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Hydroclimatic changes over the past 900 years documented by the sediments of Tiewaike Lake, Altai Mountains, Northwestern China

Yuan Li [a], Mingrui Qiang [a, *], Jiawu Zhang [a], Xiaozhong Huang [a], Aifeng Zhou [a], Jianhui Chen [a], Ganggang Wang [a], Yan Zhao [b]

[a] MOE Key Laboratory of Western China's Environmental Systems, College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, China
[b] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

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ABSTRACT

The reconstruction of variations in effective moisture over the past millennium are important for assessing potential future climatic trends in environmentally-sensitive arid Central Asia (ACA), especially in the context of ongoing global warming. However, high-resolution time series reflecting past moisture variability in the region are scarce, thus preventing a full understanding of the hydroclimatic evolution. Here we present the results of multi-proxy analysis of a sediment core spanning the past 900 years from Tiewaike Lake in the Altai Mountains, northern Xinjiang. The climatic proxies measured include grain size, organic matter and carbonate content, C/N ratio, and the stable carbon isotope composition of bulk organic matter. The results show that over the past 900 years the climatic evolution of the study area can be divided into distinct hydroclimatic phases: the arid Medieval Climate Anomaly (MCA, ~1090–1430 AD), the humid Little Ice Age (LIA, 1430–1940 AD), and the arid Current Warm Period (CWP, 1940–2012 AD). During the LIA, the water level at Tiewaike Lake was overall higher than during the other climatic intervals; in addition, the LIA climate was unstable and characterized by six intervals with the occurrence of heavy precipitation events on a multi-decadal timescale. A humid, unstable climate during the LIA is also suggested by climatic records from adjacent regions. Our results support the view that over the past millennium, on a multi-centennial timescale, the moisture variations in ACA were generally out-of-phase with those in the region affected by the Asian summer monsoon. The humid, unstable LIA climate in ACA may have been associated with changes in the North Atlantic Oscillation (NAO) index and/or with variations in solar irradiance.

1. Introduction

A thorough understanding of the spatial patterns of Holocene climatic change, especially during the past millennium, is essential for predicting regional climatic change in the future (Hansen and Lebedeff, 1987). It is also useful for enhancing our ability to distinguish natural climatic factors from anthropogenic forcing which can also cause hydroclimatic changes on various spatio-temporal scales (Jones and Mann, 2004). It is well-known that three distinct climatic intervals characterize the past millennium, i.e., the Medieval Climate Anomaly (MCA), the Little Ice Age (LIA), and the Current Warm Period (CWP) (Bradley, 2000). There is growing evidence that the LIA was cool in many parts of the world (Mann et al., 2009; Ljungqvist, 2010) and a cool LIA has been further proposed to be of global significance, although it is not clearly defined in terms of its spatial extent, duration, and magnitude (Jones and Mann, 2004; Mann et al., 2009). During the past two decades, many geological time series reflecting climatic change over the past millennium have been reconstructed in arid Central Asia (ACA) (Shen et al., 2005; Chen et al., 2006; Kalugin et al., 2007; Liu et al., 2008; Ma et al., 2008; Chen et al., 2009; Henderson and Holmes, 2009; Holmes et al., 2009; Huang et al., 2009; Yang et al., 2009; Zhang et al., 2009; Ma et al., 2011; Xue and Zhong, 2011; Fang et al., 2013; He et al., 2013; Jiang et al., 2013; Ran and Feng, 2013; Tian et al., 2013; Feng et al., 2013; Chen et al., 2014, 2015a,b; Hong et al., 2014; Song et al., 2015). However, the discrepancies in the climatic signatures of these records are more pronounced than the consistencies. The records from Chaiwobu peatland, Lop Nur Lake and three profiles from the Central Tianshan Mountains suggest that over the past millennium

* Corresponding author.
E-mail address: mrqiang@lzu.edu.cn (M. Qiang).

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ACA was characterized by a humid MCA and an arid LIA (Ma et al., 2008; Zhang et al., 2009; Hong et al., 2014). In contrast, a large number of climatic records exhibit a distinctly different climatic pattern (Chen et al., 2006, 2009; Ma et al., 2011; Xue and Zhong, 2011; He et al., 2013; Tian et al., 2013; Feng et al., 2013; Song et al., 2015). Pollen records from Khuisiin Lake, Bosten Lake and Balkhash Lake indicate relatively wet conditions during the LIA (Chen et al., 2006; Feng et al., 2013; Tian et al., 2013); and the Chironomid record from Sugan Lake, as well as the biomarker records from Manas Lake, Sugan Lake and Gahai, also suggests a humid LIA (Chen et al., 2009; He et al., 2013; Song et al., 2015). Recently, Chen et al. (2015b) suggested that the spatial and

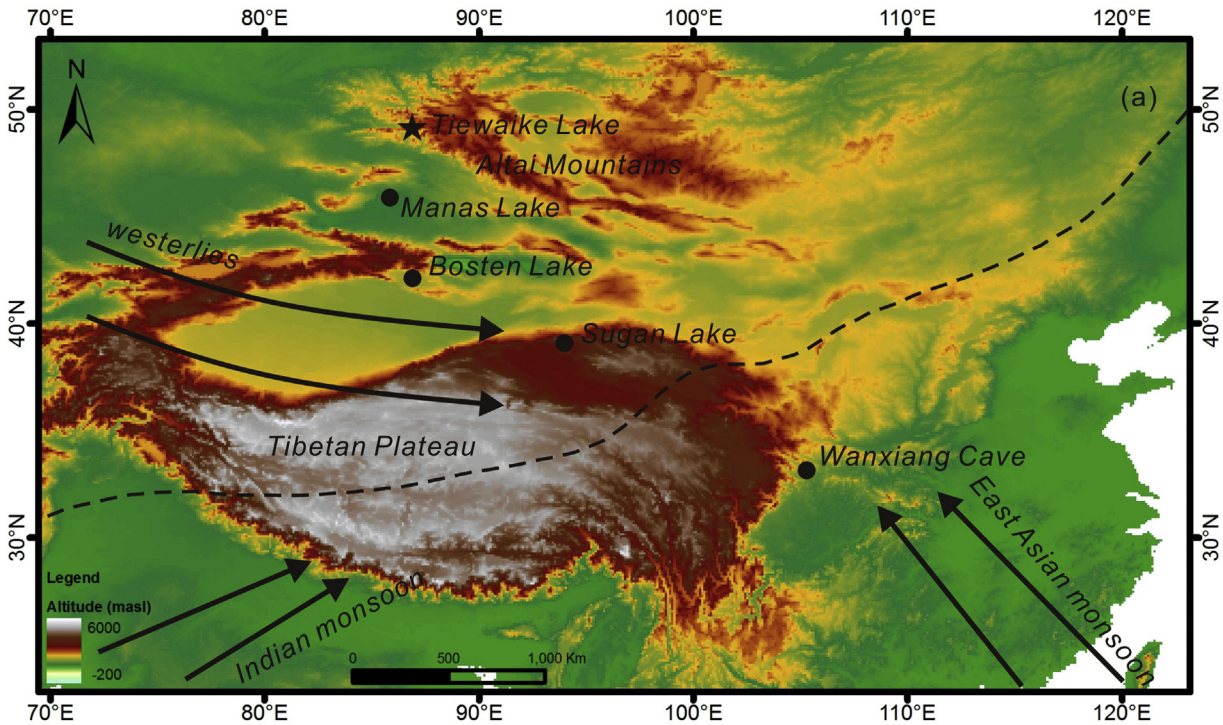

Fig. 1. (a) Overview map showing the palaeoclimatic sites referenced this study, and the dominant circulation systems of the westerlies, Indian monsoon and East Asian monsoon. The study site, Tiewaike Lake, is indicated by a star. Manas Lake (Song et al., 2015), Bosten Lake (Chen et al., 2006), Sugan Lake (Chen et al., 2009) and Wanxiang Cave (Zhang et al., 2008) are indicated by circles. The modern Asian summer monsoon limit is shown by a thick dashed line (Chen et al., 2010). (b) Photograph of landscapes around Tiewaike Lake.

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