



Bioclimatic change of the past 2500 years within the Balkhash Basin, eastern Kazakhstan, Central Asia



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ABSTRACT

On the bases of analytical data of an 850-cm-long sediment core collected from Balkhash Lake with a chronological control of seventeen AMS dates, this research reconstructed the lake salinity using carbonate content and the oxygen isotopic composition as proxies and reconstructed the basin-wide moisture using A/C ratio and pollen concentration as proxies. Basin-wide mean annual temperature (MAT) and mean annual precipitation (MAP) were reconstructed using climate-pollen response surface method. The reconstruction appears to be supportive to the early proposition that the climate in the westerlies-dominated areas has been generally characterized by cool-wet and warm-dry modes. Balkhash Basin has experienced three stages of climate change during the past ~2500 years: cool-wet from ~2500 to ~1800 cal. BP, moderate from ~1800 to 650 cal. BP, and cooling and wetting during the past ~650 years with the past ~100 showing warming and drying. The moisture evolution has closely followed the MAP variation and the MAT must have modulated the moisture evolution through controlling the evaporation. The first-order variation in lake salinity has been controlled by basin-wide temperature, i.e., low temperature raises the salinity level in the lake through reducing the ice-melt water supply to the lake. The second-order variation in the lake salinity seems to be modulated by pronounced variations in basin-wide moisture. Those low-amplitude variations in basin-wide moisture levels left no detectable imprints in lake salinity proxy records.

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1. Introduction

Climate change during the past 2500 years (i.e., the time span this paper deals with) has basically been paced by solar activities that are superimposed on orbital forcing factors (Ruddiman, 2008; Mann et al., 2009). Land-air interactions in smaller spatial scales (Anderson et al., 2002; Bridgman and Oliver, 2006) and human and volcanic disturbances in shorter temporal scales (Bauer et al., 2003; Maasch et al., 2005) are documented as “perturbation factors” affecting climate change.

The Balkhash Basin is situated in the eastern part of the Central Asian Arid Zone (CAAZ) that stretches from the Caspian Sea in the west to the Altai Mountains in the east (Fig. 1). The W–E striking

Tianshan Mountains approximately along the 40th parallel block the climatic influence of the Arabian Sea from the south and allow the climatic dominance of the westerlies from the west (Gong et al., 2001; Heorling et al., 2001; Staubwasser and Weiss, 2006). The warm-season precipitation in the CAAZ is primarily from the North Atlantic via the northward-shifted westerlies, whereas the cold-season precipitation is primarily from the Mediterranean Sea via the southward-shifted westerlies (Aizen et al., 2001; Bridgman and Oliver, 2006; Bothe et al., 2011). Frequent southward invasions of the polar front are the most important precipitation-promoting mechanism (Lydolp, 1977; Aizen et al., 2001). The cold-season climate in the study area is modulated by the interactions between the westerlies and the North Atlantic Oscillation (NAO) and that the warm-season climate is controlled by the interactions between the Asian Low occupying the interiors of Asia and the Azores High reaching CAAZ (Aizen et al., 2001; Meeker and Mayewski, 2002) (Fig. 2). The westerlies-domination over the CAAZ during the Holocene (i.e., past 11,500 years) has also been demonstrated by the temporal consistency between the records from the West Europe and the records

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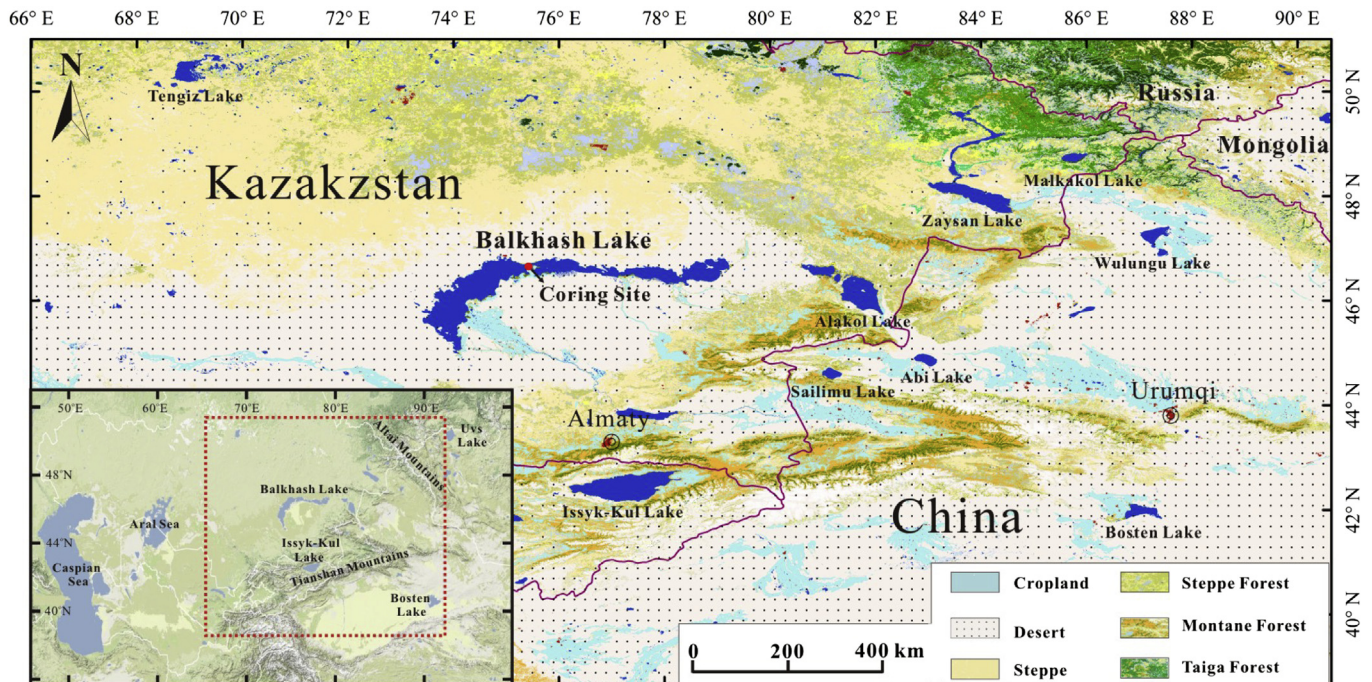


Fig. 1. Land-cover map showing the distribution of vegetation and the location of Balkhash Lake. The inset map in the lower-left corner shows the location relation of the Balkhash Lake to the Caspian Sea and the Aral Sea.

from the CAAZ. That is, unlike the Asian monsoon-dominated areas where the Holocene climate change has been characterized by either warm-wet mode or cool-dry mode (Shi et al., 1993; Holme et al., 2009), the Holocene climate change in the westerlies-dominated areas has been typified by either a warm-dry mode or cool-wet mode (see: Geel et al., 2004; Yang et al., 2002, 2009; Kroonenberg et al., 2007; Boomer et al., 2009).

Nevertheless, neither data nor interpretations are unequivocally supportive to the “warm-dry” and “cool-wet” generalization. For example, the chronological correspondence between the last two major highstands (i.e., wet events) in the Caspian Sea occurred around 2600 cal. BP and around 1600 AD (i.e., cool times) and the global cooling events associated with minima in solar activities (Kroonenberg et al., 2007) do lend strong supports to the “warm-dry” and “cool-wet” generalization (Boomer et al., 2000, 2009). More supports came from the Aral Sea where the major high-salinity events (i.e., dry times), documented by dinoflagellate cysts, of the past 2000 years occurred during warm intervals (e.g., AD 0–400, AD 900–1350 and since AD 1800). However, another high-salinity event in the Aral Sea occurred during a cool interval between AD 1500 and AD 1650 surely undermined the acceptability of the generalization. The reconstructed temporal variations in the dust deposition in the Aral Sea also fundamentally undermined the acceptability (Huang et al., 2011), being completely consistent with “warm-wet” and “cool-dry” modes generalized for the Asian monsoon-dominated areas. More eolian sediments were supplied to the Aral Sea during cold intervals under stronger Siberian High Pressure conditions. The broad similarity between the eolian record in the Aral Sea (Huang et al., 2011) and the lacustrine $\delta^{18}\text{O}$ record in Turkey (Jones et al., 2006) implies that there was less moisture entering western Central Asia from the Mediterranean during cool intervals. The pollen-indicated climate change in the Aral Sea has followed neither the generalized “warm-dry” and “cool-wet” modes nor the solar activity-dictated temperature trend of large scale. Specifically, pollen data show that cold and arid conditions prevailed between ca. AD 0 and 400, AD 900 and 1150,

and AD 1500 and 1650 with the expansion of desert vegetation and that warm and wet climate conditions prevailed between ca. AD 400 and 900, and AD 1150 and 1450 with the expansion of steppe vegetation (Sorrel et al., 2006).

However, the aforementioned discrepancies among different datasets (e.g., salinity, vegetation, and dust) may be reconcilable if different processes are involved. For example, lake salinity may be controlled by temperature-dictated amount of ice-melting and may have little to do with the amount of precipitation if the lake is mainly supplied by ice-melt water (Sorrel et al., 2007). Dust input to the lake may be controlled by large-scale atmospheric circulation and may have little to do with basin-wide vegetation coverage if availability of eolian particles in the basin is not a limiting factor (Huang et al., 2011). We intend to accept the proposition that basin-wide vegetation may be a real expression of basin-wide climate and that pollen record from a closed lake can be used to retrieve past climate (Blyakharchuk et al., 2007; Tarasov et al., 2007; Rudaya et al., 2009). This paper attempts to reconstruct the bioclimatic change of the past 2500 years within the Balkhash Basin in the eastern part of Kazakhstan in hope that some of the aforementioned discrepancies can be reconciled.

2. Regional setting

Lake Balkhash (Fig. 1) is one of the largest lakes in Asia (approximately 73–80 °N and 44–47 °E; 330 m a.s.l.). The basin drains into the lake via seven rivers. The Ili River is the most significant one originating from the Tianshan Mountains and supplying most of the inflowing water to the lake. The lake currently covers an area of 16,400 km² and it is hydrographically divided into two very different parts: the western fresh part and the eastern salty part. During recent time, the area of the lake expanded to >18,000 km² during wet years and shrank to <16,000 km² during dry years (Petr, 1992). The climate of the lake area is continental with average July temperature of +30 °C and average January temperature of –14 °C. The annual mean temperature (MAT) is ~6 °C and mean annual

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