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REFERENCES

1. Zhilich S. Environmental dynamics of the Baraba forest-steppe (Siberia) over the last 8000 years and their impact on the types of economic life of the population // Quaternary Science Reviews. – 2017. – Vol. 163. – P. 152–161. 10.1016/j.quascirev.2017.03.022

2. Rudaya N. Quantitative reconstructions of mid-late Holocene climate and vegetation in the north-eastern Altai Mountains recorded in Lake Teletskoye // Global and Planetary Change. – 2106. – Vol. 141. – P. 12–24. – URL: http://dx.doi.org/10.1016/j.gloplacha.2016.04.002.

METHODS OF CONDUCTING COMPLEX STUDIES TO RESTORE THE PALEOLIMOLOGICAL CONDITIONS AND UNDERWATER LANDSCAPES OF LARGE LAKES BY THE EXAMPLE OF PETROZAVODSK BAY OF LAKE ONEGA

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Paleolimnological studies of lakes are one of the most effective ways of restoration paleogeographic conditions in the late Neoplestocene-Holocene At the present time, at the international level, a methodology has been developed for the study of small lakes, consisting in the drilling of the entire thickness of loose sediments and carrying out high-resolution biostratigraphic and lithological studies and conducting absolute dating. One of the favorable factors in this case is the presence of thick layers of organogenic silt. Researchers of large lakes meet great difficulties from to their size, depth, and the presence of permanent water cover. The deterrent is the position of these lakes in densely populated areas, as well as the fact that they serve as strategic reserves of drinking water for large areas. This imposes restrictions on the carrying out on them of production, including geological exploration work.

Despite its great importance of European lakes - Ladoga and Onega, is still not well understood, especially in the field of modern geophysical methods. Until now, the main weapon of researchers are easy sampling of sediments. In total (using samplers and heavy seismic profiling) are also in 90 years time, serious studies have been conducted on Lake Ladoga. On the Lake of Onega at the same time, Finnish researchers conducted a comprehensive study of bottom sediments using modern research methods. Palaeolimnological new stage of work is largely associated with the Institute of Water Problems of the North Karelian Research Center, which began systematic studies paleolimnological on both lakes. These works were conducted jointly with the MSU Science Park, as well as with the involvement of the staff of the Institute of Earth Sciences of SPbSU. Within this framework, the complex geological and geophysical studies in the Lake Onega for various tasks have been organized, including palaeolimnological. Petrozavodsk Bay was chosen as an experimental polygon.

Complex of geophysical methods included: Very High Resolution Seismic (VHRS), Ultra High Resolution seismic (UHRS) sonar and echosounding. The task of this block of research was to

obtain information on the section of unconsolidated deposits, as well as on the presence of gases, manifestations of tectonic, etc. One of the important tasks of this stage was to obtain information for selecting sampling points. The total length of the profiles was about 80 km.

Geological sampling was carried out to verify seismoacoustic data, as well as obtaining material for further lithologic-stratigraphic studies. A gravity corer with a plastic liner with a diameter of 127 mm was used. Geological sampling was performed at 8 stations, the location of which was determined from seismoacoustic profiling data. At each of the points samples were taken for lithological, biostratigraphic studies. In the cores of all stations, X-ray texture analysis was carried out, and samples were taken for studying the physical and mechanical properties. In addition, gas geochemical studies were carried out at all stations.

As a result of the interpretation of seismoacoustic data, several reflecting boundaries and seismostratigraphic horizons between them were identified. The deepest reflecting boundary is associated with the roof of crystalline rocks. The next clear reflecting boundary was compared with the roof of glacial deposits. Between these horizons lies the thickness of the moraine formations of the Ostashkov glaciation. On seismograms, these deposits are usually characterized by a chaotic irregular record reflecting the scaly structure of the bottom till. The third reflecting boundary is developed locally and passes along the surface of the ridge in the central part of the test site. The thickness of the sediments composing the ridge is referred to us as fluvioglacial, and the ridge itself is interpreted as a esker. Another reflecting boundary is located on the contact between the distinctly layered and translucent strata with poorly developed undulating lamination. By analogy with the Ladoga Lake, we identify this boundary as a section between the Holocene marine and glacial-lake of Upper Pleistocene sediments. Upward along the cut, the lamination becomes more subtle and gradually passes into an unstructured thickness. In lake deposits one can sometimes observe a boundary separating the Lower Holocene and Middle-Upper-Holocene silts.

The second task, performed with the help of geophysical methods, is the detection of gas accumulations. In Petrozavodsk Bay large area gas accumulations are absent, but their distribution in the sediments is quite wide. They are determined on seismograms by the appearance of bubble accumulations or by the general weakening of the record with profiler. Often, you can see numerous points (“bright spots”), indicating the accumulation of gases, as well as the characteristic structure of the output of gas fluids from the sediments - pok-mark.

Geological methods have allowed clarify geophysical information. It concerned the choice of places for sampling, which made it possible to test the geological section , with the exception of glacial and water-glacial formations. A total lithostratigraphic section was constructed, based on cyclically repeated packet of warves. At the base limnoglacial series occur distinct warves, sometimes painted in pink or brownish colors. They pass up a section into thinlaminated soft clays. These clays are overlaped by the thickness of lakustrine silt.

Additional material on the formation of bottom sediments was obtained as a result of tomographic studies of the cores. At the base of series of the glacial-lacustrine deposits, texture features of landslides were revealed. In the strata of Holocene nepheloid sediments have been found authigenic sulfides of psammite dimension were detected. With the help of tomography was described in detail the contacts between the sedimentation packets, was revealed traces of a erosion. It was found that sometimes all thickness of Holocene silt was permeated with numerous pores oriented mainly in the subvertical direction. This is due to the infiltration of gas to the lake bottom. Inclusions of hydrotroilite were also established, as well as single white formations, which probably correspond to the half-decomposed carbonate detritus.

In addition to lithological characteristic and seismoacoustic data of bottom sediments palynological studies and radiocarbon dating were carried out. It was revealed sediments of ONG 2 core formed during the second part of Holocene and from interstadial Allerod of ONG 5 core. Radiocarbon dating is performed using conventional and AMS methods.

The study of physico-mechanical properties of bottom sediments made it possible for the first time to begin to systematize their the physical and mechanical properties in Petrozavodsk Bay.

The presented methodological complex for studying Quaternary deposits of large lakes in key areas in our opinion can serve as a kind of standard for paleoliminological research. It allows us to cover with great clarity the main features of the structure of the cover of unconsolidated deposits, dismember it to stratigraphic and genetic subdivisions, give their lithologic and biostratigraphic characteristic. Further development of the presented methodology is associated with the introduction of new research methods. In particular, the use of ocean bottom nodes in conjunction with the continuous seismo-acoustic profiling will allow to construct the depth-velocity model of the medium (Vp, Vs) from the data of reflected, refracted, surface and converted waves. Hence this will allow us to perform seismic migration, improve the reliability of data interpretation and to try predict the physical properties of rocks.

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USAGE OF NEW SEISMOACOUSTIC METHODS FOR PALEOLYMNOLOGICAL STUDY OF THE LADOGA AND ONEGA LAKES

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Regional paleolimnological reconstruction of lakes and restoration of paleogeographic evolution of regions on the basis of the received results are getting more and more widespread recently. Tracing the spatial position of stratigraphic - genetic complexes, assessment the thickness of deposits, revealing characteristic of bottom relief reflecting the gradual development of paleobasins are important factors in these studies. In the conditions of lake basins, this function is currently performed by geophysical, mainly seismoacoustic, methods. Similar studies in both the largest lakes of the North-West of Russia after 2000 were carried out only sporadically. They was stopped after 2005. A new stage of seismoacoustic research was launched in 2014 as part of a joint program of three organizations: the Institute of Earth Sciences of St.Petersburg State University, the Institute of Water Problems of the North of the Karelian Center of the RAS and of the Center for Marine Studies of the Moscow State University. A distinctive feature of these works was the use of a new generation of high-frequency seismoacoustic equipment, which allows for multi-channel profiling. This made it possible to carry out a more detailed subdivision of the upper part of the section and obtain new data on the structure of the supraglacial deposits, and also on the nature of the manifestation of modern geodynamic movements. In 2014, works were carried out on Lake Ladoga, in 2015 - on Ladoga and Onega lakes, and in 2016 -