Earth-Science Reviews 185 (2018) 847–869

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Holocene climate variations in the Altai Mountains and the surrounding areas: A synthesis of pollen records

Dongliang Zhang[a], Zhaodong Feng[b,*]

[a] Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, 818 Beijing South Road, Urumqi 830011, China
[b] College of Environment and Planning, Henan University, Jinming Street, Kaifeng, Henan 475004, China

ARTICLE INFO

Keywords:
Altai Mountains
Holocene climate change
Pollen
Atlantic Multidecadal Oscillation

ABSTRACT

Based on pollen data from 30 sequences reviewed here, we reconstruct the spatial and temporal variations in temperature and in aridity that occurred during the Holocene in the Altai Mountains and the surrounding areas (i.e., the examined area). The synthesized regionally-averaged temperature-index curves from low-elevation regions show that the climate was consistently warming from ~12,000 to ~9000 cal. yr BP and has experienced a gradual cooling trend since ~9000 cal. yr BP. It means that the Holocene temperature trend in low-elevation regions of the examined area has sensitively responded to variations in the total solar irradiance. The synthesized regionally-averaged aridity-index curve exhibits a persistent wetting trend during the Holocene in low-elevation regions. The deduced Holocene precipitation-index variations suggest that the Holocene wetting trend resulted from a combined effect of temperature decreasing and precipitation increasing. The Holocene precipitation increase seems to be associated with the Holocene AMO-like (i.e., Atlantic centennial oscillations) events in the North Atlantic Ocean. However, the early-Holocene variations of temperature and aridity in high-elevation regions were significantly deviated from the variations in low-elevation regions and this deviation was probably a result of permafrost thawing at higher elevations.

1. Introduction

The Altai Mountains range, one of the most prominent mountain ranges in central Asia, is shared by China, Kazakhstan, Russia and Mongolia (Fig. 1a). It merges with the Sayan Mountains in the east and with the Kazakhstan Hills in the west. It borders with the Junggar Basin in the south and with the Siberian Plain in the north. Climatologically, the Altai was reported to be a conjunction where the westerly airflows from the west have interacted with the monsoon airflows from the east (Aizen et al., 2001; Chen et al., 2008; Chen et al., 2016; Feng et al., 2017; Ran and Feng, 2013). Culturally, it was reported to be a bridge in the middle of the 'Eurasian Steppe Road' that linked the oriental cultures from the east with the occidental cultures from the west (Alekseev et al., 2001; Blyakharchuk and Chernova, 2013; Golden, 1990; Rudaya et al., 2012; Sinor, 1990). It should be particularly noted that the Holocene climate change in the Altai Mountains has recently regained scientific attentions (Blyakharchuk et al., 2004, 2007, 2008; Rudaya et al., 2009) and the attentions were primarily stimulated by renewed archaeological interests in understanding the relationships between climate change and cultural evolution along the "Eurasian Steppe Road" (Agatova et al., 2016; Blyakharchuk and Chernova, 2013).

Regarding the Holocene climate change in the entire Altai or in a certain part of Altai, several recent syntheses deserve mentioning. First, Rudaya et al. (2009), based on a thorough review of then-available literature, depicted the temporal and spatial patterns of the Holocene vegetation variations and the associated climate change. They proposed that in the eastern Altai within Mongolia the first half of the Holocene (~11,000-~5000 cal. yr BP) was warm and wet and the second half (~5000–0 cal. yr BP) cool and dry. In the western Altai within Kazakhstan the first half of the Holocene was warm and dry and the second half cool and wet. In the northern Altai within Russia the first half of the Holocene was warm and wet and the second half cool and wet. Second, Wang and Feng (2013) scrutinized the qualities of all published Holocene climate records in the northern Altai and used the "qualified" data that passed their scrutinizing to delineate the temporal pattern. The results showed that the Holocene climate in the northern Altai experienced a slight drying trend. Third, Ran and Feng (2013) reviewed the Holocene climate records of northern Xinjiang including the southern Altai within China and concluded that the climate was generally dry in the early Holocene (i.e., before ~8000 cal. yr BP) and experienced more or less a persistent wetting during the mid- and late-Holocene (i.e., after ~8000 cal. yr BP).

* Corresponding author.
E-mail address: fengzd@vip.henu.edu.cn (Z. Feng).

https://doi.org/10.1016/j.earscirev.2018.08.007
Received 16 January 2018; Received in revised form 2 August 2018; Accepted 13 August 2018
Available online 14 August 2018

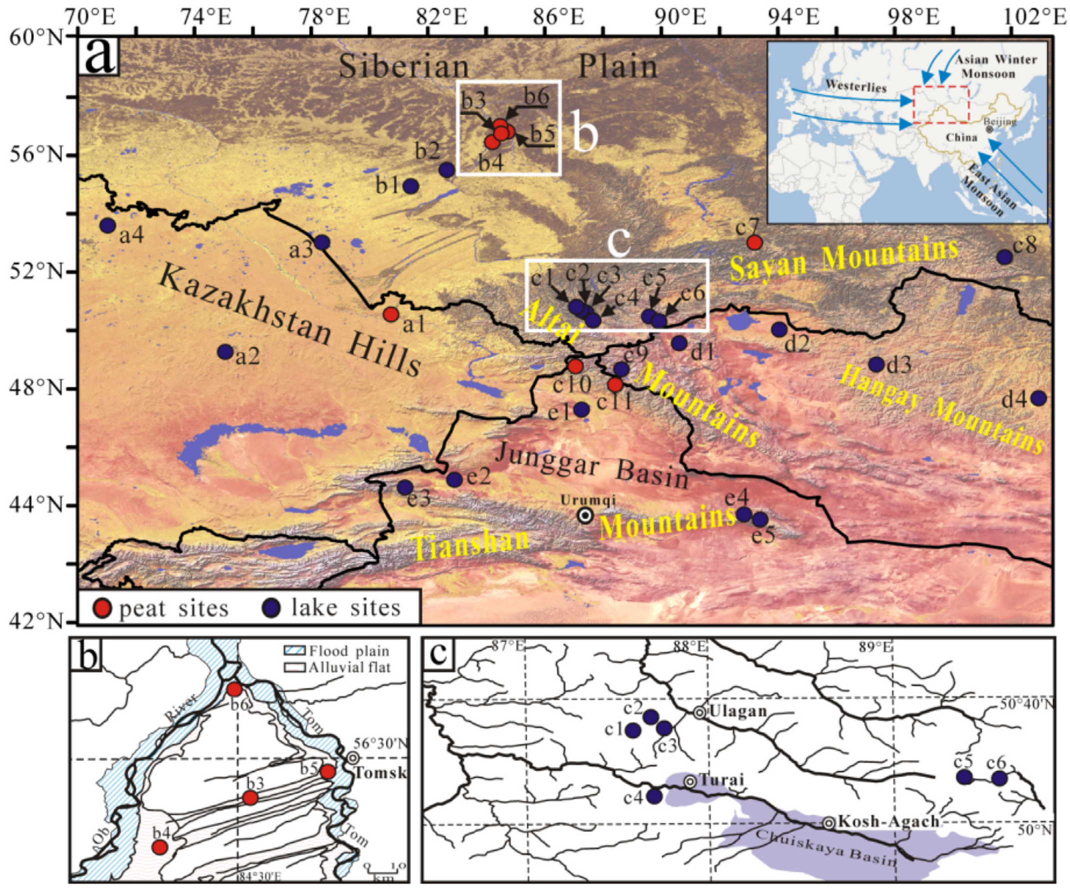

Fig. 1. Map showing the reviewed pollen sequences in the Altai Mountains and the surrounding areas (i.e., the examined area). a: Site locations of the 30 reviewed sequences; b: Zoom-in map showing the jammed cluster of sequences that are enclosed by b-labeled box in Fig. 1a (modified from Blyakharchuk et al., 2004); c: Zoom-in map showing the jammed cluster of sequences that are enclosed by c-labeled box in Fig. 1a (modified from Blyakharchuk et al., 2008).

To explain the mechanisms of the proxy-recorded Holocene climate change in the Altai Mountains and the surrounding areas (i.e., the area examined in this paper), several proposals have been put forward and followings are four dominant ones. First, the Westerlies-domination over the Altai Mountains and the surrounding areas (i.e., the examined area) during the Holocene has been demonstrated by the temporal consistency between the records from the West Europe and the records from the examined area (Chen et al., 2008; Chen et al., 2016; Long et al., 2017; Ran and Feng, 2013; Wang and Feng, 2013). Second, the East Asian Monsoon domination has extended to the examined area during the Holocene warm intervals (Cai et al., 2017; Cheng et al., 2012; Harrison et al., 1996; Li et al., 2011; Tarasov et al., 2000). Third, an unconventional proposal was put forward by Bush (2005) that was later corroborated by Prokopenko et al. (2007) and others (e.g., Feng et al., 2013a; Long et al., 2017; Zhang et al., 2015). The proposal states that the combined effect of increased atmospheric CO_2 concentration and increased winter insolation under warmed ocean-surface and lessened ice-cover conditions after ~7000 cal. yr BP may have strongly modulated the climate change in the examined area. The fourth proposal states that the Altai Mountains were the divide of the Holocene climate change within the Eurasian interior (Blyakharchuk et al., 2007; Rudaya et al., 2009). That is, the Holocene climate change in the eastern Altai was consistent with that in the East Asian Monsoon-affected areas, while the change in the western Altai was consistent with that in the Westerlies-affected areas. However, the northern Altai was proposed to be a battle between the East Asian Monsoon and the Westerlies. Specifically, the first half of the Holocene was warm and wet, being consistent with the East Asian Monsoon climate pattern; and the second half was cool and wet, being consistent with the Westerlies climate pattern.

This paper reviewed 30 published Holocene pollen sequences in the examined area (i.e., the Altai Mountains and the surrounding areas) in the context of a broader geographic extent with the hope that our understanding of the climatic change in the examined area can be elevated. According to the geographic locations of the 30 sequences, the examined area was divided into five regions and they are Kazakhstan Hills (a), southern Siberia (b), Altai-Sayan region (c), western Mongolia (d), and northern Xinjiang (e). The detailed information of the reviewed 30 sequences are presented in Table 1 and Fig. 1.

2. Physiographic settings

2.1. Large-scale air pressures and circulations

Situated in the core of the Eurasian interior, the examined area is presently under influences of several different climatic systems. Specifically, the cold-season climate is modulated by the interactions between the Westerlies-conveyed North Atlantic Oscillation (NAO) and the Siberia High. In addition, the strength of the Aleutian Low and somewhat associated North Pacific Oscillation (NPO) (Aizen et al., 2001; Bridgman and Oliver, 2006) also affect the climate in the examined area through affecting the core position of the Siberia High along the east-west direction (Fig. 2a). When the winter NAO is in a positive phase, an enhanced atmosphere pressure gradient between the Azores High and the Icelandic Low results in a more forceful eastward flowing of the Polar Jet Stream that prevents the Arctic cold air masses in the north from invading the south. The resulted eastward positioning of the Siberian High's core normally brings warmer and wetter winters