The Structure of the Volcanic Lake in the Urbich Caldera (Iturup Island, the Kuril Islands)

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Abstract. The article presents and analyzes the original data on the morphological features and the current state of a previously unexplored volcanic lake Krasivoe located in the Urbich caldera (the Southern Kuriles). The bathymetric scheme and echolocation profiles obtained with using of modern technique of digital bathymetric survey with satellite reference along the profile are considered.

1. Introduction

Volcanic lakes of the world have been studied and described in detail in many works [1-13], some of these works provide comprehensive information on the genetic or chemical classification of lakes, others consider in detail the limnological features and important aspects of the functioning of lake ecosystems, as well as the morphology of water bodies. Springer has published a very capacious work "Volcanic Lakes" [14], which considers the issues of genetic and chemical classification of crater lakes, their relationship with the geological setting, volcanism and post-volcanic processes. In Russia, volcanic lakes are common in the Kamchatka Peninsula and in the Kuril Islands. The state and morphology of Kamchatka lakes is considered in works [15-19]. Some information about the Kuril lakes is contained in the works [20-23]. However, in general, until the 2000s, the crater lakes of the Kuriles was remained practically unexplored. Since 2005, Sakhalin volcanologists at the Institute of Marine Geology and Geophysics (IMGiG FEB RAS) have been working on the study of these unique and hard-to-reach objects using a modern high-precision echolocation survey technique with synchronous satellite referencing of profiles [24-25]. In total, they surveyed 10 volcanic reservoirs, while for a long period of time Krasivoe lake, located in the Urbich caldera, was overlooked in Iturup. In this regard, the tasks were to set the survey and profiling of Krasivoe lake with the subsequent interpretation of the data obtained.

2. Materials & methods

In 2014, a group of volcanologists from the IMGiG FEB RAS carried out comprehensive volcanological studies in the island Iturup, one of the objects of research was the Urbich caldera, which is the central structure of the volcanic complex Rocco. The relative age of the caldera is estimated as interglacial [26-27], the diameter along the ridge is about 6 km, and about 9 km along the base. According to topographic maps, the highest point of the caldera is Klinok mount with an absolute height of 745 m. The hard-to-reach and poorly studied Krasivoe lake (44° 37'N, 147° 12'E) is located in the caldera (Fig. 1). The relative height of the lake surface above sea level is 82 m, the catchment area is 38.3 km². By origin, it
belongs to the type of volcanic crater lakes, by the nature of water exchange, it is wastewater – there is a channel in the southeast connecting the Pacific Ocean with the lake the Urumpet river, about 3.5 km long. The age of the lake basin is presumably Late Pleistocene.

![Figure 1. Location of the Urbich caldera and Krasivoe lake.](image)

According to the available publications, it was established that the studies of Krasivoe lake were carried out by employees of SakhTINRO, SakhNIRO and Kamchatka ichthyologists from KamchatNIRO, who are engaged in the dynamics of salmon quantity [28]. They noted that the local salmon population remain the least studied among other species of Pacific salmon of the Sakhalin region; during these surveys, a detailed bathymetric survey of the reservoir was not carried out, in connection with this we set the task of mapping and morphological description of the lake reservoir.

The study of the lake was carried out according to the previously approved technique [24-25] using a Lowrance 527 CDF-iGPS echo sounder installed on an inflatable boat. The profiles were recorded at a transmitter frequency of 200 kHz with a measurement step of 0.5 m and with synchronous satellite referencing along the profile. In total, we obtained 10 profiles with a total length of 15 km; during their processing, a sample of coordinates and depths was carried out, which amounted to about 17000 measurements. On the basis of these data, using the Surfer and Sonar Viewer programs, a bathymetric scheme was built (Fig. 2) and digital echograms were described.
3. Discussion and conclusion

As a result of work on Krasivoe lake, for the first time, we obtained important information about the shape, size and specificity of the structure of the bottom of its basin:

1. Analysis of the converted bathymetric data and information from open geoinformation resources (Google Earth and GeoMapApp) made it possible to describe the morphology of the lake basin and calculate its main morphometric parameters. The maximum depth of the lake was 50 m, while the average depth is 25.8 m, the volume of water mass reaches 0.15 km³, the length of the coastline is 9.35 km, and the surface area is 5.8 km². Detailed characteristics of the lake are given in the table of morphometric parameters (table). The lake basin has a bowl-like shape without being complicated by explosive funnels or underwater domes, the abrasive coastline has a pronounced scarp about 2-3 m high. In the southern part of the basin, there are several bays 500-700 m long and a large bay 1350 m long at its northern end.

2. It is likely that at present there is no gas-hydrothermal activity within the Krasnoye Lake, since the presence of characteristic gas flares was not revealed on the echograms. This is confirmed by the fact that the lake is inhabited by the largest population of sockeye salmon in the southern Kuril Islands [28].

3. Based on the average sedimentation rate in the volcanic lakes of the South Kuril Islands of about 0.0009 m / year [29], taking into account the compaction of precipitation and wind drift, one can calculate the thickness of the Holocene sedimentary cover in the lake 0.0009 m / year × 12000 years = 10.8 m. Bottom sediments in the lake basin can be 70-75 m (0.0009 m / year × 80,000 years = 72 m), and the total thickness, taking into account the sediments of catastrophic explosive eruptions of the Lvinnaya Past caldera, is ~ 13000 and ~ 12,300 years ago. [30] - up to 80–90 m.

4. In some places of the lake, on the echo sounder profiles, inhomogeneities in the acoustic permeability of bottom soils were noted. Such a hydroacoustic anomaly may be due to the presence of effective reflectors at the bottom - massive fragments of volcanic rocks, compacted sediments or dikes.
Structural disturbances were also noted, complicating the relief of the sublittoral (possibly faults). Krasivoe lake is a unique object located in the caldera of an extinct volcano and naturally filled with atmospheric waters, which have formed a stable lake system in it. In the future, it is necessary to carry out its comprehensive paleolimnological study and conduct a comparative analysis with similar objects in the region and the world, this will allow us to determine its significant similarities and differences, as well as get a clear idea of the history of development.

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