Genetic classification of lakes of above floodplain terraces of the valley of Oka river in the Nizhniy Novgorod region (Russia), based on its morphometric characteristics

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Abstract. The article provides a brief overview of the history of researching of the lakes of the Nizhny Novgorod region. The research area is located in the west of the Nizhny Novgorod region, and characterized by extremely poor knowledge of the main characteristics, origin and development of lakes. The exploration of morphometric and hydrological characteristics of lakes is solved by instrumental measurements in the field. Consideration of the genesis and evolution of lakes is a more complex issue, and its solution without taking into account the landscape structure of the territory and the specifics of the geological structure, geomorphological, botanical and other characteristics of the host landscape cannot be accepted as a complete logical work. In this article, along with the morphometric and hydrological features of the researched lakes, the modern physico-geographical characteristics of the researched territory are presented, based on the results of the analysis of thematic maps, remote sensing data, statistical and literary data and field researches. Bathygraphic schemes of seven largest and most typical lakes, located on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod Region, created, based on the results of field research, are presented. The main morphometric and hydrological characteristics of the researched lakes were calculated and analyzed using GIS. On the basis of morphometric characteristics and taking into account the features of the geological structure, topography, hydrographic network of the territory and vegetation features of the superaqual complex, judgments are made about the genesis of the considered lakes.

1. Introduction

The territory of the Nizhny Novgorod region up to the XXI century was characterized by a relatively weak limnological exploration, although the history of the research of lakes in the region goes back to the XVIII century – during the first scientific expeditions, conducted by P.-S. Pallas (1771), I. I. Lepekhin (1771) and I. G. Georgi (1775). In the XIX century the research was continued by a team of scientists under the leadership of V. V. Dokuchaev, in which the lakes were also researched. Based on the results of field research in 1886, was published the V.V. Dokuchaev’s work "Lakes of the Nizhny Novgorod Province", which contained the first genetic classification of lakes, developed by him, a description of each group of lakes and a spatial analysis of its placement. Later, various aspects of the structure and functioning of lake complexes were covered in the works of N. A. Varpakhovsky (1888, 1891) – fauna of lakes, B. P. Kashchenko (1904, 1905) – hydrobiology, A. F. Flerov (1904, 1907,
1908), B. A. Fedchenko, A. A. Elenkin (1909) – flora, S. D. Muraveysky (1913), V. I. Monakhov, A. S. Bulochkin (1926) – geological and geomorphological features. In the XXI century Nizhny Novgorod scientists F. M. Bakanina, A. D. Smirnova, E. V. Lukina, B. I. Fridman, N. G. Bayanov [1], T. V. Krivdina, V. V. Loginov, G. V. Shurganova, N. A. Starseva, A. E. Astashin [2], D. E. Gavrilko and other researchers researched the genesis, morphology of lake basins and the organic world of lakes of this territory. However, even at present, the process of researching of the lakes of the Nizhny Novgorod region is far from complete. Until now, the morphology of lake basins is extremely poorly researched – often there is not only no data on the relief, but even approximate data on the depths of lakes; there is practically no reliable data on the evolution of lakes and, accordingly, reasonable judgments about its genesis. Meanwhile, lakes are the most important component of the landscape, determining its hydrological regime, forming the habitat of plants and animals and being the environment. Thus, the establishment of morphometric and hydrological characteristics of lakes is an important aspect of not only landscape, but also geomorphological [3], hydrological [4-6], botanical [7], paleogeographic [8], zoological [9-10], ecological [11] researches.

In this paper we solve the problem of exploration of the genesis of lake basins, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region on the basis of its morphometric characteristics.

Aim: to explore the genesis of lake basins, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region, based on its morphometric characteristics.

Tasks:

- Make a brief physical and geographical description of the research area;
- On the basis of field researches, create bathymetric maps of lakes, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region;
- On the basis of morphometric characteristics of the researched lakes, make a reasoned hypotheses of its origin.

Object of research: lakes, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region.

Subject of research: morphometric characteristics and genesis of lake basins, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region.

Research hypothesis: the researched lakes have a diverse genesis, determined by landscape conditions.

The research area lies in the north-western part of the Pavlovsky district of the Nizhny Novgorod Region and is traditionally considered as the eastern tip of the Meshcherskaya lowland. In this paper we consider only the part of the Pavlovsky district, that lies within the terraces above the floodplain of the Oka River Valley.

The lithogenic basis of the research territory is represented by pre-Quaternary Permian deposits (sands, sandstones, siltstones, clays, marls, limestones, dolomites, gypsum, palygorskites), overlain by Pleistocene sediments (sands, siltstones, clay loams, gravel of glacial, water-glacial, alluvial, aeolian origin) and Holocene (sands, loams, clays, peat), the thickness of which in the central and western regions is reduced to 20 m or less, which makes possible the appearance of karst. In the east the thickness of the cover of Quaternary rocks increases, in the deepening of the Oka River it reaches up to 60-80 m. But in the coastal part of the Oka River, the capacity is reduced to 5 m and below, which allows pre-Quaternary deposits to come to the surface on the right-bank slope.

In the relief the third, outlier of the fourth, third, second and first above-floodplain terraces are appearance.

The surface of the high terraces above the floodplain is composed of valley zanders, which have a typical, wind-treated, shallow-framed bumpy-maned relief of periglacial-alluvial plains with dunes, blowing basins, maitugas, lakes and epilimins. In the south and east along the Oka River stretched low terraces above the floodplain (first and second).
2. Materials and methods
In 2013-14, Nizhny Novgorod geographers (A. E. Astashin, D. F. Cheburkov, M. V. Bakhireva, A.V. Samoilov, K. V. Yershova, O. A. Tumakov, Ya. S. Kokoreva, A. Kirichenko, S. N. Erastov) made field researches of lake basins in the research territory. Based on the results of field researches, bathymetric maps of lake basins were made (figure 1-7) and the main hydrological and morphometric characteristics were calculated (table 1).

Measurements of the depths of the lakes were carried out in winter from the ice using a lot. On the contour map of the lake, drawn on the basis of a satellite image, the lines of routes were applied, along which the depth measurements were carried out on the lake. From shore to shore at a fixed distance (10 or 20 m – depending on the size of the lake and the complexity of the bottom relief), holes were drilled, and using a lot, a depth measurement was carried out. From the point on the track with the maximum depth, perpendicular tracks were laid, and additional depth measurements were carried out, which made it possible to detect the deepest parts of the lake and more accurately outline the craters and hollows.

3. Results
The results of our field researches were processed by Eric Wientckowski using GIS ArcView 3.3., which allowed us to obtain spatial models of lake basins (figure 1-7). Mathematical processing of data in the Quantum GIS. GIS allowed us to calculate the main morphometric characteristics of lakes (table 1), traditionally defined in the practice of lake research both in Russia and abroad.

4. Discussion
According to the results of the analysis of the complex of characteristics, we classified the lakes of the research territory into 2 genetic groups: karst and maituga’s.

By maituga’s we mean the negative linear elements of the relief, the rill of postglacial discharge, formed as a result of the activity of meltwater flows in the epochs of melting glaciers of the late Pleistocene. The most typical morphometric features characteristic of the listed lakes, which allow us to assume its maituga’s origin, are: linear configuration, flow, lateral similarity of the configuration of lakes, relatively small depths.

Lakes Milovo (figure 3) and Glubokoe (figure 5) are elongated, flowing, have a relatively simple bottom relief, insignificant maximum depths (1.9 m and 4.7 m), and a relatively poorly developed coastline (table 1) and the organic-rich soils along the banks (as evidenced by the coastal vegetation, represented by alder, birch and spruce) are located within a long and narrow strip of swamps (especially these signs are characteristic of the lake Glubokoe).
Figure 3. Bathygraphic map of the lake Milovo.

Figure 4. Bathygraphic map of the lake Lebyazh'e.

Figure 5. Bathygraphic map of the lake Glubokoe.

Figure 6. Bathygraphic map of the lake Svyatoe Shchepachihinskoe.

Figure 7. Bathygraphic map of the lake Svyatoe Tumbotinskoe.
Table 1. Morphometric characteristics of lakes, lying on the terraces above the floodplain of the Oka River Valley within the Nizhny Novgorod region.

| Name of the lake | Lake mirror area, \( \text{м}^2 \) | The volume of water, \( \text{м}^3 \) | The length of the coastline, (м) | Length of the lake, (м) | Width of the lake, (м) | Max. depth, (м) | Medium depth, (м) | Medium width, (м) | The development of the coastline | Height of the water's edge above sea level, (м) | Shape of the basin |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Glubokoe       | 36285           | 75236           | 873             | 333             | 155             | 4.7             | 2.1             | 109.0           | 1.29             | 82              | 1.56            |
| Gluhoe         | 18644           | 16913           | 539             | 190             | 150             | 1.9             | 0.9             | 98.1            | 1.11             | 75              | 1.43            |
| Kruglicy       | 30336           | 56687           | 1064            | 258             | 208             | 4.5             | 1.9             | 117.6           | 1.72             | 88              | 1.5             |
| Lebyazh'e      | 15500           | 62123           | 521             | 200             | 90              | 7.9             | 4.0             | 77.5            | 1.18             | 92              | 1.56            |
| Milovo         | 62252           | 58748           | 1302            | 480             | 256             | 1.9             | 0.9             | 129.7           | 1.47             | 84              | 1.42            |
| Svyatoe Tumbotinskoe | 255022        | 1223349         | 6371            | 868             | 591             | 15.1            | 4.8             | 293.8           | 3.56             | 85              | 1.18            |
| Svyatoe Shchepachihinskoe | 171394        | 481041          | 2980            | 1033            | 277             | 7.4             | 2.8             | 165.9           | 2.03             | 90              | 1.44            |

All these factors indicate the occurrence of these lakes on the site of the old channel, which gives reason to assume the maituga’s origin of these lakes.

Analysis of lithogenic basis have shown a close bedding of rocks, exposed to karst, in parts of the research area, that makes possible the occurrence of karst and suggests karst origin of a series of lakes: Gluhoe, Kruglicy, Lebyazh'e, Svyatoe Shchepachihinskoe, Svyatoe Tumbotinskoe.

Morphometric features of a number of these lakes have features, characteristic for karst lakes: a significant development of the coastline, a complex bottom relief (Svyatoe Shchepachihinskoe, Svyatoe Tumbotinskoe), quite large depths (from 4.5 m on the lake Kruglicy up to 15.1 m on the lake Svyatoe Tumbotinskoe). It does not fully meet the listed characteristics of the lake Gluhoe, which has insignificant depths and a relatively simple coastline. However, we also tend to classify it as karst by a number of features: the relatively close bedding of the stratum of karst rocks to the surface; the presence of several, albeit weakly pronounced basins in the lake bowl; the absence of watercourses flowing into the lake and flowing out of it. The insignificant depth and weak appearance of the depressions, complicating the lake bottom, can be explained by a significant – up to 60 m – stratum of non-karst Quaternary deposits, which overlaps the sulfate stratum of the Sakmar stage of the Lower Permian, which is subject to karst formation, so that the projection of the karst cavity on the surface is not as sharp as it is usually characteristic to karst lakes.

Lakes of karst origin are represented by two groups of karst lakes, which have significant differences in morphometric parameters:

- Small lakes, formed by 1-3 karst craters, having a relatively poorly developed coastline (Gluhoe, Kruglicy, Lebyazh'e);
- Large lakes with complex bottom topography and intensely rugged coastline, complicated by islands, often with floating mat (Svyatoe Shchepachihinskoe, Svyatoe Tumbotinskoe). Presence in a limited area of two groups of karst lakes, with significant differences in morphometric characteristics, due to the complexity of the geological structure of the territory – rocks, exposed to karst are located at different depths, which determined by the tectonic nature and intensity of karst in the modern relief, including the relief of the lake basin.
5. Conclusion
Thus, the genesis, morphometric and hydrological characteristics of lakes are directly linked to the landscape features of the territory, lakes are an integral component of the landscape and one of its significant indicative features. Spatial patterns of distribution of lakes of different genetic groups are determined by the landscape structure of the territory and can be reliably established only in close connection with landscape researches.

Of course, in order to make a final conclusion about the genesis of lakes, additional facts are needed, in particular, very useful in this matter are the data of palynological and radiocarbon analysis of bottom sediments, which allow us to establish the hydrological regime of the lake at previous stages of development and the approximate age of the lake. The selection of bottom sediments and their analysis are seen as the next stage in the research of the lakes, considered in this work.

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