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Regional to local environmental changes in southern Western Siberia: Evidence from biotic records of mid to late Holocene sediments of Lake Beloye

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ABSTRACT

The paper presents the first paleontological data (pollen, plant macrofossil, diatom and ostracod) on the sediments of Lake Beloye, which is situated in the forest-steppe zone of Western Siberia. Our study contributes to better understanding of the Middle–Late Holocene regional to local environmental changes. Regionally, we recognized a cold stage of 3.4–2.3 calibrated ka BP and a dry stage of 2.8–1.7 ka BP. The dry stage coincides with the climate-driven lowered level of the lake at 2.6–1.5 ka BP. Later, the climate changed to warmer and wetter, which resulted in a highest stand of the lake at 1.3–0.2 ka BP and was followed by the lowering of the lake. Forest-steppe persisted in this area during the whole period under consideration, but probably shifted southward. Such a shift is reflected in the environment around Lake Beloye similar to that of modern taiga, which existed at 3.2–1.3 ka BP, however, compared to the colder and wetter climate of taiga, the conditions were colder and drier. The local plant associations and the lake ecosystem were affected by those events of climate and lake level changes. The initial eutrophic sedge-reed swamp evolved to the oligo-mesotrophic sphagnum bog, which existed around the lake at 3.2–1.3 ka BP. Later, the bogging process was interrupted by the lake transgression, after which the dried bog around the lake was occupied by the birch forest. The lake ecosystem was strongly affected by the 3.4 ka BP climate change: the low-alkaline eutrophic lake with abundant water higher plants and diatoms changed to the alkaline oligotrophic lake with calcium-fixing macrophytic algae and angiosperms. This resulted in total change of lake's bio-geochemical and sedimentation patterns.

1. Introduction

Although the Holocene climatic trend for southwestern Siberia was well constrained by early palynological studies (e.g., Khotinsky, 1977, 1984; Volkova et al., 1989; Monserud et al., 1998; Volkova, 1999) and has been recently improved by Blyakharchuk (2003; 2010), Zakh et al. (2010), Borisova et al. (2011), we still have gaps in understanding the vegetation structure and detailed environmental changes. The pre-2000 palynological data on Siberia was, to a considerable degree, summarized in the NOAA Global Pollen Database and paleoclimatically interpreted by Tarasov et al. (1998). The recently updated Eurasian macrofossil and pollen databases hosted by the University of Oxford might be useful for further investigations of climatic fluctuations in the Siberian region during the Middle to Late Holocene (Binney et al., 2008, 2009), which have not been done yet.

Pollen data shows uneven changes of vegetation throughout Siberia suggesting variable climate conditions in different regions. For example, the Baikal region has been dominated by pine since the Middle Holocene (Krivonogov et al., 2004; Bezrukova et al., 2005), and the paleoclimatic trends reconstructed for this area demonstrate a gradual decrease of precipitation and mean January temperatures toward their present-day values (Tarasov et al., 2009). In the Siberian Arctic sector, the Taimyr Peninsula, the thermal maximum occurred at 6000–4500 ^{14}C BP and was followed by a gradual decrease of temperatures, which reached the modern forest-tundra values at about 2800 BP. However, several events of warming took place at ca. 3500,

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2000, and 1000 B.P (Andreev et al., 2002). In central Western Siberia, the climate was warmer and less humid at 6 to 5 cal. ka BP; since then it has been cooling down and getting more humid resulting in the replacement of Siberian fir by Siberian spruce and Siberian pine (Blyakharchuk and Sulerzhitsky, 1999; Borisova et al., 2011). In the south-west of Western Siberia, the climate gradually changed from warm and dry in the early Atlantic period, as recorded by the expansion of steppe vegetation, to cooler and wetter since the late Atlantic (ca. 6.3 cal. ka BP) with recovered small-leave forest and forest-steppe vegetation (Zakh et al., 2010). In southeastern Western Siberia, the Middle to Late Holocene climate was wetter and warmer at 8.8–5.0, colder at 5.0–2.5 and similar to modern conditions at 2.5–0 cal. ka BP; the taiga zone started its southward migration at 6.1 cal. ka BP (Blyakharchuk, 2010). Although Levina and Orlova (1993) distinguished shorter, i.e. about 500 years, climatic rhythms in the Holocene, which found indirect support in several global (e.g., Mayewski et al., 2004) and Eurasian (e.g., Bush, 2005; Büntgen et al., 2011) climate models, no strong evidence for short-term climatic events in southern Western Siberia has been found yet.

It is well-known that palynology possesses restrictions in plant identification (Faegri et al., 1989) and often cannot provide detailed ecological and biogeographical reconstructions. Other, more sensitive plant macrofossil methods can be effectively used for the study of organic-rich lake and peat bog sediments, such as analyses of seeds, fruits and soft plant tissues. These methods appeared more useful for determination of plant species, but they are constrained by local vegetation of lakes or bogs and their surrounding areas. All this significantly shifts the focuses of paleoenvironmental studies to ecology, but climatic factors remain under consideration as well. Results obtained by those methods allow us to reconstruct natural successions of local vegetation assemblages and their breaks, which reflect the changes of climatic, hydrologic, permafrost and other conditions and even events such as wildfires, etc. (e.g., Krivonogov et al., 1985; Krivonogov and Bezrukova, 1993; Preis, 2004).

Our case study of Lake Beloye, which is situated 50 km north of Novosibirsk City (Fig. 1), gave us an opportunity to reconstruct regional and local environmental changes recorded in the biogenic sediments of the lake and surrounding peat bog. This paper presents first results of their paleontological study: higher plants, green and diatom algae flora and ostracod fauna. The detailed results of their sedimentologic and geochemical studies are discussed in a separate paper (Krivonogov et al., 2012–this issue).

2. Modern environment, geomorphologic, and geological settings

Lake Beloye (N 55°39′, E 82°70′; 107.3 m a.s.l.), which means "white" in Russian, is located on the left bank of the Ob River. The lake is small (about 1 × 0.7 km), up to 1.4 m water depth. The climate in the study area is continental with the mean January temperature of − 19.5 °C, the mean July temperature of + 19 °C, and the mean annual precipitation of ca. 450 mm (Kravtsov, 2002). The lake is situated at the boundary between the forest steppe and small-leaf deciduous forest (sub-taiga) zones. The dominant are birch and birch-aspen forests of both sedge and sedge-reed geobotanic types, which border sedge and sedge-reed swamps (Il'ina et al., 1985), occupying depressions of surface microrelief. However, the region is currently dominated by arable lands. Conifers are not typical, but single pine trees occur in the birch forest, surrounding the Beloye Lake. *Pinus sylvestris* L. (Scots pine) belt forests are stretched along the Ob River (Fig. 1).

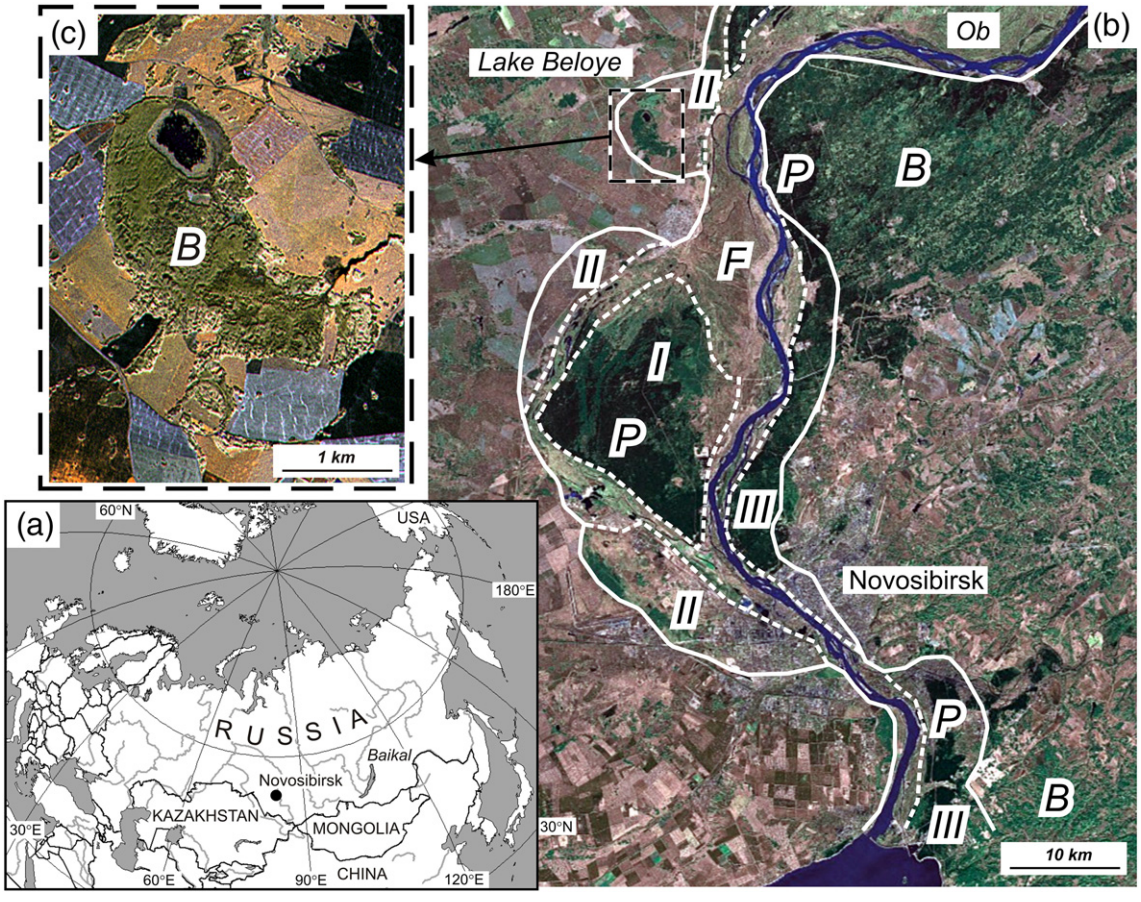

Fig. 1. The study area: (a) index map; (b) general view of Lake Beloye region on a Google Earth satellite image; (c) enlarged view of Lake Beloye on a ASTER satellite image. Forests: B — birch; P — pine. The white solid line outlines the Ob River valley and the white dashed line outlines the river terraces: F — floodplain; I–III — terraces.