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BIOTURBATION STRUCTURES IN THE HOLOVNIA SILICEOUS MARLS (TURONIAN–LOWER SANTONIAN) IN RYBOTYCZE (POLISH CARPATHIANS)

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Abstract: The Holovnia Siliceous Marls represent carbonate turbidites interbedded with non-calcareous pelagic/hemipelagic shales. This study reports on bioturbation pattern, trace fossil assemblage and distribution of bioturbation structures, i.e. structures resulting from the life activity of organisms in general, in the succession exposed in the village of Rybotycze. 20 ichnospecies were identified, with one new ichnogenus (*Squamichnus*) and one new species (*Squamichnus acinaceformis*). The ichnofossils represent nearly exclusively fodinichnia produced close to the seafloor, below calcite compensation depth. Shallow location of anoxic pore waters is indicated to be responsible for relatively shallow bioturbation depth whereas variability in frequency of turbidite sedimentation and petrographic composition of turbidites is suggested as the chief control on the vertical distribution of the bioturbation structures in the succession.

Key words: trace fossils, carbonate turbidites, Turonian–lower Santonian, Skole Nappe, Carpathians, Poland.

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INTRODUCTION

The Holovnia Siliceous Marls (Kotlarczyk, 1978) represent a conspicuous lithostratigraphic unit of the Skole Nappe of the Polish Outer Carpathians. Calcareous rocks of turbiditic origin, mainly marlstones, are the chief constituents of this unit. The marlstones are known for the frequent occurrence of structures resulting from the life activity of organisms, called in this paper the bioturbation structures. Structures of the fucoid ichnogroup (Fu, 1991) are particularly characteristic of these sediments, therefore originally they were called fucoid marls (e.g., Wiśniowski, 1905).

Książkiewicz (1977) supplied the first data on bioturbation structures, called commonly trace fossils, from the Holovnia Siliceous Marls. The unit was mentioned there with the formerly used name the Siliceous Marls. Twenty-one ichnotaxa were indicated to occur here. However, according to recent opinions on the distribution of the Holovnia Siliceous Marls, only twelve taxa were mentioned from sites where this unit is exposed. Four of these taxa, i.e., *Chondrites arbuscula*, *Ch. intricatus*, *Sabularia simplex* and *S. tenuis*, were reported from exposures in the village of Rybotycze. The other taxa are mentioned either from exposures where, in fact, a younger unit of fucoid marls occurs (i.e., Huwniki, where Campanian–lower Maastrichtian Kropivnik Fucoid Marls crop out; see Kotlarczyk, 1985b) or are mentioned without indication of the locality where they were recorded. Uchman (1998) recently published some ichnologic data reported as referring to the Siliceous Marls, in the frame of his revision of the Książkiewicz's trace fossil collection. Unfortunately, Uchman repeated the stratigraphy used by Książkiewicz. According to Uchman's opinion, of the twenty-one ichnotaxa reported by Książkiewcz (1977) from the Siliceous Marls, only three retain Książkiewicz's taxonomic classification. *Chondrites intricatus* is the only taxon of those mentioned by Książkiewicz (1977) from the exposures in Rybotycze which retains its name. *Chondrites arbuscula* was interpreted by Uchman to represent *Chondrites targionii*, *Sabularia simplex* was renamed as *Ophiomorpha annulata*, whereas *Sabularia tenuis* was renamed to *Arthrophycus tenuis*.

Some new data concerning bioturbation pattern and trace fossil assemblage in the Holovnia Siliceous Marls emerged from my recent investigations in the exposures in the village of Rybotycze. The exposures are stratigraphically and sedimentologically well documented (see Kotlarczyk, 1985b; Leszczyński *et al.*, 1995). The whole unit is here exposed, moreover, the rocks are relatively easily accessible and rich loose fragments of beds allow profound investigations on bedding surfaces. This work extends the list of trace fossils known from the Holovnia Siliceous Marls so far, provides new data on distribution and the assemblage of

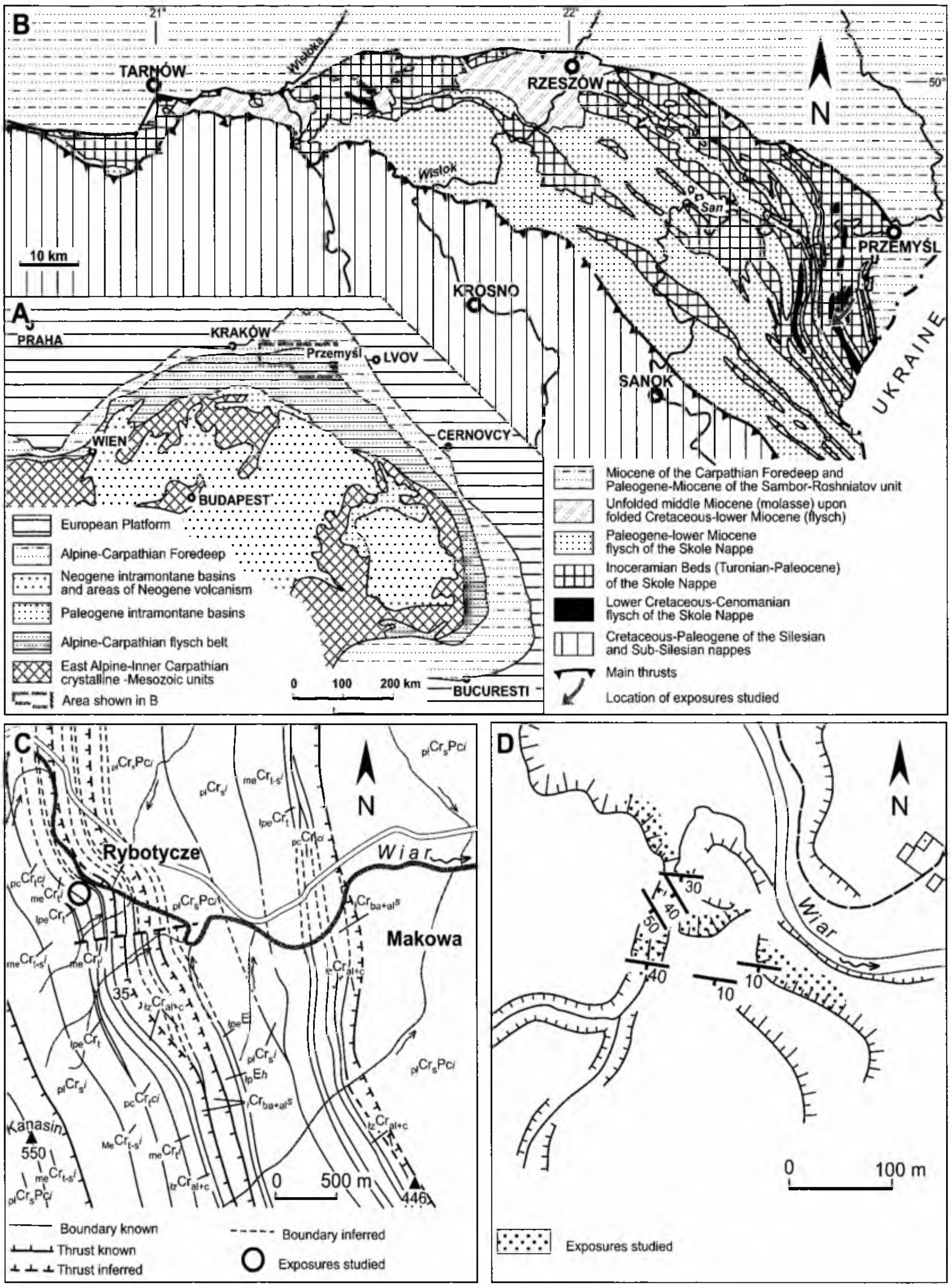

Fig. 1. Location of the investigated exposures. **A.** Location of the Polish sector of the Skole Nappe within the Carpathian–Pannonian region according to the map by Sandulescu 1988, modified. **B.** Location of the investigated exposures in the Polish sector of the Skole Nappe modified from the map by Żytko *et al.*, 1989. **C.** Location of the investigated exposures according to the map by Gucik *et al.*, 1991, changed. ${}_{ł}Cr_{ba\text{-}al}^{S}$ – dark-grey and black shales, Spass Shales (Barremian–Albian), ${}_{łz}Cr_{al\text{-}c}$ – green, radiolarian shales (Albian–Cenomanian), ${}_{me}Cr_{t}^{ci}$ – marlstones with intercalations of shales and sandstones, Siliceous Marls (Turonian), ${}_{pc}Cr_{t}^{ci}$ – sandstones, marlstones and shales, Cisowa Beds (Turonian), ${}_{łpe}Cr$ – variegated shales (Turonian), ${}_{me}Cr_{t\text{-}s}^{i}$ – marlstones with intercalations of shales and thin-bedded sandstones, Fucoid Marls (Turonian–Senonian), ${}_{pł}Cr_{s}^{i}$ – sandstones and shales with intercalations of marlstones, Ropianka Formation (Senonian), ${}_{pł}Cr_{s}Pc_{i}$ – thin- to thick-bedded sandstones and shales, Inoceramian Beds (Ropianka Formation) undivided (Senonian). **D.** Location of the investigated exposures at Rybotycze

bioturbation structures in the succession and on its sedimentary environment. The specimens figured in the paper are housed at the Institute of Geological Sciences of the Jagiellonian University (acronym and catalogue number UJ 176P).

LOCALITY

Outcrops situated on the right side of the Wiar river valley, in the south-western edge of the village of Rybotycze (Fig. 1), some 30 km to the south of Przemyśl, and several km to the west of the frontier between Poland and Ukraine were investigated. The chief exposure occurs in a small gorge of a subordinate tributary of the Wiar river and at the upper and lower entrance to the gorge. The gorge is located at the mouth of the tributary to the valley of Wiar. It is as much as twenty metres deep and is surrounded by steep walls built entirely of the rocks of the Holovnia Siliceous Marls. Moreover, three smaller exposures were investigated in the neighbourhood of the gorge; particularly a scar of a large landslide situated *ca.* 100 m east of the gorge and debris at the top of the landslide. The lower part of the Holovnia Siliceous Marls, as much as 4 m thick is exposed in the landslide scar.

GEOLOGIC CONTEXT

The area of Rybotycze is built of a continuous Cretaceous–lower Miocene succession of deep-water, mostly siliciclastic sediments of the flysch facies. Because of some individuality in lithofacies, stratigraphy and tectonic structure, compared to the flysch succession in other parts of the Carpathians, this succession is distinguished as the Skole succession or the Skole Nappe. Lithofacies indicate sedimentation of the Skole succession in a deep-sea, trough-type basin (the Skole trough), bordered in its Polish part by a passive margin of the European Platform in the north, and a submarine ridge (the Sub-Silesian ridge) in the south and southwest. The Sub-Silesian ridge separated the Skole trough from the remaining part of the Carpathian Flysch Basin. The rock succession of the Skole Nappe shows significant vertical and to some extent lateral variations resulting from basin topography, sediment supply, eustasy and tectonic processes (see Kotlarczyk, 1985a). The Rybotycze area represents the outer part of the Skole trough, close to its slope.

The Holovnia Siliceous Marls (Turonian–lower Santonian) were distinguished by Kotlarczyk (1978) as a subordinate lithostratigraphic unit representing the lower part of the Cisowa Member of the Ropinaka Formation (former Inoceramian Beds) (Fig. 2). Cream-yellow, beige and light-grey, thin-bedded, hard and soft marlstones interbedded with thin-bedded siltites and arenites, and green to dark-green, calcareous to non-calcareous muddy to clayey shales are characteristic of the Holovnia Siliceous Marls succession (Fig. 3). Components >2 mm in size occur in subordinate amount in these sediments. Marlstones (rocks containing

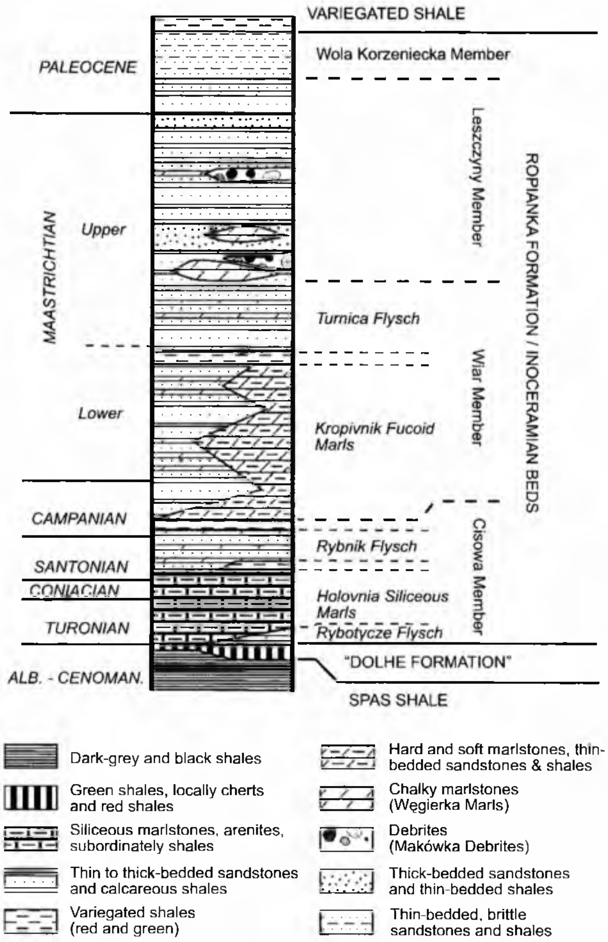

Fig. 2. Generalized stratigraphic log of the Albian–Paleocene of the Skole Nappe of the Polish Carpathians after Kotlarczyk (1988) slightly modified

14–65% carbonates, mainly $CaCO_3$, are here called marlstones; see Leszczyński *et al.*, 1995) and shales, called here collectively lutites, constitute as much as 70% of the section. The arenites and siltites consist exclusively of carbonate or mixed carbonate-siliciclastic-biosiliceous material. The whole unit is several tens to nearly 100 metres thick (Kotlarczyk, 1978).

The rocks in the succession occur in normally graded rhythms (basic rhythms), which start with arenite, siltite or sandy- to silty-lutite (marlstone to mudstone) layers showing sharp lower boundaries. Marlstone or muddy to clayey shale overlies these rocks. Marlstone constitutes sometimes the main part of a rhythm. Shale, rarely marlstone occurs at the rhythm top. The shale at the top of rhythms is nearly always non-calcareous. Thin layers of granule-size chips of shales occur in some levels of the succession and grade usually upwards into arenite. Individual rhythms are several centimetres to 20 cm thick. The arenites show structures corresponding to the divisions $T_{(a)bc}$ of the Bouma sequence, siltites correspond to the divisions $T_{(c)d}$, whereas marlstones correspond to the divisions $T_{(d)e}$ and shales to the divisions $T_{(d)e,\ ep}$. Facies C2.3 and D2.1 of the classification scheme of Pickering *et al.* (1986) predominate in the succession. The entire succession seems to represent a de-

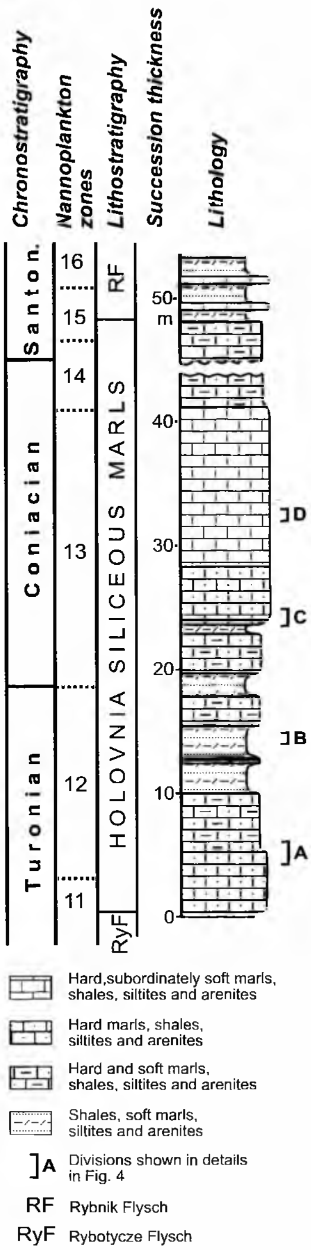

Fig. 3. Generalized lithofacies log of the Holovnia Siliceous Marls in Rybotycze after Leszczyński *et al.* (1995) slightly modified

positional system of a slope apron, and at the same time, a basinal part of a transgressive systems tract.

Bioturbation structures are frequent in marlstone layers and at soles of arenite beds. The number of burrows usually increases upward in single normally graded rhythms. Casts of current marks and load casts occur sometimes on soles of arenite beds. All the above mentioned features of the arenites, siltites, marlstones, and in part shales indicate their sedimentation by turbidity currents. Turbidite shales occur chiefly in the rhythms in which marlstones are lacking. The non-calcareous shale at the top of rhythms corresponds to the division e_p of the Bouma sequence, i.e. it represents the background sediment (pelagite/hemipelagite). The lack of carbonate material in the background sediments indicates sedimentation below the calcite compensation depth (CCD; Leszczyński *et al.*, 1995). Some arenite beds display sharp, rippled upper boundaries. This feature was interpreted by Dżułyński *et al.* (1979) and Kotlarczyk (1985b) as having been deposited by bottom traction currents. In contrast, Leszczyński *et al.* (1995) interpreted this feature as resulting from sedimentation by flows in which bypassing of fines occurred over the area where arenaceous material was deposited.

The succession shows also rhythmicity displayed by variable distribution of marlstones and shales at the scale of packages of the basic rhythms. Packages where the lutites are represented mainly by hard marlstone alternate with ones where the lutites consist mainly of soft marlstones or shales. The packages are composed of several to several tens of the basic rhythms.

Marlstone-dominated, marlstone-and-shale and shale dominated facies associations can be distinguished in the succession according to the relative proportion of marlstones and shales. The arenites and siltites usually represent the constituents subordinate or comparable in proportion relative to the lutites. The marlstone-dominated facies association is usually dominated by hard marlstones. The marlstone-and-shale facies association displays similar amount of both rock types. It occurs in two sub-associations: one in which marlstones are mainly hard and one in which both hard and soft marlstone occur in similar proportion. The shale dominated facies association usually lacks hard marlstones.

The vertical variation in lithological composition of the succession reflects variation in carbonate production in the sedimentary basin *versus* non-carbonate sediment influx. Eustasy and climate appear to be the primary controls responsible for sedimentation of the Holovnia Siliceous Marls.

The Holovnia Siliceous Marls grade downward into a succession of shaly sediments (green and red shales) called the Dolhe Formation (Kotlarczyk, 1978) or locally to a succession of thin-bedded sandstones interbedded with shales, which is called here the Rybotycze Flysch and is as much as some 20 metres thick. A succession called the Rybnik Flysch (Kotlarczyk, 1978), several tens metres up to 650 m thick, composed of thin- to thick-bedded sandstones and shales, overlies the Holovnia Siliceous Marls. The thickness of this unit increases towards the inner part of the nappe. The Rybnik Flysch separates the Holovnia Siliceous Marls and the next lithostratigraphic unit rich in calcareous sediments, called the Kropivnik Fucoid Marls (Kotlarczyk, 1978).

Sediments of the Kropivnik Fucoid Marls are similar in facies to these of the Holovnia Siliceous Marls, except for the lack of hard marlstones and arenites enriched in biogenic silica. Foraminifera and calcareous nannoplankton indicate a Campanian–early Maastrichtian age of the Kropivnik Fucoid Marls (Kotlarczyk, 1978, 1985a, 1988; Leszczyński *et al.*, 1995). Origin of this unit is similar to that of the Holovnia Siliceous Marls. It results from lowered influx/resedimentation of siliciclastics and increased production and resedimentation of carbonate material. The Kropivnik Fucoid Marls, like the Holovnia Siliceous Marls, occur

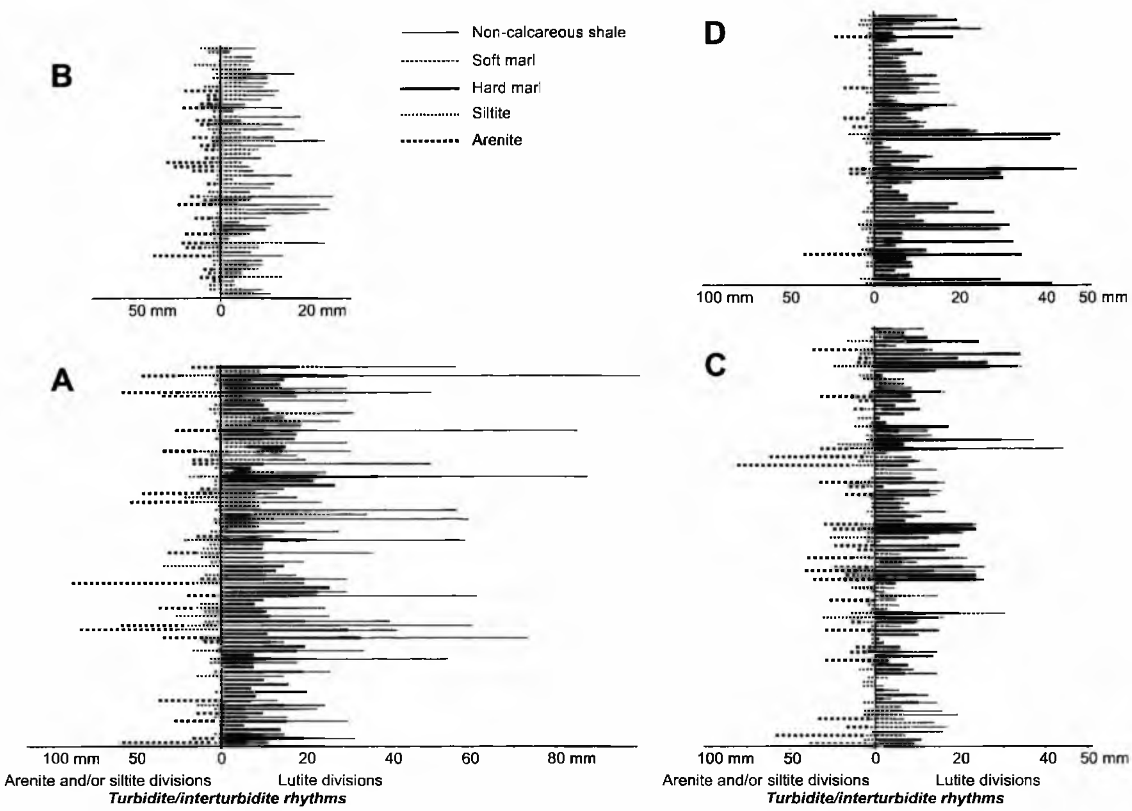

Fig. 4. Lithologic sequences in selected parts of the section, as indicated in Fig. 3 (Leszczyński *et al.*, 1995). Individual turbidite/interturbidite rhythms are marked horizontally, starting from the left side of diagrams (coarsest sediment). Interturbidite divisions are represented by the non-calcareous shale and occur at the top of rhythms. Note that interturbidite divisions do not occur in each rhythm

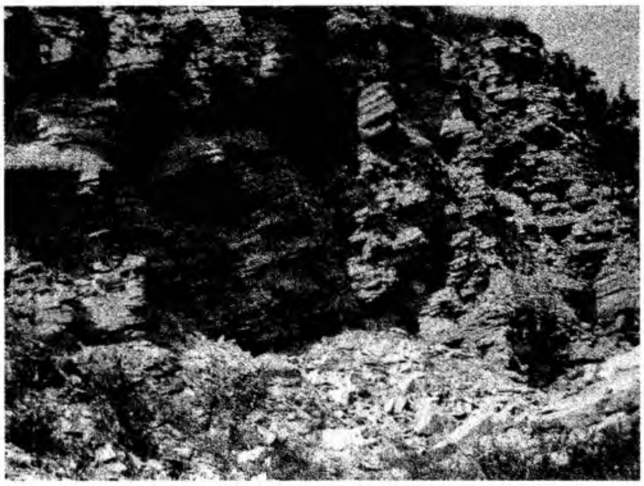

Fig. 5. Facies of the lower part of the Holovnia Siliceous Marls in the landslide scarp. Note occurrence of bedsets of less fissile rocks between packages of more fissile ones. The packages of less fissile rocks include rocks rich in $CaCO_3$ and consist of arenites, siltites and marlstones or siltites and marlstones, and sometimes negligible proportion of shales. Encircled hammer (35 cm long) as a scale

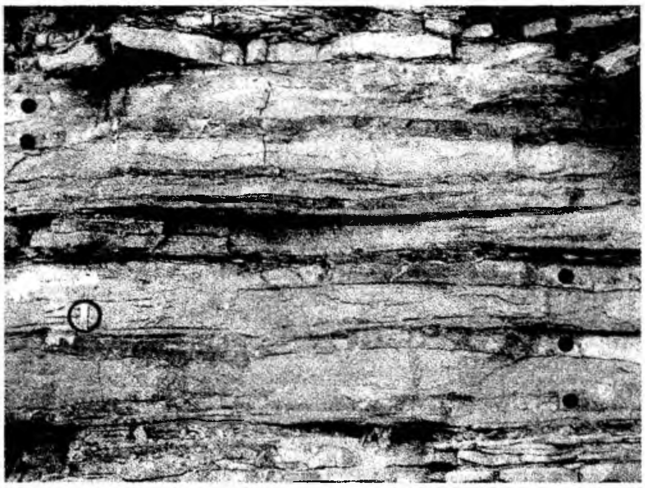

Fig. 6. Vertical distribution of rock types in a shale-poor, thin-bedded package showing predominance of arenites and siltites (light-grey layers). Layers of hard marlstones are denoted with black dot. Middle part of landslide scar. Scale, 2 cm long, encircled

in a large area of the Skole Nappe, including its Ukrainian and Romanian sectors (Golovninskaya and Stryiskaya Svita, Hangu Beds; see Kotlarczyk, 1978).

The Holovnia Siliceous Marls at the investigated site is 50 m thick (Leszczyński *et al.*, 1995; Fig. 3). All facies associations and rhythmicity characteristic of the Holovnia Siliceous Marls in general occur in the investigated exposures (Figs 4–7). The succession shows vertical variation in distribution of arenites, marlstones and shales. All rock types participate in similar proportions or shales predominate and

Fig. 7. Passage from a package of arenites, siltites, soft marlstones and shales (in the lower part of a photo) to a package of arenites and hard marlstones (marked with black dots). Note sharp both upper and lower boundaries of the uppermost bed of hard marlstone. The scale is 9 cm long

Fig. 8. A rhythm consisting of an arenite-marlstone couplet. Note subtle horizontal lamination in the lower part of the marlstone layer and a spotty structure (grey and light-grey spots) in its top part. White bar represents 1 cm

hard marlstones are lacking in the lower half of the succession. Arenites consisting mostly of calcareous material are overlain by marlstone whereas these showing significant proportion of siliciclastic material are overlain by shale, in individual normally graded rhythms. The boundary between arenite and the overlying marlstone is frequently sharp (Figs 7, 8).

The upper half of the succession, particularly the division located at 28–42 m above the bottom of the succession, displays predominance of hard marlstones (see Leszczyński *et al.*, 1995). Shales occur here only in mm-thick laminae within marlstone or between marlstone and arenite beds. Individual normally graded rhythms consist frequently of a marlstone bed showing silty or arenitic laminae in its lower part or of thin arenite-marlstone or siltite-marlstone couplets (Figs 7, 8).

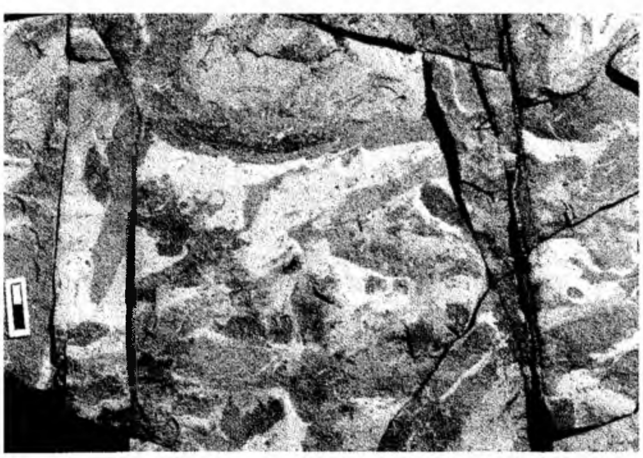

Fig. 9. Bioturbation structures in the passage zone from marlstone (whitish) to shale (grey); UJ 176P1. Burrows are accentuated with material corresponding to that of the overlying shale. Some burrows show light arcuate/oblique streaks across. Scale bar 1 cm long

The shale in the entire succession is usually calcareous in the lower part of a bed and non-calcareous in its top part. This also concerns shales, which occur in a few mm-thick laminae separating the rhythms. Single thin beds of chaotic sediment also occur in the Holovnia Siliceous Marls at the investigated site.

BIOTURBATION STRUCTURES

GENERAL ASPECTS

Bioturbation structures are recorded mainly on soles and tops of arenite and siltite beds, on tops of marlstone beds in the rhythms where marlstones are overlain by shale, and within the marlstone beds (Figs 9–11). The structures are generally more common in the lower part of the succession (0–28 m; see Fig. 3) and in sections where the rhythms include marlstones and at least several mm-thick laminae of shale at their top. In cross sections of beds, bioturbation structures are recorded mainly in marlstones. The number of burrows in individual beds increases upward (Fig. 12). Such distribution is particularly distinctive in the beds thicker than 5 cm. Trace fossils are rare or even absent in the marlstone beds, which occur in the normally graded rhythms where shale is lacking. Distinctive disappearance of burrows is observed at depths above 7 cm below the top of the normally graded rhythms. Some beds display disturbed both inorganic and biogenic sedimentary structures, indicative of postdepositional fluidisation of the sediment (Fig. 13).

Structures in the form of different sized, straight to arcuate stripes, irregular spots, and branching, plant-like structures called traditionally fucoids (cf. Fu, 1991) are the most common at bedding-parallel surfaces in marlstone and at surfaces separating marlstone from the overlying shale as well as those separating siltite from marlstone or shale (Figs 10–12). Stripe-like structures showing light-coloured arcuate streaks across are common in the lower part of the suc-

Fig. 10. Bioturbation structures in the upper part of marlstone bed. Burrows are marked with material corresponding to that of the overlying shale. Black bar represents 1 cm

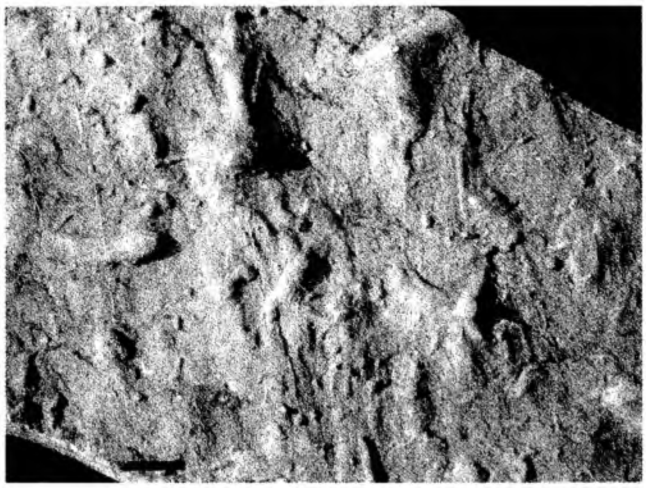

Fig. 11. Bioturbation structures on sole of arenite (sandstone) bed. The structures represent at least three different taxa differing in size and burrow pattern. All structures are predepositional (semireliefs). The thickest and intermediate burrows, which appear to branch may represent fragments of *Thalassinoides suevicus*. The intermediate burrows without a tendency of branching may be affiliated either to the latter mentioned taxon and *Planolites beverleyensis*. The thinnest burrows may embody fragments of *Chondrites intricatus* and *Ch. targionii*. Black bar represents 3 cm

cession. All these structures are composed of green or grey coloured material resembling that of the overlying shale. Simple structures in the form of different sized knobs, flattened, straight to curved, differently branching ridges of different size are recorded on soles of arenite and siltite beds (Fig. 11). The structures on the sole of arenite and siltite beds (hypichnia) usually represent semireliefs, i.e., casts of pre-turbidite burrows (Seilacher, 1953), whereas those within beds (endichnia) represent flattened full reliefs. The full reliefs of the post-turbidite burrows on soles of arenite and siltite beds are recorded only in beds which occur in normally graded rhythms less than 10 cm thick. The most numerous bioturbation structures on soles of arenite and siltite beds occur in beds underlain immediately by shale.

Dark-coloured, strongly flattened lentiform spots, dash-like marks, thin, bedding-oblique streaks and chevron-like packages of asymmetric, crescent-shaped, alternately dark and light coloured streaks are characteristic bioturbation structures at cross-section surfaces of marlstone and siltite beds (Fig. 12). Such structures are concentrated in the 1 cm-thick, top part of marlstone beds, particularly these overlain by shale (Fig. 12D). Characteristically, the most distinctive bioturbation structures in marlstones are filled with material mesoscopically similar to that forming the overlying shale. In shales, burrows filled with material similar to that forming marlstones are missing. Distinctive bioturbation structures are here very rare. These are structures accentuated with distinctive sediment arrangement, displayed in specific parting tendency or ones marked with arenitic or silty sediment. The latter occur in shales overlain by arenitic or silty sediment, which occur in normally graded rhythms less than 10 cm thick.

In marlstones, the bioturbation structures appear to be also represented by irregular, spot-like changes of sediment colour (Figs 8, 12). Such structures may result from bioturbation in a soupy sediment and subtle change in sediment chemistry due to reworking. Structures of this type are particularly characteristic of the uppermost part of marlstone beds. Burrows distinctively disappear in individual normally graded rhythms (turbidites), at depth of ~7 cm below the rhythm top.

A total of 20 different ichnotaxa were differentiated in the studied material. However, the classification concerns only the most distinctive bioturbation structures. Such structures, commonly called trace fossils, constitute a minor part of all bioturbation structures of the sediments in question. The structures recorded as knobs, short ridges, single spots, dots and stripes of different size were mentioned only descriptively as they can represent fragments of different larger burrow systems. A precise recognition of these systems seems to be questionable.

ICHNOTAXA

Trace fossils were identified to ichnospecies where possible, but are grouped for description by ichnogenera and described in alphabetical order. A majority of the specimens dscribed has been found in loose rock fragments at the foot of the landslide scar and the cliff in the gorge. Precise original location of these specimens in the succession is thus unknown.

Ichnogenus *Alcyonidiopsis* Massalongo 1856

Alcyonidiopsis isp.
Fig. 14 – 2

Material: 2 specimens found and collected (UJ 176P1, UJ 176P26).

Description: Horizontal, straight to slighthly arcuate, strongly flattened cylinders without distinctive outline, filled with elliptical pellets. The burrows are 5.5–8.0 mm wide, as much as 5 cm long,

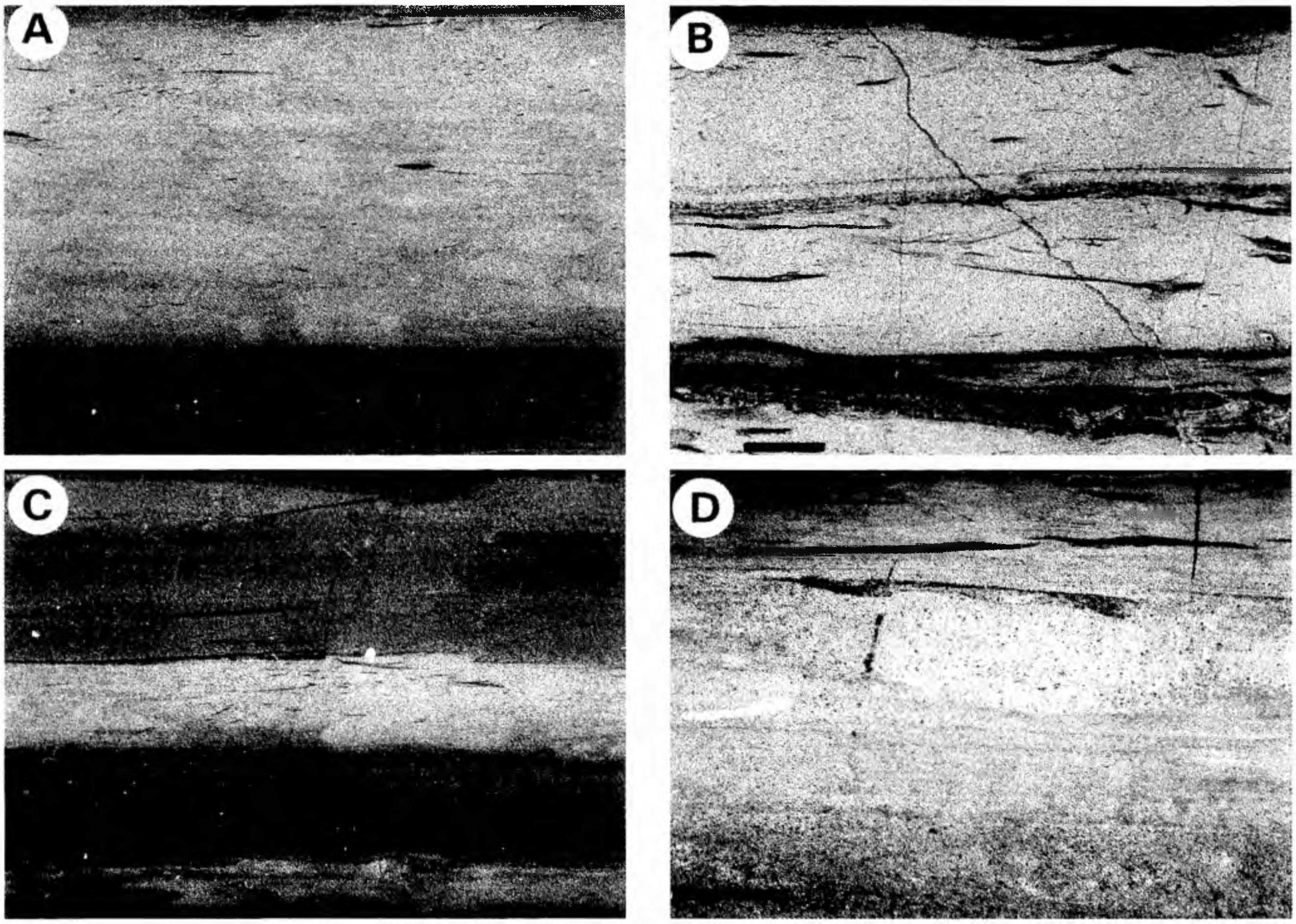

Fig. 12. Distribution of burrows in bed cross-sections. **A.** One, normally-graded rhythm consisting of siltite (grey) in the lower part of bed and hard marlstone in the upper part. Note increased number of burrows (dark flattened dots and streaks represent *Chondrites intricatus* and *Squamichnus* n.igen. in the upper part of marlstone. The spotty structure of the background may represent the oldest burrows, produced immediately after marlstone deposition, before sufficient cover of mud has accumulated. Black bar represents 1 cm. **B.** Distribution of burrows in four thin, normally-graded rhythms consisting of fine-arenitic to silty (grey) lower part and hard marlstone (light-grey) in the upper part. Note increasing upward number of dark dots, dash-like marks, streaks and lens-like spots representing the burrows. Black bar represents 5 mm. **C.** Two rhythms consisting of siltstone (grey)-marlstone (whitish) couplets overlain by a siltite layer. Note the lack of distinctive burrows except of spotty structure in the marlstone of the lower rhythm. Remnants of shale (dark) are preserved at the top of the upper rhythm. Black bar represents 1 cm. **D.** Two rhythms consisting of siltstone-marlstone couplets. Note the occurrence of burrows (grey spots, dark-grey streaks and dash-like marks) in the marlstone of the upper rhythm only. This distribution of burrows is probably due to deposition of the upper rhythm shortly after the first one. Black bar represents 1 cm

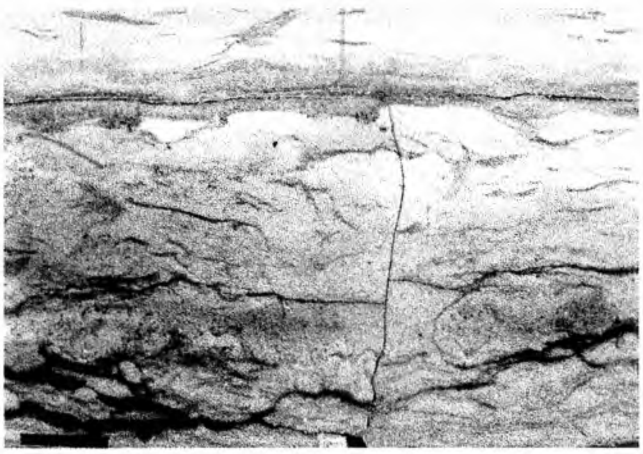

Fig. 13. Two normally graded rhythms in the lower part of photo showing sedimentary structures disturbed due to sediment fluidisation. Black bar represents 1 cm

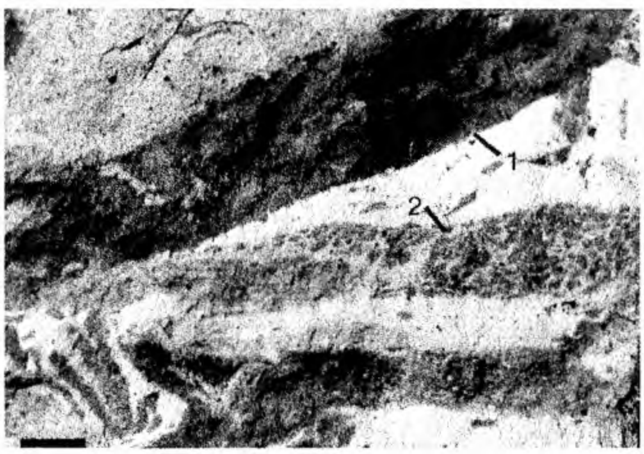

Fig. 14. Endichnial full reliefs of ?*Thalassinoides* isp. (**1**) and *Alcyonidiopsis* isp. (**2**) in marlstone; UJ 176P1. Black bar represents 5 mm

unbranched, and do not crosscut each other. Pellets are *ca.* 1 mm long and 0.6 mm wide with long axes tending to align along the burrow elongation.

Distribution: The trace fossil occurs in the top part of a marlstone layer, at a level densely filled with burrows mainly *Squamichnus* n.igen. and *Planolites beverleyensis*. The specimens were found in loose rock fragments at the foot of the landlslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3).

Ichnogenus *Chondrites* von Sternberg 1833

Chondrites intricatus (Brongniart 1823)
Figs 15 – 1, 16 – 2, 17 – 1, 25 – 2

1991. *Chondrites intricatus* (Brongniart): Fu, p. 18, text-figs 9b, f, 10, pl. 1, fig. e; pl. 2, fig. a.

Material: 4 specimens collected (UJ 176P2 – 4) and many field observations.

Diagnosis: Small *Chondrites* composed of numerous downward radiating, mostly straight branches. The angle of branching is usually less than 45°. The branches are less than 0.1 mm (mostly about 0.5 mm) wide (Uchman, 1999).

Description: A bush-like system of burrows, 1–2 cm across, consisting of 0.2–0.5 mm wide, mostly straight burrows, radiating from one place, showing two to three orders of branches and branching at angles usually smaller than 45°. In the vertical cross-sections, the burrows are *ca.* 0.1 mm thick. Second-order branches dominate in the systems. The burrows are filled with argillaceous material, darker than that in the host rock. Second-order branches are as much as 1 cm long. On surfaces perpendicular to bedding, the systems appear as clusters of flattened spots and bedding parallel to oblique streaks, darker than the host rock.

Four types of the burrow system, differing in branching pattern and burrow width, were included to this species: (A) system displaying rare second-order branching at angles usually less than 10° with second-order branches as much as 10 mm long and branches width 0.5 mm (Fig. 15 – 1); (B) system displaying frequent second-order branching at angles less than 20° with the second order branches 2–5 mm long and 0.5–0.7 mm wide (Fig. 15 – 2); (C) system displaying rare second-order branching and frequent third-order branching at angles 20–30° with the second-order branches 3–10 mm long and burrows 0.5 mm wide (Fig. 16 – 2); (D) system displaying densely distributed second-order branching at angles 20–45°, with the second-order branches only 1–2 mm long, and burrows have a width of 0.2 mm (Fig. 17 – 1).

Remarks: This is the most common trace fossil in the investigated rocks. It occurs basically in marl, at different depths of beds, at least 1 cm below the bed top. The fill of the burrows consist of material similar in colour to that composing the overlying shale. All four types of the burrow system occur together at the same surface. Each type of the system may represent separate ichnospecies. The system D shows some similarity to the fan-shaped specimens of *Chondrites stellaris* Uchman (1999).

Distribution: Trace fossil recorded in many beds scattered in the whole succession.

Chondrites intricatus (Brongniart 1823) var. *bandchondrites* (Ehrenberg 1941)
Fig. 17 – 2

1991. Bandchondriten (Ehrenberg): Fu, p. 22, pl. 3, figs a, b.

Material: 1 specimen collected (UJ 176P4); several field observations.

Description: Systems of densely packed burrows 0.5 mm wide, branching at acute angles, following fills of larger burrows (host burrows) 5–7 mm wide.

Fig. 15. Endichnial full reliefs of *Chondrites intricatus* type A (**1**), *Ch. intricatus* type B (**2**) and ?*Planolites beverleyensis* (**3**) at the passage from marlstone to shale; UJ 176P2. Black bar represents 5 mm

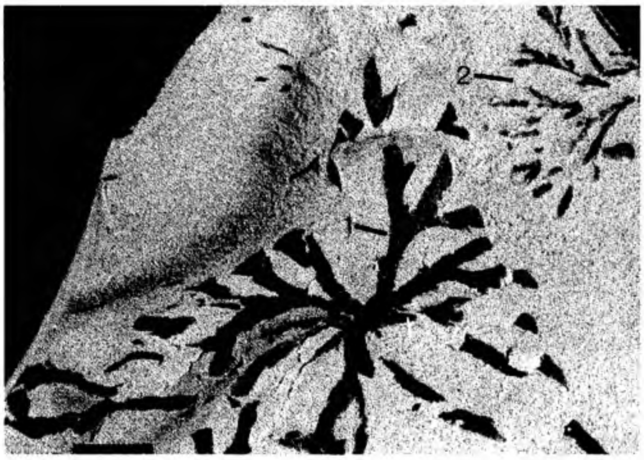

Fig. 16. Endichnial full reliefs of *Chondrites* isp. A (**1**) and *Chondrites intricatus* (**2**) in marlstone; UJ 176P3. Black bar represents 5 mm

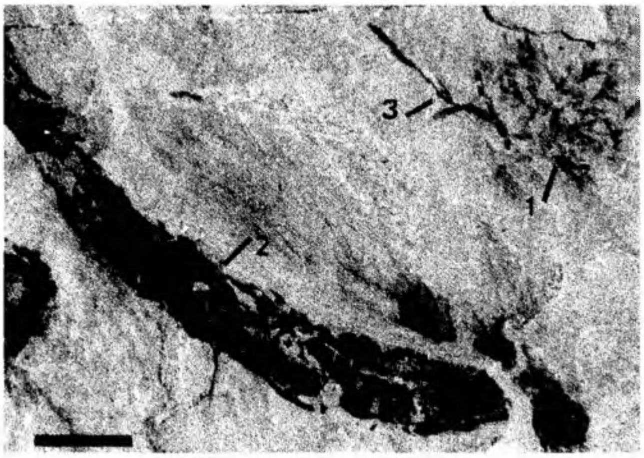

Fig. 17. Endichnial full reliefs of *Chondrites intricatus* (**1**), *Chondrites intricatus* var. *bandchondrites* (**2**), and *Chondrites targionii* (**3**) in marlstone; UJ 176P4. Black bar represents 1 cm

Remarks: The burrows are oriented in different directions, mostly parallel to the elongation of the host burrow. The host burrows resemble *Planolites* isp. The trace fossil has been found exclusively in marlstones, at different depths of beds, at least 1 cm below the bed top.
Distribution: This is a rare burrow type in general. It was recorded in loose fragments of several beds, at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3). It seems that in some beds this trace fossil is quite frequent.

Chondrites targionii (Brongniart 1828)
Fig. 18

1977. *Chondrites arbuscula* Fischer-Ooster: Książkiewicz, p. 79, pl. 4, fig. 7.
1991. *Chondrites targionii* (Brongniart): Fu, p. 22, pl. 3, figs a–b.
1998. *Chondrites targionii* (Brongniart): Uchman, p. 123, fig. 21.

Material: 2 specimens collected (UJ 176P5, 6) and many observations in field.
Diagnosis: *Chondrites* characterised by well-expressed primary successive branchings, which are commonly slightly curved. The angle of branching is usually acute (Uchman 1998).
Description: Burrows about 1 mm wide, showing well expressed primary branching at acute angles. Two orders of branches dominate. Third-order branches are very rare. Both the main branch and the lower-order branches are straight to slightly curve. Second-order branches dominate. They are as much as 2 cm in length. The burrows are 0.1–0.2 mm thick in vertical cross section and are filled with argillaceous material darker than that in the host rock. Whole trace fossil attains 5–7 cm across. It occurs as clusters of flattened spots and bedding parallel to oblique streaks, darker than the host rock on surfaces perpendicular to bedding. On the bed soles, the trace fossil occurs as clusters of small knobs or short ridges.
Remarks: The specimens recorded here are thinner than those most commonly recorded elsewhere (e.g., Uchman, 1999; Miller III, 2000). According to the width of branches and the size of the trace fossil it corresponds to the large *Ch. intricatus*. However, the general pattern of this trace fossil fits *Ch. targionii*. These burrows occur usually in the passage zones from arenite to siltite, in sediment corresponding to the division T_d of turbidites.
Distribution: Trace fossil recorded in many beds scattered in the whole succession.

Chondrites isp. A
Figs 16 – 1, 19 – 2

Material: 2 specimens found and collected (UJ 176P3, UJ 176P7).
Description: A trace fossil consisting of a cluster of arcuate burrows 1–1.2 mm wide, radiating from one point in different directions, showing two distinctive branching orders and rare third-order branching, with serrate margin usually on one side of a burrow. Burrows composed of material slightled darker than that of the host rock. Serrations of different size (0.2–1.0 mm). The branches extend at different closely spaced levels and display shingly alignement with downward oriented serrate margin. Some of the deeper serrations may represent proximal parts of third-order branches. The entire trace fossil attains 4 cm across. On surfaces perpendicular to bedding, the system is similar to *Chondrites*, i.e. occurs as a cluster of shingling dash-like marks and bedding parallel to oblique streaks, 0.1–0.2 mm thick, darker than the host rock.
Remarks: In both specimens found, the structure occurs in a marlstone bed, 1 cm below the bed top. Similar burrow system was illustrated by Fu (1991, text-fig. 14b, pl. 2, fig. f), who related it to *Chondrites*.
Distribution: The specimens were found in loose fragments of a marlstone bed, at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3).

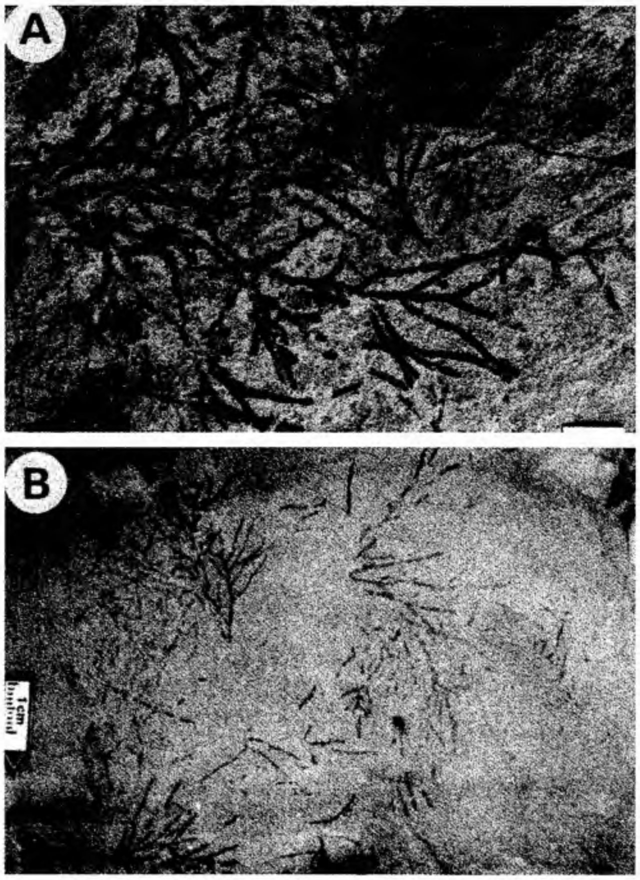

Fig. 18. Endichnial full reliefs of *Chondrites targionii*. **A**. Specimen at a parting surface in the top part of a siltite layer (T_d). Black bar represents 5 mm; UJ 176P5. **B**. Specimen at the top of a siltite layer; note variability in branching pattern; UJ 176P6

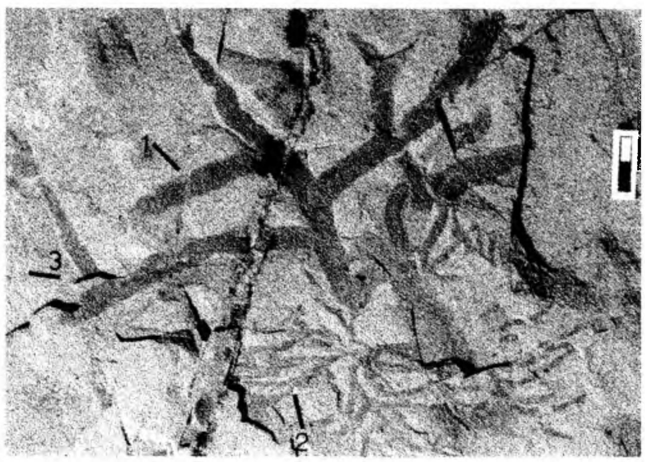

Fig. 19. Endichnial full reliefs of *Chondrites* isp. B (**1**), *Chondrites* isp. A (**2**) and ?*Trichichnus* isp. (**3**) – to the left of the arrow, in marlstone; UJ 176P7. Scale bar (black-white couplet) represents 10 mm

Chondrites isp. B
Fig. 19 – 1

Material: 1 specimen recorded and collected (UJ 176P7).
Description: A trace fossil consisting of 6 mm wide burrows showing well expressed primary branching at angles 70–80°. Two orders of branches occur. Both the main branch and the second-order branches are straight to slightly winding.
Remarks: This is the largest type of *Chondrites*. The burrows are filled with green argillaceous material corresponding to that forming the overlying shale. The first-order branches are always situated beneath the second-order ones. Burrows are distinctively retrusive. It occurs in the bed above the level at which *Ch. intricatus* occurs, and at the same level as *Chondrites* isp. A.
Distribution: The specimen was found in loose fragment of a marlstone bed, at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3).

Chondrites isp. C
Figs 20 – 1, 21 – 1

Material: 2 specimens recorded and collected (UJ 176P8, 9).
Description: A trace fossil consisting of 3 mm wide burrows showing well expressed primary branching at angles 40–60°. Both, the main branch and the second-order branches are slightly winding. The burrows are filled with green argillaceous material corresponding to that forming the overlying shale. The shape of the second-order branches is frequently arcuate. The first-order branches are situated beneath or above the second-order ones. The specimens show similarity only in the style of branching and composition, and structure of the burrow fill, whereas they differ in width, length and course of branches. It may be thus questioned whether they should be included to one ichnospecies.
Remarks: Uchman (1998, fig. 22c) illustrated analogous ichnofossil as *Chondrites targionii*. The characteristically arcuate course of the second-order branches precludes, in my opinion, including this species within *Ch. targionii*. The ichnofossil is recorded in marlstone 5–10 mm below the top of beds.
Distribution: The specimens were found in loose fragments of a marlstone bed, at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3).

?*Chondrites* isp.
Fig. 22

Material: 1 specimen collected (UJ 176P10); several smaller specimens observed in the field.
Description: Horizontal to slightly oblique, straight, regularly branching, strongly flattened, endichnial burrows, 7–10 mm wide, showing serrate outlines. The burrow is filled with material similar to that forming the overlying shale. The burrow fill displays a crumbled splitting surface. The texture of the fill and the serrate burrow outline suggest that the fill was originally granulated. The trace fossil is distinctively retrusive. With granulated fill, it resembles *Phymatoderma*, however the density of branching is here significantly lower. The second-order branches are oriented downward relative to the main branch. The trace fossil is recorded in the upper part of marlstone layers, together with rare burrows of *Planolites beverleyensis*.
Distribution: All specimens were found in loose fragments of beds at the foot of landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3).

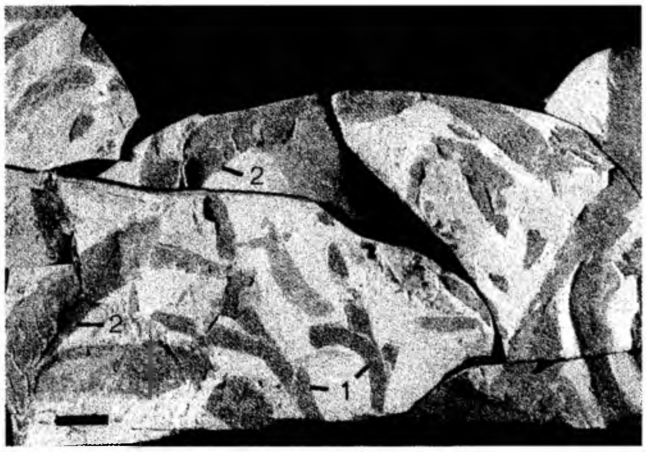

Fig. 20. Endichnial full reliefs of *Chondrites* isp. C **(1)** and *Squamichnus acinaceformis* n.isp. **(2)** in marlstone; type species of *Squamichnus*; holotype; UJ 176P8. Black bar represents 1 cm

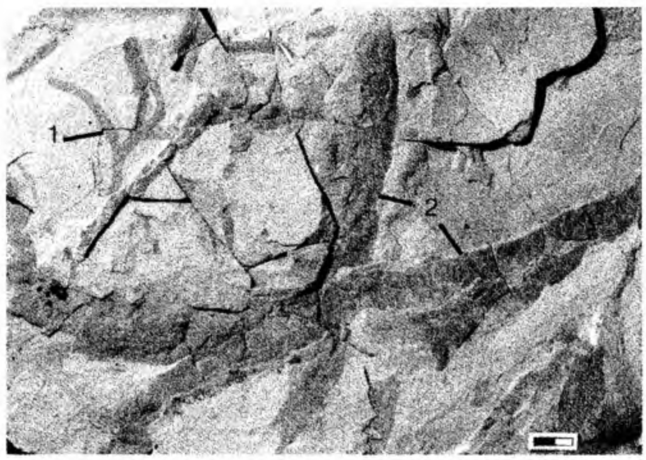

Fig. 21. Endichnial full reliefs of *Chondrites* isp. C. **(1)** and branching *Squamichnus acinaceformis* n.isp. with homogeneous to indistinctively squamate fill **(2)** in marlstone; UJ 176P9. Scale bar (black-white couplet) represents 10 mm

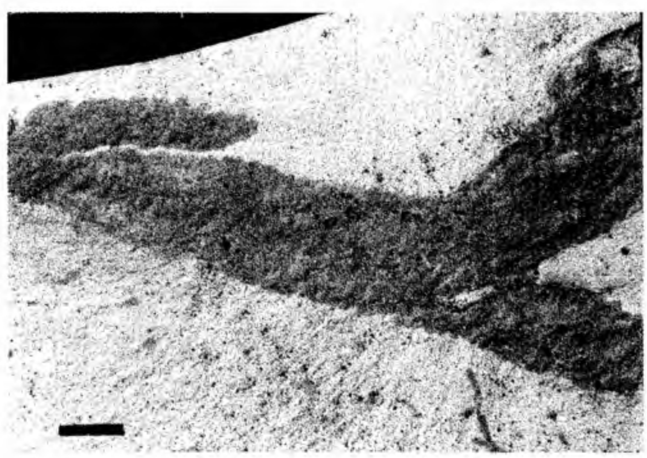

Fig. 22. Endichnial full relief of ?*Chondrites* isp. in marlstone; UJ 176P10. Black bar represents 1 cm

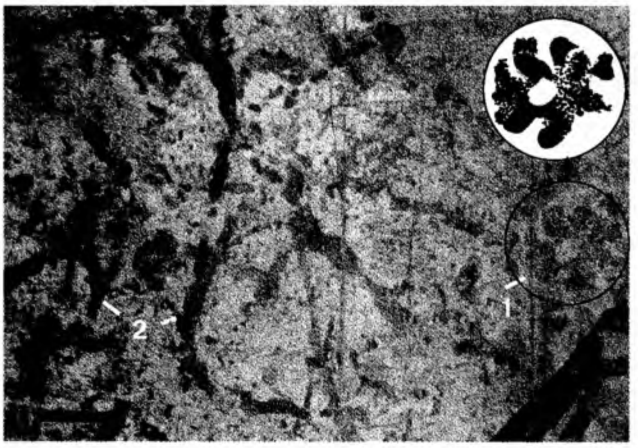

Fig. 23. Endichnial full relief of ?*Gyrophyllites petteri* (**1**, encircled, imitated in the circle above) and *Thalassinoides suevicus* (**2**) at the passage from marlstone to shale. Black bar represents 4 cm

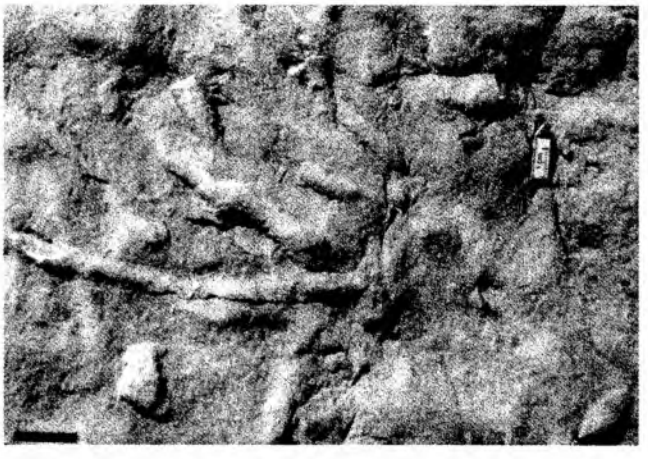

Fig. 24. Endichnial full relief of *Ophiomorpha* ?*annulata* in arenite. Black bar represents 2 cm

Fig. 25. Endichnial full relief of *Phycosiphon geniculatum* (**1**) and *Chondrites intricatus* (**2**) in marlstone. Black bar represents 2 cm

Ichnogenus *Gyrophyllites* Glocker 1841

?*Gyrophyllites petteri* Lorenz von Liburnau 1901
Fig. 23 – 1

1901. *Gyrophyllites petteri* Lorenz von Liburnau: p. 576, pl 4, fig. 9.

Material: Burrow recorded in 3 specimens in field; one specimen with fragmentarily preserved burrow was collected (UJ 176P7).
Diagnosis: Small, rose-shaped trace-fossil consisting of some 9 petal-like elements arranged around a round spot marked with sediment resembling in colour that of the host rock. The ratio of the central spot to the whole burrow is 1:4.5. The petals display rounded terminations, the length to width ratio *ca.* 1:3, and are up to the central spot separated from each other (modified after Lorenz von Liburnau, 1901).
Description: Endichnial structure, composed of 4 more distinctive and 3 less distinctive petal-like elements 9 mm long, 5 mm wide and *ca.* 0.2 mm thick, arranged into a rose-shaped pattern around a round spot marked with sediment resembling in colour that of the host rock. The petals display rounded terminations, the length to width ratio *ca.* 1:2.0, and are separated from each other up to the central spot. The ratio of the central spot to the whole burrow is 1:4. The whole structure has a diameter of 4.6 cm.
Remarks: The specimen recorded in Fig. 23 – 1, has been found preserved entirely as described; it was not sampled. A structure composed of three elongate lobes, appearing to be radially arranged has been recorded in two other specimens. The best preserved specimen is similar to *G. petteri* of Liburnau (1901) in the shape of petals and their separation from each other but differs from it in lower amount of petals. Other species of *Gyrophyllithes* are much different. They show either more numerous petals, sometimes arranged at several levels, or the petals are of different shape.
Distribution: All specimens have been found in loose fragments of beds, at the foot of landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3). The burrow was recorded several millimetres deeper than *Chondrites* isp. A, together with *Chondrites intricatus* and *Thalassinoides suevisus*.

Ichnogenus *Ophiomorpha* Lundgren 1891

Ophiomorpha ?*annulata* (Książkiewicz 1977)
Fig. 24

1977. *Arthrophycus annulatus* n. isp. Książkiewicz: p. 68, pl. 2, fig. 2, text-fig. 9e.
1982. *Ophiomorpha annulata* Frey & Howard: figs. 2b, 4a.
1998. *Ophiomorpha annulata* Uchman: p. 125, fig. 24.

Material: Observed in several loose rock fragments in field; not collected.
Diagnosis: Mainly horizontal or subhorizontal, cylindrical, rarely branched, covered with elongate pellets arranged perpendicularly to the long axis of burrow. Sharp angles prevail at branching points. Swellings are common. In flysch deposits, small hypichnial, smooth and straight forms usually 2–6 mm in diameter, are common (Uchman, 1995).
Description: Straight to irregularly curved, horizontal or oblique, hypichnial and endichnial, cylindrical full-reliefs, 4–5 mm in diameter. The burrow wall is smooth in hyporeliefs and rough in endichnial burrows. The burrows occur as full reliefs filled with sandy material.
Distribution: It was recorded in sandstone beds of the lower and upper part of the succession.

Ichnogenus *Phycosiphon* Fischer-Ooster 1858

Phycosiphon geniculatum (Sternberg, 1833)
Fig. 25 – 1

1978. *Hydrancylus* Fischer-Ooster: Kern, p. 249, fig. 8c.
1988. *Hydrancylus*: Fu, fig. 1a, c, d.
1999. *Phycosiphon geniculatum* (Sternberg, 1833): Uchman, p. 119–120, pl. 15, figs 2, 4, 5.

Material: One sample with 4 specimens (UJ 176P24).
Diagnosis: Small system of spreiten composed of different-sized radially arranged lobes, whose one side (commonly the concave one) is well defined, and which the second side (commonly convex) is lobate and indistinct. All lobes spread out from one starting point. Spreiten of the lobes asymmetric (Fu, 1988).
Description: Horizontal, endichnial lobate trace fossil composed of several separate to overlapping lobes arranged in a form of a fan and filled with green muddy sediment. Spreiten structures invisible. The lobes are as much as 7 mm long and 3 mm wide. The whole trace fossil is as much as 15 mm wide.
Remarks: None of the investigated specimens displayed distinctive spreiten, however their general shape and size correspond well with the trace fossil distinguished as *Phycosiphon geniculatum*.
Distribution: All specimens occur at the same level, together with *Chondrites intricatus Squamichnus acinaceformis* and *Planolites beverleyensis*. The sample has been found in a loose fragment of marlstone bed at the foot of the lasndslide scar where the middle part of the succeession is exposed (10–28 m; see Fig. 3).

Ichnogenus *Pilichnus* Uchman 1999

Pilichnus dichotomus Uchman 1999
Fig. 26

1999. *Pilichnus dichotomus* n. isp. Uchman: p. 98, pl. 6, figs 6, 8; pl. 8, text-fig. 7.

Material: Observed in 2 specimens; one specimen collected (UJ 176P7).
Description: Systems of endichnial, horizontal, curved, dichotomously branched thread-like burrows, 0.15 mm wide, lacking wall lining. The burrows show Y-shaped branching and are filled with argillaceous material corresponding to that forming the overlying shale.
Distribution: The trace fossil has been found in two loose fragments of beds at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; see Fig. 3). It is recorded in full relief on parting surfaces at the passage from siltite to marlstone. Deepest parts of *Chondrites intricatus* are recorded at the level where this species occurs. *Chondrites* isp. A, *Chondrites* isp. B and ?*Gyrophyllites petteri* occur at slightly higher levels in this bed.

Ichnogenus *Planolites* Nicholson 1873

Planolites beverleyensis Billings 1862
Figs 15 – 3, 27 – 2

1999. *Planolites beverleyensis* Billings: Uchman, p. 82, pl. 2, figs 2, 4, 8–9.

Material: Observed in many rock fragments in the field; one specimen collected (UJ 176P2).
Diagnosis: Relatively large, smooth, straight to gently curved or undulose cylindrical burrows (Pemberton & Frey, 1982).
Description: Horizontal to oblique, strongly flattened, simple, straight to gently curved, unlined burrows of a width ranging from 3 to 8 mm. They are filled with homogeneous material similar to that forming the overlying shale.

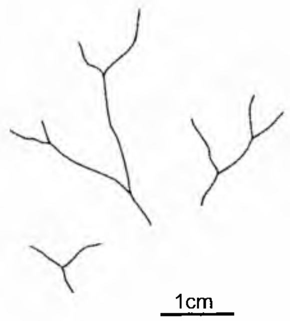

Fig. 26. *Pilichnus dichotomus* at top of silty laminae; specimen UJ 176P7

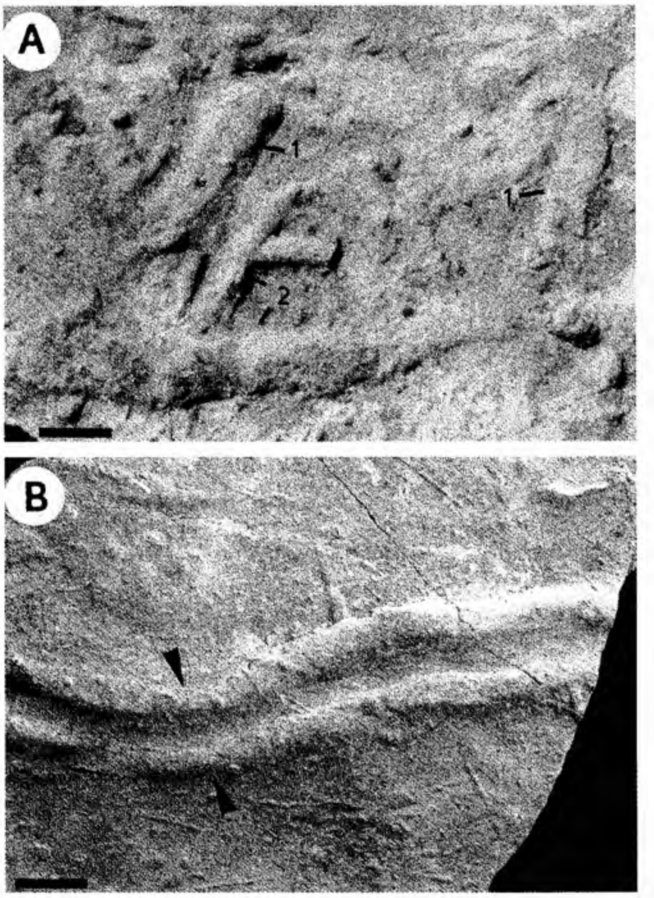

Fig. 27. **A**. Semi relief small form of *Scolizia strozzii* (**1**) and two varieties of *Planolites beverleyensis* differing in size on sole of arenite bed; black bar represents 2 cm. **B.** Semirelief of large form of *Scolicia strozzii* (arrowed) on sole of arenite bed; UJ 176P25; black bar represents 2 cm

Remarks: It appears that the burrows of *Squamichnus acinaceformis* isp. nov. may grade along their course into the burrows showing features characteristic of *Planolites beverleyensis*. Simple, flattened ridges of similar size as the endichnial forms which occur in semireliefs on soles of arenite beds appear to represent the same ichnospecies (Fig. 27 – 2).
Distribution: The trace fossil occurs together with different species of *Chondrites*, *Squamichnus* n.igen., and *Alcyonidiopsis* isp.

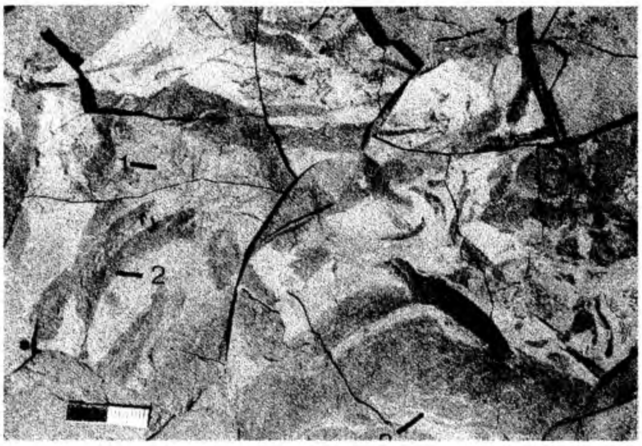

Fig. 28. Endichnial full reliefs of *Chondrites intricatus* (**1**) and *Squamichnus acinaceformis* n.isp. (**2**) in marlstone; UJ 176P23. Scale represents 2 cm

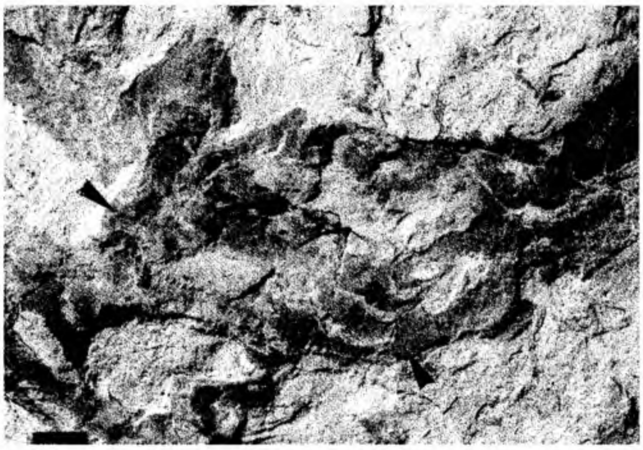

Fig. 29. *Squamichnus acinaceformis* n.isp. – irregularly branching form; UJ 176P17. Top part of a marlstone layer, at the passage to shale. Black bar represents 1 cm

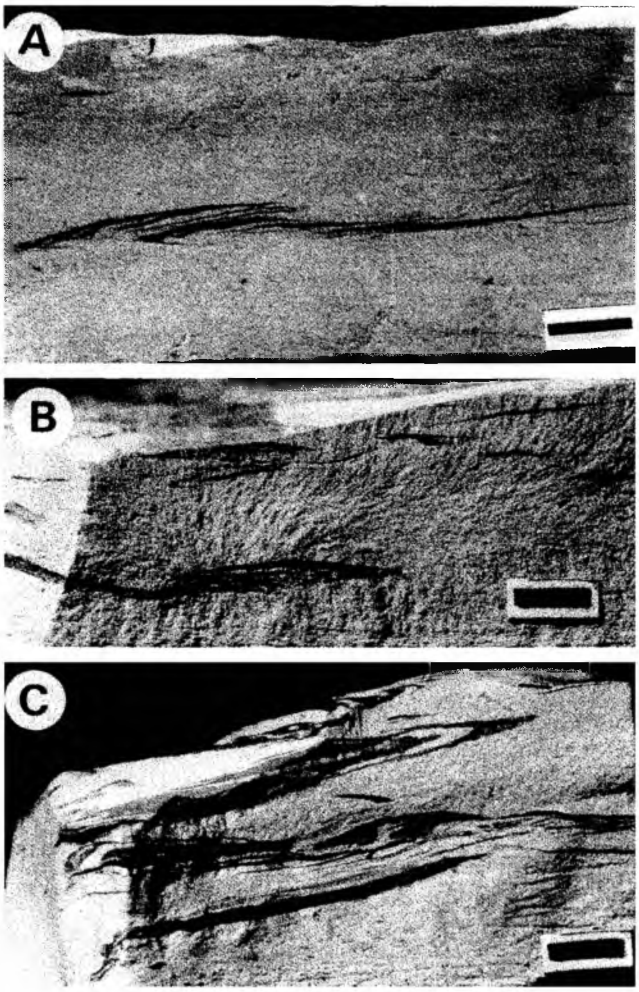

Fig. 30. *Squamichnus acinaceformis* n.isp. in vertical cross section. Black bar represents 5 mm. **A.** Single burrow, UJ 176P13. **B.** Several burrows, note the variability; UJ 176P14. **C.** Several burrows, note the variability; UJ 176P15

In some specimens, these burrows are reworked by *Chondrites intricatus* var. *bandchondrites*.

Ichnogenus *Scolicia* De Quatrefages 1849

Scolicia strozzii (Savi & Meneghini 1850) Fig. 27 – 1

Material: In several rock fragments in the field; one specimen collected (UJ 176P25).

Diagnosis: Straight to tightly meandering hypichnial bilobate ridge, preserved as semi-relief. Median groove separates the prominent zones of the ridge. The prominent zones and the groove are more or less semi-circular in cross-section. Tendency to meandering; width, depth, high, and proportions of the morphological elements may vary from specimen to specimen (Uchman, 1995).

Description: Winding, bilobate, smooth hypichnial semirelief of two sizes: 13 mm and 25–30 mm wide, 3 mm high.

Distribution: It has been found in the lower part of the succession. In all specimens, it occurs together with *Planolites*-type burrows. The specimens were found exclusively in loose fragments of sandstone beds, supposedly from the lower part of the succeesion.

Ichnogenus *Squamichnus* new ichnogenus

Type ichnospecies: *Squamichnus acinaceformis* n.gen, n.isp.

Holotype: UJ 176P8, Fig. 20 – 2.

Etymology: Latin: *squameus* – scaled.

Diagnosis: Bedding-parallel to slightly oblique, elongate, rarely branched, unlined burrows showing a segmented, scale-like (squamate) to homogeneous fill in planar view, marked in the vertical section as bedding parallel to oblique dark-coloured streaks or as a structure resembling cross-section of a rolled cake.

Species included: The ichnogenus is monotypic.

Remarks: The squamate structure makes these burrows similar to the meniscate trace fossils assigned to *Scalarituba* (see Pickerill, 1980), *Compaginatichnus* (Pickerill, 1989), and *Taenidium* (see Crimes *et al.*, 1992). However, the 'scales' in *Squamichnus* differ in outline and less regular arrangement from the meniscate segments in all these trace fossils. Moreover, *Compaginatichnus* possesses lower unsegmented fill with densely packed fecal pellets, which is lacking in *Squamichnus*. Noteworthy, in the investigated material, burrows having pelleted fill (included here to *Alcyonidiopsis* isp.) are rarely recorded at the same level in the bed with *Squamichnus*.

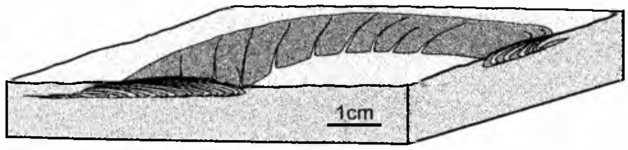

Fig. 31. *Squamichnus acinaceformis* n.isp. – idealised form in planar view and vertical cross-section

Fig. 32. Hypichnial full reliefs of burrows on sole of thin siltite bed overlain by a marlstone containing *Squamichnus acinaceformis* n.isp.; UJ 176P18. Black bar represents 1 cm

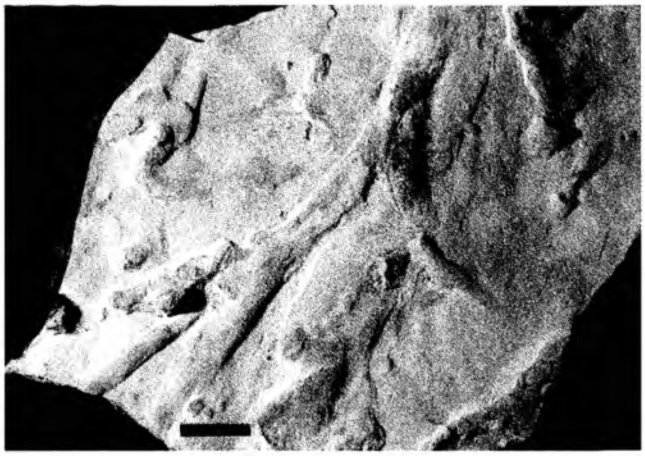

Fig. 33. Semireliefs of burrows which appear to correspond in shape and morphology with *Squamichnus acinaceformis* n.isp.; UJ 176P19. Sole of arenite bed. Black bar represents 2 cm

Fig. 34. Hypichnial full reliefs of burrows on sole of thin siltite bed overlain by a marlstone containing *Squamichnus acinaceformis* n.isp.; UJ 176P20. Black bar represents 5 mm

Distribution: The Skole Nappe (the Outer Carpathians); lower part of succesion of the Holovnia Siliceous Marls, Turonian.

Squamichnus acinaceformis new ichnospecies
Figs 20 – 2, 21 – 2, 28 – 2, 29–31

Holotype: UJ 176P8, Fig. 20 – 2.
Etymology: Latin: *acinaceformis* – a sabre-shaped; the species is usually sabre-shaped in planar view.
Material: 8 specimens collected (UJ 176P8, 9, 11–17, 23); many observations in field.
Dimensions: 8–20 mm wide, usually 4–6 cm long; burrow width constant throughout individual specimens.
Diagnosis: Bedding-parallel to slightly oblique, sabre-shaped to nearly straight, rarely branched burrows in planar view which possess a segmented, scale-like (squamate) to homogeneous fill, marked in the vertical section as bedding parallel to oblique dark-coloured streaks or as a structure resembling cross-section of a rolled cake. The squamate structure is articulated by unevenly spaced partings.
Description: Full relief burrows displaying squamate to homogeneous structure of their fill in planar viev. The squamate structure is accentuated by whitish colour of scale margins and parting surfaces between adjacent scales. Distance between adjacent partings variable, usually shorter than burrow width, with 2–3 partings per centimetre. The scales are convex upward, and dip obliquely forwards, usually toward one side of burrow. The outline of scales is oblique to burrow elongation, usually s-shaped, rarely irregular in planar view.

The full pattern of this trace fossil is hardly recognisable because it occurs in highly bioturbated levels, together with a few species of *Chondrites*, *Planolites beverleyensis* and other ichnotaxa. In one specimen, the trace fossil displays a very irregular outline due to its branching into several branches (Fig. 29).

In vertical section, the burrows are recorded either as bedding parallel to oblique dark-coloured streaks, homogeneous or composed of alternating dark and light-coloured micro-streaks, and as a structure resembling cross-section of a flattened rolled cake, consisting of alternating light and dark-coloured laminae (Figs 30, 31). The laminae are usually thickest on one side of the structure, at the turn of their course from that around the topside of the burrow to that around its bottom side and fade gradually out in opposite direction. The burrows filled with homogeneous or indistinctively squamate fill show rare Y-shaped branching (Figs 21 – 2, 29).
Remarks: The various widths of burrows are not clear. This may result from different size of the burrowers or from various burrowing styles. It seems that the squamate structure results from repeated probing of selected parts of sediment by a worm-like animal. The subsequent probes were shifted mainly aside relative to the earlier made and deformed the earlier produced burrow.

In sandstones (arenites) and on soles of sandstone beds, these burrows appear to occur as sabre-shaped, flattened rollers built of fine-grained sand, and showing rare, faint, longitudinal striations (Figs 32, 33). The hypichnial variety of these trace fossils seems to be also represented by almond-like ridges or ridges similar to the stone of dates showing distinctive longitudinal striations (Fig. 34).

Fig. 35. Endichnial full relief of ?*Taenidium* cf. *satanassi* (arrowed) in marlstone; UJ 176P26. Black bar represents 1 cm

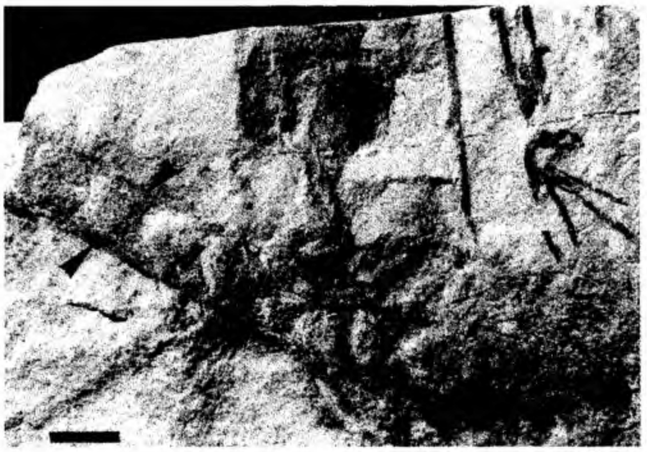

Fig. 36. Endichnial full relief of ?*Taenidium* isp. A (arrowed) in marlstone; UJ 176P4

Fig. 37. Endichnial full relief of ?*Taenidium* isp. B (arrowed) at passage from marlstone to shale; UJ 176P21. The structure is outlined with dashed lines and is marked by style of parting of the shale. It is most distinctive in the left part of the photo (some menisci marked with black line). Black bar represents 1 cm

Distribution: The burrows occur in the lower part of succession (Turonian), rich in biogenic silica, chiefly in the top part of marlstone beds which are overlain by at least several millimetres thick layer of green, non-calcareous shale. *Alcyonidiopsis* isp., *Chondrites intricatus*, *Chondrites* isp. A and B, *Planolites beverleyensis* and ?*Taenidium* cf. *satanassi* occur at the same level.

Ichnogenus *Taenidium* Herr 1877

?*Taenidium* cf. *satanassi* D'Alessandro & Bromley 1987
Fig. 35

1987. *Taenidium satanassi* D'Alessandro & Bromley: p. 755, text-fig. 8d.

Material: Fragment of one specimen in 1 sample collected (UJ 176P26).

Description: Bedding-parallel, weakly arcuate, unlined, unbranched burrow containing a segmented fill consisting of packets of pelleted sediment. The packets are of more or less equal thickness, shorter than wide and are articulated by graded concentration of pellets. The pellets are dark-coloured. The sediment between pellets is similar to that surrounding the burrow. The boundary between packets is weakly arcuate. The burrow has a width of 12–13 mm and is highly compacted. It is recorded on parting surface in the lower part of marlstone layer, close to its passage to siltite, at the level covered densely by *Squamichnus* and rarely *Chondrites intricatus*. *Chondrites* isp. A and B and *Planolites beverleyensis* occur at the same level.

Remarks: The specimen is similar to *Taenidium satanassi* in the occurence of pellets in the burrow fill and in the burrow width, but lacks distinctive packets of unpelleted sediment. Moreover the pellets show here distinctive grading in density of their packing in the packets.

Distribution: The trace fossil has been found in a loose fragment of bed at the foot of the landslide scar where the middle part of the succeesion is exposed (10–28 m; Turonian; Fig. 3).

?*Taenidium* isp. A
Fig. 36

Material: Several specimens in the field; 1 specimen collected (UJ 176P4).

Description: Straight to slightly winding, parallel to bedding, partly lined, meniscate, unbranched, endichnial burrow. Distinctively arcuate meniscate segments abut against the host sediment. The burrow is 5–6 mm wide. Its fill consists of alternating thicker, dark-grey and thinner, light-grey segments. The dark-grey segments are 2–3 mm thick. The light-grey segments occur only in the burrow centre. Their maximum thickness slightly exceeds 1 mm. Material slightly darker than that forming the dark-grey segments occurs along the burrow contour and looks like a burrow wall. In some parts, the burrow appears to be thinly lined with black argillaceous material on its outermost side.

Remarks: Burrows of this type are rare in the investigated exposures. They were recorded together with *Chondrites intricatus* (Brongniart).

?*Taenidium* isp. B
Fig. 37

1998. *Taenidium* isp.: Uchman, p. 161.

Material: Several observations in the field; 1 specimen collected (UJ 176P21).

Description: Curved to winding, horizontal, finely meniscate, unbranched, endichnial, burrow, 2.5 cm wide and 2 mm thick.

Remarks: The very small thickness of this burrow suggests that the producer was in cross section similar to a highly flattened lens. However, its present thickness results in part from sediment compaction. The meniscate structure is poorly visible and is marked with arcuate parting surfaces dipping obliquely to bedding. The lack of distinctive differentiation of material composing the structure makes it similar to *Scolicia* but it seems to be unilobate, therefore it seems to be closer to *Taenidium*. Similar structure was recorded in the Kropivnik Fucoid Marls (Campanian), exposed at the village of Huwniki (5 km to east of Rybotycze) by Uchman (1998; fig. 66c) who distinguished it as *Taenidium* isp. The burrow was recorded in the bottom part of shale layers, just at the contact with marlstone.

Distribution: The specimens were found exclusively in loose rock fragments at the foot of landslide scar where the middle part of the succession is exposed (10–28 m; Fig. 3).

Ichnogenus *Thalassinoides* Ehrenberg 1944

Thalassinoides suevicus (Rieth 1932)
Figs 11 (cf.), 23 – 2

1999. *Thalassinoides suevicus* (Rieth): Uchman, p. 106, pl. 10, figs 5–9.

Material: Several field observations.

Diagnosis: Predominantly horizontal, more or less regularly branched, essentially cylindrical burrow system, dichotomous bifurcations are more common than T-shaped branches (after Howard & Frey, 1984).

Description: Burrows preserved as horizontal endichnial fillets (flattened tunnels) with sharp margins, without visible wall and hypichnial ridges preserved both in full relief and in semirelief. The burrows are 10–15 mm wide and display dichotomous branching. It seems that this taxon is represented also by the semireliefs in the form of several centimetres long ridges which appear to branch (Fig. 11).

Distribution: The trace fossil was observed in various parts of the succession.

Ichnogenus *Trichichnus* Frey 1970

?*Trichichnus* isp.
Figs 19 – 3, 38

Material: Fragment of one specimen collected (UJ 176P7).

Description: Irregularly branched, slightly curved to irregularly winding, endichnial, strongly flattened full reliefs, parallel to bedding, 1 mm wide. The burrows are marked with a thin argillaceous fill, which is usually surrounded by a hue of hydrous ferric oxide (limonite). In some fragments, the burrows are distinctly surrounded by a halo of rock, which is cemented stronger than the rock outside. The burrows show rare irregularly distributed branching at acute angles.

Remarks: Association of this trace fossil with the ichnogenus *Trichichnus* is here suggested on the basis of its small size, occurrence of a hue around the burrows and its irregular branching. With these features it corresponds with the *Trichichnus* described by Uchman (1999). In fact, this is a hardly recognisable trace fossil due to its small thickness. It seems to be visible on clean, fresh-splitting surfaces only. This is probably the reason why it was recorded only in one rock fragment.

Distribution: The burrows occupy solely the deepest level in the bed, corresponding to the division T_d of the turbidite sequence and at the level where *Chondrites* isp. A and *Chondrites* isp. B occur. It cuts here the burrows of other ichnotaxa.

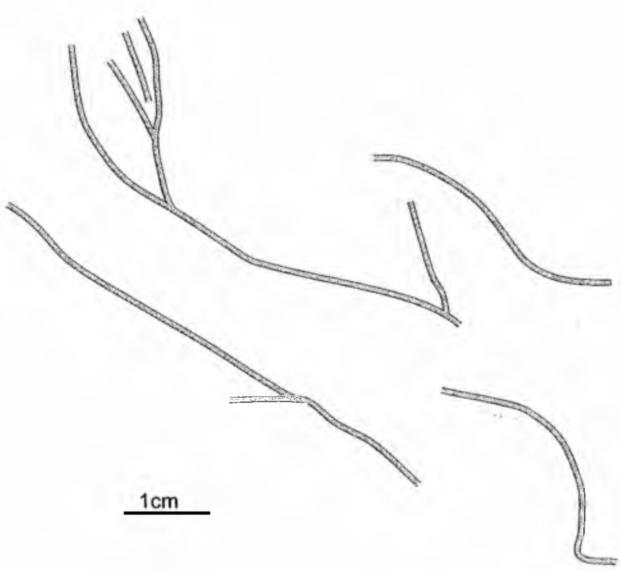

Fig. 38. Endichnial full reliefs of ?*Trichichnus* isp. in marlstone; UJ 176P7

DISCUSSION

Bioturbation structures recorded in the investigated rocks represent an association moderately rich in ichnotaxa. *Chondrites intricatus*, *Ch. targionii*, *Planolites beverleyensis* and *Thalassinoides suevicus* represent the most common taxa in the entire succession. *Squamichnus acinaceformis* n.isp. is common in some divisions of the lower part of the succession. The other taxa occur rarely. Some of them are recorded in single specimens only.

The structures, including those of *Chondrites*, appear to represent basically fodinichnia formed either through simple pushing aside of sediment (e.g., *Planolites*, *Chondrites*, *Thalassinoides*, *Pilichnus* and *Trichichnus*) or through backfilling (e.g., *Alcyonidiopsis*, *Gyrophyllites*, *Scolicia* and *Taenidium*). The origin of *Squamichnus* is not clear. It seems to be produced through repeated sediment probing.

Of the 20 ichnotaxa distinguished, only 4 occur in casts (semireliefs), the others occur usually in strongly flattened full reliefs. The strong flattening concerns the majority of burrows. This suggests that originally these structures were empty tunnels filled passively with the background sediment or were loosely filled by the burrowers (e.g., *Alcyonidiopsis* isp.). Distinctiveness of burrows was enhanced by their infilling with material different compared to the host sediment. The most common structures in the investigated succession, i.e. those recorded in marlstone, are accentuated with material resembling macroscopically that forming the shales. These structures suggest that transport of material from the seafloor to the substrate was the dominant style of burrow filling.

The majority of semireliefs in the investigated sediments occur as small fragments of larger burrow systems whose closer ichnotaxonomic affiliation is doubtful. Their differentiation in size and shape suggests that they represent several ichnotaxa (Fig. 11). Characteristically, no graphoglyptids were found.

Numerous semireliefs on soles of beds resting on shales indicate intense bioturbation of shales. This feature together with the growing upward bioturbation intensity in marlstones, and the pelagic origin of shales suggest that in fact shales are the most intensely bioturbated sediments. The rarity of distinctive bioturbation structures in shales results from low preservational potential of the majority of burrows produced in these sediments. Burrows were produced here mainly at the sediment/water interface and close to it, in a water-laden sediment, having a fluid consistency (soupground). This precluded preservation in original form and any distinctiveness after sediment burial of the burrows produced by simple pushing aside of the sediment. Only the excavations with strengthened walls and/or filled with sediment differing distinctively in texture or mineralogical composition as well as the actively filled burrows had a chance to be preserved here (cf. Bromley, 1996 and references therein). In fact, burrows filled with material of contrasting composition relative to shale (exichnia) are very rare in the investigated succession.

The restricted occurrence in shales of burrows filled with arenitic material only to the beds where the shale is overlain by arenitic sediment, occurring in normally graded rhythm less than 10 cm thick, as well as the occurrence of post-turbidite burrows only on soles of the sediment of such rhythms, designates the maximum burrowing depth in these sediments. Considering that the present thickness of the rhythms represents about 40 to 70% of their original thickness, the maximum burrowing depth seems to have ranged 15–25 cm in these sediments. The reason for such relatively shallow sediment penetration is not clear. Burrowing depth is commonly considered to show a positive correlation with benthic oxygen regime (e.g., Savrda & Bottjer, 1986). One cannot exclude that this was also the reason in the case of the Holovnia Siliceous Marls. In fact, the frequent occurrence of burrows of the ichnogenera *Planolites* and *Thalassinoides* indicates benthic oxygenation regime rather close to oxia but the predominantly fine-grained sediments could have displayed low permeability and rapid disappearance of oxygen from their pore water.

The rarity of bioturbation structures on soles of arenite and siltite beds, which rest immediately on marlstone, seems to result from restricted access of these sediments to burrowing. The absence of shale between marlstone and the overlying arenite suggest a short time interval of the background conditions at the sea floor, i.e. the time period when the shale is deposited and the substrate may be burrowed. Frequent sedimentation of turbidites thicker than an average burrowing depth could restrict or even preclude chances of burrowing of the lower part of such beds. The frequent sedimentation of turbidites in general appears to be responsible also for the lack or rarity of burrows in marlstones covered immediately by arenite and for the lowest bioturbation grade of the upper part of the succession showing rare occurrence of distinct shale layers.

To some extent, the vertical distribution of bioturbation structures in the investigated succession results from vertical variability of lithofacies. The richest trace fossil assemblage recorded in divisions where marlstone beds are overlain by shale and the impoverishment recorded in divisions lacking marlstone interbeds may at least in part result from the lack of sufficiently contrasting sediment which could make the burrows distinctive in the latter mentioned divisions.

CONCLUSIONS

Bioturbation structures in the Holovnia Siliceous Marls at Rybotycze are much more differentiated than it appeared from the data presented by Książkiewicz (1977). Seventeen ichnotaxa were identified for the first time in these sediments. They include one new ichnogenus called *Squamichnus* n.igen. represented by one ichnospecies called *S. acinaceformis* n.isp.

Chondrites intricatus, *Ch. targionii*, *Planolites beverleyensis* and *Thalassinoides suevicus* are the most common taxa in the entire succession. *Squamichnus* is common in the lower part of succession consisting of thin-bedded turbidites with thin marlstone division.

The middle part of the succession, rich in shales is also richest in bioturbation structures. It also contains the richest trace fossil assemblage. The bioturbation structures occur here mainly in marlstones and on soles of arenite beds, rarely on top of arenite beds or within arenites. The shales even here do not show distinct bioturbation structures.

The variability in bioturbation intensity in the investigated succession, displayed mainly in the marlstone beds, was controlled chiefly by variable frequency of turbidite sedimentation. The packages lacking shale, consisting exclusively of marl, arenite and siltite are the poorest in bioturbation structures.

The bioturbation structures in the investigated succession represent a deep-water association formed below calcite compensation depth in slope apron sediments. The burrows indicate rather oxic conditions at the seafloor and a shallow location of anoxic pore water in the substrate.

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REFERENCES

Billings, E., 1862. New species of fossils from different parts of the Lower, Middle and Upper Silurian rocks of Canada. In: *Palaeozoic Fossils*, vol. 1 (for 1861–1865). Geological Survey of Canada, Dawson Brothers, Montreal, pp. 96–168.

Bromley, R. G., 1996. *Trace Fossils – Biology and Taphonomy*. Chapman & Hall, London, 361 pp.

Brongniart, A. T., 1823. Observations sur les fucoids. *Sociéte d'Histoire Naturelle de Paris, Mémoire*, 1: 301–320.

Brongniart, A. T., 1828. *Histoire des végétaux fossiles ou recherches botaniques et géologiques sur les végétaux renfermés dans les diverses couches du globe. Vol. 1.* G. Dufour & E. d'Ocagne, Paris, 136 pp.

Crimes, T. P., Garcia Hidalgo, J. F. & Poire, D. G., 1992. Trace fossils from Arenig flysch sediments of Eire and their bearing on the early colonisation of the deep seas. *Ichnos*, 2: 61–77.

D'Alessandro, A. & Bromley, R. G., 1987. Meniscate trace fossils and the *Muensteria-Taenidium* problem. *Palaeontology*, 30: 743–763.

Dżułyński, S., Kotlarczyk, J., Krawczyk, A. & Ney, R., 1979. Wycieczka: Przemyśl – Rybotycze – Przemyśl. (In Polish). In: Kotlarczyk, J. (ed.), *Stratygrafia Formacji z Ropianki (fm) Poziomy z olistostromami w Karpatach Przemyskich. Materiały Terenowej Konferencji Naukowej w Przemyślu. Przemyśl 28–29.06.1979*, pp. 31–44.

Ehrenberg, K., 1941. Über einige Lebensspuren aus dem Oberkreideflysch von Wien und Umgebung. *Palaeobiologica*, 7: 282–313.

Fischer-Ooster, C., 1858. *Die fossilen Fucoiden der Schweizer Alpen, nebst Erörterungen über deren geologischer Alter.* Huber, Bern, 72 pp.

Frey, R. W., 1970. Trace fossils of Fort Hays Limestone Member of Niobrara Chalk (Upper Cretaceous), West-Central Kansas. *The University of Kansas Paleontological Contributions*, Lawrence, Kansas, 53: 1–41.

Frey, R. W., & Howard, J. D., 1982. Trace fossils from the Upper Cretaceous of the Western Interior: potential criteria for facies model. *The Mountain Geologist*, 19: 1–10.

Fu, S., 1991. Funktion, Verhalten und Einteilung fucoider und lophocteniider Lebensspuren. *Courier Forschungsinstitut Senckenberg*, 135: 1–79.

Glocker, E. F., 1841. Über die kalkführende Sandsteinformation auf beiden Seiten der mittleren Marc, in der Gegend zwischen Kwassnitz und Kremsier. *Nova Acta Academiae Caesarea Leopoldino-Carolinae, Germanicae Naturae Curiosorium*, Breslau & Bonn, 19 (Suppl. 2): 309–334.

Gucik, S., Jankowski, L., Rączkowski, P. & Żytko, K., 1991. *Szczegółowa Mapa Geologiczna Polski. Arkusz 1043 – Rybotycze, 1044 – Dobromil, 1:50 000.* Państwowy Instytut Geologiczny, Warszawa.

Häntzschel, W., 1975. Trace fossils and Problematica. In: Moore, R. C., Teichert, C. McCormick, L. & Williams, R. B. (eds), *Treatise on Invertebrate Paleontology*, Part W, Miscellanea, Suppl. 1. Geological Society of America and University of Kansas Press, Boulder, Lawrence, pp. W1–W269.

Herr, O., 1877. *Flora Fossilis Helvetiae. Vorweltliche Flora der Schweiz.* J. Wurster & Comp., Zürich, 182 pp.

Howard, J. D. & Frey, R. W., 1984. Characteristic trace fossils in near shore to offshore sequences, Upper Cretaceous of east-central Utah. *Canadian Journal of Earth Sciences*, 21: 200–219.

Kotlarczyk, J., 1978. Stratigraphy of the Ropianka Formation or of Inoceramian Beds in the Skole Unit of the Flysch Carpathians. (In Polish, English summary). *Prace Geologiczne Oddział PAN w Krakowie*, 108: 1–75.

Kotlarczyk, J., 1985a. An outline of the stratigraphy of marginal tectonic units of the Carpathian orogen in the Rzeszów–Przemyśl area. In: Kotlarczyk, J.(ed.) Geotraverse Kraków – Baranów – Rzeszów – Przemyśl – Ustrzyki Górne – Komańcza – Dukla. *Guide to Excursion 4. Carpatho-Balkan Geological Association, 13th Congress, Cracow.* Wydawnictwa Geologiczne, Warszawa, pp. 39–64.

Kotlarczyk, J., 1985b. Third day: Przemyśl – Rybotycze – Dubnik – Koniusza – Przemyśl. In: Kotlarczyk, J. (ed.), Geotraverse Kraków – Baranów – Rzeszów – Przemyśl – Ustrzyki Górne – Komańcza – Dukla. *Guide to Excursion 4. Carpatho-Balkan Geological Association, 13th Congress, Cracow.* Wydawnictwa Geologiczne, Warszawa, pp. 111–132.

Kotlarczyk, J. (ed.), 1988. *Przewodnik LIX Zjazdu Polskiego Towarzystwa Geologicznego, Przemyśl 16- 18.09.1988.* (In Polish), Wydawnictwo AGH, Kraków, pp. 1–298.

Książkiewicz, M., 1977. Trace fossils in the Flysch of the Polish Carpathians. *Palaeontologia Polonica*, 36: 1–208.

Leszczyński, S., Malik, K. & Kędzierski, M., 1995. New data on lithofacies and stratigraphy of the siliceous and fucoid marl of the Skole Nappe (Cretaceous, Polish Carpathians). *Annales Societatis Geoogorum Poloniae*, 65: 43–61.

Leszczyński, S. & Malik, K., 1996. Carbonates in flysch of the Polish Outer Carpathians. (In Polish, English summary). *Przegląd Geologiczny*, 44: 151–158.

Lorenz von Liburnau, J. R., 1901. Zur Deutung der fossilen Fucoiden-Gattungen *Taenidium* und *Gyrophyllites*. *Denkschriften der Kaiserlichen Akademie der Wissenschaften*, Mathematisch-Naturwissenschaftliche Classe, Wien, 70: 523–583.

Lundgren, B., 1891. Studier öfver fossilförande lösa block. (In Swedish). *Geologiska Förenningen i Stockholm Förhandlinger*, 13: 111–121.

Massalongo, A., 1856. *Studi Palaeontologici.* (In Italian). Antonelli, Verona, pp. 1–53.

Miller, W., III, 2000. Trace fossil assemblages in Cretaceous–Paleogene pelagic limestones of the Belluno area, northeastern Italy. *Memorie di Scienze Geologiche*, 52: 175–192.

Nicholson, H. A., 1873. Contributions to the study of the errant annelids of the older Paleozoic rock. *Proceedings of the Royal Society of London*, 21: 288–290.

Pemberton, G. S. & Frey, R. W., 1982. Trace fossil nomenclature and the Planolites-Palaeophycus dilemma. *Journal of Paleontology*, 56: 843–881.

Pickerill, R. K., 1989. *Compaginatichnus*: a new ichnogenus from Ordovician flysch of eastern Canada. *Journal of Paleontology*, 63: 913–919

Pickering, K., Stow, D., Watson, M. & Hiscott, R., 1986. Deep-water facies, processes and models: a review and classification scheme for modern and ancient sediments. *Earth-Science Review*, 23: 75–174.

Quatrefages, M. A. De, 1849. Note sur la *Scolicia prisca* (A. de Q.) annélide fossile de la Craie. *Annales des Sciences Naturelles*, 3 série, *Zoologie*, 12: 265–266.

Rieth, A., 1932. Neue Funde spongeliomorpher Fucoiden aus dem Jura Schwabens. *Geologisch-Paläontologische Abhandlungen*, 19: 257–294.

Sandulescu, M., 1988. Cenozoic tectonic history of the Carpathians. In: Royden, L. H. & Horvath, F. (eds), *The Pannonian Basin: a study in basin evolution. American Association of Petroleum Geologists, Memoir*, 45: 17–26.

Savi, P. & Meneghini, G. G., 1850. Osservazioni stratigrafiche e paleontologiche concernati la geologia della Toscana e dei paesi limitrofi. Appendix in: Murchison, R. I. (ed.), *Memoria sulla struttura geologica delle Alpi, degli Apennini e dei Carpazi.* Stemparia granucale, Firenze, pp. 246–528.

Savrda, Ch. E. & Bottjer, D. J., 1989. Trace-fossil model for reconstructing oxygenation histories of ancient marine bottom waters: application to Upper Cretaceous Niobrara Formation, Colorado. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 74: 49–74.

Seilacher, A., 1953. Studien zur Palichnologie. I. Über die Methoden der Palichnologie. *Neues Jahrbuch für Geologie und Paleontologie, Abhandlungen,* 98: 421–452.

Sternberg, K. M., Graf von, 1833. *Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt.* Teil 5–6, Fleischer, Leipzig, Prague, pp. 1–80.

Uchman, A., 1995. Taxonomy and palaeoecology of flysch trace fossils: the Marnoso-arenacea Formation and associated facies (Miocene, Northern Apennines, Italy). *Beringeria,* 15: 3–115.

Uchman, A., 1998. Taxonomy and ethology of flysch trace fossils: revision of the Marian Książkiewicz collection and studies of complementary material. *Annales Societatis Geologorum Poloniae,* 68: 105–218.

Uchman, A., 1999. Ichnology of the Rhenodanubian Flysch (Lower Cretaceous–Eocene) in Austria and Germany. *Beringeria,* 25: 67–173.

Wiśniowski, T., 1905. O wieku karpackich warstw inoceramowych (In Polish). *Rozprawy Wydziału Matematyczno-Przyrodniczego Akademii Umiejętności,* ser. III B, 5: 132–182.

Żytko, K., Gucik, S., Ryłko, W., Oszczypko, N., Zając, R., Garlicka, I., Nemčok, J., Eliaš, M., Menčik, E., Dvořak, J., Stranik, Z., Rakuš, M., & Matejovska, O., 1989. Geological Map of the Western Outer Carpathians and their Foreland without Quaternary Formation. In: Poprawa, D. & Nemčok, J. (eds), *Geological Atlas of the Western Outer Carpathians.* Państwowy Instytut Geologiczny, Warszawa.

Streszczenie

STRUKTURY BIOTURBACYJNE W MARGLACH KRZEMIONKOWYCH Z HOŁOWNI (TURON–DOLNY SANTON) W RYBOTYCZACH (KARPATY POLSKIE)

Stanisław Leszczyński

Margle krzemionkowe z Hołowni reprezentują jedną z charakterystycznych jednostek litostratygraficznych płaszczowiny skolskiej (Fig. 1). Tworzy ją sukcesja skalna o miąższości od kilkudziesięciu do około 100 m, zdominowana beżowymi lub szarymi marglami, często z laminą piaszczystą (arenitową) lub pylastą (siltytową) w spągu, przekładającymi się z cienkimi warstwami arenitów (osadów piaszczystych zbudowanych w przewadze z materiału kalcyklastycznego lub w podobnych proporcjach z materiału silikoklastycznego i kalcyklastycznego; Leszczyński *et al.,* 1995) i ciemnozielonych lub szarych łupków mułowych i ilastych. Utwory te tworzą rytmy o normalnym uziarnieniu frakcjonalnym, rozpoczynające się warstwą lub laminą arenitu lub siltytu nadścieloną marglem twardym lub miękkim, lub łupkiem. Niektóre rytmy ograniczone są do warstwy margla, cechującej się normalnym uziarnieniem frakcjonalnym lub też do zespołu warstw piaskowiec-łupek albo arenit-margiel. Ponadto, w profilu pionowym sukcesji zaznacza się zróżnicowanie udziału poszczególnych rodzajów skał. Pakiety o przewadze margli przekładają się z pakietami o przewadze arenitów i łupków lub pakietami o podobnym udziale poszczególnych rodzajów skał.

Margle krzemionkowe z Hołowni stanowią spągową część formacji z Ropianki a zarazem jej dolnego ogniwa, nazywanego ogniwem z Cisowej (Kotlarczyk, 1978). Ich wiek jest interpretowany na podstawie mikroskamieniałości jako turon – wczesny santon (Kotlarczyk, 1978, 1988; Leszczyński *et al.,* 1995; Fig. 2).

Arenity, siltyty, margle i w części łupki są turbidytami. Łupki występujące w przewarstwieniach między warstwami margli oraz margli i leżącego wyżej arenitu bądź siltytu są osadami pelagicznymi/hemipelagicznymi (osadami tła depozycyjnego). Osady o innej genezie mają znaczenie podrzędne.

Rozmieszczenie utworów margli krzemionkowych z Hołowni w obrębie płaszczowiny skolskiej wskazuje, że tworzą one kołnierz wokół skłonu basenu skolskiego. Wyłącznie niewapniste osady tła depozycyjnego przy dominacji synsedymentacyjnego materiału wapiennego w resedymentach wskazują na sedymentację sukcesji na głębokościach poniżej poziomu kompensacji kalcytu.

Praca poświęcona jest opisowi struktur bioturbacyjnych w sukcesji margli krzemionkowych z Hołowni w kilku sąsiadujących ze sobą odsłonięciach, znajdujących się w pobliżu wsi Rybotycze na Pogórzu Przemyskim. Odsłonięcia te są jednymi z lepszych, w ogólności nielicznych odsłonięć sukcesji margli krzemionkowych z Hołowni na terenie Polski. Cała sukcesja ma tu miąższość 50 m (Fig. 3, 4). Jej cechy litofacjalne odpowiadają opisanym wyżej (Fig. 5–8).

Utwory sukcesji margli krzemionkowych z Hołowni, szczególnie margle oraz spągi ławic arenitów, cechują się licznym występowaniem struktur bioturbacyjnych – skamieniałości śladowych (Fig. 9–13). Książkiewicz (1977) wymienił 21 taksonów skamieniałości śladowych z utworów tej jednostki, aczkolwiek tylko 12 było wymienionych z miejsc, w których, według obecnych poglądów (Kotlarczyk, 1978), jednostka ta występuje. Cztery taksony: *Chondrites arbuscula*, *Ch. intricatus*, *Sabularia simplex* oraz *S. tenuis* były wymienione z odsłonięć w Rybotyczach.

Autor niniejszej pracy wyodrębnił w badanych utworach 20 ichnotaksonów (Fig. 14–38), w tym jeden nowy ichnorodzaj – *Squamichnus* n.igen., oraz jeden nowy ichnogatunek: *Squamichnus acinaceformis* n.isp. (Fig. 20 – 2, 21 – 2, 28 – 2, 29–31). 17 spośród wyróżnionych ichnotaksonów nie było dotąd rejestrowanych w tych utworach.

Chondrites intricatus, *Ch. targionii*, *Planolites beverleyensis* oraz *Thalassinoides suevicus* spotykane są najczęściej w całej sukcesji. Rodzaj *Squamichnus* jest pospolity w dolnej części sukcesji, zbudowanej z cienkoławicowych zawiesinowców zawierających cienkie człony margla.

Występowanie wyłącznie niewapnistych łupków w stropie prostych rytmów o normalnym uziarnieniu frakcjonalnym, wskazuje na sedymentację sukcesji na głębokościach poniżej głębokości kompensacji kalcytu, a zarazem na głębokowodny charakter asocjacji występujących tu struktur bioturbacyjnych.

Maksymalne zubożenie struktur bioturbacyjnych, a nawet ich brak, w pakietach zbudowanych wyłącznie z margla, arenitu i siltytu, pozbawionych przewarstwień łupkowych, wskazuje, że decydujący wpływ na przebieg bioturbacji w czasie miała częstotliwość sedymentacji ze spływów zawiesiny.

Opisany zespół struktur bioturbacyjnych wskazuje na raczej niezłe natlenienie wód przy dnie zbiornika (dobre do lekko niedotlenionego), jednocześnie stosunkowo niewielkie głębokości penetracji osadu (do 10 cm poniżej stropu rytmu o normalnym uziarnieniu frakcjonalnym) wskazują na szybki zanik tlenu w wodach porowych w osadzie.