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A 16-ka oxygen-isotope record from Genggahai Lake on the northeastern Qinghai-Tibetan Plateau: Hydroclimatic evolution and changes in atmospheric circulation

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ABSTRACT

Moisture source history and changes in atmospheric circulation are the most important attributes for portraying past climate changes and for estimating possible future trends. However, few climate records reflecting these attributes are available from the marginal zones of the Asian summer monsoon. Here, we present a record of the oxygen isotopic composition of authigenic carbonates ($\delta^{18}O_{carb}$) of sequential sediments from Genggahai Lake in the northeastern Qinghai-Tibetan Plateau (QTP). Isotopic analyses were performed on the fine-grained carbonate fraction (<38 μm), mollusc shells, and stem encrustations from submerged plants. The stratigraphic variations of the $\delta^{18}O$ record from the different carbonate components exhibit a remarkably similar pattern, probably reflecting the fact that $\delta^{18}O_{carb}$ variability was controlled primarily by changes in the oxygen isotopic composition of the lake water ($\delta^{18}O_{LW}$). Disequilibrium effects and water temperature are precluded as major factors affecting the $\delta^{18}O_{carb}$ variations. Genggahai Lake is hydrologically open and characterized by a rapid discharge rate, as indicated by analysis of the hydrological setting of the lake system and by the observed significant positive correlation between $\delta^{18}O_{LW}$ and the oxygen isotopic composition of the inflowing water ($\delta^{18}O_{I}$). Under such hydrological conditions, we argue that the isotopic signals of different moisture sources should be reflected in the carbonate isotopic composition. Furthermore, placing the $\delta^{18}O_{carb}$ record in the context of regional palaeoclimate archives, we found that the isotopic signals, particularly the negative shifts from the average values, cannot be interpreted consistently, despite a process of evaporative enrichment at the lake surface. During the early- to mid-Holocene, low $\delta^{18}O_{carb}$ values during 10.6–9.4 and 7.4–6.3 ka were associated with higher lake levels, and thus the record may have been significantly affected by a strengthened Asian summer monsoon at those times and hence by a positive moisture balance. Isotopic depletions with similar magnitudes occurred at 15–14.5, 13.8–13.3, 12.5–11.4, 5.3–4.8, 3.7–3.4, 2.8–2.3, 1.7, 1.3, and 0.6 ka, i.e., within the Lateglacial and the late Holocene. These negative shifts in $\delta^{18}O_{carb}$ corresponded to lower lake-level phases, and most likely were a response to intensification of the mid-latitude westerly circulation that may have transported significantly more ^{18}O-depleted moisture to the region, compared to that from the Asian summer monsoon. Overall, our results suggest that the alternating influence of the Asian summer monsoon and the westerlies played a significant role in determining the pattern of atmospheric circulation on the northeastern QTP.

1. Introduction

The northeastern Qinghai-Tibetan Plateau (QTP) is very sensitive to climatic changes because of its high elevation (>3000 m a.s.l.) and marginal position relative to the regions dominated by the Asian summer monsoon (Fig. 1A) (Yao and Thompson, 1992;

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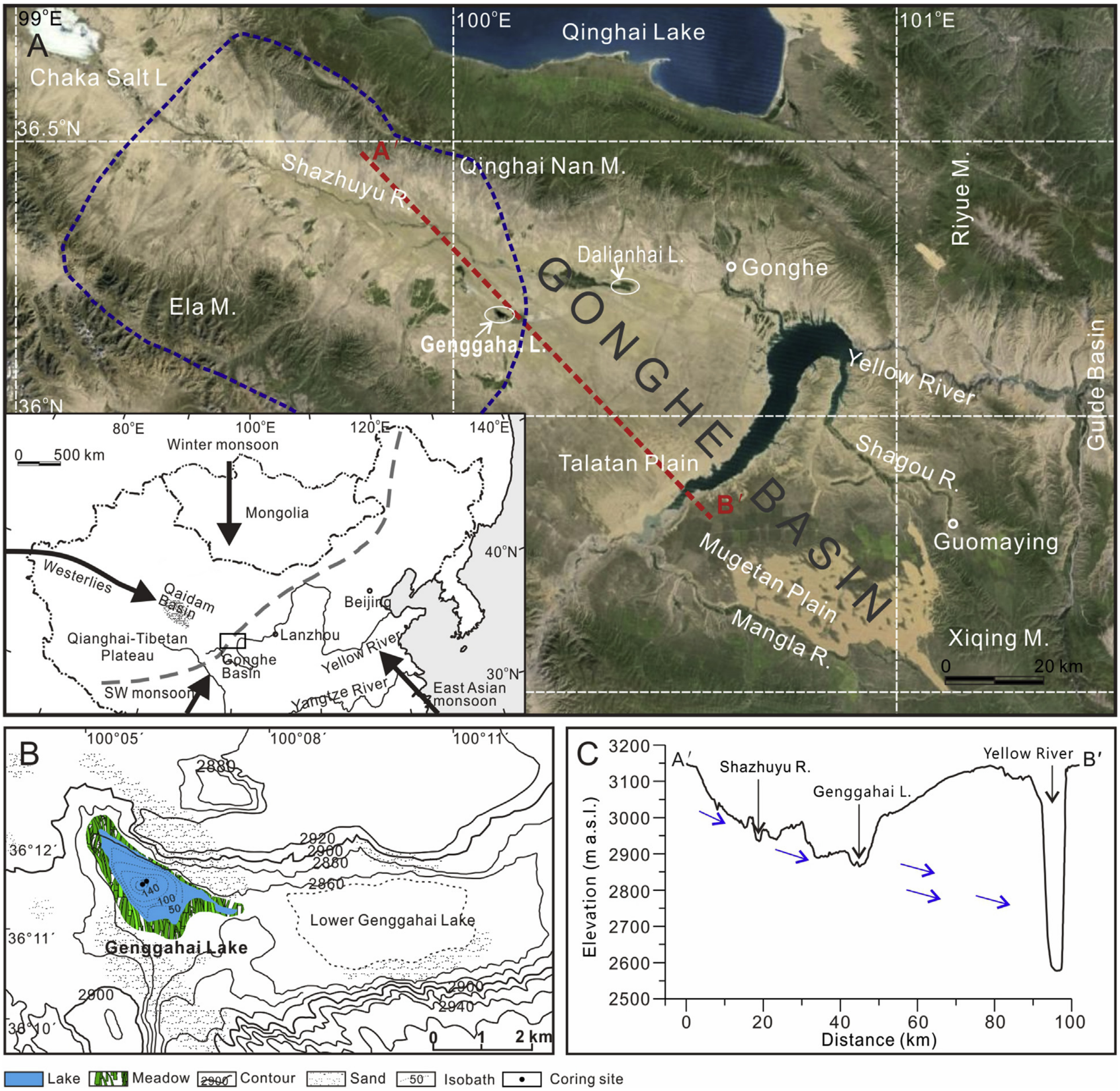

Fig. 1. (A) Physical environments of the Gonghe Basin (Google Earth™). Genggahai Lake is located in the central western sub-basin. The potential catchment area of groundwater feeding Genggahai Lake is delineated by the blue dashed line. Inset: Location of the study area. It is situated on the northwestern margin of the regions affected by the Asian summer monsoon, as indicated by the gray dashed line (after Gao et al., 1962). (B) Close-up view of the environments surrounding Genggahai Lake and topography around the lake. (C) Elevation variability along the A′B′ transection in (A). Blue arrows indicate groundwater flows in the study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Zhao and Yu, 2012). In addition, the region is affected not only by the Asian summer monsoon, but also by the westerly jet stream and by the surface wind regimes related to the Siberian High in the cold season (Domrös and Peng, 1988), making it particularly suitable for studies of the interactions of these various climate sub-systems.

Numerous climatic records show that late Quaternary climates on the northeastern QTP were dominated mainly by the Asian summer monsoon, in response to changes in orbitally-induced summer insolation (Lister et al., 1991; Shen et al., 2005; Ji et al., 2005; Liu et al., 2007; Mischke et al., 2008; An et al., 2012; Dietze et al., 2013; Qiang et al., 2013, 2014; Herzschuh et al., 2014; Liu et al., 2014a; Jin et al., 2015). A warmer and wetter climate occurred during the early- to mid-Holocene and a colder and drier climate during the Lateglacial and the late Holocene (Zhao and Yu, 2012), similar to the monsoonal records from low latitudes recorded by speleothems (e.g. Dykoski et al., 2005). However, the long-term trend of climate changes on the northeastern QTP differs from the general climatic patterns reconstructed from the adjacent regions with relatively low elevations (Herzschuh, 2006; Mason et al., 2009), and from the westerly-dominated areas (Chen et al., 2008). An obvious common feature of these areas is that an arid climate prevailed in the early Holocene, caused by either the enhanced subsidence of dry air masses in the areas to the north and northeast of the Tibetan Plateau, due to the strengthened monsoonal circulation over low latitudes, or decreased water vapor transport by the westerlies to these areas. In fact, an early Holocene arid episode is also suggested by lower lake levels at Qinghai Lake (Li and Liu, 2014; Liu et al., 2015b), as indicated by optically-stimulated