Geological Monuments of Transnistria: Types, State, Economic Use

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Abstract. Geological monuments are a special type of natural monuments that reflect the features of the geological structure of the territory and the peculiarities of the occurrence of layers of the earth’s crust, the composition of rocks and minerals. In the relief geological monuments are expressed by various geomorphological objects and rock outcrops. The presence in them of unique remains of fossil flora and fauna gives particular value to geological monuments. The territory of Transnistria as a region on the left bank of the Dniester within the Republic of Moldova has the peculiarity of geological monuments. This territory mainly has a flat relief character, but in the north of Transnistria, the spurs of the Podolsk Upland have created here rocky forms, similar in manifestation features to the mountainous terrain. These features determined the presence in the region of a number of specific geological monuments that require identification, analysis and systematic monitoring of their qualitative state and changes under the influence of natural and anthropogenic factors.

1. Introduction
Geological monuments are one of the varieties of natural monuments. They belong to the category of specially protected areas and are geological objects of scientific value and natural originality. Geological monuments are wholly or partially open for observation and visiting, since they, as fragments of the geological environment, carry a certain information load. Geological monuments are diverse and are represented by waterfalls, rocks, volcanic craters, caves, outcrops of minerals, sand dunes, rock forms, river valleys, seashores, coral formations [1].

Geological monuments are specific depending on their location, the geological history of territory in which they are located and the degree of anthropogenic impact. At the same time, they are subject to destruction under the influence of natural and economic processes. Every geological, paleontological, or geomorphological object that scientists attribute to geological monuments is part of the natural and cultural heritage of society [2]. As an especially valuable natural area, geological monuments need constant monitoring to determine the degree of their condition and, if necessary, implement measures for their protection and conservation [3]. The data on geological monuments obtained in the course of the study enable their structuring, which forms the basis for their classification. This classification is not only of theoretical importance, but also of serves as a basis for determining the possibilities of using different types of geological monuments for cognitive and recreational activities.

2. The relevance and scientific significance of the issue
Geological monuments are considered by scientists from different points of view – as natural objects, as outcrops of minerals, as objects of natural heritage that need to be studied and preserved. The
International Union for Conservation of Nature (IUCN) made a significant contribution to the study of geological monuments [2]. He considers geological monuments as one of the varieties of natural monuments and approved different categories of regimes for their preservation.

Scientists from different countries develop their own methods of studying geological monuments, conduct field research, systematize the information received and draw up programs for the conservation and use of geological monuments in cultural, educational and economic activities. Among the individual scientists whose results of scientific research are most significant to us, we mention D.A. Ruban [4, 5], M.N. Hiern [6], E.R. Brilha [7]. Some of the research carried out was applied in nature. They were associated with the development of methods for registering geological monuments in the state land cadastre [8], monitoring the state of geological monuments, assessing the possibilities of their use for tourist and recreational purposes [9, 10]. The study of geological monuments is particularly difficult in areas with dense urban development, where there is a high anthropogenic load on nature [11]. In such areas, the preservation and preservation of existing geological objects and their complexes is necessary [12].

Geological monuments are widespread on all continents and in many countries in the world. They are most studied in the countries of Europe [13, 14] and Africa [15, 16]. Such studies have been carried out relatively recently in the post-Soviet states [17, 18, 19, 20]. One of the regions where geological monuments have their own specifics is Transnistria – the western part of Republic of Moldova, which includes the left bank of the Dniester River. The peculiarities of the geological structure and development of the territory determined the location on this relatively small territory (about 4.2 thousand sq km) of a large number of geological monuments that are of interest for our study (Figure 1).

![Figure 1. Relief of Transnistria.](image)
3. Problem definition

The purpose of this article is to characterize the road infrastructure of an urban agglomeration as the basis for forming its transport framework. The scientific objectives of this study are as follows:

- Clarification of the essence of geological monuments as specially protected natural objects of value for the whole society.
- Identification of the main types of geological monuments in Transnistria and their classification.
- Description of the features of geological monuments in territory of Transnistria, analysis of the degree of their preservation and significance.
- Determination of the possibilities of cultural, educational and economic use of geological monuments of Transnistria and the necessary environmental protection measures for their preservation.

4. Materials and methods

This study has a longitudinal character. The initial stage of the study took place in 2008-2010 and was associated with the fixation of geological monuments in territory of Transnistria, their visualization and description. Until this point in time, geological monuments as an independent category of natural monuments in this area were considered only in the 1960s by a team of authors including Yu.P. Kravchuk, V.N. Verina, I.M. Sukhov [21]. In subsequent years, there were only detailed studies of individual geological monuments of Transnistria based on an expeditionary research method in order to describe them in detail and determine their scientific and cognitive value for the museumification of paleontological and archaeological artifacts found on their territory.

This study was carried out by the author in 2019-2020 in the form of field observations related to the inspection of previously identified geological monuments of Transnistria in order to determine changes in them under the influence of geological processes (landslides, talus, earthquakes, wind and water erosion), as well as irrational economic activities of local residents. The results of this study served as the informational basis for this article.

5. Theoretical part

Geological monuments are natural heritage objects that in a concentrated form reflect the specifics of the geological structure and geological processes of a given territory. The main criterion by which a natural object can be attributed to a geological monument is its uniqueness. This uniqueness is manifested in the special structure of geological monuments, the manifestation in them of typical or atypical rocks and minerals for this area, paleontological inclusions of ancient extinct plants and animals. Geological monuments are represented by areas of plains or mountain systems that are well exposed in terms of rock composition and have morphological manifestations in the form of meso- and micro-relief (caves, rocks, ravines, alluvial deposits on river banks, lacolites, etc.) [1].

The variety of geological monuments requires their classification. In science, various criteria for the classification of geological monuments have been adopted, which are constantly being refined and supplemented by scientists. In our study, taking into account the specifics of the territory under consideration, the classification of geological monuments by types of origin is in demand. The groups of geological monuments identified in this classification reflect the prevailing geological processes and features that best reflect the specifics of each group. These groups include:

- Stratigraphic monuments are rock outcrops that are characteristic of a specific geological age. These geological monuments are represented by typical sections of the earth's crust that are used as reference when describing similar geological outcrops of a certain age. They contain a strictly established and typologically fixed sequence of rock layers that reflect the geological history of the area [22].
- Paleontological monuments are geomorphological objects in the rocks of which the remains of ancient animals or plants have been found, identified and described. By the age of these
paleontological finds, it is possible to determine the age of the rock layers and by the types of organisms found, the paleogeographic situation in a given area can be reconstructed.

- Mineral and petrographic monuments are outcrops in which rare minerals are found, and deposits of rocks typical of the area, which have good preservation and typical occurrence.
- Tectonic monuments are areas of a mountainous or flat landscape, a relief shape and features of the bedding of rock layers in which reflects the results of the manifestation of tectonic processes in this territory. They reflect the correct, disturbed or discontinuous bedding of layers of rocks of different ages or their bedding. The study of tectonic monuments makes it possible to understand the nature of the processes taking place in the earth's crust.
- Geomorphological monuments are landscapes that most clearly reflect the exogenous and endogenous processes of relief formation in this area. These include caves, outliers, spits, canyons and other forms of micro-relief. They can be divided into subtypes depending on the prevailing exogenous process that dominates in their formation. According to this criterion, we can distinguish the following subtypes: aeolian (accumulation and denudation), cryogenic, erosional, glacial, map, abrasive, landslide, hydro-geological (outcrops and reservoirs of groundwater) [23].

The classification we have presented is not exhaustive, but the types of geological monuments identified in it were used to identify them as part of our study. We have described geological monuments based on information from field research by visualizing them and measuring the parameters of rock outcrops. In addition, rock samples were taken and some of them were analyzed chemically. All these data became the basis for characterizing the geological monuments of Transnistria.

6. Practical importance, offers and results of introductions

The Transnistria region has an insignificant area of the territory, but it differs in the originality of the history of development and tectonic structure. These features of nature have led to the placement of a number of geological objects here, which have received the status of geological monuments of nature. Geological monuments are unevenly distributed in territory of Transnistria. Most of them are located within the Kamensky, Rybnitsky districts, as well as near the city of Tiraspol. This can be explained by the natural conditions of the territory, the different degree of preservation of natural objects, their condition and anthropogenic load in the past and now.

Among the geological monuments of the Transnistrian territory, geomorphological monuments predominate. Geomorphological monuments associated with the manifestations of typical exogenous and endogenous relief formation processes and their consequences in the form of erosion landscapes, landslides, landslide areas, coastal rocks. Among them, on the territory of Transnistria, the following groups can be distinguished:

6.1. Objects of landslide origin

This type includes a landslide on the western outskirts of the village of Grushka in the Kamensky district. The site of this landslide is bounded from the north and south by ravines with strong flowing water. This ensures the stability of the landslide slopes. Geologically, chalk marly limestones, clays, sands and reef Volyn limestone’s, as well as limestone’s and sandy-gravel sediments of the Middle Sarmatian are presented here. The total area of the landslide, together with the ravine, was recorded by us at 8 hectares. Observation of the dynamics shows the growth of the ravine, but the landslide is subject to slight changes under the influence of weathering.

6.2. Complex erosion-karst areas of rocky natural landscapes in canyon-like valley of Dniester rive

They are steep, partially forested slopes with protruding rocks of mountainous arcuate limestone ridges, called “Toltry” in this area. In some places, due to karst processes, grottos and caves complicate them. We have identified as such on the territory of Transnistria a section’s of landscapes Valya-Adynke in the Kamensky district and Stroenetsky Yar near the village of Stroentsy in Rybnitsa region, the high...
slopes of Yagorlyk river valley on the territory of Yagorlyk reserve in the shore of Goyansky bay of Dubossary reservoir.

6.3. **Objects of erosive origin on the numerous terraces of the Dniester**, which sometimes are cut through by its small tributaries. During the expedition, we studied:

- The Dry Valley of Tomashlyk River near the village of Novaya Lunga in the Dubossary district is a wavy plain with absolute elevations of 100-200 meters above sea level, crossed by ravines and girders composed of limestones of ancient Dniester terraces with pebbles, loess-like loams and clays.
- Areas of the landscape Telitsa in the Dniester valley between the cities of Dubossary and Bendery.
- Rypa Vie ravine to the north of village Grushka in Kamensky district - here are exposed Proterozoic mudstones, limestones and marls of the Cretaceous and Neogene with a numerous mollusk fauna are exposed here.
- Maftey ravine near the village of Vykhvatintsy in Kamensky district - here are exposed Proterozoic mudstones, limestones and marls of the Cretaceous and Neogene with a numerous mollusk fauna are exposed here.
- A quarry of pebbles and sands of the Ice Age (Mindel-Ris interglacial) south-west of the village Malaeshty in Grigoriopol district.

6.4. **Geological monuments of alluvial origin**

This is Kremenchug sandy hill, about 1 km long and 0.5 km wide, which is located on the right bank of Dniester River opposite the city of Tiraspol, near the village Kremenchuk. The hillock rises above the floodplain of the Dniester River by 12-15 m and is a relic dune that was formed during a drier, arid climate. Currently, this hillock has no scientific significance and is used as a beach for recreational purposes.

6.5. **Karst complexes**

Due to the peculiarities of the relief structure, karst complexes on territory of Transnistria are not distinguished as independent objects, but they act as a structural unit in the composition of other geological monuments of the region. Karst processes are developed on the limestone slopes and bottoms of the Dniester Valley in the north of the region. Their result is the forms of micro-relief - caves, grottoes, funnels, wells, waterfalls. Among the karst forms on the territory of Transnistria, in terms of scientific and aesthetic significance, we should especially note the Rashkovsky complex, within which there is the so-called Chervona Gora. It is a high slope of a landslide and contains outcrops of limestone interspersed with red Etulian clays penetrated by cavities of karst caves, wells and cracks. The overhanging cliffs of the high slope remind here of bizarre sculptural groups. A unique natural formation is also a hanging natural passage over the abyss-the Devil's Bridge, which has the shape of a bridge between two high-raised rocks. On the territory of the neighboring village of Valya-Adynke, karst manifestations are represented by caves, numerous sources of karst water with a flow rate of 10-20 to 200 liters per second.

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8. Conclusions
Geological monuments are rare and unique natural objects. They have scientific and educational significance and require limited, rational economic use. Due to their location in areas with high economic development, geological monuments experience a significant anthropogenic influence. Therefore, in relation to geological monuments, constant or periodic monitoring of their condition and the implementation of environmental protection measures are necessary [5].

In general, the study of geological monuments of Transnistria conducted in 2008-10 and 2019-20 shows their satisfactory condition [7]. At the same time, the problem of preserving their natural state is very relevant. Identification of geological monuments and their constant monitoring is one of the fundamental tasks. This requires detailed cataloging of geological monuments and status assessments, and clear and strict laws at both state and local levels should regulate environmental measures.

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