Modern exodynamic processes of relief formation under conditions of anthropogenic impact on the territory of the Klyazma river basin

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Abstract. The basin approach is the basis of this study of the factors of modern relief formation. Modern exogenous morphogenesis of landscapes of the river basin and its parts is not well researched. In this regard, the study of the dynamics of exogenous processes characteristic of the landscapes of the Klyazma river basin in areas with different types and degree of anthropogenic impact is relevant. Based on the results of field geomorphological studies, locations of modern relief-forming processes (hydromorphism, karst, ravine erosion, landslide formation, lateral erosion of rivers) that are most characteristic of the study areas have been identified and mapped.

1. Introduction
The morphometric characteristics of the structure of the river basin reflect the physical-geographical, geological, tectonic, geomorphological conditions and processes [1]. Regularities of the structure of river basins with the aim of analyzing their origin, evolution and development history, using the system of dividing watercourses into orders, was first identified by R. Horton, 1948 [2]. This idea was developed in the works of V.Yu. Abakumova, W. E. Dietrich; D.G. Bellugi, D.F. Ritter and in a number of other works [3–6].

The morphogenesis of the territories of the European part of Russia is described at the level of physical and geographical areas and administrative entities. U.G. Simonov and others noted the influence of Quaternary glacial deposits on the formation of the modern relief. The IV volume of USSR Geology summarizes huge factual material about the geology of the center of the European part of the USSR, including the territory under study [5]. A wide and detailed description of the Klyazma river basin and its tributaries is currently being carried out at the Department of Biology and Ecology of VlSU under the guidance of prof. T.A. Trifonova [7, 9, 10].

2. Methods and materials
The study of the forms and types of relief of the Klyazma river basin of exogenous origin and relief-forming processes was carried out using a methodological approach to assessing the transformation of landscapes. In the aspect of the basin approach, the study is original, since the functioning of geosystems – river basins – with fairly clear natural boundaries is investigated. The novelty of the study lies in an attempt to apply a complex of methods (remote sensing and automated decoding of satellite images; cartographic, aerospace, statistical, geomorphological) from the perspective of the basin approach. This enables a more detailed interpretation of the data obtained.
Field geomorphological studies and subsequent mapping helped to identify the features of modern exogenous relief formation processes in the river basin.

In the course of the project, a basin approach and standard research methods were used. Geomorphological field studies in basin geosystems were preceded by cameral: archival, cartographic and statistical methods for collecting and analyzing data on the forms and types of topography of the study area. Remote sensing data (aerial and satellite imagery) allowed the use of GIS technology (ArcGIS) to create and adjust electronic databases of the territory of the Klyazma river basin and its tributaries, followed by their visualization (maps and spatial 3D models), reflecting dynamic changes in the relief on selected key areas and in small river basins. Based on them, the factors of modern exogenous relief formation under various natural and natural-anthropogenic conditions are studied.

Using the remote sensing method, based on the analysis of satellite images of different resolutions and analysis of the associated research data, the selection of sites for laying geomorphological profiles and constructing cartographic models was carried out. This method gives a more accurate, detailed picture of the position of the studied objects and phenomena in space than the use of traditional topographic maps.

3. Results

The relief of the Klyazma river basin was formed in the preglacial period. The ice ages deeply deformed and transformed it. The flat-hilly nature of the relief is determined by the location of the study area within the Yuryev-Polskaya Upland on a residual denudation base from the Mesozoic sediments of the axial zone of the Moscow syncline; the Klinski-Dmitrovskaya ridge subarea of a moraine-erosion hill with groups of large hilly-ridge forms of the marginal zone of Moscow glaciation; Oksko-Tsinsky rampart, which is part of the Kovrov-Kasimovsky plateau [9].

A study of the forms and types of the modern relief of the Klyazma river basin in 2018 was conducted on the territory of the natural regions of Opole and the Kovrov-Kasimov Plateau.

In geomorphological terms, the Opole is almost entirely, with the exception of the northwestern peripheral areas, confined to the preglacial erosion plain. The general topography of the pre-quaternary relief is close to modern. In the Vladimir Opole, Pleistocene glaciations only slightly smoothed the watersheds. Morena is almost everywhere blocked by a complex of moraine sediments. In modern watersheds, they are often the bottoms of beams and runoff hollows, the slopes of which are composed of cover loams.

Within Opole there is a high degree of plowing, which led to the development of ravine-gully erosion. Gully erosion is manifested everywhere, but its speed is reduced due to the construction of numerous dams and dams on all channels of small rivers, as well as due to the preservation of plant associations and sodding of soils at the sources of ravines. Gullies and beams in Opole are widespread everywhere, the degree of erosion of the territory is 20–22 %.

Suffusion processes are manifested on the peaks at the upstream watersheds of small catchments. A striking feature of Opole is the lowland microrelief. It is often leveled on arable land as a result of centuries-old soil cultivation. Defluxion processes, expressed in the form of plastic movement and slow extrusion, of slightly moistened ground masses under the soil and vegetation cover, are observed mainly in the bases of the slopes of the northern and north-western exposure. Deluvial slope processes are manifested in the form of thin jets that cover the surface of gentle slopes with a dense network, washing away weathering products, which leads to a decrease in the fertility of gray forest soils. Especially deluvial processes can be traced in violation of the technology of plowing slopes.

The nature of agricultural use was studied in the basins of the small rivers Kamenka, Sodyshka and Rpen. In the course of the study, a similarity of exogenous geomorphological processes occurring in them was found, mainly erosion and suffosion (Fig. 1).

In 1970–80 two hydraulic structures were built on the Kamenka River, raising the water level in the river Russ by 1 meter, which led to the flooding of the floodplain and floodplain terraces, as a result, an increase in hydromorphism, the appearance of wetlands and a change in ecosystems.
The Sodyshka River Basin is the right tributary of the Rpen River, flowing along the northwestern outskirts of Vladimir in the southern part of the Opole natural region. On the urbanized territory of Vladimir city within the Lybed river basin, natural geomorphological processes are leveled by anthropogenic activity or completely replaced by the latter. As a result of the drainage of the territory by the construction of transport routes, water supply and sewage networks and stormwater drainage, as well as clay quarries, its surface runoff was disrupted and the catchment boundary changed. Over the past 20 years, mining, dumps and embankments in the construction of new residential areas of multi-storey buildings in the source of the river. Swan, backfill of the channels of the lateral adjacent ravines, ravine-beam erosion was terminated. Channel processes are sent to artificially created collectors. In the spring of 2017 and 2018, according to our observations, breakthroughs of groundwater discharge occurred at the mouths of previously existing ravines, which led to short-term flooding of sections of the former floodplain and clogging of the reservoir. This situation arose as a result of engineering, technical and construction errors in the design of the highway and required new investments to create and improve additional storm sewer systems (Fig. 2).
The geomorphological aspect of the territory of the Kovrov-Kasimovsky plateau is represented by gently undulating and hilly-steep plain surfaces folded by moraine covered by a cover of loam with gravel and boulders, with weakly divided hollows and beams. This territory is geomorphologically divided into Gorokhovets spur and Oka valley. The root coast in most of the plateau is strongly dissected by erosion complexes. The ravine-girder network on the Gorokhovets-Vyaznikovsky plateau is characterized by a significant depth of cut. At the tops of the elements of the ravine-girder network, intensive erosion growth is observed. The root coast on the edge of the Gorokhovets-Vyaznikovsky plateau contains a large number of springs with high debit.

The ravine-beam network is formed by permanent and temporary streams and has more than 20 large ravines with steep, high slopes. Erosion processes are partially attenuated and in fact most of the ravines are turned into beams.

The basis of the base of the Gorokhovets spur is composed of alluvial floodplain sediments of the Klyazma and Suvoroshcha rivers – mainly brown loams, as well as sands with a significant content of clay and silty particles, sandy loam, loesslike loams and non-boulder clay. The slope of the right bank of the Gorokhovets spur is currently experiencing a relatively small anthropogenic load.

During the study on the Gorokhovets spur, landslide-bearing processes were identified, the development of which was affected by weathering, erosion, abrasion, suffusion, the amount of precipitation and the nature of their infiltration, hydrogeological factors, thawing and freezing, as well as accumulated phytomass and multilateral activity person. In the 2000s, there was a landslide destruction of the root shore at the top of the Klyazma watershed near the village of Pirov Gorodishche of the Vyaznikovsky district, and we also recorded a landslide on the slope of the ravine near the village of Krutovo, Gorokhovets district. The linear dimensions of landslides do not exceed 10 m x 20 m. Abrasive landslide processes occur when the Klyazma river is washed away at the root coast near Vyazniki and the village of Oltushevo (Fig. 3).

On the Kovrovsko-Kasimovsky plateau – karst Klyazminsko-Okskoye interfluve area in the area of the village of Nikologora and the village of Serkovo, processes of karst occurrence have been activated three times over the past 100 years (the area of Lake Pivovarovsky area at the beginning of the 20th century, as well as Lake Sakantsy in 1958 and 2017 years). The main forms of manifestation of failed formations in the study area are dry craters, karst lakes, swamps and wetlands in the resulting relief depressions. The last activity of karst processes appeared in October 2017. In the Vyaznikovsky district. The arch of the underground cavity under the bottom of Lake Sakantsi failed. Throughout 2018, there is a restoration of the water level of Lake Sakantsy, due to the drawdown of the funnel and the decay of the karst process. (Fig. 4, 5).
4. Conclusion
The study examined the forms of modern exogenous morphogenesis in the morphological parts of the Klyazma river basin: rivers of the second and third orders (Rpen, Lybed, Sodyshka and Kamenka).

Field geomorphological studies have revealed the features of modern exogenous relief formation processes within the natural region of Opole, as well as in landscape structures on the territory of the Kovrov-Kasimovsky plateau. In the present period, natural geomorphological processes are leveled by anthropogenic activity or completely replaced by the latter. Based on the results of field geomorphological studies, locations of modern relief-forming processes (hydromorphism, karst, ravine erosion, landslide formation, lateral erosion of rivers) that are most characteristic of the study areas have been identified and mapped.

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