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Some new ichnospecies stored in the Geological Department of the National Museum of Natural History, NAS of Ukraine

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Some new ichnospecies stored in the Geological Department of the National Museum of Natural History, NAS of Ukraine. — V. P. Grytsenko. — During the last decades, many scientists worldwide have focused on the study of activity signs of animals. Such signs of various animals have appeared in the geological history since Ediacaran rocks and can be found until today. They can be signs of sedentary lifestyle or tracks of moving of animals (both vertebrates and invertebrates), evidence of birth (e.g., eggshell fragments), sliding traces of molluscs and other organisms. In some cases, the study of ichnofossils is of great importance, especially for the so-called "palaeontologically dumb" sequences. However, the identification of the nature of ichnofossils is an issue. Sometimes, particular kinds of animals can be identified based on the shape and trajectory of traces. But usually such identifications are impossible, therefore an artificial nomenclature is used for these ichnospecies. In particular cases, ichnofossils help to resolve the problem of identification of ancient facies. It is often impossible to identify their position in the biological system, but the behaviour of animals can be clarified. Different animals leave imprints of their traces and tracks depending on the specifics of facies in the bottom of the sea or on the surface of the ground nearby to continental waterbodies. These can be traces of invertebrate and vertebrate animals. Soft soil is the most favourable for the formation of traces, although specific conditions are required for the preservation of these traces. There are organisms that leave signs of drilling on the solid bottom and on rocks. In the results, we can obtain some information, but only a part of it allows to obtain correct identifications. It is often impossible to identify animals according to their traces. Ichnofossils from deposits of various age and facies are studied by specialists in all continents and in the seabed. Ichnology, a new scientific branch emerged that develops rapidly. Ichnological approaches allow to identify ecological (facies) conditions of the geological past and are used in searches for oil and gas fields. The disadvantages of ichnology are the ambiguous interpretation of ichnospecies and the use of the same name for different objects (synonyms). In this paper, some new ichnospecies of various geological age are identified and described along with images of traces of unknown animals in situ.

Key words: ichnospecies, ichnology, palaeontology, geology, facies, museum collections.

Introduction

The investigations of ichnofossils that are observed on bedding surfaces or inside sedimentary rocks were started due to practical needs for geologists and palaeontologists when conducting geological prospecting. The traces are especially informative at the mapping of intensively distorted thicker of flysch to clarify normal or upset bedding of sedimentary rocks. Scientists collected a huge amount of samples and a necessity appeared to divide them into two groups: "biogliphs" and "mechanoglifs." The first group is evidence of vital activity, i.e. tracks of seating, moving, eating, birth and so on. The second group has inorganic nature: imprints of rain drops, ice crystals, tracks of rolling stones or moving pieces of wood under the influence of currents or waves, strokes that were abandoned by algae in shallow water and so on.

The study of the tracks has been more intense in the last few decades. The tracks are used in stratigraphy (especially sequence stratigraphy), in the study of facial features of sedimentary rocks, during mineral prospecting and other directions of geological research.

A history of ichnological studies

Palaeoichnology is a branch of geological science that studies fossil tracks and imprints of ancient life. It was the well-known Austrian researcher A. Seilacher who proposed the scientific term

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"ichnology" (Seilacher 1953). A quite broad interpretation of the term was given by W. Häntzschel, who considered that ichnology deals with all kinds of tracks (Häntzschel 1962). So, palaeoichnology is a geological science, whereas traces of life of modern organisms are the object of study of neoichnology or simply ichnology.

The term "palaeoichnology" is used in a narrow and a wide sense. The narrow understanding is dealing with tracks and imprints of fossil animals. O. Vialov (1987: 3) considered palaeoichnology a science that studies signs of all phenomena and all activities of organisms from birth to death. O. Vialov named the signs of life (*Vestigia vitae*), which could be divided into two groups: *Vivichnia* — mechanical signs of limbs or the entire body of animals on soft soil, holes of benthic animals on soft sediments or hard bottom, and *Vivisignia* — the diverse signs and evidence or remains of physiological functions of animals, including their vital manifestations and states from birth to death (Vialov 1966).

The author of this paper thinks that it is logically right to combine palaeoichnology and neoichnology into a general concept — ichnology.

A. Seilacher (1953) and O. S. Vialov (1966, 1987) are considered to be the authors of the classification of signs of vital activity of fossil organisms and of their nomenclature and ecology. A number of symposiums and workshops focusing on ichnology were hold in the last few years: IX IIW, 2007, Calgary, Alberta, Canada; VI IBW, 2008, Salt Lake City, Yutah, USA; X IIW, 2009, DzhandzhouCity, China; Workshop on bioturbation of shellfish — fossil and modern, 2010, Lepe, Spain. The participants of international ichnology workshops were grouped into subgroups that use different methods and solve separate tasks.

There are various methods and techniques used in ichnology. CT (computer tomography) is used to study modern and fossil signs and allows getting promising results. DOI (digital optic images) is a wonderful tool to investigate cores of boreholes. NMR (nuclear magnetic resonance) could be useful for hydrogeology and oil industry and to solve some issues of ichnology, but it is unsuitable for most of ichnological investigations. SPR (soil permeable radar) has low permeability and image resolution. Portable gamma-ray spectrometer used in the University of Valencia could be useful on outcrops to receive geochemical data of different parts of holes. Gamma-ray radiograph (GRR) is useful for the imaging of holes. Thin sections are useful to study the petrography of holes.

Another subgroup of scientists combine biologists and palaeontologists to study modern holes. There is a method of study of actual holes and imprints. Most of the imprints come from the tidal and shallow water zones of a sea. Ichnologists know nothing about holes of crustaceans in the deep sea, so studying these holes in the deep sea is essential. Box coring could be helpful to understand patterns of activity of animals that made holes. The series of the sections of the fossil holes of crustaceous and others animal that construct hole systems could be studied using 3D digital tools. The others task of this subgroup is field investigation of ichnofossils.

The subgroup of palaeontologists and geologists has a goal to study ichnofossil associations, which reflect latitude distribution of burrowing animals (e.g., signs of fossil crustaceans are more common and diverse in seas of the tropical zone). From the other side, the recognition of trails can help to reveal palaeoclimatic cycles or climate fluctuations.

Ichnofossils play one of the main roles in sequence stratigraphy as indicators of boundaries of sections and surfaces of parasequences of the maximum of flooding and so on.

The study of porosity in and near the holes is important for hydrogeology and oil geology. The role of the holes for fluids penetration in the water and oil reservoirs could provide useful information (Gingras *et al.* 2002).

There are issues with the identification of tissues that had left the traces, so it is important to consider the information from neoichnologists about the investigation of holes and their producers. It could allow comparison with modern signs that has similar geometric forms and morphological attributes.

The facial spread of sedimentation structures that were made by burrowing organisms under modern conditions is useful for the reconstruction of the past environments.

The subgroup of biologists and palaeobiologists is called to study the holes of crustaceans. These investigations could be useful in the field of protection and conservation especially in areas, where human activity quickly changes environmental conditions. In addition, the study of holes is a component of crustaceous zoology. Many ichnogenera are described in the chronicles of fossil signs, for which have no obvious actual analogues. Thus, palaeoichnologists have more questions than biologists could answer. For instance, the first useful question is which anatomic characteristics (appendages, form of the bodies and so on) and mode of activities (mobility, possibility to catch and so on) are needed for the creation of specific fossil signs.

The subgroup of biologists and the palaeontologists works on the improvement of our knowledge on the morphology of modern holes, which is important for the attempts to compare ones with fossils signs. More efforts are needed for describing the configuration of hole systems using excavations or the series of sections, or with the help of modern non-destructive geophysical methods. The other perspective direction is studying the micromorphology of walls of insect holes.

Palaeontologists could get new ideas from the works of biologists, which are presented on the ichnological workshops. The meetings of ichnologists and biologists are useful for both groups of specialists, because there is a possibility of getting information on investigations of modern holes and their producers, which could be important for the deeper understanding of the fossil record. Investigations of the fossil record of holes of crustaceans and other animals provide additional information, which is impossible to get from the studying of modern holes.

Ichnological symposiums and workshops are hold once in three years with the participation of about 80 ichnologists (scientists and students) and often with representatives of oil industry. The symposiums and workshops were accompanied by field excursions, during which the participants could see the shallow water, the sea off the shore and continental deposits of different ages that include the ichnofossils.

Therefore, communication and cooperation among biologists and palaeontologists is highly valuable and palaeontologists can get more knowledge on ichnological investigations of the modern life.

The ichnological association publishes news and scientific publications in the edition "Ichnonewsletter" providing the opportunity to get actual information on current investigations (Dashtgard & Carmona 2011).

O. S. Vialov initiated ichnology in Ukraine (Vialov 1966; Palij 2013). He got huge collections of ichnofossils and mechanogiphs from Carpathian Neogene and Paleogene (flysches and molasses) deposits. The collections of ichnofossils and mechanogliphs of academician O. S. Vialov are stored in the Palaeontological Museum of Ivan Franko National University of Lviv (PM). A few collections are stored in the Geological Department (GD) of the National Museum of Natural History, National Academy of Sciences of Ukraine and in the Geological Museum (GM) of Taras Shevchenko National University of Kyiv.

Material and Methods

We know that most of the signs of ichnofossils appear on the surface of beds. Therefore, we need to search for such surfaces in the outcrops or in the cores of boreholes. Weathering reveals separate surfaces of beds and shows us imprints that are preserved on it. Often, we have to cut sedimentary rocks with the help of geological tools (hummers and chisels). More complicated is the search for vertical signs. It is very good if signs of burying of any animas are visible on the weathered wall of the outcrop. Usually, entrances of holes or the sections could be visible on the surfaces of beds, but it is only two-dimension projection and the trajectory of the buried animal often remains enigmatic.

In such case, ichnologists use the digital *three-dimension method*. Now ichnologists use three-dimension method of visualization through computer programs that are needed for the reconstruction

based on serial thin sections of holes. For example, non-destructive technology was applied and described in a few papers, including the image of *Macaronichnus* with the use of magnetic resonance imaging (Gingras *et al.* 2002), X-ray analysis *Zoophycos* (Wetzel & Werner 1980; Löwemark & Schäfer 2003), and *Monesichnus* (Genise & Laza 1998).

The imprints of vertebrates were investigated using multiband laser scanning (MLT) (Platt *et al.* 2010).

The serial grinding had benefits because it allows directly to watch and to measure properties of the vertical holes (signs of drillings). The main drawback of serial grinding is the destruction of samples. *Phycosiphon*-like ichnofossils were the first rest of animals for which that method was applied (Naruse & Nifuku 2008; Bednarz & McIlroy 2009).

Descriptions of Fossils

In the last ten years, the author of this paper has amassed a large collection of ichnofossils of Ediacaran (Vendian) and of other age during geological field expeditions and revisions of the monographic collections stored in the GD.

In particular, part of the new important finds has been described in the paper. Some of the ichnofossils due to bid size of slabs were left on the place (in situ). The Silurian sequence in Ukraine is represented mainly by different varieties of limestone, which include a rich diversity of fossils. The feature explains less attention to Silurian ichnofossils. For example, one of the brightest cases was found in a quarry near Dzvenigorod village on the left bank of the Dniester River. There are tracks of bivalves on the lower side of grain limestone slab, which belongs to the Trubchin Suite of Přidolian Series of Podolian Silurian. The find came from the quarry near Dzvenygorod village. The tracks have straight and ring-like trajectories that cross one another, have and include cores of bivalves in some cases (Fig. 1).

The second case is a location near Kytaigorod village, Khmelnitsky Oblast. There is a big platform on the erosional boundary among Silurian thicker and Cretaceous one, which was excavated by bulldozer for demonstration during the geological field excursion of the International Symposium of the Subcommision on Silurian Stratigraphy, 1983 (Tsegelnyuk, Gritsenko, Konstantinenko, Ischenko, Abushik, Bogoyavlenskaya, Drygant, Zaika-Novatsky, Kadletz, Kiselev, and Sytova 1983). Many holes of crustaceans are visible on the platform (Fig. 2).

Then signs of ancient animals could be stored on bedding surfaces, especially when the contacting sediments have different consistence (for example, sandstone and argillite, i.e. sand and clay) (Figs 1–6). On argillaceous substrate, the animals leave different negative signs. The sand fills in the furrows and on the lower surfaces appears as positive *hyporelief* and the opposite on the upper surface — negative *epirelief*. Such scenario of signs formation is the most common.

Fig. 1. Low surface of a big slab of grey grain limestone (positive hyporelief). It is a bright example of preservation of tracks of bivalves crawling on soft seabed. The furrows show different signs similar to tracks of modern bivalves. Then the furrows were filled by lime with detritus. The imprints of tracks had straight and ring-like tracts that cross over in some cases. The plot of the slab is more than 1 m^2. The location is in the quarry near Dzvenigorod village on the left bank of the Dnister River.

Рис. 1. Нижня поверхня великого блоку сірого зернистого вапняку (позитивний гіпорельєф). Це яскравий приклад збереження слідів двостулок, які повзали по м'якому морському дну. Борозни показують різні знаки, які нагадують сліди сучасних бівальвій. Згодом в борозни потрапив вапняковий мул з детритом. В деяких випадках відбитки кільцевих треків перетинаються прямими і навпаки. Площа блоку більша за 1 м^2. Знайдений у колишньому кар'єрі біля с. Дзвенигород на лівому березі р. Дністра.

Fig. 2. The artificial outcrop was ordered from the local administration for demonstration to participants of the International Symposium, 1983. The clearing opens contact among Silurian and Cretaceous deposits near an old road from Demshin village to Kytaigorod village. The area of the outcropping platform is more than 2000 m^2. On the flat surface of the contact were found many rounded drilling holes of crustaceans, which are filled by dark grey mineral — phosphorite. On the picture are visible some holes (white arrows); the crossing is near 3 cm. The depth of holes is 2-3 cm (Photo by the author).

Рис. 2. Штучне відслонення було замовлено зі згоди місцевої адміністрації для учасників Міжнародного симпозіуму, 1983. Площадка відкриває контакт між відкладами крейди та силуру біля древньої дороги від с. Демшин до с. Китайгород. Площа відслонення більше 2000 м^2. На плоскій поверхні контакту знаходяться численні округлі нірки, просвердлені в твердому дні ракоподібними. Нірки заповнені темно-сірим фосфоритом. На знімку помітні кілька нірок (деякі відмічені білими стрілками). Діаметр отворів 3 см, глибина 2 см. Фото автора.

Some modern brachiopods, for example *Lingula* sp., are buried in soft silt with the help of muscular leg and shells with sharp ribs like drill. We found fossil shells of *Lingula* sp. in vertical positions in Silurian and Ordovician deposits. But the cases when we could recognise the animal that produced the signs are unique. Usually, we could only suppose what organism made the signs, tracks, or holes. The organism that produced the signs could dig into sediments searching for food or hiding from enemies (or predators) in vertical direction or under certain incline. The digging trajectory may change the sinusoid shape in horizontal or vertical planes (undulation). The signs may have different trajectories, which is common for some "species" of ichnofossils. Commonly, the morphology (thickness, width, depth, height and trajectory) and ornament of the surfaces are the main features that are useful for the definition of ichnospecies and ichnogenus. For the naming of ichnofossils, an artificial taxonomy is used. The main reason of such approach is that we cannot know exactly what animal made the signs.

The one of many examples of positive solving was found in Jurassic clayey limestone in the ravines of Melanchin Potik and Kostianets Yar in Kaniv Reserve. There are fossil populations of bivalves *Pholadomya* sp., which drilled vertical pear-shaped holes (Fig. 3) into the clay substrate (now it is clayey limestone). The bivalves walled up and only the siphon was stuck out of the holes.

Fig. 3. The core of the hole of *Pholadomya* sp. filled up by clayey limestone. The picture is turned horizontally.

Рис. 3. Ядро нірки *Pholadomya* sp. заповнене глинистим вапняком. Рисунок розвернутий горизонтально.

Descriptions of Species

All specimens are stored in the hall of monographic collections of the Geological Department of the National Museum of Natural History of the National Academy of Sciences of Ukraine.

Harlaniella Sokolov, igen,. 1972

***Harlaniella podolica* Sokolov, 1972** (Fig. 4 *a*-*b*)

Diagnosis. "Braid-like molds (positive hyporelief) covered by oblique hatching that was created by densely and regularly located furrows. The negative epirelief has an appearance of grooves with oblique ribbing" (Paliy 1976).

The nature of *Harlaniella podolica* Sok. is controversial. It is mostly found as convex rollers with oblique hatching. The species is located on the lower surface of beds as positive hyporelief. The ichnospecies is characterised by none-regular trajectory. The hatching is weakly expressed because of the special way of conservation of remains. The described sample was taking from the outcrop of Komariv beds of Studenitsa suite, Kanylivka series of the upper Vendian on the bank of Bakota Bay (cave monastery near the former village). The outcrop is near the water level and sometimes it could be covered by water and the bedded rock is divided in winter by ice on the separate thin plates.

A. Yu. Ivantsov found one specimen of *Harlaniella podolica* Sokolov with a film of *Vendotaenia* on it, because of which he proposed to consider this species as representative of brown algae.

Remarks. In our opinion, it is only an accidental co-occurrence of *Harlaniella* and *Vendotaenia*, because these two species usually occur separately.

The diversity and variability cause some issues for ichnologists with the identification of the signs. On the other hand, representatives of one species have different look through features of fossilisation and deficit of fossils record. The study of ichnofossils is complicated by features of lithological content of deposits on which they rest or if it is in fauna burying into sedimentary rocks.

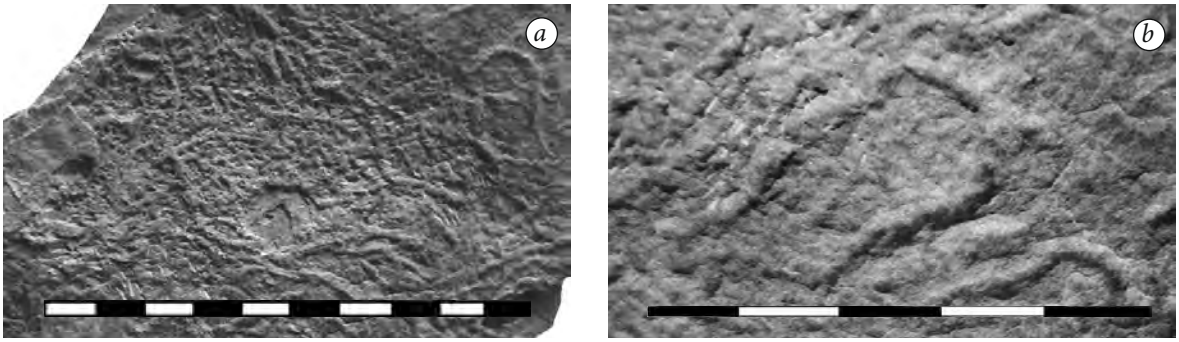

Fig. 4. *Harlaniella podolica* Sok., the association of mostly curved signs (tracks) with oblique hatching ornament. Positive hyporelief, sample GD No. 2525/1635.

Рис. 4. *Harlaniella podolica* Sok. Щільне угрупування у більшості зігнутих знаків (треків) орнаментованих косою штриховкою. Позитивний гіпорельєф; ГВ №2525/1635: *a* — загальний вигляд; *b* — деталь (збільшено)

***Harlaniella ternavensis* Grytsenko isp. nov.** (Fig. 5 *a*–*b*)

Description. The positive hyporelief is represented by elongated and slightly curved rollers, which are 2 to 4 cm long with a cross section length of 2.5–3 mm. The surface is covered by thin and unclear oblique hatching. The hatching somewhere has wedge-shaped ornament.

The origin of such signs could be related to feeding activities of the animals. The separate signs form two almost perpendicular directions. The most distinctive signs direction diverge on unglue within near 30° on the same plate. It seems that the signs are lying on some close levels in the rock.

Material. One plate (specimen) with few signs from the outcrop near Kytaigorod village.

Comparison. The new ichnospecies differ from *Harlaniella podolica* Sokolov, 1972 by more straightforwardness of the tracks.

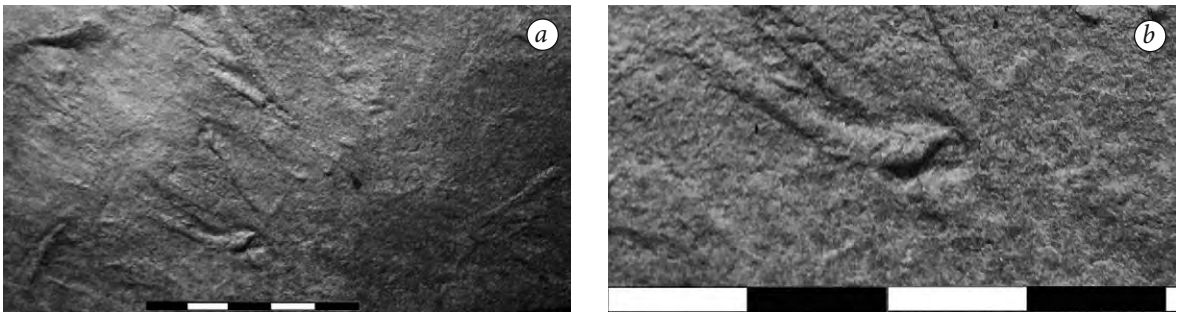

Fig. 5. *Harlaniella ternavensis* Grytsenko isp. nov. Mostly direct separate signs (tracks) on different levels in the rock. Positive hyporelief; holotype GD No. 2525-110. Scale bar — 10 mm.

Рис. 5. *Harlaniella ternavensis* Grytsenko isp. nov. Розріджене угрупування здебільшого прямих знаків (треків) орнаментованих косою штриховкою. Розташовані в породі на різних рівнях. Позитивний гіпорельєф; голотип ГВ №2525-110: *a* — загальний вигляд; *b* — деталь (збільшено)

Location. Outcrop located near a bridge over the Ternava River nearby to Kytaigorod village on the left slope of the river valley.

The specimen is stored in the Geological Department of NMNH NAS of Ukraine.

Remarks. The partial immersion of signs on the sediment is shown in Fig. 5 *b*. The impression of the signs divergence could depend on such immersion of the tracks. The ichnospecies name is derived from the Ternava River.

Holotype. Stored in the GD, No. 2525-110, found in the upper part of the Komariv subsuite, which is a unit of Studenitsa suite of the Kanylivka Series of the Upper Vendian (Ediacaran).

The signs show scraping (feeding) bacterial-algal biomate, which was left by an unknown animal on the ancient sea bottom. Now it is siltstone of the Yampil bed of Mogyliv suite in the Bernashivka quarry near Novodniestrovsk (Fig. 6). It was described earlier (Grytsenko 2020: 12). It is the first mention and picture of such phenomenon in an Ediacaran object of Ukraine's most ancient stratigraphic unit of the Panerozoic succession.

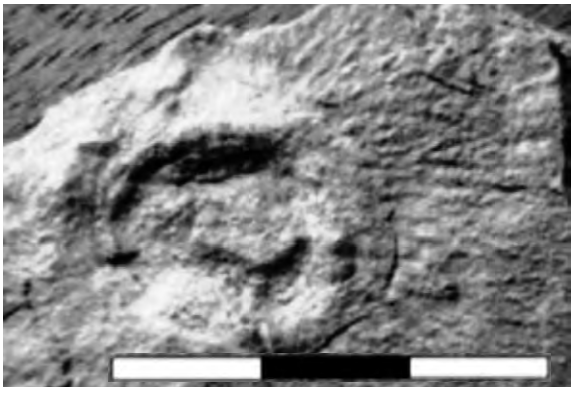

Fig. 6. *Scratchichnus dniestery* isp. GD No. 2525/1609, found in the upper part of the Yampil Member of the Mohiliv Formation.

Рис. 6. *Scratchichnus dniestery* isp. ГВ № 2525/1609 зразок був знайдений у верхній частині ямпільських верств могилівської світи в Бернашівському кар'єрі.

***Rugoinfractus ovruchensis* Paliy, 1973** (Fig. 7)

Description. Few samples of problematic signs were found and described from the Ovruch quartzite by V. M. Palij and they are stored in the exhibitions of GM of Taras Shevchenko National University of Kyiv and of PD of NMNH NAS of Ukraine (Fig. 7). It resembles a deformed chain of *Paleodictyon* sp., but differs by more complicated cross section. The signs are problematic also due to the controversial age of the series and different understanding of the tracks. The biological nature of the signs is also debated. Moreover, the similar structures are given at amounts of pictures among of the images of the "Atlas of structures and textures of sedimentary rocks. Part I" (Vikulova 1962). The branches form a network. Each thick branch has up to three ridges. The thick branch (trunk) varies from 10 to 12 mm. Among the thicker so-called "trunks" are branches of lesser cross sections (near

Fig. 7. *Rugoinfractus ovruchensis* Paliy, 1973 (No. 701/32) found in Ovruch quarry on the lower surface of bedding quartzite (positive hyporelief).

Рис. 7. *Rugoinfractus ovruchensis* Paliy, 1973 (№ 701/32) знайдений у Овруцькому кар'єрі. Сліди розташовані на нижній поверхні нашарування кварциту (позитивний гіпорельєф).

Fig. 8. The signs of mechanical origin on the lower surface of Bernashivka beds that are casts of negative furrows created by flows on surface argillites and rounded protrusions on the same level created by unknown agents.

Рис. 8. Сліди механічного походження на нижній поверхні базального шару Бернашівських верств, які є відбитками негативних борозен, що виникли завдяки течіям на поверхні аргілітів лядівських верств. На поверхні розрізняються також округлі в перетині ямки (сліди конусів створених невідомими агентами.

Fig. 9. Different signs of unclear origin on sandstone of Lomoziv units of the Mohyliv Suite from Bernashivka quarry.

Рис. 9. Різноманітні сліди неясного походження на пісковику ломозівських верств Могилівської світи з Бернашівського кар'єру (позитивний гіпорельєф).

5 mm). The trunks are slightly curved and have angles of directions attaching from 90° up to 120°. The less thick branches differ by simpler cross section with one or two ridges. The chain constructs a triangular to pentagonal form of lacunas.

The other interpretation argues on the biological nature of the signs. It could be signs of desiccation of sediments on the lower surface of the bed, but such conclusion needs further discussion.

Remarks. In the "Atlas of structures…," there is a structure similar to the one described here (Vikulova *et al.* 1962). But the picture in the "Atlas" lacks complications by ridges. The geological age of Ovruch series is also questionable. Some researchers based on the degree of metamorphism consider it as of Riphaean age, but others are confident in a different opinion. They have another understanding based on findings of fossil remains of Middle Palaeozoic age. Thus, there are at least two controversial points of view on the nature and age of these signs.

Holotype. GM No. 2010 (Paliy 1973), Paratype GD No. 701/32 (designated here).

On the basal surface of the lower part of Bernashivka beds, there are specific signs (imprints) of mechanic origin (so-called "mechanogliphs"), which were created by temporary flows on the cover surface of Liadova beds of Mogyliv suite (Fig. 8). Just on the boundary between both suites. There are mostly elongated signs of flows on the lower surface of Bernashivka sandstone. Among them spreads a rounded negative structure on the positive hyporelief, which could be represented by a positive epirelief on the top of Liadova beds. The nature of such structures remains unknown.

In the many cases, we cannot determine the nature of these signs, but they are mainly related to Ediacaran ichnofossils. The sample of bioturbation of the sediments is shown on the photo (Fig. 9), which represents few different signs (small holes are filled with sediments, arcuate sign similar to tangled hair and others) on the lower surface of the bedding plates.

***Didymaulichnus nerodenkoi* Grytsenko, 2016** (Fig. 10)

Description (after Grytsenko 2016: 13, Fig 2. *12*): "These are moderately elongated tracks with close to straight trajectories. Maximum width in the middle part is ca 5–6 mm. The length of some of them reached from 12 to 40 mm. They appear on the bedding surface and disappear again. The tracks are divided by negative line (grove) up to 2 mm in width. Poorly distinct structure like ticks oriented in one direction are seen in the groves."

Comparison. The species differs from *D. tirasensis* Palij and *D. cf. miettensis* Young by smaller size and stratigraphic position. The first species was found in the Lower Cambrian, whereas the second one in the Lomoziv member of Mohyliv Formation.

Ichnofossils are more diverse in Cambrian deposits than in Ediacaran and are often more densely located on the surface or in the rocks. The interruptions of signs or tracks on the surfaces of the beds could be related to geochemical heterogeneity of the environment. Possibly, it depends on the different index of redox (Grazhdankin *et al.* 2019) or just on direction changes in vertical (i.e. undulation) or horizontal planes (Figs 11–14). Commonly, a huge amount of different signs of ichnofossils can be found on/in sandstones of the Khmelnitsky Suite, but coarse graining of the rock does not contribute to good preservation and interpretation of signs.

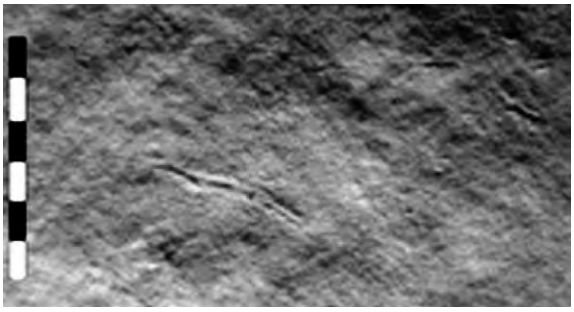

Fig. 10. *Didymaulichnus nerodenkoi* Gryts. 2016. No. 2525/1860 was found in the upper part of Jampil beds (unit).

Рис. 10. (*Didymaulichnus nerodenkoi* Gryts. 2016. № 2525/1860 був знайдений у верхній частині ямпільських верств.

Fig. 11. Different signs on a sandstone plate from the Lower Cambrian Khmelnitsky Suite. The outcrop is located on the left bank of the Ternava River near Kytaigorod village, Khmelnitsky Oblast, GD No. 81-44.

Рис. 11. Різноманітні знаки плитці пісковику Хмельницької світи нижнього кембрію. Відслонення розташоване на лівому березі р. Тернави на околиці с. Китайгород (Хмельницька обл.). Зразок ГВ № 81-44 (2135).

The diversity and density of small ichnofossils located on the lower surfaces of plates do not allow determining separate ichnospecies in many cases. It seems that higher levels of magnification are needed together with light manipulation and applying new methods of investigation with cutting and without destroying the specimen. For example, tomography or/and X-ray, which ichnologists abroad started using in many cases. Nevertheless, the specimen needs a more detailed investigation.

The specimen is stored in the GD No. 2514/192. It is a plate of green-grey sandstone from the Khmelnitsky Suite of the Baltic series (Cambrian system), which was found in the outcrop on the left bank opposite to the bridge over the Ternava River near Kytaigorod.

The divisions of the scale bare are equal to 1 mm.

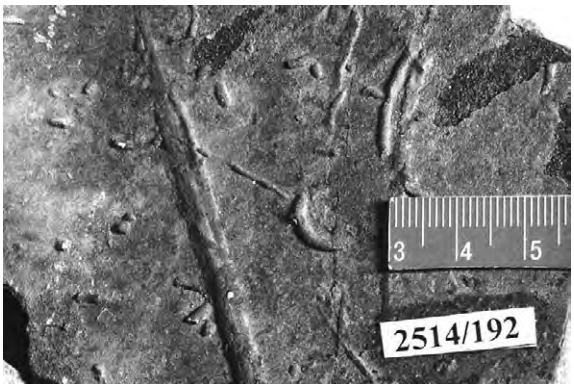

Fig. 12. The track of *Planolites* sp. stretches by the whole picture. On the plate, they are short and thin (up to 2 mm in cross section). Straight and curved trails are up to 15 mm in length. It is a positive hyporelief.

Рис. 12. Слід *Planolites* sp. Перетинає всю плитку. На ній розташовані прямі та вигнуті сліди довжиною до 15 мм та короткі і тонкі (до 2 мм в перетині). Це позитивний гіпорельєф. Зразок зберігається у ГВ — №2514/192. Плитка зеленкувато-сірого пісковику з хмельницької світи балтійської серії нижнього кембрію знайдена у відслоненні на лівому березі р. Тернави проти мосту на околиці с. Китайгород. Поділки масштабу — 1 мм.

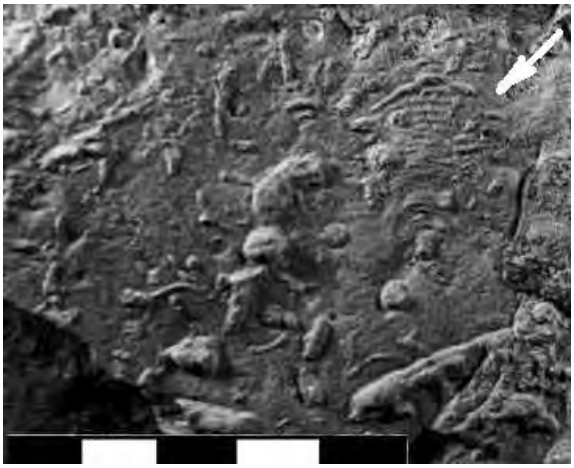

Fig 13. The sign of *Paleopascihnus delicatus* Paliy is distinct on the plate among others. There are different kinds of tracks visible on the plate: straight sign of *Didymaulichnus* sp. on the lower part of the figure, signs of vertical holes filled by sand, weakly curved short thin tracks up to 15 mm long and others. They are from the same outcrop and stratigraphic position (Kytaigorod, Lower Cambrian).

Рис. 13. Слід пасьби *Paleopascihnus delicatus* Paliy помітний на плитці поміж інших слідів. На плитці також помітні треки різної будови: прямий знак *Didymaulichnus* sp. на нижній частині зображення, сліди вертикальних нір заповнені піском, слабко вигнуті короткі тонкі треки довжиною до 15 мм та інші. Ті самі відслонення та стратиграфічне положення (с. Китайгород, нижній кембрій). Зразок зберігається у Геологічному відділі ННПМ НАН України (ГВ).

Fig. 14. *Planispiralichnus rarus* Menasova 2003, holotype GM No. 17p41 found in 1999 by the author (Volodymyr Grytsenko) in the sandstone of the Khmelnitsky suite on the left bank of the Ternava River near Kytaigorod. The divisions of the scale bare are equal to 10 mm.

Рис. 14. *Planispiralichnus rarus* Menasova 2003, голотип ГМ № 17p41. Зразок знайдений автором 1999 р. у пісковиках хмельницької світи на лівому березі р. Тернави біля с. Китайгород. Позначки масштабної лінійки дорівнюють 10 мм.

Recently, we have carried out a revision of Yu. O. Gureev's collection. The revision has shown some interesting and unique specimens, which includes ichnospecies. Some specimens, in our opinion, represent new ichnospecies and ichnogenera of fossils and remains of new yet unknown animals (Figs 15–16).

***Ternavites gureevi* Grytsenko gen. et sp. nov.** (Figs 15,16)

Description. There are two samples of large and long tube-like structures, which take the whole place over the plate. In the first view, these remains seem as ichnofossils, but after a more detail study under a doubled magnification, they turned out to have noticeable short roots. The erosion process showed the inner structure of the tubes, which is as a "cone in cone" structure.

Both tubes are crossing one another in the upper part. There was an expansion in the upper parts of the tubes (like a cap of corals). Two buds grew from the "capes."

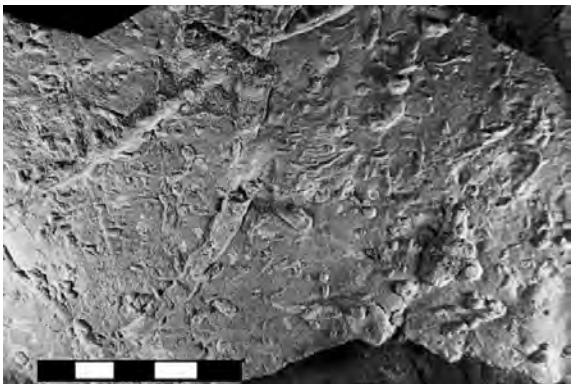

Fig. 15. A plate of sandstone belonging to the Khmelnitska suite of the Baltic series (Cambrian system) found in the left slope of the canyon-valley of the Ternava River near Kytaigorod. It is a positive hyporelief. General view of the plate with different ichnofossils — GD-G No. 81-44. The divisions of the scale bare are equal to 10 mm.

Рис. 15. Плитка пісковику з хмельницької світи балтійської серії (кембрійська система) була знайдена на лівому схилі долини каньйону р. Тернави біля с. Китайгород. Загальний вигляд плитки з різноманітними іхнофосиліями — ГВ-Г № 81-44. Позитивний гіпорельєф. Позначки масштабної лінійки дорівнюють 10 мм.

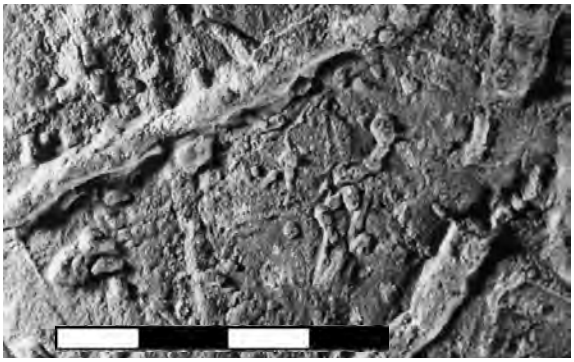

Fig. 16. The details of the plate on an enlarged scale. Two larger and longer tube-like structures differ among the diverse small horizontal and vertical signs, which after a more detailed study turned out to have noticeable short offshoots (roots) and "cone in cone" structure of the tube.

Рис. 16. Деталь плитки у збільшеному масштабі. Серед різних дрібних горизонтальних та вертикальних знаків розрізняються дві більших та довших трубкоподібних структури, у яких завдяки більш детальному вивченню у двічі більшому масштабі помітні короткі відростки (корінці) та утворення "cone in cone"в трубці.

Dimensions. The length of the tubes is more than 150 mm, their visible diameter varies from 5 to 7 mm. The diameter of the cap is about 10 mm.

Remarks. The genus's name is derived from the locality's name on the bank of the Ternava River. The species name is given in the memory of Yuriy Gureev, who made a considerable contribution to the study of Vendian and Cambrian ichnofossils of Podillia. The structural features of these animals allow to consider them as the most ancient representatives of coelenterates (*Auloporida*).

The remains of fossils were found on the lower part of the plate among few various ichnospecies, including unclear signs of *Paleopascichnus delicatus* Paliy (Fig. 15).

Results of a comprehensive study of the collection of *Oldhamia recta* raised doubts regarding the affiliation of these ichnofossils to this species and assumed they are body remains animals (Tacker *et al.* 2010). On the other hand, it could be a case of dealing with animal body and its signs. Such cases sometimes happen in the practice of palaeontologists and ichnologists.

Holotype. Stored in the GD-G No. 81-44. It was found in the middle part of the Khmelnitsky Suite on the left bank of the Ternava River near Kytaigorod. Two tubes on one sandstone plate.

Relatively new materials were obtained by us during the expedition conducted by the NMNH NAS of Ukraine in 2017 in the cooperation of the Departments of Palaeontology and Geology. We visited a few outcrops of "Old red sandstone" near Nyrkiv village, which is of continental origin and represents lake, river, and swamp facies.

Such Lower Devonian deposits are spread from North America to Australia. The remains of diverse *Agnatha,* mostly Pteraspida and Cephalaspida, including *Sclerodus sp.* and *Cephalaspis sp.,* as well as ichnofossils are preserved there in favourable conditions (Fenton *et al.* 1989, 1996). The fish remains were studied by many researches from Ukraine, Poland, and Estonia, but ichnofossils from the same deposits remained less studied compared to other real fossils.

In the summer of 2012, an interesting find was made in vicinities of Nyrkiv village on the valley slope of the Dzhuryn River. Remains of bone breccias, fragments and whole skeletons mostly of *Agnatha* were found in Lower Devonian "old red sandstones" on the location on the canyon-valley near Nyrkiv village, Zalischiky Raion. The revision of the photos allowed determining one, possibly new,

Fig. 17. The lower surface of clayey sandstone with paired tracks of unknown animals. It is a positive hyporelief. On the lower surface of the slab are seen few (two) shields of *Agnatha*, possibly of *Pteraspis* sp. If the assumption is correct, such tracks could be named as "*Pteraspisichnis.*" Geological hummer used as scale (53 cm).

Рис. 17. Нижня поверхня глинистого пісковику з подвійними треками невідомої тварини (позитивний гіпорельєф) та двома щитами *Agnatha possibly Pteraspis* sp. Якщо припущення вірне, сліди можна назвати "*Pteraspisichnis*". Великий розмір блоку примусив нас залишити цю знахідку з унікальними слідами на місці. Я сподіваюсь знайти його «in situ». Геологічний молоток використаний для масштабу (53 см).

Fig. 18. The fragment of the slab twice enlarged. Not only double signs of "*Pteraspisichnis*" of unknown animals can be seem, but also part of the shield of small *Pteraspis* sp. with attached tale. The shield has a spoon-like shape and it covered the frontal part of the animal's body. That part of the shell has much better preservation compared to others.

Рис. 18. Фрагмент блоку у двічі збільшеному масштабі. Ми бачимо подвійні сліди невідомої тварини — «*Pteraspisichnis*» та два щита. *Pteraspis* sp. Ці частини панцира зберігаються краще інших. Щит покривав передню частину тулуба тварини. Він має ложко-подібну форму.

ichnospecies, which was found on the lower surface of a clayey sandstone slab. It has an appearance of nearly parallel tracks located close one to another and accompanied by shields possibly of small *Pteraspis* sp. In our opinion, the weight of the shell did not allow active swimming of these animals, which simply crawled on the bottom. We can see a negative epirelief on the slab (Figs 17–18).

***Pteraspisichnis djurinensis* Grytsenko igen. et isp. nov.** (Figs 17,18)

Description. On the photos (Figs 17–18) there are images of the lower surface of a sandstone slab and isolated plots with signs of crawling of *Pteraspisichnis djurinensis* Grytsenko igen. et isp. nov and shields of *Pteraspis*. The signs form paired trajectories of different length, which are directed almost parallel with insignificant deviations from the general direction.

Remarks. The interpretation could be changed after getting additional materials. Derivation of names are related to the locality (ichnospecies name) and preliminary definition of affiliation (ichnogenus name).

The lower surface of the clayey sandstone is with paired tracks of unknown animals. It is a positive hyporelief. On the lower surface of the slab are seen few (two) shields of *Heterostraci*, possibly of *Pteraspis* sp. If the assumption is correct, such tracks could be named as "*Pteraspisichnis*." The large size of the slab forced us to leave the unique block in the place with hope to find it next time *in situ*.

Holotype. The slab with ichnofossils is located on the outcrop in the valley of the Dzhuryn River near Nyrkiv, Zalischiky Raion, Ternopil Oblast.

The accurate revision of the other sample shows us signs of ichnofossils and mechanogliphs. Tracks of high-level bilateral animals were found among others signs (Fig. 19).

***Egoreichnis yaroslavi* Grytsenko igen. et isp. nov.** (Fig. 19)

Description. Short signs with two "ridges" possibly left by limbs of armoured fish. The imprints were found in red clayey sandstone of the Dniester series (Lower Devonian). The outcrop is located near Nyrkiv, Zalischiky Raion, Ternopil Oblast.

Fig. 19. *Egorichnis yaroslavi* Gtytsenko igen. et isp. nov. The imprints of tracks of an unknown animal have two ridges on the lower part. The distance among the imprints is higher than the length. The substrate on the bottom was soft for the imprinting of the footprints. Near the footprints are possibly located some remains of undetermined bivalves (cores) and slightly curved unclear imprints.

Рис. 19. *Egorichnis yaroslavi* Gtytsenko igen. et isp. nov. відбитки слідів пересування невідомої тварини мають два ребра на нижній поверхні. Відстань між слідами більша їхньої довжини. Грунт на дні був сприятливим для відбитківю Біля відбитків кінцівок (кистеперих?) можливо розташовані рештки (ядра) невизначених бівальвій та слабко вигнуті короткі відбитки.

Remarks. Field studies were carried out together with two students (Yaroslav Lapka and Egor Antakov) of the Geological Department of Taras Shevchenko National University of Kyiv. The names of the students were used for naming the tracks of the ichnofossils.

Holotype. Stored in the GD, No. 2485-32. It was found in red clayey sandstone of the Dniester Series, Nyrkiv village, Zalischiky Raion, Ternopil Oblast.

Other plates have some different signs and imprints (Figs 20–21).

Fig. 20. The sample of ichnofossils and mechanogliphs on a clayey sandstone plate. It was found in the same location near Nyrkiv village, where the author together with two students (Ya. Lapka and E. Antakov) collected samples of Devonian sandstones with various signs mostly of *Agnatha* and ichnofossils, which are stored in GD No. 2578. The sample GD No. 2579/1, which is stored in GD, is presented here. In the upper part of the figure, there is a series of wedge-shaped mechanogliphs, which could be imprints of ice-crystals. In the lower left part are seen crescent signs, on which continuations are parallel hatching. In the central part of the picture are two parallel rows of short signs, which are located obliquely to the direction of the tracks. The length of separate stroke is near 5 mm and the same distance among them. Positive hyporelief. The divisions of the scale bare are equal to 10 mm.

Рис. 20. Зразок іхнофосилій та механогліфів та плитці глинистого пісковику був знайдений автором під час експедиції разом з двома студентами (Я. Лапка та Є. Антаков), які допомагали збирати взірці девонських пісковиків з різними слідами на них. В колекції ГВ № 2578 — переважно *Agnatha* та іхнофосилії. На фото зразка ГВ № 2579/1 (представленого тут) у верхній частині зображення видно серію трикутних механогліфів, які можуть бути відбитками кристалів льоду (?). У нижній лівій частині знаходиться вигнуті знаки, на продовженні яких є паралельні штрихи. В центральній частині — два паралельних ряди коротких знаків, що розташовані косо до напрямку треків. Довжина окремих штрихів близько 5 мм, така сама відстань між ними. Позитивний гіпорельєф. Позначки масштабної лінійки дорівнюють 10 мм.

Fig. 21. On the photo is shown the left lower quadrant of the neighbouring picture in natural size. Here are visible crescent signs, on which continuations are parallel hatching (length of 10-11 mm). They form a 20 mm long track. Two crescent convex signs could be connected with these parallel hatching. The divisions of scale bar are equal to 10 mm.

Рис. 21. На фото показаний лівий нижній квадрант сусіднього рисунка в натуральну величину. Тут видно вигнуті сліди, на закінченнях яких знаходяться паралельні штрихи довжиною 10-11 мм. Вони утворюють трек довжиною 20 мм. Два серпоподібно опуклих сліди можливо пов'язані з цими паралельними штрихами. Позначки масштабної лінійки дорівнюють 10 мм.

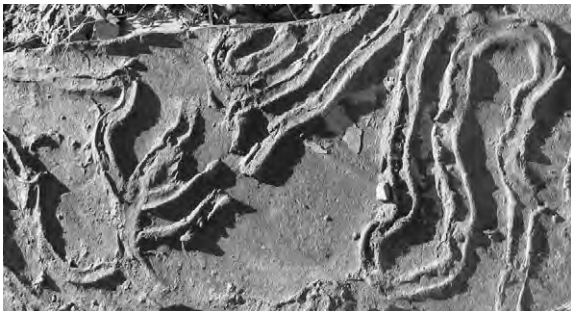

Fig. 22. Tracks of *Scolicia strozzii*, Transcarpathia, Pryborzhavsky sandstone quarry (Lower Cretaceous) (Photo by E. Veklich).

Рис. 22. Чудовий трек *Scolicia strozzii* — Закарпаття, Приборжавський кар'єр (нижня крейда) з видобутку пісковиків. Фото О. Веклич.

On a big slab of sandstone (possibly of Cretaceous age) in the Pryborzhavsky quarry (one of the Transcarpathian quarries), we found excellent, wide and long crawling signs possibly of *Scolicia strozzii* (Fig. 22). Unfortunately, we left the slab with the sample on the place because of its big size and weight. We hope to come back for the sample with tools to take the sample to the museum. Similar ichnofossils are depicted in A. Uchman's paper (Uchman 2004, Fig. 7 B).

Many years ago, our museum staff had an opportunity to carry out field studies in different regions of Ukraine and to collect samples for the exhibition. Among other samples, few finds of ichnofossils were collected from the Dobrotiv Suite of Neogene age near Drohobych, Ivano-Frankivsk Oblast. The samples are exhibited in the collection devoted to the Geological History of Ukraine (Figs 23–24).

Fig. 23. *Deliatynichnis verii* Grytsenko isp. nov. (signs that diverge marked by black arrows) and *Triacliichnis yurii* Grytsenko, 2021 isp. nov (thin "triacles" marked by white arrows). Positive hyporelief.

Рис. 23. *Deliatynichnis verii* Grytsenko isp. nov., сліди що розгалужуються дихотомічно (позначені чорними стрілками) та — *Triacliichnis yurii* Grytsenko, 2021 isp. nov тонкі трипроменеві «зірки» — сліди діляться на три напрямки (позначені білими стрілками). В усіх випадках позитивній гіпорельєф.

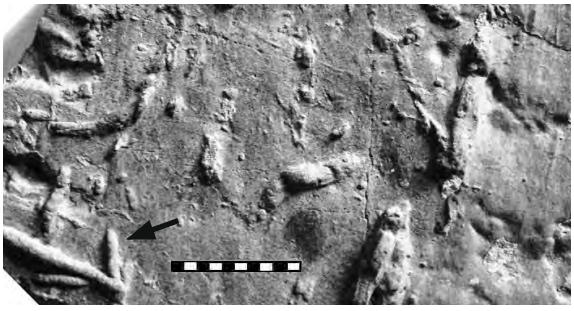

Fig. 24 . Two variety of tracks—thin diverged (black arrow) and thick short (white arrow)—from the same locality and stratigraphic position, GD No. 1971-1.

Рис. 24. Два різновиди треків — тонкі, що розгалужуються (позначені чорною стрілкою) та товсті короткі — ті самі місцезнаходження та стратиграфічне положення — ГВ № 1971-1.

Invertebratichnia Vialov, 1966

Endoglyphia Vialov, 1968

Deliatynichnis Grytsenko, 2021 igen. nov.

Diagnosis. Dichotomous ramified cylindrical signs with roots on the lower side of a sandstone.

***Deliatynichnis verii* Grytsenko isp. nov.** (Fig. 23)

Description. Filled up dichotomous ramified structures of cylindrical shape with short and long roots.

Remarks. The genus name is derive from Deliatyn and the species name is given in memory of Vera Franchuk, the former director of the Geological Museum.

Holotype. Stored in GD, No. 1840-5. The signs were found near Deliatyn, Ivano-Frankivsk Oblast. Neogene, Dobrotiv series.

***Triacliichnis* Grytsenko, 2021 igen. nov.**

Diagnosis. A three-beam system of thin signs, which have vertical offshoots in the centre of each structure (marked by white arrows in Fig. 23).

***Triacliichnis yurii* Grytsenko, 2021 isp. nov.** (Fig. 23)

Description. The structure forms an unclear network as "paleodyction" (honeycomb structure), but it is thinner and each element is separated from the others. Every beam has a length of 5-6 mm and is 1.0–1.5 mm in cross section.

Remarks. The genus name is derived from the three-beam structure of signs and the species name is given in memory of Yuri Rousko, former director of the Geological Museum.

Positive hyporelief. Scale bar — 10 mm.

Holotype. Stored in GD, No. 1840-5. The signs were found near Deliatyn, Ivano-Frankivsk Oblast. Neogene, Dobrotiv series.

Fig. 25. Imprints of eels or marine snakes on the Bulgarian coast of the Black Sea near Varna. The thanatocoenosis was found in carbonate rocks, which could be of Neogene age. The imprints show long neck, small head with closely spaced eye socks, ribs, and flat vertical tails. The picture was sent to the Geological Department of the NMNH NAS of the Ukraine by an unknown tourist. It is a negative epirelief. Such imprints could be attributed to either ichnofossils or real fossils according to the understanding of the researcher.

Рис. 25. Відбитки вугрів або морських змій (?) знаходяться на болгарському узбережжі Чорного моря біля м. Варна. Цей тафоценоз був відкритий у карбонатних породах неогенового віку. Довгі шиї, маленькі голови, тісно посаджені очниці, тіла мають ребра та плоскі вертикальні хвости. Зображення було направлене до Геологічного відділу ННПМ НАН України невідомим туристом. Негативний ерірельєф. Такі відбитки можуть бути віднесені до категорій іхнофосилій та звичайних скаменілостей одночасно в залежності від розуміння дослідника.

Discussion

The development of ichnology was facilitated by the needs of the oil and gas industry and appropriate financial support of ichnological projects. The main goal was to study the role of ichnofossils for effective porosity, which is especially important in geological prospecting of oil and gas deposits. Further development of ichnology was connected with the creation of ichnological associations and establishment of scientific editions on the topic that cover achievements of this branch of science. A number of scientific meetings of ichnological workgroups were organised in the field aimed to exchange with experience.

Investigations of ichnofossils of Vendian (Ediacaran) and Cambrian age in Ukraine were conducted by V. M. Paliy (Paliy *et al.* 1983) and Yu. O. Gureev (1983 a, b). A special contribution was made by academician B. S. Sokolov and M. O Fedonkin (1977, 1992) and by scientists D. V. Grazhdankin and A. Yu. Ivantsov (the latter two took part in field expeditions to Podillia several times).

The mollusc *Lithophaga* sp. drilled short holes in horizontal direction in the steep rock marine bank below the sea level. During geological excursion in Greece, the author observed horizontal holes of lithophages in the limestone wall of ancient surf niche, the territory of which was raised by tectonic forces on some tens of metres. The definition is correct because cores of the molluscs were found in those holes.

In the past, ichnofossils were not in centre of researchers' attention. The study of ichnofossils have been developing in the last decades and it has reached all continents and seabed.

The ichnological association edits a journal of ichnological news and scientific publications, the "Ichnonewsletter", through which everybody can get access to actual information on current investigations of ichnologists (Dashtgard & Carmona 2011).

Ichnology now solves many tasks that are important for industrial (oil and gas) geology.

Conclusions

Ichnological investigation is in focus in many countries worldwide. In the past, ichnofossils were used only as indicators of the upper or lower surfaces of beds in tectonically deformed layers of rocks, which is very important in structural geology and geological prospecting. Palaeoichnology at its current level of development is a powerful branch of geological science allowing to solve a number of geological issues. Firstly, determinations of ichnofossils are used to correlate geological sections of different regions in wider or global sense. Secondly, evidence of a certain complex of ichnofossils with lithological features of the sections is used to solve facies issues. Thirdly, ichnofossils produced a higher porosity in Cenozoic and sometimes in Mesozoic reservoirs of oil and gas deposits. In such sense, it is valuable for industries.

Specialists in ichnology use a certain set of morphological signs to determine taxa or different ranks: dimensions of the tracks (holes), form, trajectory, relief of the surface, ornamentation and so on. In this regard, they experience certain difficulties related to the variability of morphology and different interpretations of specific and generic features.

Certain complications appear due to the different levels of deformation of ichnofossils up to total elimination of traces under the influence of waves, currents, and bioturbation of deposits on the seabed and in the process of accumulation of deposits and following changes in lithogenesis.

If we use a broad understanding of the term "ichnofossils," almost all Ediacaran finds fall into this category of fossils because they are preserved only as imprints and traces.

The widest variety of ichnofossils in the geological history but for different periods are characteristic for certain complexes, so it is necessary to focus attention on facies and palaeogeographic features.

All of the aforementioned are the reasons of casual errors and other possible mistakes made by researchers of ichnofossils.

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