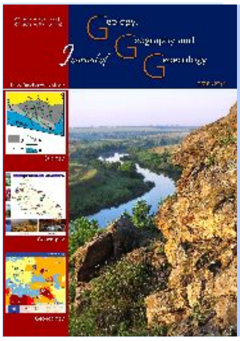

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New biocenosis model of Vendian (Ediacaran) sedimentation basin of Podilia (Ukraine)

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Abstract. The aim of this study is to fully research all aspects of the distribution, development, conditions of burial and preservation of the Ediacaran biocomplex. This work summarizes and extends all data on the unique Vendian invertebrates that are distributed in the natural and artificial outcrops of the Dniester River Basin within Podilia (Ukraine). One of the basic locations of the annual observation was a quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city, which exposes a continuous section of the deposits of the Lomoziv, Yampil, Lyadova and Bernashivka Beds lying on a crystalline basement. This paper shows the outcomes of long-term fieldwork of the Upper Ediacaran which include deposits of the Mogyliv-Podilsky and Kanylivka Group. The researched section is characterized by its clastic composition and the absence of carbonate formations. The basic paleontological collection has more than two thousand specimens, for instance, the imprints of molluscous fauna, traces of their live activity, the remains of flora and fossils of a problematic nature. The most numerous and informative collection of these fossils is located in the stock of the Geological Museum of the Taras Shevchenko National University of Kyiv. The collection contains unique material, including a number of Ediacaran fossils described for the first time. On the whole within Podilia region, more than 100 species have been described in detail. The main areas of biota accumulation in the outcrops are associated with argillites, argillite-siltstones and their contact with sandstones. The best preservation of the imprints is detected in the boundary of facial transitions. Research has revealed that there is a decrease in the numerical and species composition of the molluscous biota, and the dynamic increase in evolution of burrowing organisms and plants within the Podilia Basin during the late Vendian. Such a phenomenon led to an environmental change, increase in oxygen and appearance of new groups of organisms that were subsequently displaced invertebrates. This occurred at the Precambrian/Cambrian transition, and in the geological literature is described as the «Cambrian explosion». Studies have found that the total number of taxonomic composition of the Eidacaran in Podilia is similar to the orictocoenosis of Southern Australia and the White Sea. Nevertheless, the Podilia biocomplex is more ancient than the Southern Australian and the White Sea, it is much younger than the Avallonian.

Keywords: Podilia, the Vendian, the Ediacaran, invertebrates, molluscous biota, taxonomic ranks.

Нова картина біоценозу вендського (едіакарського) седиментаційного басейну Поділля

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Анотація. Розглянуто унікальний комплекс вендської безскелетної біоти, встановлений у природних та штучних відслоненнях басейну річки Дністер у межах Поділля. Мета роботи - повноцінне розкриття всіх аспектів поширення, розвитку, умов поховання та збереження біокомплексу Едіакарію. Палеонтологічна колекція, що зібрана у результаті багаторічних систематичних досліджень та нині демонструється у Геологічному музеї КНУ імені Т. Шевченка, нараховує понад 2000 екземплярів. Вона включає відбитки м’якотілих організмів фауни та сліди їх життєдіяльності, рештки флори та скам’янілості проблематичного характеру. Найбагатший на палеонтологічні знахідки комплекс порід, що входить до складу могилів-подільської серії. Відклади канилівської серії мають значно бідніший видовий та чисельний склад біоти. Особливість розрізу з фауністичними залишками становлять теригенні породи з різним фаціальним та фракційним складом. Основні скупчення біоти тяжіють до аргілітів, аргіліто-алевролітів та контакту їх із пісковиками. Найкраща збереженість відбитків установлена на межі гранулометричних переходів. Усього в межах даного регіону детально описано понад 100 таксонів видового рангу. Дослідженнями встановлено, що в межах подільського басейну протягом пізнього венду спостерігається закономірне зменшення чисельного та видового складу м’якотілої біоти та динамічне збільшення масового розвитку рийних організмів та рослин. Це спричинило до збільшення кисню і появу нових груп організмів, які, у свою чергу, витіснили безскелетну біоту едіакарського типу. У статті доведено, що подільський біокомплекс Едіакарію дещо давніший, ніж південно-австралійський та біломорський, але значно молодший, ніж авалонський.

Ключові слова: Поділля, венд, едіакарій, безскелетна біота, м'якотіла біота, таксономічні ранги.

Introduction. The d**is**covery of the Ediacara biota was the most important paleontological discovery of the 20th century. Of all the locations in the world, the Vendian (Ediacaran) geological section of Podilia is the most complete and available for research.

Outcrops of Podilia were studied intensively in the period preceding the preparation for the flooding of a large part of the canyon of the Dniester River in connection with the construction of the reservoir of the Dniester HES-1 (near Novodnistrovsk city). The work of a large group of Ukrainian and Russian geologists has revealed, explored and described the unique complex of the late Precambrian biota. The obtained results have become an important stimulus for studying the deposits of this age interval in other regions.

Unfortunately, after flooding the valley of the Dniester River, we lost a lot of beautiful outcrops and stratotypes. An important problem was the suspension of public funding for research on this topic. In the eighties of the last century, the systematic study of the Vendian Period of Ukraine was discontinued, and Soviet researchers were reoriented to study the Ediacaran deposits of the White Sea, the Urals and Siberia.

At the beginning of the new century, the study of the Precambrian biota was conducted in many countries of the world with increasing intensity. This is especially true for China, Russia, India, Canada and Brazil. Therefore, now the geological study of Podilia outcrops from the global level significantly lags behind.

In this paper, we present the results of studies performed in recent years by the Geological Museum of Taras Shevchenko National University of Kyiv in collaboration with scientists from the Institute of Paleobiology of the Polish Academy of Sciences, the Institute of Geological Sciences of the Jagiellonian University (Poland) and the University of Poitiers (France).

Materials and methods. For several years, the research group carried out systematic field studies of numerous outcrops of the late Vendian (Ediacara) Period and the Proterozoic-Paleozoic transition on the territory of Podilia Upland. One of the most important research objects was a quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city (Fig.1.). The annual monitoring of the geological situation in the work of a quarry has allowed us to collect a substantial collection of fossils of late Ediacara biota. These findings made it possible to create an objective model of the Podolsk biodiverse orictocoenosis of that time, carry out detailed studies of the sedimentation processes in the protruding zone of the shelf, and discover new aspects of the processes of fossilization of the Precambrian molluscous biota.

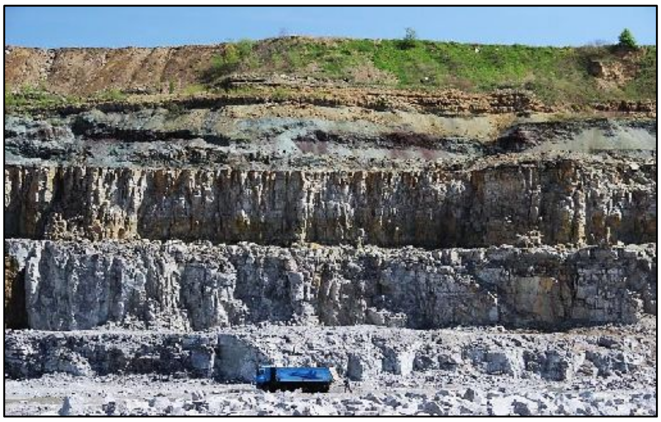

Fig.1. Outcrop of Precambrian deposits in the quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk.

We also believe that the set of results obtained gives us the right to consider this location as a unique Lagerstatte of the late Ediacaran fauna. By the number of taxa biota found, regions such as the Flinders Ranges (South Australia), the White Sea (northwest of Russia) and the island of Avalon (Canada) are similar to the Podilia Vendian Complex.

In the process of systematic field research, the authors studied numerous natural and artificial outcrops of Ediacaran deposits along the Dniester River canyon and its left tributaries, and several outcrops adjacent to the territory of Moldova. The collection of fossils includes more than two thousand samples with molluscous organisms, traces of active and passive benthos, residual vegetable origin and many problematic specimens. At the beginning of our group's work in Podilia, about 50 species of macrofauna, macroflora and ichnofossils were described. Today, we can state that the Podilsky biocomplex of the late Vendian (Ediacaran) Period contains more than a hundred taxa of species rank. Each field study gives new additions to this list. Further researches substantially broaden our understanding of the picture of life in the seas of the late Precambrian, not only within a specific territory, but also on a planetary scale.

Geology of Vendian (Ediacaran) sedimentation basin of Podilia. Scientists began to investigate deposits of the upper Vendian (Ediacaran) Period on the Podilsk hill nearly a hundred years ago. A long time has passed from the moment of the first description of the mysterious fossils on the bottom surfaces of sandstone boards, which for a long time failed to be convincingly interpreted, correctly determined their geological position and age (Kaptarenko, 1928; Krasovskyy, 1916). By the efforts of a large group of geologists, only in the second half of the 20th century was a detailed stratigraphic scale of the Vendian deposits in Podilia, which is shown in Fig.2. (Velikanov et al., 1983; Ryabenko et al., 1976; Stratigraphy, 2013) created.

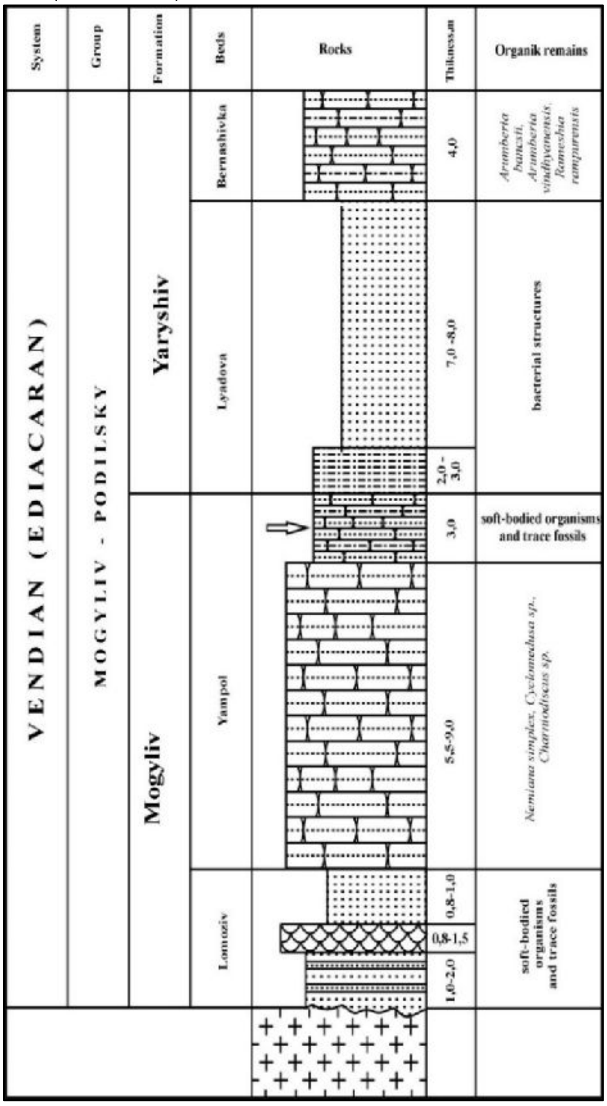

Fig.2. Stratigraphic section of Vendian (Ediacaran) deposits of the quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk.

The thickness of this rock formation complex demonstrates numerous cycles of sedimentation with periods of transgression and regression. These cycles are used for a more detailed stratigraphic partition on beds and formations.

The Vendian (Ediacara) deposits of Podilia are divided into three parts (Groups). The oldest sedimentary rocks form the Volyn Group (lower Vend). Conglomerates, gritstones and arkosic sandstones of various grain sizes represent this stratum predominantly. The granularity of the rocks decreases upward along the section and in the upper part we can detect siltstones and argillites. In the deposits of the Upper Vendian Period, besides the sandstones, there are siltstones, argillites and volcanic tuffs. This upper layer is divided into the

Mogyliv-Podilsky and Kanylivka Groups. Often the sedimentary complex of the Mogyliv-Podilsky Group lies directly on the crystalline basement – granitic rocks of the lower Proterozoic. Above the section, the Kanylivka Group, which is composed of monotone argillite and siltstone interlayers and fine-grained sandstone thin layers, borders the deposits of the Mogyliv-Podilsky Group.

For the sedimentation complex within the Podilia region, the Ediacaran/Cambrian transition (Baltic Group, Okunets Formation) is gradual. This level is characterized by the disappearance of all taxa of the Ediacaran molluscous biota and fossil traces. The only macroscopic residues occurring in the transition zone are coalificated algae Tyrasotaenia from the group Vendethenii. In its upper part (in argillites), there are numerous petrified traces of swallowing organisms that are common of the Cambrian deposits and filled with siltstone material. Glauconitic sandstones and siltstones with numerous complexes of the Cambrian ichnofauna, which was retained by active benthos, and with the molds of colonies of probable polyps *Bergaueria*, *Conichnus*, finished the transitional zone. Sometimes there are Sabelliditida imprints and their traces *Kullingia* (Stratigraphy, 2013; Jensen at al., 2002).

Results of research. Paleontology of deposits of the Mogyliv-Podilsky Group. The most numerous paleontological remains are found in the lower part of the Mogyliv-Podilsky Group: the Lomoziv and Yampil Beds of Mogyliv Formation (Ivantsov, Gritsenko et. al., 2015; Martyshyn, 2012). This orictocoenosis can be attributed to the typical prodelta shallow association of continental shelf areas (Grazhdankin et al., 2009). Lomoziv The beds are interbedding of blue-gray argillites with sandstones and silty sandstones. The Yampil Beds are composed of light grey medium-grained sandstones with zones of platy clayey sandstones. Our paleontological findings contain many taxa that are common to biotic associations of the Flinders Ranges (South Australia), the White Sea, the Middle Urals, Yakutia (Russia), the Mackenzie Mountains (British Columbia, Canada), and some underdeveloped locations in China, India, and Finland (Fedonkin et al., 2007). In addition, a number of Podilsky taxa are endemic, for example: cyclic fossils of *Paliella patelliformis* Fedonkin, 1980, *Elasenia aseevae* Fedonkin, 1983, *Glaessneria imperfecta* Zaika-Novatski et al., 1968, *Jampolium wyrzykoowskii* Bekker, 1996, *Planomedusites grandis* Sokolov, 1972, *Sekwia kaptarenkoe* Gureev, 1987. The interpretation of the abovementioned taxa belonging to different groups of organisms has been repeatedly changed. According to the authors, the fossils of *Paliella* and *Elasenia* are probably remains of primitive polyps. This is indicated by morphological features of the finds, as well as budding and vegetative cloning reproduction.

The preserved remains of *Glaessneria*, *Planomedusites*, including numerous fossils of the genera *Cyclomedusa*, *Ediacaria*, *Charniodiscus*, *Aspidella*, *Medusinites*, *Tirasiana*, *Irridinites*, *Protodipleurosoma*, *Evmiaksia*, and others, probably belong to a large group of attachment structures of frond-shape organisms. During field research in 2017, V.A. Nesterovsky found a perfectly preserved copy of *Protodipleurosoma rugulosa* Fedonkin, 1980 in the upper layer of clay sandstones of the Yampil Beds. At the same stratigraphic level, in the outcrop near Bandyshivka village in 2013, Martyshyn A.I. discovered a sandstone formation with massive settlements of a rare Australian taxon *Cyclomedusa gigantean* Sprigg, 1949, which reached 50 cm in diameter and was probably the attachment structure of a gigantic body from the frond-shape group. Their upper (over-bottom) part is preserved very rarely. The explanation for this phenomenon is probably the taphonomic features of the non-skeletal Precambrian biota, known as the «posthumous mask» (Mapstone et al., 2006). According to findings at other Ediacaran locations, it can be argued that various rhizoids and combinations of «disk plus rhizoids», genera *Hiemalora*, *Eoporpita*, *Mawsonites* were also attachment structures (Hofmann et al., 2008). Apparently, this group includes fossils with three-radial and tetra-radial symmetry (*Tribrachidium*, *Conomedusites*). J. Dzik's and A. Martyshyn's investigation (2017) showed that the organisms of the frond-shape group were one of the first creatures of the end of the Precambrian which penetrated the anoxic environment under the bacterial mats and used the extracted components to maintain their biological processes. This indicates the probable existence of chemoautotrophic symbiosis with bacteria in their biological mechanism, which provided the processes of metabolism.

Among other endemics in the Ediacaran section, there are attached saccate organisms of obscure provenance. For instance, there are *Vaveliksia velikanovi*, Fedonkin, 1983 which may be primitive Spongia (Ivantsov et al., 2004); dendritic, attached to the biomat substrate *Lomosovis malus* Fedonkin, 1983; complex bilateral organisms from the group Dipleurozoa (Dzik) – Proarticulata (Fedonkin), *Podolimirus mirus* Fedonkin, 1983 (Fig.3.a). Moreover, there are «*Spriggina*» *borealis* Fedonkin, 1979, *Dickinsonia costata* Sprigg, 1947 representatives of a small active benthos at the bottom of the Precambrian sea (Dzik and Martyshyn,2015).

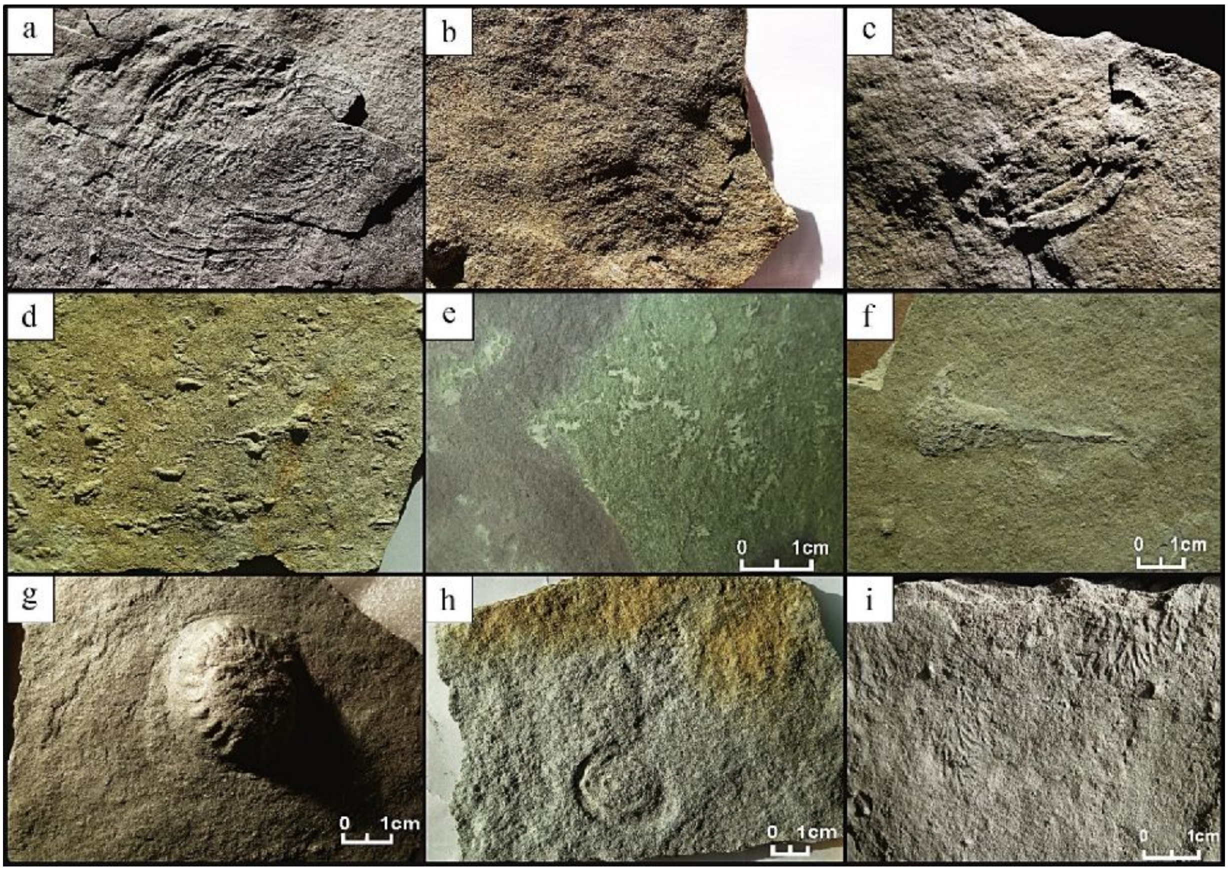

Fig.3. Examples of samples with Vendian biota traces within Podilia:
a) *Podolimirusmirus* Fedonkin,1983. Negative epirelief. The late Ediacaran. Mogyliv-Podilsky Group. Lomoziv Beds. A quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 174.
b) imprint (trace of nutrition) *Dickinsonia costata* Sprigg,1947. Trace fragment. Positive hyporelief. Lomoziv Beds. Popelyukhy village. Vinnitsa region. Sample nom. 17 p 181.
c) *Kimberella quadrata* Glaessner, 1959. Negative epirelief. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 182.
d) traces of bulldozer sediment. Positive hyporelief. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 183.
e) *Shaanxilithesningqiangensis* Xingetal.,1984. Three-dimensional fossils in petrified tuff. Yaryshiv Formation. Bronnitsa Beds. Bernashivka village. Vinnitsa region. Left slope of the valley of Zhvan River, 1 km from the mouth. Sample nom. 17 p 184.
f) a organism of the family Conulariida. Positive hyporelief. Bronnitsa Beds. Outcrop in Borschiv ravine, Mohyliv-Podilskyi city. Sample nom. 17 p 185.
g) *Astropolichnus sp.* Positive hyporelief. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 186.
h) *Charniodiscus spinosus* Laflamme et al., 2004. Negative epirelief. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 187.
i) *Nilpenia rossi* Droser et al., 2014. Problematic specimens. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 188.

During field research (2010 – 2014), authors found very rare traces of dipleurozoa movement and nutrition – *Dickinsonia costata* (Fig.3.b) and *Podolimirus mirus*. Similar ichnofossils are described from the shores of the White Sea and from South Australia (Ivantsov, 2013; Sperling and Vinter, 2010). In the same period in the Lomoziv Beds (quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city) A. Martyshyn discovered several specimens of dipleurozoa – *Yorgia waggoneri* Ivantsov, 1999 (Ivantsov, 1999).

Numerous populations of *Sekwia kaptarenkoe* are probably remains of attached to biomat substrate saccate colonies of cyanobacteria close to *Nemiana simplex* Palij, 1976 / *Beltanelloides sorichevae* Sokolov, 1965, and attached algae *Tymkivia* sp. colonies (Pali, 1976; Ivantsov et al., 2014) which was recently found by one of the authors.

We were able to make some interesting conclusions about the widely distributed *Nemiana* / *Beltanelloides* in deposits of the Mogyliv-Podilsky Group. Analysis of numerous previous publications and own observations of a large number of samples showed that this species is close to modern colonies of cyanobacteria *Nostoc*. It had two types of existence, namely: attached to biomat substrate and passively moving benthos. The first type of organisms, which are buried in situ, preserved with characteristic zones of attachment in the middle part of body, chains of gradually smaller individuals that multiplied by budding. The second type is chaotic multi-layered accumulations of different age specimens in areas with lowered paleorelief. Such a taphonomic diversity led to the formation of *Nemiana* molds not only in a positive hyporelief but also in a positive epirelief.

The abovementioned phenomenon of different types of existence is important for the analysis of the general strategies of colonization of the seabed organisms in the late Ediacaran. The vast majority of paleontological materials from the sediments of that time indicate that life on the seabed was represented mainly by sedentary benthos attached to the bacterial substrate.

The authors and previous researchers in Podilia found fossilized remains of floating organisms from the group of dickinsonia and yorgia, as well as animals such as *Kimberella quadrata* Glaessner, 1959 (Fig.3.c), which are probable ancestors of Lophotrochozoa (Fedonkin and Vaggoner, 1997).

Occasionally in sediments of the Mogyliv-Podilsky Group, we can detect traces of the life of the swallowing creatures, which indicates the fact of significant evolutionary changes in the late Precambrian biosphere. Findings of ichnofossils allow us to assert that already at the beginning of the late Ediacaran, some animals began to develop in the anoxic zone under bacterial mats, which completely covered the seabed. The morphology of the ichnofossils is quite diverse, ranging from the simple burrow of muloids *Planolites*, *Helmintoidichnites*, to rather complicated traces of *Treptichnus*, traces of nutrition *Oldchamia*, traces of the meniscus structure *Nenoxites*, traces of bulldozer sediment and of eating biomat by floating biolateral organisms (Fig.3.d). Interestingly, the creatures that left them show a unique phenomenon of group behaviour - the movement along sub-trajectories. This fact may be due to the ability of these creatures to interact with the bottom currents.

A new group of passive- floating organisms in argillites and siltstones of Lomoziv Beds was detected during fieldwork in 2010. Apparently, these organisms were free to lie on the seabed and could be carried by the water stream. This is evidenced by the repeated finding of them in the lenticular zones together with *Nemiana* / *Beltanelloides*. Such lenticular layers of siltstones are nothing more than a material for filling the sludge on the seabed. The morphology of these creatures was also unusual. They had a shape very similar to some types of Phanerozoic foraminifera, with a characteristic spiral twisted, organic envelopes. On the top of the envelopes there are located on the helix relief blows, internal depression, sometimes acute germs, as in some forums. Occasionally, the degree of preservation of these organisms is such that it allows you to see the thin radial ridges around the cubes around the periphery, which are very similar to the pseudo-events of foraminifera. The cross-section also shows similarities with the spiral single-chamber Foraminifera. The size of fossils is up to 6 cm long, and 5cm wide. Until now, no similar fossils have been discovered in any Ediacaran outcrops of the Podilia.

Later than the abovementioned findings, a number of mysterious new creatures, similar to foraminifera in external morphology, as well as details of the internal structure (agglutinated and organic envelopes, rudimentary camera, possible prints of pseudo-events, etc.) were detected in other outcrops of the Podilia. The studies of various authors showed the deep Precambrian origin of foramen (Bosak et al., 2012). The moment of the pulse phenomenon of diversification of this group of organisms was established, which occurred in a period that is roughly the same as the Vendian (Bosak et al., 2012; Pawlowski et al., 2003). In Pawlowski's publication (Pawlowski et al., 2003), it was predicted that fossilized remains of foramen would be found in Precambrian rocks.

Paradoxically, one of the first Vendian taxa to be described in Podilia was the smallest representative of the macrofauna – a few millimeters in size - *Bronicella podolica* Zaika-Novatski, 1965 (Zaika-Novatski, 1965). The species was described as a possible primitive Cnidaria, although this hypothesis was questioned based on more recent research. For a long time, most Precambrian researchers did not attach importance to these fossils since they looked like very small-deformed spheres, unsystematically scattered in the lower horizons of separate tuff argillites of Bronnitsa Beds. In the outcrops, they are found in association with probable attachment discs of the frond-shape *Glaessneria*, *Planomedusites*, mass detritus of problematic *Shaanxilithes ningqiangensis* Xing et al., 1984 (Fig.3.e), *Palaeopascichnus jiumenensis* Deng et al., 2008 and the traces of swallowing organisms of *Planolites*, *Torrowangea* (Velikanov, Gureyev, 1984 ; Shen et al., 2007).

During the fieldwork in 2010 at the location of the Borshchiv ravine (Mohyliv-Podilsky city), A. Martyshyn discovered several samples of micro-grained tuffs with numerous *Bronicella* that were preserved along with their traces of translational motions in complex trajectories. These movement tracks are very similar to the modern trail of deep-water spherical shell-unicellular organisms from the group Rhizaria *Gromia sphaerica* Gooday, 2000 (Matz et al., 2008). In addition, it was possible to detect several specimens of *Bronicella* with preserved protective outer layer that can identified as a seashell.

Another important discovery in the same tuff argillic layer were finds of conical shape fossils – the possible ancestors of the Paleozoic Conularia (Cnidaria), (Fig.3.f). Individual fossilized remnants of animals belonging to this group were discovered in China, Brazil, and Russia in the late Ediacaran (Ivantsov and Fedonkin, 2002; Pacheco et al., 2011; Yuan et al., 2011). Detailed research on these organisms is scheduled for 2018. Up till now, paleontologists did not know about certain finds of Cnidaria fossils, other than conlyarids. A. Martyshyn collected a unique material of several taxa that undoubtedly represent these organisms according to morphological features. For instance, in 2012 three-dimensional casts, morphologically similar to the polyps of *Astropolichnus* sp. (Fig.3.g) from the deposits of the lower Cambrian of Spain and the Czech Republic (Pillola and Vintaned, 1995; Mikulas and Fatka, 2017), were found. A unique taxon was found in argillites of Lomoziv Beds. The fossils represent a number of features that distinguish them from the other Vendian species. Certain specimens retain radial internal structures similar to septa. In some cases, there are radial elements around the casts of the bodies, tentacle analogues, etc. In 2014, S.S. Solodkiy discovered two three-dimensional casts with a six-radius internal structure in Dzhurzhivka Beds, Nagoryany Formation.

At the beginning of the active phase of study of the Ediacaran in Podilia, evidence of the movement of polyp forms along the seabed was found (Velikanov et al., 1983). This finding, at that time, did not attract much attention. The recently discovered sediments in the late Ediacaran of Canada, namely numerous fossilized polyps moving along the bottom surface caused an active discussion among experts about the lower boundary of the coelenterates appearance (Menon et al., 2013). A. Martyshyn represented material on this topic for discussion at paleontological conferences in Ukraine and at the «18th CZ - SK – PL Paleontological conference, 2017» in the Slovak Republic. The study of these petrified remains continues and soon the results will be published.

For a long time among scientists, there has been a discussion of the interpretation of the unusual sedentary representatives of the Ediacaran fauna classified in the Petalonamae group. These organisms were first discovered by German paleontologists in Namibia, 1908 (Pflug, 1970). Despite long study and numerous findings in many parts of the world, the nature of these creatures is still unclear . Recently, the authors and our colleagues have managed to find a lot of taxa of this group in Podilia. For instance, they detected *Charnia masoni* Ford, 1958, *Charniodiscus spinosus* Laflamme et al., 2004 (Fig.3.h),, *C. arboreus* Glaessner, 1959, *C. oppositus* Jenkins and Gehling, 1977, and new species of leafy, calyx, sacky and tree-like forms. Unfortunately, remains of the upper part of the body are very rarely fossilized. We commonly detect only the attachment structures of different types of discoid, onion- and root-shaped morphology (Seryozhnikova, 2010). Podilia's outcrops are unique and rich in the number and variety of petrified attachment structures of frond-shape organisms to the bacterial substrate (Ivantsov etc. 2015).

During the last study of Lomoziv Beds in 2014, A. Martyshyn discovered new specific imprints in the layer of siltstone directly below the gritstone layer. They were of two types: one has the form of unidirectional-branched root-like structures, and others - radially spaced, rather long and thin root-like formations that deviated from central depression (hyporelief). In the same year, similar finds were described by a group of authors at a location of South Australia and named *Nilpenia rossi* Droser et al., 2014 (Droser et al., 2014) (Fig.3.i). Researchers could not relate these formations to any of the known groups of the organic world. Probably this is one of the organisms with the level of organization of Protozoa. In 2015, the authors detected a fossil in Lomoziv Beds, which is a conical growth of needle-like elements (probably spicules) (Fig.4.a). The specimen is similar to *Choia striata* Xiao et al., 2005 from the Lower Cambrian deposits in Anhui Province, Southern China [Xiao et al., 2005]. This species was classified as Demospongea (Porifera).

During research in a Chinese outcrop near the village of Lantian, a rich complex of uniquely preserved biota of the Ediacaran and lower Cambrian was discovered. Among the finds, a number of species is interpreted as Spongia. One species of the Ediacaran biota that was found in South Australia is described as a possible sponge. The taxon was named *Palaeophragmodictya reticulata* Gehling & Rigby, 1996 (Gehling and Rigby, 1996). The authors found similar fossils in Lomoziv Beds in a quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city.

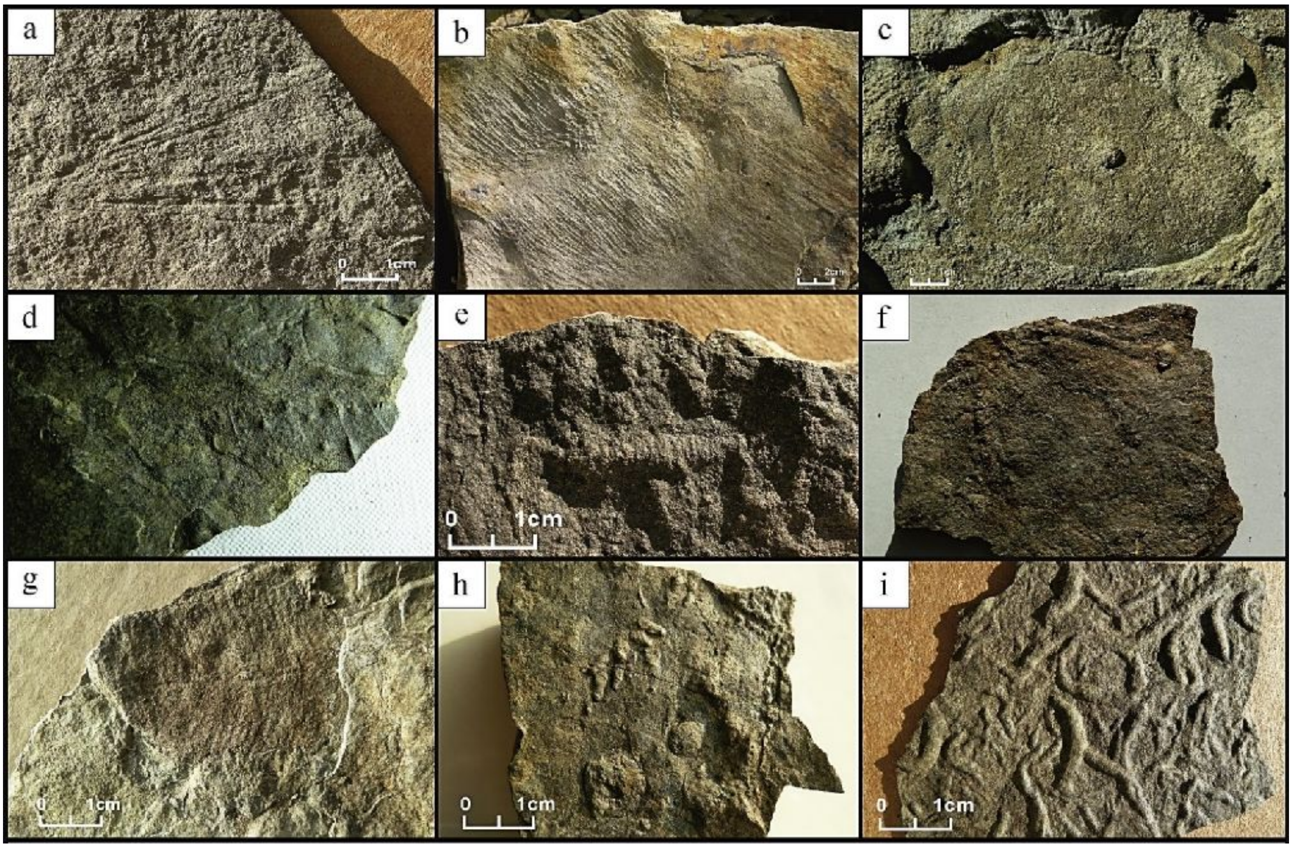

Fig.4. Collected remains of the Ediacaran deposits with traces of the molluscous fauna, its life activity, and flora that were collected within the Dnister River:

a) the imprint of spicular elements of a problematic organism. Negative epirelief. Lomoziv Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 189.

b) *Arumberiabanksii*GlaessneratWalter,1975. Positive hyporelief. Bernashivka Beds. Yaryshiv Formation. Bernashivka village. Vinnitsa region. Left slope of the valley of Zhvan River. Not selected from the outcrop.

c) a problematic organism, probably Tunicata. Positive hyporelief. Yampil Beds. A quarry near the Dniester hydroelectric station-1, Novodnistrovsk city. Sample nom. 17 p 190.

d) *Burykhia hunti* Fedonkin et al., 2012. Positive hyporelief. Kanilivka Group. Studenitsa Formation. Komarovo Beds. The outcrop is located 1 km southwest of Kitajogorod village. Khmelnytsky region. Sample nom. 17 p 191.

e) *Wutubus annularis* Chen et al., 2014. Positive hyporelief. Dzhurzhevka Beds. Nagoryany Formation. Lyadova village. Left bank of the Dniester River. Sample nom. 17 p 192.

f) probable traces of movement *Lamonte trevallis* Meyer et al., 2014. Positive hyporelief. Dzhurzhevka Beds. Lyadova village. Left bank of the Dniester River. Sample nom. 17 p 193.

g) *Dickinsonia costata*Sprigg,1947. Negative epirelief. Kanilivka Group. Danylivka Formation. Pilipy Beds. The western part of Tymkiv village. Khmelnytsky region. Sample nom. 17 p 194.

h) *Tymkivia stuzhuki*Martyshynsp.nov. Positive hyporelief. Kanilivka Group. Studenitsa Formation. Komarovo Beds. The outcrop is located 1 km southwest of Kitajogorod village. Khmelnytsky region. Sample nom. 17 p 195.

i) *Harlaniella vermiformis* Martyshyn, sp. nov. Massive population of probable algae. Positive hyporelief. Kanilivka Group. Studenitsa Formation. Polivanov Beds. The left bank of the Dniester River, 3 km southwest of Horayivka village. Khmelnytsky region. Sample nom. 17 p 196.

At the several stratigraphic levels of the late Ediacaran, A. Martyshyn detected numerous fossils of *Arumberia banksii* Glaessner at Walter, 1975 (Glaessner and Walter, 1975) (Fig.4.b). These problematic structures appear for the first time in the section in the upper sandstone layer of Bernashivka Beds (Yaryshiv Formation of the Mogyliv-Podilsky Group) and form mass settlements. Above the section, they are found sporadically to the top of the Kanylivka Group. Findings of this genus from Australia, India, the Urals, Yakutia, Great Britain, and Ukraine have a remarkable resemblance (Kolesnikov et al., 2012; Kumar and Pandey, 2008). On qualitative specimens from Podilia and other regions it is clearly seen that *A. banksii*, *A. vindhyanensis* Kumar and Pandey, 2008, *A. multykensis* Kolesnikov et al., 2012, and other types are morphologically similar to the modern brown and red algae of genera *Fucus*, *Ascophyllum*, *Odonthalia*, *Himanthalia*, etc.

Recently, a group of scientists published the data of the morphological study of modern bacterial structures in the salt-water reservoirs of the Salines de Guérande, Loire-Atlantique, Region of Pays de la Loire (Western France). In our opinion, these data cannot be the reason for identifying them with fossils of the *Arumberia* genus (Kolesnikov et al., 2017). Our statement is based on numerous arguments. Firstly, *Arumberia* generally occurs in rocks that occurred in the conditions of active seaside hydrodynamic. In Podilia, these are massive, oblique sandstones of the Bernashivka Beds and the basal sandstone layer of the Kanylivka Group. In rocks with more stable conditions, the sediment accumulation of *Arumberia* is rare. Secondly, *Arumberia* have the same morphology in different parts of the planet. The bacterial structures that were described in salt basins have a random nature associated with seasonal water level variations in the stagnant conditions of a shallow salt evaporation reservoir in the absence of currents. With the appearance of hydrodynamic pressure, they are deformed and destroyed. Fossil evidences of effects of the interaction of water streams with bacterial structures of this type are often present in the section of the Kanylivka Group of the late Ediacaran. They are clearly morphologically different from *Arumberia*. As a result, we plan to describe the unique findings of the volume of preserved *Arumberia*. In transverse sections, it can be observed that one of the species was an elastic tubular body with a diameter of 3-5mm and a length up to 500mm. It formed a colony and dense thickets on the seabed in the coastal zone with active hydrodynamics.

During fieldwork in a quarry of rubble stone production near the Dniester hydroelectric station-1, Novodnistrovsk city, the authors repeatedly detected low-relief oval prints on the lower surfaces of argillites and siltstones of the Lomoziv Beds and sandstones of the Yampil Beds. In 2012, A. Martyshyn discovered the remains of oval creatures with visible holes on the lateral surface. In 2015, an amateur paleontologist S. Finko found similar fossils (Fig.4.c). The time of the partial decomposition of organisms is observed on some specimens. Then, these structures can be interpreted as creeps of the internal organs that have become visible through the destruction of the outer shell. Further analysis and the general morphology of the imprints revealed the absence of analogues of such organisms in the sediments of the Ediacaran in other regions of the planet. Among the paleontological remains of Phanerozoic and modern living creatures, this morphology is typical only for Tunicata (Chordata type, Ascidiacea class). The probability of such an interpretation is consistent with the finding of a specimen of *Burykhia hunti* Fedonkin et al., 2012 that was made by S. S. Solodkiy in 2013 in the Kanylivka Group sediments (Fig.4.d). This taxon is described from the late Vendian sediments of the White Sea coast as a probable representative of Tunicata (Fedonkin et al., 2012). According to numerous studies, Tunicata was the most likely ancestor of vertebrates. They are widespread in modern seas and are important for an ecosystem, as active filters and carbon dioxide absorbers.

A diverse biotic complex was discovered by the authors in the Dzhurzhivka Beds (Nagoryany Formation). In addition to the already mentioned spherical colonies of *Nemiana* / *Beltanelloides*, there are colonies of polyps – *Bergaueria hemispherica*, *B. perata*, *B. radiata*, *Conichnus conicus*, and a new species with bulk preservation and six-beam structure inside organisms. Among the finds in these deposits, fossils in the form of segmented tubular bodies can be detected. Morphologically, they are similar to the rare *Wutubus annularis* Chen et al., 2014 from carbonate rocks of the Dengying Formation of the late Ediacaran of China (Chen et al., 2014). Presently, there is an ongoing discussion about the nature of these organisms , which are identified either as representatives of sedentary benthos or worms.

One of the important finds are traces of movement and siege sensing similar to *Lamonte trevallis* Meyer et al., 2014 that were also described in China (Meyer et al., 2014) (Fig.4.f). These ichnofossils demonstrate the beginning of the era of penetration into the sediment and its bioturbation that eventually led to the end of the dominance of bacterial mats on the bottom of the Precambrian seas.

Very widespread at the end of the Ediacaran of Podilia was the Vendotenid flora. Well preserved, carbonated remains of plants of this group can be found on Podilia outcrops from Dzhurzhivka Beds. At this stratigraphic level, in 2015, we collected the fossils of a new taxon of algae that is preserved simultaneously in two taphonomic forms - carbonated and bulk. Based on the information given in the publications, this is one of the first examples of such taphonomy in the world practice of research of flora remnants of the Ediacaran. The aforementioned plants had significant dimensions (to 10mm in diameter, to 200mm in length), and tubular structure. They grew up on the seabed in the form of single specimens, chimney-type colonies and dense thickets.

Paleontology of the Kanylivka Group. The authors collected important information during the study of deposits of the Kanylivka Group. As already mentioned, this stratigraphic level begins with the basal horizon of sandstones of Pylypy Beds that occur unconformably in the comminuted phosphorite argillites of Kalyus Beds. Several morphotypes (species) of *Arumberia*, single casts of

Harlaniella podolica Sokolov, 1972, fragments of Vendotenid algae, several types of bacterial structures and interesting traces of life represent the fossils of this layer.

Ichnofossils show the infrequency and the poverty of the active benthos of this time interval. Ichnofauna is represented by linear traces of movement similar to *Didymaulichnus*, *Psammichnites*, and radial traces of food close to *Asterophycus*. During fieldwork in outcrops located south of Berezivka village (left bank of the Dniester River) in 2015, A. Martyshyn discovered traces of the movement of a segmented worm-like organism, similar to the traces of *Gyrichnites sauberi* Zessin, 2010 from the upper Ediacaran of Namibia (Zessin, 2010). Sometimes in the lower part of the sections, there are isolated fossils of the species of the Ediacaran fauna. For instance, there are *Beltanelloides*, *Nimbia*, *Cyclomedusa*, *Arumberia*, *Platypholinia*. In Danylivka Beds, the authors detected a representative of the active benthos *Dickinsonia costata* Sprigg, 1947 (Fig.4.g), three-radially symmetrical, foliate organism *Swartpuntia germsi* Narbonne et al., 1997. Among the algae, the most widespread group is the Vendotenid - various morphotypes of *Vendotaenia antigua* Gnilovskaja, 1971, sometimes *Kanilivia insolita* Istchenko, 1983, twisted shapes similar to *Grypania spiralis* Walter, Oehler and Oehler, 1976, and oval elongated shapes that do not have a systematic description yet. The fossilized remnants of a new type of algal *Tymkivia stuzhuki* Martyshyn sp. nov. (Fig.4.h) that formed settlements attached to the bacterial mats of sacked individuals have been found on many levels of the Kanylivka Group. Probably, the carbonated remains of the Middle Proterozoic of China and Canada *Longfengshania stipitata* Du, 1982 (Hofmann, 1985; Du, 1982) are close to *Tymkivia*. Their modern morphological analogues are probably green algae *Valonia*, *Derbesia*, *Boergesevia*. Sporadically there are three-dimensional fossils of round form, probably colonies of cyanobacteria *Beltanelloides* sp.

The most important paleontological indicator of the Kanylivka Group can certainly be bodily imprints of tubular fossils *Harlaniella podolica* (Ivansov, 2013; Sokolov, 1972). One of the morphological differences of this genus was found on the outcrop of the White Sea and was named *H. ingriana* Ivantsov, 2013. The authors collected similar fossils from the sediments of Studenitsa Formation in Podilia. In the outcrops of Kitaigorod and Bakota, massive imprints of a new morphological difference of this genus which previous researchers considered as ichnofossils, traces of the life of swallowing organisms were discovered. However, moles of mulches cannot form splits and branches. The decisive argument was to find similar fossils on the outcrop of Buchay, where three-dimensional casts together with relics of carbonated shells were observed, and where bulky casts were encountered along with relics of coaly shells. The species was named *Harlaniella vermiformis* Martyshyn, sp. nov. (Fig.4.i). Similar variants of finding the bodily casts of *H. podolica* together with coaly fragments of bodies have been repeatedly received by the authors, as well as described in the research of A.Yu. Ivantsova (Ivantsov, 2013). This phenomenon led the abovementioned author to interpret *Harlaniella* as probable flora remnants.

One of the few taxa of genital rank that can be found at different levels of the late Ediacaran is the problematic fossils of the *Palaeopascichnus* Palij genus. Their colonies are often found in the siltstone and sandstones of the upper part of the Lomoziv Beds, in the upper part of the clay sandstones of the Yampil Beds (the Mogyliv Formation, the Mogyliv-Podilsky Group), and sometimes in the argillites of Studenitsa Formation of the Kanylivka Group. A first find of these fossils was made in deposits of Kanylivka Group and described as *Palaeopascichnus delicatus* Palij, 1976 (Palij, 1976). During fieldwork, the authors compiled a collection of various morphotypes of *Palaeopascichnus*. Studying this material could help in elucidating the nature of these widespread, problematic fossils. A detailed analysis of the fossils of this group from different locations in the world has shown that they are likely to be body fossils of an unknown protozoa (Antcliffe etc., 2011).

The sedimentation of this time occurred in relatively calm conditions of shallow continental slope or lagoon. The rocks are intensively laminated with bacterial mats and often contain a large number of redeployed fragments of bacterial structures. Often, these fragments were filled with bottom sediment, and then flows moved them along the surface of the bottom. Due to the plasticity of such aggregates, three-dimensional shapes of arbitrary shape and size were formed that often resemble the remains of living organisms. Such pseudofossils are found in the form of single intraclasts in the mass of the rock, and in mass clusters. The sedimentation cycle of the Kanylivka Group ends with argillites and siltstones of Okunets Formations that are a transition zone to the deposits of the lower Cambrian. According to the authors, the stratigraphic boundary between the Proterozoic and the Paleozoic can be measured by the level of the first occurrence of typical Cambrian ichnofossils (traces of vital activity of swallowing organisms) that appear suddenly and massively in the upper part of Okunets Formations. Siltstones and glauconite sandstones of the Baltic Formation of the Lower Cambrian with rich ichnofauna and isolated remnants of Sabelliditida are found above (Ryabenko et al., 1976; Stratigraphy, 2013).

Conclusions.

1. This study provides new, extremely interesting results for the reproduction of the biocenosis pattern in the seas of the late Vendian (Ediacaran), and for an understanding of the ways of early diversification of the oldest stem groups of the animal world.

2. In the outcrops of the Mogyliv-Podilsky and Kanylivka Groups, a large number of fossilized remains of molluscous organisms, traces of active benthos, three-dimensional and coaly plant remnants have been collected and analyzed.

3. Analysis of biotic complexes at different stratigraphic levels confidently demonstrates several trends in the evolution of the Podilia sedimentation basin in the Ediacarian. The beginning of the late Vendian was marked by the explosive dissemination of molluscous biota, and the entire set of living creatures passed the original path of development in another, more ancient basin and was introduced into this segment of the continental slope in the form of an already formed biocomplex.

4. The total taxonomic composition of the Vendian complex in Podilia is similar to the orictocoenoses of Southern Australia and the White Sea. Statistical comparisons show less quantitative and species diversity in Podilia of the rather difficult animals of the group Dipleurozoa (Proarticulata).

5. The isolated findings of the probable ancestors of molluscs (Lophotrochozoa), the proliferation and diversity of the group of problematic organisms of Petalonamae typical of the more ancient, Avalonian biota, give reason to consider that the biotic complex of the late Vendian (Ediacaran) of Podilia is slightly more ancient than Southern Australian and White Sea, but significantly younger than the Avalonian.

6. In the section of the late Vendian Podilia Basin, the number and species composition of molluscous biota rapidly decrease. At the same time, in the same direction, diversity increases and the morphology of swallowing organisms that can penetrate an anoxic environment under the surface of bacterial mats becomes more complicated.

7. During the late Ediacaran in this basin, the situation in the plant kingdom changed quite dynamically: from the massive development of probable colonies of cyanobacteria at the beginning of the Mogyliv-Podilsky Group to numerous and varied plant remains in the Kanylivka Groups.

8. The massive evolution of algae caused a sharp increase in free oxygen in the ecosystem, but it was found to be too toxic to Ediacaran organisms, since they arose and were adapted to life in association with bacterial mats on the border of the anoxic environment of the bottom and oxygen-poor water zone. It was precisely at this time that new types of organisms began to appear that, together with algae, began to displace the molluscous Ediacaran biota. The living creatures of the basin continued to develop new ecological niches. The life activity of various organisms, capable of subsistence in the depths of the bottom sediment, led to active bioturbation of the seabed and reduction of areas covered with bacterial mats.

9. Abrupt change in the ecological situation caused a crucial turning point in the history of the planet, the massive extinction of the Ediacaran biota, which gave way to those organisms that were able to adapt to new conditions. These were the global changes that are now called «Cambrian explosion».

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