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Paleolimnological changes in the composition of diatom complexes in the context of the Holocene Baltic Sea transgressions (Lake Zaychikhinskoye)

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ABSTRACT. The study examines the issues of changes in the level of the Baltic Sea over the past 10 thousand years. According to the data of domestic and foreign authors on time, there is no unambiguous data on the duration and level of littorina transgression, which is considered the largest during the Holocene period. By the research, with the financial support of the RFBR grant-graduate students No. 20-35-90089, studies of bottom sediments of lakes Goluboye, Bolshoye Molochnoye and Zaychikhinskoye are being carried out. The report presents the results of the diatom analysis of Lake Zaychikhinskoye. The main stages of the lake's development are determined, it is established that in the early Holocene its development was determined by the transgressive-regressive stages of the Baltic. At the initial stage, the reservoir was part of a deep oligotrophic Ancyclus lake. During the littorina transgression, the Baltic Sea level most likely did not rise to lake level in this area.

Keywords: diatom analysis, changes in the Baltic Sea level, littorina transgression, paleoreconstruction, Holocene

1. Introduction

The Karelian Isthmus, located at the junction of Lake Ladoga and the Baltic Sea, remains controversial in the issue of sea level change during the Holocene (Subetto et al., 1999). An important paleogeographic task of this territory is to establish the maximum level of littorina transgression, which occurred about 7,500 cal. l.n., as well as its duration and the number of such transgressions. The most detailed study of this issue will allow the method of studying the bottom sediments of lakes, since bottom sediments are one of the most important data sources capable of identifying local and regional natural and climatic changes (Kuznetsov et al., 2019).

The lakes of the Primorsky Lowland were flooded by littorina transgression 8 200 – 7 200 cal. BP. According to the bottom sediments of the Lakhtinsky swamp, 2 stages of transgression were identified, while no traces of transgression were detected in the Gluchoye Lake, which is located at the 9m mark, and in the Ozyornoye settlement. According to Lake Vysokinskoye, the highest coastline of the littorina Sea is marked at the level of 12-13m (Miettinen et al., 2007). There are also studies of the territory of the Luga Bay and the Narva Bay (Rosentau et al., 2013; Sandgren et al., 2004).

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2. Materials and methods

3 lakes on the Karelian Isthmus were chosen as the object of research: 2 in the north-western part and 1 in the south-western part. When choosing the objects of the study, was considered their geographical location and different heights above sea level were taken into account: Bolshoye Molochnoye 9m, Goluboye 11m and Zaychikhinskoye 12 m, which will allow more accurately determining the transgressive-regressive cycles of the Baltic Sea. In October 2017, field work was carried out on the lake. Blue, in July 2020, the study continued on the lakes Bolshoye Molochnoye and Zaychikhinskoye. Sampling was carried out from a raft, using a peat drill of different diameters (GOST 17.1.5.01-80, 1980) (Subetto, 2016). After removing the columns of bottom sediments, the cores were cleaned and packed for further transportation to the laboratory.

3. Results and discussion

Zone 1. At the base of the section, there is an alternation of sedimentation of greenish-brown interlayers of clay gitty and gitty clay. Diatoms during this period are characterized by an extremely low content of species, which indicates unfavorable

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habitat conditions for the development of diatoms. The presence of such species as *Aulacoseira islandica*, *Navicula scutelloides*, *Navicula jaernfeltii*, *Ellerbeckia arenaria*, *Cymbella sinuata* indicates the Early Holocene stage of development of the Baltic Sea – Ancylus Lake (Hedenström et al., 1999). A similar composition of diatom complexes was found in Lakes Goluboye and Bolshoye Molochnoye, located on the Karelian Isthmus north of Zaychikhinskoye at 27 km and 45 km, respectively. According to the data of the diatom analysis of Lake Goluboye, a stage of ancylus transgression was identified, which dates 10100-9700 cal. BP, after which the lake developed in isolation (Ludikova et al., 2020). In the sediments of the Nizhneosinovsky swamp, located 16 km east of Lake Goluboye, at 23 m, the age of ancylus deposits was about 9200 cal. BP (Subetto, 1999). The change of sedimentation from clay to gittyta indicates a change in natural conditions towards warming, however, based on diatoms, we can say that this period corresponds to the freshwater stage – Ancylus Lake. A small number of planktonic diatoms (10-25%) indicates a relatively small depth of the lake during this period.

Zone 2. The predominance of homogeneous gittyta in the lithological composition, as well as a significant increase in the content of diatoms and FDI (from 0.03 to 0.07) reflects the improvement of natural conditions in the direction of warming. Since the maximum percentage (up to 5%) of individual “ancylus species” (*Didimosphenia geminata*, *Ellerbeckia arenaria*, *Navicula scutelloides*, *Navicula jentzschii*) is observed in this zone, it can be argued that the ancylus period continues in this zone. Planktonic *Aulacoseira islandica* remains co-dominant in this zone (25-5%), along with an increase in epiphytes *Fragilaria pinnata* and *Fragilaria construense*. This fact can be explained by the relatively small depth of the lake, which made it possible for epiphytes to develop more actively after an increase in temperature. The proportion of halophilic diatoms increases due to such species as *Epithemia sorex*, *Epithemia turgida*, *Cyclotella radiosia*, *Fragilaria pinnata*. *Epithemia turgida* reaches 7% at a depth of 5.38 of the total content of diatoms, *Fragilaria pinnata* - 10% at 5.32m, but the proportion of *Epithemia sorex* and *Cyclotella radiosia* does not exceed 2% in the zone. The predominance of “ancylus species”, as well as the low content of halophiles according to N.N. Davydova (1985), suggests that the ancylus period is still continuing in this zone.

Zone 3. In the lithological composition there is a homogeneous dark olive gittyta, which is reflected in the composition of diatom communities. The complete reduction of the “ancylus species” indicates the isolation of the Zaychikhinskoye Lake from the Ancylus Lake. After that, the gradual increase in the share of *Aulacoseira ambigua* and *Aulacoseira granulata* to 77% and 42% in the zone, respectively, indicates an increase in the water level in the lake. Most likely, the waters of the Littorina Sea did not arrive during this period, since halophiles were reduced to the lowest values

throughout the section (0.018). According to data from Lake Goluboye, this period falls on 7,570 - 7,500 cal. BP and is distinguished by such species as *Epithemia sorex*, *Navicula tuscula*, *Mastogloia smithii*, *Navicula cari* (Ludikova et al., 2020). In Bolshoye Molochnoye Lake this period is characterized by the appearance of *Cyclotella radiosia*, *Epithemia sorex*, *Navicula cari*, *Fragilaria pinnata*, *Cyclotella schumannii*, however, the number of a single species is no more than 5% of the total number of species (Shatalova et al., 2021). Consequently, littorina transgression did not cause an increase in the water level in this lake. It can be estimated that at this time a channel opened between Zaychikhinskoye Lake and Pioneer Lake, which made it possible for a large amount of fresh water to flow from a lake located less than 1 km southwest of the studied one.

Zone 4. Above the section, the olive color of the gittyta is replaced by dark brown. Diatoms during this period are characterized by a monodominant *Aulacoseira ambigua* complex, the proportion of individual epiphyte species is also close to 0, which indicates the preservation of a high water level. *Cyclotella stelligera* began to develop in zone 4, reaching 6% of the total number of species in the upper boundary of the zone, being one of the leading species after the co-dominant *Aulacoseira granulata* (up to 20% by 499 cm) and *Aulacoseira subarctica* (up to 6% by 455 cm). Audra De Vault (2007) explains this feature in his study «Links Between Climate Change and the Abundance of *Cyclotella stelligera* in Alpine Lakes» by the ability of this species to develop well at high levels of UV- radiation and a reduction in precipitation. It can be assumed that *Cyclotella stelligera* attested the onset of a drier Subboreal period.

4. Conclusions

The results of the analysis of diatoms of Lake B. Molochnoye allowed reconstructing the dynamics of natural and climatic conditions in the Holocene in the northwestern part of the Karelian Isthmus.

At the beginning of the Holocene, the lake was part of a deep - water oligotrophic Ancylus lake. At the final stage of the Ancylus lake, an increase in the number of halophilic species was recorded, but their small total number and the predominance of «ancylus species» does not give grounds to assert the beginning of littorina transgression. This was followed by isolation from Ancylus Lake and an increase in the water level in Lake Zaychikhinskoye. But littorina transgression did not cause an increase in the water level in the lake, because during this period there were no halophilic diatoms at all.

Unlike the lakes Goluboye (11m) and Bolshoye Molochnoye (9m), where the level of littorina transgression was not much higher than the current height of the lake, lake Zaychikhinskoye, located at 12 m, was not at all affected by littorina waters (Ludikova et al., 2020).

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Conflict of interest

The authors declare that there is no conflict of interest.

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