Application of the cartographic method of research for the detection of the dangerous zones of mining industrial territories

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Abstract. The collection, analysis and processing of information on hazardous geological processes in the city of the Shakhty of the Rostov region was carried out. On the map of the city, zones of spreading loessial subsidence soils, zones of mining operations at relatively shallow depths and the territory of man-made flooding are constructed. The areas of merging of two or more dangerous factors affecting the normal operation of mining areas are identified.

1 Introduction

The necessity of assessing the risks of violation of the normal operation of the mining and industrial territories of the Eastern Donbass (hereinafter referred to as risks) was considered by us in publications [1, 2], etc. The authors proposed a method for regionalizing coal-mining territories by the category of the danger of development of negative technogenic and geological processes [1, 3].

The purpose of this article is to develop and approbate an approach to the assessment of geological risks by the example of Shakhty, which belongs to one of the problem mining areas of the Rostov Region.

2 Methodology

The initial data for risk assessment can be given by data on the following negative geological processes:

- displacement of the earth's surface due to underground mining works at relatively shallow depths;
- foci of possible flooding and flooding of mining areas as a consequence of disturbance of the natural regime of groundwater by technogenic impact;
- the spread of loess quaternary deposits, prone to the development of subsidence of the foundations of the foundations of buildings and structures after water saturation.

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For the convenience of assessing the impact of each of these factors, cartographic data was used, while the areas of propagation of negative processes are marked as separate independent layers, attached to the coordinate system in the territory under consideration. The most difficult task in the framework of this study was the selection of relevant and reliable cartographic sources on a sufficiently large scale, which makes it possible to "superimpose" these layers within the framework of a inhabited locality.

This made it possible to link the boundaries of dangerous zones to territorial units (urban and rural settlements, districts and micro-districts of large cities, etc.) [1, 2].

In Soviet times, namely the 50-60-ies. In the 20th century, when the most intensive construction of miners' towns in the East Donbass with multi-apartment buildings took place, the collection and analysis of the parameters of run-in, the spread of loess subsidence soils and groundwater regimes with various schemes and maps were carried out. After the lapse of time and the transfer of archives to private research organizations, it became very difficult to obtain the necessary data for scientific applications. In the current situation, it is advisable to use the widely available legislation that regulates the principles of urban development and land use of large settlements.

To study the mining zones at relatively shallow depths, a map of the city of Shakhty with special conditions for the use of territories was used [4]. To assess the distribution of loess soils in the territory of the city of Shakhty, a map of the Quaternary deposits of the Rostov region at a scale of 1: 200,000 was used. The map of the flood zones of the city of Shakhty was adopted according to the monograph [5], based on a generalization of the results of the Ingeo research, and also studies [6].

Thus, it was possible to assemble the necessary set of layers and display them in the environment of the applied map program SAS.Planeta based on the PC (Figure 1).

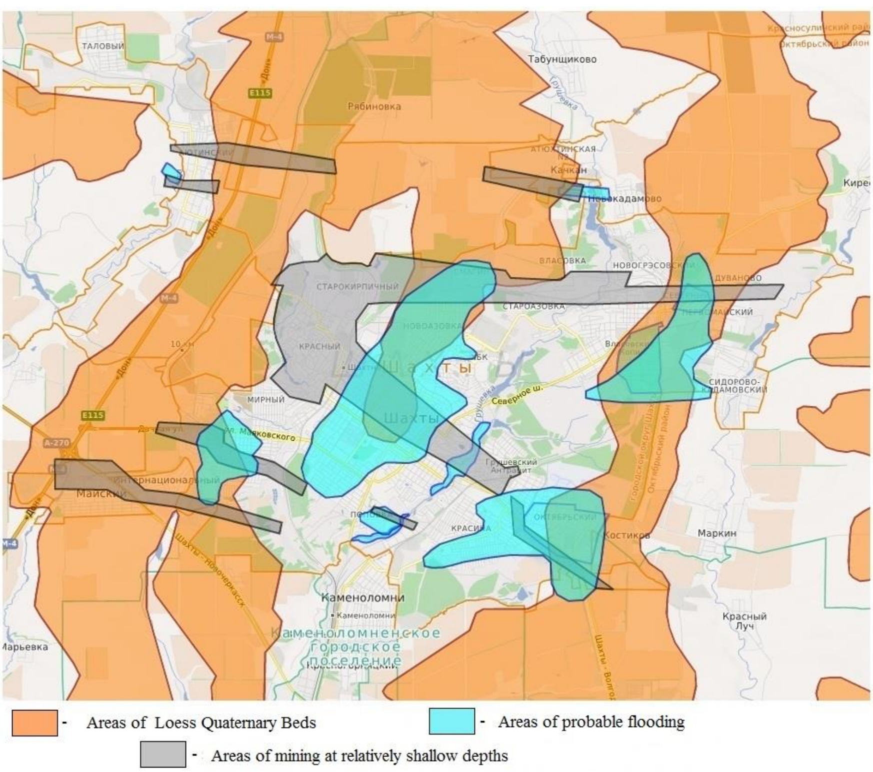

Fig. 1. Displaying polygons in the SAS program using the basis of Open Street Maps

The most useful were the following features of this program:

- loading of numerous cartographic bases (Google, Yandex, Open Street Maps, etc.), including data on the terrain;
- Simultaneous overlap of a large number of auxiliary layers with thematic data (data on water resources, cadastral boundaries, transport routes, etc.);
- A simple procedure for creating and editing labels, paths and polygons;
- the ability to quickly create (glue) the required portion of the map at the required scale with subsequent conversion to raster images.

The disadvantage of this program is the lack of the possibility of directly overlaying a raster layer, which can be cut out of the map of interest. Thus, the application of all the necessary polygons is accompanied by the computation of the coordinates of the characteristic points of the boundaries of the regions. As a result, the process of mapping layers is a very laborious process, especially if the accuracy of determining the position relative to the coordinate system is important.

3 Results

In Figure 1, the brown polygons represent the zones of distribution of forest subsidence soils, the gray ones represent mining zones at relatively shallow depths, and blue areas show areas in the risk zones of the flooding of the city of Shakhty. Thus, risk factors are identified that initiate negative geological processes in accordance with the current norms [7].

Separately, each of the allocated zones may not represent a danger of violation of normal operation of buildings and structures, if the necessary engineering protection measures are provided for in the design and construction, minimizing the threat of failure of the design work.

Proceeding from the intensity and simultaneity of the action of dangerous factors, the categorization of territories by the danger for construction objects is proposed, which provides for their differentiation into 4 categories - from neutral to critical [1]:

I. Neutral. These include the territories where observational data for the past 20 years have not been recorded or noted, but dangerous geological and hydrogeological processes affecting the bearing capacity of buildings and structures as well as infrastructural objects are not predicted in the future. The normative life of buildings and structures does not change.

II. Warning. The areas where dangerous geological processes have been recorded according to observations over the past 20 years, their further development is expected, but with less intensity. With a decrease in the influence of technogenic processes, further development is not expected. The carrying capacity of buildings and the functionality of infrastructure facilities are not violated, but the regulatory lifetime is reduced, a current or capital repair is required.

III. Dangerous. Territories on which dangerous geological processes have been recorded according to observations over the past 20 years are expected to strengthen and develop them. The carrying capacity of buildings and the functionality of infrastructure facilities are partially violated, further maintenance requires major repairs or reconstruction.

IV. Critical. Territories on which dangerous geological processes are actively developing. The carrying capacity of buildings and the functionality of the infrastructure facilities are disrupted and in an emergency condition [1].

The allocation of neutral territories is not difficult. These are zones where none of the selected polygons are projected. At the same time, the areas of subsidence soils can be treated as neutral, since at the design and construction stage necessary measures should be provided to reduce the negative impact of uneven sediments on building structures. When inspecting existing or when designing new buildings and structures, the type of subsidence soil (I or II) and the degree of subsidence (from weakly intercalary to extremely sluggish) should be specified in accordance with GOST 25100-2012 [8]. In this case, the zone of distribution of loess soils by itself can have both a neutral and a warning category.

Areas of moonlighting at relatively shallow depths carry several negative impacts on mining areas. First of all, these are the processes of displacement of the earth's surface with the formation of troughs, accompanied by horizontal, vertical displacements and slopes. These displacements, as well as subsidence, cause uneven deformations of the basement under the foundations of buildings and structures. In addition to the shifts, the failures are no less dangerous, accompanied by the immediate destruction of the rock mass in the upper layers of the lithosphere, with subsequent impact on the construction of buildings and structures. One more kind of hazardous effect should be mentioned. It is about the release of mine gases, so called "dead air", into the atmosphere. Most often, the content of gases is observed in the cellars of buildings. Directly, these gases do not affect the integrity of the structures of buildings, but they pose a threat to the life and health of the population in the area of underworked territories. Thus, mining zones at relatively shallow depths can be classified as a warning, dangerous or critical category.

As for the areas at risk of flooding and flooding, it is necessary to analyze a number of factors that affect the integrity of the structures of buildings and structures. First of all, the risk of flooding is related to the regime of groundwater level. According to paragraph 5.4.9 of SP 22.13330.2016 on the nature of the man-made impact, the built-up areas are divided into unsecured, potentially flooded and drained [9]. In order to relate the territory to any of the above categories, it is necessary to study in detail the influence of the relief and the geomorphological conditions of the construction site on the movement of groundwater. In addition, the groundwater regime can be affected by surface sources of soaking, leaks from water-bearing communications, and lack of organized disposal of surface water.

Separately, it is worth considering the effect of the chemical composition. This is due to the progress of highly mineralized mine waters from flooded mining operations due to "wet" conservation of mines. These waters are solutions with various salts and mineral components that can adversely affect the material of underground constructions of buildings and structures. Another danger is the water supply for residential and agricultural areas. The presence of a large amount of dissolved substances has a negative effect on the fertile properties of soils, when entering the daytime surface, they contribute to bogging processes.

Thus, the areas in flood and flood areas can be classified as a warning, dangerous or critical category.

4 Analysis

After the establishment of the distribution zones for each of the main parameters (sub-work, subsidence, flooding), the next stage identifies areas in which at least two factors act simultaneously. To do this, the operations of adding polygons (layers) are performed in the SAS.planet program and each of the four types of regions is highlighted with its own color.

For convenience of description of each of the categories of zones assigned its own index:

Ia - zones of probable flooding;

Ib - zones of mining operations at relatively shallow depths;

Ic - zones of distribution of loess soils;

IIa - areas of confluence of mining zones at relatively shallow depths and probable flooding;

IIb - areas of confluence of zones of distribution of loess soils and probable flooding;

IIc - areas of confluence of zones of distribution of loess soils and carrying out of mining operations at relatively shallow depths;

III - areas of confluence of loess soil distribution zones, mining operations at relatively shallow depths and probable flooding.

The map of the zones formed as a result of a combination of all unfavorable factors is shown in Figure 2.

For the zones shown in Figure 2 as a result of logical operations with ligated areas, an analysis is performed with the description:

- the area of the zone in km^2, with description of the peg (streets, house numbers, etc.);
- information on construction objects within the allocated zone (type of development, area, number of storeys, years of construction, etc.);
- Typical series of houses.

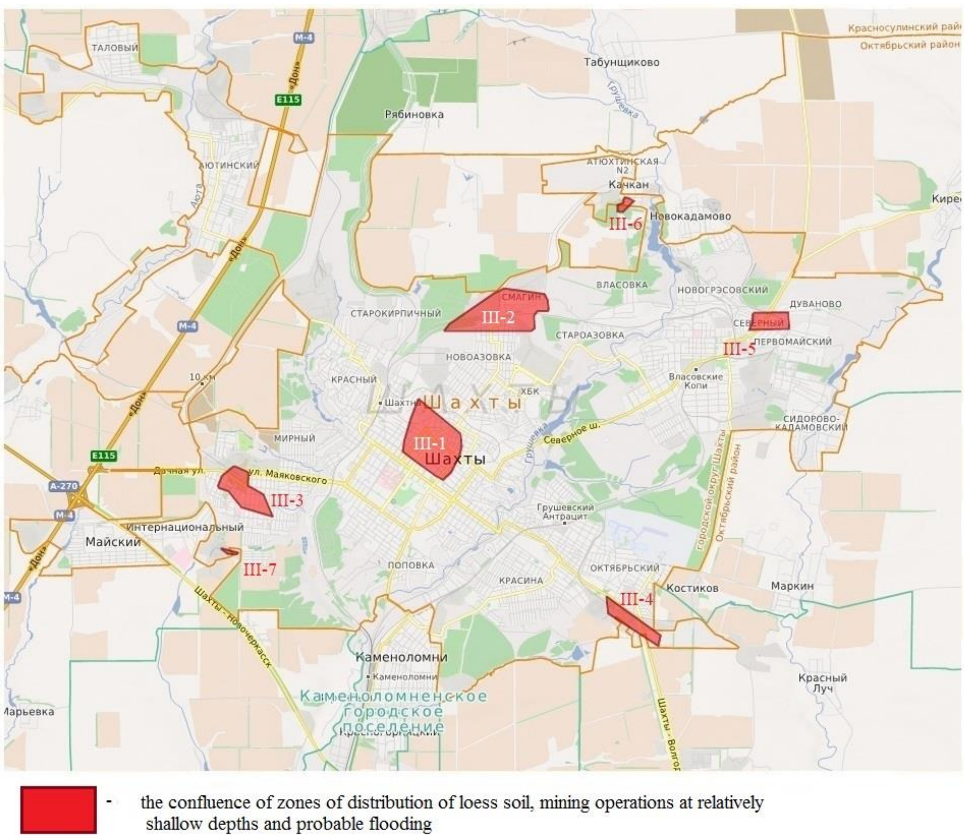

Fig. 2. Map with the regions of confluence of zones of distribution of loess soil, mining operations at relatively shallow depths and probable flooding

According to the portal of the administration of the city of Shakhty, the area of the urban territory is a total of 16065.3 hectares. The population is 235,500 people. (according to data for the I quarter of 2017). The population density is 1574 people / km². The city includes 4 settlements: Ayutinsky, Maisky, Talovy, Sidorovo-Kadamovsky. The city of Shakhty is surrounded by the lands of the Oktyabrsky rural district. The green zone of the city covers an area of 831 hectares.

We will describe in detail the nature of the building with the identification of the main typical series of buildings in the areas (zones) located in the most dangerous areas (with index III), characterized by the fusion of all three negative factors. This will allow us to evaluate the most common planning and constructive schemes of multi-apartment buildings for further modeling of the behavior of structures under the influence of negative factors.

As a result of the analysis of the 7 zones of the most dangerous type III, isolated in the territory of the city of Shakhty (Figure 2), the following was noted:

- the total area of the allocated zones is 5.44 km^2, which is 3.4% of the area of Shakhty;
- Within the allocated zones, at least 60 multi-apartment houses with a floor area of at least 65 thousand m2 were found, in which about 2,350 people live, which is approximately 1% of the population of the city of Shakhty;
- Based on the average population density of 1,488.57 people / km^2, in the territory of the allocated zones there are approximately 8,100 people, which is 3.4% of the population of the city of Shakhty;
- the average age of residential apartment buildings is 60 years, the average number of storeys is 2;
- 9 residential buildings located within the allocated zones, are recognized as emergency;
- the most common typical series of residential houses - 1-460, 1-447, C25, 86, II-03.

5 Discussion

The proposed approach to identify the hazardous zones of mining territories, based on the application of the cartographic method of research on the basis of modern information mapping technologies, showed high practicality and efficiency. On the basis of this zoning, it was possible to separate the entire analyzed mining territory (the city of Shakhty and its surroundings) into 7 zones, different in degree of danger for the buildings and structures under construction and exploitation.

The most dangerous zones, obtained by the simultaneous imposition of three factors of geological hazards, correlate well with the actual sites of maximum violations and deformations of buildings and structures.

The carried out analysis of zones of occurrence of negative geological processes showed that the problem of violation of normal operation of mining areas in the city of Shakhty of the Rostov region is actual.

In connection with the high risk of further deformations of buildings and structures in zones of types IIa, IIb, IIb and III, it is recommended that in cooperation with the Department of Architecture and Urban Planning of the city develop measures for geotechnical monitoring of existing buildings and continue monitoring of the groundwater regime in zones, prone to flooding.

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