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The Late Cretaceous phosphatized ichnofauna fossils from the Eocene basal horizon of the Middle Dnieper area

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Abstract. The object of our study was phosphatized remains of ichnofaunas from the basal horizon of the Kanivska suite (Eocene), which transgressively overlies here the eroded top of the Burimska suite. The goal of the research was to reconstruct some sedimentation features of the final stages of the Late Cretaceous basin's existence and during of the Early Eocene

transgression on the Middle Dnieper area (Ukraine). The specimens of the basal horizon of the Kanivska suite (P_2^{kn}) were sampled from the outcrops in the Melanchin Potik gulley and in a branch of the Glyadovy gulley. It is a complex of rough-medium grained gravel sandstones with shark teeth, fish bone fragments, detritus of Bivalvia and Brachiopoda. The nature of preservation and arrangement suggests that the fossils were relocated. The sample from the Glyadovy gulley is an agglomeration of phosphatized debris of various types of ichnofauna, cemented with a phosphate and sand substrate. The first type, in our opinion, is a fragment of a burrow nucleus of a crayfishlike decapod *Thalassinoides* Ehrenberg ichnogenus, as indicated by the surface, absence of a constructed wall and its size. The phosphorite features of the second type are cores of the burrows of the *Ophiomorpha* Lundgren genus with a characteristic ophiomorphic sculpture in the form of knobbls on the outer surface. The structures of the second type have certain differences in the distribution and nature of phosphate material. The described cores are interpreted as domichnia: dwelling places of fossil fauna. They were not known earlier within the Middle Dnieper area. The animals constructed a system of void ducts in the well ventilated middle ichnofossil layer with depth up to 60 cm (as can be inferred from the diameter of *Thalassinoides*). Although crayfish burrows can be present in any formation, it is generally thought that they are more specific for the littoral and shallow water environments. Based on the fauna composition and the phosphatized debris preservation, we can assume the age of ichnofaunas is Late Cretaceous. An indirect indication of this can be the bones and teeth of Cretaceous vertebrates, found in the same basal layer, in particular, ichthyosaurus genus (*Platypterygius* sp.) and a phosphate concretion with ammonite remnants. Besides phosphatized ichnofauna debris, the basal level contains black odd-shaped nodules and microconcretions, composed of amorphous phosphate minerals. They contain a considerable amount of microscopic fossils of presumably phytoorganic nature and fragments of undetermined groups. From the fact that the phosphate material is not completely decrystallized, and that some microfossils have their initial composition, we infer that they belong to the Early Eocene.

Keywords: paleogeography, Cretaceous Period, Eocene, Kanivska suite, phosphatized remains, ichnofauna

Фосфатизовані рештки іхнофауни з базального горизонту еоцену Канівського Придніпров'я

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Анотація. Об'єктом нашого дослідження були фосфатизовані рештки іхнофауни з базального горизонту київської світи еоцену, яка в межах Канівського Придніпров'я трансресивно залягає на розмитій поверхні верхньої крейди. Мета роботи - на основі дослідження мінеральних компонентів, органічних решток та слідів життєдіяльності базального горизонту з'ясувати особливості умов осадконакопичення на заключних етапах існування крейдового моря і під час ранньеоценової трансресії на території Канівських дислокацій. Базальний горизонт в основному складений масивними середньо-грубозернистими гравелітистими слабозцементованими кварцовими пісками і пісковиками з поодинокими включеннями фосфатних стяжінь неправильно округлої форми та з численною фауною представленою зубами акул, фрагментами кісток риб, детритом двостулкових молюсків і брахіопод. Характер розташування стулок і ступінь їхньої збереженості говорить про те, що фосилії були перевідкладені. Зразок, відібраний з Глядового яру представляє собою скупчення фосфатизованих уламків іхнофауни різного типу, зцементованих фосфатно-піщаним матеріалом. Перший тип, на нашу думку, представляє собою фрагмент ядра нірки десятиногого ракоподібного іхнороду *Thalassinoides* Ehrenberg, на що вказує характер поверхні, відсутність побудованої стінки і його

розміри. Фосфоритові утворення другого типу представляють собою ядра нірок роду *Orhiomorpha* Lundgren з характерної офіоморфною скульптурою у вигляді бугорків на зовнішній поверхні. Описані нірки інтерпретуються як *Domichnia* – житло викопних організмів і раніше в межах Середнього Придніпров'я не відомі. За життя тварини формували систему незаповнених ходів середнього, добре вентиляюмого іхноярусу глибиною до 60 см (виходячи з діаметра *Thalassinoides*). Найчастіше вони характеризують різноманітні умови прибережної області і мілководдя. Виходячи зі складу фауни, явно перевідкладений характер нірок тощо, цілком імовірно, що дані уламки мають крейдовий вік. Непрямим підтвердженням чого можуть слугувати знахідки в цьому ж базальному горизонті кісток і зубів представників крейдової фауни, зокрема іхтіозаврів (*Platyrtergygius* sp.). Крім уламків фосфатизованих решток іхнофауни в базальному горизонті присутні стягнення чорного кольору неправильної форми та мікроконкреції, складені аморфними фосфатними мінералами. У складі мікроконкрецій в значній кількості знаходяться мікроскопічні рештки, імовірно, фітоорганіки. Виходячи з того, що фосфатний матеріал ще не роз кристалізований, а частина мікрофосилій зберегла свій первинний склад, ми вважаємо, що дані мікроконкреції є наймолодшими у складі базального горизонту і мають ранньеоценовий вік.

Ключові слова: палеогеографія, крейдовий період, еоцен, канівська світа, фосфатизовані рештки, іхнофауна.

Introduction and background. The Cretaceous period is characterized by an extensive development of shallow epicontinental basins, where the sedimentation was controlled by three factors: eustatic variations of the sea level, epeirogenesis and climate (Naydin et al., 1986). The whole sedimentary rock mass, deposited during the Late Cretaceous in the epicontinental seas of the western part of Eurasia, is referred to as the chalk-glaucinite litho-tectonic complex (“formation”, introduced by N.S. Shatsky) with the paragenesis of chinks, chalky marlstones, silica clays, glauconite rocks, phosphorites and grey-coloured terrigenous sediments (Shatsky, 1965). This complex was formed during a single eustatic cycle, which started with a slow transgression and ended with a rapid regression at the end of the Cretaceous. These changes of sedimentation environment determined its structure: lower layers are glauconite sands and sandstones, the main part of the formation are carbonate rocks, and the end of the cycle is characterized by regressive sequences: sands, sandstones and sandy carbonate rocks.

Within the Middle Dnieper area the lower part of the formation is represented by rocks of the Burimska

suite (**K₁₋₂br**), composed of glauconite-quartz sands and sandstones, which were deposited mostly in the littoral environment. Upwards in the cross section the sands acquire more carbonate material, and in certain areas tracing interlayers appear with carbonate nodules of considerable sizes. The top of the Cretaceous outcrop is a rock mass of writing chalk stone and marls of the Genichevsky horizon (**K₂km**), distributed along the western and south-western boundary of the Kaniv dislocation region (Tsyba et al., 2012). All boundaries between different lithologies are concordant (wherever they can be traced). Higher in the succession the Cretaceous rocks are overlapped with Paleogene, Neogene and Quaternary formations (Fig. 1).

We studied the basal horizon of the Kanivska suite (Eocene), which transgressively onlaps here the eroded top of Burimska suite. Its lower part is represented by fine-grained dark-green quartz-glaucinite, carboniferous or loamy sands, with interlayers of coarse grained sands. This sequence outcrops in the gulleys of Kaniv area.

These formations and the whole area are rather well represented in the literature. The study of

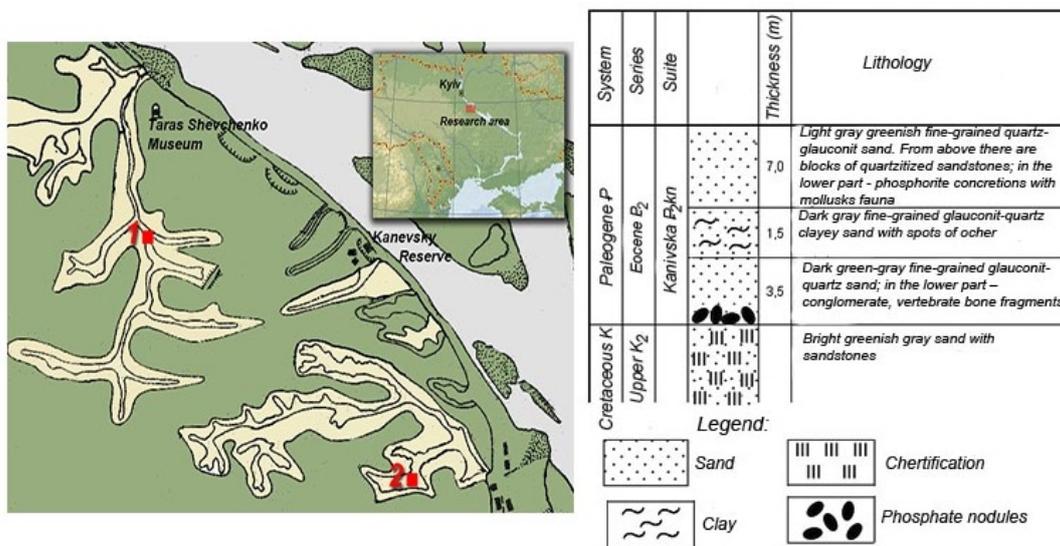


Fig. 1. Study area, lithology of Upper Cretaceous and Lower Paleogene rocks, outcrops of basal horizon of Kanivska suite (the stratigraphic column acc. to (Sokolov and Makarenko, 1983)): 1 – Melanchin Potik gully, 2 – Glyadovy gully

these rocks was initiated in the late XIX and early XX century timeframe by G. Radkevich and P.Ya. Yermashevsky (Syabryay, 1963). G. Radkevich was the first to distinguish and describe the lower stratum of the Kanivska suite under the name “*Horizon a*” (Radkevich, 1900). The basal layer in the floor of the Kanivska suite on the contact with Senoman deposits was also described in (Sokolov and Makarenko, 1983). Its outcrops in the area of Kaniv dislocations were also described elsewhere (Syabryay, 1963; Kaptarenko-Chernousova, 1971; Palienko et al., 1971; Krochak et al., 2016).

Goal, materials and methods. On the base of the analysis of petrography and fossils in the basal horizon of the Kanivska suite, we studied the sedimentation and deposition environment in the final stages of the Late Cretaceous sea’s existence and during the Early Eocene transgression in the area of Kaniv dislocations. We used both literature and our own collected data for the analysis. The specimens of the basal horizon of the Kanivska suite (P_2kn) were sampled from the outcrops in the Melanchin Potik gulley and in a branch of the Glyadovy gulley (points 1 and 2 in Fig. 1 respectively) for the petrographic (a polarizing microscope *Micros MC 300(S)* was also used for research) and paleontological analysis. The results of the study are presented below.

Principal results and discussion. In Melanchin Potik gulley, ca. 50–70 m from its mouth, in the right wall of the gulley, at a height of 7 m from the gulley thalweg, there is an outcrop of a layer of sand and sandstone in the sedimentary rock mass. The outcropped rock is a strongly cemented greenish-grey medium- and coarse grained gravelite sandstone with carbonate cement (Fig. 2). It has a pronounced boundary with lower strata. The layer is mostly composed of

massive medium- and coarse grained gravelite quartz sandstone with occasional inclusions of phosphate nodules of irregular rounded shape. Apparent bed thickness is up to 15 cm. Numerous inclusions of carbonate organics are seen in the upper part of the layer. They are represented by almost intact 3-5 cm shells and detritus of bivalvia Pectinidae, Gryphaeidae (*Exogyra conica*) and one brachiopod species from the *Rhynchonellidae* order. The phosphatized organic fossils contain shells of inarticulated brachiopods of the Lingulidae family, small (up to 1 cm) fragments of bones, a fishbone and a shark tooth with a length of 1.5 cm. All remnants of Bivalvia and Brachiopoda are from benthic fauna. The layout of shells and their condition indicate at the redeposition of fossils.

The deposits also contain a considerable amount of phosphate concretions of irregular form, with sizes 1-3 cm.

This coarse grained quartz sandstone (non-lithified sand in some outcrops) is markedly traced in the area of Kaniv Nature Reserve and presents a basal horizon of the Kaniv suite (Krochak et al., 2016, Popova et al., 2015).

This basal level is also outcropped in Glyadovy gulley (near Khmilna village). The bed thickness there reaches up to 25 cm. A large amount of phosphate nodules with varying sizes, petrified wood, invertebrates: bivalvia, ammonites, brachiopods, as well as teeth of sharks, fish bones, and remnants of marine reptiles are encountered there. A bedrock specimen was sampled from this level in the left wall of the first right ravine tributary of Glyadovy gulley at a height of ca. 1.5 m from the thalweg.

The sample is an agglomeration of phosphatized debris of various types of ichnofauna, cemented with a phosphate and sand substrate. Such kind of phosphate



Fig. 2. Gravelite sandstone with detritus of benthic organisms (general outline)

structures are widely known in Cretaceous deposits of the East European platform (Shvanov, 1987). The phosphatized constituents of the sample with different shapes, colours and sizes can be classified into three types according to their morphology.

The first type is the largest straight rod-like fragment of ovate and cylindrical shape with length 10–12 cm and major diameter 5–6 cm (Fig. 3 a). The surface is slightly rough, and its fresh fracture shows the granulated well cemented rock. The cross section markedly reveals the zonation with a clear peripheral part (3–5 mm) and dark center.



Fig. 3. Phosphatized debris of ichnofauna: a – *Thalassinoides* Ehrenberg, b – *Ophiomorpha* Lundgren, c – cross section

In our opinion, this is a fragment of a burrow nucleus of a crayfishlike decapoda of *Thalassinoides* Ehrenberg ichnogenus, which can be inferred from the condition of the surface, absence of a constructed wall and its size. The cylindrical shape can be an indication that the fossil is a part of a vertical “mine” (the terminology is borrowed from Yanin, Baraboshkin, 2013); and the size would infer *Th. suevicus* type II (Reith) species, described in (Monaco, Giannetti, 2002) and some other works.

The cylindrical fragment is the fine grained sandstone, with predominant quartz content (90%) and phosphate cement. The cement filling of the intergranular space is different according to the area. In the edge zone the cement shows only contour filling, and there are many void pores. This results in the light-

er colour of this zone (Fig. 4a). The cement content in the rock does not exceed 8–10%. In the transition zone, the ratio of debris and phosphate is about the same; and in the center the amount of cement exceeds the volume of debris. (Fig. 4b). This fragment can be classified as a sandy phosphorite. The increase in the decrystallisation degree of the phosphate towards central zones is typical for diagenetic structures.

The structures of the second type are dark reddish and black. These are fragments of pipe-like (or cone-like) debris with diameter from 1 to 2.5 cm and length up to 6 cm with a specific hummocky surface, some

fragments are branched (Fig. 3b). They also feature a zonal structure with darker peripheral parts compared to central areas (Fig.3c). The outer phosphorite shell is more rigid compared to the inner part, which is subject to destruction and gradual emptying of material due to weak cementation, so the pipe is a semi-hollow channel from its edge.

We believe that the phosphorite features of the second type are cores of the decapod burrows – *Ophiomorpha* Lundgren genus with a characteristic ophiomorphic sculpture in the form of knobbls on the outer surface. The wall is composed of rounded or oval rock grains; the structure is like a tube constructed with a flat inner surface. One of the fragments has a Y-shaped branching at the edge. Since the principal feature for distinguishing between

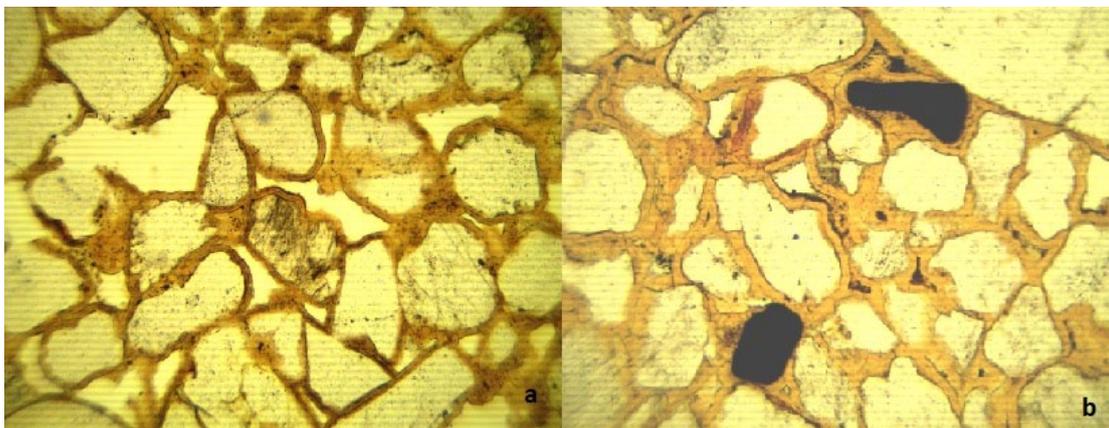


Fig. 4. Cement filling of the intergranular space: a- periphery, b - central zone. Thin section, PPL, 10x10. Frame length is 1 mm

species is the diameter of the burrow, which indicates the size of the animals (Vyalov, 1966), the described forms can be attributed to the species *O. nodosa* Lundgren (outer diameter range 1.5-3.3 cm). After the analysis of W. Häntzschel (Häntzschel, 1952), the ophiomorphs are considered as dwelling pipes of burrowing Decapoda. A specific sculpture of the walls was probably formed as a result of their lining with balls of sedimentation material.

The structures of the second type (compared to the first) have certain differences in the distribution and nature of phosphate material. They also feature a zonal structure, but different from the former case. The outer shell, 1-3 mm thick, is formed with amorphous phosphate with tiny debris of phytoorganics and quartz grains. Phosphates make up 60-70%, sometimes up to 80% of the bulk. The substance has globular structure. Possibly, phosphates were removed from the sediments into the burrows and precipitated on the walls, permeated with organic matter. The inner part of the burrow is clogged with fine-grained quartz sandstone with glauconite and phosphate cement with contour and basal type filling (Fig. 5).

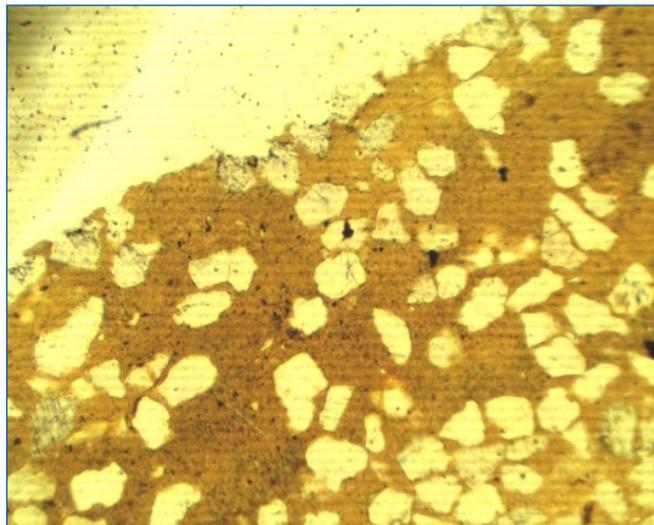


Fig. 5. A burrow with phosphate walls. Thin section, PPL, 4x10. Frame length is 2.5 mm

The burrows of both types are passively (gravitationally) filled. According to the appearance, the representatives of both genera differ essentially, although, according to some researchers, the shape of the burrows mostly depends on the nutrition, rather than on the substrate type, and is related to the specific features of the species (Griffis, Suchanek, 1991). Others (Yanin, Baraboshkin, 2013) note that according to the substrate nature a change of *Ophiomorpha* morphological patterns into *Thalassinoides* may occur.

The described burrows are interpreted as domicnia: dwelling places of fossil fauna. They were not

known earlier within the Middle Dnieper area. The animals constructed a system of void ducts in the well ventilated middle ichnofossil layer with depth up to 60 cm (as can be inferred from the diameter of *Thalassinoides*). Although crayfish burrows can be present in any formation, it is generally thought, that they are more specific for the littoral and shallow water environments (Singh et al., 2008).

The modern burrow builders as analogs of the described fauna could be prawns – the representatives of the *Callinassa* genus, which permanently reside in excavated burrows. They feed on small organisms and detritus with the use of a filtration system. Modern *Callinassidae* reside in warm ocean waters, massively occupying areas from littoral to bathyal zones (Yanin, Baraboshkin, 2013).

Taking into account marked traces of secondary deposition (chipped edges, eroded surface etc) and the fact that the described ichnofossils do not belong to any species attributed by G.A. Radkevich as Eocene fauna, we believe that these fragments are probably of Cretaceous age. An indirect indication of this can be the bones and teeth of Cretaceous

vertebrates, found in the same basal layer, in particular, ichthyosaurus genus *Platypterygius* sp. (Sokolov and Makarenko, 1983; Kyselevych, Ogienko, 2018), and a phosphate concretion with ammonite remnants (pers. com. Ogienko O. S., Mitrokhin A.V.). Since the top of the Cretaceous outcrop (Genichevsky horizon, **K₂km**) is represented by a layer of writing chalk stone and marls, it can be inferred that the final stages of the existence of a marine basin were periodically marked with the “hardground” features, as specific structures, caused by the interruptions in the sedimentation, which are well abundant in Cretaceous

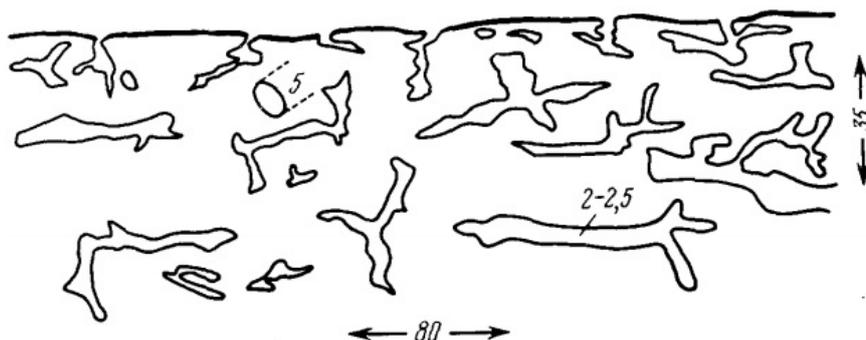


Fig. 6. “Hardground” at the contact of Maastricht and Danian, Aksyyirtau cross section, Mangyshlak. Numbers are dimensions (cm) by (Naydin et al., 1986)

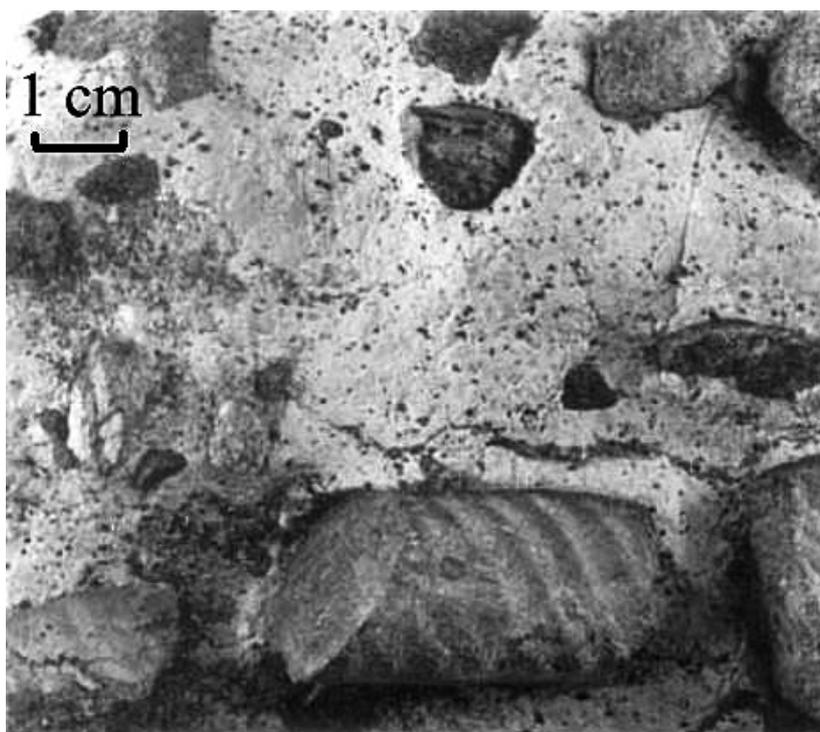


Fig.7. Phosphate nodules and phosphatised ichnofossils. The limestone hardground. Specimen 10 cm across. Mid-Cretaceous, French Alps by (Tusker M.E., 2003)

rocks of the East European platform and its frames (Fig. 6, 7). These surfaces are formed on the bottom of a sea basin with a predominantly carbonate sedimentation, when the steady sedimentation process is interrupted. Mild calcareous muds undergo gradual contraction and lithification in this environment down to the depth from 5-8 cm to several dozens of cm, and the sea bottom becomes a hard surface, suitable as a habitat for various sessile and free benthic organisms (their remnants were documented in the outcrops of Melanchin Potik gulley, Fig. 2). A ramified system of *Thalassinoides* burrows is characteristic for the mature stage of the hardground (Naydin, 1986).

Subsequently, a rapid shallowing of the basin took place, and the change of the facial environment resulted in the crayfish burrows filling with sand. Later on the sandstone with phosphate cement formed

in the process of diagenetic transformation. This assumption is supported/favored by the zonality of these features, which is observable both visually and in thin sections.

Besides phosphatized ichnofauna debris, the basal level contains black odd-shaped nodules and micro concretions with sizes 2-5 mm, composed of amorphous phosphate minerals. They contain a considerable amount of microscopic fossils of presumably phytoorganic nature and fragments of undetermined groups (no studies have been performed yet). Microfossils, which have preserved the initial composition, are semi-transparent, red-brownish and black-brown. The remaining part of the fossils is phosphatized. Fig. 8 shows, that phytomaterial was redistributed and squeezed into peripheral parts of concretions during their growth (a dark ring on the

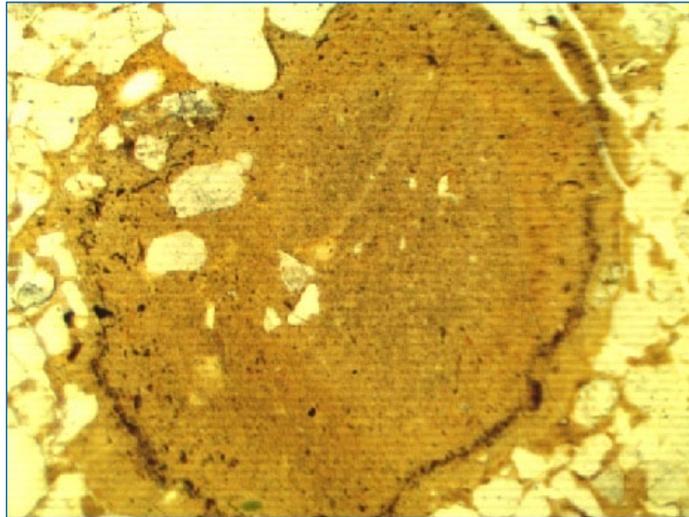


Fig. 8. Phosphorite micro concretion with phyto organics, squeezed towards periphery. Thin section, PPL, 4x10. Frame length a=2.5 mm.

photo under small magnification). From the fact that the phosphate material is not completely crystallized, and that some microfossils have preserved their initial composition, we infer that these structures are the youngest, that is they belong to the Early Eocene.

Conclusions. The burrows of *Thalassinoides* and *Ophiomorpha* are referred to as domichnia – dwelling structures; they are widely represented, especially in Cretaceous deposits of the East European platform. They are built mostly by Crustaceans, which is supported by data from many sources, although they were not described earlier for the Upper Cretaceous and Eocene sequences in the Middle Dniepr area.

In spite of a rather wide range of environmental conditions where such dwelling structures can be found, their most frequent occurrence is in the shallow water facies.

Together with phosphatized fragments of ichnofossils (which is described), the basal horizon of the Kanivska suite contains younger phosphorite structures, represented by concretions of irregular shapes and microconcretions, the formation of which was triggered by the presence of agglomerations of microfauna remains.

The age of redeposited phosphatized fragments of ichnofauna in the basal horizon of Eocene is Late Cretaceous, although the sedimentation conditions and the age of fauna of the phosphorite concretions of the basal horizon and lower strata of Kaniv suite still is questionable.

Further findings of the Cretaceous biota in the Eocene basal level can provide additional information about the paleofacial environment, persisting during the prolonged period of progressive degradation of the marine basin in the Late Cretaceous.

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