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SEISMOACOUSTIC INVESTIGATIONS OF LAKE BOLSHOYE BELE BOTTOM SEDIMENTS (THE REPUBLIC OF KHAKASIA, RUSSIA)

Krylov P.S.[1], Nurgaliev D.K.[1], Yusopova A.R.[1], Sitdikov R.N.[1] and Krylova A.S.[2]
[1]Department of Geophysics and Geoinformation Technologies, Institute of Geology and Petroleum Technologies, Kazan Federal University, Kazan, Russia
[2]Department of Foreign Languages, Kazan National Research Technical University named after A. N. Tupolev - KAI, Kazan, Russia
E-Mail: pskrylov@kpfu.ru

ABSTRACT

This work shows for the first time the structure of Lake Bolshoye Bele bottom sediments, one of the lakes investigated as a part of grant №671-2020-0049 in the sphere of scientific activities. These works were carried out to detect bottom sediments in lakes and for further sampling of core columns for reconstruction paleoclimatic changes based on these sediments. The results were obtained using the high-resolution seismoacoustic method (single-channel 3 kHz sub-bottom profiler) and coring campaign (gravity corer). This data set enables detailed characterization of the sedimentary subsurface. This paper focused on the central part of the Lake Bolshoye Bele, in which significant thickness of sediments up to 20 m was found, which was divided into 3 seismic facies.

Keywords: seismoacoustic, lake, lake sediments, republic Khakassia.

INTRODUCTION

Many modern lakes are located in key geographic locations whose bottom sediments archived detailed records of changes in climate, landscapes, the evolution of lakes, and their ecosystems (Subetto D.A, *et al*., 2020). A comprehensive study of lakes bottom sediments of different depths and hydrological regimes located in different landscape and climatic zones provides a basis for paleoclimatic reconstructions of different periods. Comparison of data for different objects will allow in the future to identify trends in climate change in study region. However, the completeness of research on these issues is extremely uneven. This is due to both the large size of the study region and the laboriousness of such works. At the same time, by the joint efforts of researchers, the ‘blank spots’ are gradually eliminated (Ptitsyn A.B., *et al.,* 2014). The main problem is to detect and collect such layered not mixed, not blurred sediments. Today there are many different types of coring. And to detect sediments, morphological and stratigraphical features associated with depositional history the seismoacoustic method is widely used (Krylov, P., *et al.,* 2019). But often high-resolution seismic reflection surveying is carried out only on large lakes where the necessary equipment and boats are readily available. On small lakes, such works are rare. Nevertheless, the study of small lakes in sufficient detail can give the result of a change in the paleoclimate for a region located far from large lakes.

In 2020, within the framework of a grant from the Russian Science Foundation, we conducted investigations on Lake Bele (Republic of Khakassia). From a priori information about Lake Bolshoye Bele, it was only known that there were no detailed measurements of its depth, and the composition of all underground sources hasn’t yet been determined. Thus, this lake is potentially interesting from different points of study.

STUDY SITE

Lake Bolshoye Bele is situated in the northern part of Khakassia, on the territory of the Shirinsky region, 130 km north-west of Abakan (Figure-1). This lake is the largest mineral reservoir of the republic which located 8 km north of the lake Shira and 16 km from the Zhemchuzhny village. The lake is situated in the intermountain hollow of the treeless hilly Dzhirim steppe, at an altitude of about 376 m. The surrounding mountains don’t exceed 614 m above sea level, and the northern coast is steep in some areas. The lake of tectonic origin hasn’t yet been fully explored until now.

Lake Bele consists of two streams: Bolshoye Bele (southwestern) and Maloe Bele (northeastern), connected by a narrow channel. The area of the water surface of the Bolshoye Bele is reach 52 km², the average depth is 17 m, the maximum is 29 m; Maloe Bele is 26 km², the average depth is 23 m, the maximum is up to 46 m. The length of the lake coastline is 68.6 km, including 41,7 km Bolshoye Bele and 26.9 km – Maloe Bele (Berezovsky A.Ya., *et al.* 1999).

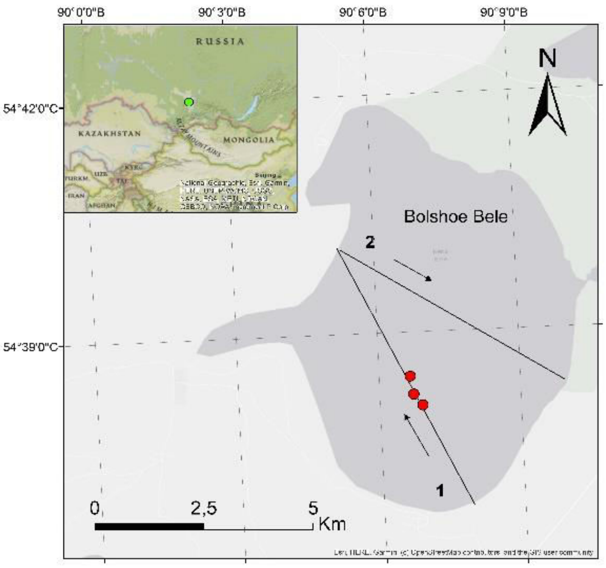

Figure-1. Location of Lake Bolshoye Bele, location of seismoacoustic profiles and sampling.

The catchment area of Bele is 435.2 km². The lake is fed by atmospheric precipitation and underground sources, as well as by the flow of the Tuim River (in the western part). Lake Maloe Bele is not covered in this article.

The composition of the lake water is moderately mineralized, alkaline, sulfate-chloride, sodium-magnesium. Its mineralization over the area varies from 9 to 14 g/l of water. By the nature of the environment, the water is alkaline. There are reserves of balneological mud. The vast territory of the lake basin is occupied by sediments of the Oidanovskaya suite (variegated and cherry-red mudstones), from the north - the Beiskaya suite (gray limestones), deposits of the Kokhai and Tubinskaya formations (variegated mudstones and siltstones). The southern coast is formed by alluvial deposits, clay and silt 6–8 meters thick. Bele is a closed lake, from the west the only watercourse flows into it - the Tuim River.

METHOD

For research in 2020, the same seismoacoustic equipment was used as in 2019 (Krylov P. *et al*. 2020). Continuous seismic profiling was applied based on the principle of central beam, which enables remote investigation of the lake bottom structure owing to the recording of acoustic waves reflected from the lake bottom. On this basis, it is possible to establish borders between sediment layers of different physical properties. The seismoacoustic profiling was carried out using specialized complex, designed and manufactured on the base of Kazan Federal University (Krylov P. *et al.* 2015). The complex includes: a source of elastic waves, a receiver, a seismic station, a laptop, a GPS-receiver, an inflatable boat, an electric motor, and power supply elements. The complex enables us to get seismic acoustic sections with vertical resolution at least 15 cm; depth study of various types of lake sediments at least 10 m; geodetic positioning system within several meters. It also provides the digital recording of information. As a source of elastic waves an inductive oscillator "boomer" was used. A storage battery was used as a source of electric power. The GPS receiver was used to coordinate profiles and boat location (Kosareva L., *et al*. 2018).

For laboratory investigations 3 cores of surface bottom sediments was selected using Uwitec sampling equipment (gravity corer).

The laboratory investigations included the measurements of magnetic susceptibility (MS) and analysis of the chemical composition of sediments.

The MS was measured for 134 samples from all the core columns using MFK-1A (AGICO) (Pokorny et al., 2011). The measurements were carried out at a frequency of 976 Hz. The obtained values of the MS were normalized by weight.

The element composition of each sample of core #1 was measured on Bruker S8 Tiger X-ray Fluorescence spectrometer. The output values were corrected with loss on ignition parameter, which was determined through heating samples at 1100 °C for about 2h.

RESULTS

In the course of the field work, 2 seismoacoustic sections with a total length of 12 km were obtained. Three short bottom sediment cores of 36-55 cm were collected. The sediments were submitted for laboratory biological, geochemical, paleomagnetic studies, the results are beyond the scope of this article and require special attention and analytics.

The seismoacoustic section 1 shows that the maximum depth in studied area reached 30 m, the maximum apparent thickness of bottom sediments was about 20 m (recalculation of the time scale into depth scale according to the speed of sound propagation in water - 1500 m/s) (Figure-2). By the nature of the wave pattern, the seismoacoustic section can be divided into 3 seismic facies. The facies I with layered intense reflections. In the facies II the section is also layered in places with a chaotic record. Facies III is characterized by layered low-intensity reflections. Down the section, there are oblique boundaries of the likely acoustic basement (the actual angle of inclination of the boundaries is less, due to the compressed horizontal scale of the seismic section).

From 200 to 280 pickets a decrease in the depth of the lake is observed. In this interval, the in-phase axes form a complex picture on the seismoacoustic section.

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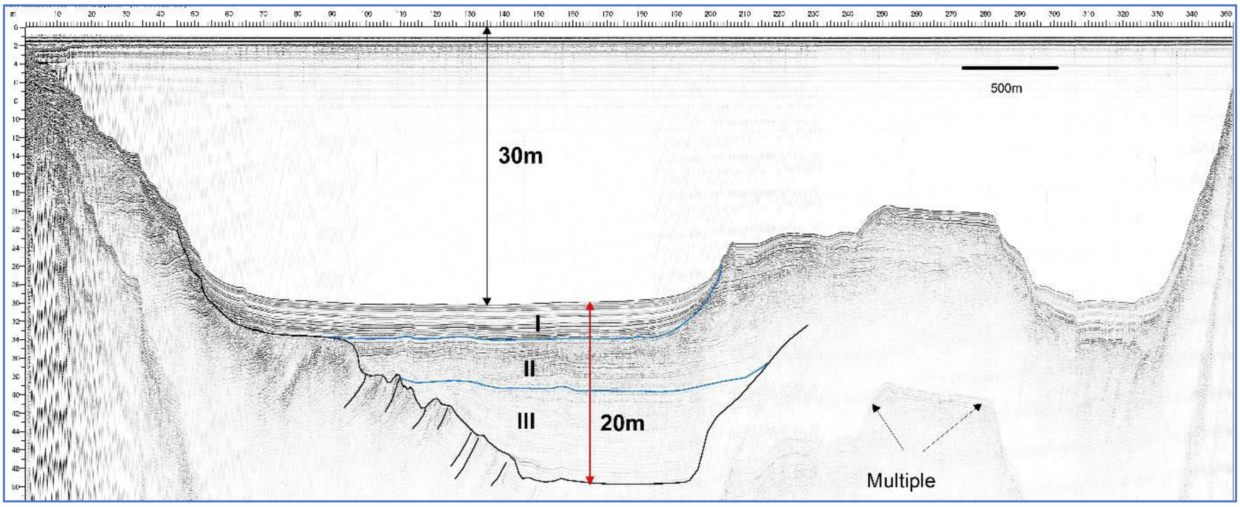

Figure-2. Seismic section 1 of Lake Bolshoye Bele. The left scale is the depth below the lake water level (in meters). Upper scale - number of points of acoustic pulse generation. Three seismic facies are clearly visible on the seismoacoustic section.

The Figure-3 presents the MS measurement results. The values of MS of core #1 are changed from $0.87*10^{-7}$ to $3.14 *10^{-7}$ m^3/kg. MS of core #2 vary between (0.92-2.81) $*10^{-7}$ m^3/kg. The values of MS of core #3 are changed from $0.89*10^{-7}$ to $3.64 *10^{-7}$ m^3/kg.

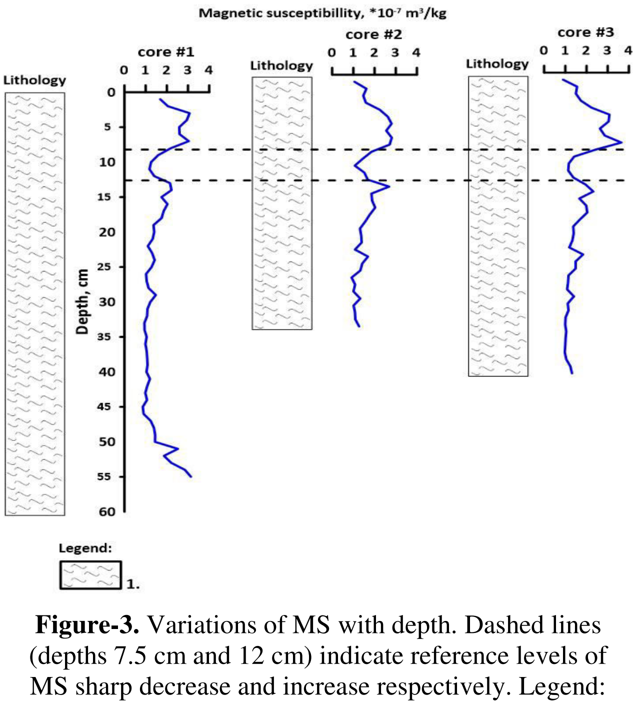

Figure-3. Variations of MS with depth. Dashed lines (depths 7.5 cm and 12 cm) indicate reference levels of MS sharp decrease and increase respectively. Legend: 1 - reddish-brown silt.

Variations of major and minor oxides are shown in Figure-4.

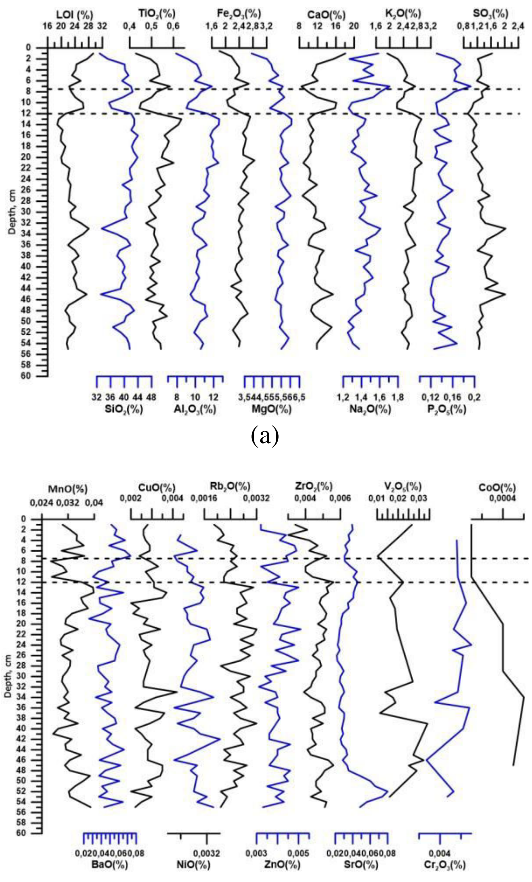

Figure-4. Variations of major oxides (a) and minor oxides (b). Core #1. Dashed lines indicate reference levels.

Values of LOI are varied from 18.8 to 29.3%, SiO_2 from 32.8 to 44.0%, TiO_2 (0.56-0.38) %, Al_2O_3 (7.87-12.6) %, Fe_2O_3 (1.82-2.84) %, MgO (3.88-6.07) %, CaO (6.02-12.9) %, Na_2O (1.25-1.7) %, K_2O (1.93-2.94) %, P_2O_5 (0.12-0.19) %, SO_3 (0.92-2.02) %.

Minor oxides are changed: MnO (0.026-0.04) %, BaO (0.026-0.073) %, CuO (0.002-0.0042) %, NiO

(0.0022-0.0036) %, Rb_2O (0.0019-0.0032) %, ZnO (0.0031-0.005) %, ZrO_2 (0.003-0.0056) %, SrO (0.022-0.08) %, V_2O_5 (0.01-0.02) %, Cr_2O_3 (0.0027-0.007) %, CoO (0.0001-0.0006) %.

DISCUSSIONS

Numerous examples of seismoacoustic profiling proved its usefulness in research on both tectonic origin with great sediments thickness and postglacial lakes of small depth and sediment thickness (Scholz 2001). Such unique lakes include Bolshoye Bele. The significant thickness of the bottom sediments indicates the great age of the lake. The detected three seismic facies indicate changes in the sedimentation process. And this, in turn, is closely related to climate changes.

According the comparison of MS and results of element composition (Figure 5), at depths of 12 cm and 7.5 cm (reference levels), there are sharp changes in the values of all parameters.

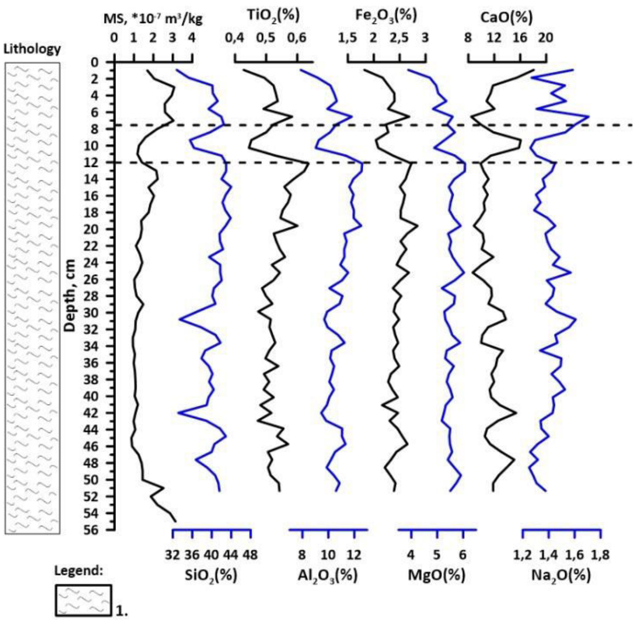

Figure-5. Comparison of MS and results of element composition. Core #1. Dashed lines indicate reference levels. Legend: 1 - reddish-brown silt.

These changes can be explained by sharp events in lacustrine sedimentation as well as lake level changes (rise and fall) and clastic input decrease and increase respectively.

Sampling of longer cores will allow a detailed reconstruction of the paleoclimate of the region and also to supplement the existing data.

The core of the near-surface bottom sediments of Lake Bolshoye Bele had a reddish-brown color, which indicates redeposition and accumulation for the most part of coastal erosion and sediments introduced by the inflowing river. Direct observations showed that during bad weather (wind with waves) the coastal part of the water (up to 100-150 m from the coast) turns red-brown. Nevertheless, there were also blotches of black color, probably organic material, on which laboratory studies will be performed.

ACKNOWLEDGMENTS

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LITERATURE

[1] Berezovsky A.Ya., Vladimirov V.V., Dmitriev V.E., Limansky M.E. 1990. The nature of the Shirinsky region. Publishing House of the Khakass State University named after N.F. Katanova, p. 70., (In Russian) ISBN 5-7810-0101-8

[2] Kosareva L., Kuzina D., Nurgaliev D., Krylov P., Antonenko V. 2018. Seismic and magnetomineralogical investigations lake Maloe Miassovo (South Ural, Russia)//International Multidisciplinary Scientific Geo Conference Surveying Geology and Mining Ecology Management, SGEM. 18(Is.4.3): 383-390.

[3] Krylov, P., Nurgaliev, D., Yasonov P. 2019. Seismic investigations of lakes sediments as the basis of paleogeographic and paleoclimatic reconstructions. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM. 19(1.1): 913-921.

[4] Krylov P. S., D. K. Nourgaliev and P. G. Yasonov. 2015. Seismic investigations of Lake Chebarkul in the process of searching Chelyabinsk meteorite / ARPN Journal of Engineering and Applied Sciences. 10(2): 744-746.

[5] Pokorny J, Pokorn´y, P, Suza P, Hrouda F. 2011 A multi-function Kappabridge for high precision measurement of the AMS and the variations of magnetic susceptibility with field, temperature and frequency The Earth's Magnetic Interior. 1: 292-301.

[6] Ptitsyn A.B., Chu G., Dar'in A.V., Zamana L.V., Kalugin I.A., Reshetova S.A. 2014. The rate of sedimentation in Lake Arakhlei (Central Transbaikalia), from radiogeochemical and palynological data. Geology and Geophysics. 55(3): 473-480

[7] Scholz C. 2001. Applications of seismic sequence stratigraphy in lacustrine basin, [in:] Last W.M., Smol

J.P. (eds.), Tracking Environmental Change Using Lake Sediments. Vol. 1: Basin Analyses, Coring and Chronological Techniques, Kluwer Academic Publishers, Dordrecht: 7-22.

[8] Subetto D.A, Fedotov A.P. 2020. Paleolake records as sedimentary proxies of climate changes of Northern Eurasia in the past. Limnology and Freshwater Biology. (4): 439-439.