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Present sedimentation in the volcanic lakes of the Kurile-Kamchatka region (Russia) as a basis for paleoreconstructions

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ABSTRACT. The results of modern processes observations of the sedimentation in the volcanic lakes of the region are summarized with the use of material from other regions of the world. The available data on the drained volcanic lakes deposits, Uzon-Geysernaya caldera as example, was analysed. The main sources of material (volcanic and post-volcanic activity, gravitational displacements on slopes, and erosion-denudation processes) and the mechanisms of its entry into volcanic lakes, as well as the features of the subsequent deposits transformation as a result of hydrothermal, seismic, and volcano-tectonic activity, are identified. The results of the studies carried out allow us to conclude that the volcanic lakes deposits are complexly constructed polyfacial complexes with alternating fine-grained lacustrine and lacustrine-swamp deposits with pyroclastic horizons and interlayers of untreated or poorly processed coarse clastic material coming as a result of volcano-tectonic activity, gravitational and erosion processes. The irregularity of horizons along strike is typical; and is characterized by the large-scale sediments deformation under the influence of seismic activity, growth of effusive and extrusive domes, phreatic explosions, etc. Hydrothermal activity contributes to the weathering and cementation of the lake sediments. Lava outpourings and the high-temperature pyroclastic flows provokes sintering of contacting horizons sediments.

Keywords: level fluctuations, volcanic activity, gravitational processes, pyroclastic deposits, gas hydrotherms

1. Introduction

The volcanic - crater and caldera - lakes of the Kuril-Kamchatka region have not been studied extensively. Due to their inaccessibility there were very few special studies of their sedimentation features (Kremenetskaya, 1977; Kraevaya et al., 1979; Egorova, 1993), in contrast to the coastal-marine (lagoon and deltaic) lakes of the region, which are considered in sufficient detail in the numerous works Far Eastern researchers led by A.V. Lozhkin and N.G. Razzhigaeva. Due to the specifics of the volcanic lakes functioning there is often a certain difficulty in carrying out paleoreconstructions and interpreting the mechanisms and conditions of sedimentation. The purpose of this work is to generalize and analyze the results of modern geological and geomorphological processes observations within the basins of predominantly caldera lakes in the Kurile-Kamchatka region, the nature of volcanic and post-volcanic activity and the sedimentation features, to determine the main sources of material entering the basins, its characteristics, the nature of distribution and diagenesis features.

2. Materials and methods

The modern geomorphological processes in the Golovnin (Kunashir Island), Ksudach, Kuril'skoe Lake, Uzon-Geysernaya (Kamchatka) calderas were studied by the author during the field observations in 2015-2021, also the interpretation of high-resolution images was done. The structural features of a number of lake's basins under the consideration were established by D.N. Kozlov earlier according to the detailed echolocation survey data (Kozlov, 2015; Kozlov et al., 2019; and others). The constructed bathymetric maps analysis made it possible to conclude that the caldera lakes basins in the region are often complicated by the volcanic structures, amongst which the extrusive and effusive domes and the explosive funnels of various sizes are distinguished (Kozlov et al., 2019). The sources of water and the dissolved mineral components in the lakes are not only atmospheric precipitation and surface runoff, but also the gas-hydrothermal vents, the activity of which depends on the degassing process of the nearest magma chamber. As a result, in many lakes, water has a high mineralization, and its temperature

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is increased compared to non-volcanic reservoirs. Traces of hydrothermal activity are recorded both on the lakes shores and in the deep parts of basins; often, gas hydrotherm outlets are directly related to the revealed underwater volcanic structures. An important distinguishing feature of many volcanic lakes is the periodic rapid changes in their main characteristics (shape, volume, temperature, water chemical composition etc.) over a wide range, which is due to the peculiarities of the nearby volcanic centers functioning (Kozlov and Lebedeva, 2022).

3. Results

The following sources and mechanisms of material supply to the lake basins have been established.

3.1. Volcanic activity is the main source of volcanic lakes deposits. First of all, these are various types of volcanic cones eruption nearby or inside the lakes. Lava outpourings (a) with the formation of lava flows, as well as the explosive eruptions (b), not only with the release of a large volume of pyroclastic (c), but also with the partial destruction of the volcano cone (d), stand out among them. Such phenomena leads to the active filling of calderas with pyroclastics, the large-block material inflow into the lakes, and sometimes to temporary blocking of the water outflow. Abundant ash falls and the formation of intracaldera pyroclastic flows (e) lead to the filling of lake basins with finer tuff material.

An important influence is exerted by the volcanic structures growth - effusive and extrusive cones (f) within lakes and in their immediate vicinity. This process occurs quite quickly: an average rate of an underwater cone growth in the lake Shtyubel (Ksudach caldera) ranged from 1 to 1.6 m/year (Kozlov and Lebedeva, 2022). In the lake Karymsky (Academy of Sciences caldera, Kamchatka), a tuff cone with a crater about 600 m in diameter and up to 60 m deep formed just in a few days - directly during the eruption in January 1996 (Muravyev et al., 1997).

During the grow of these volcanic structures, not only the lake bottom morphology changes: a single lake can break up into several ones, or acquire a specific shape (rings or horseshoes), occupying the lowest areas. At the same time, sedimentation conditions also change: young lacustrine deposits can be deformed or raise above the lake level, and the intracaldera river network is forced to restructure according to changes in the surface slopes, and the alluvial and proluvial accumulation zones also change accordingly (Lebedeva, 2017a; 2017b). Due to high temperatures, sintering of contacting lacustrine deposits can occur, as it is in the formation of lava and pyroclastic flows, as a result of which the deposits structure and mechanical properties change fundamentally. The extrusions growth in the adjacent territory may be accompanied by the formation of their marginal parts collapses, the entry of coarse clastic material into the lake, and even the blocking river outflow from it, as happened in the Kuril'skoe Lake caldera (Ponomareva et al., 2006).

3.2. Postvolcanic gas-hydrothermal activity. Gas-hydrothermal activity is often observed in the basins and within the volcanic lakes coastal zone, which persists even when volcanic activity subsides. The treatment with highly mineralized thermal waters leads to the material deposited in the lakes weathering, and in some cases to the lake sediments cementation. It is possible to form specific underwater accumulative forms - spiers and towers - directly at the gas hydrotherms outlets, and when the level of lakes fluctuates, subaerial accumulative hydrothermal forms - sinter terraces and geyserite cones - can also be flooded. The traces of hydrothermal explosions in the form of a specific breccia deposits can be found periodically.

3.3. Gravitational displacements on the basins slopes. Entry of the significant volumes of the clastic material into the lake baths is also facilitated by various scales gravitational displacements on the basins slopes. These include both debris avalanches as a result of the nearby volcanic cones destruction (Uzon-Geysernaya caldera), as well as small collapses and the landslides. Results of multi-temporal images analysis of the Mal. Semyachik volcano's crater (Kamchatka) showed that the total amount of the material that entered the lake Zelenoe located there from the slopes over 44 years amounted to 1.5 million m^3 (Svirid et al., 2013), or about 34 thousand m^3/year.

3.4. Erosion-denudation activity includes active removal of the pyroclastic material by rivers into the lakes from the calderas walls, as well as the lahars descends both along valleys and from the slopes. Thus, in the Ksudach caldera, there was one of the most intensive relief formation processes during 25 years of observations the growth of alluvial fans at the river mouths (Kharchenko et al., 2020).

4. Discussion and conclusions

In modern volcanic lakes, there is a rapid filling of their basins with pyroclastic material carried from the sides and carried out by intracaldera streams, as well as deposits of pyroclastic flows, lahars and debris avalanches, volcanic bombs and lava flows. Thus, volcanic lakes accumulate material of various sources, morphometric characteristics, and composition: from lava layers, boulders up to 5–7 m in diameter to poorly processed and sorted mudflow material, as well as pumice pebbles rounded during transportation by water flows, to large volumes of finely dispersed pyroclastic. As a result, lake sediments are complexly built polyfacial complexes with alternating thin cemented tuff with layers of poorly processed coarse clastic material coming as a result of volcanic and volcano-tectonic activity, gravitational and erosion processes. Lacustrine sediments are often deformed as a result of seismic activity, the effusive and extrusive domes growth, and phreatic explosions. Hydrothermal activity leads to sediment cementation. The underwater cones growth, lava outpourings and high-temperature pyroclastic flows provokes to contacting horizons sediments cementation.

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Conflict of interest

The author declares no conflicts of interest.

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