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Geological heritage of Valerian Domger in the Middle Dnipro Region

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Abstract. The paper looks at the significance of the scientfic geological studies of the famous geologist Valerian Domger and their importance for the development of geotourism in the region and Ukraine in general. We analyzed his works in the historical aspect from the beginning of his work as a geological practitioner to his becoming a reseracher of stratigraphy, paleontology and lithology of sedimentary deposits and geology of Precambrian formations of the Ukrainian Shield. We focused on the geological routes he took when travelling along the lines of railroad construction, including Orenburg, Ural, Mariupol (Donetsk) and Katerynoslav, analyzing the conclusions on the structures of those territories, as well as perspectives of finding natural resources in them. We characterized the most important routes V. Domger travelled when he was conducting geological surveys of the 47th sheet of the ten-versta map on the area of about 13 thou versts in Verhniodniprovsk and Katerynoslav powiets of Katerynoslav governorate, and also Kherson and Oleksandria powiets of Kherson governorate, which led to his most notable discoveries, namely the Nikopol deposits of manganese ores, a unique location of the Mandrykivka fossil fauna of the Upper Eocene and others. The achievements of V. Domger as a paleontologist were ahead of his time and – despite attempts of some notable researchers to refute the Late Eocene age of the Mandrykivka layers, the first identifications of the researcher were accurate and have been convingcingly confirmed by moderndday studies. Despite their high popularity, the layers had no status in the stratigraphic resarch until 2000. The Commission of the Stratigraphic Classification and Nomenclature of National Stratigraphy Committee of Ukraine had examined the application from the author of this article regarding the Mandrykivka layers and recognized them as an individual stratigraphic unit (layers with a geographic name). For the first time, we noted the importance of the V. Domger's routes and the outcrops he described when creating the data base of those geological heritage objects, their further inclusion to the Nature-Protection Fund of Ukraine and their use in the development of the region's geotourism.

Keywords: geotourism, geosite, Domger, geological routes, Mandrykivka fauna, Skeliuvatka suite

Геологічна спадщина Валеріана Домгера у Середньому Придніпров'ї

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Анотація. В статті розглядається значення наукових геологічних досліджень видатного вченого-геолога Валеріана Домгера та їх значення для розвитку геотуризму в регіоні та в Україні в цілому. Проаналізовані результати його діяльності у історичній площині від початку його роботи як геолога-практика до становлення як вченого-дослідника у питаннях стратиграфії, палеонтології і літології осадових відкладів та геології докембрійських утворень Українського щита. Досліджені геологічні маршрути вченого, які він здійснював вздовж ліній будівництва залізниць, серед яких були Оренбурзька, Уральська, Маріупольська (Донецька) та Катеринівська та проаналізовано висновки як щодо геологічної будови цих територій, так і перспектив виявлення у їх межах корисних копалин. Охарактеризовані найбільш важливі геологічні маршрути В. Домгера при проведенні геологічної зйомки 47 аркушу десятиверстної карти на площі близько 13 тис. верст у Верхньодніпровському та Катеринославському повітах Катеринославської губернії, а також у Херсонському та Олександрійському повітах Херсонської губернії, наслідком яких були найбільш значні його відкриття, а саме відкриття Никопольського родовища марганцевих руд, унікального місцезнаходження мандриківської викопної фауни верхнього еоцену та інші. Висвітлені досягнення В. Домгера, як палеонтолога, які випередили час і попри намагання деяких відомих дослідників спростувати пізньоеоценовий вік мандриківських верств, перші визначення вченого виявилися вірними і переконливо доведені сучасними дослідженнями. Попри їх надзвичайну популярність, верстви до 2000 р. не мали будь-якого статусу у стратиграічних дослідженнях. Комісія

із стратиграфічної класифікації на номенклатури НСК України, розглянула подання автора даної статті стосовно виділення «мандриківських верств» та прийняла рішення затвердити «мандриківські верстви» як самостійну стратиграфічну одиницю (верстви з географічною назвою). Вперше акцентовано увагу на значення маршрутів В. Домгера та описаних ним відслонень для створення бази даних об'єктів геологічної спадщини, подальшого їх включення до Природно-заповідного фонду України та використання їх для розвитку геотуризму в регіоні.

Ключові слова: геотуризм, геосайт, Домгер, геологічні маршрути, мандриківська фауна, скелюватська світа.

Introduction

The Middle Dnipro region, or Middle Prydniprovia, is considered to be the territory situated on both sides of the Dnipro, which tectonically corresponds to the Seredniоprydniprovsky geoblock of the Ukrainian Shield and parts of the Black Sea and Dnipro-Donetsk depressions that border it. This region has been extensively explored by one of the most famous researchers of the Ukrainian south, represantative of the Geological Committee, Valerian Domger. Among many researchers of the region's geology, V. O. Domger was notable for his bright personality, extrordinary talents, skills, exceptional enthusiasm, and persistence, which he demonstrated during his geological journeys. It would be hard to find any printed material or even a manuscript dealing with the region's geology that does not reference V. Domger. His observations and the conclusions he drew after his journeys are widely quoted. Most of his short life, and therefore short, but nonetheless extremely discovery-saturated geological career, was devoted to the systematic geological studies of then Katerynoslav governorate (modern day Dnipropetrovsk Oblast). After graduating from the Saint-Petersburg Institute in 1873, the young researcher was sent to work for the Department of Mining and Salt Industry of the Province of the Don Cossack to execute practical tasks in 1874. He made thorough descriptions of the geology, and moreover the technical and ecological conditions of ore-processing enterprises of the Russian Steam Navigation and Trading Company (Domger, 1874). The same year, he was assigned to the Main Mining Department and dispatched to Odesa to study briquette making, which he completed by publishing the article «Malking briquettes of small-sized bituminous coal» in the Mining Journal (Domger, 1876a). His further work was familiarizing himself with the geology of Katerynoslav governorate. Commissioned in 1875 by the Mining Department to explore the Dnipro-Inhyl interfluve, he searches for and reveals the potential of discovering the world's largest Kryvyi Rih deposits of iron ore (Domger, 1876b). As is known, the first person who noticed the presence of rich iron ore in the valley of the Inhylets River, near the small village of Kryvyi Rih, was academician Vasily Zuyev, while traveling from Saint Petersburg to Kherson (Travel notes, 1787; Kavun, 2002; Manyuk, 2002). Later, in 1881-1883, V. Domger would return to the search for iron ores in the basins of the Saksahan and Inhulets rivers. In the summer of 1876, he surveys the Devonian and Cretaceous deposits in Orel and Kursk Oblasts. Being interested in paleontology, he gathers a large collection of fossil fauna (Domger, 1878).

Results and their analysis

From 1876 and until the end of his life, the studies of V. Domger were focused on the geological structure of various regions along the railroad lines that were then being actively buildt including the Orenburg (1876), Ural (1877), Mariupol (Donetsk, 1879-1880) and Katerynoslav railroads (Domger, 1879, 1881). His interest lay far beyond the railways – the number of artificial and natural outcrops he had examined is astonishing. When traveling Domger's routes, it becomes clear that he left none of the outcrops there unnoticed, no matter whether they were various-age sedimentary or crystalline deposits or those dating back to the Precambrian. Neither has any – even a smallest – ravine or gully nearby escaped his attention. Domger made his greatest discoveries during the last 4 years of his life. One of the achievements is finding a location containing unique remains of ancient fauna that he identified as dating back to the Upper Eocene, which is impressively accurate (Domger, 1902; Sokolov, 1894, 1905). Nonetheless, the conclusions he made were then debated and «refuted» by respectible stratigraphists and paleontologists, whom nobody had the courage to oppose: M.O. Sokolov, A.V. Gurov, O. Iekel, V.S. Slodkevych and others. What is described here is obviously the Mandrykivka layers, named after Mandrykivka settlement in Katerynoslav (now Dnipro). The 1882 finding of rocks that survived on Monastyrskyi Island during the survey of a foundation for a railway bridge was a great stroke of luck since usually the material from caissons was simply thrown away into the river. As noted by M.O. Sokolov (Sokolov, 1894), Domger was then lucky enough to be in Katerynoslav and select interesting fossils. Based on primary analysis of the collection,

V. Domger concluded that the deposits that hosted them are of Upper Eocene age, comparing them to «coarse limestone» of the Paris basin. Having analyzed Domger's collection, M.O. Sokolov – for many years to come – misattributed the Mandrykivka fauna to the Early Eocene (Sokolov, 1894, 1905).

Obviously, at the time, M.O. Sokolov had reasons for such conclusions. Now, however, the Upper Eocene age of the Mandrykivka layers has been reliably confirmed (Maniuk, 2007, 2012). The story continued in 1891, when – during geological surveys on the outskirts of Katerynoslav – M.O. Sokolov found out that a local enterpreneur of a German descent who is interested in nature studies, A.A. Oswald, has noticead a large accumulation of various mollusk shells discovered in his fruit garden while digging a well. As Sokolov's interest was not exhausted by the collection he received from A. Oswald, in 1894 with permission from the household's owner, he drilled a borehole in the vineyard, near the well, exclusively for extracting fossils (Sokolov, 1895). The further analysis of the collected fossils finally convinces M.O. Sokolov to compare the Mandrykivka fauna to the Oligocene fauna of southern Europe, especially the Lower Tertiary deposits of outskirts of Vicenza as the most well-studied examples. In 1903, to fulfill this idea, he works with collections of Oligocene fossils in major paleontological museums of Europe, particularly the collections of the University of Vienna (Naturhistorisches Museum) and the Hofmuseum. He received considerable support from the president of the Vienna Academy of Sciences E. Zuess, Director of the Paleontological Museum T. Fuchs, K. Mayer-Eymar, A. von Koenen and others (Fig. 1).

Fig. 1. The Imperial Natural History Museum (Naturhistorisches Museum Vienna) and portrait of Eduard Suess Retrieved from: https://en.wikipedia.org/wiki/Imperial_Natural_History_Museum, https://uk.wikipedia.org/wiki/Едуард_Зюсс

Disagreements between M.O. Sokolov and V.O. Domger regarding the age of the Mandrykivka fauna was finally solved after identifying the Upper-Eocene age of the Latdorfian stage in Europe, which had been formely considered Oligocene. In 1947, based on the studies of the fauna gathered using the borehole and from the well that had been formely owned by A.A. Oswald, and also the materials from other sites, M.M. Kliushnikov came to the conclusion that the range of detritis limestone-clayey sands with fossils spreads far beyond Mandrykivka village. Also, he provided numerous evidences of the Upper-Eocene age of the Mandrykivka layers, suggesting that the Oligocene age of the Latdorfian stage with fauna that is remarkably similar to the Mandrykivka one should be reconsidered, and so it happened later (Koliushnikov, 1950).

In 2000, when the author was conducting a GDP-200 geological survey in the territory of the Dnipropetrovsk Sheet, there arose an objective need for designating the Mandrykivka layers as an individual stratigraphic unit. Despite their high popularity, the layers had unsurprisingly no status. The Commission of the Stratigraphic Classification and Nomenclature of the National Stratigraphy Committee of Ukraine had considered the application regarding designation of the Mandrykivka layers, filed by Municipal Enterprise Pivdenukrheolohia, and decided positively, designating the layers as an individual stratigraphic unit (layers with a geographic name) (Manyuk, 2002). The studies carried out using GDP-200 have well substantiated that the Mandrykivski layers are a shallow-water analogue of the Obuhivka suite, which has been typically spreading

over paleodepressions of the southeast slope of the Ukrainian Shield, primarily, the Vilnohirsk, Borodaivka, Samotkan, Shatohynska, Troitske, Murolіubivka and Synelnykove depressions that fall into the Dnipro-Donetsk depression. Most of the sections contain layers with signs of washout on carbonate-terrigenous deposits of the Buchach series, or carbonate rocks of the Kyiv suite (in the mouths of depressions, where they become carbonate-free and with almost no organic remains, deposits of the Obuhiv suite). At higher hypsometric levels, there are embedded layers with Mandrykivka-type fauna, right on the rocks of Precambrian basement or their weathering crust (Maniuk, 2002).

The only place where the Mandrykivka layers can be seen on the surface is the Rybalskyi quarry in the city of Dnipro. Despite the fact that this quarry is in operation, the outcrops of the Mandrykivka layers are almost the most visited object of geological routes of the Sicheslavshchyna (Dnipropetrovsk) region (Maniuk, 2002). For about 50 years since the group of scientists led by the notable paleontologist M.F. Nosovskyi for the first time researched the fauna of the Mandrykivka layers of the Rybalsky Quarry, the outcrops have been visited by geology students of various institutes, as well as school pupils, local historians, paleontologists and geologists from the Netherlands, Germany, France, England, Poland, etc (Fig. 2).

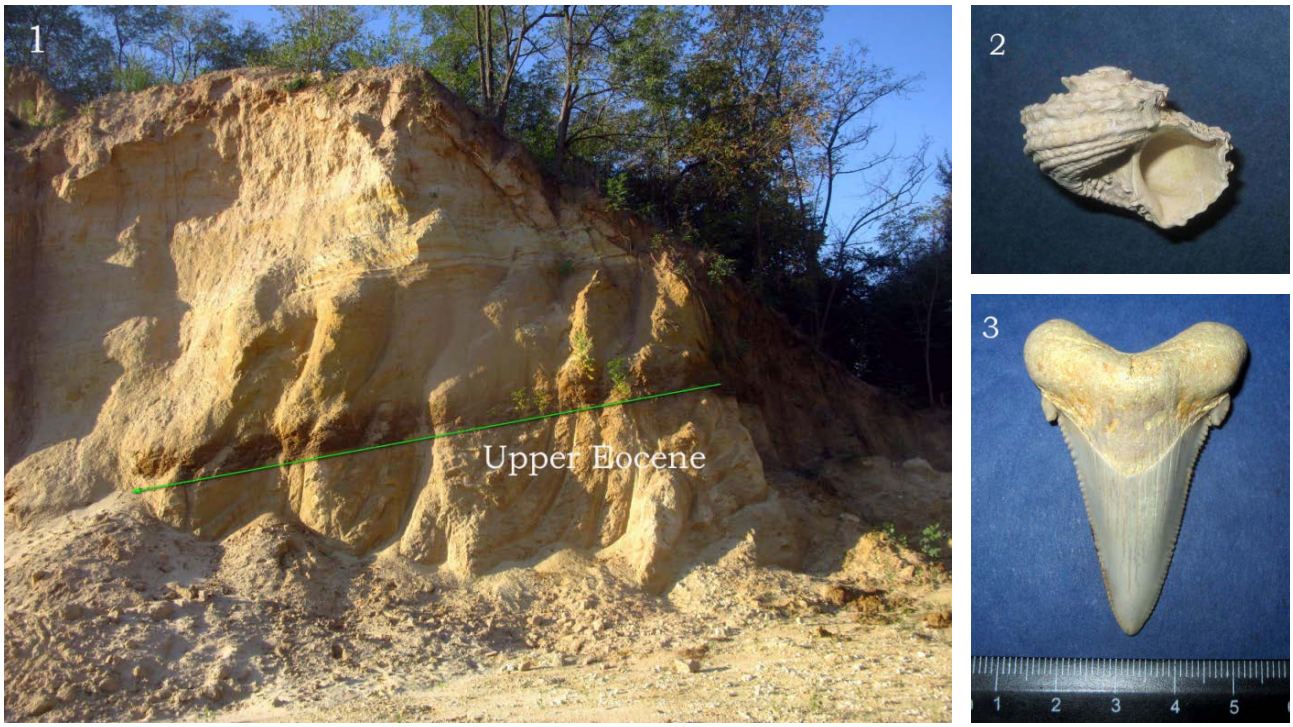

Fig. 2. The outcrops of the Mandrykivka layers in the Rybalskyi quarry (1), *Angaria ostreaeformis* K o e n e n. (2) and *Carcharocles sokolovi* (J a e k e l, 1895) (3) from the Mandrykivka layers (photos by the author).

Despite the fact that the part of the quarry containing the Mandrykivka layers has been out of operation for almost 50 years, attempts to protect the object as a geological monument had no success. However, the heads of the mining enterprise are well aware of the paleontological and geological values of the outcrops of the Mandrykivka layers and continue to restrain the mining works, thus preserving a unique object of geological heritage of European significance.

A bright example of increased interest to the Mandrykivka was the proposition from the International Fossil Shell Museum in Rhenen, the Netherlands, to send the museum a collection of the Mandrykivka mollusks in exchange for any of the collecions of classic sections of the western Europe. As a result of a long communication, an agreement was achieved, enriching the museum with the best Upper-Eocene mollusk shells from the former USSR. In exchange, we received an exceptionally well-preserved collection of late Eocene mollusks from well-known sites in France, Belgium and the Netherlands (114 species) (Maniuk, 2002b). (Fig. 3).

In April, 1882, V. Domger is appointed as an associate geologist of the recently created Geological Committee. He participates in charting of the general geological map of the Russian Empire. During 1882-

84, he carries out geological surveys of the 27th sheet of ten-versta map in the area of around 13 thou versts (14,795 km^2) in Verhniodniprovsk and Katerynoslav powiets of Katerynoslav gevernorate, and also Kherson and Oleksandria powiets of Kherson geovernorate. During a 1883 journey to the south of Nikopol district, V. Domger made one of his greatest discoveries, which has etched his name in history. He finds a rich site of manganese deposits, which was named Nikopolske, after the settlement. According to the manganese reserves, the field is now considered the largest in the world. In his field diary, he wrote: «on the opposite side of the Solona River, near the mouth of the Fomina ravine, on the land of Mr Seyfert, I discovered a layer of manganese ore using a borehole. It is around 1.5 arşın thick, its outcrops are on the surface, and it is embedded on yellow-green clay. This layer is mostly composed of black earthy mass of manganese ore, containing pieces of solid porous ore» (Domger, 1884, 1902).

Fig. 3. Fossil fauna of the Mandrykivka layers from the Rybalskyi Quarry in the International Fossil Shell Museum

Those routes of V. Domger currently play an important role in the development of geotourism in the south of the Sicheslavshyna. Our efforts in cooperation with tourist agencies have helped the organization of geological excursions to abandoned quarries, of visits to a variety of landscapes in the Kahovski Kruchi ravines, where visitors can see an array of fossil fauna-rich outcrops of marine deposits of the Pontiac and Sarmatian stages of the Neogene, which were first described by V. Domger. In this area, V. Domger first determined the presence of Oligocene marine deposits in the basin of the Solona River according to the findings of valves of Panopea Heberti Desh. and *Ostrea califera* Lam. As the author points out, the discovered forms are very characteristic for the Mainz and Paris basins, for Switzerland and Alsace–Lorraine. Later, he found manganese ores in the Pekelne tract and in the area of Olgo-Ivanivka village. Domger's discoveries promoted rapid and powerful development of the mining industry in the region. In 1886, in the area of the Fomyna ravine, the first mines were established – the Pokrovsk Manganese Mines (Nikopol manganese-ore basin, 1964). Nowadays, it is impossible to imagine oneself in the role of a pioneer by reconstructing the routes travelled by Domger when he found the manganese ore, since the natural outcrops he stumbled upon are forever lost, absorbed by large quarries (Fig. 4).

An interesting fact is that the curious researcher V. Domger found signs of manganese ore in the south of Kryvyi Rih, in Novoselivka village, even before the discovery of the Nikopolske field. He writes: «In Novoselvka (Mr Yanytsky), the entire uplifted left bank of the Inhylets River is composed of Sarmatian lime-

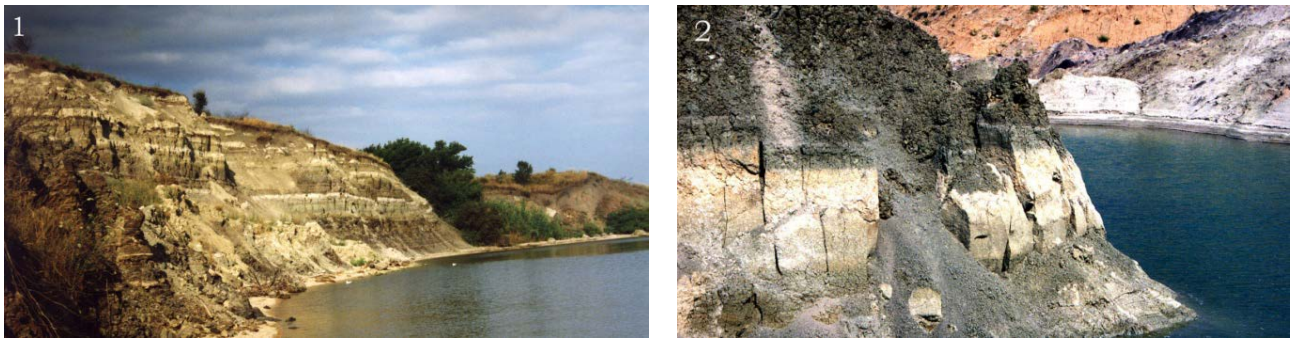

Fig. 4. The outcrops of marine deposits of the Neogene system on the bank of the Kahovka (1) reservoir and the quarry (2)

stones, under which, almost in the stream bed, there could be seen white and brown sands, at some places significantly soaked in black manganese substance, the amount of which is so large that the sand has become black and cemented into an ore mass» (Domger, 1902). The chemical analysis V. Domger performed revealed 22% manganese content. The presence of manganese ore in the area was confirmed by S.O. Frontskevych and S.O. Kontkevych (Kontkevych, 1881). Presence of manganese ore in the south of Kryvy Rih was for the first time determined by H. Feodosiev in 1873 (Feodosiev, 1874). Currently, this layer can be seen further south, in one of the Vizyrka quarries, where the best geotouristic routes of the Kryvyi Rih geological heritage lead. Three abandoned iron ore quarries are united into the Vizyrka Geological Reserve (actually, despite its obvious geological value, it has the status of landscape reserve), a picturesque and important object of geological heritage.

Over the recent years, one of the features of geotouristic routes in the Middle Dnipro Region has been the Appolonivsky volcano. Probably, there are no local TV channels left that would not ask us to show them the Applolonivsky quarry and obtain some film footage. Nobody even though of such popularity of a small abandoned quarry of mining crystalline rocks for construction purposes, located north of Apolonivka village, containing outcrops of fragments of an Archean paleovolcanic structure.

In the times of V. Domger, no quarry was there, but the metabasalts were not left unnoticed. He examined and described all outcrops near the quarry, writing: «On the right bank of the Mokra Sura River, in Uhov's land, there appears to be a hornblende rock of greenish colour, porphyry-like, cut by numerous fractures into sharp-angled fragments…» (Domger, 1902).

The line of the Domger's route runs across this node where the Mokra Sura, Kamyshuvata, Trytuzna and Suha Sura fuse, and where the Apolonivsky quarry is located. In the quarry, there is an outcrop of a fragment of an Archean paleovolcanic structure, which has been generating lava of the main composition. The degree of metamorphic transformations of rocks does not exceed such of the facies of green slates, and therefore on the walls and surface of the quarry, there can be seen unique Precambrian fragments of the paleovolcanic structures of the central type. The zonality of volcanic facies of the paleovolcano has a concentric-symmetric pattern and is manifested by a consecutive change of various genetic types of metavolcanoes from the center to periphery. Formations of the lava group of facies are represented by fine-grained to massive glassy and pillow tholeitic metabasalts, spread in marginal parts of the paleovolcano. Right near it, there are outcrops of large-fragment pyroclastic formations – agglomerations and psammite tuff with no signs of sorting of the fragments by size and shape. In the bed of the quarry, there is a contact between metabasalt currents, the lowest of them is massive and uniform, whereas the upper one is of the same composition, but saturated with fragments (5-20 cm) of discoloured (as a result of syn- and postvolcanic hydrothermal changes) fragments of portions of lava material (from metapelites to meta-metagravelites). The contact line is distinct, tortuous, with numerous streaks (Sivoronov, 1987).

Travelling the routes of V. Domger can be continued in the Dnipro valley, north of the city currently known as Dnipro, where he examined not only the banks of the Dnipro, but also the valleys of the Domotkan, Samotkan, Omelnyk rivers, every small ravine that stood in front of him. We should also note the observations he made when travelling the Samotkan river valley, the mouth of which connects the Dnipro in the city of Verhniodniprovsk (Hryhorivka sloboda until 1806). In this area, near a sawmill, according to V. Domger, there was extraction of rubble for the mentioned Katerynoslav railway, but gneisses of this outcrop turned out to be unsuitable as an artificial stone, similarly to any gneiss. Therefore, a stone quarry in Hlynske village (the Domotkan) was set up, from where all the necessary stone material for piers of the railway bridge across the Dnipro was delivered (Fig. 5.1). As V. Domger believed, the entire bank of the Dnipro, from Katerynoslav to Hlynske is the only

location of outcrops of solid massive pink leucocratic granites that are suitable as rubble (Domger, 1902). The flooded quarry, together with the area of a picturesque ledge of the bank of the Dniprodzerzhynsk Reservoir and the neighbouring water divide, segmented by a dense network of gullies, formed of fluvioglacial currents of the Dnipro (Riss) glacial epoch, are attractive objects for the development of geotourism (Fig. 5.2). Moreover, the entire territory is included in the geologic monument the Domotkan Boulders, which is a definite culmination on the route. In that particular area, there was an ablation zone of the Dnipro glacier, where it has left giant erratic boulders on the site between the quarry and Domotkan village. A recognized fact is that the Riss glacial cover in that region expanded to the south the most, giving reasons to recommend the Domotkan Boulders for the international status of geological monument (Fig. 5.3).

Fig. 5. Quarry in Domotkan village (Hlynske) (1), one of the erratic boulders of the Domotkan Boulders geosite (2), and the position of the southern margin of the Dnipro (Riss) glacier (3).

V. Domger could not have gone past unusual gullies, characteristic for the area north of Verhniodniprovsk. He attributes them to glaciers, but describes their two various types, no doubt owing their origins to the cut-through water of the Dnipro glaciation (Fig. 6).

Fig. 6. Pattern of erosive segmentation of the post-glacier terrain near Domotkan village (photo and satellite image)

The geotouristic route in the basin of the Samotkan and Domotkan rivers has one more attraction, which can be interesting for mineral collectors. During the research on the Samotkan River, V. Domger notes the abundance of gypsum crystals that have grown together in red and grey clays, weighing sometimes

even several poods. He wrote: «The richest gypsum deposits are no doubt in the upper reach of the Samotkan River, in Vilni Khytory village, from where alabaster is taken to fairs» (Domger, 1902). According to the modern stratigraphic scheme, there are Eopleistocene and Lower Pliocene clays. Today, a large amount of gypsum concretions can be seen in stockpiles of quarries of one of the world's largest Samotkan (Malyshevske) field of placer titanium.

Likewise, V. Domger mentions boulders of red quartzite-like sandstone in white quartzitic sands, which now play an important correlation role in the stratigraphic differentiation of the Miocene section of the Neogene. Those gigantic concretions are confined exclusively to the roof of the Novopetrivska suite of the Miocene and are widespread in the outcrops on the bank of Dnipro from the City of Dnipro (Taromske village) to the Samotkan River (Manyuk, 2017). Similar boulders of quartzite-like sandstones, varying yellow-brown to red, were found far away from the Taromski ones, in the mouth of the Skelka ravine, which is a tributary of the Byk river, north of Slovianka village. Those exotic boulders were also described by V. Domger, who characterized them as follows: «In this place (opposite Slovianka village), the right bank of the river is composed of numerous hills, cut by numerous gullies. The hills are constructed from sand, with large amounts of scattered pieces of grey sandstones. One of such hills is 10 sazhen-high (21.3 m); the lower part being comprised of sands of white, grey and greenish colours, and the top containing a layer of brown-yellow sandstone in the form of cornice, up to 1.5 sazhen (3.2 m) thick. This layer is now in many places fragmented into several parts, which from time to time break off the rock and lie lower on the slope» (Domger, 1902). This is what we also observe now, 140 years after V. Domger (Fig. 7).

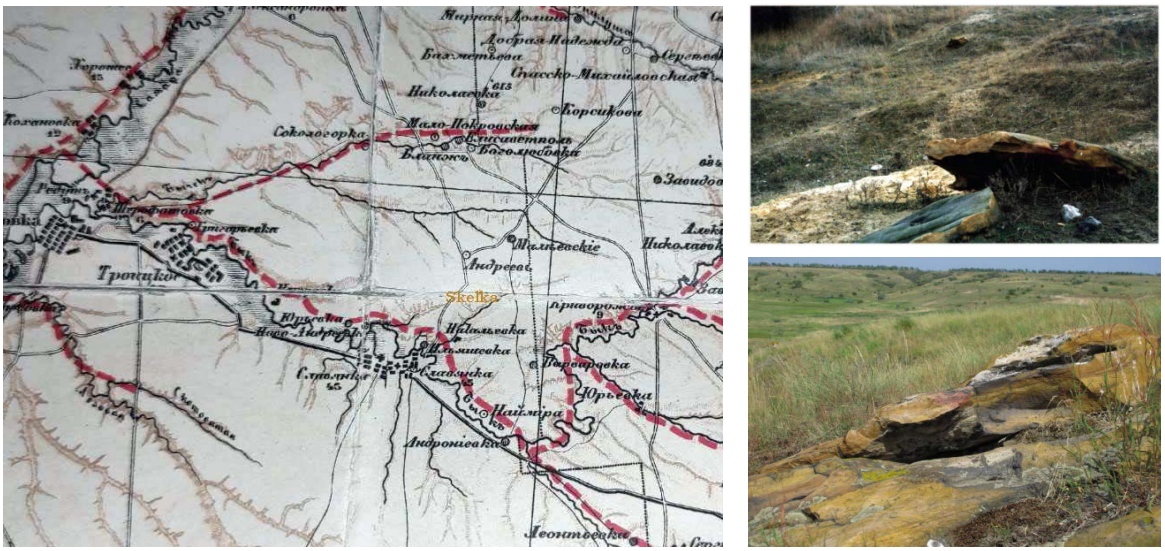

Fig. 7. Fragment of the map of routes of V. Domger (red dash line) with the Skelka ravine and sandstone boulders of Taromske village (above) and the Skelka ravine (below).

A popular object of the geological heritage of the Middle Dnipro region is the geological monument Bila Skelia, located south of the city of Pavlohrad, in the area of Vasylivka village. In 1882, V. Domger found quartzite outcrops on a river curve while examining the valley of the Vovcha River. As he informs us, the outcrops back then were called «Labuzynova skelia» (Fig. 8).

Fig. 8. The Bila Skelia geological monument. Outcrops of quartzites.

Quartzite, according to V. Domger, is in proper strata with general northwest-tended dip under the angle of 45° – 55° and is to a high degree permeated by ferrous garnet in the form of poorly faceted crystals, up to 5 cm in diameter (Domger, 1905). He also noticed the outcrops of the same quartzites somewhat further south, in the Skeliuvata ravine, where now a non-ore quartzite quarry is operating. For a long time, the quartzites have been mined in a quarry near the geological monument, leading to the ruination of both natural landscape and the monument itself. Since 2000, the mining has been stopped, and as of now nothing threatens the geological heritage. The geotouristic routes to the Bila Skelia have been opened and geological excursions for students engaged in education practice have been resumed (Fig. 9).

Fig. 9. Abandoned quarry as an element of a picturesque landscape geosite «Bila Skelia»

Within the Bila Skelia tract, there are outcrops of sections of the Novopavlivska and Vovchanska suites of the West Azov series of the Paleoarchean (AR_1zp). In this area, the *Vovchansk layer* was determined to have a stratotype that has been studied not only in numerous outcrops, but also in wells of the Vasylkivsky structural profile. The sedimentary-volcanogenic metabasite formations of the *Novopavlivka layer* are seen along the Vovcha River in the form of narrow extended anticlinal folds of the third order. They are composed of deeply metamorphosed amphibolites with garnet and amphibole-pyroxen-plagioclase crystalline slates with biotite and magnetite, and also various-compound gneisses: biotite, amphibole- and pyroxene-biotite, garnet-biotite, and in some places magnetite-containing. To a low degree, there are ferrous-silicateous rocks spead, represented by magnetite-garnet-pyroxene slates and garnet-sillimanite gneisses. The boundaries between various petrographic types of gneisses are not always distinct, often have gradual, almost unnoticeable macroscopic boundaries. Within the geosite, the mapped thickness of the Novopavlivska layer accounts for 700-1,500 m. The natural outcrops of crystalline Precambrian rocks – from the remains of the old quarry to their northern border – span around 0.8 km, the height of some rocky outcrops is up to 20 m. The Vovchansk thickness, the rocks of which form almost continuous section, transecting the strike of the linear submeridional structures, is represented by deeply metamorphed gneisses, ferrous-silicaceous rocks, non-ore quartzites, highly-clayey slates and paraamphibolites. The rhythmic structure of the thickness of rocks was determined , allowing for its classification to terrigenous-flysh type. In the outcrops of the Bila Skelia, the metamorphic rocks of clay-earth slates – biotite gneisses – quartzites correspond to the primary-sedimentary differentiation of rhythm: clays – carbonate-clayey sediments – aleurites – sandstones. The ferrous-siliceous rocks have heightened magnetization and are controlled in the magnetic field by positive abnormalities of up to 15-25 thou nT intensity. In this particular area, back in 1928-33, there were found the region's most intensive magnetic anomalies: Troitska, Oleksandrivska, Pavlivska and others. The Paleoarchean age of the rocks of the Bila Skelia geosite was reliably confirmed by isochronous identifications of isotopic age of the rocks, determined in 2001. According to zircon with garnet-biotite gneisses, an isochrone was developed, which corresponds to the age of 3085±8 M years. However, the high samarium-neodymium modal age of those gneisses – T_{nd} (DM) – 4,100 M years – indicates the much older age of their substrate. For plagiogranites (tonalites) of the

Novopavlivskyi complex, which develop on the rocks of the Vovchansk layer, in the northern part of the outcrops of the Bila Skelia geosite, isochrones were identification which correspond to the age of 3400±25 M years (Shpylchak, Manyuk, Sukach, Nekriach, 2007).

In the valleys of the Saksahan and Inhulets, particularly in those areas that cross the Kryvyi Rih iron-ore basin, there is concentrated the largest share of geological monuments that are most important for understanding the geological structure of this district. More than 20 objects of the geological heritage include 10 of the Nature-Reserve Fund of Ukraine and have official nature-protection status (Manyuk Vad., Manyuk Vol., 2011). Some of them are fragments of abandoned quarries that did not exist in the times of V. Domger. They are open to visitors, and some of them are located off his routes. Others are in one way or another mentioned in his field diaries and published materials. Let us look at two most important geosites that are well known in Ukraine and outside its borders. Those are the Skeliuvatski rocks in the south of Kryvyi Rih and the Aspydni slates in its central part. In the official register of the nature-reserve fund of Ukraine, they are known from 1972 as Skeliuvatski outcrops and Slate rocks, or the Outcrops of the rocks of the Kryvyi Rih series near the Kirova mine (Manyuk Vad., Manyuk Vol., 2010).

In his 1881 routes, V. Domger describes the aspide [from Greek iaspidos – Translator's note] (phyllite) slates: «In the garden in Dolhintsevo, including the place where the Saksahan River makes a small curve, there are aspide slates, which spread further to the left bank of the river, forming the so called Pokrovski breccias» (Domger, 1902). In the area of the former Kirova mine, between the Artema-1 and Pivnichna mines, there are fragments of the section of the Skeliuvatka and Saksahan suites of the Kryvyi Rih series of the Lower Proterozoic. The stripe of almost entirely rocky outcrops of the Saksahan suite of the Lower Proterozoic is confined to the so-called Dekontska Petlia (Dekonska loop), a large meander of the Saksahan River in the area of the Kirova mine. The river curve received its name after the surname of a landlady O.M. Nikolska, who owned those lands. The river in this land crosses 5 ferrous and 5 slate horizons of the seven that comprise the Saksahan suite. However, on the surface, there are only slates and a small fragment of the 5th ferrous horizon, and the other are uncovered by underground mining. The length of rocky outcrops is around 1.5 km, the height of rocks is up to 20 m. The slate horizons are composed of association of quartz-chlorite, carbonaceous-quartz-sericite, quartz-sericite-chlorite, quartz-biotite and quartz-amphibole slates. The easternmost position, near the upstream of the Saksahan, belongs to aspide (roof, phyllite) slates of the second and third slate horizons. By composition, those are carbonaceous-quartz-sericite, of thin-plate textures, dark-grey to black slates that were earlier used as roof material. Oleksandr Pol, who for the second time after Vasyl Zuiev, not only discovered the field of iron ores, but implemented the idea of ore mining, started a powerful industrial development of roof slates in the region. The middle subsuite of the Skeliuvatka suite is represented by alternation of metasandstones and quartz-biotite-sericite slates with interlayers of ore-free, but noticeably ferruginized hornblendes, which provides them with a red colour. Unlike the phyllite slates, the rocks are /large-plate (the thickness equals 4-10 cm), but the texture is thin-striped (Fig. 10).

Fig. 10. Geological monument Aspide (phyllite) slates. Left – phyllite slates, right – quartzites.

Thirty-forty meters down the current of the Saksahan River, at the foothill of a road embankment, there is a thickness of light-grey rocks with greenish tone, well slated and greasy-feeling. They are chlorite-talc slates of the upper subsuite of the Skeliuvatka suite. Other than talc, the slates contain chlorite in the form of small, almost colourless or greenish scales and, very rarely, scattered plaques of biotite. In fractures, there are developed iron hydroxides. In the lowland outcrops, among slates, there occur singular gravel of non-ore quartzites and metasandstones (2 to 7 m). Other than V.O. Domger, the aspid slates were studied by S.O. Kontkevych (1889), A.S. Myhalsky, A.V. Faas (1904), I.I. Tanatar (1916), M.I. Svitalskyi (1932), Y.M. Bielievtsev (1939-1958), N.P. Semenenko (1938-1979) and many others. Another object in the geological monument that attracts tourists is a cave known since the times of Oleksandr Pol. It actually is a small adit that was once used for mining of roof slates. It is 28 m long, 3 m wide and 0.5 to 1.9 m high.

A separate mention should be made for the geological monument the Outcrops of the Skeliuvatska suite of the Kryvyi Rih series, located in the southern part of the Kryvyi Rih, in a working-class village Pivdenne of the mining and enriching enterprise. This is a relatively narrow strip of almost continuous rocky outcrops of the Skeliuvatska suite on the left slope of the Inhulets River, of around 0.8 km length. According to V. Domger, «Skeliuvatka village is located on the left bank of the Inhulets, which is mostly composed of slate rocks, particularly clayey, partly aspide (phyllite), greenish, talc-chlorite, which include a small outcrop of ferrous-quartzite slate. All of them form a number of folds and white Sarmatian limestone that overlaps them. The said slates span in parallel to the Inhulets bank, right next to the place where the latter changes is orientation from southern to northwest (Domger, 1902) (Fig. 11).

Structurally, the terrigenous deposits of the Skeliuvatska suite are confined to the eastern limb of the main graben-syncline of the Kryvbas. There is an outcrop of a fragment of the section of metaconglomerate-sandstone-slate formation. From the south to the north, there is seen an association of various graben metaconglomerates, metagravelites and metasandstones, which compose the two- and three-component rhythms and further are gradually changed into average- and fine-gravel and puddingstone conglomerates. Fragmented material is cemented by various-grain metasandstone from fragments of quartz and quartz-sericite filling. One hundred and fifty meters upstream, there is an outcrop of metagravelite-sandstone thickness that is a structure above the formation section. Similarly to metasandstones by mineral-petrological peculiarities, the metaconglomerates are the same as those that make up benches, interlayers and lens-like bodies in metaconglomerates. The metasandstones contain interlayers of meta-aleurolites of 3-5 cm thickness. The northernmost are phyllite slates that can be seen on the slope in the forms of fragment accumulations and small native outcrops. The slates ate thin-plated and laminar, with silky gloss, composed of sericite, biotite and quartz.

The geological monuments (geosite) the Outcrops of the Skeliuvatka suite of the Kryvyi Rih series is one of the best known and the most visited objects of the geological heritage of Ukraine. Such Lower Proterozoic rocks are believed to have no outcrops on the Earth's surface elsewhere in Europe, they are considered an analogue of the famous gold- and diamond-bearing conglomerates of the South Africa (Kazakov et al., 2005). The geosite has unsurprisingly been visited by many international excursions, including the participants of the 33rd International Geological Congress in 2008 (Bobrov et al, 2008; Manyuk, 2009).

An important role in the structure of the Skeliuvatska suite is played by talc slates, spread over various areas of the Kryvyi Rih structure. The largest outcrop is on the right bank of the Inhulets, near Rudnychne village, where up to 5 m-high rocky outcrops are seen 80 m along the slope. Also, their outcrops are in the Inhulets quarry, in Quarry №3 of the Novokryvorizky Mining and Ore-Processing Plant, on the right bank of the Saksahan River, in the area of the abovementioned Dekanska meander. Those peculiar sericite-chlorite-talc slates were for the first time noted by Valerian Domger on his journey through the valleys of the Saksahan and Inhulets rivers. He makes numerous mentions, referring to them as **itacolumites**. This term is not currently used in Ukraine, but Domger called them so for a reason. The name itacolumnite was given to the rock by Alexander von Humboldt in 1823 in his book «Geognostic experiments on rock deposits in both hemispheres of the Earth» (Humboldt, 1823). So what is understood by this term? It is a *metamorphic slate rock with quartzitic cement of regeneration type, composed of quartz, mica, chlorite, talc, sometimes hematite*, rutile, zircon, xenotime, tourmaline, disthene and diamonds. The synonyms are flexible sandstone and articulite (Natural Museum, 2023). The text in Italics directly corresponds to chlorite-sericite-talc rocks of the Skeliuvatka suite, any plate of those slates is bendable, which is the

Fig. 11. Outcrops of the Skeliuvatska suite of the Kryvyi Rih series: 1 – talc-sericite-chlorite slates; 2 – arcose fine-grained metasandstones; 3 – arcose fine-grained metasandstones with ferricretes; 4, 5, 6 – large-debris metaconglomerates

main peculiarity of itacolumites. Earlier, itacolumite was considered a Brazilian diamond-bearing rock, but not all itacolumites were found to contain diamonds. On the other hand, the spread of itacolumites in the section of the Skeliuvatska suite, their inclusion in the metaconglomerate-sandstone-slate formation indicate a possibility of finding diamonds in those rocks (Fig. 12).

Fig. 12. Outcrops of itacolumnites (quartz-chlorite-sericite-talc rocks) of the Skeliuvatka suite near Rudnychne village near Kryvyi Rih (1) and Itacolomi State Park, Minas Gerais, Brazil (2). Retrieved from: https://melhoresdestinosdobrasil.com.br/os-melhores-destinos/ouro-preto-mg/parque-nacional-do-itacolomi-2

Conclusions

The area where the Ukrainian Shield is connected to the Dnipro-Donets and Black Sea depressions is one of the most attractive places for geotourism. More than 60 geological monuments in the area are a bright example of the diversity of the region's geological structure, a significant stratigraphic spectrum of deposits, ranging the Precambrian to the Quaternary (Precambrian, Carboniferous, Triassic, Jurassic, Paleogenic, Neogenic and Quaternary deposits), and a variety of fossils in the area. Just to mention deposits of the global significance within a relatively small area, there are the Kryvyi Rih iron-ore, Nikopol manganese, Malyshevske titanium and circonium deposits, and the Ukraine's largest deposits of kaolin – the Prosiana field. The first most in-depth and productive studies of this whole geological and stratigraphic diversity are in one way or another related to the routes of Valerian Domger, which gave ground to future researchers, encouraging them to make new discoveries. The present study – from the standpoint of evaluation of the geological heritage – covers a large part of his most important studies and discoveries, but nonetheless, a large amount of the researcher's field material still remains to be analyzed and presented. Over 140 years have passed since the times when V. Domger was making the geological surveys in the Middle Dnipro, but the conclusions he made from his trips continue to be relevant today. Currently, in the conditions of increasing interest in the development of geotourism, when any data on geological monuments (geosites) are becoming more significant, we look at the geological legacy of V. Domger more and more often, and therefore are grateful to the talented geologist for providing it to us.

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