

Climate and lake development history in the south of West Siberia

LIMNOLOGY
FRESHWATER
BIOLOGY

www.limnolwbiol.com

Zhilich S.V.^{1,2*}, Krivonogov S.K.^{2,3}, Gavrilov D.A.⁴, Rudaya N.A.^{1,2}

¹ Institute of Archaeology & Ethnography Russian Academy of Sciences, Siberian Branch, Lavrentieva Ave., 17, Novosibirsk, 630090, Russia

² Novosibirsk State University, Pirogova str., 1, Novosibirsk, 630090, Russia

³ V.S. Sobolev Institute of Geology and Mineralogy SB RAS, Prospekt Ak. Koptyuga 3, Novosibirsk, 630090, Russia

⁴ Institute of Soil Science and Agrochemistry, Siberian Branch, Russian Academy of Sciences, Lavrentieva Ave., 8/2, Novosibirsk, 630099, Russia

ABSTRACT. There is a huge number of small lakes in south of West Siberia and such lakes are very useful local for climate and environmental reconstructions. The previously studied objects in the area are mostly peat-bogs and geologic sections; the lake history and natural interactions between paleoenvironmental and climate changes in the region are understudied. Here we present results of multiproxy investigation of three lakes located in different parts of the Baraba forest-steppe region along a 300km north-south transect: Bolshie Toroki, Chany (Yarkov subbasin), and Malye Chany. Vibrational drilling technology method was used to recover undisturbed columns of lake sediments and penetrate to non-lacustrine substrata. The obtained cores were investigated basically by sedimentological and palynological analyses (with the reconstruction of vegetational cover) and radiocarbon dating, additionally we used other paleontological (diatom, ostracod, chironomid analyses), geophysical, and biogeochemical methods to obtain information about environmental and climate changes, as well as lake level, biotic, ecosystem, and geochemical changes. This and our previous studies showed complicated picture of lake evolution histories and climate change in the south of West Siberia. According to our data most of investigated lakes (Chany, Malye Chany, Belaye, Minzelinskoye, Bolshie Toroki, and Kirek) are very young and started to form in the middle Holocene or later as marshy lowland with peaty sediments. Then they became deeper with mostly sapropel sediments.

Keywords: Lake development, south of West Siberia, sedimentological analysis, pollen analysis, Chany Lake.

1. Introduction

There is huge number of small lakes in Siberia and great portion of them locates in the south of West Siberia. The lakes accumulate different kinds of organic matter formed inside them and transported from their catchment, including pollen. Such lakes are promising for climate and environmental reconstructions because their sediments record mostly local signals of the climate and vegetation changes. In spite of great amount of climate and environmental history studies conducted at the south of West Siberia, a consistent global scheme of climate change in Holocene for that area is still not created. The previously studied objects are mostly peat-bogs and geologic sections; lakes are investigated in lesser degree and mostly in paleoclimatic context. The lake history and natural interactions between paleoenvironmental and climate changes in the region are discussed in a limited number

of papers (Krivonogov et al., 2012a, 2012b; Khazin et al., 2016); southern West Siberia is lesser studied than Europe and Siberian north. Our research team includes scientists from Novosibirsk and several other national and foreign institutions studying lakes in Siberia and Central Asia. Here we present results of multiproxy investigation of three lakes located in different parts of the Baraba forest-steppe region along a 300 km north-south transect: Bolshie Toroki, Chany (Yarkov subbasin) and Malye Chany. The Baraba occupies terrain between Ob and Irtysh rivers; its surface is poorly dissected, waterlogged, and heavily swamped. Local climate is continental with mean January temperatures ranged from -19 to -21 °C and mean July temperatures of 17.5-19 °C. Annual precipitation varies and decreases from 400 mm in the north to 250 mm in the south. The forest-steppe vegetation of Baraba consists of birch groves interspersed with swamps and meadow steppes.

*Corresponding author.

E-mail address: snezhy@yandex.ru (S.V. Zhilich)

2. Objects

The freshwater Lake Bolshie Toroki (55.3935°N, 80.6186°E) locates in the northern part of the Baraba forest-steppe on the border with southern taiga. Its area is about 9.57 km² and depth about 1 m. The lake water is weakly alkaline and slightly mineralized (845 mg/l). A 1.8 m long core obtained in 2012 reveals sapropelic bottom sediments.

The brackish water Yarkov subbasin (54.9624°N, 77.9595°E) is a part of the Chany Lake system, which is the largest West Siberian lake. It has an average depth of about 2 m and its maximum depth is 6 m. The lake consists of four subbasins; the Yarkov is the deepest of them, with an average depth of 3.1 m. Vegetation around the lake is presented by steppe meadows and meadow steppes with aspen-birch groves. Two-meters long clay sediment core was obtained in 2008.

Lake Malye Chany (54.55220° N, 77.99580°E) is a slightly brackish lake of the Chany Lake system (mineralization of 1.3 g/l) with the area of about 200 km², average depth ~1.4 m and maximum depth about 3 m. The Kargat and Chulym rivers flow into the lake. A 3.6-meter long core of the lake bottom sediments was retrieved in 2006 and opened sandy deltaic sediments in the lower half and sapropelic sediments above them. The lake locates near the southern border of the Baraba forest-steppe where it transforms into the Kulunda steppe overgrown with mixed grass and feather grass steppe communities.

3. Methods

The investigated cores were retrieved at the deepest points of the lakes to avoid wave stirring of the sediments using vibrational drilling technology by a Livingston-type piston corer. This drilling method allows us to recover undisturbed columns of lake sediments and penetrate to non-lacustrine substrata. The drilling was executing from an inflatable pontoon in summer and from ice in winter. The obtained cores were investigated basically by sedimentological and palynological analyses (with the reconstruction of vegetational cover) and radiocarbon dating, additionally we used other paleontological (diatom, ostracod, chironomid analyses), geophysical, and biogeochemical methods to obtain information about environmental and climate changes, as well as lake level, biotic, ecosystem, and geochemical changes. For Lake Bolshie Toroki we applied multivariate statistical analysis to reconstruct climate change (Zhilich et al., 2017). Totally 283 samples (2.5-5 ml standard volume, 2 cm sampling interval) were studied by pollen analysis (84 from Bolshie Toroki, 99 from Yarkov, and 100 from Malye Chany). The samples were chemically treated according to the technique for lake sediments. The prepared samples were studied under a microscope with counting at least 300 pollen grains per sample. For determining pollen species and genera, we used the reference collection of PaleoData Lab IAET SB RAS and atlases. The method of biomisation was used for the quantitative reconstruction of the dominant vegetation types (biomes) (Prentice et al., 1996). Radiocarbon

dates were obtained in different laboratories, totally 22 dates.

4. Histories of the lakes

Lake Bolshie Toroki emerged as small marshy lowland with stagnant water overgrown by aquatic vegetation, and it became a relatively deep oligotrophic lake gradually filling with sediments about 6.1 ka cal BP. After 1.5 ka cal BP, the lake shallowed and became filled with sediments and regrown with aquatic vegetation similarly to our days. The Yarkov subbasin started to form as a shallow swampy reservoir at about 9.9 ka cal BP. The conditions of sedimentation haven't been changing up to 3.8 ka cal BP, after that time the lake entered a more waterlogged phase of its development. During the shallow phase of the Yarkov 3.8-2.2 ka cal BP it was weakly saline, overgrown with aquatic macrophytes. After 2.2 ka cal BP, the level of the lake increased, and it became similar to the present day, but the hydrological regime of the Yarkov was not constant: we distinguish periods of flooding 1.4 and 0.8 ka cal BP and period of low water level about 1.0 ka cal BP. During the deep-water phase, the lake became saltier and the organic matter content increased (Zhilich et al., 2015). Since the Chulym River flows into the Malye Chany, according to sedimentological analysis (Zhilich et al., 2016) we assume formation of the lower layer of terrigenous material (290-190 cm, up to 3.8 ka cal BP) under low water level conditions, when the river delta advanced far into the lake and brought the sand deposited in the center of the lake basin. Younger lake sediments are sapropelic, and in this layer we distinguish two stages: shallow water phase 3.8-2.6 ka cal BP, when authigenic carbonates precipitated in large amount, and deep water phase 2.6-0 ka cal BP with mostly organic sedimentation. Salinization of the lake started at the end of the sand accumulation phase (after 3.7 ka cal BP), which may be due to a decrease in the fresh water supply: reduced precipitation and/or river runoff. The ratio of organic matter to the mineral authigenic fraction of the sediments indicate that the lake has been gradually desalinated and eutrophized after 3.3 ka cal BP, which implies a constant flow of the river. Palynological data also testify absence of higher aquatic plants in the lake up to 3.3 ka cal BP, i.e. before the beginning of the shallow phase. The ostracod analysis data show that water in the Maloe Chany Lake was brackish and warm up to 3.5 ka cal BP. Then, up to 2.4 ka cal BP, the water was colder and salinity decreased. At the beginning of the deepwater stage, the water level dropped, the water became warmer and its salinity varied. After 1.1 ka cal BP, the level rose again and the water became colder. After 0.2 ka cal BP, a slight warming of water occurred (Khazin et al., 2016; Zhilich et al., 2016).

5. Climate and vegetation changes

Based on the results from the three lakes, the following scheme of vegetation and climate change was arranged.

A coniferous forest consisting of Scotch pine, Siberian pine, and spruce spread over the Bolshie Toroki Lake area between 7.2 and 6.7 ka cal BP. That vegetation corresponds to the southern taiga subzone, and the climate at that time was colder with higher precipitation levels than in the modern forest-steppe zone. It became drier and warmer near the Bolshie Toroki after 6.7 ka cal BP. The border of the steppe advanced far to the north. Mean July temperatures of the warmest period were 2°C higher than in the present, and precipitation level was probably much lower.

The lake water level was low. More southern lakes (like Yarkov and Malye Chany) either did not exist or were very small during this period. Then forest-steppe spread in the Bolshie Toroki area, and the climate became more humid; however, the climate remained rather dry and warm in the southern part of our investigated region. Starting from 3.4 ka cal BP, birch forests spread around Lake Chany. To the south, the Malye Chany area was dominated by grass steppes, while desert communities declined. The share of taiga components increase and steppe communities decrease around all lakes. However, a short-term increase in precipitation, decrease in average winter temperatures, and shift of the southern boundary of the taiga to the south occurred during this period. After 1.5 ka cal BP, the borders of natural zones did not undergo significant changes. We register increase of the influence of steppe and desert components in the southern areas in the last 200 years. This may be due to increased anthropogenic pressure (forest cutting, pastures) or/and to reduced precipitation.

6. Discussion

This and our previous studies depict complicated lake evolution history in the south of West Siberia. Our data shows that most of our investigated lakes (Chany, Malye Chany, Belye, Minzelinskoye, Bolshie Toroki, and Kirek) are very young and started to form only in the middle Holocene 8-7 ka BP (Krivonogov & Zhilich, 2014), so we suggest this feature is typical for the region. Most of our investigated lakes have characteristic sedimentation pattern: peats and swamp sediments accumulated during their initial stages deeper water lake sediments, mostly sapropels, accumulated at the latter stages.

Krivonogov et al. (2018) showed that evolution of the Lake Chany system is closely related to the hydrological features of its feeding Chulym and Kargat Rivers. These rivers flow through a series of depressions that served as a chain of intermediate lakes, intercepting the river runoff. The sediments of the depressions include lacustrine layers overlain by swamp deposits. The lakes existed in the depressions between 6.3 and 2.0 ka cal BP and accumulated the river runoff and served as additional evaporators of water, because of which the river inflow into Lake Chany was absent or insignificant. The lakes disappeared when became full due to sedimentation and lowering of the river runoff thresholds. As a result, the rivers reached Lake Chany

and its level significantly increased only about 2 ka cal BP.

Lakes from the Kulunda steppe (Kuchuk and Maloye Yarovoye) located to the south of the Baraba forest-steppe show another pattern of origin and development. They appeared in the warm and humid phase of the late Pleistocene (about 14 ka BP). Lake Ebeyty located on the border with Kazakhstan appeared ca 11 ka cal BP (Zhilich et al., 2018).

Acknowledgment

The study was supported by the Russian Foundation for Basic Research (grants 19-29-05085, 19-05-00403).

References

- Khazin L.B., Khazina I.V., Krivonogov S.K. et al. 2016. Holocene climate changes in southern West Siberia based on ostracod analysis. *Russian Geology and Geophysics* 57(4): 574-585. <https://doi.org/10.1016/j.rgg.2015.05.012>
- Krivonogov S., Zhilich S. 2014. Small lakes of Siberia: ages and eventual correlations. In: *11 Present Earth Surface Processes and Long-term Environmental Changes in East Eurasia*. pp. 57-58.
- Krivonogov S.K., Gusev V.A., Parkhomchuk E.V. et al. 2018. Intermediate lakes of the Chulym and Kargat river valleys and their role in the evolution of the Lake Chany basin. *Russian Geology and Geophysics* 59(5): 541-555. <https://doi.org/10.1016/j.rgg.2018.04.007>
- Krivonogov S.K., Takahara H., Yamamuro M. et al. 2012a. Regional to local environmental changes in southern Western Siberia: evidence from biotic records of mid to late Holocene sediments of Lake Belye. *Palaeogeography, Palaeoclimatology, Palaeoecology* 331-332: 177-193. <https://doi.org/10.1016/j.palaeo.2011.09.013>
- Krivonogov S.K., Yamamuro M., Takahara H. et al. 2012b. An abrupt ecosystem change in Lake Belye, southern Western Siberia: palaeoclimate versus local environment. *Palaeogeography, Palaeoclimatology, Palaeoecology* 331-332: 194-206. <https://doi.org/10.1016/j.palaeo.2012.02.030>
- Prentice C., Guiot J., Huntley B. et al. 1996. Reconstructing biomes from palaeoecological data: a general method and its application to European pollen data at 0 and 6 ka. *Climate Dynamics* 12: 185-194.
- Zhilich S., Rudaya N., Krivonogov S. et al., 2017. Environmental dynamics of the Baraba forest-steppe (Siberia) over the last 8000 years and their impact on the types of economic life of the population. *Quaternary Science Reviews* 163: 152-161.
- Zhilich S.V., Krivonogov S.K., Parkhomchuk E.V. et al. 2018. Landscape reconstructions for the latest 28 thousand years based on pollen data from lake Ebeyty (Omsk region). *Problems of archaeology, ethnography and anthropology of Siberia* 24: 91-95.
- Zhilich S.V., Rudaya N.A., Krivonogov S.K. 2016. Late holocene climate and vegetation changes around lake Malye Chany. *Environmental Dynamics and Global Climate Change* 7(1): 68-75.
- Zhilich S.V., Rudaya N.A., Nazarova L.B. et al. 2015. Changes in Chany Lake and surrounding landscape in the second half of Holocene. *Problems of archaeology, ethnography and anthropology of Siberia* 21: 232-236.