual average air temperature of 3.5°C and the highest temperature of around 15°C in July. The precipitation is around 255 mm and mainly contributed by rainfalls from May to September.



Figure 1. Location of the study region.

3. Materials and methods

3.1. Surface pollen data and site precipitation data

The surface pollen data mainly comes from the East Asian palynological database, with part of it retrieved from published papers. 484 surface pollen sites (Figure 2), mainly distributed on the QT Plateau and its adjacent regions, and were chosen, basically covering all modern vegetation types existed on the northeastern QT Plateau. Compared with each fossil pollen from Genggahai Lake, the same pollen types found in 484 modern surface pollen data were recognized and sorted out. The annual average precipitation data of surface pollen points derives from GIS interpolated meteorological data (1951-1980), retrieved from China Meteorological Science Data Sharing Service Network. The fossil pollen data derives from the Genggahai lake GGHA fossil pollen diagrams of previous publications [9].

3.2. Modern analog technique

Within the Quaternary geosciences, the modern analog technique (MAT) [10,11] has become an increasingly popular method for the reconstruction of past environments [12]. The MAT has been used to infer past climates and vegetation from fossil pollen [13,14] as well as marine/ocean sea surface temperature and salinity at numerous time-scales [15].

The MAT provides an objective way of quantifying past environments. The MAT technique compares a fossil biological assemblage (F) to all modern assemblages (M) within a given geographic extent. The modern assemblage with the smallest dissimilarity is in theory the ‘best’ modern analog [16]. It calculates a dissimilarity coefficient which measures the difference between the assemblage of the sample and that of the analog [17]. The MAT calculation of the dissimilarity coefficient is based on the squared chord distance (*SCD*). *SCD*, ranges from zero for a perfect analog (no dissimilarity) to two at maximum dissimilarity and is given as:

$$SCD_{ij} = \sum_k (P_{ik}^{1/2} - P_{jk}^{1/2})^2 \quad (1)$$

where, *SCD* is the dissimilarity coefficient, P_{ik} is the proportion of pollen type *k* within the fossil assemblage *i* and P_{jk} is *k* within the modern assemblage *j* [10].

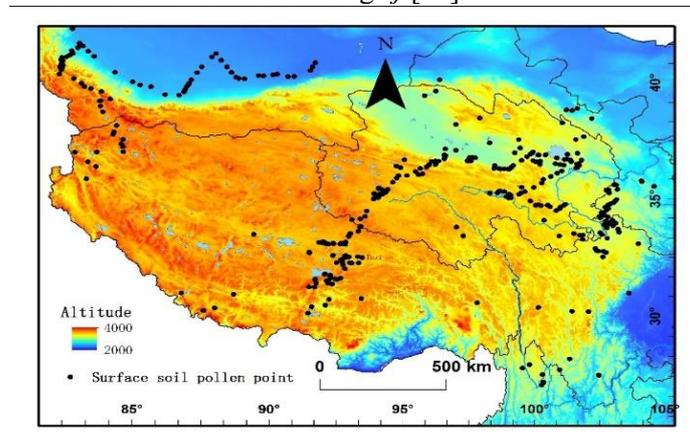


Figure 2. The modern surface soil pollen of the QT.

4. Result

Polygon software was applied to calculate the reliability (R) of data of Genggahai fossil pollen types and that of modern types. The result is an average value of 0.68, which implies a consistent similarity between the chosen pollen types of fossil and modern surface.

The curve of rainfall variation of Genggahai section shows that the environmental change within the region has gone through four major phases since 6300 aBP (Figure 3), namely:

Phase I (6300-5000 aBP) - Holocene Humid Phase. It has a rainfall variation range of 225-461 mm, and an annual average precipitation of 352 mm, which is 95 mm higher than modern precipitation (1950-1980: 257 mm). The maximum rainfall period is among 6300-5500 aBP, with an annual average precipitation of around 390 mm, about 133 mm higher compared with the modern time. The region's biggest rainfall during Holocene occurred at 6090 aBP with the precipitation reached 462 mm. 5500~5000 aBP has an annual average precipitation of 312 mm, 78 mm less than the previous period;

Phase II (5000-3900 aBP) - Late Middle Holocene Sub-Humid Phase. With a rainfall variation range of 205-432 mm, it saw a violent precipitation fluctuation. The annual average precipitation is around 321 mm (64 mm higher than modern time);

Phase III (3900-2900 aBP) - Late Holocene Fluctuation Phase. With a rainfall variation range of 119-384 mm, the overall tendency of precipitation goes down. The annual average precipitation is around 241 mm (16 mm lower than modern time);

Phase IV (2900-0 aBP) - Late Holocene Stationary Phase. With a rainfall variation range of 145-341 mm, it sharply declined to the lowest rate of 119 mm at 2890 aBP since the beginning of the

Middle Holocene. The annual average precipitation is around 231 mm (26 mm lower than modern time).

A number of wet and dry events by centennial scale can be identified from the reconstructed precipitation series. The main wet events include 6000 aBP, 4100 aBP and 1600 aBP; the main dry events include 4900 aBP, 3800 aBP and 2800 aBP.

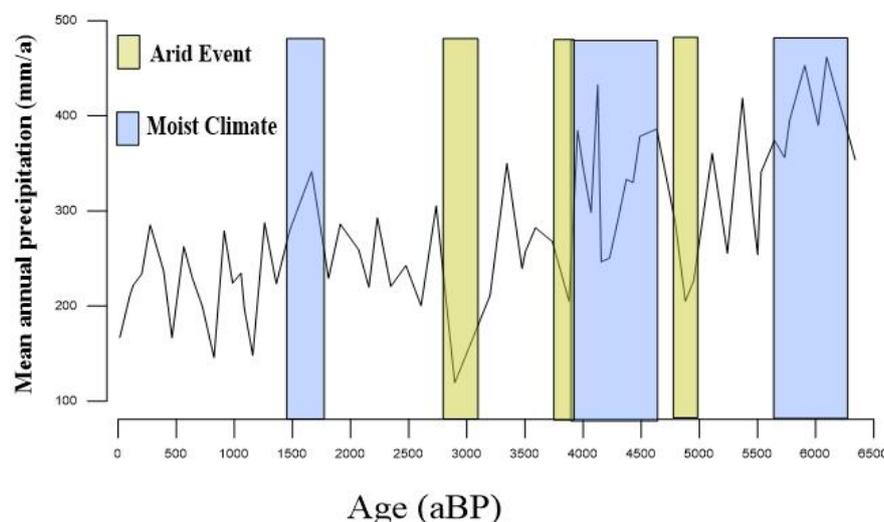


Figure 3. Reconstructed paleo-precipitation sequence.

5. Discussion

With due consideration to the evolving process of vegetation and prehistoric human society development in northeastern QT Plateau, we are able to find the characteristics of environmental changes of those four major phases in Holocene (Figure 4).

6300-5000 aBP: the abundant rainfall during this phase ensured the outcome of a certain region of forest vegetation in the mountains around the lake. The prehistorical human activities in this phase show that, Yangshao Culture from Loess Plateau spread to the Huangshui River Valley at 6000 aBP, which indicates the primitive millet agriculture had entered the region. Andaqiha site is one of the earliest Neolithic sites found on the QT Plateau, it belongs to the Yangshao Culture (around 6000 aBP). It is believed to be the earliest evidence of foxtail, broomcorn millet planting on the QT Plateau [18,19]. The fluctuated number of carbon grains over 10 Yangshao Culture relics represents the intensity of prehistorical human activities. The abundant rainfall in the Middle Holocene contributed to spread of prehistoric agriculture to the Plateau's northeastern margin, with the increased prehistorical human activities traces.

5000-3900 aBP: the environmental feature of this phase includes decreased precipitation, mostly humid, grassland based vegetation with increase in *Artemisia* and *Gramineae* contents and *Pine* dominated forest region began to retreat. The primitive agriculture developed consistently in this phase. Majiayao Culture period (5300-4000 aBP) saw the millet farming's great development, with the planting region extended to the whole Huangshui River valley [20]; Changning site pollen results (4700-3960 aBP) show that *Gramineae* contents increased conspicuously, which implies a fast agriculture development [21]; Liuwan tomb complex of Machang period found millet remains in the coarse pottery, which shows that Majiayao Culture in the late period is still agriculture-based economic structure [20]. As it shows in Figure 4, the population, sites and carbon chips increased steadily, and reached its climax at 4100 aBP of Machang period. The number of Machang period sites has reached more than 580, which indicates that the scope of prehistorical human activities has reached a new climax.

3900-2900 aBP: the environmental feature of this phase includes plummeted precipitation, continuously decreased tree pollen, forest vegetation disappeared in mountains around Gonghe Basin, and a drying climate. The number of Qijia Culture (4000-3600 aBP) sites at this period is around 430, smaller than Machang period, and that of carbon grains decreased violently, which indicates declined prehistorical human activities [20]. Starch grain analysis on the stone knives found in Qijia Culture sites revealed crops like barley, buckwheat, etc., existed at that time, which reflects the characteristic of diversified plant resources acquired by people then. With a declined status for agriculture and a rising proportion for animal husbandry, the plant cropping structure began to adjust. Kayue and Xindian Culture of bronze age (3600-2000 aBP), experienced a gradually severe arid climate, and with the animal husbandry became the primary in contrast with a declined proportion of agriculture. The scope of Kayue Culture sites covered the majority field of the region with a number of nearly 1800 and a population reached the climax of prehistory. All these show that the adjustment of economic structure impelled the expansion of prehistorical human activity regions and enhancement of intensity. For instance, there are 22 Majiayao Culture sites, 6 Qijia Culture sites, 484 Kayue Culture sites located in Hainan County, Qinghai province [20]. The shift of production mode of prehistorical culture results from the human adjustment to a declined precipitation climate.

2900-0 aBP: environmental change in this phase saw a rising size of quinoa dominated desert grassland accompanied with a declined size of *Gramineae* & *Artemisia* dominated grassland, and an increased content of *Ephedra* and *Nitraria*. This implies an even severe arid climate compared to the previous one [9]. The precipitation kept a steady level, which became the climatic background for the formation of a semi-farm & semi-husbandry economic structure.

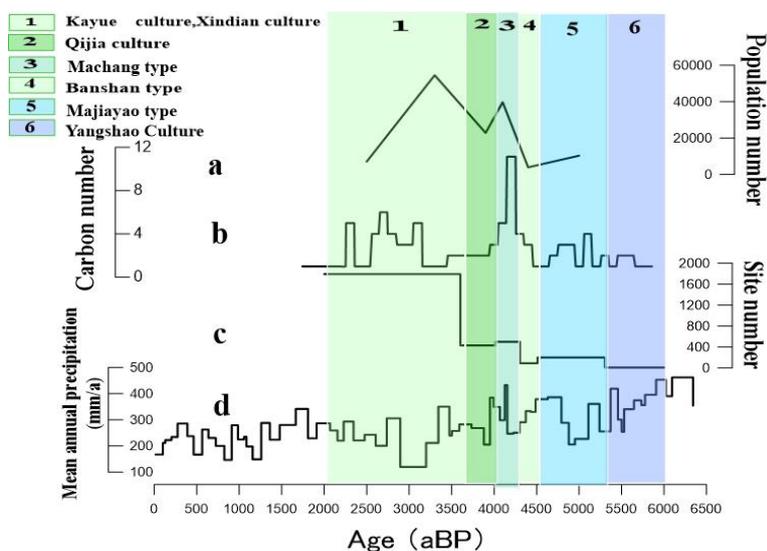


Figure 4. Precipitation changes and prehistorical human activities (northeastern QT plateau).

a Prehistoric population;
b Number of carbon grains;
c Number of prehistorical sites;
d Reconstruction of paleo-precipitation.

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