Hydroacoustic study of the basin of Biryuzovoe Karyernoe lake (Korsakovsky district, Sakhalin Island)

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Abstract. For the first time, the paper presents the results of a detailed hydroacoustic study of the basin of the Biryuzovoe Karyernoe Lake (Novikovo village, Korsakovsky District, Sakhalin Region), formed after the conservation of the germaniferous coal deposit of the same name. On the basis of 12 hydroacoustic profiles, a detailed bathymetric scheme of the lake was compiled, its main morphometric parameters were calculated, and the morphological appearance was described. Preliminary conclusions have been made about the rates of sedimentation within the basin of the lake, and perspective points for monitoring the dynamics of bottom and slope sedimentation have been established. Based on the results of the chemical analysis of the lake waters, a conclusion was made on the prospects of its use for tourist and recreational purposes.

Keywords: Biryuzovoe Karyernoe lake, Sakhalin, hydroacoustic research, morphometry, bathymetric map, geochemistry of waters, sedimentation

1. Introduction

Biryuzovye Karyernye lakes are a group of unique anthropogenic reservoirs located in the vicinity of the Novikovo village (Korsakovsky district, Sakhalin region) (figure 1).
Figure 1. Geographic location of the research object. Some of the largest Karyernye lakes are marked with numbers: 1 – Biryuzovoe, 2 – Utinoe, 3 – Zelenoe.

These lakes are 6 large and 14 small reservoirs, which were formed after the flooding of open pits, where industrial production of germaniferous coals was carried out from the 1960s to the early 2000s. It should be noted that, from a theoretical point of view, a more accurate name for these water bodies is not lakes, but watered quarries, however, on various websites, in documents and in media publications [1, 2] they are called lakes, so we consider it quite acceptable to name and designate them using both versions. Today, Biryuzovye Karyernye lakes are one of the most visited water bodies in the south of Sakhalin [3] due to the uniqueness of their morphology and specific water color (figure 2), associated with the content of dissolved sulfates. Despite the popularity of these water bodies, data on the morphology of the basins and modern processes occurring in their water area are not available in the open press. Such gaps in the cadastre of water bodies cause the existing and very urgent problem of assessing water resources in the Far East as one of the least developed, and at the same time, the most promising regions for the development of the country. In addition, the recording and updating of information on the state of lake basins and the rate of sedimentation allow solving fundamental issues of lithogenesis and quantifying vertical movements in sedimentation basins. The lack of data in the scientific literature on the chemistry of waters of certain objects also complicates their development. In this regard, a group of specialists from the IMGG FEB RAS conducted a hydroacoustic study of the basin of the most visited and deepest lake, called the Biryuzovoe Karyernoe lake, from September 16 to 17, 2021, and took samples of its waters. The objectives of the study aims to obtain a high-precision digital bathymetric scheme of the lake and its subsequent analysis to identify promising areas for monitoring sedimentation processes, assess the chemistry of waters.

Figure 2. Biryuzovoe Karyernoe lake. Echo-sounding survey. Photo by R.V. Zharkov, 2021.

2. Materials and methods
A hydroacoustic survey of the basin of Lake Biryuzovoe Karyernoe was carried out in mid-July 2021. The work was carried out using a proven methodology [4–6] using a Lowrance LMS-527c DF iGPS echo-sounder with synchronous satellite referencing of profiles; the echo-sounder emitter frequency was 200 kHz, the shooting step was 1 m. The equipment was installed on a light motor boat CatFish 240. Data processing was performed using software packages Lowrance Sonar Viewer 2.1.2 (echo-
sounder data export with georeference SR-ORG Projection 8230 – Lowrance Mercator), QGIS v. 3.20.3 (data rebinding in WGS 84, measurement of surface morphometric characteristics of the lake) and Surfer v. 13.0 (building of a bathymetric scheme, calculation of the morphometric characteristics of the lake basin). The calculation of the morphometric characteristics of the lake was carried out according to generally accepted methods [7–10]. Chemical analysis of water was carried out according to standard methods in a testing laboratory center Federal Budgetary Institution of Health Care «Center of Hygiene and Epidemiology in the Sakhalin Region» (Yuzhno-Sakhalinsk, Russia). In a water sample, odor (at a temperature of 20 °C and 60 °C), pH, hydrogen sulfide, silicon, sulfates, chlorides, hydrocarbonates, sodium, potassium, calcium, magnesium, and total mineralization were determined.

3. Results and discussion

Based on the results of the echo-sounding survey, 12 profiles of various lengths were made. The total number of measurement points that were obtained during the survey was about 7 thousand. Based on these data, an accurate bathymetric scheme with an interactive component was compiled; it is possible to change the detail over a wide range by setting the step of isobaths from detailed (from 1 to 5 m) to generalized (from 10 to 20 and more m). In addition to the bathymetric scheme, a 3D modeling of the lake basin was carried out on the basis of these data, also with an interactive component for visualizing the survey results (figure 3).

Figure 3. Bathymetric map of Biryuzovoe Karyernoe lake, isobaths are given at 20 m intervals. The dotted line in the diagram marks the location of the AB and CD profiles, white asterisks mark promising sites for sampling bottom sediments.

Calculations based on data of GIS and the echo-sounder navigator have shown that today the Biryuzovoe Karyernoe lake has the following morphometric characteristics: mirror area is 0.21 km², abs. mirror height above sea level is 45 m, the coastline tortuosity coefficient is 1.34, the maximum length is 0.78 km, the maximum width is 0.4 km, the volume is 8.6 $10^3$ km³, the maximum depth is 106 m, the length of the coastline is 2.17 km. Some additional parameters were also calculated: catchment area – 0.9 km², area index – 0.23, specific catchment area – 4.29, average width – 0.269 km, average depth – 41 m, capacity coefficient – 0.39, openness index – 0.005.

The data obtained in the course of interpretation, calculations and modeling allow us to draw a number of conclusions:

– today, the Biryuzovoe Karyernoe lake with a maximum elevation of 106 m is the deepest reservoir on Sakhalin (formally, while being a watered quarry), traditionally, lake Tunaicha was the leader here with a maximum depth of about 42 m;
– analysis of bathymetric profiles (figure 4) has shown that the serpentine observed along the perimeter of the above-water part of the basin is clearly traced with depth, down to the bottom
of the basin. In many places in the western part of the lake, the serpentine ledge is practically absent (at a depth of about 60 m). It is possible that the walls of the basin are more susceptible to erosion here;

- on the received echograms there are no significant, clearly distinguishable thicknesses of bottom sediments, which corresponds to the age of the basin. For a relatively short period of time (15 years) with low rates of erosion, sedimentation processes proceed rather slowly;

- analysis of profiles and bathymetric maps made it possible to identify a number of areas of prospective monitoring of the thickness and composition of bottom sediments. In the future, it is possible to use these areas for monitoring the rates and specifics of sedimentation;

- the calculated morphometric parameters (area index, specific catchment area, capacity coefficient and openness index) and the morphological appearance of the basin of Biryuzovoe Karyernoe lake suggest a significant similarity with volcanogenic crater lakes in the Kuril-Kamchatka region, such as Lake Kipyashcheye (Kunashir Island), Glazok (Ketoy Island), Verkhnee (Kamchatka Peninsula), Stubel (Kamchatka Peninsula).

![Bathymetric profiles of the Biryuzovoe Karyernoe lake AB and CD](image)

**Figure 4.** Bathymetric profiles of the Biryuzovoe Karyernoe lake AB and CD, the position of the profiles is given in figure 3. UL – underwater ledge.

In addition to hydroacoustic surveys, a physicochemical analysis of the lake water for the content of the main macronutrients was also carried out. Laboratory studies have shown that water is odorless at temperatures of 20 °C and 60 °C, refers to slightly alkaline (pH 7.8), fresh (mineralization 0.22 g/l), hydrocarbonate-sulphate sodium-calcium. The content of iron, hydrogen sulfide and silicon in the water is insignificant. A similar, but more intense color is found in Lake Biryuzovoe in the caldera of Zavaritsky volcano (Shiahkhotan Island), the waters of which are mineralized (up to 4 g/l) and are classified as chloride-sulfate sodium in composition [11].

4. **Conclusion**

Biryuzovoe Karyernoe lake today can be considered the deepest of the surveyed water bodies of Sakhalin. A high-precision bathymetric scheme with georeferencing has been compiled for it, a number of morphometric calculations have been performed, they are necessary to describe the morphology of the bottom of the basin of the reservoir. To assess the rates of sedimentation processes within the lake bottom, several promising areas for long-term monitoring were noted.
At present, it can be argued that no significant bottom sediments have been found according to hydroacoustic studies. Chemical analysis has shown that the lake waters are weakly alkaline, fresh, hydrocarbonate-sulphate sodium-calcium. The water is suitable for swimming, and its turquoise color, especially bright in sunny weather, is due to the sulphate content [11]. Considering the great interest of residents and guests of Sakhalin Island to the Biryuzovoe Karyernoe lake, recreational and ecological tourism can be developed here.

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