Palaeogeography, Palaeoclimatology, Palaeoecology 426 (2015) 75–84

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Tracing the North Atlantic decadal-scale climate variability in a late Holocene pollen record from southern Siberia

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ARTICLE INFO

Article history:
Received 25 October 2014
Received in revised form 28 January 2015
Accepted 25 February 2015
Available online 5 March 2015

Keywords:
Pollen
Non-pollen palynomorphs
Lake level
Atlantic Multidecadal Oscillation
Human impact
Late Holocene
Siberia

ABSTRACT

This paper presents a new palynological record from a 146 cm long finely laminated sediment core obtained in 2009 from the deep-water meromictic Lake Shira (54°30′38″N, 90°12″09′E; ca. 353 m a.s.l.) situated in the Khakassian steppe region of southern Siberia between the rivers Ob' and Yenisei. The area is rich in lakes and represents an exceptionally well preserved sequence of Bronze and Iron Age archeological cultures. Little is known about the changes in vegetation and climate of the region during the Holocene. The palynological analysis of the core allows us to partly fill up this gap in current knowledge. The record of pollen and non-pollen palynomorphs presented here covers the past 2450 year interval with an average resolution of 22 years. The results obtained support the interpretation that the late Holocene vegetation changes around Lake Shira are mainly associated with large-scale atmospheric circulation processes controlling the regional water balance rather than with human activities. An attempt to trace human impact in the pollen assemblages provides no clear evidence for anthropogenic activity, except for the last few decades since ca. 1955, though the region has a long history of mobile pastoralists. For explanation of decadal-scale changes in the regional vegetation cover, the *Artemisia*/Chenopodiaceae (A/C) pollen ratio proved to be a reliable indicator of effective moisture availability. Using available fossil and published instrumental data our study suggests a link between the North Atlantic warmer/colder temperatures and higher/lower atmospheric precipitation (or moisture availability) in southern Siberia at multidecadal to centennial scales.

1. Introduction

An accurate understanding of the past two thousand years of the Earth's climate history is critical for placing recent warming in the context of natural climate variability (e.g. McKay and Kaufman, 2014 and references therein). Despite significant progress in multi-proxy temperature reconstructions at the global and regional scales, the precise sequence of changes related to regional climate forcings and feedbacks, internal climate variability, and the responses of surface climate, land cover and hydrosphere is still not sufficiently understood (PAGES 2k Consortium, 2013).

High-resolution proxy records of climate are vital for comparison with model simulations and high-resolution instrumental records in order to advance our understanding of Holocene climate changes, their causes and interactions (e.g. Wanner et al., 2008; Masson-Delmotte et al., 2013) or to address some important archeological questions (e.g. van Geel et al., 2004). Nevertheless, the most recent data syntheses demonstrate a lack of adequate paleorecords in many parts of the globe (PAGES 2k Consortium, 2013 and references therein). In particular, vast steppe dominated areas of central Eurasia, rich in archeological material (e.g. Parzinger, 2006) and having high economic potential, are poor in paleoclimatic archives (Tarasov et al., 2012). In the absence of long tree-ring, speleothem and ice core records, pollen and other proxy records stored in annually laminated lake sediments (e.g. Stebich et al., 2009) could become an important source of high-resolution and precisely dated information about the past climate, vegetation, and human activities. To date, however, this source of information remains unexplored, mainly because lakes with annually laminated sediments are rare, while radiocarbon dating of non-laminated sediments in the semi-arid regions reveals chronological uncertainties due to a varying reservoir effect.

In this paper we present a new palynological record from a 146 cm long sediment core obtained from the deep-water meromictic Lake Shira (54°30′38″N, 90°12″09′E) situated in the Minusinsk Depression of southern Siberia between the rivers Ob' and Yenisei. Though this area is rich in lakes and represents an exceptionally well preserved sequence of Bronze and Iron Age archeological cultures, little is known about the changes in vegetation and climate of the region during the Holocene

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http://dx.doi.org/10.1016/j.palaeo.2015.02.037
0031-0182/

(e.g. van Geel et al., 2004), with the nearest long pollen records originating from western Siberia, northern Kazakhstan and the Altai Mountains (e.g. Rudaya et al., 2012; Andreev and Tarasov, 2013 and references therein). The core recovered in 2009 revealed an annually laminated sediment structure, which made possible the construction of a robust age–depth model and investigation of mechanisms of seasonal to centennial-scale carbonate accumulation in the lake during the past ca. 2500 years (Kalugin et al., 2013). The palynological analysis of the sediment core in 5 mm steps results in ca. 22-year average resolution of the record. The results are then interpreted in terms of the vegetation, aquatic ecosystem and climate development, with special attention being paid to the possible links between the vegetation changes around Lake Shira and large-scale circulation processes controlling the regional water balance.

2. Site setting and regional environments

Lake Shira (54°30′38″N, 90°12″09′E; ca. 353 m a.s.l.) is situated in the southern part of the large Minusinsk Depression in central Eurasia (Fig. 1a). The area is also known as the Khakass-Minusinsk or Abakan-Minusinsk Hollow (Alpat'ev et al., 1976) and belongs partly to the "Khakasskii" State Nature Reserve. The lake has a length of about 9.4 km, a maximum width of about 5 km (Fig. 1b) and a water surface area of 35.9 km^2. The water depth reaches 24 m in the central part (Kalugin et al., 2013). Earlier hydrological studies attest Shira as a saline meromictic lake without outflow (e.g. Genova et al., 2010). The Son River flows into the lake from the south (Fig. 1b) and provides about half of the fresh water supply (Rogozin et al., 2010). Other sources of water are atmospheric precipitation and seepage water. The groundwater input to the lake budget varies from one publication to another, i.e. from ca. 9% (Belolipetsky et al., 2010) to 17% (Kalugin et al., 2013).

The absence of surface outflow results in a brackish-water environment. Measurements performed in 2004 revealed salinities as high as 14‰ (Belolipetsky et al., 2010), although higher salinity values have been reported too, i.e. 18–19‰ in 2003 (Genova et al., 2010), about 20‰ in the 1980s, and up to 27‰ during the period from 1920s to 1930s (Rogozin et al., 2010 and references therein).

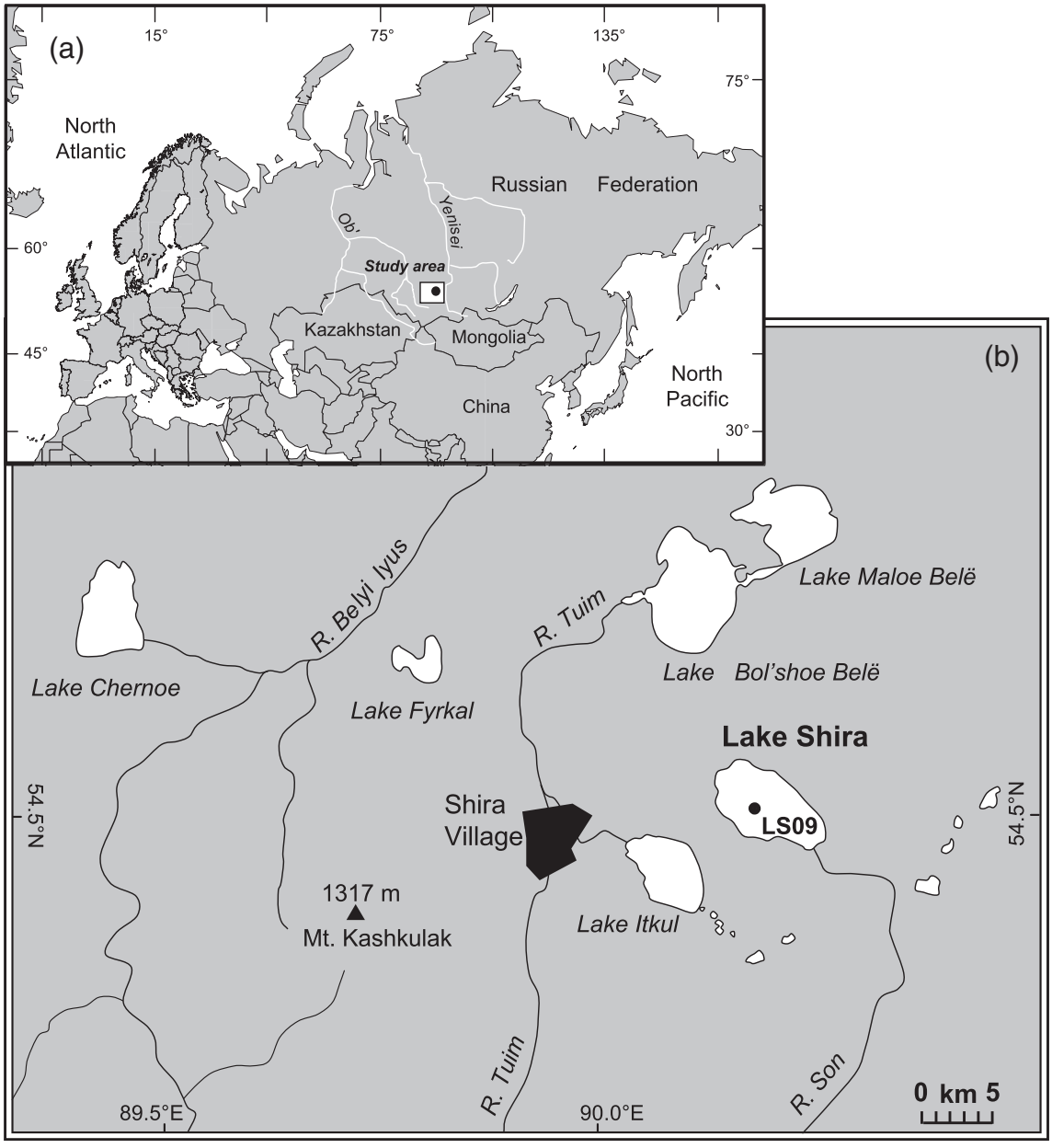

Fig. 1. (a) Map of northern Eurasia with location of the study area around Lake Shira (white rectangle) enlarged in (b). The location of the LS09 coring site and the pollen record is indicated with a black dot.