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Vegetation and climate history reconstructed from an alpine lake in central Tienshan Mountains since 8.5 ka BP

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ABSTRACT

High mountains are humid islands in arid central Asia, and alpine vegetation is sensitive to climate change, especially to temperature variations. Here we present a palynological sequence and discuss the past vegetation and climate changes based on core BY10A from the Swan Lake, an alpine lake situated at an inter-montane basin in the central Tienshan Mountains, Xinjiang, northwestern China. We collected 52 modern pollen surface samples at different elevations to aid in the interpretation of fossil-pollen data, which provide a reconstruction of vegetation and climate history for the last 8.5 ka (1 ka = 1000 cal yr BP). *Artemisia* and Amaranthaceae (=Chenopodiaceae) are the main pollen types in desert steppe zone below 1800 m elevation, while Poaceae and *Picea* dominate the mid-elevation forest steppe zone (1800–2800 m). Cyperaceae is the main indicator of high alpine meadows (>2800 m). From 8.5 to 6.9 ka, the vegetation was steppe meadow suggesting relatively warm climate. From 6.9 to 2.6 ka generally high values of Cyperaceae and peaty sediments indicate a fen environment and cooler, more humid conditions. Interrupting this mid-Holocene period is a 5.5–4.5 ka millennium of lacustrine sediments with lower Cyperaceae, higher Poaceae and *Artemisia*, and high values of *Myriophyllum* and *Pediastrum* indicating higher water levels and warmer temperatures. After 2.6 ka, pollen data indicate alpine steppe and warmer climate. The mid-Holocene pattern of cooler climate interrupted by a warmer period is consistent from other regional records from Xinjiang, including the Guliya ice core and Kesang Cave speleothem record. During the cooler periods, the regional record indicates that a weakened summer Asian monsoon is countered to some extent by a stronger winter monsoon.

1. Introduction

Research on spatial and temporal patterns of Holocene paleoclimate changes are essential for understanding the forcing mechanisms and further explore possible variations in the future (Chen et al., 2008; Wanner et al., 2008; Zhao et al., 2009c). Little is known about how vegetation will respond to the global warming in the future at centennial timescale (Zeng and Yoon, 2009). Past vegetation dynamics and climate change will provide important references in this respect (Cao et al., 2015). On one hand, the global and regional temperature variations are still poorly understood. On the other hand, different proxies and different sites show different patterns of reconstructed temperature variations during the Holocene (Bond et al., 1997; Thompson et al., 1997; Davis et al., 2003; Andersen et al., 2004; Huang et al., 2013; Rasmussen et al., 2014). Fossil-pollen analysis has been widely applied for reconstructing past variability in regional vegetation and climate (e.g., Rull et al., 1987; Sauchyn and Sauchyn, 1991; Grimm et al., 2001; Davis et al., 2003; Blyakharchuk et al., 2007; Rudaya et al., 2009; Tarasov et al., 2009; Leroy et al., 2013; Herzschuh et al., 2014; Mathis et al., 2014).

The highly variable ecological system of arid and semi-arid China makes it an ideal area for studying vegetation evolution and the ecological response to dynamic Holocene climate conditions (Sun et al., 1994; Huang et al., 2009; An et al., 2012; Mathis et al., 2014). A number of investigations have been carried out in the region of Xinjiang and in the Tienshan Mountains since the 1980s (e.g., Sun et al., 1994; Wu et al., 1996; Xiao et al., 2006; Huang et al., 2009; An et al., 2012; Jiang et al., 2013; Mathis et al., 2014), but well-dated high-resolution records are still limited when compared to the vast area and diverse climate of this region.

In addition, previous studies mainly focused on large lakes in the low-lying basins (Lake Aibi, Lake Manas, Lake Bosten and Lake Wulungu), where vegetation is highly sensitive to changes in humidity. However, temperature variations have induced significant ecological response as well (MacDonald et al., 1993; Körner, 1998), and the mountains in northwestern China show a distinct vertical variation of vegetation. Hence, it is insufficient to understand the vegetation response

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pattern to climatic change based only on records from the lower basins. On the other hand, although most of these Holocene paleoclimatic records suggested that the early Holocene was dry (Chen et al., 2008; Huang et al., 2009; An et al., 2012; Jiang et al., 2013), some other records in the Yili Valley and other areas indicated possibly humid early Holocene (Rudaya et al., 2009; Cheng et al., 2012; Li et al., 2011). Moreover, the humidity variations within middle to late Holocene are still not in a unique pattern because of chronological uncertainties and interpretation of proxies (Ricketts et al., 2001; Huang et al., 2009; An et al., 2012; Cheng et al., 2012; Mathis et al., 2014). Therefore, the Swan Lake pollen data will provide new additional evidence.

In order to better interpret the fossil-pollen record, it is important to investigate the relationship between modern pollen and vegetation (Prentice, 1985; El-Moslimany, 1990). Some modern pollen studies are available in arid and semi-arid China. Luo et al. (2007) discussed the distribution of pollen and its relationship to vegetation based on 218 surface samples in Xinjiang province. Yan et al. (2004) used 131 surface samples to explain the main factors that influence the abundance and dispersal of *Picea* pollen in Xinjiang. Other studies have evaluated a small dataset of modern pollen on the southern slope of the Tienshan Mountains (Xu et al., 1996). Yet few have been done in the interior of the Tienshan Mountains based on dense sampling along elevation changes, and very few studies of Holocene vegetation and climate have been based on both fossil-pollen and surface-pollen data in this region.

In this paper we explore the relationship between modern pollen spectra characters and vegetation zone distributions in the interior of the Tienshan Mountains, based on which we interpret the pollen record retrieved from an alpine lake located at an intermountain basin in the central Tienshan Mountains and reconstruct vegetation dynamics and climate history. When combined with other paleoclimate records this record is expected to show more temperature variations.

2. Regional settings

Swan Lake (43°02′45″N, 84°22′55″E, elevation 2541 m) is located at the Yourdusi Basin on the southern slope of central Tienshan Mountains, northwestern China. The surrounding mountains of the Yourdusi Basin rise to an elevation of >3500 m and are snow or glacier-capped, while the average elevation of the basin is 2500–2700 m (Xu, 1999). Upstream the Kaidu River meanders through the basin, creating oxbow lakes, meanders and flood plains, and flows downstream into Lake Bosten (elevation 1048 m) in the Yanqi Basin (Fig. 1a, c).

Swan Lake is ~0.5 km^2 large and has a water depth around 1 m, mainly fed by small inlets of melt water and precipitation of ~22 km^2 drainage basin, and discharge through small outlets to the Kaidu River. According to the Bayanbulag meteorological station (20 km away from the lake), from 1958 to 2003, mean annual precipitation is ca. 274 mm and mean annual temperature is −4.5 °C with a mean January temperature of −26.4 °C and a mean July temperature of 10.7 °C

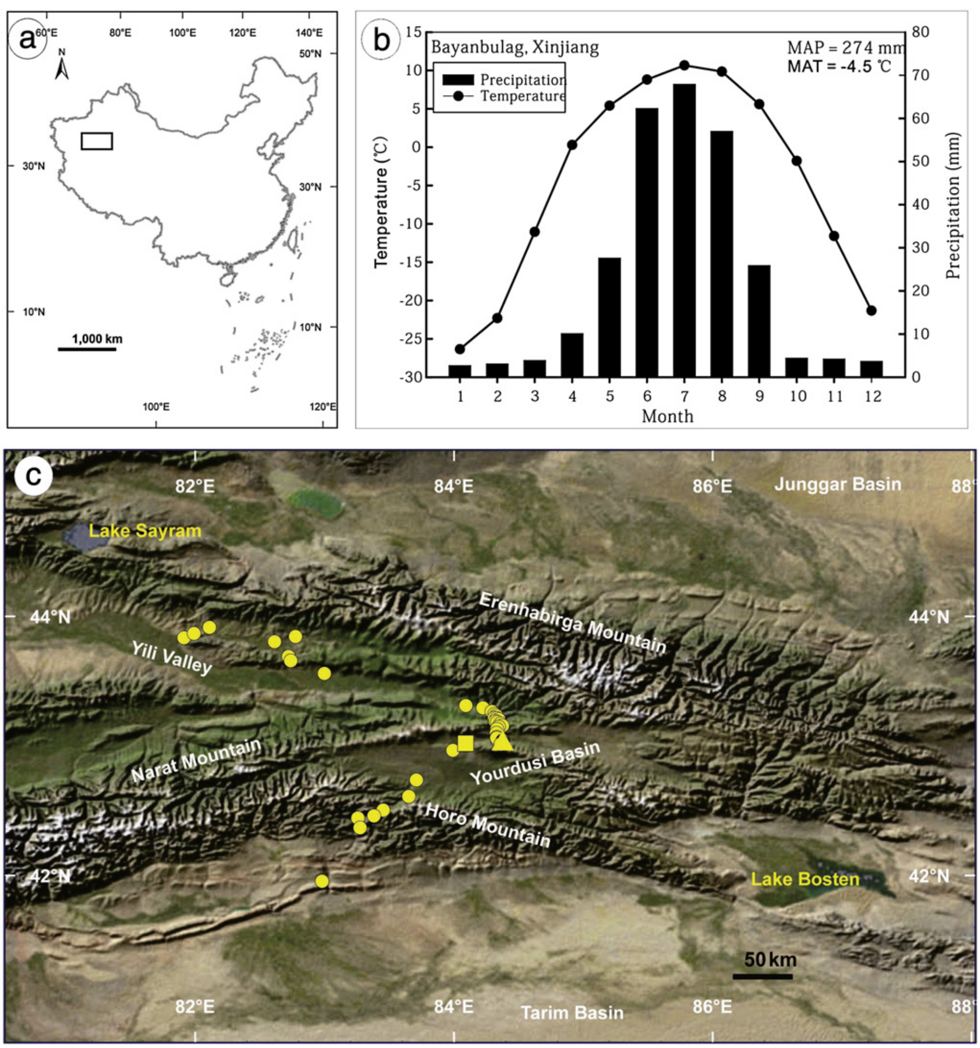

Fig. 1. a. Location of study region (shown as a rectangle) in China. b. Monthly temperature and precipitation from Bayanbulag meteorological station during 1958 to 2003. c. Satellite map of the study region. The dots, triangle and square refer to surface soil sampling sites, the location of Swan Lake, and Bayanbulag meteorological station respectively.