Short communication

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Cryptotephra of Lake Khorlakel (Northern Caucasus, Russia)

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ABSTRACT. A tephrochronological study of the core HOR-1 of bottom sediment from Lake Khorlakel, located 24 km northwest of the Elbrus summit, was carried out. The core was 253 cm length. Deposits are represented by interbedding of thin-layered loams and bio-mineral silt. Six intervals of increased content of cryptotephra from 37,000 to 111,000 shards g dry weight^{-1} were identified. For a prominent peak of cryptotephra concentration in 214-215 cm, which is hardly noticeable as a whitish layer in the core, a geochemical relationship has been established with the proximal tephra of the Elbrus volcano. The age of this peak is estimated at 5950-6250 cal. yr BP.

Keywords: tephra, tephrochronology, cryptotephra, Lake Khorlakel, volcanic ash

1. Introduction

Within the Greater Caucasus Range, active eruptive centers are located. They are represented by the grandiose edifices of the Elbrus (5642 m a.s.l) and Kazbek (5047 m a.s.l) volcanoes and a group of monogenic volcanoes of the Kely Highland. These centers were repeatedly active during the Late Pleistocene – Holocene, and that is why they can resume their eruptions and constitute a danger to the densely populated southern regions of Russia and adjacent countries. To develop a long-term forecast of volcanic activity in the region, it is necessary to reconstruct in detail the regime of volcanic activity over the past thousand years.

The existing data about Late Pleistocene-Holocene volcanic activity within the Greater Caucasus Range are based mainly on lavas' study (Lebedev et al., 2010; 2011; 2018). These studies identified the main stages in Elbrus, Kazbek, and the Kely Highland volcanic centers activities. According to these authors, the last phases of activity began on Elbrus $<$35,000 years ago, Kazbek $<$50,000 years ago, and on the Kely Highland $<$30,000 years ago. However, information about the products of recent explosive activity is exceptionally scarce (Bogatikov et al., 1998; Gazeev et al., 2011). Radiocarbon dates obtained in different sections from bulk samples of coals and paleosols allowed to estimate roughly the age of several Elbrus tephras (7200-7500, 4600-5500, and ~2000 years ago) and two lahars in the valley of the Baksan River (7200 and 5800-6000 years ago), which are possibly related to the Elbrus eruptions (Bogatikov et al., 1998). Holocene scorias and pumices are mentioned in the Kely Highland, but their age is unknown (Gazeev et al., 2011; Lebedev et al., 2011). Deciphering the detailed history of young explosive eruptions in the region is hampered by the poor preservation of tephra horizons in high mountains due to intense erosion.

To obtain a complete record of the Caucasian volcanoes eruptions, we undertook the study of the lake sedimentary archive. This work aims to search for tephra and cryptotephra horizons, i.e., sediment horizons enriched in ash material. In such studies, along with ashes from local volcanoes, ashes from very distant sources can also be identified (Davies, 2015). Since tephra fallout occurs almost instantly, its layer forms an isochrone, which allows to correlate remote sections directly. This correlation is based on the uniqueness of the chemical composition of volcanic ash for each eruption. Small lakes and peatlands represent the most complete and continuous paleo-archives of the Holocene in the Caucasus. Due to constant sedimentation and lack of erosion, they preserve a

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more comprehensive and detailed record of explosive volcanic eruptions than the soil-pyroclastic cover of volcano foothills.

So far, only a few studies of cryptotephra have been carried out on the territory of the European part of Russia, which made it possible to detect several Icelandic tephras in the north of the European part (Haflidason et al., 2019; Vakhrameeva et al., 2020; Wastegård et al., 2000). The studies of the Holocene cryptotephra in the North Caucasus have not been carried out early.

2. Materials and methods

Lake Khorlakel (N 43.493145, E 42.218746) is located in the mountains of the Karachay-Cherkessia on the slope of the Front Range in the interfluve of the Khudes and Khurzuk Rivers at an altitude of 2040 m a.s.l, and 24 km to the northwest from the western peak of the Elbrus volcano. The core from Lake Khorlakel is 2.5 m length, and was samled during the expedition of the Institute of Geography of the Russian Academy of Sciences in 2017. We ^{14}C dated 12 samples from this core. According to the data, these samples were formed during 1000-8000 cal. yr BP.

The search for cryptotephra horizons was carried out according to S.M. Davies (2015) and S.P.E. Blockley et al. (2005). Thus, continuous channel samples 10 cm long were taken from the core to detect cryptotephra. The material was dried, and its dry weight was determined. Next, dry samples were treated with 20% H_2O_2 to remove organic matter and washed in a 25 μm sieve. With the help of density separation, a light "rhyolite" fraction (2.3–2.5 g/cm^3) and a heavy "basalt" fraction (>2.5 g/cm^3) were separated by the heavy HPS-V liquid. A glass microscope slides in Canada balsam was made from the obtained sediment of the "rhyolite" fraction. Using a polarizing microscope with a magnification of 100-400x, identification was made among the particles of the light fraction of volcanic glass based on their specific properties: shape, structure, optical isotropy, relative refractive index, and color.

At the Shirshov Institute of Oceanology of RAS, a high-resolution core scan was also carried out using a Geotek scanner. As a result, additional lithological characteristics were obtained - magnetic susceptibility, color, and chemical composition.

For a sample from a depth of 213-223 cm, which has high volcanic glass content, a slide in the epoxy resin was made, and microprobe analysis of ash particles (EMPA) was carried out at the GEOMAR Institute (Kiel, Germany).

3. Results and discussion

The study of glass microscope slides with a "rhyolite" fraction showed that in the sediment, along with small volcanic glasses (30-50 μm), there are also large (up to 300 μm) pumiceous and composite particles (scorias), which, along with glass, include many microcrystals in their structure. The concentration of volcanic particles varies along the core from 75 shards g dry weight^{-1} to very high values – 111,000 shards g dry weight^{-1}. Concentration peaks fall within the intervals: 10-20 cm (> 37,000 shards g dry weight^{-1}, 1406-2259 cal. yr BP), 50-60 cm (> 37,000 shards g dry weight^{-1}, 2972-3498 cal. yr BP), 193-203 (> 111,000 shards g dry weight^{-1}, 5108-5854 cal. yr BP), 203-213 cm (>68,000 shards g dry weight^{-1}, 5375-6116 cal. yr BP), 213-223 cm (> 35,000 shards g dry weight^{-1}, 5923-6475 cal. yr BP).

According to the results of core scanning, an interval of 205-215 cm was revealed, which has increased magnetic susceptibility values. Furthermore, according to the photos obtained from the scanner, light layers are also distinguished at depths of 205-207 cm and 213-214 cm.

According to the calculation of cryptotephra, peak concentrations are observed in the intervals of 193-203 cm (5108-5854 cal. yr BP), 203-213 cm (5375-6116 cal. yr BP) and 213-223 cm (5923-6475 cal. yr BP). Moreover, the largest tephra particles (150-300 μm) predominate in the lower interval. Based on the data obtained, we assume that the interval of 213–214 cm with a high probability corresponds to the eruption. The overlying interval (193–213 cm), enriched in volcanic ash, probably formed as a result of secondary redeposition of tephra particles due to washout from the adjacent watershed.

Chemical analyzes of volcanic particles from slide 213-223 cm showed that they are represented by fragments of porous rocks, which contain high-silica glasses, similar in composition to the Holocene tephra of Elbrus. This tephra is a product of the crushing of a viscous lava dome.

4. Conclusions

The study of the bottom sediments of Lake Khorlakel revealed a high content of cryptotephra in the deposits. The interval 193-215 cm with very high content of cryptotephra stands out in particular. Therefore, we assume that the bottom of this interval (214-215 cm) corresponds to the largest eruption of the Elbrus volcano in the Holocene. According to a sediment growth model based on a series of radiocarbon dates, the age of this eruption is estimated at 5950-6250 cal. yr BP.

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Conflict of interest

The authors declare no conflict of interest.

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