Geodiversity, geological heritage and renewal of the network of geosites of the Dnipropetrovsk region

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Abstract. This paper is focused on the relatively new terms in the Earth Sciences – geodiversity, geological heritage, geoconservation, geosites, geoparks – and their practical usage in Ukraine. The diversity of geological processes that have occurred in Dnipropetrovsk Oblast, its structural-tectonic position, and the long complex history of its development, since the Precambrian until the Quaternary Epoch, combined with a large amount of natural and mining-exposed outcrops, has made it rich in various objects of geological heritage. The article gives a brief analysis of history of how the Oblast’s objects of geoecological heritage have been provided with an official state-protected status and examines those with promising natural geological monuments (geosites) that require protection. We emphasize the problem of how little attention the government nature-protection organizations of Ukraine are paying to the necessity of preserving the geological heritage, despite all positive changes in its protection at international level, including establishment of European Association for the Conservation of Geological Heritage, and a steadily growing UNESCO-supported movement of establishing geoparks, etc. We provide a qualitative and quantitative assessment of the geosites and their types according to the modern classification. We recommend analyzing a possibility of including one of the promising objects that is located in the Dniprovi Porohy Regional Landscape Park to the European Register of Geological Heritage. The paper presents the results of geological monitoring, carried out in Dnipropetrovsk Oblast after publication of the book Geosites of Ukraine, which increased the fund of promising geosites up to 70. According to the criteria by which geosites are chosen, we determined 4 geological monuments that correspond to the state protection level. Most of the objects of local-significance require further field studies, and after examination some of them were found to deserve protection as geosites of national significance. Each of the geological relics from the list, objects which are proposed for the first time, has been given a preliminary characteristic consisting of a geosite’s location, stratigraphical position, tectonic structure, lithological or petrographic composition of the rocks, protected status of the relic.

Keywords: geoconservation, monitoring, geology, geotourism, Landscape Park

Георізноманіття, геологічна спадщина та оновлення мережі геосайтів Дніпропетровської області

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Анотація. Розглядаються відносно нові поняття у Науках про Землю, такі як георізноманіття, геологічна спадщина, геоконсервація, геосайти, геопарки та їх практичне використання в Україні. Різноманіття геологічних процесів, структурно-тектонічне положення Дніпропетровської області, складна і тривала геологічна історія розвитку території, яка охоплює інтервал часу від докембрію до четвертинної епохи, у поєднанні з великою кількістю природних і штучних виходів гірських порід зумовили надзвичайну насиченість її різноманітними об’єктами геологічної спадщини. Стило проаналізовано історію надання об’єктам геологічної спадщини області офіційного статусу таких що охороняються державою та співвідношення їх кількості з перспективними геологічними пам’ятками природи, які потребують охорони. Акцентовано увагу на проблемі вкриття недостатньої уваги владних природоохоронних організацій України до необхідності збереження геологічної спадщини попри всі позитивні зрушення у відношенні до збереження геологічної спадщини на Міжнародному рівні, серед яких створення Європейської асоціації зі збереження геологічної спадщини, стрімкий рух зі створення геопарків за підтримкою ЮНЕСКО тощо. Надається якісна і кількісна оцінка геологічних пам’яток природи та розподіл їх за типами у відповідності з діючими класифікаціями. Рекомендовано розглянути можливість включення одного з перспективних об’єктів, який входить до складу

Klychëvi slava: geo-konservatsiïï, moïitoring, geologiïï, geoturiizm, landshafnt park

Introduction

After the term biodiversity had been long used in the nature sciences, in the 1990s there emerged the term geodiversity as a geological equivalent to biodiversity and this is rapidly gaining popularity in various spheres of the Earth sciences (Gray, 1993, 2001). Prior to this term, the terms landscape diversity and geomorphological diversity had been in circulation, used by an Australian geologist Kevin Kiernan in Tasmania (Kiernan, 1991). One of the most well-known definitions of geodiversity is considered to be the one given by a Polish geologist S. Kozlovskyi: «geo diversity is the diversity of the Earth’s surface in geological and geomorphological aspects, soils and surface waters, as well as other systems created first of all as a result of natural processes (endogenous and exogenous), and also human activity» (Kozlowski, 2004a; Kozlowski, Migaweski, & Galushka, 2004b). Based on the vast diversity of geological phenomena and processes, the list compiled by S. Kozlovskyi can be expanded and improved, since all abiotic objects surrounding us are actually geodiversity (Samoilova, Samoilich, Manyuk, 2015). Along with geodiversity, there have emerged and quickly gained popularity terms such as geological heritage, geoconservation, geosites, geoparks and geotourism, without which it is now hard to imagine a substantial scientific study in the sphere of natural sciences, especially in a geological aspect.

Results and analysis

Dnipropetrovsk Oblast, situated at the conjunction of the Ukrainian Shield and the Dnipro-Donetsk and the Black-Sea Depressions, can be without exaggeration called a pearl of the geological heritage of Ukraine. At the moment of the inventory checking of the geosites of Ukraine, carried out since 2003, there were 14 objects in the Oblast with the official status of the geosites, included in the Register of the Protected Nature Fund of Ukraine (PNF) (Manyuk Vad.V., Manyuk Vol.V., 2011). Nineteen years later, despite all the positive changes in the preservation of the geological heritage at international level, includ-
ry and Outcrops of the Ovseieva Ravine (Geological landmarks of Ukraine, 2007). Characteristics of each of those objects, particularly the geological description, stratigraphic and tectonic position, mineralogical and petrographic compositions, ecological condition, the possibility of using the objects for geotourism and other information are given in the author’s numerous reports published in various years.

After the 4 edition of the Geological Landmarks of Ukraine, the studies assessing the potential of the geological heritage of Dnipropetrovsk Oblast and further development of the network of geosites of nature have not been stopped, and – according to the results of field monitoring – the known objects were expanded by 30 new geological nature relics, making the total number of geosites 72. Taking into account the great number of natural and mining-exposed outcrops of Precambrian crystalline rocks, it is no surprise that among the geological relics, objects of petrographic, mineralogical and tectonic types predominate, accounting for 22, against 2 paleontological, 1 glacial and 8 stratigraphic. It has to be noted that the type-based classification is conventional and most geosites are complex. Most of them create special forms of relief, distinct elements of landscape and can be classified to geomorphologic type. Others characterize specifics of sedimentogenesis and can be considered as lithological-sedimentational. Many of the geosites are associated with mining of natural reserves and therefore have a historical-geomorphologic aspect.

Returning to the qualitative evaluation of new objects of geological heritage in Dnipropetrovsk Oblast, we have to conclude that most of them – despite their high aesthetic attractiveness as objects of geotourism – belong to the category geosites of local-significance. Four geosites that characterize various important aspects of geodiversity of the region could be considered as monuments of national significance – according to the B.Wimbledon’s criteria of selection (Wimbledon, 1999). As for objects that can be nominated for inclusion the list of geosites of the European level, there are quite sufficient reasons to propose the numerous natural and mining-exposed Precambrian crystalline outcrops in the Dniprovi Porohy Regional Landscape Park (RLP), which have even a greater significance if one takes into account the historical aspect of the territory, which includes the world-renowned Dnipro Rapids, which are now deep underwater (Maniuk, 2018, 2019).

Identifying new geological-heritage objects in Dnipropetrovsk Oblast implies providing them with a scientific characteristic so as to substantiate the official nature-reserve status in the new post-war Ukraine, when hopefully there will be conditions for a better attitude to the conservation of both geodiversity and biodiversity.

1. **The Dnipro Rapids** are one of unique creations of nature on the great Dnipro that carries water across three countries and cuts through the Ukrainian Crystalline Shield (US). It is the latter that was in the river’s way, its ancient Precambrian rocks crossing the river over a large distance between Stari Kodaky village, the northern Kodatskyi Rapid, and Velykyi Luh village in the south, where there was Yavlena Zabora [zabora refers to a «fence» of rocks – Translator’s note], and slightly upstream there is the last of the Rapids – Vlïny. After construction of the Dnipro Hydroelectric Plant and flooding of the rapids, their vibrant life became history, but their continuation on the Dnipro banks as picturesque rocky outcrops have made for remarkable picturesque landscapes. Therefore, it is no surprise that ordinary people, scientists and nature protectors have always wanted to preserve this beauty for future generations. The first step towards making the dream come true was 1974 creation of the Dnipro Rapids Geological Reserve of National Significance in Zaporizhia. Twenty years later, thanks to the efforts of researchers, in particular Hubkin A.A. and geobotanist Manyuk V.V., the second step to conservation of geo- and biodiversity of the Rapid Dnipro was taken and the part of the Dnipro rapids became a RLP. After five years of laborious work following the writing of the project, the Prydniprovskyi RLP covering 4,917.9 ha was established. Despite great hopes and expectations, for long 9 years the park existed only on paper. The year of the park’s rebirth, or rather actual birth but under the name Dnipro Rapids, was 2017, when the initiative group took decisive actions to bring back the idea of serious conservation of the unique object of nature heritage, supported by all the branches of power. This can be considered the third step, aimed at protecting wildlife in the area where in the past the river could be heard making its way down through the famous Rapids. The current area of the park accounts for 49 km², though complete preservation of the landscape of the Dnipro Rapids requires expansion of the protected area to 150-200 km², with the prospect of subsequently reorganizing it into a national nature park (Fig. 1).

It is the diversity of geological processes, which have been acting for a long time, and vibrant geological history, which is etched in the stone chronicles or rocks and minerals, that had created the object for many generations to admire – the Dnipro Rapids. All this natural diversity brought about the inimitable rocky landscapes of the Dnipro banks, which – com
combined with the historical value of the Dnipro Rapids, unique biodiversity of the territory – are an unsurpassed geotouristic object of international significance (Manyuk, 2018, 2019).

The geosites proposed to be accorded the status of nationally significant objects are as follows:

2. **The section of lake-glacial deposits in the mouth of the Kilchen River.** Dnipropetrovsk Oblast is where the largest southern margin of the Dnipro (Riss) Glaciation is located, marked by erratic boulders in Domotkan village (already mentioned above, the Borodaivski Boulders). The position of the southern margin of the glacier remained untouched on maps since 1939 (Herasymov, Markov, 1939). However, in 2012, there emerged grounds to update the boundary. The field studies in the interfluve of the Kichen and Samara rivers, between Pidhorodne and Spaske villages, found conclusive evidence to delineate the southern border of the glaciations much more to the south of the known position (Fig. 2).

![Fig. 1. Granite outcrops of the Dnipropetrovsk Complex within the Dnipro Rapids RLP](image1)

![Fig. 2. Outcrops of marine loams (1) and layered limnoglacial deposits (2) in the mouth of the Kilchen River](image2)
Beneath the layer of Kodatskyi fossil soil (ePIIkd), there were found limnoglacial deposits of the Dnipro horizon (lgPIIIdn) with small relics of moraine deposits in the roof of the layer (Manyuk, 2013, 2021). Fragments in the moraine are represented by quartz, granite and quartzitic sandstone.

3. Tokivske Granite Canyon. In 1974, it was included in the register of NRF of Ukraine under the name Picturesque Canyon on the Kamianka River in Tokivske Granites. A deep canyon, cut by the Kamianka river, is a geosite that is unique for the steppe Ukraine. It characterizes a fragment of the structure of the Tokivske granite massif and is known for its attractive landscape.

The Tokivske Massif is located between a strip of metamorphic rocks of the Vysokopillia syncline structure and the layer of metamorphites of the Chortomlynsolohivske greenstone structure and among the granitoids and gneiss-migmatite formations of the Dnipropetrovsk Complex. In relation to the containing layers, they are discordant, which to a certain degree determines their position in the tectonic structure of the area as post-folding formations. The granites that make up the Tokivske Massif are characterized by a massive homogenous structure, and therefore the elements of internal structure are hard to identify. In some zones, there is notable fluidal location of microcline porphyroblasts, much rarer there are seen flat-parallel structures, caused by the oriented position of biotite plaques. Almost ubiquitously within the Tokivske Massif, there are observed small fault-like dislocations, zones of folding and fragmentation. According to the system of orthogonal fractures, the granites are saturated with diabase dikes. By the composition, those are pink porphyry-like granites with distinct violet tone. Besides the normal granites, there are broadly represented subalkaline rocks with up to 10% alkali contents. Usually, they have a low amount of quartz and by mineral composition correspond to granosyenites and even syenites. Amid pink granites, there are areas of grey granites. Numerous vein-like bodies in granites are composed of microcline, albite or plagioclase (monomineral). Local greisenization, sulfidation, and epidotization were also observed. Because of metasomatosis, chlorite-biotite slates form with well-developed granite crystals. Strangely, this object was not included in Geological Landmarks of Ukraine, published in 2007. However, this is one of the most attractive and most visited geosites in the Oblast (Fig. 3).
4. Outcrop of carbon sandstones near Andronivka village. One of the least studied objects of the geological heritage in the plains of the east of the Oblast, bordering with Donetsk Oblast. It is the only place in the region with outcrops of the Carboniferous System in an abandoned quarry. Those are limestones and sandstones of the Efremivskyi Horizon of the Samarska Suite of the Serpuhivskyi Stage of the Lower Carboniferous. Structurally-tectonically, the quarry is situated in the Leliakivske-Oril Structural and facial zone (SFZ) of the Dnipro-Donetsk Depression (Fig. 4,5).

5. Beleliubskoho Rocks. During the revision monitoring in 2003, none of the surveyed local historians, researchers and geologists of Kryvyi Rih mentioned this object, leaving it out of attention. Therefore, visiting it in 2021 became a real discovery. Not only is it a large rocky structure near the Beleliubskoho Bridge, composed of hematite-martite quartzites, but it also exposes rocks of an old quarry, specifically the Pivdennyi Quarry of pre-Revolutionary ATKZR, which form a picturesque landscape on the Inhulets river curve (Fig. 6).

At first, the rocks under the bridge were thought to be residuals of quarry mining, but these doubts were dispelled by a well-known researcher of the region Valerian Domger, who travelled there in 1883. He wrote: «Near the railroad bridge of the Katerynivska Railway and somewhat higher, there are large ferrous-quartzitic slates, to a high degree represented by ferrous-micaceous rocks…» (Domger, 1902). All the outcrops belong to the Saksahanska Suite of the Kryvyi Rih series of the Lower Proterozoic and are highly acidic limonite-hematite-martite ores, often with a large amount of large-scales ferrous mica, cavernous, nostrilled, thin-slate textures (Fig. 7, 8).

The geosite is also of high historic value, because it is the place where the Kryvyi Rih Iron Ore Company, founded by Oleksandr Pol in 1881, established its first mine in 1889 (Kazakov, 2020).

The rest of the geosites are provisionally considered promising objects of local significance, which
Fig. 6. Geosite Beleliubskoho Rocks

Fig. 7. Rocky outcrops of limonite-hematite-martite ores of the Beleliubskoho Rocks geosite

Fig. 8. Geological relics Beleliubskoho Rocks (1) and the Piskovykova Rock (2) on the map of Precambrian formations.
does not rule out the possibility of raising its status after additional research.

6. Plagiogranite outcrops of the Dnipropetrovsk Complex in the Osokorivka Ravine. On the right slope of the Osokorivka River, near the southern outskirts of Zelene village, the ravine erosion has exposed Precambian crystalline outcrops. They comprise a group of rocky outcrops jutting 8-10 m above the river talweg, have various forms and constitute an interrupted strip along a distance of around 100 m. Besides angular, staircase-boulder rocks, in the upper parts of the slope there are many peculiar weathering-formed rounded boulders, and such that look like boulders shaped by the glacier or rounded basalt lavas, though they are of completely different origin, associated with deep metamorphism of the rocks and their subsequent weathering (Fig. 9).

Fig. 9. Outcrops of plagiogranites of the Dnipropetrovsk Archean Complex in the Osokorivka Ravine (1, 2) and the fragment of the Sarmatian Stage section
Those rocks belong to the Dnipropetrovsk Complex of ultrametamorphic Early Archean rocks with 3.4 B years absolute age. The complex is distributed the most within the Serednioprydniprovskyi Geoblock of the Ukrainian Shield, and significantly predominates over the rocks of other complexes. The rocks of this complex are characterized by increased density and varying magnetism. By petrographic composition, the complex is non-homogenous. In the outcrop in the Osokorivka Ravine, it is represented by diorite-like grey-pink, average-large-grained plagiomigmatites, considered as products of granitization of basites of the Slavhorodska Layers and the Oleksandrivskyi Complex. By texture, the rocks are mostly striped-injected, somewhere massive, folded and spotted. They are composed of plagioclase, potassium feldspats, quartz and notable amount of pyroxenes and small admixtures of ore and accessory minerals. The geosite is even more significant because of nearby outcrops of marls and quartz ochre-yellow sands of the Sarmatian Stage under aeolian-deluvial Quaternary loams.

7. Huliai-Pole Outcrop of metabasites and ultrabasal metavolcanites near Huliai Pole village. On the left bank of the Bazavluk River, there is a group of rocky outcrops with individual rocks reaching the height of 15 m. The river crosses the north-west fragment of the Sura greenstone structure. The structure of rocky outcrops involves metabasites of the Sura Suite of the Konkska Series of the Middle Archean with thin bodies of basites and ultrabasites of the Devladovo Complex (Bazavluk tributary – Koshuvata Ravine) (Fig. 10).

8. Piskovyka (Sandstone) Rock. This geological nature monument south of Kryvyi Rih was brought under protection under this name in 1974. Similarly to other objects, it was not identified during the revision monitoring of Kryvyi Rih area and was not included in the Geological Landmarks of Ukraine book. The terrigeneous deposits of the Kryvyi Rih Suite of the Lower Proterozoic Series form a large rocky outcrop on the left bank of the Inhulets, where the river makes a straight-angle turn west, running to Rudnychne village. By composition, it is a sort of metasandstone-slate rock with intensive manifestation of boudinage (Fig. 11).
A. Lohest (Lohest, 1909) was the first to introduce the term boudinage, deriving from French word *boudin*, meaning blood sausage. The boudinages were first noticed and described by Belgian geologists in a Collignon quarry near Bastogne in the Ardennes (Belgium). Boudinage can emerge in rocks of any age, but is more characteristic for Precambrian layers and folded Mesozoic-Paleozoic areas. A necessary condition for boudinage is presence of a stratum of alternating hard and non-hard rocks that are experiencing high compressing and expanding loadings at the same time. Manifestation of boudinage also ranges microlevel to giant-level boulders in lithosphere plates. Unlike similar rocks of the geological relic Outcrops of Skeliuvatska Suite of the Kryvyi Rih Series, the Piskovykova Rock large-fragment metasedimentary rocks have up to 30 cm boudinages, thus being incredibly similar to the formations that were observed in the outskirts of Oslo during the 33rd International Geological Congress.

**9. Olenivka Quarry.** In a small abandoned quarry on the left slope of the Mokra Sura River valley, there is an individual section of the Sura Intrusive Middle-Archean Complex. In the greater part of the quarry, highly metasomatically altered biotite granites were discovered with high amount of mica (up to 27% of the thin petrographic sections of the rocks comprised biotite, sericite and muscovite). Biotite is chloritized to various degrees (in terms of cleavage ranging plaque-like separations of chlorite to complete dislocation pseudomorphosis). Quartz is seen in several generations: as the main rock-forming element (in areas with relic granite structure) and the later-developed, which is corroding grains of feldspats and «healing» fractures in the rocks. The rock is highly epidotized, chloritized and silicified, with high amount of molybdenite at some places (impregnation, spots, and admixtures). Highly micaceous rocks are often gneiss-like, highly dislocated, deformed and folded, forming ball-like and dome-like structures (Fig. 12).

![Fig. 12. Deformations of metamorphic rocks of the Sura Intrusive Complex in the Olenivka Quarry](image-url)

Petrographic thin sections were typically observed to have the development of sericite as a specific grid on the rock tissue. A similar pattern of sericitization was observed in fault-related metas-
matically altered structures of the Middle Dnipro Region.

10. Outcrops of granites and migmatites of the Dnipropetrovsk Complex in abandoned quarries in the Tatarka Ravine near Kamianuvatka village. In the floodplain and the first above-floodplain terrace of the Tatarka River, quarry mining and also some small outcrops near Nadiezhdovka and Kamianuvata villages has exposed a fragment of the section of plagiogranites and migmatites of the Early Archean (3.2 B years) Dnipropetrovsk Complex. In the migmatites, there are manifestations of striped, spotted and cleavage textures. One of the two abandoned quarries has been flooded and is used by the locals for recreation, and the second is observed to have the most complete and diverse array of crystalline tocks. The granitoid structure is divided by the system of fractures directed in various ways, and further weathering and denudation have created various forms of boulders and blocks. It is where up to 5 cm thick epidote veinlets were found in veins of aplite-pegmatoid granites that cross the granitoid structure (Fig. 13).

11. Erastivka Quarry. The Erastivka field of granites has been known since 1910, but a detailed survey was carried out only in 1987. The quarry is located near the Erastivka Railway of Piatyhatky District. On the upper stages of the southern wall of crushed-stone quarry, there is an outcrop of contact of lower section of the Sura Suite with blue-quartz plagiogranites of the Sura Complex (tonalite-plagiogranite formation) (Fig. 14). The layer of metavolcanites of the Sura Suite represents the lower parts of the section of the northern wing of the Alferivske ramification of the Verhivtseve greenstone structure. The contact pattern is uneven. Right at the contact, the metabasites are observed to have thick (1-3 m) zones of biotite and phlogopite accumulations. Structure of the Sura Suite section includes metavolcanites of the main composition (amphibolites, metabasalts, green slates), veinlets of ultramafic metavolcanites (actynolites, tremolitites), tuffaceous-sedimentary formations and comagmatic cutting and sill-shaped bodies of metagabroids, metadolerites, metadiabases, and also diabase dikes. The lavas of the metabasalts contain ball-like and pillow-like textures. The balls range from non-deformed to flattened (Geological Landmarks of Ukraine, 2007).
12. Ovseieva Ravine. In the pre-mouth part of the Ovseieva Ravine, there is an outcrop of section of deformed pillow lavas of metabasalts and migmatites, intruded by plagiogranitoids of the Sura Complex. Metavolcanites are represented by various-grain amphibolites, metabasalts, and green slates. The latter are in paragenesis with veinlets of ultramafic metavolcanites (pyroxenites, metakomatiites, actinolites, tremolitites – up to 1-3% of the section), tuffaceous-sedimentary formations of the main composition, bodies of metagabroids, dolerites and diabases. It is important to note that in the ravine there was determined a contact of plagiogranites of two principally different structure-formation Precambrian complexes of the Ukrainian Shield, distributed within the Middle-Dnipro granite-greenstone region. One of the petrotypes of plagiogranites is involved in the structure of the basement of greenstone structures and is geologically ancient, while the second is included in the association of intrusive formations of tonalite-plagiogranite formation that formed at the final stage of development of the greenstone structures (Fig. 15).

![Fig. 15. Outcrops of metabasalts of the Sura greenstone structure in the Ovseieva Ravine](image)

13. Paleogenic and Neogenic outcrops in the Skelka Ravine. In the Skelka Ravine, which cuts the right slope of the Byk River in the area of Natalivka and Slovianka villages, in the lower pre-mouth part of its right slope, there is a quite large sand quarry. The walls of the quarry contain a fragment of section of Quaternary, Neogene and Paleogene deposits (Fig. 16).

![Fig. 16. Paleogene and Neogene outcrops in the quarry in the Skelka Ravine. The general view of the quarry (left) and quartzite-like sandstones (right)](image)

In the lower part, there are deposits of light-green glauconite-quartz fine-grained clayey sands of the Berekska Suite of the late Paleogene (3-4 m). With an erosive washout, they above are overlapped by sands and gravelites of the Novopetrivska Suite (3 to 8 n) and Quaternary loams (0.5-4.5 m).

The great value of the sands in the area was described by the well-known researcher of the area Vа-
lerian Domger, «The largest thicknesses of sands, in my opinion, are between Novoandronivka and Iliashchivka, especially on Lypko’s land, opposite Slovianka village…Opposite Slovianka, one such hill reaches 10 m height; below it is composed of white, grey and green sands, and at the top, as a cornice, there is a layer of up to 1.5 sazhen-thick sandstone (Domger, 1882).

A section of the Novopetrivska Suite has the greatest scientific and practical value. It is represented by typical delta facies, characterized by various types of cross-bedding, overlapping with gravel and large-grain sand, presence of silification with formation of thin layers of gray quartzite-like sandstone. Ukraine’s best titanium and zirconium fields are associated specifically with sands of the Novopetrivska Suite.

Somewhat below the quarry, but on the slope of the Byk River valley, there are large ochre-brown and red boulders of very solid quartzite-like sandstone, drifted from the Novopetrivska suite sands by the slope processes.

**14. Rocky outcrops of granites and migmatites on the Saksahan River between Ordo-Vasylivka and Mariivka villages.** The area of the Saksahan River between Mahorty and Ordo-Vasylivka villages is decorated with numerous outcrops of granites and migmatites. As individual rocky ledges and groups of rocks above the river, mostly its right bank, they configure a picturesque landscape. By age, the rocks belong mostly to the late Archean Demurynskyi Complex (2.965 B years), the formations of which make up the Demurynskyi granite-gneiss Dome within the Middle-Dnipro Block of the Ukrainian Shield. Furthermore, the main mass of the Demurynski granitoids contains small bodies of amphibole-biotite gneisses and migmatites of the Skeliuvatska Layer. Petrologically, there are mostly pink-grey average-sized crystalline plagiogranites and plagiomigmatites, often with distinctly impressed injection-striped texture, with boulder-staircase jointing, significantly smoothened by weathering and denudation (Fig. 17).

**Fig. 17.** Rock outcrops of granites and migmatites on the Saksahan River

**15. Petrykivka Quarry on the Byk River with outcrops of the Sarmathian Stage and the Novopetrivska Suite.** In a high ravine on the right slope of the Byk River, near Petrykivka village and near a picturesque river curve, there is a sand quarry that hosts an exposed fragment of typical section of the
Novopetrivska Suite and the Sarmatian Stage of the Neogene. The quarry is deeply cut into a high bank ledge in the form of amphitheatre, with up to 15-20 m high walls. In the lower part of the section, there is an outcrop of a thickness of alternation of light-grey to white and yellow gray fine-grained, well-sorted quartzitic sands, which belong to the Middle-Novopetrivska Miocene Subsuite. Crumbling and loose sands alternate with compacted and darker clayey sands.

The upper part of the section contains the thickness of alternation of light-grey, grey and ochre-yellow, average-grain quartz loose or slightly clayey sands, belonging to the Volyn and Bessarabia Sub-stages of the Sarmathian Stage of the Miocene Section of the Neogene System. The age of the rocks has been confirmed by discoveries of fossil Ostracoda and Foraminifera, typical for the Sarmatian Stage.

16. Malomykolaivskyi quarry on the curve of the Samara river with Neogene and Paleogene outcrops. In a high ravine on the right slope of the Samara River, near the northern outskirts of Novomykolaivka village, there is a sand quarry where a fragment of typical section of the Novopetrivska Suite of the Neogene System and Mezhyhirskaya Suite of the Upper Oligocene has been exposed. The quarry is deeply cut into a high bank ridge in the form of amphitheatre, about 300 m long with up to 10-15 m tall walls. In the upper part of the section, under the aeolian-deluvial loams of the Quaternary System, there is a layer of homogenous, white, loose, well-sorted quartzitic sands, which belong to the Neogene Novopetrivska Suite. In the lower part of the section, there is an outcrop of layer of greenish-gray aleurolites of the Mezhyhirskaya Suite (Fig. 19). Because the only Paleogene outcrop on the Vovcha River near Pryvovchanske village is inaccessible for examination (buried beneath the scree), this section is unique.

Fig. 18. Petrykivka Quarry on the Byk River with outcrops of the Sarmatian Stage and Novopetrivska Suite

Fig. 19. Outcrops of Neogene (1) and Paleogene (2) rocks in Malomykolaivkyi Quarry
17. Outcrop of the Sarmatian Stage with fossil molluscs in Horoshevo village. The faunistic and floristic diversity of the Horoshevo Tract harmonically supplements the aesthetically attractive landscape of the upper part of the Vorona Ravine, the relief pattern of the slopes down to the ravine bed, and specifics of geological structure of this territory. Together with the geological nature relic Suha Kalyyna, located in the pre-mouth part of the Vorona River, those are the only northernmost outcrops of carbonate deposits of the Sarmatian Stage of the Neogene System of the Cenozoic (Fig. 20).

Fig. 20. Outcrops of the Sarmatian Stage with fossil molluscs in Horoshevo village

There, one can see impressions of the last marine transgression in history, when the sea ran deeply into the Ukrainian Shield. Marls and limestones, outcrops of which are located on the ravine’s slope, contain well-preserved shells of various molluscs that once had lived in the warm Sarmatian Sea. Besides the dominant *Solen subfragilis* M. Hörn, *Mactra vitaliana*, *Cardium fittoni*, etc are found.

Conclusions

The powerful technogenic impact on the environment, depletion of and construction on the lands ruination and destruction of outcrops of rocks and minerals, manifestations of tectonics, volcanism, glacial and aeolian processes, karst-formation and weathering – all of this accentuates the need to draw attention to conservation not only of biodiversity, but geodiversity as well. By contrast to wildlife, vanishing of the objects of geological heritage is irreversible, because its components took millions and even billions of years to develop. The entire territory of Ukraine is characterized by a high level of geodiversity, quantitatively and qualitatively. There are impressive columnar basalts in Rivne and Zakarpattia Oblasts, unique deposits of amber in Polissia, beryls and topazes in chamber pegmatites of the Europe’s largest deposits – the Volyn Field, thick and extremely informative manifestations of salt diapirism in the Dnipro-Donets Depression, snow-white chalk mountains in Kharkiv Oblast, the Crimea and the Donbass, various manifestation of Jurassic volcanism in the Crimea, the Hercynian orogeny-uplifted folded structures of the Donets Ridge of the Devonian, Carboniferous and Perm periods, unique flysch thicknesses of the Crimea and Carpathians and many others. The absence of mountainous landscapes in Dnipropetrovsk Oblast is compensated by numerous natural and mining-exposed Precambrian rocks characterizing the structure of greenstone and dome structures of the Ukrainian Shield, Kryvyi Rih deposits of iron ore, Nikopol manganese deposits, Malyshevske deposits of placer titanium, Tokivskyi and Kudashivske deposits of granites, notable signs of Dnipro (Riss) Glacial Epoch, fragments of sections of paleontologically well characterized deposits of the Paleogene and Neogene epochs, detailed and stratotype Quaternary sections. All this has created powerful grounds for development of geotourism in the region, and shows the need to move beyond mere recognition of promising objects of geological heritage towards recognition of their uniqueness, providing official nature-protection status at both local and national levels.
References


