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Dramatic level changes of shallow lakes in the southern part of East Siberia, (Russia) based one high-resolution reflection seismic data and sediment cores

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ABSTRACT. In this study, we carried out to correlate of high-resolution reflection seismic patterns of sediment covers Lakes Gusinoye and Shuchye located near the eastern coast of Lake Baikal. For this purpose, we used high-resolution seismic data and sediment cores up to 2.7 m. Seismic stratigraphy records contain three contrasting episodes when the lake levels dramatically decreased. In result, there are probably hiatuses in the paleorecords from these lakes due to erosion of sediment cover at the lowest lake levels at the Late Pleistocene and Holocene.The core sediment record was based on distribution of biogenic silica, quarts, feldspar and total organic carbon obtained by FTIR method. The maximal age of the cores was 23.2 cal. ka BP. Significant climate changes in Baikal region happened ca. 22, 17.5 and 1.5 ka BP.

Keywords: High-resolution seismic data, FTIR, level changes, Lakes Gusinoye, Shuhye, Baikal, East Siberia

1. Introduction

The southern part of East Siberia is characterised by a variety of landscapes, from steppe to mountain zones, and, according to, lake paleorecords from this region, can be very sensitive to climate changes. For example, the northern depression of Lake Gusinoe completely dried *ca.* 14 cal. ka BP (Chensky et al., 2019). According to historical records, there were two lakes on the place of Lake Gusinoye in 1728, and it is very likely that similar changes also happened before. Lake Shuchye level and other small regional lakes were extremely low and high saturated with salts during the final period of the Little Ice Age (Fedotov et al., 2013). However, the core records from shallow lakes in the Baikal region are often no older the Middle Holocene (e.g. Bezrukova et al., 2010; Fedotov et al., 2013; Mackay et al., 2013; Solotchina et al., 2014). The longest Baikal region sediment (9 m) core was obtained from Lake Kotokel and dated in 33 ka cal. BP (Shichi et al., 2009).

However, there still is gap in know about structures of sediments cover of small lakes from this part of East Siberia. In our study, based on the analysis of high-resolution seismic data on the sedimentary infill of shallow lakes located near Lake Baikal, we attempt to reconstruct the evolution of the lakes as regional climate proxy the Late Pleistocene-Holocene.

2. Regional setting and Methods

Seismic data were collected using a Frequency Modulated (FM) sub-bottom profiler consisted of tree transducers that receive and radiate FM signal (frequency 1-10 kHz). Forty-five and 21 kilometers of seismic profiled were obtained on Lakes Gusinoe and Shuchye, respectively, in 2018 on. The FM profiler enables to study stratification of sedimentary layers with a resolution of up to 10 cm. For conversion of the acoustic travel time into depth, we assumed velocity of 1.45 m/ms in water and 1.5-1.6 m/ms for the uppermost unconsolidated sediments.

Lake Gusinoe is located in approximately 60 km to the south of Lake Baikal (Fig. 1). The lake is situated at 551 m above sea level. It is approximately 24 km long and 8.4 km wide, with a maximum depth of 26 m. Lake Shuchye (approximately 5 km^2) is located near (13 km) Lake Gusinoe at 643 m a.s.l.

In 2019, a sediment cores were taken from the northwestern part of Lake Gusinoye (Fedotov et al., 2019) and the east part of Lake Shuchye using a Uwitec Corer sampler. The water depth were 20 m at the core-sampling sites. The cores were 80 and 270 cm long from Lakes Gusinoe and Shuchye, respectively. However, the core sampler cannot penetrate deeper due to a high density of bottom sediments of Lake Gusinoe.

Total content of of quartz, feldspar, biogenic silica

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($BiSiO_2$) and organic carbon (TOC) these components were investigated using the Fourier-transform infrared (FTIR) technique with KBr (3 mg sample/170 mg KBr) at wavelength from 700 to 4,000 cm^{-1}. Absorbance bands for the calculation of these components were approached according to Petrovskii et al. (2016).

Graphitization and AMS-analysis were carried out in the laboratory AMS Golden Valley using AMS constructed at Budker Institute of Nuclear Physics (Novosibirsk, Russia) (Parkhomchuk and Rastigeev, 2011). Calendar date was evaluated from the radiocarbon one by CalPal ver.1.5.

3. Results and Discussion

Seismic profiles clearly distinguish a two-part subdivision of the stratigraphic section from the sedimentary infill: -a lower part, acoustically un- or poorly stratified; - an upper part, thinly and regularly stratified, with good lateral continuity (longitudinal and transverse) (Fig. 1). A lower part – the basement is chaotic unstructured low-amplitude reflections (Fig. 1). Thickness is approximately 2-3 m (deeper, seismic signal damped). It is most likely that reworked fluvial and eolian sediments represent these sediments in the lakes.

The upper parts are represented by low-amplitude sub-parallel reflections. High-amplitude of reflectors and a distinct thinning of its rhythmic pattern are increased towards the upper boundary of sediment covers. In general, this reflection pattern can be interpreted as normal lacustrine filling, and its thinning seems to show that the lake depths gradually increased. However, there are packets of chaotic low-amplitude reflections embedded into packets of parallel reflections can be associated with a silty sand-rich mudslide, sandslide or river fan. In addition, this lacustrine sediment sections can be divided into units based on erosion surfaces.

The sizes of studied lakes are very different, however, thickness of lacustrine sediments were similar at about 5-7 m (Fig. 1). Thus, it likely assumes that these lakes began to form at the same time.

The sediment cores are presented by two lithological parts. The upper parts 0-28 and 0-100 cm of Lakes Gusinoe and Shuchye, respectively, were composed of fine, light grey and black silty clay with high content of pore water (80%). In contrast, density of sediments toward to the bottom cores is increase, while water contents approximately are 20-25%. In addition, the bottom layers were enriched with shells of ostracods and gastropods, however, content of biogenic silica are only 0-4% (Fig. 1). It seems that these high-density sediments formed under lacustrine conditions; however, it likely was a shallow lake.

AMS dating indicates that the layer of 79-80 cm in Lake Gusinoe likely deposited ca. 5 cal. ka BP, while three AMS dates from 121-270 cm of Lake Shuchye show age between 17.5-23.2 cal. ka BP. It is some surprised, because the level of Lake Baikal, being by 40-50 m lower than the modern lake, as well as a low and irregular discharge of the Selenga River are evidence of high regional aridity in the LGM (Urabe et al., 2004; Osipov and Khlystov, 2010). According to these reconstructions, shallow Lake Shuchye would be fully dried, however it was not happened. The seismic pattern indicates that short episodes dramatically drop of Lake Shuchye can occurred around 18 and 22 ka BP (Fig. 1).

However, dramatic drops of small Baikal region lakes were not only at the LGM. Thus, there are lithological, seismic and depth–age evidences that lacustrine condition were interrupted in the Holocene. For example, in the core Lake Shuchye layers 138, 121 and 115 cm were dated by 20.7, 17.4 and 7.0 cal. ka BP. It is an unreal scenario that a layer with thickness 6 cm formed from 17.4 to 7.0 ka BP. Thus, it should be a gap in the sediment record. For instance, there is an erosion surface in the upper boundary of layers 17.4 ka BP (Fig. 1), and according to AMS data lacustrine sedimentation approximately begun since ca. 7.0 ka BP.

The second Holocene episode of low stands of Baikal region lakes was *ca.* 1.5 cal. ka BP. Thus, in Lake Gusinoe, a change in sedimentation (approximately 25 cm in the core) occurred *ca.* 1.5-2 cal. ka BP (Fig. 1) and black and olivedark silty-clay began to form. In Lake Shuchye layer 95 cm dated by 1.2 cal. ka BP while 110 cm was 6.3 cal. ka BP. In addition, the bottom layers of 0- 95 cm is the seismic unconformity. It is not possible clearly determinate when was the beginning of the drop level but it is most likely that the level

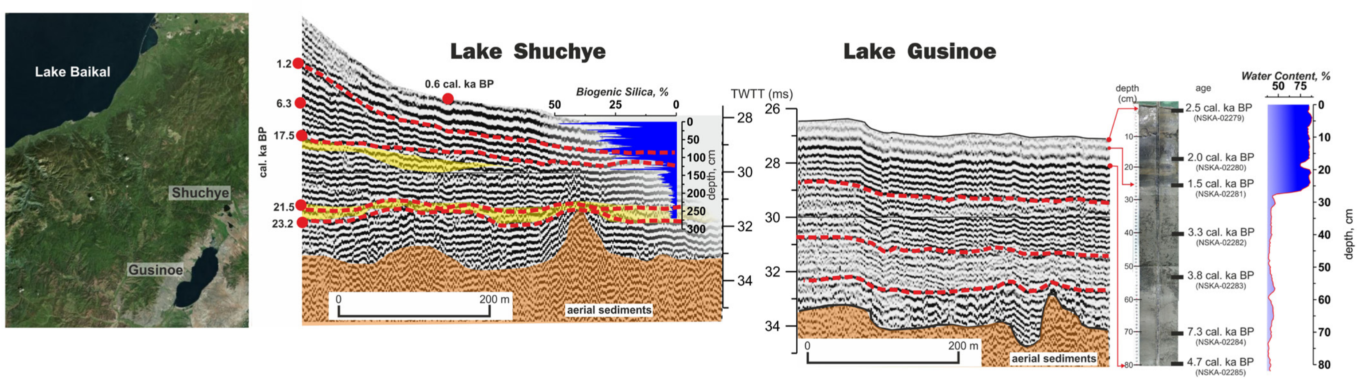

Fig.1. Seismic stratigraphy and the core image, ^{14}C age-dates were converted into calendar ages until present (cal. BP). *Red ditched lines* – erosion surfaces, *yellow*- layers enriched by coarse sand material.

began since ca. 1.5 cal. ka BP. For instance, between 2.12 and 1.87 cal ka BP there was a significant decline in mean annual precipitation and mean temperature of the coldest month but an increase in mean temperature of the warmest month (Mackay et al., 2013). Regional oxygen isotope records marked change at ca. 3-2.5 ka BP (Kostrova et al., 2013).

4. Conclusions

We have studied sediment cover of shallow Baikal region Lakes Gusinoye and Shuchye based on high-resolution seismic data and sediment cores. The thickness of lacustrine sediments cover are similar 9-6 m. Seismic pattern, sediment characteristic and AMS date indicate about dramatic level drop at the LGM-Holocene when the lakes were dry. Significant climate changes in Baikal region happened ca. 22, 17.5 and 1.5 ka BP.

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