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Evidence of Holocene millennial-scale climatic change from Gonghe Basin peat deposit, northeastern Qinghai-Tibet Plateau

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ABSTRACT

The northeastern Qinghai-Tibetan Plateau (QTP) lies at the convergence of the Asian winter and summer monsoons and westerlies, making it an ideal place for studying the effects of climatic change, owing to its fragile ecological environment and unique geographical location. This paper reports on a multi-proxy analysis consisting of magnetic susceptibility, total organic carbon content (TOC), pollen, grain size, and geochemical parameters from the peat deposit in the Gonghe Basin to reconstruct the Holocene millennial-scale climatic variation. The results indicate that the climate tended to be warm and humid since 10.0 cal ka BP, but it deteriorated obviously (cold and dry) in 8.6–7.1 cal ka BP. The regional optimal warm and humid period was from 7.1–3.8 cal ka BP, although there were frequent climatic fluctuations during that time. Thereafter, the climate became cold and dry. 10 millennial-time-scale cold events were recorded, which were coincident with climatic records from deep sediments in the North Atlantic Ocean, ice cores, lakes, peat, and aeolian deposits in the QTP. In addition, we discovered that the southwestern monsoons forced by solar insolation in the Holocene have crucial effects on regional climatic change, and the millennial-scale cold fluctuations are possibly related to the thermohaline circulation (THC).

1. Introduction

Numerous paleoclimatic records consisting of ice cores (Alley and Agustsdottir, 2005; O'Brien et al., 1995), deep-sea sediments (Bianchi and McCave, 1999; Bond et al., 1997; Gupta et al., 2003; Overpeck et al., 1996), stalagmites (Dykoski et al., 2005; Fleitmann et al., 2003), and peat deposits (Hong et al., 2003; Zhou et al., 2002) in the high and low latitudes of the Northern Hemisphere indicate that the Holocene climatic systems were obviously unstable and had periodic fluctuations. In the Qinghai-Tibetan Plateau (QTP), previous researches demonstrate that the Holocene climatic changes experienced several millennial-scale oscillations and present multi-stage and multi-cycle characteristics (e.g., Hong et al., 2003; Mischke and Zhang, 2010; Yu et al., 2006; Zhou et al., 2002). However, research is still relatively scarce on whether similar changes occurred in the northeastern QTP during the same period. If there were similar changes in the northeastern QTP and the global climate, what is the possible relationship between them? If spatial differences exist between them, what mechanism leads to this diversity? Obviously, if we want to understand this, we must seek more long-term, high-resolution records of climatic and environmental changes and extract information about abrupt events, and further discuss the laws of regional climatic change and possible forcing mechanisms.

The Gonghe Basin is located at a triple junction of influences from the Asian summer monsoons, the winter monsoons, and the westerlies, which makes it an important component of the transition zone between desert and loess and the fragile landscape belt in northern China (Fig. 1A). Surveys of periglacial geomorphology by Xu et al. (1984) in the northeastern QTP indicate that there have been several cold phases in the Gonghe Basin during the Holocene period. Based on paleosol-loess-aeolian sand sequences, Dong et al. (1993) and Gao et al. (1993) reconstructed the regional climatic change and desert evolution since the Late Pleistocene, and the relationship between them. Recently, Cheng et al. (2010), through comprehensive studies at Dalianhai Lake, concluded that the regional warmth and humidity reached maximum in the Middle Holocene, while Liu et al. (2008) found that the temperature and humidity gradually tended to be lower during the Holocene around Chaka Salt Lake. The aforementioned results demonstrate different climatic change processes in the Gonghe Basin during the Holocene period, and millennial-scale climatic fluctuations are still relatively scarce. Here,

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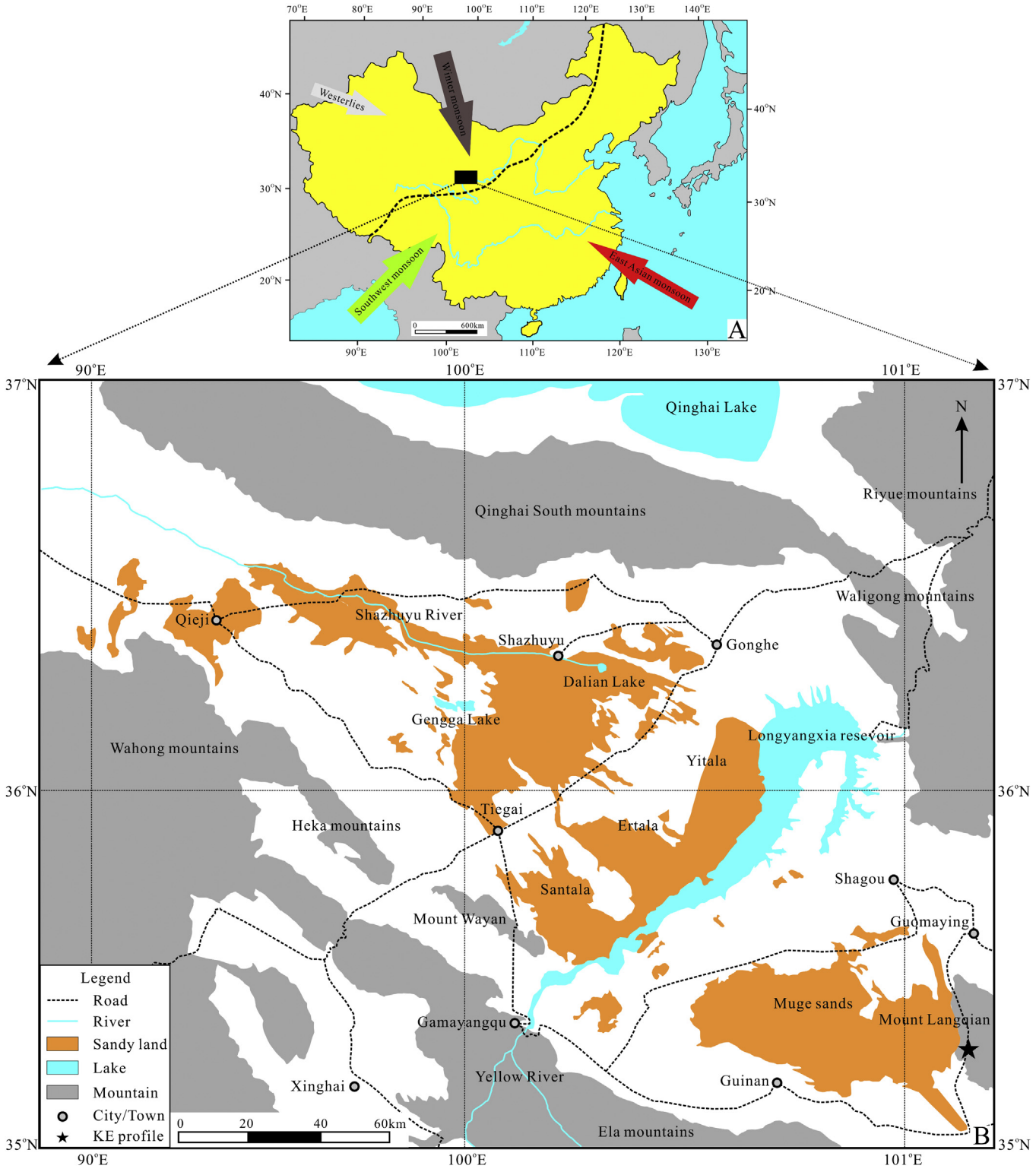

Fig. 1. Location of the study area. (A) The Gonghe Basin (black rectangle); dashed line shows the present limit of the Asian summer monsoon influence. (B) Details of the Gonghe Basin and the Kaie (KE) profile.

we focused on the >4-m-thick peat-paleosol profile in the eastern Gonghe Basin, and used the multi-proxy approach, including magnetic susceptibility, total organic carbon content (TOC), pollen concentration, grain size, and geochemical parameters, to assess the regional Holocene millennial scale climatic and environmental changes and possible forcing mechanisms.

2. Regional setting

The Gonghe Basin is a large Cenozoic intermontane depression on the northeastern margin of the QTP. The ground surface is predominantly fixed and semi-fixed, primarily concentrated on the Muge Sands, the Tala Sands, and the middle and lower reaches of