

Conditions of sedimentation in the Sarskoye Swamp (Yaroslavl region, Russia) in the Late Glacial and Holocene

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ABSTRACT. A comprehensive lithological analysis of bottom sediments from the central part of the Sarskaya depression was carried out. We determined that a shallow lake existed in the Sarskaya depression as least from 22500 to 12400 years ago. The bottom sediments potentially contain traces of global climate change - in particular, a presumable trace of the Bølling-Allerød interstadial has been established in sediments formed about 13500 years ago. There are signs of activation of erosion processes during the period from 13100 to 12400 years ago. Since the time the sediment condition stabilized and the water body began to swamp.

Keywords: Quaternary sedimentary archives, Holocene, Pleistocene, Sarskoy Swamp, East European Plane

1. Introduction

The Sarskoye Swamp is an oval basin with length 1.8 km and width 2.5 km and 35–40 m depth. It is located on the Borisoglebskaya Upland in the marginal zone of the Moscow glaciation and was not affected by the Last Valdai glaciation. The Sarskoye Swamp is located at the interfluvium, has a limited catchment and feeding only atmospheric precipitation. In this reason, its deposits represent a detailed sedimentary paleo-archive of the Late Pleistocene and Holocene and can serve as a reliable basis for paleogeographic reconstruction.

2. Materials and methods

In 2021 a reconnaissance survey of the Sarskoye Swamp was carried out. We drilled the slopes and the central part of Sarskaya depression with a Livingstone piston sampler. A core with a total length of 19.35 m was taken. The grain size analysis, LOI and magnetic susceptibility measurement were carried out. Radiocarbon dating of ten samples was also performed in the Laboratory of Radiocarbon Dating and Electron Microscopy of the Institute of Geography of the Russian Academy of Sciences. Using the available radiocarbon dates and correlation with the oxygen isotope curve of the NGRIP GICC05 glacial core, an age-depth model was created in the Rbacon program. In addition, the species composition of diatom associations was determined for

8 samples from an interval from 770 to 970 cm of the core.

3. Results

The drill profile made on the northern side of the basin confirmed the glacial origin of the surrounding hills. We also found out that low terrace-like surfaces (0.5-1.5 m above the level of the peat surface) are composed by moraine deposits.

The age of sediments from the lower part of the core, according to the results of radiocarbon dating, is 22349-22625 cal. years ago. Thus, the sampled core represents a detailed sedimentation archive of the center of the East European Plain for the last 22000 years.

It is possible to distinguish 5 stages of the development of the Sarskaya depression (age estimation inferred from the age-depth model):

1. 22500-14800 years ago (1935-900 cm of the core). The grain size composition is quite similar throughout the depth, silt dominates 75-80% from the total, the content of sand is about 5-7%, the content of clay is 20%, the content of organic matter and carbonates is about 3-5%.
2. 14800-14300 years ago (900-800 cm of the core). The content of silt is about 74 – 78%, the content of sand slightly increases to 8-10%, the content of clay decreased to 8-12%. The content of organic matter and carbonates does not change.

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3. 14300-13100 years ago (800-640 cm of the core). The content of silt varies from 62 to 78%, the content of sand decreases to a few percent, the content of clay increases to 20-35%. The content of carbonates is about 3-6%, the content of organic matter increases from 6% at the depth 800 cm to 20% at the depth 640 cm. It is noteworthy that there is a very high content of organic matter (40-50%) in the interval 700-750 cm (about 13500 years ago).
4. 13100-12400 years ago (640-550 cm of core). The content of silt varies from 60 to 85%, the content of sand varies from 5 to 20%, the content of clay varies from 8 to 15%. The content of organic matter is 20-30%, the content of carbonates greatly increases in comparison with the lower part of the core – from a few percent to 20-30%.
5. 12400-0 years ago (of 550-0 cm of the core). The deposits are represented by peat (the share of organic matter is almost 100%).

In the interval 950-900 cm of the core (15100-14800 years ago) according with the age-depth model) the diatom associations are represented by 21 species, the concentration of valves in sediment is about 20000 valves/cm³. Approximately 85-90% of all valves belong to the benthic oligotrophic and mesotrophic species *Cymbopleura inaequalis*. It prefers slightly alkaline habitats (Kulikovskiy et al., 2016). The next largest species belong to the genus of *Gyrosigma* (*G. attenuatum* and *G. spenceri* species), their content is only 4-5% of all valves.

In the interval 900-860 cm of the core (formed 14800-14500 years ago) content of *C. inaequalis* decreases, it varies from 20 to 70%. The content of other dominant species varies from 2-3 to 12%. These include diatoms that prefer alkaline mesotrophic and eutrophic habitat conditions (*Pseudostaurosira brevistriata*, *Punctastriata lancettula*) and diatoms that can live in water bodies of different trophic status: the alkaphile *Staurosira consrtruens* and the neutrophile *Staurosira venter*.

There are only few valves belong to the species *C. inaequalis*, *G. attenuatum*, *P. brevistriata*, *S. consrtruens* and *S. venter* were found from the sample from a depth of 850 cm. In the interval of 830-770 cm of the core (formed 14400-14100 years ago) 36 diatom species were identified. The dominant species are *P. brevistriata* (its content varies from 8 to 19%), *Punctastriata lancettula* (up to 35%), *Staurosira venter* (about 35%). The content of valves of *Cymbopleura inaequalis* significantly decreases compared to the interval of 950-860 cm – it is less than 1%.

In the interval 770-0 cm of the core (formed during the last 14000 years) no diatoms were found.

4. Discussion

The study of bottom sediments of Sarskoye Swamp allows us to assert that the lake existed in the Sarskaya depression at least from 22500 to 12500

years ago. In the period from 225000 to 14800 years ago sedimentation conditions were relatively stable. The composition of diatom associations indicates the existence of a shallow oligotrophic reservoir with low bioproductivity.

Granulometric composition of bottom sediments at the stage 14800-14300 years ago indicates a possible activation of erosion processes in the watershed. In the period from 1400 to 14100 years ago, according to the dominant species of diatoms, the lake became mesotrophic, its shallow depth preserved.

An increase of the content of carbonates at the stage 14300-13100 years ago may be associated with an increase in the bioproductivity of the lake. The organic matter peak observed in sediments around 13500 years ago may be associated with the the Bølling–Allerød interstadial. At this stage of the development of the lake, diatoms could have disappeared due to the low transparency of the water or the lack of oxygen for photosynthesis.

Content of sand in the bottom sediments formed 13100-12400 years ago indicates significant activation of erosion processes in the watershed. According to the age-depth model, approximately 12400 years ago the lake in Sarskaya basin begun to swamp and the peat accumulation started. It corresponds to the Pleistocene-Holocene boundary.

The absence of peat or lacustrine sediments on the terraced surfaces in the northern part of the basin indicates that the level of the lake in the past never exceeded the present level. That means that the present water level in the basin reaches its maximum in its entire history of development.

5. Conclusions

In the Late Pleistocene, at least from the time of the Last Glacial Maximum to 13100 years ago there was a shallow lake with stable sedimentation conditions in the Sarskaya basin. 13100-12400 years ago erosion processes on the sides of the lake basin became significantly more active. 12400 years ago the surface stabilized and the peat accumulation began. The bottom sediments also show a signal of the the Bølling–Allerød interstadial about 13500 years ago. This confirms the assumption that a global paleoclimatic signal was recorded in the deposits of the Sarskaye Swamp, and this makes their further more detailed study very promising.

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Conflict of interest

The authors declare no conflict of interest.

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