Short communication

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Sedimentological records of catastrophic mass movements in the lake bottom-sediments of north-western Kola Peninsula and possible scenarios to explain the seismogenic trigger

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ABSTRACT. In this present article, we describe disturbances in the sedimentary records of lakes on the western flank of Lake Imandra (NE Fennoscandia, Kola Peninsula). The research framework comprises sedimentological and textural criteria for a visual description of sedimentary structures, borehole drilling data, chronological (radiocarbon dating) data, and ground-penetrating radar (GPR) data. Synchronicity specific features and fast spontaneous sediment accumulation in lakes, as well as traces of strong prehistoric and historical earthquakes and geomorphic setting in the studied area suggest that the observed mass movements in lake sediments are potentially generated by earthquake shaking.

Keywords: isolated reservoirs, paleolimnology, paleogeography, earthquake, Holocene, Kola region, Russia

1. Introduction

Lacustrine sediments are a great source of information concerning different environmental changes including the Holocene tectonic settings. Landslides, homogenites, turbidites, and mass movements that occur in lake bottom sediments may form in the result of climate changes, lake or sea level variations, slope overloading and etc. It is also not uncommon that they are generated during the earthquake shaking. These processes can be revealed not only in seismically active areas and subduction zones but also in regions of moderate or low seismicity (Chapron et al., 1999; Ojala et al., 2019). Disturbances in the primary stratigraphy of lake bottom sediments caused by extreme events (earthquakes, tsunami) of the Kola Peninsula were first discovered a few years ago (Nikolaeva et al., 2017; Tolstobrov et al., 2018). These disturbances were discovered in one water basin for the most occasions and in two water basins for a less common part of them. Therefore, the identification of disturbances was rather complicated as well as the bringing of disturbances into undeniable correlation with a seismic event.

In this article we provide new results of the studies sedimentary records of four lakes on the western flank of Lake Imandra (NE Fennoscandia, Kola Peninsula). In addition to the previous research (Nikolaeva et al., 2017) we studied new cores from 4 lakes where we found traces of catastrophic processes. The studies have focused on sedimentological characteristics of the sediments, geochronological data (^{14}C), paleogeographic reconstructions, and GPR surveys.

2. Materials and methods

The lake bottom sediments were studied using the Russian peat corer. Holes were drilled to parent rocks or moraine. Each core sample was of 1 m length and 54 mm in diameter, the samples were picked with an overlap of 5–10 cm. Visually recognizable core attributes (color, texture, inclusions and mechanical composition) were studied to compose a lithological description of core and mark its stratum boundaries. The lake elevation was determined using topographical maps of 1:25 000 scale. Radiocarbon dating of ten bulk organic sediment samples was processed in the Radiocarbon Laboratory of St. Petersburg State University using the conventional approach. Measurements and calculations of radiocarbon dates were provided according to the techniques described by Arslanov et al. (1993).

3. Results and discussion

Bottom sedimentary sequences from small lake basins at the altitudes of 128.7 to 136.4 m a.s.l. in the coastal area of Lake Babinskaja Imandra consist

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of the lower minerogenic unit (basal part) and the upper organogenic one. The basal part is represented by intercalation of sands and silt. The upper unit is represented by gyttja. Sand and silt deposits were formed in a periglacial environment, from the end of the Younger Dryas to the beginning of the Preboreal, under glacial degradation conditions. Gyttja are deposited in the Holocene.

A typical feature of the sediments is the occurrence of brecciated horizon (BL layers) in the gyttja unit. It consists of a mixture of different-shape and different-size pieces and fragments of black and brown ("variously colored") gyttja, silt, peat, sand, plant remains and wood fragments (4–5 cm) enclosed in sapropel matrix. The occurrence of brecciated horizon in the sections implies catastrophic changes in sediment deposition at an early period of quiescent sedimentation.

Radiocarbon dates obtained from the BL layers correspond to the Atlantic Period of the Holocene. A gyttja sample from non-damaged layer underlying the BL in Lake 1 (133.4 m a.s.l.) was dated 7350 ± 270 cal. yr BP, and a wood fragment from the upper part of the BL was dated 6450 ± 340 cal. yr BP. The age of the BL formation in Lake 4 (128.7 m a.s.l.) is ranged 6600 ± 150 – 6080 ± 160 cal. yr BP. The radiocarbon dates of lakes 1 and 4 are close which indicates the synchroneity of the BL formation, and the updated age of the event is determined approximately as 6400–6100 cal. yr BP.

Georadar sensing of the Lake 1 also showed sediment disturbance and dislocation. The 1.3–1.7 m vertical displacements of layers along the top of the sand and silt unit, as well as and sediment-slide areas in gyttja, are clearly defined on the obtained radarograms (Rodionov et al., 2018).

Synchronicity specific features and fast spontaneous sediment accumulation in lakes, as well as traces of strong past earthquakes and geomorphic setting in the studied area suggest that the observed deformations in lake sediments are potentially generated during earthquake shaking.

The studied lakes with BL layers are spatially distributed in a special way, i.e., they are located along the esker of the north-westward trending. We may suggest two conceptual models.

Model I. The formation of BL layers in the bottom sediments of the lakes could be associated with the catastrophic water breakthrough of the Lake 2 across the esker ridge. In accordance with the paleogeographical reconstructions (Korsakova et al., 2020) we may assume that Lake 2 occupied a bigger area ca. 6000–6500 years ago compare to the present. The seismic shock caused the breaching of esker that bounded the lake from the east and discharging of water from the lake. The lake sediments were carried with water currents downward the slope eroding the local environment. These "mud streams" moved from north to south along a narrow zone between the two esker ridges and deposited on the already accumulated non-damaged gyttja in the basins of lakes 1, 3, and 4. The elevation difference could be about 4–5 m judging by the altitudes of the esker and the lake itself and also by possible erosion.

Model II. Synchronous landslides. Off-fault coseismic deformation structures in lacustrine sediments comprise mass movements and small-scale landslides. Sub-aqueous mass failure takesplace at the lake sides and can involve different processes of sliding, slumping and flowing of near-shore lake sediments.

The earthquake, which presumably was a trigger for the formation of the landslides, was generated by the activation of ancient fault zone of the NE strike or by the activation of sublatitudinal faults bounded of Babinskaya Imandra depression.

Anyway, whatever the model might be, we have clearly established the sudden and instantaneous character of sediment formation indicating the catastrophic event most probably triggered by an earthquake. The simultaneous formation of anomalous sediments in several lakes and their lithology along with the Holocene tectonic activity of the Lake Imandra depression all substantiate the idea of a seismic trigger.

4. Conclusions

The studies allow us to enlarge our knowledge on seismically induced events and processes in the lake bottom sediments. The observations from the present study extend the paleoseismic catalogue by identifying new evidence of Mid-Holocene earthquake in northeastern Fennoscandia. They also provide basis for adjustment of seismic hazard assessments of the platforms that were long considered nonseismic and contribute to the identification of release mechanisms of a seismic shock.

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Conflict of interest

The authors declare no conflict of interest.

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