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Quantitative assessment of carbon sequestration by sapropel deposits inferred from Lakes Peschanoe and Nizhnee (Western Siberia, Russia)

Malov G.I.*, Ovdina E.A., Strakhovenko V.D.

Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences (IGM SB RAS), 3 Akad. Koptyug Ave., Novosibirsk, 630090, Russia

ABSTRACT. Comprehensive studies of chemical and mineral composition of two lake systems on the territory of the Baraba lowland in the south of western Siberia was carried out. The reserves of sapropel and carbon were calculated for each lake. Sources supply of material and forms of carbon burial in the bottom sediments were identified.

Keywords: sapropel, small lakes, Baraba lowland, Novosibirsk region, carbon, carbon sequestration

1. Introduction

One of the most significant consequences of human impact on the natural environment is planetary changes in the optical properties of the atmosphere in the infrared region of the spectrum as a result of anthropogenic emission of greenhouse gases and their subsequent accumulation. This process leads to a change in the radiation balance of the Earth and global climate change (Izrael et al., 2002). Emissions from fossil fuels began before the industrial era, but they are the dominant source of anthropogenic emissions to the atmosphere (since 1920) at the moment (Le Quéré et al., 2013). The main component of emissions from fossil fuels is carbon dioxide (CO_2). It is the leading biogenic chemical agent involved in the carbon cycle (C), as well as one of the most important greenhouse gases (Climate change, 2014) Stabilizing elements of the Earth's climate system providing runoff and accumulation carbon is vegetation, mainly forest ecosystems of the planet (Pan et al., 2011; Le Quéré et al., 2013). For the territory of Russia, forest ecosystems are also objects of carbon accumulation (Shvidenko and Schepashchenko, 2014). However, for the territory of Western Siberia, especially for the southern and middle parts, lake and swamp ecosystems are carbon depositing ecosystems (Isaev et al., 1995).

A review study (Tranvik et al., 2009) showed that global storage of organic carbon in inland water sediments exceeds organic carbon sequestration at the ocean floor, making it necessary to account for carbon stocks in inland water sediments for regions with high swampiness and lakeness.

*Corresponding author.
E-mail address: malovgi@igm.nsc.ru (G.I. Malov)

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The objects of study in this work are two lakes (Peschanoe and Nizhnee) located in the forest-steppe landscape zone on the territory of the Baraba lowland in the south of Western Siberia. The studied lakes are located in 10 km from each other.

Both lake basins were formed in a suffusion-subsidence pattern in an interridge depression (Strakhovenko et al., 2019). In terms of area, the lakes are small ($S_{Peschanoe}$ = 126 ha, $S_{Nizhnee}$ = 64 ha), by geographical location they are intrazonal, according to thermal classification they belong to lakes with changing temperature stratification, they are drainless, shallow (the depth of Lake Peschanoe - 1.67 m, Lake Nizhnee - 1.25 m), freshwater and mesatrophic-eutrophic reservoirs. The waters of the lakes are bicarbonate-sodium in composition.

2. Material and methods

Fieldwork was carried out in the summer. In each lake, the morphometric and hydrological characteristics water, soils of catchment areas, bottom sediments (BS), and prevailing vegetation were studied. Sampling of BS was carried out with a cylindrical sampler with a vacuum lock designed by NPO Typhoon (diameter 82 mm, length 100 cm) from a catamaran at pre-marked sampling points (sampling network density 1 point per 12 ha). The design of the sampler allows sampling without disturbing the stratification of sediments. The core analysis of bottom sediments was carried out on site. The structure of the sapropel deposit was studied using an echo sounder and direct sounding (the density of the sounding network is 1 point per 1.6 ha). The total volume of sapropel is defined as the product of the average thickness of sapropel and the area of the lake. Sapropel reserves are defined as the product of the volume of sapropel and the yield of sapropel at 60% moisture.

Water sampling is carried out according to standard methods (GOST 31861-2012, 2014). In the fieldwork, the pH, Eh and mineralization were determined using the ANION-7000 device. Soil sampling was carried out with a metal ring (diameter 82 mm and height 50 mm). The binding of sampling and sounding points was carried out using a GARMIN GPSMAP 86S GPS navigator. Sample preparation consisted in drying to an air-dry state, followed by grinding.

The multi-element spectra of the averaged values of the studied elements normalized to the values of the concentrations of the Upper Continental Crust by (Wedepohl, 1995) with further comparison with the data of morphology and phase composition and mineral composition of BS.

Analytical studies were carried out at the Analytical Center for multi-elemental and isotope research SB RAS, Novosibirsk: AA, ICP-MS, X-ray diffraction analysis, gamma spectrometry, SEM studies, isotope studies and the elemental composition of the organic part of sapropel.

3. Results and discussion

To determine the sources of material for sapropels from Lakes Peschanoe and Nizhny, we compared the chemical composition of the substrate, soils, and sapropel. The chemical composition of the sapropel of Lake Nizhnee almost completely corresponds to the substrate and soils, but has lower values due to impoverishment by organic matter. Grains of quartz, feldspars, micas, and chlorite represent the mineral composition. Biochemogenic formation is represented by fromboidal segregations of pyrite indicating about reducing conditions. The composition of deposits along the section was slightly varied. In general, the deposit is homogeneous and belongs to the organic-mineral type and the siliceous class of sapropel. According to Ermolaeva et al. (2022), sapropel in Lake Nizhnee has a macrophyte-planktonic genesis. The rate of autochthonous organic matter is 34%, and more than half of the sediment flow comes from the watershed. The rate of accumulation of sapropels is on average 1.25 cm per year. The calculated reserves of sapropel are 700 thousand tons at water content in 60%. With an average ash content in 38.7% and 33.97% carbon content in the organic part. Thus, about 58 thousand tons of organic carbon were buried in the sapropel deposit. The calculation of dissolved carbon in water was also carried out - 0.05 thousand tons.

Unlike Lake Nizhnee, two classes of sapropel are identified in Lake Peschanoe – calcium and siliceous. In the lake, the formation of a sapropel deposit proceeded not only by detecting the inflow of terrigenous material, also an authigenic mineral formation of low-magnesian calcite played a significant role. The authigenic formation is associated with biochemogenic processes at the bottom of the lake, where the decomposition of organic matter will release abundant CO_2 in concentrations sufficient for the formation of carbonates (Ovdina et al., 2020). The silicon class of sapropel is widespread in the northern part of the lake and occupies the middle part of the deposit, wedging out closer to the center of the lake. The terrigenous part throughout the lake is the same and is represented by quartz, feldspars, mica, and chlorite. Biochemogenic authigenic formation is represented by low-magnesian calcite, aragonite and fromboidal pyrite. The biogenic component is represented by frustules of diatoms consisting of silica, as well as fragments of calcite shells. The calculated reserves are equal to 1412 thousand tons and 252 thousand tons of calcium and silicon classes of sapropel, respectively. Organic carbon reserves are estimated at 97 thousand tons and 7 thousand tons for each class. Since our study showed that the main forms of calcium in BS are calcite and aragonite, it became possible to estimate the reserves of carbon buried in the form of mineral matter. The calculated reserves are equal to 29.4 thousand tons, which is almost a third of all buried carbon in the lake. Dissolved carbon in water is estimated at 0.39 thousand tons.

4. Conclusions

The total carbon reserves for each lake are 58.005 and 133.79 thousand tons. The main source of carbon in BS is vegetation, which in turn captures carbon from the atmosphere in the process of photosynthesis. At the same time, there are lakes in which the decomposition of organic matter in the bottom of the lake creates favorable conditions for the biochemical authigenic formation of carbonates. As result, a significant amount of carbon can be accumulated.

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Conflict of interest

The authors declare no conflict of interest.

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