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Estimation of sediment sources and budget at Lake Onego watershed after the last glaciation with GIS modeling and sediment geochemistry

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ABSTRACT. GIS modeling was performed to assess sediment budget of Lake Onego in the Late Glacial time. For this purpose, the procedure of river valley recognition was conducted using Digital Elevation Model and Topographic Position Index for the watershed of Lake Onego. The lake lost its connection with a glacier *ca.*12 ka BP. This time silty clays began to accumulate in the lake, thus this period was selected as a starting point for our calculation. The Lake Onego watershed was at least twice larger as compared with the modern one and extended more than 300 km southward out of the modern watershed border. The calculated sediment budget was varied from 13.4 to 49.4 km^3. Our estimates also demonstrate that the share of sediments eroded from the Russian Platform was on several times higher, than from the Baltic Crystalline Shield. This was also evidenced by vertical geochemical structure of Lake Onego sediments. A gradual increase was observed in the share of the Russian Platform clays sedimentary rocks from north to south direction achieving their full prevalence in sediments of the southern part of Lake Onego.

Keywords: Lake Onego, Late Glacial, watershed, sediments, GIS

1. Introduction

Lake Onego is the second largest lake in Europe with surface area approximately 10 000 km^2. The lake is located in the tectonic depression in suture zone of the Baltic Crystalline Shield and the Russian Platform. Mainly tectonic forces formed the Onego lake depression; however, Pleistocene Scandinavian glaciations significantly affected its structure. The lake depression was numerously enveloped by the ice streams during glaciations and fresh and sea waters in interglacial periods. In the Late Weichselian time, the lake depression was covered with the Onego ice stream of the White Sea ice stream complex located in the southeastern part of the Scandinavian Ice Sheet. The retreat of the ice stream in the Late Glacial time led to the formation of the proglacial lake and evolution of lake and its watershed during and after the ice sheet retreatment.

2. Materials and methods

GIS modeling was performed to assess sediment budget of Lake Onego in the Late Glacial time. For this purpose, the procedure of river valley recognition was conducted using the Lake Onego (LO) watershed Digital Elevation Model, DEM (Zobkov et al., 2019) and Topographic Position Index, TPI (Weiss, 2001). ArcGis 10.2.2 was applied for data procession. River valleys were recognized as on the actual lake watershed, as well as at paleo-watershed, identified based on the postglacial rebound model ICE-6G_C (VM5a) (Argusetal., 2014) and DEM of the territory (Zobkov et al., 2018). As we were engaged in assessment of areas of loose deposit (glacial, lacustrine-alluvial and glaciolacustrine) where formation of river valleys was undergone (Quaternary deposits…, 1993), areas of denudation topography were excluded from DEMs. On the first stage, river valleys were identified using TPI index. On the second stage they were removed from the topography raster and generated blank areas were interpolated using remained cells. As a result, raster of flat surface representing the topography in early glacial time was obtained. Further, DEM representing the erosion depth was obtained as the difference of contemporary and early glacial time flat topography DEMs using Map Algebra tool from Spatial Analyst package. On the last stage, volumes of sediment budget were calculated using the erosion DEM and 3D Analyst package for corresponding watersheds (contemporary and Late Glacial).

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Table 1. The erosion area, mean erosion depth and sediment budget at the Lake Onego' watershed in different time.

Period	Erosion area, km²	Sediment budget, km³	Mean erosion depth, m
Contemporary	1389	13.4	9.6
ca.12 ka BP	6653	49.4	7.4

3. Results and discussions

The lake lost his connection with glacier ca.12 ka BP (Zobkov et al., 2019). This time silty clays began to accumulate in lake; thus, this period was selected as a starting point for our calculation. The LO watershed was at least twice larger as compared with the modern one and extended more than 300 km southward out of the modern watershed border achieving the contemporary the Rybinskoye Reservoir (Fig. 1) (Zobkov et al., 2018). The comparison of the identified valleys with the previously measured in-field studies was conducted based on literature survey. In general, their cross sections were very close to each other for rather narrow valleys (up to several hundreds of meters). For wider valleys cross sections were not comparable. It is noteworthy, that the method applied was also unable to calculate the overall sediment pool discharged in to the lake from underwater part of the river valleys. The calculations were also unable to account the volume of material accumulated in lakes and other water bodies.

The calculated sediment budget accumulated at the present time in the Lake Onego was varied from 13.4 to 49.4 km^3 (Table 1). Unfortunately, the analysis applied here were unable to calculate the sediment budget more precisely, as the river cutting speed was unknown. However, it is normally to suppose that the maximum cutting was occurring at the earliest stage of watershed formation. The unstable soil cover and vegetation cover, the weak soil stabilization and changes in the erosion basis due to catastrophic water drops from the lake have contributed to its achievement. Thus, we able to suppose, that the major part of the material was eroded in the beginning of the watershed formation and the real sediment budget is close to the highest estimated value 49 km^3.

4. Conclusions

Our estimates also demonstrate that the share of sediments eroded from the Russian Platform is several times higher, than from the Baltic Crystalline Shield. This was also evident in vertical geochemical structure of Lake Onego sediments. A gradual increase was observed in the share of the Russian Platform clays sedimentary rocks from north to south direction achieving their full prevalence in sediments of the southern part of Lake Onego. The trace elements content in stratified layers of bottom sediments from Late Glacial varved clays of glacial lake and achieving lacustrine sediments varies insignificantly in the exception of the Maloe Onego and the Central Onego. In these areas the impact of land wastes of the Baltic Crystalline Shield is more evident in varved clays, that in southern part of the lake. This demonstrates the gradual decreasing of role of Russian Platform' sedimentary rocks in formation of lacustrine sediments of Lake Onego in whole, and in its northern part particularly. This also able to support our hypothesis about significant changes in Lake Onego watershed after the Last Glaciation.

Acknowledgments

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References

Argus D.F., Peltier W.R., Drummond R., Moore A.W. 2014. The Antarctica component of postglacial rebound model ICE-6G_C (VM5a) based upon GPS positioning, exposure age dating of ice thicknesses, and relative sea level histories. Geophysical Journal International 198(1): 537-563.

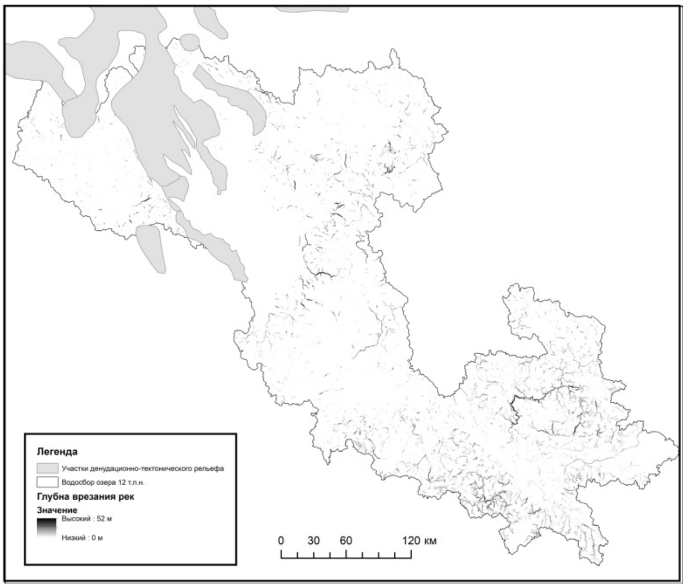

Fig.1. The Lake Onego' watershed, areas with denudation topography and erosion depth of hydrographic network ca.12 ka BP.

Quaternary deposits of Finland and northwestern part of Russian Federation and their resources. Scale 1:1 000 000. 1993. In: Niemela J., Ekman I., Lukashov A. (Eds.) Petrozavodsk: Geological survey of Finland and Russian Academy of Sciences. Institute of Geology.

Weiss A. 2001. Topographic position and landforms analysis. Poster presentation. In: ESRI user conference, San Diego, CA, pp. 200.

Zobkov M., Potakhin M., Subetto D., Tarasov A. 2019. Reconstructing Lake Onego evolution during and after the Late Weichselian glaciation with special reference to water volume and area estimations. Journal of Paleolimnology 62(1): 53-71.

Zobkov M.B., Subetto D.A., Potakhin M.S. 2018. The watershed reconstruction of the Onego paleolake with GIS. Lateglacial-Interglacial transition: glaciotectonic, seismoactivity, catastrophic hydrographic and landscape changes. Petrozavodsk, pp. 126-127.