PALEOLIMNOLOGY OF THE LARGEST EUROPEAN LAKES – LADOGA AND ONEGA

Subetto D.A.[1,2], Belkina N.A.[1], Potakhim M.S., Rybalko A.E.[3,4], Strakhovenko V.D.[5], Zobkov M.B.,

[1]Northern Water Problems Institute, Karelian Research Center of the Russian Academy of Sciences, Alexander Nevsky 50, Petrozavodsk, 185030, Russia
[2]Herzen State Pedagogical University of Russia, St. Petersburg, Russia
[3]Institute of Earth Sciences of St. Petersburg State University, St.Petersburg, Russia
[4]Seismic Data Analysis Centre (SDAC) at Lomonosov Moscow State University, Moscow, Russia
[5]V.S. Sobolev Institute of Geology and Mineralogy of the Russian Academy of Sciences, Novosibirsk, Russia

The largest European lakes, Ladoga and Onega, have a long history of development. Lakes, in their modern form, began to form after the glacier's degradation of the last Valdai glaciation about 15000-14500 years ago. Morphometric, bathymetric, limnological characteristics of both lakes changed significantly over the course of 15000 years, due to changes in the physico-geographical characteristics of the drainage basins, climate, hydrological regime, hydrographic network. The main stages of lakes development are revealed and their interrelation with sedimentation conditions and corresponding genetic types of bottom sediments is shown.

The RF Security Council on 20 November, 2013, called for special attention to the study and recovery of Russia's three largest lakes: Baikal, Ladoga and Onega. Both Ladoga and Onega are Europe's largest freshwater lakes. Lake Ladoga is located close to St. Petersburg, NW Russia. The lake is 219 km long and 125 km wide, covering an area of 18,740 km^2 with the maximum water depth of 235 m, the average depth is 47 m, and the water volume of about 848 km^3. Lake Ladoga is a dimictic lake with vertical stratification in summer, when the water temperature rises up to 15-18°C in the epilimnion (the uppermost 15-20 m) while in the hypolimnion it does not exceed 4°C (Lake Ladoga Atlas, 2002). The ice-free period lasts ca. 120-130 days per year. Lake Ladoga is a soft-water low-mineralization lake with an ionic concentration ca. 60-65 $mg \cdot l^{-1}$. By 2010 the total phosphorus content in Ladoga water was ca. 11-13 $\mu \cdot l^{-1}$ assessing its present trophic state as oligo-mesotrophic (Ladoga, 2013). The catchment area of Lake Ladoga is about 283,000 km^2 and includes the basin of Ladoga itself (48,339 km^2), the watersheds of the Lake Onega-Svir' system (82,255 km^2), the Ilmen'-Volkhov - (82,232 km^2), and the Saimaa-Vuoksa - (69,838 km^2). The lake is fed by direct precipitation (11.6 km^3 yr^{-1}) and inflow from numerous rivers and streams (71,1 km^3 yr^{-1}), of which the largest are Svir' (34%), Vuoksa (27%), and Volkhov (23%) Rivers. The coefficient of water exchange is 0.088. Ladoga discharges via the Neva River into the Gulf of Finland (Rumyantsev and Drabkova, 2002).. Lake Onega is Europe's second largest lake (area: 9720 km^2; maximum depth: 120 m; mean depth: 30 m; volume: 295 km^3; catchment area: 53100 km^2; $\sum_{ions}$: 37 mg/l). It is a cold-water lake. Its water has low mineralization, most of the lake remaining oligotrophic. They are part of the River Neva watershed basin, the only source of water supply of St.Petersburg, the largest city in Northwest Russia, and the factor largely responsible for the water quality of the Gulf of Finland and the entire the Baltic Sea. The study of bottom sediments, conducted to reconstruct the evolution of water bodies and their ecosystems, is an essential aspect in the study of the current state of lakes.

The northern part of the Ladoga catchment, including Lake Onega' catchment, consists of Precambrian crystalline bedrocks of the Baltic Shield, while its southern part belongs to the Russian Plate consisting of Paleozoic sedimentary rocks.

First geological studies of the Lake Ladoga sediments started in 1906-1907, when a project for a water pipeline construction had stimulated some drilling activities in the area of Cape Osinovets (Erassi, 1910) and later in 1934–1935 the survey has been repeated. Based on the study results Krasnov and Reineke (1936) concluded that lake sediments consisted of interglacial Mikulino (Eemian) clays, moraines and varved glaciolacustrine clays, which are interbedded with postglacial sands.

Later, the numerous investigations of Lake Ladoga deposits (mostly gravity-type sediment cores up to 4 m) give the knowledge about the Late Glacial and the Holocene evolution of Lake Ladoga (e.g. Subetto, 2009 and references therein). Aquatic sedimentation in Lake Ladoga started as its basin has been deglaciated between 14.200 and 13.300 cal yr BP according to Saarnisto and Saarinen (2001), or even earlier, ca. 15.400 cal yr BP according to Bakhmutov et al. (1993). Following the deglaciation, Lake Ladoga became the eastern bay of the extensive periglacial basin, the Baltic Ice Lake (BIL) extended along the southeastern margin of the Scandinavian Ice Sheet. At that time glaciolacustrine sedimentation (varved clays) took place in the lake basin (Subetto et al., 1998). The clay deposition lasted for over 2000 years (Subetto, 2002). These glaciolacustrine sediments cover Lake Ladoga bottom nearly throughout, and their thickness estimated by seismoacoustic studies reaches 10-20 m (Subetto et al., 1990, 1998). The clays can be subdivided into three main sedimentary units: gray silty-clay with indistinct subhorizontal ribbon lamination with couplet thickness of 10-15 mm (the lowermost unit 1), overlain by typical grayish and brownish varved clays with 5-8 mm couplet thickness (unit 2), and gray microlaminated clays with 1 to 0.5 mm couplet thickness, characterized with a higher density (unit 3). The second unit is often missing, therefore unit 3 usually overlays unit 1 with erosive contact. The subsequent catastrophic short-term drainage of the BIL ca. 12.000 cal (10.300 ^{14}C) yr BP (Björck, 1994), resulted in the isolation of Lake Ladoga from the Baltic Sea basin. It was accompanied by intensive denudation and erosion of previously accumulated sediments in the southern Lake Ladoga basin recorded as a sandy intercalation at the interface of varved clay and overlying sediments or as an abrupt transition suggesting a hiatus in sedimentation. After the isolation, Lake Ladoga started to drained to the Baltic Sea basin via the network of channels in the Vuoksa lake-river system in the northern part of the Karelian Isthmus having its threshold at the area of Veshchevo (Heinjoki), presently located at 15.4 m a.s.l. (Subetto, 2009).

The history and evolution of Lake Onego since deglaciation and in the present time were revealed as a result of paleogeographic investigations, based on the study of sediment cores. Paleogeographic maps for individual time periods were drawn; the main hydrological characteristics of the lake at different stages of its development were calculated using ArcGis and Surfer. The basic morphometric characteristics of Lake Onego in its present state and its mirror for a number of historical periods have been identified (http://onegolake.ru).

Time-space variations in the sedimentogenesis and diagenesis of Lake Onega at all stages of its evolution from its basin deglaciation ca.15000 years ago to the present is reconstructed for the first time using a digital relief model. Long drill cores of bottom sediments from Lake Onega were collected, based on seismoacoustic profiling data to obtain more detailed objective information on the distribution of Holocene and Late Peistocene sediments. Palaeogeographical reconstructions of the Onego ice-dammed lake development ca 14500-125000 yrs BP were based on the GIS approach. The palaeo-water-level surfaces were interpolated using a point–kriging approach. 14500-14000 yrs BP: An ice-dammed lake occupied the southern part of the Lake Onega depression. The level of this lake was at 130-120 m a.s.l. and was controlled by a threshold of the water divide between the River Oshta and River Oyat', with discharge southwestward into the Oyat' basin. The surface area of the ice-dammed lake was 3500 km^2. 14000-13300 Yrs BP: When the ice melted away from the mouth of the River Svir, the lake level dropped to 85-80 m a.s.l. and runoff was directed into the Lake Ladoga - easternmost part of The Baltic Ice Lake at that time. 13300-12500 Yrs BP: As the glacier retreated from the Lake Onega depression, the ice-dammed lake was occupied it and reached the maximum sizes (the surface area was 33000 km^2). The new threshold in the northern part was opened and runoff was directed into the White Sea basin.

REFERENCES

1. Bakhmutov V.G. Late- and postglacial development history of Lehmalahti Bay. In: Davydova, N.N., Koshechkin, B.I., Eds. Evolyutsia okruzhaeshei sredy i sovremennyi status geosistem Ladozhskogo ozera (The evolution of natural environments and current state of the Lake Ladoga geosystem). St. Petersburg, Russian Geographical Society. – 1993. – P. 34–43. [In Russian].

2. Erassi N.I. Journal of the Geological survey of shoreline of Lake Ladoga to the south of the village Osterman to Cape Sosnovets in September–October 1905. Lake Ladoga as a source of water supply for St. Petersburg. St. Petersburg. – 1910. – P. 67. [in Russian].

3. Krasnov I.I. About gas-bearing capacity of the Leningrad Region Quaternary deposits. In: Golubyatnikov, V.D., Khlopin, V.G. Eds. Prirodnye Gazy. Sbornik 11, Glavnaya redaktsiya geologo-razvedochnoi i geodezicheskoi literatury, Leningrad-Moscow. – 1936. – P. 3–31. [In Russian].

4. Lake Ladoga. Atlas. In: V.A. Rumyantsev, G.V. Khvorov, G.N. Utin (eds.). St. Petersburg. – 2002. – P. 128 [In Russian].

5. Rumyantsev V.A. (eds.). Ladoga Lake: Past, Present, Future. Nauka, St. Petersburg. – 2002. – P. 327. [In Russian].

6. Saarnisto M. 2001. Deglaciation chronology of the Scandinavian Ice Sheet from the Lake Onega Basin to the Salpausselkä End Moraines. Global and Planetary Change 31. – P. 387–405.

7. Subetto D.A. The structure, characteristics and formation history of bottom sediments. In: Drabkova, V.G., Rumyantsev, V.A. (eds.). Lake Ladoga: Past, Present, Future. Nauka, St. Petersburg. – 2002. – P. 122–136. [In Russian].

8. Subetto D.A. Lake sediments: paleolimnological reconstructions. Publishing House of A. Herzen Russian State Pedagogical University, St. Petersburg. – 2009. – P. 339. [In Russian].

9. Subetto D. Contribution to the lithostratigraphy and history of Lake Ladoga. Palaeogeography, Palaeoclimatology, Palaeoecology 140. – 1998. – P. 113–119.

10. Subetto D.A. An overview of bottom sediments. Lake Ladoga. In: Kvasov D.D., Martinson G.G., Raukas A.V. (eds.). The History of Lakes Ladoga, Onega, Pskovsko-Chudskogo, Baikal and Khanka. Nauka, Leningrad. – 1990. – P. 35–42. [In Russian].

The study is financially supported by the Russian Science Foundation (#18-17-00176).

THE DATABASE PALAEOLAKE IN MODERN PALAEOGEOGRAPHICAL STUDIES

Syrykh L.[1,2], Subetto D.A. [2,3]

[1]Kazan (Volga region) Federal University, Kazan, Russia
[2]Northern Water Problems Institute, Karelian Research Centre of Russian Academy of Sciences, Petrozavodsk, Russia
[3]Herzen State Pedagogical University of Russia, Saint-Petersburg, Russia

The lake bottom sediments are often used for the palaeolimnological studies as an indicator of dynamics of lakes' physical, chemical and biological parameters and the extent of anthropogenic influence.

The database PalaeoLake (DB) was developed to systematize the data on the sediment sequences and on the genesis of lakes situated on the East European (Russian) Plain (Subetto and Syrykh, 2014; Subetto et al., 2017; Syrykh et al., 2014). DB created on base of existing data, information and maps contains the information on over 200 lakes studied using palaeolimnological methods. The metabase includes geographical (geographical coordinates, altitude, the region), morphometric (mean and maximum depths, area) and palaeolimnological (type and thickness of sediments, type of sediment sampling, dating methods, the sedimentation time interval, types palaeolimnological methods) data (Syrykh et al., 2014, Grekov et al., 2018).

The data were collected in MS Excel files that allows introducing it to different GIS-program easily. Additionally, structuring and mapping of information makes possible to perform spatial analysis of the territory on different periods of time and at the set requests. The sources of the PalaeoLake database consists of publications, references, fundamental monographs, international and national journals, proceedings of conferences, authors' own field data.

The analysis of the DB can show features of palaeoecological events on the studied territory. This research continues of the previous studies on lake zoning and on the reconstruction of the timing of