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The response of the environment of the Angara–Lena Plateau to global climate change in the Holocene

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Abstract

The paper is focused on the regularities and character of the response of the regional landscapes of the Angara–Lena Plateau to variations in the global climate system during the Holocene. They were revealed by integrated studies of four peat bogs of the plateau—an important area for the understanding of the environmental dynamics in the entire Baikal region. Age models for the records obtained were provided by 16 radiocarbon dates. A spatiotemporal correlation of spore–pollen indices with the trend of $\delta^{18}O$ records from the global stratotypes was used to find out the possible causes of changes in the landscapes and climate of the Angara–Lena Plateau in the context of past changes in the global climate system. The plateau environment showed a dramatically varying response to global climate variations in the Middle–Late Holocene. Moreover, the observed intervals of reorganization in the regional environment took place in a quasi-millennial regime, in accordance with global climate rearrangement. However, not all the studied regions of the Angara–Lena Plateau exhibited a synchronous or analogous response to global environment change. This emphasizes the complicated character of regional climate manifestations in the Holocene and necessitates the use of paleogeographical data from a wider range of territories.

Keywords: pollen analysis; peat deposits; Holocene; dynamics of regional climate and landscapes; interregional correlation; Angara–Lena Plateau

Introduction and problem formulation

In the last few decades, studies have shown considerable instability in the climate of the recent interglacial—the Holocene. The intervals of change in the Holocene environment and their age boundaries were reflected in different natural records of climate change, and part of them received the status of Holocene global stratotypes (Bond et al., 2001; Svensson et al., 2008; Wang et al., 2005). The conventional Blytt–Sernander system for the European Holocene includes five stages (ka): Preboreal (11.5–10.5), Boreal (10.5–7.8), Atlantic (7.8–5.7), Subboreal (5.7–2.6), and Subatlantic (2.6–present) (Roberts, 1998). However, researchers now prefer to divide the evolution of the Holocene environment into three periods: Early (11.7–8.0 ka), Middle (8.0–2.5 ka), and Late (the last 2.5 kyr) (Roberts, 1998). The Holocene optimum in different regions of the Northern hemisphere took place at (10)9–(7)6 ka (Roberts, 1998). The climate cooling which began at 6000–4000 years BP is regarded as the start of the Neoglacial Holocene (Crockford and Frederick, 2007). Also, the climate variations which took place at 7–6 ka led to a global transformation of vegetation. This is clearly evidenced by pollen records from the sediments of the Western Alps (Fauvart et al., 2012), Spain (Jiménez-Moreno and Anderson, 2012), Mongolia (Fukumoto et al., 2012), China (Chen et al., 2013), and some other regions. During the Holocene postoptimum, the ice sheets which caused dramatic changes in the Earth's environment and climate in the last glacial period waned to the present size (Dyke and Prest, 1987). The present level of the World Ocean was also reached at ~6 ka and has shown only slight fluctuations since then (Horton et al., 2007). However, a summary of more than 50 global paleoclimate records from both hemispheres yields five periods of significant climate changes during the postoptimum time: 6.0–5.3, 4.2–3.8, 3.2–2.4, 1.2–1.0, and 0.60–0.15 ka (Mayewski et al., 2004).

Analysis of palynostratigraphic data on the Baikal region revealed three long periods of climate and vegetation change: (a) 11.7–9.5 ka, with low atmospheric humidity, lower average winter and summer temperatures than present ones, and

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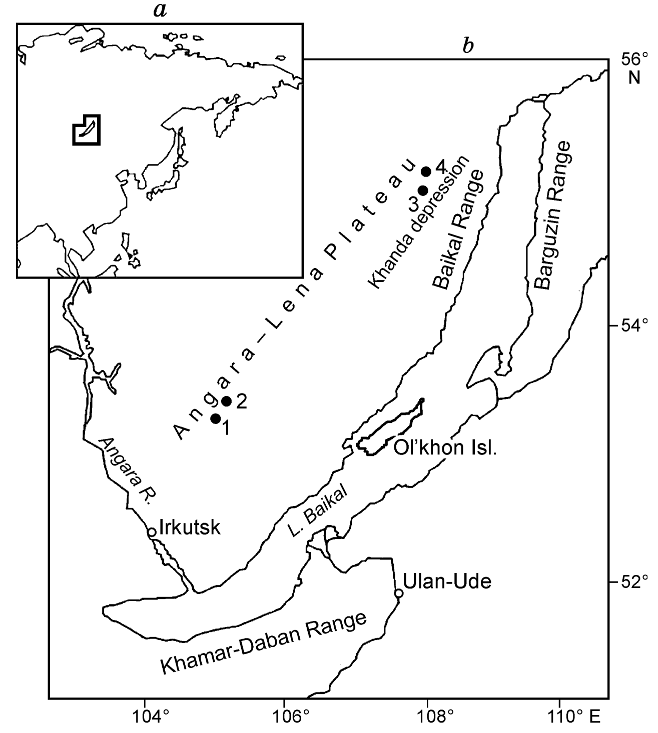

Fig. 1. Sketch map of North Asia and the Baikal region (*a*), with study areas (*b*). The location of the study areas is shown by black circles: 1, Khyndyrkul tract; 2, Lake Valley; 3, Khanda-1 peat bog; 4, Khanda-2 peat bog.

predominant forest tundras; (b) 9.5–6.5 ka, the most favorable period for the development of dark coniferous fir-tree taiga with the maximum average annual precipitation and the highest average winter temperature in the Holocene; and (c) 6.5 ka–present, when the values of all the above-mentioned climate parameters decreased with respect to those in the previous period and light coniferous forests began to predominate (Bezrukova et al., 2010; Demske et al., 2005; Tarasov et al., 2007, 2009).

To test this Holocene periodicity for Baikal, biostratigraphic data on its other large regions were required. One of them is the Angara–Lena Plateau, which occupies most of Cisbaikalia as the main structural and morphologic element of its topography. This region is key to the understanding of the evolution of the Baikal environment because of the predominance of primary boreal forests (taiga). As they are on the way of western moisture-bearing air masses, they retain a considerable part of moisture, thus reducing the amount of precipitation in the Baikal region and ensuring the accumulation of water resources in the Baikal Trough. The landscapes of the Angara–Lena Plateau are located on permafrost, which makes them sensitive to climate change. Nevertheless, the change in the environment and climate of this region remained almost unknown till now. The present study is concerned with the regularities in the reaction of the plateau landscapes and climate to regional climate change caused by the Holocene transformations of the global climate system. To meet this objective, we carried out the first integrated study of peat bogs in this region.

Materials and methods

Southeastern Angara–Lena Plateau. The Khyndyrkul tract is located in the southern part of the plateau (Fig. 1), in the upper reaches of the valley of the Ilga River, left tributary of the Lena River (53°30′45.15″ N; 104°48′51.76″ E). The area is characterized by the sparse patchy distribution of frozen rocks, waterlogging, the presence of long-term and seasonal frost mounds, and extreme continental climate. According to the data of the Bayandai weather station, the average temperature of January is –22.9 °C; that of July, +16.8 °C; and the average annual precipitation is ~350 mm. The present vegetation in the area is dominated by forests of *Pinus sylvestris*, *Larix* sp., and *Betula sect. Albae*, part of which substituted dark coniferous taiga. Dark coniferous forests with *Pinus sibirica*, *Picea obovata*, or, more rarely, *Abies sibirica* occupy small areas. The frost peat mound itself is covered with birch-forb vegetation, and the bog sustains sedge-grass communities with *Betula sect. Nanae*.

The Lake Valley tract (Fig. 1) is located 5 km north of the Khyndyrkul peat bog (53°30′43.47″ N; 104°48′35.68″ E). The climate and vegetation in this area are almost identical to those in the Khyndyrkul tract.

Northeastern Angara–Lena Plateau. We studied two peat bogs in the upper reaches, on the right bank of the Khanda River, left tributary of the Kirenga River. The Khanda-1 section (55°44′30.60″ N; 106°58′0.38″ E) is localized at the second bottom, where the peat bog is undermined by the river. The Khanda-2 section (55°59′50.60″ N; 106°59′40.38″ E) is localized at the second bottom of the river, 7 km north of the first peat bog. The studied peat bogs are located in the Khanda basin, whose sides have an altitude of up to 250 m more than the bottom. The area is marked by extreme continental climate, with a long cool winter and a short warm summer. Owing to winter inversions, the temperature here decreases to –45 to –50 °C, ensuring the existence of permafrost. According to the data of the closest Davan weather station, the average temperature of January is –26.1 °C; that of July, +14.2 °C; and the average annual precipitation is from 300 to 400 mm (Galazii, 1993).

The vegetation of the basin sides and bottom is very different. The western slope is dominated by spruce–Siberian pine forests with larches, and the eastern one sustains Siberian pine–larch and Scots pine–larch forests with dwarf birches. Vast expanses of primary forests on the basin sides were destroyed by fires and then replaced by larches and birches. The basin itself is occupied by stunted larch forests, and sand deposits in this area sustain Scots pine forests. The surfaces of both peat bogs have similar vegetation—sparse larch forests with *Betula sect. Nanae*, Cyperaceae, and *Sphagnum* sp.

Sampling process. The peat bog in the Khyndyrkul tract was drilled into using an Instorf sampler. Three other peat bogs were sampled in situ by cutting peat monoliths (5 × 5 × 5 cm) out of cleared outcrops.

Radiocarbon dating. The age models for the peat profiles are based on 16 radiocarbon dates (Table 1). The radiocarbon ages were converted to calendar years BP using the CalPal