

Short communication

ISSN 2658-3518

LIMNOLOGY
FRESHWATER
BIOLOGY

www.limnolwbiol.com

Lake sediments of the Kindo Peninsula and its surroundings (Karelian Coast of the White Sea) – Holocene stratigraphy and dynamics of organic accumulation

Kuznetsov D.D.^{1*}, Ludikova A.V.¹, Subetto D.A.², Kublitsky Yu.A.²,
Leontev P.A.², Potakhin M.S.^{3,4}¹ Institute of Limnology of the Russian Academy of Sciences – SPC RAS, Sevastjanova Str., 9, St.-Petersburg, 196105, Russia² Herzen State Pedagogical University of Russia, Moika Emb., 48, St.-Petersburg, 191186, Russia³ Karelian Research Center of the Russian Academy of Sciences, Pushkinskaya Str., 11, Petrozavodsk, 185910, Russia⁴ Petrozavodsk State University, Lenin Str., 33, Petrozavodsk, 185910, Russia

ABSTRACT. Sediment stratigraphy and dynamics of organic accumulation of eight small isolation basins at the Kindo Peninsula and its surroundings (Karelian Coast of the White Sea) were studied. The sediments structure and organic matter dynamics were found to depend on the age of the isolation that, in turn, depends on the lake's elevation. The thickest gyttja layer (up to 3 m) with loss-on-ignition values ca 60% formed in the lakes at the highest elevations. The thickness of marine-lacustrine transitional units varies from few cm to tens cm. The earlier isolation from the sea took place the thinner the transitional unit. In the lakes where isolation has not finished yet, the transitional sediments with LOI values ca 20-30% still form.

Keywords: lacustrine sediments, organic matter in lake sediments, loss-on-ignition, isolation basins

1. Introduction

The area of the Kindo Peninsula and its surroundings (the Karelian Coast of the White Sea), has turned into a testing ground for detailed natural science research, including studies of isolation basins, due to the White Sea Biological Station of the Moscow State University (e.g. Krasnova et al., 2016). The isolation basins are the lakes that once were sea bays and lost their connection to the sea in the past, or have been still isolating and thus experiencing an irregular influence of the sea. Studying the isolation basins provides important information both for the hydrochemistry and hydrobiology of the isolation process, and for paleogeographic reconstructions, primarily those devoted to the relative sea-level changes. Some results of the isolation basin studies at the Kindo Peninsula in the context of reconstruction of the Holocene shoreline displacement of the White Sea have been published elsewhere (Dreßler et al., 2009; Romanenko and Shilova, 2012). The dynamics of organic matter in the sediments provides important stratigraphic markers for studies of isolation basins. Studies of the organic matter content in the sediments of some recently isolated or currently isolating lakes at the Kindo Peninsula and the surrounding area were performed (Dreßler et al., 2009;

Vakhrameeva and Losyuk, 2020; 2021). However, there are still few studies of the organic matter dynamics in sediment sequences covering pre-isolation, isolation and post-isolation stages, while the others were focused on the uppermost part of the sequences.

The present study provides information on the stratigraphy and organic matter content in the sediments of 8 lakes at the Kindo Peninsula and the surrounding area. Retrieving the sediment cores from the central part of the lake basins, i.e. the integrated sedimentation point, provided discontinuous sediment successions.

2. Materials and methods

Sediment cores from 8 lakes were retrieved from the isolation basins located at different elevations. Some of the study lakes still receive the seawater during the springtides (Fig., Table). The coring was performed with a Russian peat corer from the central parts of the lakes from a floating platform (in autumn 2018) or from the ice surface (in spring 2019). Limnos sediment sampler was applied to collect the uppermost (up to 40 cm) sediments. In some lakes, a transect coring was carried out at different depths. The organic matter content in the sediments was studied using the loss-on-ignition

*Corresponding author.

E-mail address: dd.kuznetsov@mail.ru (D.D. Kuznetsov)

Received: June 19, 2022; Accepted: July 26, 2022;

Available online: September 02, 2022

© Author(s) 2022. This work is distributed under the Creative Commons Attribution-NonCommercial 4.0 International License.



Table. List and characteristics of the study lakes (the lakes' elevations are from Dreßler et al. (2009), Romanenko and Shilova (2012), Krasnova et al. (2016)).

Lake, coring site №	Elevation above sea level, m	Area, 10 ³ m ²	Depth at the sampling point, m	Sediment thickness, m	Gyttja thickness, m (LOI average value, %)
Verkhnee, 1	87	17.1	2.1	3.1	3.0 (61)
Vodoprovodnoe, 1	72	2.9	3.0	3.2	2.6 (64)
Krugloe, 1	27.5	5.4	2.0	1.8	1.7 (60)
Verkhnee Ershovskoe, 1	2.3	100.3	1.5	0.2	0.1
Nizhnee Ershovskoe, 2	1.6	79.9	2.8	1.1	0.9 (24)
Kislo-Sladkoe, 18-2	<1	16.7	4.1	1.6	0.6
Trekhtsvetnoe, 2	<1	35.2	3.4	2.3	0.3
Lagoon on Cape Zelenyj, 1	<1	19.1	5.9	2.8	0.5

(LOI) analysis following to the procedure adopted at the Institute of Limnology (500-550°C, 6 hours). One and 2-cm thick samples were discontinuously collected from corer.

3. Results

The lower parts of the sediment sections consist of sands/silts replaced by gyttja upwards. Depending on the lake's elevation above the sea level, two stratigraphic types are distinguished. In the lakes with no connection to the sea, there is a complete sediment sequence, with a thin transitional unit between the lower minerogenic sediments and the upper gyttja. The transitional sediments are sandy gyttja, occasionally laminated. In the lakes at the final stage of isolation, the sediment sequence is incomplete, and the transitional sediments represented by occasionally laminated gyttja, still form above the sands/silts. The lamination appears in sediments accumulated in deeper parts of a lake.

The dynamics of the organic matter content corresponds to the lithostratigraphy of the sediments. In the lower, mineral sediments, the LOI values range from 0.2 to 6.7%. The average LOI values in gyttja are about 60-65% ranging from 13 to 77%. In the lower part of gyttja in the lakes Vodoprovodnoe and Verkhnee, an episode of moderately high (about 50%) organic matter content is distinguished followed by the subsequent growth to the highest values.

In the currently isolating and recently isolated lakes, the organic matter content is not as high. For instance, in the upper part of the transitional gyttja in the lakes Kislo-Sladkoe and Trekhtsvetnoe the LOI values are about 20-30%. Besides, different trends in the organic matter dynamics were observed in the upper 10 cm of the sediments from Lake Kislo-Sladkoe collected from different depths. In the sediments retrieved from 3-m depth an upward increase in LOI was recorded, while in the core obtained from 4-m depth LOI values decrease upwards.

4. Discussion and conclusions

The maximum thickness of gyttja (3 m) was observed in Lake Verkhnee, located at the highest elevation, and consequently isolated from the sea earlier than the others. The earliest date obtained from

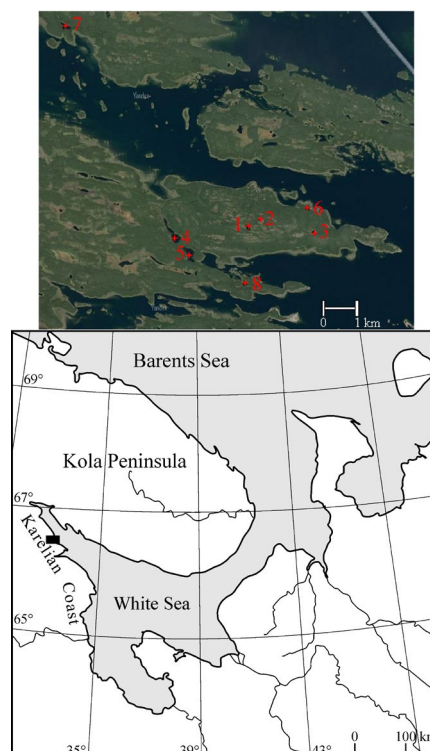


Fig. Location of the study sites (lakes are indicated by the numbers they are given in the table).

the bottommost part of the organic sediments from the peat bog surrounding the lake is about 9400 cal. yrs BP (Romanenko and Shilova, 2012), allowing an approximate estimation of the sedimentation rate in higher-elevated lakes after the isolation to 0.3 mm/year.

Our results enable identifying several characteristic features of the accumulation of organic matter in the sediments of the study lakes. Organic-rich sediments with an organic matter content of 60-70% formed in the lakes located at higher elevations (Verkhnee, Vodoprovodnoe and Krugloe). In the lakes that have recently lost the connection to the sea or are still isolating (Nizhnee Ershovskoe, Kislo-Sladkoe, Trekhtsvetnoe), the organic matter content in the transitional sediments is much less, about 20-30%. These values are consistent with the data previously obtained from the sediments corresponding to the transition from sea to lake, retrieved from the isolation

basins at the Solovky Archipelago (Ludikova et al., 2021; Kuznetsov et al., 2022).

The difference in the trends of organic matter dynamics recorded in the recent sediments of Lake Kislo-Sladkoe collected at different lake depths can be attributed to different chemical sedimentation environments in meromictic lakes that retain salt waters in their deepest parts. Another possible explanation could be in the diagenetic transformations unevenly occurring in the recently accumulated sediments.

The process of the isolation from the sea at the beginning of the Holocene differed from the recent one in terms of the organic matter accumulation. In Verkhnee and Vodoprovodnoe lakes, an explosive increase in organic matter was recorded in the transitional – post-isolation sediments while in Lake Krugloe this growth is smoother and can be traced in about 20 cm of sediments. In Trekhtsvetnoe and Kislo-Sladkoe lakes where the isolation process started in the second half of the 20th century, transitional organic-rich sediments still form, and their thickness can exceed 40 cm.

Acknowledgements

The research of Denis Kuznetsov and Anna Ludikova contributes to the State Research Program of the Institute of Limnology RAS – SPC RAS (no 0154-2019-0004); Maksim Potakhin to the State Research Program of NWPI KRC RAS (no 0218-2019-0050). The work of Dmitry Subetto, Yuriy Kublitsky, Petr Leontev was supported by Ministry of Education of the Russian Federation (FSZN-2020-0016). The authors are grateful to Elena Krasnova, Dmitry Voronov and Olga Shilova for their help during fieldwork and to students of the Herzen University for assistance.

Conflict of interest

The authors declare no conflict of interest.

References

Dreßler M., Schult M., Schubert M. et al. 2009. Basin elevation and salinity changes: late Holocene development of two freshwater lakes at the Karelian White Sea coast, northwest Russia as reflected in their sediments. *Hydrobiologia* 631: 247-266. DOI: [10.1007/s10750-009-9814-9](https://doi.org/10.1007/s10750-009-9814-9)

Krasnova E.D., Voronov D.A., Demidenko N.A. et al. 2016. For inventory of relict basins separated from the White Sea. In: *Kompleksnye issledovaniya Bab'ego morya, poluizolirovannoj belomorskoj laguny: geologiya, gidrologiya, biota – izmeneniya na fone transgressii beregov*. *Trudy Belomorskoj biostancii MGU [Proceedings of the Belomorskaya Biostation of Moscow State University]* 12: 211-241. (in Russian)

Kuznetsov D.D., Ludikova A.V., Subetto D.A. et al. 2022. Chrono- and lithostratigraphy of lake sediments of Anzer Island (Solovetsky Islands) in the context of the post-glacial history of the White Sea. *Izvestiya Rossiyskoy Akademii Nauk. Seriya Geograficheskaya [Proceedings of the Russian Academy of Sciences. Series Geographic]*. (in Russian) (in press)

Ludikova A.V., Subetto D.A., Kuznetsov D.D. et al. 2021. From a large basin to a small lake: Siliceous microfossils stratigraphy of the isolation basins on Big Solovetskiy Island (the White Sea, NW Russia) and its implication for paleoreconstructions. *Quaternary International*. DOI: [10.1016/j.quaint.2021.07.007](https://doi.org/10.1016/j.quaint.2021.07.007) (in press)

Romanenko F.A., Shilova O.S. 2012. The postglacial uplift of the Karelian Coast of the White Sea according to radiocarbon and diatom analyses of lacustrine-boggy deposits of Kindo Peninsula. *Doklady Earth Sciences* 442(2): 242-246. DOI: [10.1134/1028334X12020079](https://doi.org/10.1134/1028334X12020079)

Vakhrameeva E.A., Losyuk G.N. 2020. Distribution of the granulometric composition of bottom sediments in the core of Lake Kislo-Sladkoe. In: *Geografiya: razvitiye nauki i obrazovaniya. Tom 1 [Geography: development of science and education. Vol. 1]*. Saint-Petersburg: Herzen State Pedagogical University of Russia, pp. 277-280. (in Russian)

Vakhrameeva E.A., Losyuk G.N. 2021. Distribution of organic matter in the bottom sediments of the meromictic Lake Trekhtsvetnoe (Kandalaksh Bay of the White Sea). In: *Geografiya: razvitiye nauki i obrazovaniya. Tom 1 [Geography: development of science and education. Vol. 1]*. Saint-Petersburg: Herzen State Pedagogical University of Russia, pp. 290-293. (in Russian)