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GEOLOGICAL POSITION OF EDIACARAN TERRIGENOUS ROCKS IN THE TERRITORY OF THE MIDDLE DNIESTER REGION OF UKRAINE

The results of summarizing literary data and own observations on the distribution of terrigenous rocks — sandstones, conglomerates, siltstones in the deposits of the Ediacaran of the Middle Dniester region are presented. Terrigenous complexes of various compositions were identified in the deposits of the Grushka Formation, which directly overlay crystalline basement rocks. Rocks of psammitic and siltstone structure in various proportions, thicknesses, granulometric, and mineral composition were identified in the deposits of the Mogylyiv (Olchedaiv, Lomoziv, Yampil beds), Yaryshiv (Bernashivka beds), Nahoryany (Dzhurdzhuvskabeds), Danylivka (Pylypybeds), Zharnivka (Kuleshivska beds), Krushanivka (Kryvchany, Durniakivska beds), and Studenytsia (Polyvaniv beds) formations. The Olchedaiv, Yampil, and Lomoziv sandstones are the most widespread and accessible for further research. These rocks mostly consist of quartz, feldspar-quartz composition, have a platy structure, and light-yellow coloration. The thickness of the sandstones in the most complete sections reaches 25—30m, which is economically advantageous for extraction. The next stage of the study involves selecting samples for laboratory research to refine the peculiarities of the chemical composition, texture, structure, physical-mechanical properties, as well as determining parameters for optimal use.

Keywords: *Middle Dniester region, Ediacaran deposits, terrigenous rocks.*

Introduction

The Ediacaran period, established as an independent taxonomic unit in the International Stratigraphic Scale in 2004, correlates with the Vendian period, previously distinguished in the territory of the former USSR, encompassing all spheres of life on Earth at the end of the late Proterozoic. The Ediacaran lasted for 94 million years from

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the end of the Cryogenian (635 million years ago) to the beginning of the Cambrian period (541 million years ago), marking the end of the Proterozoic eon and the beginning of the Phanerozoic eon. This period is significant because it witnessed the emergence and widespread distribution of the first multicellular non-skeletal organisms (Metazoa) on our planet. They provided impetus for the mass appearance of skeletal fauna in the Cambrian [4].

During the Ediacaran period, sedimentary accumulation processes occurred under special conditions, as the saline regime of the marine environment and physical weathering processes differed from those of the Cambrian or Ordovician periods. Previous studies [1] in the geological sections of the Ediacaran of this territory identified deposits of continental, transitional (lagoon), and marine genesis. They form various lithotypes, which are found in different proportions in terms of thickness, depositional conditions, and extent of layers. This indicates significant variability in lithogenesis conditions and the alternation of transgressive-regressive cycles.

The terrigenous part of the Ediacaran section, which is the subject of this study, accounts for approximately 40% of the total thickness. Studying it is important for paleogeographic reconstruction of the region in the late Proterozoic and provides an opportunity to determine the prospects for the use of these rocks in the national economy.

Most publications regarding the Ediacaran deposits for this territory are dedicated to issues of paleontology and stratigraphy. They focus on studying the aspects of biota distribution along the vertical section, investigating the morphology and preservation conditions of fauna, its classification, taxonomy, and so on. Among the recent works, mention should be made of the works: [5, 7—9].

Lithological studies of the Ediacaran section in this territory were carried out within the framework of the State Geological Survey at a scale of 1:200 000. They are reflected in the work [2] and have a general nature. Some questions about the composition and genesis of individual horizons were considered in publications devoted to the study of ore and non-ore mineralization, including phosphorite [6], kaolinite [10], oil and gas [9], environmental monitoring, and geological environment inventory [3].

The aim of this study is to establish comprehensive information on the distribution of terrigenous deposits on a regional scale, refine the depositional conditions, thickness, and composition in the stratigraphic section. This will provide opportunities for planning detailed studies and assessing their practical use.

Materials and Methods

To obtain a regional picture of sedimentary basin development in the late Proterozoic within Podillya (Podolia) and the study area, archival and published materials related to geological mapping, drilling, mineral extraction, tectonics and stratigraphy, lithology, etc. were processed. In addition, the authors used their own material collected in the field (2015—2019) during the International Ukrainian-French expedition.

To achieve the goal of the work, methods of geomorphological, lithological, cartographic, topographic, hydrological, and paleogeographic analysis were employed.

Research Results

The Podilskyi geological section of the Ediacaran is of global significance and serves as the hypostratotype of the Ediacaran system of the Precambrian [1]. Within the Dniester

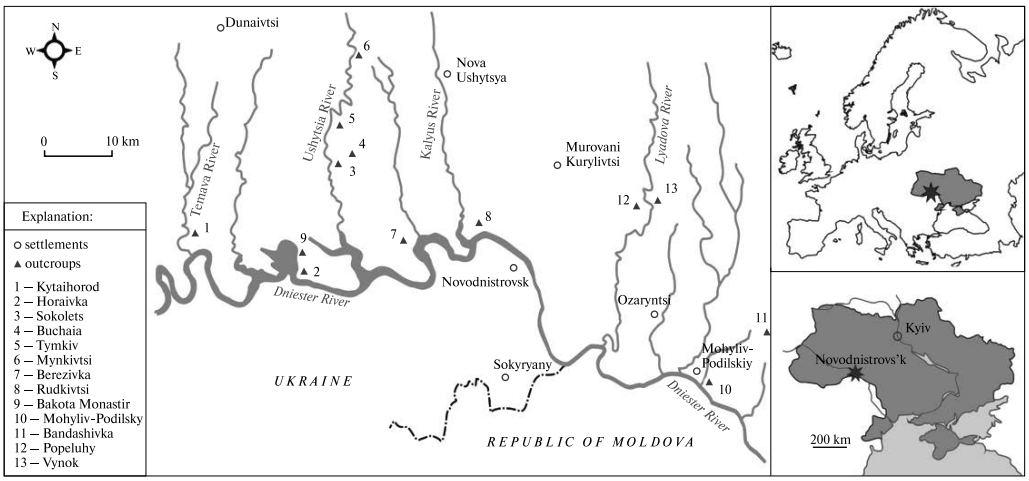

Fig. 1. Scheme of the study area and observation points

structural-facial zone, it is represented by the lower (Volyn Group) and upper (Mogyliv-Podilska and Kanylivka groups) divisions.

The territory of the Middle Dniester region (Podillya) encompasses adjacent areas of Vinnytsia, Khmelnytskyi, and Chernivtsi regions of Ukraine, as well as adjacent areas of the Republic of Moldova, and in geographical terms, it constitutes part of the Podolian Upland. Its relief is a gently undulating plain heavily dissected by rivers, gorges, ravines, and canyons.

The Ediacaran deposits in the study area are exposed on the slopes of ravines, valleys of the Dniester and its tributaries — Derlo, Nemia, Lyadova, Karaiets, Kalius, Ushytsia, Studenytsia, Ternava (Fig. 1). Fragmentary exposures of rocks from the Ediacaran section can currently be observed from the settlement of Kytaihorod in the west of the study area to the city of Yampil in the east. The total length is over 150 km [4].

In tectonic terms, the study area belongs to the southwestern slope of the Ukrainian Shield, with the depth of the crystalline basement ranging from 100 — 150 m in the east (emerging at the surface in deep river valleys) to 1—1.2 km deep in the west. The basement rocks are metamorphosed and composed of granitoid complexes of the Archean and Paleoproterozoic. They are dislocated and complicated by fault disturbances. The Ediacaran deposits overlie the basement rocks with stratigraphic and tectonic unconformities. Often, weathering crust is developed between them. The Ediacaran deposits vary in thickness, lithological, and facies composition.

From bottom to top, three series of sedimentary rocks are distinguished within the Ediacaran deposits: the Volyn, Mogylyiv-Podilska and Kanylivka groups (Fig. 2).

Volyn Group. This group includes the oldest sedimentary rocks, which directly overlie the crystalline basement. In this territory, they are represented by deposits of the ***Grushka Formation***. Mostly, they fill the depressed parts of the erosional relief. Lithologically, they consist of conglomerates, coarse-grained arkose sandstones, conglomerates, breccias. In the upper part, they facies change to thin layers of argillites and siltstones. The thickness of the terrigenous deposits varies from minimal (a few centimeters) to 30—35 meters. The sediments are mostly red, indicating its formation under continental conditions. Mostly, it is composed of a mixture of fragmental components

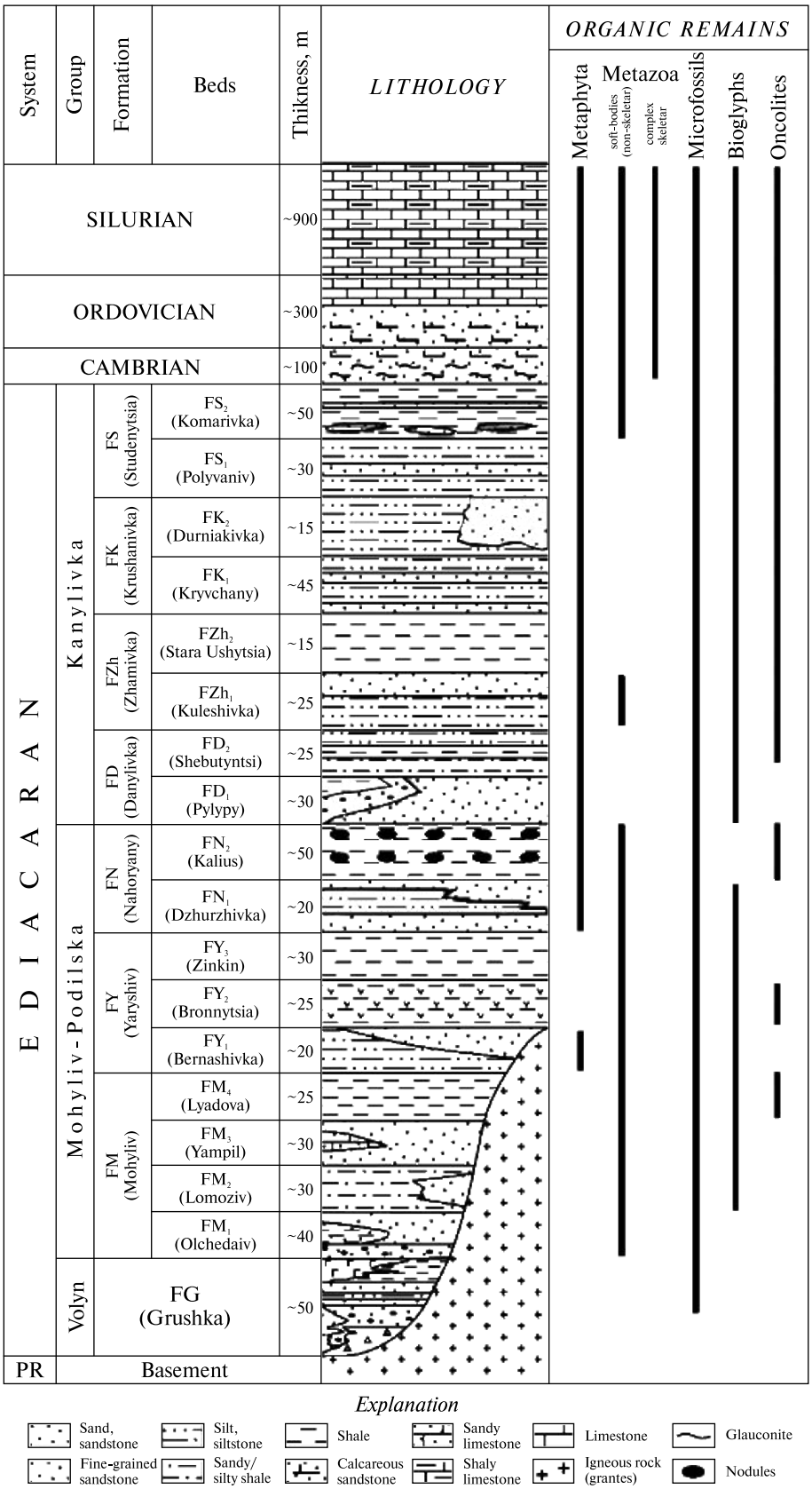

Fig. 2. The stratigraphic scale of the Ediacaran deposits of the Middle Dniester region, based on the materials of previous years [2]

of rocks of magmatic, metamorphic, and volcanic origin and actively altered by chemical weathering processes.

In the root placement, the rocks of the Grushka Formation can be observed on the banks of the Murafa River (Grushka village) and the Lozova River (Sadky village). Their possible mineralization is of interest for further study.

Mogyliv-Podilska Group. On the territory of the study this series is represented by deposits of three formations: the Mogylyiv, Yaryshiv, and Nahirnyany. Terrigenous rocks are identified in the sections of all three formations, but their distribution and composition are different.

Mogyliv Formation is the most representative. From bottom to top, the following layers are distinguished by lithological features: *Olchedaiv, Lomoziv, Yampil*, and *Lyadova* beds.

Olchedaiv beds spread across the entire territory, except for areas with outcrops of crystalline basement. They are revealed in outcrops along the valleys of the Lyadova and Zhvana rivers, as well as in local quarries for sandstone extraction. The thickness in the most complete sections reaches 25—30 m. The main part of the section is represented by arkosic sandstones and conglomerates. Lomoziv beds directly overlie the Olchedaiv beds, composed of interbedded dark-gray argillites, siltstones, and sandstones. Siltstones and sandstones mostly form the upper part of the section and gradually transition into the Yampil beds. The most complete section of the Lomoziv beds is exposed along the valleys of the Lyadova and Zhvana rivers, where their total thickness reaches 20 m. Of these, the terrigenous part accounts for more than 60%. Yampil beds are represented by light-gray, oligomictic, or quartzose, heterogeneous sandstones, with a total thickness of 15—30 m. The deposits of these layers are the most resistant in terms of composition and have a widespread distribution in the research area. In most locations, they lie directly on the Lomoziv beds, except for areas where they rest on crystalline rocks or weathering crusts of these rocks. Yampil sandstones are exposed in natural outcrops along the left bank of the Dniester River, as well as in numerous quarries on the same bank. Lyadova beds do not contain terrigenous facies. They consist of uniformly thick argillites of various colors (greenish, gray, brown). Outcrops of these rocks can be observed along the valleys of the Lyadova, Derlo, Nemiy, and Zhvana rivers. Their thickness ranges from 8 to 20 m.

Yaryshiv Formation includes unites the *Bernashivka, Bronnytsia*, and *Zinkin* beds. Terrigenous rocks are identified only in the Bernashivka beds, where they interbed with argillites. They are exposed in many locations along the rivers Derlo, Lyadova, Kalyus, Zhvana, and the Dniester. Typically, the lower part of the Bernashivka beds consists of argillite, interbedded with argillite and siltstone, while the upper part consists of sandstones of various grain sizes. Sandstone layers have a platy texture and a gray-green color. Their thickness is 0.5—2 m, while siltstones reach up to 10m in thickness. The total thickness of the Yaryshiv Formation deposits in individual locations reaches 15—20 m.

Nahoryany Formation contains the *Dzhurzhivka* and *Kalius* beds. Terrigenous rocks are identified to a lesser extent in the Dzhurzhivka beds. In the lower part of the section, they are represented by sandstones up to 1.5 m thick, and above, by interbedding of sandstones with siltstones and argillites. The Dzhurzhivka beds are exposed along the left tributaries of the Dniester — Lyadova, Zhvana, Kalyus, and Ushytsia. The sandstones are greenish-gray, often kaolinized. In terms of mineral composition, they are mostly two-component, feldspar-quartz, with varying grain sizes. The total thickness of

the Dzhurzhivka beds in the research area ranges from 10 to 20 m, with the thickness of the sandy component being 0.5—4 m. The upper part of the Dzhurzhivka beds gradually becomes clayey and transitions smoothly into the Kalius beds. The latter have an argillitic composition and do not contain sandy or siltstone layers.

Kanylivka Group deposits lie on the rocks of the Mohyliv-Podilska Group with stratigraphic unconformity. A basal horizon and weathering crust is between them. The deposits of the Kanylivka Group are divided into four formations: Danylivka, Zharnivka, Krushanivka, and Studenytsia.

Danylivka Formation is represented by the *Pylypy* and *Shebutyntsi* beds on the research territory. The Pylypy beds, with a thickness of up to 30 m, consist of greenish-gray sandstones. In their composition the presence of volcanic fragmental material is established. The Shebutyntsi beds consist only of clayey rocks and have variegated coloring. Their thickness is about 20—25 m. The sandstones of the Pylypy beds are accessible for study in outcrops near the villages of Pylypy and Kytaigorod.

Zharnivka Formationis represented by the *Kuleshivska* and *Stara Ushytsia* beds on the research territory. Terrigenous rocks (sandstones, siltstones) are encountered only in the Kuleshivska beds, which lie in the lower part of the Zharnivka Formation section. Mainly, this is interbedding of fine-grained sandstones with siltstone-sandstones, with a total thickness of about 10m. Sand layers can be observed along the Dniester near the villages of Stara Ushytsia, Kulishivka, Korshana, and Bakota.

Krushanivska Formation is divided into two parts based on lithological features. The lower part is represented by the *Kryvchany* beds, and the upper part by the *Durniakivka* beds. Terrigenous deposits are present in both parts, but in the Kryvchany beds, they are more homogeneous and thicker, up to 30 m. In the Durniakivka beds, the sandy component is represented by insignificant (up to 0.5 m) layers.

Studenytsia Formationis divided into *Polyvaniv* and *Komarivka* beds on the research territory. Terrigenous rocks are identified only in the Polyvaniv beds. They are represented by interbedding of sandstones, siltstones, and argillites. Approximately 40 % of the total thickness of outcrop deposits is accounted for by the sandy and siltstone part. However, full sections of this formation in outcrops have not been established by us. In the location near the villages of Komarivka and Studenets, their thickness does not exceed 10 m.

Discussion

Terrigenous rocks (conglomerates, sandstones, siltstones) have significant distribution in the Ediacaran section and in many places of the Middle Dniester region they come to the surface. This complex marks the regime of active weathering and erosion, with the transportation of fragmental material to the marine basin from the continent. The nature of the position of terrigenous rocks in the section and their interbedding with clayey facies indicates that the depth of the basin of sedimentation was constantly changing. However, the overall trend was its subsidence with corresponding compensation of eroded material. The processes of terrigenous sedimentation were most active during the Mohyliv-Podilska Group time.

The main supplier of fragmental material to the marine basin was the crystalline rocks of the Ukrainian Shield. This is indicated by the mineral composition of terrigenous deposits, the degree of sorting, and rounding of fragmental grains. The main rock-

forming minerals of the sandstones of the Olchedaiv, Lomoziv, and Yampil beds are quartz, feldspars, and biotite. These minerals also form the bodies of granitoid rocks that were located on the periphery of the Ediacaran basin. The transport distance was short because the final products — sandstones and siltstone-sandstones — are mostly heterogeneous with a slight degree of secondary alteration. They also contain minerals vulnerable to transport over significant distances.

Secondary and accessory minerals of the investigated samples from the Yampil and Lomoziv beds include garnets, light micas, tourmaline, zircon, and sphene.

Sandstones of the Yampil and Lomoziv beds were mined in the 1960s for local needs. According to the inventory results [3], over 30 locations of sandstone extraction in the deposits of the Mohyliv-Podilska Group were identified. Unsystematic, chaotic mining led to environmental degradation, abandoned and un-reclaimed quarries, and accumulation of a significant amount of unutilized raw materials, which often create artificial barriers in riverbeds. Calculating the volumes of extraction due to uncontrolled development is quite difficult. Therefore, the next step in our research is to develop an algorithm for a modern approach to the optimal and efficient use of the natural potential of these rocks.

Conclusions

Terrigenous rocks, mainly sandstones, prevalent in the Ediacaran deposits in the Middle Dniester region, can have significant importance for expanding the resource base of non-metallic minerals during post-war reconstruction if systematically studied.

The main directions of these studies should include: 1) detailed investigation of the physical, chemical, and decorative properties; 2) creation of a registry and determination of priorities for the development of sandstone deposits, considering geological structure, volume, raw material quality, and logistics; 3) development of business projects.

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ГЕОЛОГІЧНЕ ПОЛОЖЕННЯ ТЕРИГЕННИХ ПОРІД ЕДІАКАРІЮ НА ТЕРИТОРІЇ СЕРЕДНЬОГО ПРИДНІСТРОВ'Я УКРАЇНИ

Наведено результати узагальнення літературних даних та власних спостережень, щодо поширення у відкладах едіакарію Середнього Придністров`я теригенних порід - пісковиків, гравелітів, конгломератів, алевритів. Грубоуламкові теригенні комплекси різного складу встановлено у відкладах грушкинської світи, що залягають безпосередньо на породах кристалічного фундаменту. Породи псамітової і алевритової структури в різних співвідношеннях, потужності, гранулометричного і мінерального складу встановлено у складі відкладів могилівської (ольчедаївські, ломозівські, ямпільські верстви), яришівської (бернашівські верстви), нагірнянської (джурджувські верстви), данилівської (пилипівські верстви), жарнівської (кулешівські верстви), крушанівської (кривчанські, дурняківські верстви) та студеницької світ (поливанівські верстви). Найбільшу поширеність і доступність до подальшого дослідження мають поклади ольчадаївських, ямпільських та ломозівських пісковиків. Ці породи в більшості мають кварцовий, полевошпат-кварцевий склад, плитчасту окремість, світло-жовте забарвлення. Потужність пісковиків в найбільш повних розрізах досягає 25—30 м, що є економічно вигідним для їх видобутку. Наступний етап дослідження передбачає відбір проб з відслонень для лабораторних досліджень з метою уточнення особливостей речовинного складу, текстури, структури, фізико-механічних властивостей, а також визначення параметрів для оптимального використання цих порід як корисної копалини.

***Ключові слова*:** Середнє Придністров`я, едіакарські відклади, теригенні породи.