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Short communication

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Geomorphological evidence of Lake Ladoga Holocene regressions after the Baltic Ice lake drainage (derived from sediment echosounder data)

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ABSTRACT. Lake Ladoga has been experiencing frequent water-level fluctuations during the Holocene. Plenty surveys about reconstructions of lake level were published during the last century. They focused on the onshore transgressive sediments and landforms, while a regression below present level was only an assumption. Here for the first time, we present indications of lake-level lowstands by means of sediment echosounder data collected within the "PLOT-project". Three types of landforms of coastal and terrestrial origin are detected in the basin. These are coastal bars, erosional terraces and buried erosional valleys. Three paleo-shorelines were determined at depths of 13, 21 and 40-42 m. The first two shorelines are identified by the presence of the coastal bars, while the level of maximum regression is obtained from erosional marks. Reported landforms are assumed to be formed in the Early Holocene following the Baltic Ice Lake drainage.

Keywords: Lake Ladoga, the Holocene, the Postglacial, water-level fluctuations, paleo-shorelines, lacustrine geomorphology

1. Introduction

It was assumed, that lacustrine sedimentation in Lake Ladoga began formed following the Baltic Ice lake (BIL) drainage during the Late Pleistocene-Holocene transition (Gromig et al., 2019). It is considered that the basin was isolated and experienced a major regression after this event. Afterwards, it occurred several Holocene transgressive-regressive phases detected in onshore (Kvasov et al., 1990). However, there were no studies of regression marks in the basin. Abramova et al. (1967) proposed that paleo-shorelines of maximum regression might be detected at a depth of 55 m (50 m below sea level (b.s.l.)). Subetto et al. (1998) assumed the regression at the level of 45 m (40 m b.s.l.). The goal of this research is to identify landforms of lake lowstands and level at maximum regression.

2. Materials and methods

Hydroacoustic data obtained by Innomar sediment echosounder in the frame of the Russian-German project "PLOT" were used in this study. The IHS Kingdom Software was used for data proceeding. To calculate depth values two-way travel-time was converted using a velocity of 1600 m/s. Depth values are presented in meters below lake level (i.e. + 5 m a.s.l).

3. Results

Two seismic units were defined. According to Lebas et al. (2021), we correlate them to Late Pleistocene glacial lacustrine sediments, mostly varved clays (the lower unit) and Holocene lacustrine sediments presented by silts, muds and sands (the upper unit).

Three types of landforms were identified in the central and the southern parts of the lake. At depths of 13, 21 and 41 m some ridges similar with coastal bars are recognized (Fig. 1). Figure. 1A shows clear prograding reflectors and sediment tail at the distal part of the bar. Its altitude is 3 m, while length is 1120 m. Underneath the bar a lens-shaped body was identified. We assume that the sediments was presented by buried lagoon gyttia and peat. It seems that this bar was formed during a transgressive-regressive cycle.

At the southern flank of the Konevets ridge another bar was observed at the 40-41 m depth (Fig. 1B),

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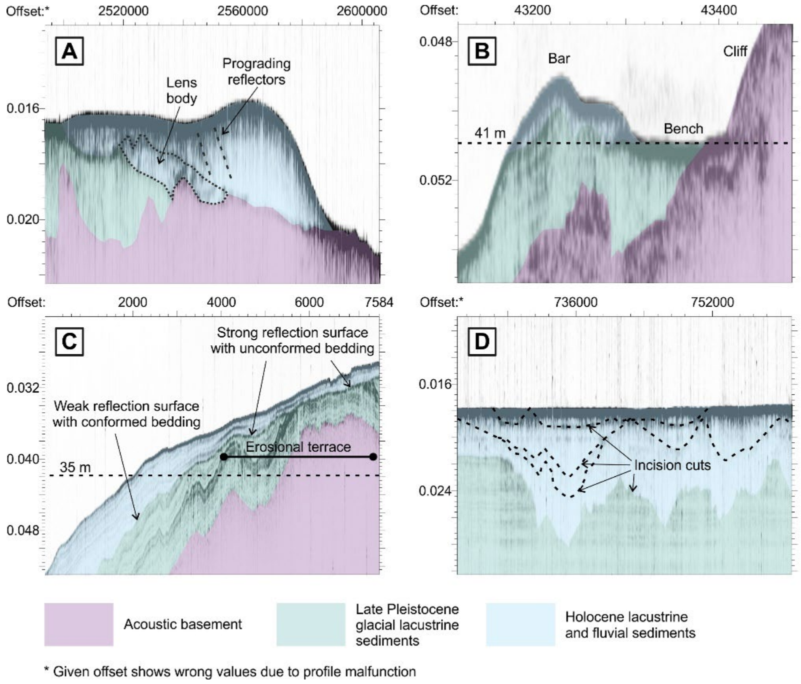

Fig.1. Examples of different bedforms derived by the echosounder data. The upper scale shows offset (m), the left scale is a two-way-time (s). A – a coastal bar at the southern part of the lake. B – an erosional platform, including cliff, bench and coastal bar. Southern slope of the Konevets ridge. C – an erosional terrace buried under the Holocene sediments. The southwestern slope of the Mantsinsaari ridge. D – an erosional valley with 4 incision cuts at the mouth of the Petrokrepost bay.

but with smaller proportions (1 m high and 76 m long). The erosional platform with bench and cliff are also witnessed at this section.

Erosional terraces were another type of landforms. These features were situated on the eroded surface of the Late Pleistocene deposits and was mostly buried by the Holocene sediments. They are characterized by strong reflection surface crossing layering of varved clays (Fig. 1C). Mostly, they are distributed in the SE littoral zone, on flanks of the Mantsinssari ridge and at the foothills of moraine ridges (central part of the lake).

Erosional valleys were identified at the mouth of the Petrokrepost bay (13-21 m deep) cutting the Late Pleistocene sequences (Fig. 1D). Their erosional basis reaches up to 30 m depth. There are three valleys with multi-thalweg, saw-shaped cross-profile. Four erosional surfaces were detected.

4. Discussion and conclusions

Different types of landforms reflecting subaerial conditions of formation were reported here. We assume that the presented features were formed during the Early Holocene. This is supported by the assumption that lake level after the Ancylus transgression was never lower than present (Sheetov, 2007). So, the only period of the Holocene when they could have formed is following the BIL drainage (the Yoldia stage at the Baltic sea).

Three coastal bars are identified at 13, 21 and 41 m below modern lake level. These are clear indicators of Lake Ladoga paleo-shorelines.

The maximum depth of erosional terraces varies widely. We divide these landforms into 3 groups relating to their maximum depth and spatial distribution: 34-35, 41-42 and 58-64 m. We suppose that 41-42 m should be accepted as the level of the deepest regression. The 34-35 m erosional marks are located at Mantsinsaari flanks (northern part of the lake), consequently they might be related to tectonic uplift. The 58-64 m group is marked at the foothills of the moraine ridges with steep slopes, thus gravity processes might have affected their formation.

The erosional valleys crossing the Late Pleistocene sediments were also identified in the central part of the basin by Lebas et al. (2021) and were interpreted as channels of glacial meltwater discharge. However, our valleys are located in the southern shallow water area. Considering that they erode the varved clays of the BIL, which stopped accumulating when the ice sheet located at the Salpausselkä II moraine. It is highly unlikely that meltwater effluxes reached this area. Thus, we believe that these valleys was fluvial origin. Several rivers flow into the Petrokrepost bay at present, so the valleys might connect with them. Moreover, basing on the assumption that the Paleo-Mga River entered into the lake before the Ladoga transgression (Ailio, 1915), we may assume that one of the valleys could represent the Paleo-Mga valley.

Four incisions were documented, suggesting that the lake experienced several fluctuations. Multiple thalwegs are evidence of stabile and continuous water supply with channel migration.

To sum up, the following conclusions are drawn:

1. Coastal bars, erosional terraces and erosional valleys were identified in the basin of Lake Ladoga;
2. Age of their formation correlates to the Late Pleistocene-Holocene transition, when the BIL drained out and Lake Ladoga became isolated;

3. Three shorelines were identified – 16, 21 and 41 m, where 41 m is associated with the maximum regression level;
4. The regression was not smooth and experienced several minor oscillations.

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Conflict of interest

The authors declare no conflict of interest.

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