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Trace fossils from the Kosov Formation of the Bohemian Upper Ordovician

Ichnofosilie v kosovském souvrství českého svrchního ordoviku

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Abstract: A variety of fossil traces assemblages was found in the Kosov Formation (altogether 56 ichnospecies). Their character changes from the *Skolithos* ichnofacies up to the mixed *Cruziana* and *Nereites* ichnofacies. Assemblage changes are in agreement with concepts of eustatic changes during the Kosovian. The paper determines new ichnogenus *Monofungites* and several new ichnospecies. Number of ichnotaxons has been determined in the Bohemian Palaeozoic for the first time.

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Introduction

Ichnofossils from the Bohemian lower Palaeozoic have been sporadically studied in comparison with fossil remnants of fauna and flora. An extensive monography of FRITSCH (1908) originated in the time when modern ichnology did not exist yet and therefore its conclusions are in most cases unfit for use. Several other publications on traces from the Bohemian Palaeozoic have a narrow scope (BOUČEK 1937, PRANTL 1946, MAREK 1982, VLČEK 1902, ŽELÍZKO 1903, CHALOUPSKÝ - CHLUPÁČ 1984). Recently, an ichnologic study was published by CHLUPÁČ (1987). Findings of traces have been mentioned also in other papers, e.g. sedimentologic works

(BOUČEK - PŘIBYL 1958, KUKAL 1963) and in textbooks (BOUČEK 1965) but usually they were not figured or described.

In the course of several years I have been systematically collecting ichnofossils in the central Bohemian Palaeozoic. During this relatively short time I have gathered great amount of material from several formations. Up to the present I have described findings from the Polyteichus Facies of the Bohdalec Formation (Ordovician, Berounian) and from pelitic sediments of the Bohemian Upper Ordovician (MIKULÁŠ 1988, 1989). So far, the richest ichnoassemblages have been obtained from the Kosov Formation (Ordovician, Kosovian). The aim of this work is their comprehensive evaluation. The results can be certainly complemented and made more accurate by further terrain investigations. However, it is evident that the degree of knowledge of fossil traces in the sediments of the Bohemian lower Palaeozoic cannot be matched with that of the body fossils which have been collected and studied here from the thirties of the last century.

FRITSCH (1908) payed considerable attention to the traces in the Kosov Formation. His collections together with new findings from a number of usually occasional exposures were newly described and illustrated. In connection with the works of ŠTORCH (1986) and ŠTORCH and MERGL (1989) a correlation between the character of ichnoassemblages in the Kosov Formation and presumed changes of the depth of the Prague Basin during the Kosovian is studied. This part of work is based on the ichnofacies concept; its terminology observes classical works of SEILACHER (1964, 1967) and FREY and CHOWNS (1972), FREY (1973) and FREY et al. (1975). The terminology describing the mode of preservation and toponomy of the traces is taken from the papers of WEBBY (1969) and OSGOOD (1970). A special remark deals with the used system of traces classification.

I should like to thank Dr. R. Prokop and Dr. V. Turek from the National Museum, Prague, for their kindness and for enabling me to study findings deposited in the National Museum. I am also very grateful to Dr. I. Chlupáč and Dr. P. Štorch from the Geological Survey, Prague and Dr. J. Marek from the Department of Paleontology of the Faculty of Natural Sciences, Charles University, Prague for lending me literature, for their interest in my work and stimulating comments. I am also greatly indebted to Dr. L. Marek from the Institute of Geology and Geotechnics of the Czechoslovak Academy of Sciences, Prague, for lending me ichnofossil findings.

Characteristics of the Kosov Formation

Knowledge and conceptions of lithology, sedimentology and paleontology of the Kosov Formation and of the development of the Prague Basin during the Kosovian were published namely in the works of MAREK (1951), BOUČEK and PŘIBYL (1958), KUKAL (1961, 1963), HAVLÍČEK (1982), ŠTORCH (1986), CHLUPÁČ and KUKAL (1988)

and ŠTORCH and MERGL (1989). The most important data from these works are summarized in the following passage.

The beginning of the Kosovian is in the Barrandian characterized by a drastic change in sedimentation. Claystone sediments of the underlying Králův Dvůr Formation were abruptly overlapped by a 1.5 to 8 m thick layer of coarse-grained sandstone to conglomerate with numerous pebbles and fragments of Ordovician and Proterozoic rocks (HAVLÍČEK 1982).

Sequences of the lower and upper parts of the Kosov Formation resemble a flysch facies by alternating quartz sandstones, greywackes, siltstones and clayey shales. They frequently exhibit crossbedding, wash-outs, landslides, curly bedding and various current marks (HAVLÍČEK 1982). Phenomena such as rill marks, shrinkage cracks and little grading of psammitic precipitates testify of a shallow-water environment (KUKAL 1963).

The sedimentation was affected by turbidity currents detailedly described by BOUČEK and PŘIBYL (1958) from Hlásná Třebaň. However, according to KUKAL (1963) they were not of decisive influence.

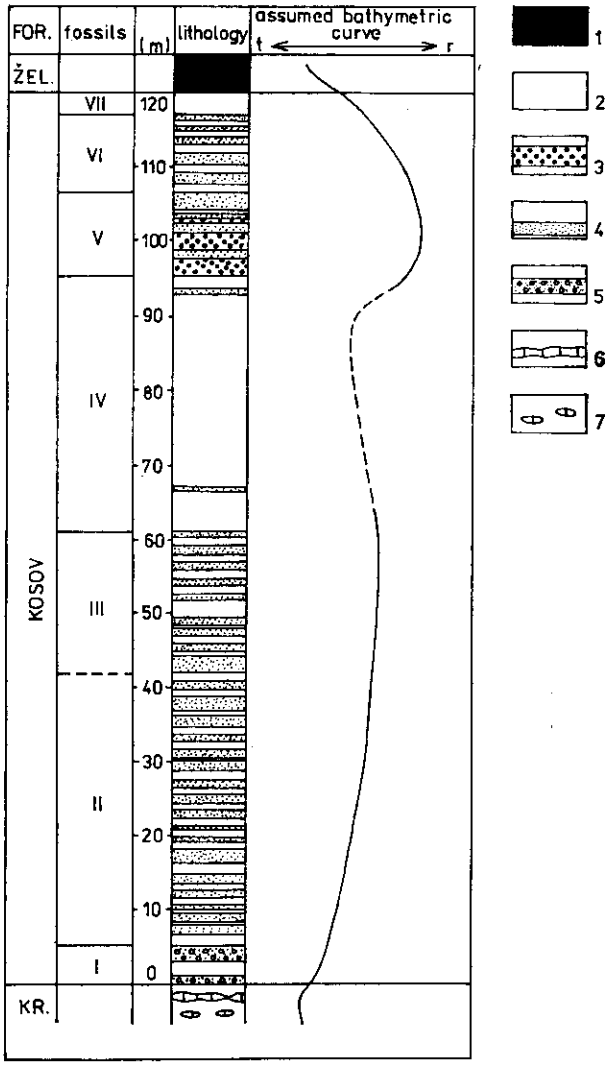
The overall lithological character of the formation suggests a considerable deformation of the Prague Basin during the Kosovian. Marginal segments were uplifted and became a source of clastic material, which is evidenced by the presence of grains and fragments of Ordovician rocks sometimes exhibiting also fauna documenting their age (HAVLÍČEK 1982).

The change in sedimentation resulted in extinction of benthic communities of the Kralodvorian Stage: almost all shelly fauna disappeared. By the end of the Kosovian, after a change in the intensity of basin deformations and quieting of sedimentation, a new fauna shortly occurred – *Hirnantia sagittifera* Community according to HAVLÍČEK (1982).

During sedimentation of the Kosov Formation a basin environment prevailed: a great part of the formation exhibited also a shallow water plain (KUKAL 1963). Psammitic and silty-clayey facies can be roughly distinguished but they cannot be differentiated on the map due to the lack of profiles (KUKAL 1963).

In 1986 ŠTORCH published a report of research into the event on the Ordovician/Silurian boundary; his work yielded a number of new data on the Kosov Formation. An exhaustive study of the Kosov Formation with detailed illustrations of profiles from various sites of the Barrandian was published by ŠTORCH and MERGL (1989). The results of these works permit new interpretations of previously discovered facts.

ŠTORCH and MERGL (1989) documented a number of new exposures of the Kosov Formation (Raitknechtka, Levín, Nové Butovice) and gained very detailed knowledge of the lithology and paleontologic content of the formation. The Kosov Formation shows almost uniform development in the whole Prague Basin – its division into facies is unsubstantiated. On the contrary, individual layers and beds exhibit very stable development. At the bottom, above clayey shales of the Králův Dvůr Formation containing a layer with calcareous concretions and benthic fauna (*Pro-*



1. Scheme of the Prague Basin development during the Kosovian Stage (lithology, paleontologic content, expected bathymetric curve). Lithology and bathymetric curve are after P. Štorch (1986)

1 — graptolitic shales, *2* — claystones and siltstones, *3* — coarse-grained sandstones and conglomerates, *4* — fine- to medium grained sandstones, *5* — coarse-grained greywacke sandstones, *6* — clayey limestone layer, *7* — limestone concretions and lenses; FOR. — Formation, ŽEL. — Želkovice, KR. — Králův Dvůr, t — transgression, r — regression; I—VII: Units of the Kosov Formation distinguishable according to paleontologic content (for their detailed description see the text)

boscisambon Community) there is an approximately 20 cm thick layer of green clayey to silty shales with rare fauna (*Mucronaspis* Assemblage) and ichnofossils (*Bifungites*). Above lies usually a 1 to 3 m thick layer of subgreywacke similar to that on the base of the formation. Then follows roughly 60 m of fine-grained sandstones rhythmically alternating with silty and clayey shales. The next 10 to 30 m of the formation is composed predominantly of shales. Above the shale lie coarse-grained sandstones to conglomerates frequently with graded bedding forming dm benches (cca 15 m). This layer passes into a rhythmic development similar to that in the middle layers, with gradual prevalence of shales (approximately 10 m). The topmost layers of the formation are shaly, sometimes with calcareous concretions. These layers exhibit a rich benthic fauna (*Hirnantia sagittifera* Community).

Conversely to HAVLÍČEK (1982) who explains the character of the formation by tectonic activity of the Prague Basin, ŠTORCH (1986) presumes that the major agent were eustatic movements of the sea level connected with the upper Ordovician glaciation. This phenomenon is discussed in many foreign works (e.g. BRENCHLEY 1984).

The concept of the Prague Basin development in the Kosovian is shown from various aspects in fig. 1. ŠTORCH (l.c.) presumes that two phases of regression occurred during the Kosovian and the second of them, the stronger one, falls into the period of coarse-grained sandstone to conglomerate sedimentation in the upper part of the formation (see the transgression-regression curve in fig. 1).

The bathymetric curve recently published by CHLUPÁČ and KUKAL (1988, p. 131) is slightly different. It stems from an idea of a significant event (strong regression) on the Kralodvorian/Kosovian boundary.

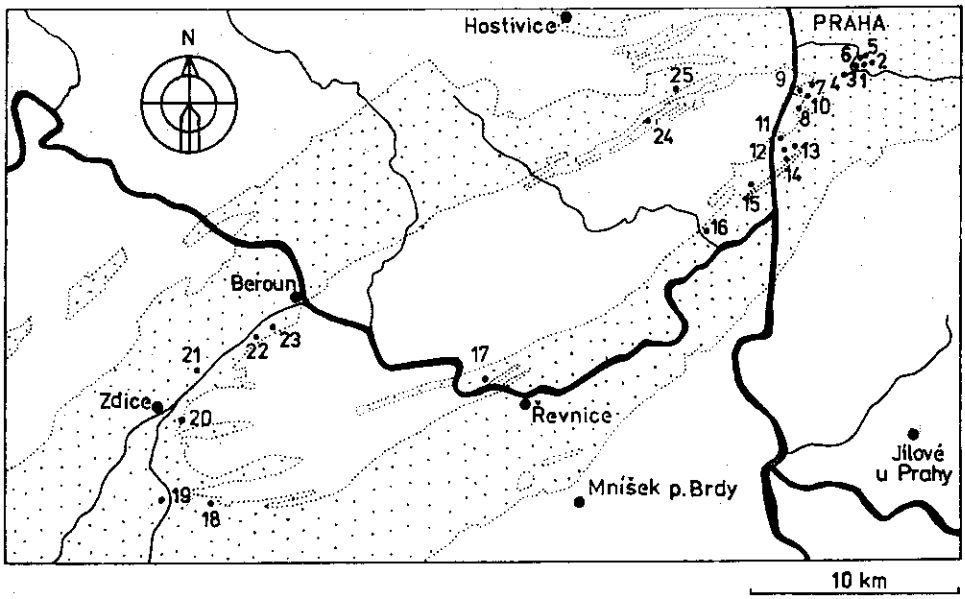
An overview of ichnofossil collecting localities in the Kosov Formation

The major part of the material described by FRITSCH (1908) was collected at the locality Řeporyje ("Řepora" in FRITSCH). Some of the material comes from other localities which are very difficult to determine precisely today (Lahovská, Vonoklasy, Chodouň, Malá Chuchle and others).

Material which I obtained from L. Marek is from the top level of the Kosov Formation, from the localities Prague 5-Nová Ves and Prague 4-Pankrác.

My own finds come namely from 25 localities marked in the plan on fig. 2 and from the locality Prague-Běchovice which is not situated on the plan. A detailed description of the location and geological situation of the localities is presented in the work of MIKULÁŠ (1987) and is not relevant for the aim of this paper. A number of outcrops of the Kosov Formation is also described in detail in the works of BOUČEK and PŘIBYL (1958) and ŠTORCH and MERGL (1989).

The stratigraphic level of individual localities (numbered I to VII in accord with fig. 1) is given in the explanation to fig. 2.



2. Plan of the area between Prague and Zdice with indicated places of ichnofossil occurrences in the Kosov Formation. Dots indicate Ordovician rocks

Names and stratigraphic level of individual localities (corresponding with indications of units in fig. 1): 1 — Tyršův vrch Hill (unit II); 2 — Bohdalec (II); 3 — U plynárny (?); 4 — Reitknechtka (I—II); 5 — Kapitol (II—III); 6 — Kořínkovo pole (II); 7 — Pod Pekařkou (I—II); 8 — Mezivrší (V, VI); 9 — Vysoká cesta (I, II); 10 — Zapadlá (I—II); 11 — Nad strouhou (IV, ?V); 12 — Hodkovičky (V—VI); 13 — Braník-pivovar (brewery) (I); 14 — Hodkovičky-Modřany (I—II, V); 15 — Velká Chuchle (?); 16 — Radotín (II—III); 17 — Hlásná Třebaň (III, IV, V); 18 — Libomyšl-Želkovice (II, ?III); 19 — Libomyšl-nádraží (railway station) (I, II); 20 — Zdice-Slavíky (?); 21 — Levín (I—III); 22 — Karlova Huť (?); 23 — Kosov (IV); 24 — Řeporyje (?III); 25 — Nové Butovice (V, VI, VII)

Remarks to the used classification of traces

Fifty-six ichnospecies of the Kosov Formation are described in the systematic part of this paper. This rather large number was reached in spite of my effort to critically evaluate isolated and poorly preserved findings. Eleven ichnospecies were not classified with any ichnogenus due to their unclear original morphology, ethologic significance, etc., and they are described as ichnogen. indet. in the text. Due to this fact and the intention to place similar taxons close together in the text I have used the system of VYALOV (1968, 1972b) instead of the common alphabetical arrangement of the ichnogenera.

Classification of the described ichnogenera with the higher taxons of Vyalov's classification follows from table 1.

Table 1

Classification scheme of the described ichnogenera according to the system of O.S. Vyalov (1968, 1972)

Ichnophyllum *Vivichnia* VYALOV, 1968
- Subichnophyllum *Invertebratichnia* VYALOV, 1968
  - Ichnoclass *Fossiglyphia* VYALOV, 1968
    - Subichnoclass *Apodichnacea* VYALOV, 1968
      - Ichnoorder *Endotubida* VYALOV, 1968
        - Superichnofamily *Rectotubae* VYALOV, 1968
          - *Monocraterion* TORELL, 1870
          - Ichnogen. indet.
        - Superichnofamily *Arcotubae* VYALOV, 1968
          - Ichnofamily *Rhizocoralliidae* VYALOV, 1968
            - *Rhizocorallium* ZENKER, 1836
            - *Corophioides* SMITH, 1893
          - Ichnofamily *Bifungitidae* ichnofam. nov.
            - *Arthraria* BILLINGS, 1872
            - *Bifungites* DESIO, 1940
            - *Monofungites* ichnogen. nov.
          - Ichnofamily *Arenicolitidae* VYALOV, 1968
            - *Arenicolites* SALTER, 1857
      - Ichnoorder *Lissotractida* VYALOV, 1968
        - Superichnofamily *Unipartoidea* VYALOV, 1968
          - *Planolites* NICHOLSON, 1873
          - *Gordia* EMMONS, 1844
          - *Cochlichnus* HITCHCOCK, 1858
        - Superichnofamily *Bipartoidea* VYALOV, 1968
          - *Aulichnites* FENTON and FENTON, 1937
          - *Taphrhelminthopsis* SACCO, 1888
      - Ichnoorder *Ornotractida* VYALOV, 1968
        - Superichnofamily *Unilobatoidea* VYALOV, 1968
          - *Rhabdoglyphus* VASSOEVICH, 1951
          - *Arthrophycus* HALL, 1852
          - *Scalarituba* WELLER, 1899
          - Ichnogen. indet.
        - Superichnofamily *Bilobatoidea* VYALOV, 1968
          - *Cruziana* D'ORBIGNY, 1842
          - *Gyrochorte* HEER, 1865
        - Superichnofamily *Trilobatoidea* VYALOV, 1968
          - *Scolicia* DE QUATREFAGES, 1849
          - *Curvolithus* FRITSCH, 1908
      - Ichnoorder *Crustolithida* VYALOV, 1968
        - *Phycodes* RICHTER, 1850
        - *Treptichnus* MILLER, 1889
        - Ichnogen. indet. A
        - Ichnogen. indet. B

Table 1 (*continued*)

Ichnoorder *Interruptida* VYALOV, 1968	
	Ichnogen. indet. A
	Ichnogen. indet. B
	Ichnogen. indet. C
Ichnoorder *Asterichnida* VYALOV, 1968	
	Asteriacites VON SCHLOTHEIM, 1820
Ichnoorder *Dictyonida* VYALOV, 1968	
	Protopaleodictyon KSIĄŻKIEWICZ, 1970
	Ichnogen. indet. A
	Ichnogen. indet. B
Ichnoorder *Circulichnida* VYALOV, 1968	
	Laevicyclus QUENSTEDT, 1879
	Palaeoscia CASTER, 1942
Ichnoorder *Farraginida* VYALOV, 1968	
	Rusophycus HALL, 1852
	Lockeia JAMES, 1879
	Isopodichnus BORNEMANN, 1879
	Ichnogen. indet.
Subichnoclass *Podichnacea* VYALOV, 1968	
	Beaconichnus GEVERS, 1973
	Monomorphichnus CRIMES, 1970
	Palmichnium R. RICHTER, 1954
	Ichnogen. indet.
Ichnophyllum *Vivisignia* VYALOV, 1972	
	Cilindrotomaculum GUTIÉRREZ MARCO, 1984

Systematic part

Ichnophyllum *Vivichnia* VYALOV, 1968

Diagnosis: Products of organisms activity with the shape reflecting morphological features of the agent. Biostratification and body fossils were not included in the group.

Subichnophyllum *Invertebratichnia* VYALOV, 1968

Diagnosis: *Vivichnia* from invertebrates.

Ichnoclass *Fossiglyphia* VYALOV, 1968

Diagnosis: *Invertebratichnia* originated in unconsolidated material.

Subichnoclass *Apodichnacea* VYALOV, 1968

Diagnosis: Traces from *Fossiglyphia* group not representing prints of agents' extremities.

Ichnoorder *Endotubida* VYALOV, 1968

Diagnosis: Traces predominantly formed by tubes or tunnels more or less perpendicular to the sedimentary surfaces.

Superichnofamily *Rectotubae* VYALOV, 1968

Diagnosis: Endotubida in the form of simple vertical tubes.

Ichnogenus *Monocraterion* TORELL, 1870

Diagnosis: Vertical, almost cylindrical tubes with wide, hopper-shaped opening on the upper end. Tubes are several mm to cm wide, smooth (FREY and CHOWNS 1972).

Monocraterion sp.

Pl. XIV, fig. 2

Material: A single find of a tube with opening from the locality Hodkovičky (upper part of the formation).

Description: See the diagnosis of the ichnogenus. The tube is 29 mm long (its lower part delimited by the size of the sample) and 2 to 3 mm wide. Depth of hopper-shaped opening is 2.5 mm. The find is fossilized in coarse-grained sandstone with clayey shale shreds, non-weathered part of the filling is formed by clayey matter.

Remarks: Typically developed tubes of *Monocraterion* are most frequently interpreted as burrows of worms (see FREY and CHOWNS 1972). The find from the upper part of the Kosov Formation is not individual; according to oral communication of Dr. Štorch, there were found already several specimens.

Rectotubae ichnogen. et ichnosp. indet.

Pl. IV, fig. 3

Material: Three finds from the locality Praha-Běchovice (Na Vinici).

Description: Tubes of circular cross-section, approximately perpendicular to the sedimentary bedding, found in flags of fine-grained laminated sandstone. Laminae

near tubes are bent towards the overlie. The tubes are 2 to 3 mm wide and several cm long. They are filled with fine-grained sandstone similar to the surrounding rock.

Remarks: The tubes are probably escape structures originated immediately after a sudden deposition of a sandstone layer.

Superichnofamily *Arcotubae* VYALOV, 1968

Diagnosis: *Endotubida* with a predominant part formed by usually vertical tubes, in the lower part connected by a tunnel ("U" or "H" or inverted letter π scheme).

Ichnofamily *Rhizocoralliidae* VYALOV, 1968

Diagnosis: Representatives of the *Arcotubae* group whose vertical parts are interconnected by a thin layer of reworked sediment (spreite).

Ichnogenus *Rhizocorallium* ZENKER, 1836

Diagnosis: U-shaped tubes with cross-texture after sediment reworking (spreite). Tube branches are almost parallel. The texture runs obliquely through the bed or is parallel with the bedding. Feeding burrows (HÄNTZSCHEL 1962 and others).

Rhizocorallium sp.

Pl. XIV, fig. 6

1908 *Crossochorda costata* ? Fr.; FRITSCH, pl. 9, fig. 3.

Material: A single original Fritsch's find from the locality Řeporyje.

Description: See the description of the genus: The whole structure in the shape of recumbent U is 34 mm long and 22 mm wide. Tubes are clearly separated from spreite. The structure is preserved as a full relief.

Remarks: Even though there is only one find, there is no doubt that it belongs to *Rhizocorallium*.

Ichnogenus *Corophioides* SMITH, 1893

Diagnosis: U-shaped vertical tube with parallel U-shaped arches in the trace level (spreite). Arms are parallel or approaching each other with increasing depth. Spreite can be protrusive or retrusive. Tube walls are striated. Tube openings are not bell-shaped (OSGOOD 1970).

Corophioides cf. *biclavata* (MILLER, 1875)

Pl. II, fig. 5

Material: Two basal parts (convex hyporelief and concave epirelief) from the locality Kosov.

Description: Tube bases roughly of dumbbel shape (convex hyporelief and concave epirelief). Marginal base widenings are rounded (Pl. II, fig. 5) or triangular with rounded corners. The tube connecting both widenings in the found specimens is strongly arched towards the structure underlie. Length of the found bases is 32 and 45 mm.

Remarks: OSGOOD (1970) describes *C. biclavata* (MILLER) as vertical U-shaped tubes with arms lengthened below the base as blind appendices. The species is most frequently preserved as a concave epirelief of dumbbel shape, i.e. as two depressions joined by a stem. Central depression resembles a shallow concave "U" and may or may not be directly connected with end depressions.

However, OSGOOD (1970) wrongly considered the genera *Bifungites* DESIO and *Arthraria* BILLINGS as synonyms of the genus *Corophioides* and as bases of *C. biclavata* he depicted a number of structures which evidently belonged to *Bifungites* or *Arthraria*.

It is easy to differentiate perfectly preserved specimens of the three above mentioned genera. But in the Kosov Formation, except for rare cases, only bases fossilized usually as convex hyporeliefs were preserved. It seems that a suitable criterion for distinguishing bases of *Corophioides* from bases of *Bifungites* or *Arthraria* is the shape of the stem joining the "end depressions". In *Corophioides* the stem is always conspicuously convex towards the underlie ("U" shape), in *Athraria* it is mildly convex towards the underlie or straight and in *Bifungites* it is mildly bent towards the overlie. It follows from the diagnoses of the discussed genera.

Two fossils of bases described here as *C.* cf. *biclavata* exhibit stems conspicuously bent to the shape of "U" and therefore I assign them to the genus *Corophioides* SMITH. Of the representatives of this genus described by OSGOOD (1970) only *C. biclavata* exhibits arms prolonged below the base in the form of blind appendices which may fossilize as "end depressions".

Ichnofamily *Bifungitidae* ichnofam. nov.

Diagnosis: Representatives of the group *Arcotubae*, with dumbbel, arrow, pestle or hammer shape of the horizontal base; "spreite" is absent. Primarily or secondarily even the entire vertical part of the trace may be absent; in such a case the trace exhibits a surface character.

Representatives: *Bifungites* DESIO, 1940; *Arthraria* BILLINGS, 1872; *Monofungites* ichnogen. nov.

Ichnogenus *Arthraria* BILLINGS, 1872

Diagnosis: A dumbbel-shaped trace preserved usually as a convex hyporelief composed of a rather shallow stem connecting deeper sections on its ends. The trace shows no vertical tubes or other formations (FILLION and PICKERILL 1984).

Remarks: The relationship between *Bifungites* DESIO, *Arthraria* BILLINGS, *Corophioides* SMITH, *Diplocraterion* TORELL and other genera has been discussed several times in the literature. This paper is based on the concept of FILLION and PICKERILL (1984) who assign to the ichnogenus *Arthraria* surface dumbbel-shaped formations without vertical part, to *Bifungites* burrows with a dumbbel-shaped horizontal part and simple vertical tubes and to *Diplocraterion* similar formations with a layer of reworked oriented sediment (spreite).

I did not consider the opinion of OSGOOD (1970) who derives the above mentioned forms from the ichnogenus *Corophioides* SMITH.

Arthraria sp. A

Pl. II, figs. 6, 7, 8

Material: 15 specimens from various localities (usually convex hyporeliefs); systematic appurtenance of some of them is, however, doubtful.

Description: See the description of the genus; endings commonly oval-shaped. Length of specimens is usually from 10 to 20 (40) mm. Width of the endings generally does not exceed the double of the stem width which is usually 3 to 5 (8) mm wide.

Remarks: In some cases it is practically impossible to decide whether the trace had or had not a vertical part (it might have been effaced by erosion). In such cases, systematic assignment of the trace is uncertain since it may belong both to *Arthraria* or *Bifungites*.

Arthraria sp. B

Pl. X, fig. 3

Material: A single find (convex hyporelief) from the locality Tyršův vrch.

Description: A long horizontal furrow of semioval cross-cut, on one side terminated by a pestle-shaped widening, on the other side delimited by the size of the rock sample. Width of the furrow is 3.5 mm, length of the preserved part 47 mm.

Ichnogenus *Bifungites* DESIO, 1940

Diagnosis: Burrow in the shape of inverted letter π; it consits of a horizontal part and two vertical tubes. The horizontal part (base) of the trace is of oval cross-section, on both ends terminated by pestle, hammer, arrow, knuckle or heart shaped widenings. The top part of these ends tapers to smooth, cylindrical vertical or subvertical tubes.

The diagnosis is based on descriptions, discussions and illustrations of GUTSCHICK and LAMBORN (1975).

Bifungites sp.

Pl. XIV, figs. 3, 8

Material: One find from the locality Levín (full relief), several finds from the locality Branik-pivovar (brewery) are deposited in the collections of the Geological Survey, Prague (collected by M. Mergl).

Description: The specimen from the locality Levín is free of any matrix, of approximately dumbbel shape. The connecting stem is conspicuously arched towards the structure overlie. On both ends the stem widens into a hemispherical terminations. The upper parts of both endings exhibits round "scars" after broken off vertical tubes. Length of the better preserved half of the base is 9.5 mm, width of the connecting tube is 4.0 mm, diameter of "scar" after vertical tube (on the better preserved half) reaches 5 mm.

Remarks: All finds of *Bifungites* from the Kosov Formation that were at my disposal come from clayey shale layers since vertical burrows cannot fossilize on the back side of sandstone benches and flags.

The burrows of *Bifungites* are described and illustrated also in the works of VLČEK (1902) and FRITSCH (1908). Both authors incorrectly determine them as *Bythotrephis impudica* HALL. However, none of the Vlček's and Fritsch's finds comes from the Kosov Formation and therefore they are not discussed in this paper.

Ichnogenus *Monofungites* ichnogen. nov.

Diagnosis: Horizontal part in the shape of a reclining "T". Scheme of the trace is similar to that in *Arthraria*. However, one end of the connecting stem (or furrow) rectangularly branches off into two blind appendices representing an extreme modification of hollows of *Arthraria* or terminal widenings of *Bifungites*. The other end of the stem shows a slight widening passing into an inconspicuous drop-shaped ending. Length of the connecting furrow is 4—10 mm, length of vertical stem originated from both the blind appendices is about 6 mm, furrow width about 1 mm.

Type ichnospecies: *Monofungites udubuensis* ichnosp. nov.

Monofungites udubuensis ichnosp. nov.

Pl. I, figs. 1—4, 6, 7

Holotype: Specimen figured in pl. I, fig. 1.
Type horizon: Ordovician, Kosovian, Kosov Formation.
Type locality: Praha 4-Braník, Vysoká cesta.

Name derivation: After local name in the surroundings of the type locality (U dubu).
Material: Seven specimens from a single bedding plane from the locality Vysoká cesta.

Description: See the diagnosis of the genus.

Remarks: The trace probably comes from organisms similar to the *Bifungites* and *Arthraria* tracemakers. Relations between the ichnogenera *Bifungites, Arthraria* and *Monofungites* follow from the above diagnoses.

Ichnofamily *Arenicolitidae* VYALOV, 1968

Diagnosis: U-shaped tube. Spreite is absent.

Ichnogenus *Arenicolites* SALTER, 1857

Diagnosis: U-shaped burrows, perpendicular to bedding planes. Tunnels are variously wide with round or secondarily flattened cross-sections. Tunnel walls are smooth or sculptured (HÄNTZSCHEL 1962).

Arenicolites sp. A

Pl. VII, fig. 1

Material: A single rock fragment with five pairs of tubule openings from the locality Nad struhou.

Description: Ten tubule openings on a sandstone bedding plane. The arrangement of openings suggests that they form pairs. Tubules of each pair are 2–8 mm distant from each other; tubule diameter is about 0.5 mm. Two polished sections made between the opening pairs did not reveal even in one case a complete U-shaped structure. However, in one case it was found that the tubule bends in the expected direction to a horizontal position.

Remarks: In my opinion the described traces are probably incompletely preserved burrows of *Arenicolites*.

Arenicolites sp. B

Pl. XIV, fig. 7

Material: A single find of a burrow base filling from the locality Levín (lower layers of the Kosov formation).

Description: Filling of a horizontal tunnel, 36 mm long, on both ends sharply, approximately rectangularly bending upwards. Cross-section of vertical parts of the tunnel preserved in the length of several mm is round, cross-section of the horizontal part is elliptical. The tunnel diameter is 4 to 5 mm. The find is fossilized in clayey shale; filling shows a greywacke appearance.

Ichnoorder *Lissotractida* VYALOV, 1968

Diagnosis: Smooth surface traces or subhorizontally deposited tunnels.

Superichnofamily *Unipartoidea* VYALOV, 1968

Diagnosis: Lissotractida of the simplest shape, morphologically longitudinally inarticulated.

Ichnogenus *Planolites* NICHOLSON, 1873

Diagnosis: Unlined, rarely branched, straight to tortuous, smooth to irregularly walled or annulated burrows, circular to elliptical in cross-section, of variable dimensions and configurations. Infilling essentially structureless, differing in lithology from host rock (PEMBERTON and FREY 1982).

Remarks: The ichnospecific classification of *Planolites* proposed by PEMBERTON and FREY (1982) is not used in this paper because of the considerable uniformity in preservation of *Planolites* in the Kosov Formation (usually convex hyporeliefs on the base of sandstone flags, more or less disturbed by erosion).

Planolites sp. A

Pl. III, figs. 1, 2

1908 *Bythotrephis ramosa* HALL; FRITSCH (partim), pl. 2, fig. 7.
1908 *Spongolithus flabellum* FR.; FRITSCH, pl. 12, fig. 14.
1908 *Spongolithus chalinoides* FR.; FRITSCH, pl. 12, fig. 12.
1908 *Spongolithus irregularis* FR.; FRITSCH, pl. 4, fig. 7.
?1908 *Spongolithus hamatus* FR.; FRITSCH, pl. 4, fig. 9.
?1908 *Digitolithus rugatus* FR.; FRITSCH, text-fig. 7.
1908 *Bythotrephis impudica* HALL; FRITSCH (partim), pl. 1, fig. 3.

Material: Several hundreds of passage sections practically from all the followed outcrops of the Kosov Formation.

Description: Passages of oval cross-section (usually convex hyporeliefs, exceptionally full reliefs), smooth on the surface. Individual preserved sections are usually 1–5 (10) cm long, frequently mildly bent. There are usually big numbers of traces preserved on the back side of sandstone flags; individual sections frequently overlap and cross each other. Width of passages fluctuates around 3 (max. 5) mm.

Remarks: FRITSCH (1908) described this ichnospecies under a number of generic names, most frequently as "*Spongolithus*". He used signs which can be considered as random and his illustrations are almost always considerably idealized. However, due to a fragmentariness of some of the Fritsch's finds, their assignment to the *Planolites* sp. A should be considered approximate. A detailed discussion of these species was presented elsewhere (MIKULÁŠ 1987).

Planolites sp. B

Pl. IV, fig. 7

Material: Several tens of finds e.g. from the localities Reitknechtka and Tyršův vrch.

Description: Passages with elliptical cross-section, flattened in the bedding direction (convex hyporeliefs). Traces are smooth on the surface, 3–8 mm wide, always straight. Length of preserved sections is usually 5–10 cm.

Remarks: *Planolites* sp. B differs from *P.* sp. A in exhibiting a wider trace and longer preserved sections and in having a straight course of passages.

Planolites sp. C

Pl. XII, fig. 1

Material: A single bedding plane with traces of *P.* sp. C from the locality Reitknechtka.

Description: Smooth, narrow (1–2 mm) distorted passages (convex hyporeliefs): individual sections are usually about 1 cm long.

Planolites sp. D

Pl. III, fig. 3

Material: About 10 finds from the localities Pod Pekařkou, Tyršův vrch, Karlova Huť.

Description: Wide, mildly bent, smooth passages (convex hyporeliefs) out of which short blind appendices branch off. Width of main passages is up to 10 mm, length of preserved sections over 10 cm.

Planolites sp. E

Pl. VI, figs. 1, 3

Material: Three finds from the localities Tyršův vrch and Reitknechtka.

Description: Wide, non-stop sinuous or meandering passages (full reliefs of convex hyporeliefs). The found sections are not naturally limited; length probably does not exceed 15 cm, width is 10 to 20 mm. Their surface is frequently irregularly transversely undulated.

Planolites sp. F

Pl. VII, figs. 2, 3

Material: Four tubes from the locality Hodkovičky; two of them are hollow, two are fossilized as full reliefs.

Description: Thin, straight tubes (hollow or full reliefs) running through the

sediment at an angle of approximately 45°. Their width is roughly 1 mm, length 10 mm. Surface is smooth.

Remarks: *Planolites* sp. F belongs to a small percentage of the Kosov Formation ichnofossils which are found inside sandstone flags. It differs from other representatives of *Planolites* in the Kosov Formation by oblique attitude in coarsely clastic sediment.

Ichnogenus *Gordia* EMMONS, 1844

Diagnosis (HÄNTZSCHEL 1962): Long, thin and smooth trails of uniform thickness, usually sinuous but without regular meanders.

Gordia vermicularis (FRITSCH, 1908)

Pl. XVI, fig. 3

1908 *Spongolithus vermicularis* FR.; FRITSCH, pl. 12, fig. 2, pl. 15, fig. 3.
Lectotype (SD herein): Specimen figured in FRITSCH, pl. 12, fig. 2.
Type horizon: Ordovician, Kosovian, Kosov Formation.
Type locality: Praha 5-Řeporyje.
Material: Two specimens from Fritsch's collection from the locality Řeporyje, several new finds e.g. from the locality Reitknechtka.

Description: Narrow, smooth, sinuous trails often crossing each other (convex hyporeliefs). Their length ranges from several mm to several cm, width 0.5–1 mm.

Ichnogenus *Cochlichnus* HITCHCOCK, 1858

Diagnosis: Regularly meandering surface trails resembling a sinusoid (HÄNTZSCHEL 1962).

Cochlichnus sp.

Pl. IV, fig. 5

Material: One find from the locality Hlásná Třebaň.

Description: Smooth, regularly meandering trail (convex hyporelief). Trace is 13 mm long. Amplitude of individual curves is 0.5–1 mm. Distance between individual arches is 1–1.5 mm. Trail width is 0.4 mm.

Remarks: The ichnofossil was found in a layer with numerous "mesh" textures (*Torrowangea, Protopaleodictyon*). It is probably a trace after feeding on organic deposits on the floor surface.

Superichnofamily *Bipartoidea* VYALOV, 1968

Diagnosis: *Lissotractida* longitudinally divided into two lobes by a central groove or ridge.

Ichnogenus *Taphrhelminthopsis* SACCO, 1888

Diagnosis: Two-lobe trails 1 – 3 cm wide, often very long, of various morphology (more or less straight, loosely undulated or meandering), flat. Central trail is usually 3 – 10 mm wide, lateral ridges may be transversely striated (HÄNTZSCHEL 1975).

Taphrhelminthopsis sp.

Pl. VIII, fig. 6; pl. XV, fig. 1

1908 *Palaeophycus marginatus* FR.; FRITSCH, pl. 11, fig. 10; p. 18.

Material: Three specimens from the localities Řeporyje, Bohdalec and Kosov.

Description: Shallow, sinuous surface trails. Transverse segmentation agrees with the diagnosis of the genus. Trail surface is smooth. Width of the found traces is 12.5, 8 and 7 mm.

Remarks: The finds are probably traces after gastropod crawling (see HÄNTZSCHEL, 1975).

Ichnogenus *Aulichnites* FENTON and FENTON, 1937

Diagnosis: Two-lobe straight or mildly bent trails with a conspicuous central groove and smooth lateral lobes. If the traces were preserved as full reliefs, they exhibit a one-lobe bottom surface (HAKES 1977).

Aulichnites sp.

Material: A single find from the locality Hlásná Třebáň.

Description: Straight trail (full relief). Length of the preserved part is 32 mm, width 8.5 mm. Marked central groove, trace sides are smooth. The exposed upper surface of the trace is bilobate, bottom surface is probably longitudinally undivided.

Remarks: This single poorly preserved find seems to correspond morphologically with the description of *Aulichnites* after HAKES (1977).

Ichnoorder *Ornotractida* VYALOV, 1968

Diagnosis: Transversely segmented surface traces or subhorizontally positioned tunnels.

Superichnofamily *Unilobatoidea* VYALOV, 1968

Diagnosis: Ornotractida, morphologically longitudinally unsegmented.

Ichnogenus *Arthrophycus* HALL, 1852

Diagnosis: Undulated tubes or their filling decorated with subtle rings, simple or more frequently in bunches with ramification. Individual "branches" may have several dm in length. They probably come from organisms feeding on unconsolidated sediment. Diagnosis is based on the works of SEILACHER (1955) and HÄNTZSCHEL (1962).

"Arthrophycus" corrugatus (FRITSCH, 1908)

Pl. XIV, fig. 1

1908 *Radix corrugatus* FR.; FRITSCH, p. 8, 25, 27.
1908 *Radicites rugosus*; FRITSCH, pl. 6, fig. 8.

Lectotype (SD herein): Specimen illustrated by FRITSCH (1908) in pl. 6, fig. 8, in this paper shown in pl. XIV, fig. 1 (collections of the National Museum, Prague, L 7798).
Type horizon: Ordovician, Kosovian, Kosov Formation.
Type locality: Vonoklasy near Prague.
Material: The original Fritsch's find from the type locality, several dubious fragments from the locality Tyršův vrch.

Description: Convex hyporelief of the tunnel, 12 cm long, on both ends delimited by the size of the rock sample. The tunnel shows an oval cross section with irregular swelling, it is usually 10–12 mm wide, bent in several places, with two blind branches. Surface of the fossil is covered with irregular low rings which, if developed, are on average 2 mm apart.

Remarks: The described find resembles *Arthrophycus* by its transverse rings. Several findings of similar morphology come from the locality Tyršův vrch (pl. X, figs. 4, 5). However, I found none among them that could be assigned to any of the existing ichnogenera without doubt.

Ichnogenus *Rhabdoglyphus* VASSOEVICH, 1951

Diagnosis: Cylindrical tubes composed of short, dense and intergrowing calyces. In some cases the tubes exhibit short arms. The traces are of unknown origin (HÄNTZSCHEL 1975).

?Rhabdoglyphus annulatus (FRITSCH, 1908)

Pl. V, figs. 1–6

1908 *Spongolithus annulatus* FR.; FRITSCH, pl. 12, fig. 17; p. 16

Lectotype (SD herein): Specimen depicted by FRITSCH (1908) in pl. 12, fig. 17 (collections of the National Museum, Prague, no inv. n.) is here in pl. V, fig. 1.

Type horizon: Ordovician, Kosovian, Kosov Formation.

Type locality: Praha 5-Řeporyje.

Material: About 25 reliefs of tunnels from the localities Tyršův vrch, Reitknechtka, Řeporyje, Běchovice, Nová Ves.

Description: Passages fossilized as convex hyporeliefs or full reliefs, usually bent, 6–12 mm wide, with circular cross-section. Their walls exhibit annular widening in regular intervals of 7–20 mm; otherwise the surface is smooth. Individual rings usually show more rapid narrowing toward one end of the passage which can be considered a direction orientation of the trace. Length of the preserved parts of the trace is up to 20 cm. Tunnel fossils frequently occur in greater numbers on bedding planes. I suppose that they are most probably the trails of worms.

Remarks: According to its basic scheme the described ichnofossil is similar to *Rhabdoglyphus* described and figured by HÄNTZSCHEL (1975). *Rhabdoglyphus* was found in rocks of Cretaceous age.

?Rhabdoglyphus annulatus is usually found in the lower, middle or upper layers of the Kosov Formation. L. Marek found three tunnel fossils in shaly layers with *Hirnantia* fauna at the locality Nová Ves (Praha 5).

Ichnogenus *Scalarituba* WELLER, 1899

Diagnosis: Tunnels of circular cross-section, usually 2–4 mm wide, sinuous, with transverse ridges 1–2 cm apart (HÄNTZSCHEL 1962). Transverse ridges are reflected in the characteristic inner (scalariform) texture (HAKES 1977). The traces come from worms feeding on the sediment (HAKES 1977, CONKIN and CONKIN 1968). Geological occurrence ranges from the Ordovician to the Permian.

Scalarituba missouriensis WELLER, 1899

Pl. IV, figs. 1, 6

Material: A group of six tunnel hyporeliefs on a single rock fragment from the locality Praha-Běchovice. Additional hyporelief of the tunnel from the same locality.

Description: Tunnel hyporeliefs of oval cross-section, 1–3 mm wide, sinuous. Transverse ridges are usually 0.4–0.6 mm apart.

Remark: The found remnants are morphologically identical with *S. missouriensis* described or figured e.g. in the works of HÄNTZSCHEL (1962, 1975), CONKIN and CONKIN (1968).

Scalarituba michlensis ichnosp. nov.

Pl. IX, figs. 1, 2, 3; ? pl. X, figs. 2, 8

Holotype: Specimen illustrated in pl. IX, fig. 1.
Type horizon: Ordovician, Kosovian, Kosov Formation.
Type locality: Praha 4-Michle, Tyršův vrch.
Derivation of name: After the name of the Prague quater (Michle).
Material: Three tunnel fossils from the type locality, one uncertain find from the same locality.

Description: Tunnels of oval cross-section crossing through bedding planes (convex hyporeliefs). The found specimens are 3.5, 6.5 and 11.5 mm wide, 6, 19 and 20 mm long. The tunnel surface is densely and irregularly covered with transverse ridges which probably reflect the original inner texture which is not preserved on convex hyporeliefs.

Remarks: *Scalarituba michlensis* differs from *S. missouriensis* WELLER in having wider tube and irregular structure of inner tunnel segments.

The species *Scalarituba* sp. was described by HAKES (1977) from the lower Pennsylvanian of Kansas. The material was preserved in the similar way as the remains of *Scalarituba* from the Kosov Formation. *Scalarituba* sp. differs from *S. michlensis* in having wider and more regular interspaces between transverse ridges.

Unilobatoidea ichnogen. et ichnosp. indet.

Pl. IV, fig. 4

Material: A single find from the topmost shaly layers of the Kosov Formation, locality Praha-Pankrác (from the collections of L. Marek).

Description: Straight passage of elliptic cross-section (full relief). The preserved fragment is 27 mm long and 4 mm wide. The passage is superficially sculptured with regular, narrow, longitudinal ridges (3–4 ridges per 2 mm of width).

Remarks: The find is probably a trace after worm or gastropod trailing.

Superichnofamily *Bilobatoidea* VYALOV, 1968

Diagnosis: *Ornotractida* longitudinally divided by a central groove (ridge) into two lobes.

Ichnogenus *Cruziana* D'ORBIGNY, 1842

Diagnosis: Shallow, straight or bent furrows with a central carina usually from the reverse side of sandstone bedding planes. Lateral parts are obliquely gently striated. Traces after crawling trilobites (BOUČEK, 1965, and others).

?Cruziana sp.

Pl. VIII, fig. 4; pl. XIII, fig. 2

1908 *Crossochorda costata* FR.; FRITSCH (partim), pl. II, fig. 8.

Material: The original Fritsch's find preserved as a concave epirelief projecting itself into the inner texture of the specimen as "cleavage-relief" (the locality Řeporyje); one find (convex hyporelief) from the locality Vysoká cesta.

Description: The find inaccurately depicted by FRITSCH (1908) in pl. 11, fig. 8 and wrongly determined as *Gordioides spiralis* Fr., is a shallow, straight bilobate furrow, vaultedly terminated on one end and delimited by the size of the rock sample on the other end. The total length of the preserved part of the trace is 44 mm, width 11–12 mm. Central carina well visible. It exhibits several inconspicuous transverse striae irregularly distant from each other. The find from the locality Vysoká cesta has a similar morphology.

Remarks: According to the overall disposition and size the described traces are close to the representatives of *Cruziana* as described by SEILACHER (1970), HÄNTZSCHEL (1962), FREY and CHOWNS (1972) and by a number of other authors. Due to the fact that there were not preserved details of the trace surface it is very difficult to determine more precisely the generic or species appurtenance.

Superichnofamily *Trilobatoidea* VYALOV, 1968

Diagnosis: *Ornotractida* longitudinally divided by furrows or ridges into three lobes.

Ichnogenus *Scolicia* DE QUATREFAGES, 1849

Diagnosis: Trails of surface or subsurface origin, usually irregularly sinusoid ("grater" shaped). Furrows or surface of subsurface passages are trilobate, usually striated. The side striae are commonly oblique. Morphology of individual representatives is considerably variable. Diagnosis is based on the description and illustrations of HÄNTZSCHEL (1962), FREY and HOWARD (1970) and KSIĄŻKIEWICZ (1970).

"*Scolicia*" sp.

Pl. VIII, figs. 3, 7

Material: Ten finds from the localities Mezivrší, Pod Pekařkou, Bohdalec and others.

Description: Shallow, sinuous, superficial furrows (convex hyporeliefs), 2–4 mm wide, with a smooth surface; they show no longitudinal or transverse sculpturing. They are very long, almost always delimited by the size of the rock fragment or sample.

Remarks: The described furrows are close to *Scolicia* due to their sinuous course on the beds surface; such traces are frequently described as "*Scolicia*" sp. (e.g. by GUTSCHICK and RODRIGUEZ 1977). The traces are probably from gastropods and worms.

Ichnogenus *Curvolithus* FRITSCH, 1908

Diagnosis: HÄNTZSCHEL (1962) writes: 'Interior tracks ribbon-shaped, flat, composed of three parts. Central band usually broad and smooth.

The above diagnosis is probably based on the material assigned as *Curvolithus* by ABEL (1935). The original Fritsch's diagnosis is: "Restes courbés, deforme courte, conique, dont la surface est ornée de nombreux sillons" (short converging arch remnants with surface decorated with numerous furrows).

FRITSCH (1908) determined two species of *Curvolithus: C. multiplex* FR. and *C. gregarius* FR. Out of the two, *C. multiplex* conforms to both the diagnoses while *C. gregarius* only to the "definition" of Fritsch. I am in favour of the Fritsch's assignment of both the genera since *C. multiplex* and *C. gregarius* exhibit many common features and thus their assignment to two different ichnogenera seems unsubstantiated.

Curvolithus multiplex FRITSCH, 1908

Pl. VI, fig. 2; pl. XV, fig. 3; pl. X, fig. 6

1908 *Curvolithus multiplex* FR.; FRITSCH, pl. 12, figs. 5, 6.
?1908 *Spongolithus flagellifer* FR.; FRITSCH, pl. 4, fig. 8.
?1908 *Spongolithus lobatus* FR.; FRITSCH, pl. 4, fig. 12.

Lectotype (SD herein): Specimen illustrated by FRITSCH (1908) in pl. 12, fig. 5 (here in pl. XV, fig. 3).

Type horizon: Ordovician, Kosovian, Kosov Formation.

Type locality: Praha 5-Řeporyje.

Material: Three original Fritsch's finds from the locality Řeporyje, one find from the locality Kapitol, one uncertain find from the locality Kosov, several uncertain finds from the Fritsch's collection, with various genus and species names given by FRITSCH (1908).

Description: Flat, curved convex hyporeliefs of furrows or tunnels, 25–45 mm long and up to 20 mm wide, usually narrowing toward one end. Hyporeliefs are divided by two furrows into three big lobes of unequal size; the widest is usually the lobe attached to the inner trace margin. Lobe surface is smooth or very gently transversely striated.

Remarks: The ichnotaxons *Spongolithus flagellifer* and *S. lobatus* determined by Fritsch are discussed in the work of MIKULÁŠ (1987).

Curvolithus gregarius FRITSCH, 1908

Pl. XV, figs. 2, 5

1908 *Curvolithus gregarius* FR.; FRITSCH, p. 13, 14; fig. 1 on p. 14.

Lectotype (SD herein): A group of furrows depicted by FRITSCH in fig. 1 (p. 14, here in pl. XV, fig. 5).

Type horizon: Ordovician, Kosovian, Kosov Formation.

Type locality: According to the label probably Hlásná Třebaň (Vorder-Třebaň), although Fritsch erroneously states Řeporyje in the explanation to the figure.

Material: Sixteen more or less isolated hyporeliefs from one bedding plane from the locality Hlásná Třebaň from the original Fritsch's collection. My own collecting yielded five hyporeliefs from a single bedding plane in the locality Levín.

Description: Flat convex hyporeliefs of furrows and tunnels usually about 30 mm long and 15 mm wide. Traces do not taper on ends as in the species *C. multiplex*. Four longitudinal ridges separated by three wide furrows usually protrude from the hyporelief creating an image of trigonal arrangement. If the trace exhibits more than four ridges (pl. XV, fig. 5 in the middle and below), it is probably a sign of its doublure or treble. Transverse sculpturing is absent.

Remarks: *Curvolithus* in the sense of ABEL (1935) is by all contemporary authors (HÄNTZSCHEL 1962, HAKES 1977, HEINBERG 1973) regarded as a trace of gastropods. The origin of *C. multiplex* and *C. gregarius* is probably similar.

Ichnoorder *Crustolithida* VYALOV, 1968

Diagnosis: Shrub- or bunch-like arranged tubes or tunnels.

Ichnogenus *Phycodes* RICHTER, 1850

Diagnosis: Fillings of tunnels of circular cross-section, usually fossilized on the lower surface of quartzite beds. On the end they radially diverge in bunches. Transverse striation is frequent (HÄNTZSCHEL 1962).

Phycodes sp.

Pl. X, fig. 9

Material: A single find from the locality Tyršův vrch.

Description: A bunch of seven smooth mildly upward bent passages (convex hyporeliefs). The initial common part of the bunch is not preserved (if ever existed). Marginal branches diverge under the angle of 60°. Passage diameter on the thicker end is around 2 mm.

Remarks: If the convex hyporelief is correctly interpreted as a cast of passage bunch then there is no doubt about its appurtenance to *Phycodes*.

Crustolithida ichnogen. et ichnosp. indet. A

Pl. XIV, fig. 5

Material: A single find from the locality Hlásná Třebaň (concave-convex hyporelief).

Description: Smooth horizontal tunnel of oval cross-section on one end delimited by the size of the sample, on the other end dividing into three branches. Each of the

branches abruptly bends towards the underlie in the close vicinity of the described tunnel. Width of the tunnel is 10 mm.

Remarks: Probably a trace after feeding on the sediment which cannot be detailedly described and assigned to the system due to fragmentariness of preservation.

Crustolithida ichnogen. et ichnosp. indet. B

Pl. XI, fig. 2

Material: A single find (convex hyporelief) from the locality Běchovice.

Description: A smooth mildly convex furrow, 2 mm wide and 20 mm long. Height of the relief is about 1 mm. On one end the furrow exhibits three blind appendices branching off under the angle of 25 – 30°.

Remarks: The origin and purpose of the structure is probably similar as that of the above described case; however, this structure originated on the surface of sediment.

Ichnogenus *Treptichnus* MILLER, 1889

Diagnosis: Straight or bent surface traces in the form of a characteristic "feather-stitch" pattern (HÄNTZSCHEL 1975: . . . "in form of a zigzag feather-stitch pattern"). In the literature one can often find an incorrect name of the trace as "feather-stitch trail" (HÄNTZSCHEL 1962, BANKS 1970, COWIE and SPENCER 1970). Häntzschel re-introduces the name *Treptichnus* (1975).

Treptichnus sp.

Pl. XI, fig. 3

Material: A single find from the locality Bohdalec.

Description: See the diagnosis of the genus. Trace is 25 mm long and composed of five segments. Width of the segments of approximately semicircular cross-section is about 1 mm, total width of the trace is 7 mm.

Remarks: BANKS (1970) reports that the trace is closely related with *Phycodes*; it can be also similarly interpreted as furrows after feeding on the sediment.

Ichnoorder *Interruptida* VYALOV, 1968

Diagnosis: Surface traces interrupted in regular intervals.

Interruptida ichnogen. et ichnosp. indet A

Pl. X, fig. 1

Material: A single find from the locality Tyršův vrch.

Description: Six oval depressions forming a straight row 42 mm long (convex hyporelief). The first depression is declined by approximately 70° from the row direction and is the shortest of them, the second is declined by cca 30° and the third and longest depression is declined by 15°. The remaining three depressions are analogically arranged. Interspaces between individual depressions are 1–3 mm.

Remarks: The origin and purpose of the structure are unknown. It occurs together with a well preserved specimen of *Asteriacites lumbricalis* and *Planolites* sp. furrows.

Interruptida ichnogen. et ichnosp. indet. B

Pl. XIII, fig. 5

Material: A single find (convex hyporelief) from the locality Hlásná Třebáň.

Description: Five fillings of passage openings. The openings are arranged in a row. Whole trace is 95 mm long, individual segments are 7–13 mm long and 4–5 mm wide. They are 10–20 mm apart.

Remarks: The preserved structure might be a remnant of originally coherent passage, mildly and almost regularly meandering in vertical plane. But it is more probable that the structure was incoherent in origin and resulted from crawling of the animal which in regular intervals passed through the upper sediment layer and came out on the surface.

Interruptida ichnogen. et ichnosp. indet. C

Pl. XVI, fig. 1

Material: One find (concave-convex hyporelief) from the locality Nad strouhou.

Description: Hyporelief, originally zigzagging trail with one margin markedly uplifted. Length of the trace is 40 mm, width about 1 mm. In two sites the trail is interrupted and the trace continues in slightly different direction in close proximity of the end of some segment.

Remarks: The described structure is probably a trace after crawling of a wormlike organism.

Ichnoorder *Asterichnida* VYALOV, 1968

Diagnosis: Surface traces; star-shaped resting structures.

Ichnogenus *Asteriacites* VON SCHLOTHEIM, 1820

Diagnosis: Cubichnia of starfish and brittle stars, copying their shape. Both vertical and horizontal repeating of the trace is frequent. "Arms" sometimes show transverse sculpturing and may bifurcate on ends (BOUČEK 1965, HÄNTZSCHEL 1962).

Asteriacites lumbricalis VON SCHLOTHEIM, 1820

Pl. X, fig. 1; pl. XII, figs. 3, 4; pl. XIV, fig. 4

1908 *Spongaster falax* FR.; FRITSCH, pl. 8, figs. 1—11

Material: About 25 finds (convex hyporeliefs or cleavage reliefs), namely from the localities Řeporyje, Tyršův vrch, Nad strouhou, Zdice-Slavíky, etc.

Description: The shape of the trace conforms to the shape of starfish or brittle stars with five arms. The arms are usually not separated from the central disc. They exhibit usually smooth or regularly granulated or irregularly transversely undulated surface. A narrow, shallow groove sometimes runs along the arms center. The arms are of various widths and shapes. The extreme values are: Arm's width at the central disc side is 3 mm with 19 mm length and/or 7 mm width with 6 mm length. The size of the central disc significantly fluctuates, too. Center of the disc sometimes shows a shallow depression.

Remarks: Morphology of the described structures does not differ from forms assigned by SEILACHER (1953) to the ichnospecies *A. lumbricalis*; SEILACHER (1953) also ranges *Spongaster falax* FR. into the synonymy of *A. lumbricalis*.

"*Asteriacites*" sp.

Pl. VIII, figs. 2, 5

Material: Five finds from the locality Řeporyje, Velká Chuchle, Levín.

Description: Straight or mildly bent rows of tiny protuberances (up to 1 mm in diameter) most frequently arranged into 4—5 lines. The rows occur in great numbers on a bedding plane (out of five finds there is only one exception illustrated in pl. VIII, fig. 5). In two cases the forms resemble starfish.

Remarks: The traces are probably from brittle stars (*Ophiuroidea*). The trace will be described and assigned to the system by dr. R. Prokop from the National Museum, Prague and therefore it is not described and compared with other ichnofossils here.

Ichnoorder *Dictyonida* VYALOV, 1968

Diagnosis: Pascichnia covering parts of bedding planes, exhibiting usually reticulate morphology.

Ichnogenus *Protopaleodictyon* KSIĄŻKIEWICZ, 1970

Diagnosis: Initial irregular forms of *Paleodictyon*. Usually irregular polygonal forms, frequently meandering trails with projections (HÄNTZSCHEL 1975).

Protopaleodictyon sp.

Pl. IV, fig. 2; pl. XVI, fig. 4

Material: Several finds from the localities Hlásná Třebaň, Tyršův vrch, Karlík.

Description: Forms on lower planes of sandstone flags, with short, irregularly sinuous passages with numerous projections and closed irregular forms of oval or polygonal shape. Width of passages ranges from 0.5 to 2 mm, size of "ovals" or "polygones" from 3 to 15 mm.

Remarks: The traces are probably of similar origin as *Paleodictyon* MENEGHINI, 1850.

Ichnogenus *Torrowangea* WEBBY, 1970

Diagnosis: Curved to meandering trails 1 – 2 mm wide, characteristic by irregular transverse narrowing most frequently after 1 – 4 mm. Traces tend to form randomly arranged nets (HÄNTZSCHEL 1975).

Torrowangea sp.

Pl. XVI, fig. 2

Material: Very frequent trace at the localities Tyršův vrch, Řeporyje, Hlásná Třebaň, Mezivrší, and others.

Description: Agrees with the description of the genus: transverse narrowing in the Barrandian specimens is probably more irregular and random compared with finds from the Australian upper Proterozoic described and figured by WEBBY (1970).

Dictyonida ichnogen. et ichnosp. indet. A

Pl. XVI, fig. 5

Material: Several bedding planes with the described trace was found at the localities Hlásná Třebaň and Tyršův vrch.

Description: Short, straight stick-like forms (convex hyporeliefs), irregularly and in great numbers distributed on the bedding plane. Width of sticks is 0.5 – 1 mm, length 2 – 4 mm.

Remarks: Origin of the trace is unclear. Planar distribution suggests that the traces are pascichnia of unknown organisms.

Dictyonida ichnogen. et ichnosp. indet. B

Pl. XVI, figs. 6, 7

Material: Two groups of below described forms from the locality Libomyšl-Želkovice.

Description: Irregular oval passages (convex hyporeliefs) found in groups of five or four on lower bedding planes of sandstone flags. Width of passages is about 1 mm, diameter of oval forms ranges from 3 to 14 mm. Individual "ovals" do not touch each other and are 1 to 20 mm apart. Some "ovals" are not closed.

Remarks: They are probably inorganic forms, but a certain analogy with the structures described as *Laevicyclus* sp. A and *Protopaleodictyon* suggests, that they might be pascichnia of unknown organisms (for comparison see figs. 4 and 6, 7 in pl. XVI).

Ichnoorder *Circulichnida* VYALOV, 1968

Diagnosis: Surface traces of circular shape (most frequently domichnia or pascichnia).

Ichnogenus *Laevicyclus* QUENSTEDT, 1879

Diagnosis: Approximately cylindrical corpuscles perpendicular to the bedding planes; specimen may consist of one or more corpuscles. In the center of each specimen there is a vertical central tube. On the bedding plane the specimen appears as a set of concentric circles of up to several cm diameter.

The diagnosis is based on the description and illustration of HÄNTZSCHEL (1962) and FREY and HOWARD (1970). *Laevicyclus* is most frequently interpreted as burrows with circular feeding trails, sometimes even as inorganic structures.

Laevicyclus sp. A

Pl. II, figs. 1–4

Material: Fifteen specimens from the locality Reitknechtka and Vysoká cesta (convex hyporeliefs).

Description: Circular traces (convex hyporeliefs) of 2–8 mm diameter. Two of the found specimens show a minute bulge in the center, probably cast of the central tube mouth.

Laevicyclus sp. B

Pl. II, fig. 9

Material: A single find (convex hyporelief) from the locality Reitknechtka.

Description: The specimen is composed of a central depression cast and five concentric adjacent circular furrows. Diameter of the whole specimen is 5 mm. Only half of the structure is preserved.

Remarks: The described specimen perfectly corresponds with the description and illustration in quoted literature. However, the interpretation of a single find is uncertain. Inorganic structure cannot be excluded.

Ichnogenus *Palaeoscia* CASTER, 1942

Diagnosis: A series of regular or irregular concentric ovals usually with a central "pore"; some forms exhibit even radial costation. Either feeding traces, or inorganic structures (OSGOOD 1970).

"*Palaeoscia*" sp.

Pl. XV, fig. 4

1908 *Crossochorda* sp.; FRITSCH, pl. 12, fig. 13.

Material: A single Fritsch's find from the locality Řeporyje (convex hyporelief).

Description: A bowel-shaped structure arched in the direction of the underlie, preserved as a convex hyporelief. Specimen is decorated with more or less regular, concentric furrows. Central "pore" is not developed. "Disc" diameter is 42 mm, height cca 12 mm.

Remarks: Structure resembles traces described by OSGOOD (1970) as *Palaeoscia floweri* CASTER, 1942, and by its origin and signification is close either to *Laevicyclus*, or it is an inorganic structure.

Ichnoorder *Farraginida* VYALOV, 1968

Diagnosis: Surface traces of almost oval shape, symmetrical along one axis (most frequently cubichnia).

Ichnogenus *Rusophycus* HALL, 1852

Diagnosis: Two-lobe forms resembling a coffee bean, frequently diagonally articulated, always with inconspicuous central groove. Surface casts sometimes repeat in horizontal rows (HÄNTZSCHEL 1962).

?*Rusophycus* cf. *cryptolithi* OSGOOD, 1970

Pl. X, fig. 7

Material: One find from the locality Tyršův vrch.

Description: Shallow circular cast (convex hyporelief) with a shallow central groove. Surface of the cast is almost smooth, transverse striation not visible. Width of the cast is 5.0 mm, length (in the direction of the groove) 6.0 mm.

Remarks: By its two lobes the cast resembles *Rusophycus* HALL; in 1970, OSGOOD described similar forms from the Ordovician of the Cincinnati region as resting traces of trilobite *Cryptolithus*. However, the single, poorly preserved find can be explained in many ways.

Ichnogenus *Lockeia* JAMES, 1879

Diagnosis: Tiny, legume-shaped traces, conspicuously tapering and sharpening towards margins: most frequently traces after pelecypod resting (HÄNTZSCHEL 1962, OSGOOD 1970). OSGOOD (1970) used a forgotten name of the genus *Lockeia* JAMES, 1879. HÄNTZSCHEL (1975) prefers this name to a younger synonym *Pelecypodichnus*.

?Lockeia sp.

Pl. XIV, fig. 4

Material: Four finds (convex hyporeliefs) from one bedding plane from the locality Zdice-Sla-víky.

Description: Deep elliptic depressions preserved as convex hyporeliefs: length of depressions is 5.5, 5.0, 4.5 and 3.5 mm, width about 2.5 mm. The depressions have unsharp edges. Surface is smooth. Traces were found on one bedding plane together with ten specimens of *Asteriacites* and with inorganic structures.

Remarks: It is obvious, that these morphologically poor forms occurring on one bedding plane can be also classified differently with the same probability as their ranging with *Lockeia*.

Farraginida ichnogen. indet.

"*Spongolithus*" *strobilifer* FRITSCH, 1908

Pl. XIII, pl. 3

1908 *Spongolithus strobilifer* FR.; FRITSCH (partim), pl. 12, fig. 8 (non pl. 12, fig. 7).

Lectotype (SD herein): Specimen illustrated by FRITSCH in pl. 12, fig. 8, here depicted in pl. XIII, fig. 3.
Type horizon: Ordovician, Kosovian, Kosov Formation.
Type locality: Praha 5-Řeporyje.
Material: Lectotype only.

Description: An egg-shaped depression, 7 mm long and 4.5 mm wide. On its wider margin sets on another, larger depression of probably different origin which I do not consider a part of the described find. On each side the egg-shaped depression is

covered with five shallow lobes proportionate to each other along the longer axis of the depression. The lobes of the two halves contain an angle of about 80°. The structure is preserved as convex hyporelief.

Remarks: In my opinion the specimen may be of organic origin, most probably an anthropod resting trace. However, an isolated find does not permit its accurate evaluation and classification within the system.

Ichnogenus *Isopodichnus* BORNEMANN, 1889

Diagnosis: Dimorphic traces composed of minute, straight or bent bilobate furrows 1–6 mm wide, transversely costated and divided by a central ridge. Furrows may be interrupted; they occur together with coffee-bean impressions of corresponding size (HÄNTZSCHEL 1962).

Isopodichnus sp.

Pl. XIII, fig. 1

Material: One find (convex hyporelief) of bilobate imprint linked with the furrow from the locality Tyršův vrch Hill.

Description: Smooth, bilobate passage 7.5 mm wide, on one end delimited by the size of the rock sample, on the other end sharply passing into a characteristic smooth bilobate depression of a hoof shape.

Remarks: Morphology of the depression is close to *Rusophycus*. *Isopodichnus* was assigned to the synonymy of this genus (SEILACHER 1954). The origin and purpose of the structure is probably also comparable with *Rusophycus* HALL, 1952 (depressions) or *Cruziana* D'ORBIGNY, 1842 (furrows). The described finding probably represents traces after crawling and resting of a small trilobite.

Subichnoclass *Podichnacea* VYALOV, 1968

Diagnosis: *Invertebratichnia* with significant part formed by prints of extremities (usually the crawling traces).

Ichnogenus *Beaconichnus* GEVERS, 1973

Diagnosis: The ichnogenus includes three different types: 1) two narrow parallel furrows 9–18 mm apart, straight or slightly curved. Length of the trace is usually 1 m, depth and width of furrows ranges from 1 to 4 mm. Wider traces of this type may exhibit preserved very tiny regular imprints of extremities; 2) paired parallel rows of very regularly arranged imprints of extremities; the rows are 2–4 mm apart, usually variously curved; the imprints look like small circular depressions,

wider traces exhibit oval shape of depressions; 3) up to 30 cm wide traces composed of short parallel rows of extremities imprints arranged in groups oblique (35°) to the central line representing a trace after telson dragging (HÄNTZSCHEL 1975).

?Beaconichnus sp.

Pl. XIII, fig. 6

Material: A single find (concave epirelief) from the locality Řeporyje.

Description: Sample with a bedding plane showing five (? six) doubled rows of "finger-like" impressions. Some are simple, others are bifid (resembling *Allocotichnus* OSGOOD, 1970) or trifid (resembling *Asaphoidichnus* MILLER, 1880). The bedding plane also shows narrow, usually mildly bent furrows obliquely oriented to the rows of "finger-like" imprints. The imprints in one row are usually 6–10 mm apart, width of doubled rows is 10–15 mm. Individual imprints exhibit great variability in morphology and size.

Remarks: Although the finding is isolated and its systematic classification is not unequivocal it is most likely that the traces (repichnia or pascichnia) are after trilobites.

Ichnogenus *Monomorphichnus* CRIMES, 1970

Diagnosis: Narrow ridges, straight or mildly bent, repeated usually in regular intervals on a bedding plane. The traces often occur on a certain bedding plane in big numbers (CRIMES 1970).

Monomorphichnus lineatus CRIMES, LEGG, MARCOS and ARBOLEYA, 1977

Pl. VIII, fig. 1

Material: A single find from the locality Řeporyje.

Description: Four narrow, high, more or less straight and parallel ridges (convex hyporelief). Length of ridges gradually decreases from one side to the other; the longest ridge has 40 mm, the shortest 19 mm. The ridges are cca 3 mm apart.

Remarks: The described structure is morphologically identical with *M. lineatus* described from the Spanish Cambrian. The trace is probably of various origin; according to the quoted authors it comes from trilobites. According to written communication of Dr. Plička the trace of identical morphology has been found also in the Cretaceous and recent sediments.

"*Monomorphichnus*" sp.

Pl. XI, figs. 1, 3, 4, 5

Material: Five finds from the localities Kosov, Bohdalec, Reitknechtka and U plynárny.

Description: Rounded ridges (convex hyporeliefs) of various length and width, four to eight times laterally repeating on a bedding plane. The length of the ridges ranges from 4 to 20 mm, width from 1 to 4 mm. Distance between the ridges usually equals to half of their width. Findings depicted in pl. XI, figs. 3, 4, 5 give evidence that the height and length of the ridges decreases towards the trace margin.

Remarks: The scheme of morphology of the described structure corresponds to *Monomorphichnus* CRIMES, 1970. However, the ridges of the remaining described ichnospecies *M. lineatus* CRIMES, LEGG, MARCOS and ARBOLEYA, 1977, *M. bilineatus* CRIMES, 1970 and *M. multilineatus* ALPERT, 1976 are narrower and higher and the spaces between them are significantly wider than the width of the ridges (CRIMES 1970, ALPERT 1976, CRIMES - LEGG - MARCOS - ARBOLEYA 1977).

It is evident on the specimen depicted in pl. XI, fig. 3 that the ridges are oriented parallelly with mechanogenic torrent structures which casts doubt on appurtenance of "*Monomorphichnus*" sp. among trace fossils in general. However, other specimens do not show agreement between the direction of the ridges and mechanogenic structures.

The origin of the traces may be identical with that of the remaining species of *Monomorphichnus*. But it should be allowed for the possibility that the traces originated from traction of dead bodies or tests of articulate or ribbed organisms; the size and number of ridges suggests that the traces are probably after trilobites.

Ichnogenus *Palmichnium* R. RICHTER, 1954

Diagnosis: Wide, plantlike arthropod track with a central keel and opposed, symmetrical imprints of extremities in regular intervals. The extremity imprints are club-shaped; towards interior they are clearly delimited, towards exterior the demarcation is indistinct (RICHTER 1954, HÄNTZSCHEL 1962).

Palmichnium sp.

Pl. I, figs. 5, 8, 9

Material: Two furrows (concave epireliefs) in one bedding plane from the locality Karlova Huť.

Description: Two tracks on an identical bedding plane, morphologically comparable with *Palmichnium* R. RICHTER. The first is 14.5 mm long, formed of a central keel, simple, narrow furrow and three pairs of club-like imprints. Interval between the imprint pairs is 4.7 or 4.4 mm. The total width of the track including lateral imprints is 2.7 mm.

The second track exhibits much more conspicuous bent central keel with four irregularly delineated club-shaped imprints. Its length is 23 mm.

The same bedding plane showed also a trace figured in pl. I, fig. 9. Its origin and

interpretation is unclear; transverse segmentation suggests that it may be a trace after arthropod resting.

Remarks: Classification of the described finds within the system is rather questionable due to poorly preserved material. Most probably the traces are after arthropod crawling.

Podichnacea ichnogen. et ichnosp. indet.

Pl. XI, fig. 7

Material: A single find (concave-convex hyporelief) from the locality Řeporyje.

Description: Preserved track segment is 42 mm long. It is formed of a central keel (projected as a furrow on the hyporelief) and straight, roughly opposed conspicuous extremities imprints. Individual imprints are 3–6 mm apart. They are smooth, 3–4 mm long and 0.8–1.5 mm wide and contain an angle of 50° with the central keel.

Remarks: The overall arrangement of the found trace can be compared with that of *Palmichnium* R. RICHTER; however, the morphology of single extremity imprints differs from this genus. *Palmichnium* has bent, vaguely delimited imprints while the described find has straight and clearly delimited imprints.

Ichnophyllum *Vivisignia* VYALOV, 1972

Diagnosis (VYALOV 1972): Traces after physiological activity of organisms.

Ichnogenus *Cilindrotomaculum* GUTIÉRREZ MARCO, 1984

Diagnosis: Elliptical pellets about 1 mm long, filling the shells of gastropods. They are probably fecal pellets of organisms living in shells of died gastropods or fecal pellets of organisms feeding on shell contents (GUTIÉRREZ MARCO 1984).

Cilindrotomaculum cf. *melendezi* GUTIÉRREZ MARCO, 1984

Pl. XI, fig. 8

Material: Several finds from the topmost layers of the formation from the locality Nová Ves (collections of Dr. L. Marek).

Description: Elliptical pellets 1 to 1.3 mm long, tightly filling closed brachiopod shells.

Remarks: *C. melendezi* was described from the Late Ordovician of Spain. The

difference between the Bohemian and the Spanish material is the different systematic appurtenance of the host shells.

Survey of ichnotaxons from the Kosov Formation incorrectly classified by Fritsch (1908) and Vlček (1902)

VLČEK (1902) and namely FRITSCH in "Problematica silurica" (1908) determine many new ichnotaxons on species and generic level. Fritsch considered majority of traces to be flora or fauna fossils; thus he classified many taxons wrongly. These taxons are detailedly discussed in the work of MIKULÁŠ (1987).

The results of this discussion are summarized in tab. 2. There are included also species described by Fritsch and Vlček from the Kosov Formation which were left out from the systematic part of this paper since they were unclear or did not belong among ichnofossils and younger synonyms determined by Fritsch.

Table 2

Ichnotaxons determined by A. Fritsch and V. Vlček from the Kosov Formation and their classification in the paper of R. Mikuláš

A. Fritsch (1908), V. Vlček (1902)	R. Mikuláš (1987)
Spongolithus irregularis FR.	*Planolites* sp.
Spongolithus flagellifer FR.	?*Curvolithus* sp.
Spongolithus discus FR.	?*Asteriacites* sp.
Spongolithus spinosus FR.	inorganic
Spongolithus lobatus FR.	?*Curvolithus* sp.
Spongolithus flabellum FR.	*Planolites* sp.
Spongolithus chalinoides FR.	*Planolites* sp.
Spongolithus tuberosus FR.	?
Spongolithus hamatus FR.	*Planolites* sp.
Bythotrephis impudica HALL s. FRITSCH (1908)	(partim: FRITSCH, pl. 1, fig. 3) *Planolites* sp.
Bythotrephis ramosa FR.	(partim: FRITSCH, pl. 2, fig. 7) *Planolites* sp., (partim: FRITSCH, pl. 2, fig. 8) inorganic structure
Radicites rugosus FR.	?*Arthrophycus corrugatus* (FRITSCH, 1908)
Spongaster falax FR.	*Asteriacites lumbricalis* VON SCHLOTHEIM, 1820
Sphenopus pectinatus FR.	inorganic
Palaeophycus marginatus FR.	*Taphrhelminthopsis* sp.
Crossochorda costata FR.	div. ichnogen. et ichnosp.
Ophioglossites antiqua	?(nomen nudum)
Digitolithus rugatus FR.	*Planolites* sp.
Lepidotruncus fortis FR.	?inorganic
Aspidiaria silurica VLČEK	inorganic
Vexillum simplex FR.	inorganic
Vexillum lactuca FR.	inorganic
Vesicolithus guttalis FR.	inorganic
Septarie s. VLČEK (1902)	inorganic

Ichnofossil assemblages of the Kosov Formation and their bathymetric relevance

The author delimited several ichnologically different units in the Kosov Formation which are usually associated with various lithologic characters of individual parts of the formation. The results are summarized in fig. 3. The formation is divided into seven units which are described below from ichnologic point of view.

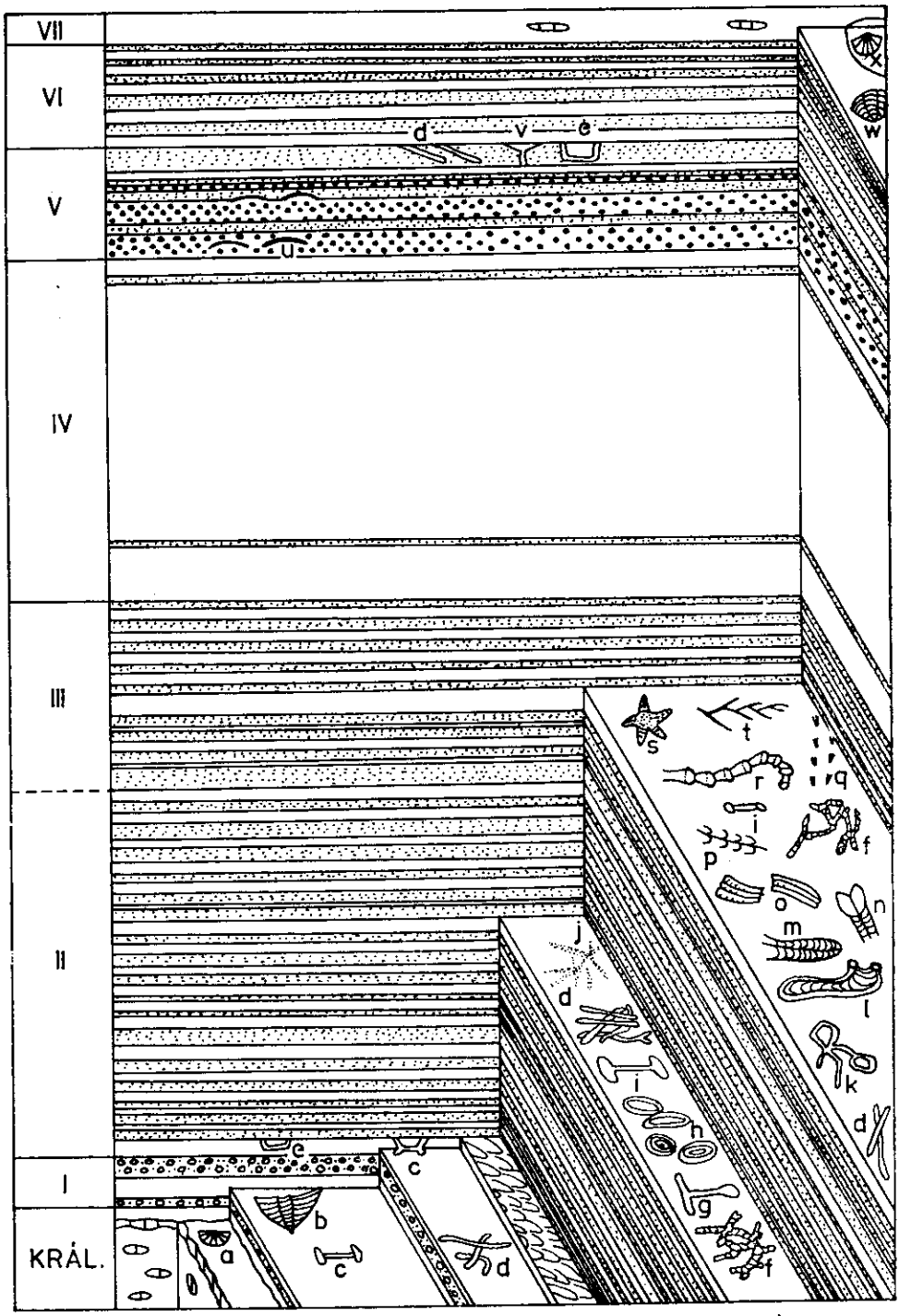
Unit I: Basal greywacke sandstones usually forming two layers exhibited no ichnofossils. In clayey shales between the two layers there were found trilobites *Mucronaspis* (ŠTORCH and MERGL 1989). Finds of *Bifungites* sp., *Arthraria* sp. and *Planolites* sp. were abundant. I studied these layers at the localities Pod Pekařkou, Reitknechtka, Braník-pivovar (brewery), Levín, Běchovice and others.

Unit II: Sandstones rhythmically alternating with siltstones and shales containing ichnofossil assemblage poor in species: *Arthraria* sp., *Bifungites* sp., *Planolites* sp., *Torrowangea* sp., *?Rhabdoglyphus annulatus, Asteriacites lumbricalis, Laevicyclus* sp., *Monofungites udubuensis.* Presence of *Bifungites* testifies in favour of conditions unsuitable for life of benthic organisms, in accordance with the opinion of GUTSCHICK and LAMBORN (1975). The findings of forms which can be interpreted as pascichnia (*Torrowangea, Laevicyclus*) give evidence of the fact that on the floor of the then Prague Basin sedimentation of organic detritus locally took place, which is typical of an environment below the level of the daily wave effect. On the whole, the described assemblage cannot be assigned to any of the ichnofacies determined by Seilacher. It should be stressed that the assemblage is poor and exhibits little diversity of benthic organisms.

Unit II was studied in massive exposures at Běchovice and at localities such as e.g. Tyršův vrch Hill, Reitknechtka, Hodkovičky-Modřany, Libomyšl-nádraží (railway station), Libomyšl-Želkovice.

Unit III: Sandstones and clayey on silty shales petrologically identical with those in the unit II containing rich assemblage of ichnofossils: *Planolites* div. sp., *Curvolithus* div. sp., *Arthraria* sp., *Asteriacites lumbricalis* SCHLOTHEIM, *Torrowangea* sp., *Gordia vermicularis* (FR.), *Protopaleodictyon* sp., *Scalarituba* sp., and rarely *?Rusophycus* sp., *Cruziana* sp., *?Beaconichnus* sp., *Monomorphichnus* sp., *Isopodichnus* sp., *Palmichnium* sp., *Taphrhelminthopsis* sp., *Treptichnus* sp., *Phycodes* sp., *?Aulichnites* sp., *Rhizocorallium* sp., and others.

A considerable diversity of the assemblage, occurrence of traces which could be interpreted as resting traces and findings of characteristic genera of *Asteriacites* and *Cruziana* suggest that this unit can be most probably ranged with Seilacher's *Cruziana* ichnofacies. The genera *Protopaleodictyon, Torrowangea* and other finds interpretable as pascichnia can be regarded as elements of the *Nereites* facies. The assemblage serves as an evidence of a considerable spread of benthic organisms and can be well compared with the association described (MIKULÁŠ 1988) from certain parts of the Polyteichus facies of the Bohdalec Formation which sedimented in the vicinity of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rising elevations in the Prague Basin. There were found no body fossils but there is no doubt about presence of organisms with capacity to fossilize in the assemblage (ophiuroids, trilobites).

Compared with the unit II the unit III contains many ichnogenera typical of a more shallow water environment (Cruziana facies = shallow sublittoral zone).

Unit III was studied at the localities Řeporyje, Hlásná Třebaň and other.

Unit IV: Clayey shales and siltstones, greywacke shales with inferior amount of sandy intercalations. The following ichnofossils were rarely found: *?Corophioides* cf. *biclavata* (MILLER), *Curvolithus* cf. *multiplex* (FR.), *Planolites* sp., *Taphrhelminthopsis* sp., *Torrowangea* sp. The unit was detailedly studied only at the localities Kosov and Nové Butovice.

The above given record should be considered with a view to the fact that shales offered different conditions for trace preservation than rhythmically developed layers. According to its diversity and occurrence of common elements the assemblage might be compared with the assemblage of the unit II.

Unit V: Coarse-grained sandstones to conglomerates, often showing graded bedding, usually in dm benches, with very rare ichnofauna. *Monocraterion* sp. was found only at the locality Hodkovičky in coarse-grained sandstone. Finer-grained layers in the overlie yielded obliquely deposited tubes determined as *Planolites* sp. F. In the scree of the unit IV overlie there was found a specimen of *Arenicolites* with tubes.

Very rare findings of ichnofauna in the unit V correspond to the Seilacher's Skolithos ichnofacies (very shallow-water environment). The unit was studied at the localities Hodkovičky, Nad strouhou (in scree), Hlásná Třebaň and Nové Butovice.

Unit VI: Rhythmical development of the Kosov Formation, proportion of shaly component increases towards the overlie. The unit was never studied from an exposure (with the exception of Nové Butovice); findings from the scree at the localities Nad strouhou (*Asteriacites, Planolites, Gyrochorte, Interruptida* indet.) and Zdice-Slavíky (*Asteriacites, ?Lockeia*) probably come from this unit. This unit cannot be ichnologically evaluated due to lack of authentic material.

Unit VII: Clayey shales, in highest layers (in calcareous concretions or in shales) showing fauna of the *Hirnantia sagittifera* assemblage. The following ichnofossils

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3. Paleontologic content of the Kosov Formation (schematically, according to data obtained from localities plotted in fig. 2)

Fossils and traces: a — *Proboscisambon*, b — *Mucronaspis*, c — *Bifungites*, d — *Planolites*, e — *Arenicolites*, f — *Torrowangea*, g — *Monofungites*, h — *Laevicyclus*, i — *Arthraria*, j — "*Asteriacites*", k — *Protopaleodictyon*, l — *Rhizocorallium*, m — *Cruziana*, n — *Isopodichnus*, o — *Curvolithus*, p — *Palmichnium*, q — *?Beaconichnus*, r — *Rhabdoglyphus*, s — *Asteriacites*, t — *Treptichnus*, u — *Modiolopsis*, v — *Monocraterion*, w — *Brongniartella*, x — *Hirnantia*

KRÁL. — Králův Dvůr Formation; I—VII — units distinguishable according to paleontologic content (described in the text)

were determined: *?Rhabdoglyphus annulatus* and *Cilindrotomaculum* cf. *melendezi*. Very strong and rather undeterminable bioturbation ("*Planolites, Arenicolites*") was found in the highest part of this unit at the locality Nové Butovice.

The determined ichnoassemblages can be compared with a bathymetric curve plotted by ŠTORCH (1986) in fig. 1. It follows from the figure that this bathymetric curve explains very well the cause of changes of the described assemblages and thus corroborates ichnological conclusions.

CHLUPÁČ and KUKAL (1988) arrived at different conclusion than ŠTORCH (1986) when studying lithology and sedimentary structures and the bathymetric curve published by them shows a different course. The authors presume a very strong eustatic regression on the boundary between the Kralodvorian-Kosovian and markedly shallow-water conditions also in the lower parts of the Kosov Formation. In my opinion the bathymetric curve published by ŠTORCH (l.c.) better explains the changes in the ichnoassemblages of the Kosov Formation because the ichnofossil assemblages from lower layers of the Kosov Formation (namely the unit II) do not exhibit a pronounced shallow-water character.

K tisku doporučil M. Plička
Přeložila T. Hlavatá

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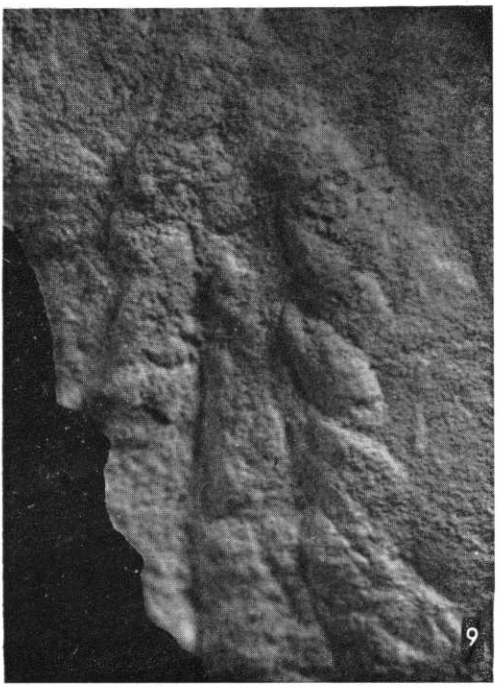
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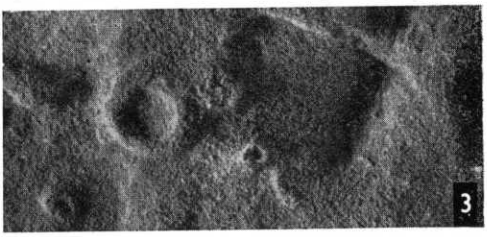
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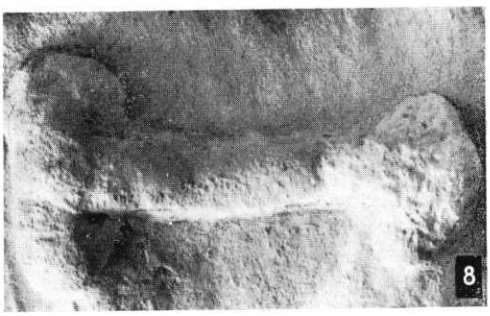
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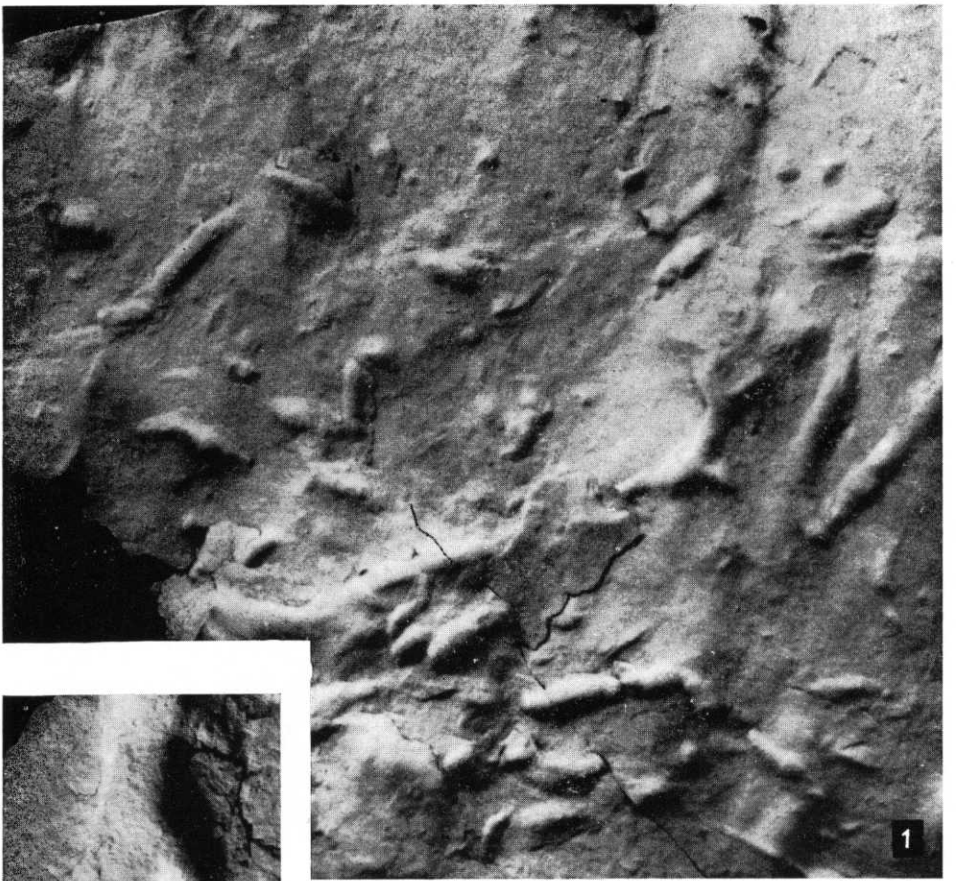
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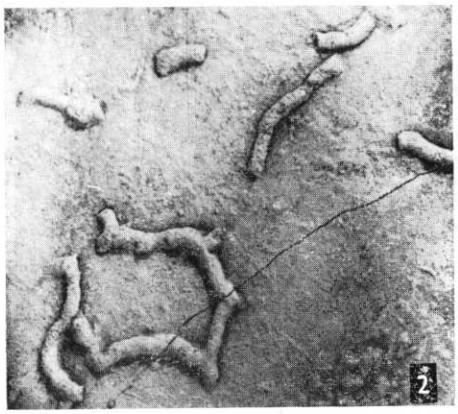
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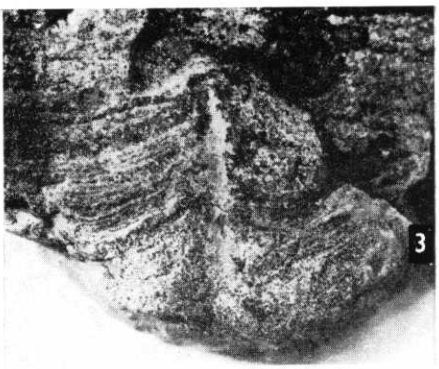
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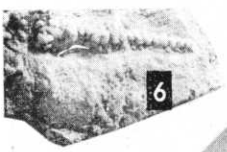
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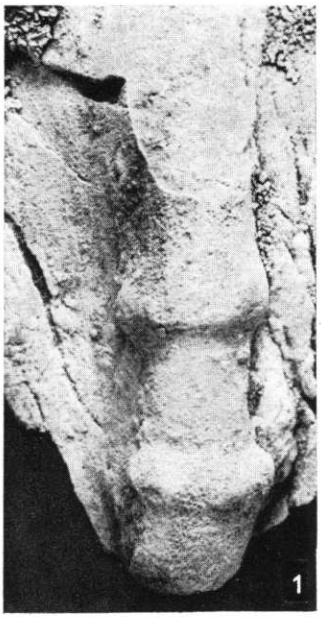
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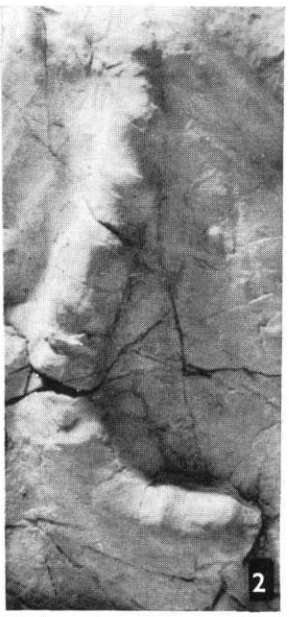
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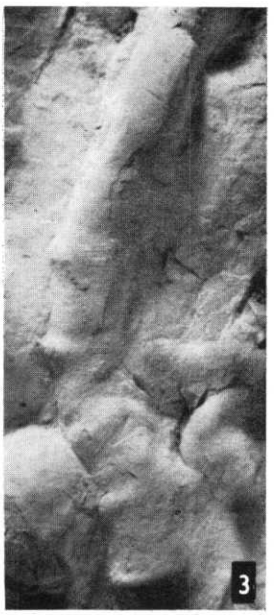
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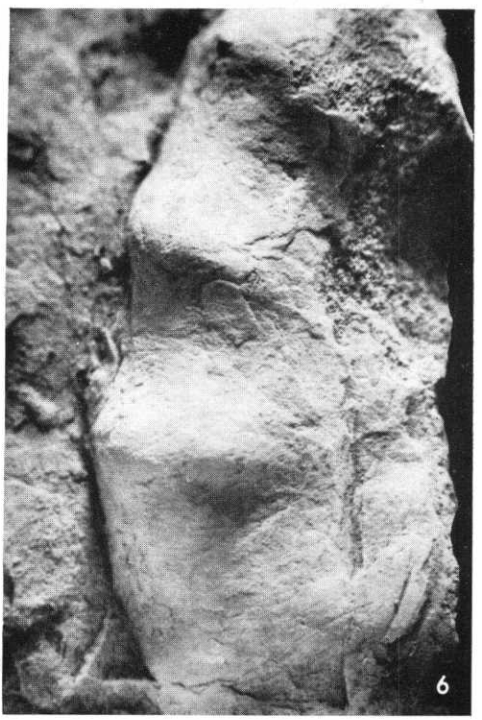
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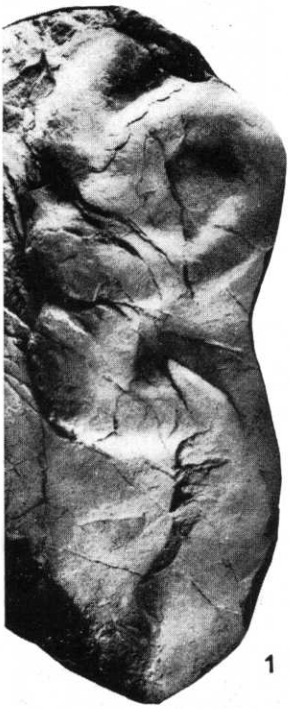

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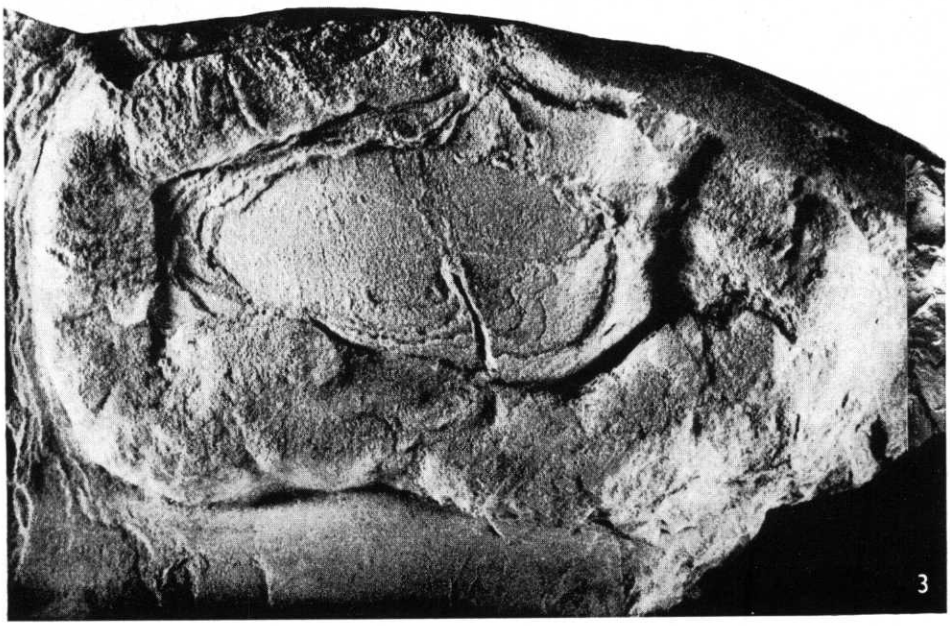

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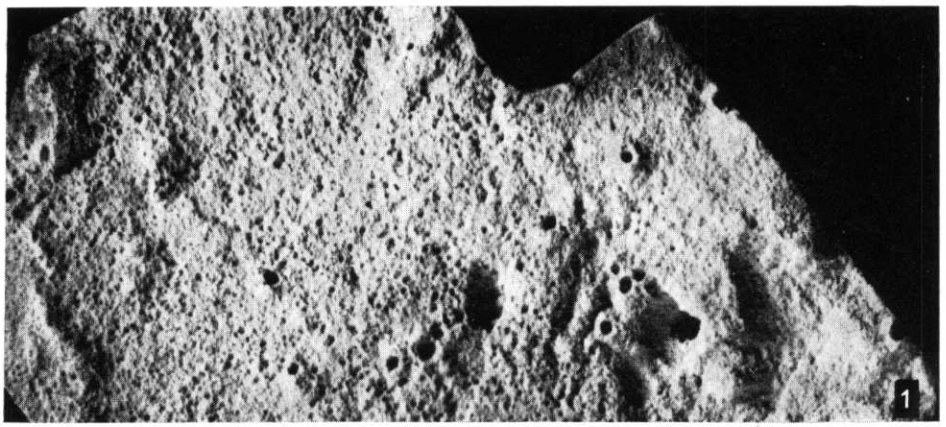
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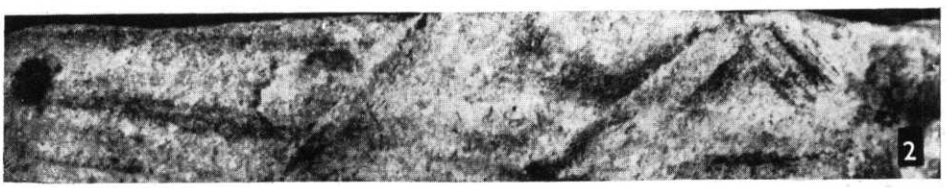
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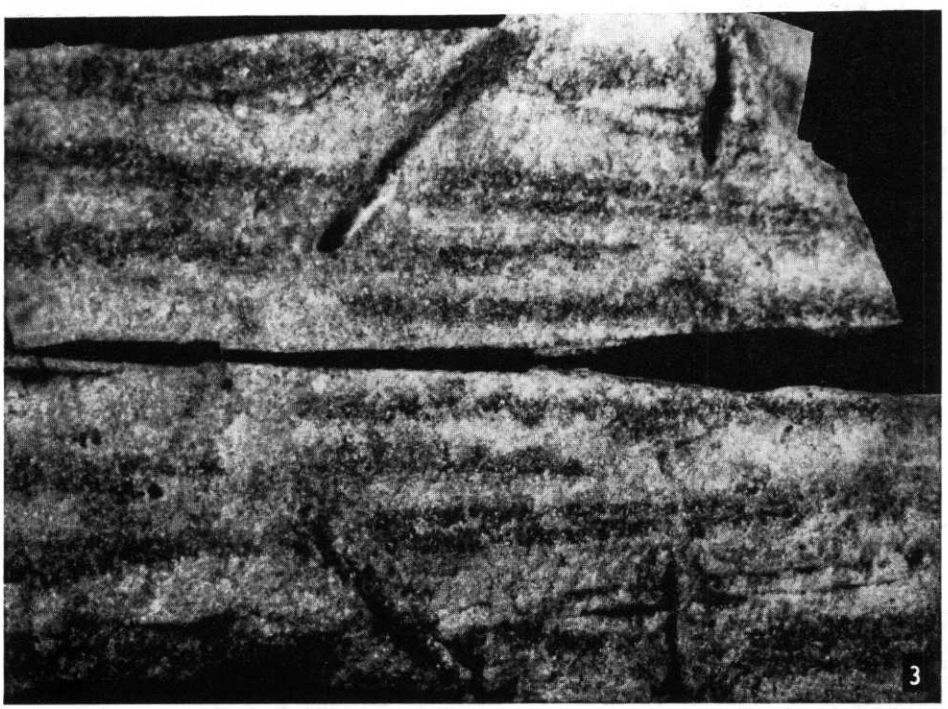
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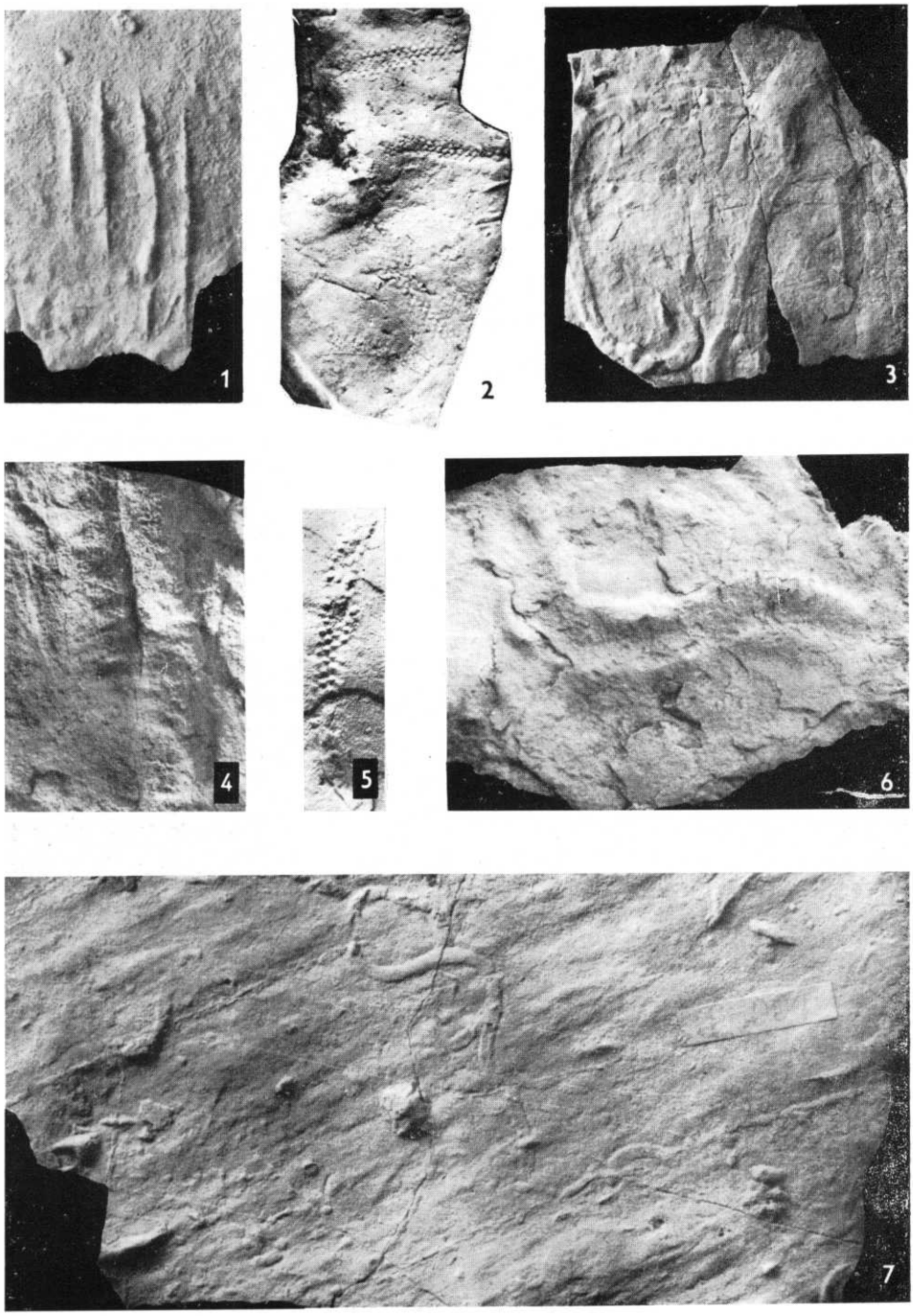
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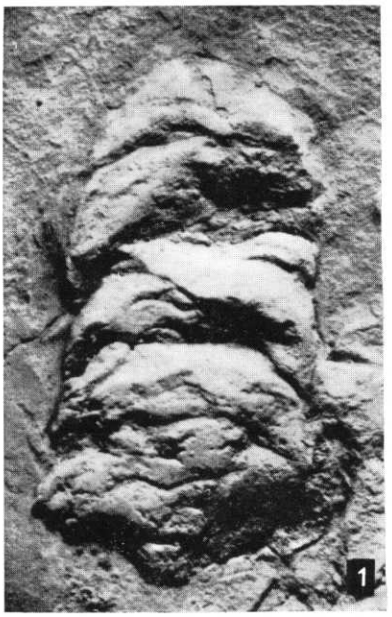

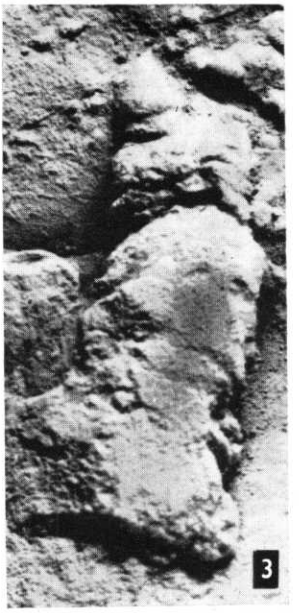

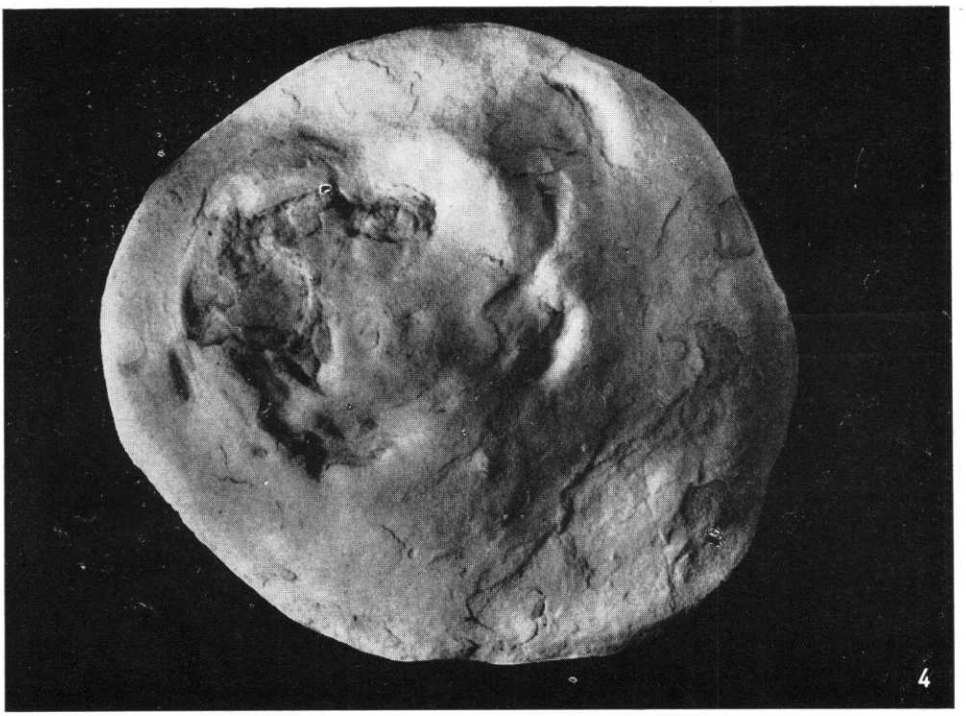


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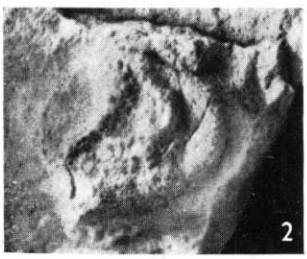
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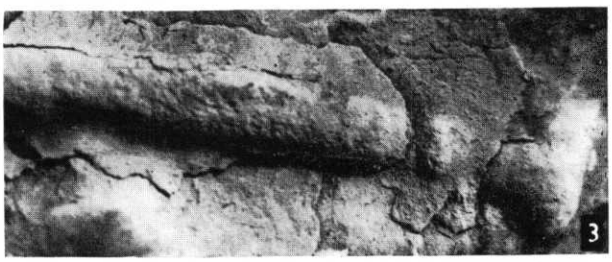
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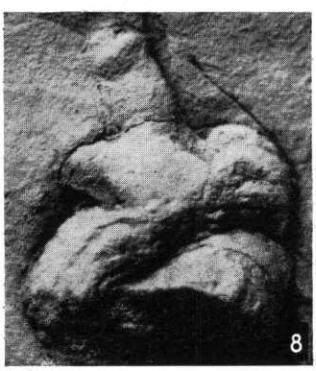
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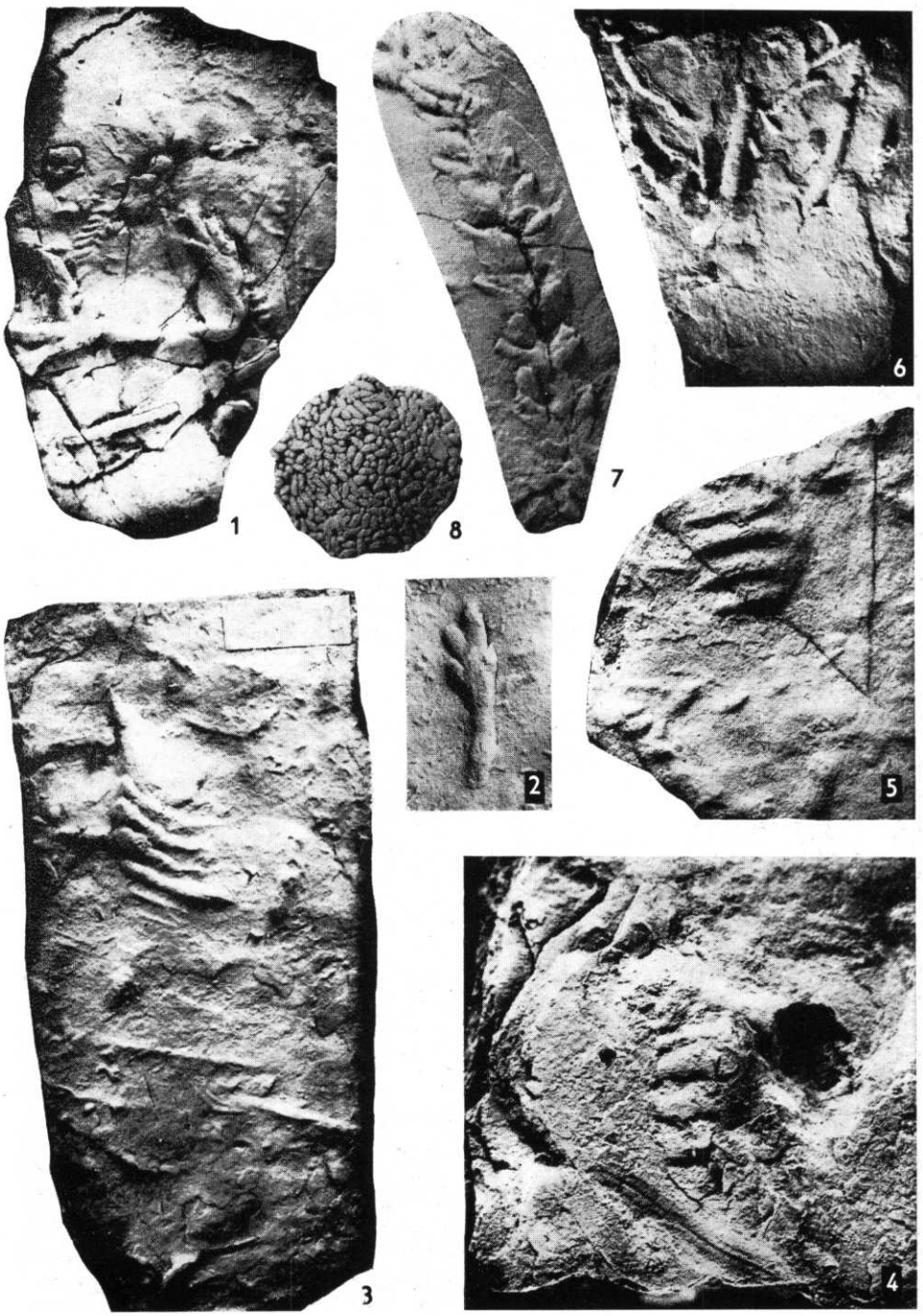
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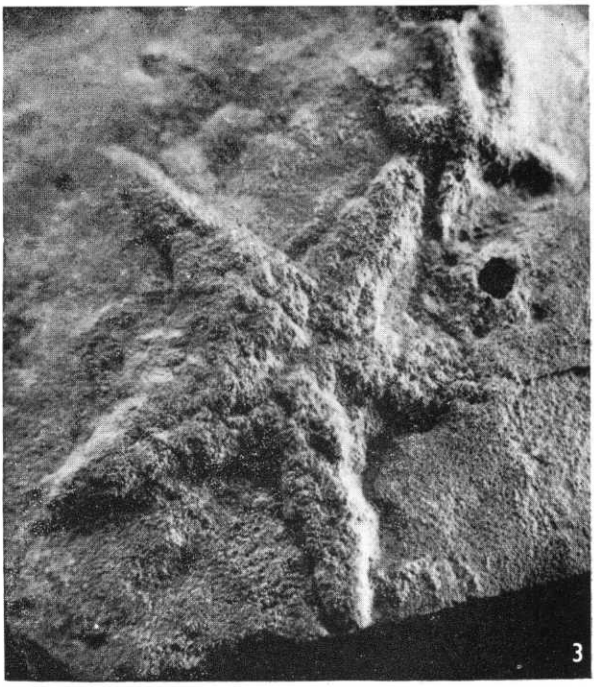

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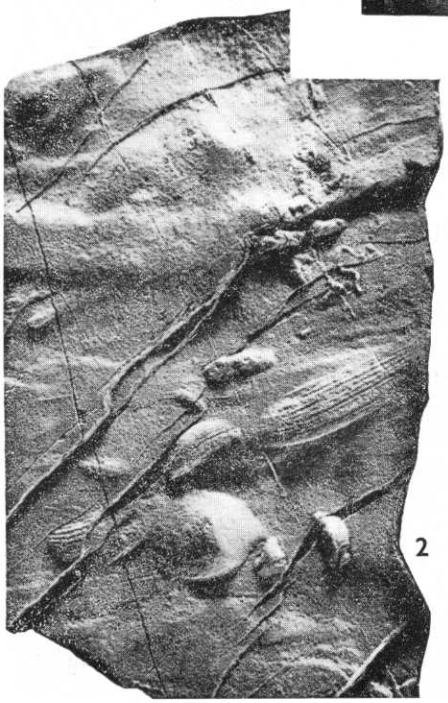

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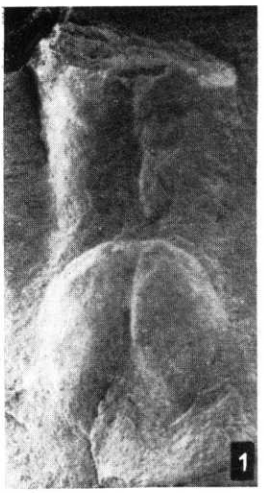
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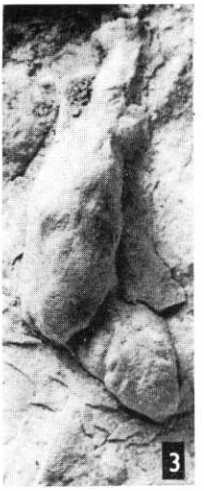
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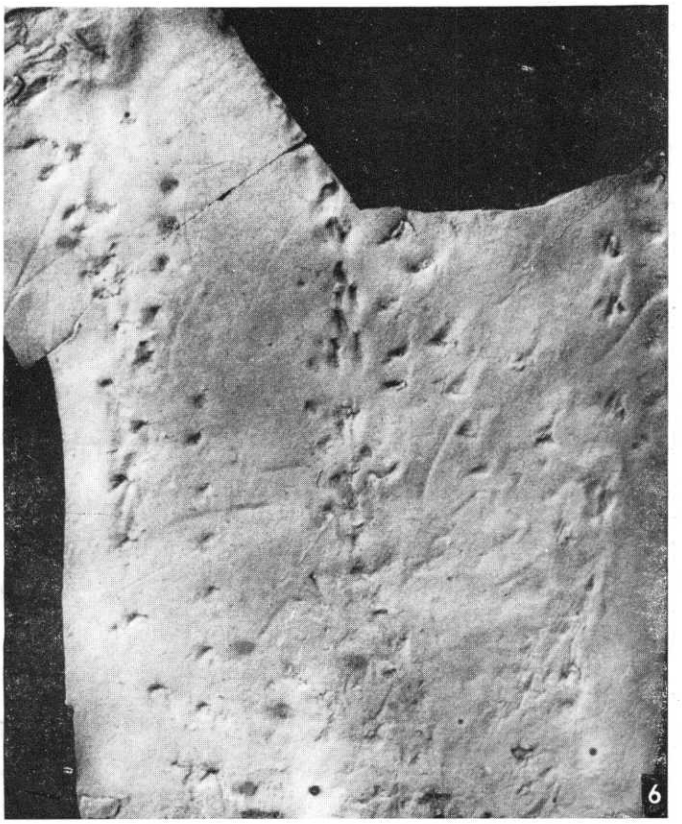
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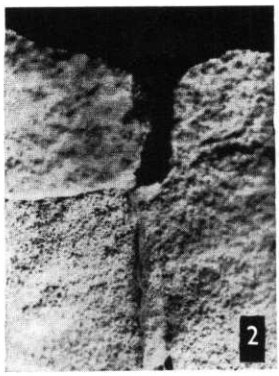
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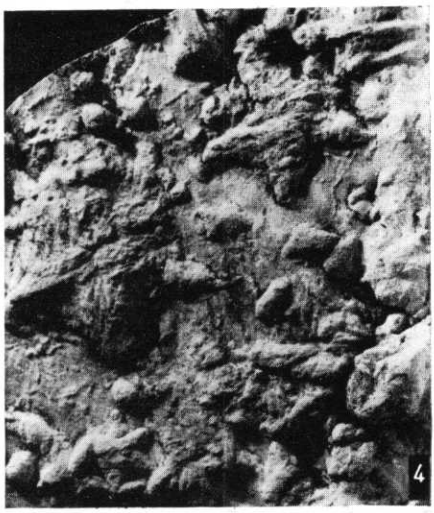
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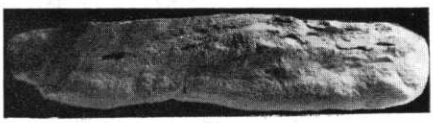
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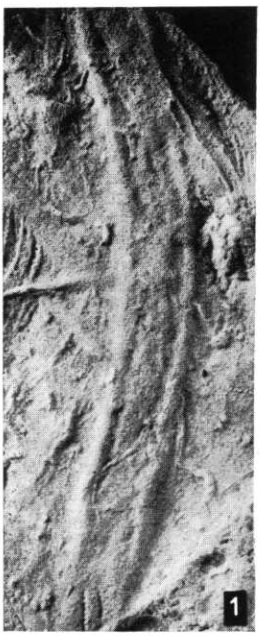
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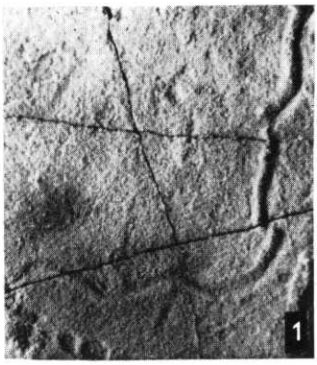
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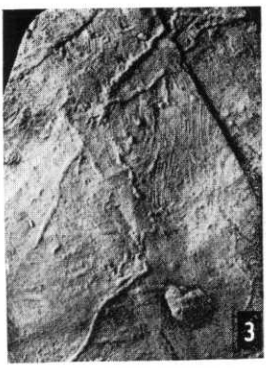
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Explanation of plates

All the specimens come from the Kosov Formation (Ordovician, Kosovian Stage, Central Bohemia). Deposition of the material: P2 = collections of the National Museum, Prague; PřFUK = collections of the Faculty of Science, Charles University, Prague.
Photographs by the author.

Pl. I

1—4, 6, 7. *Monofungites udubuensis* ichnogen. et ichnosp. nov.; 1 — P2-L 28758 a, ×7.3.

2 — P2-L 28758 b, ×5.1. 3 — P2-L 28758 c, ×7.0. 4 — P2-L 28758 d, ×7.9. 6 — P2-L 28758 e, ×5.9. 7 — P2-L 28758 f, ×5.3. Locality: Praha-Braník, Vysoká cesta Street.
5, 8. *Palmichnium* sp.; 5 — P2-L 28780, ×2.5. 8 — P2-L 28780, ×2.4. Locality: Karlova Huť.
9. Ichnogen. et ichnosp. indet.; P2-L 28780, ×3.6. Locality: Karlova Huť.

Pl. II

1—4. *Laevicyclus* sp. A; 1 — P2-L 28805 a, ×2.8. 2 — P2-L 28805 b, ×2.2. 3 — P2-L 28805 c, ×3.0. 4 — P2-L 28805 d, ×1.9. Locality: Praha-Michle, Reitknechtka.
5. ?*Corophioides* cf. *biclavata* (MILLER); P2-L 28798, ×0.4. Locality: Kosov.
6, 7, 8. *Arthraria* sp. A; 6 — P2-L 27864, ×2.5. Locality: Tyršův vrch Hill (Praha-Michle).
7 — PřFUK, ×2.7. Locality: unknown. 8 — P2-L 28736, ×1.3. Locality: Libomyšl-Želkovice.
9. *Laevicyclus* sp. B; P2-L 28754, ×3.0. Locality: Praha-Michle, Reitknechtka.

Pl. III

1, 2. *Planolites* sp. A; 1 — P2-L 28728, ×1.1. Locality: Praha-Radotín. 2 — P2-L 28741, ×1.0. Locality: Praha-Michle, Tyršův vrch Hill.
3. *Planolites* sp. D; P2-L 28794, ×1.0. Locality: Praha-Podolí, Pod Pekařkou Street.

Pl. IV

1. *Scalarituba missouriensis* WELLER; P2-L 28800, ×1.5. Locality: Praha-Běchovice.
2. *Protopaleodictyon* sp.; P2-L 28803, ×1.0. Locality: debris in the forest between Karlík and Vonoklasy.
3. *Rectotubae* ichnogen. et ichnosp. indet.; P2-L 28807, ×1.0. Locality: Praha-Běchovice.
4. *Unilobatoidea* ichnogen. et ichnosp. indet.; P2-L 28790, ×2.0. Locality: Praha-Pankrác.
5. *Cochlichnus* sp.; P2-L 28793, ×2.0. Locality: Hlásná Třebaň.
6. ?*Scalarituba* cf. *missouriensis* WELLER; P2-L 28791, ×1.5. Locality: Praha-Běchovice.
7. *Planolites* sp. B; P2-L 28783, ×0.95. Locality: Praha-Michle, Reitknechtka.

Pl. V

1—6. ?*Rhabdoglyphus annulatus* (Fritsch); 1 — P2-L 27727, ×1.4. Locality: Řeporyje. Lectotype.
2 — P2-L 28689, ×1.0. 3 — P2-L 28786, ×0.8. 4 — P2-L 28795, ×1.1. 5 — P2-L 28749, ×1.7.
6 — P2-L 28767, ×2.0. 2—6. Locality: Praha-Michle, Tyršův vrch Hill.

Pl. VI

1, 3. *Planolites* sp. E; 1 — P2-L 28787, ×0.7. Locality: Praha-Michle, Tyršův vrch Hill. 3 — P2-L 28799, ×1.5. Locality: Praha-Michle, Reitknechtka.
2. ?*Curvolithus* cf. *multiplex* (Fritsch); P2-L 28760, ×1.5. Locality: Kosov Hill.

Pl. VII

1. *Arenicolites* sp. A; P2-L 28744, ×3.2. Locality: Praha-Braník, Nad strouhou Street.
2, 3. *Planolites* sp. F; 2 — P2-L 28748, ×3.0. 3 — P2-L 28748, ×3.7. Locality: Praha-Hodkovičky.

Pl. VIII

1. *Monomorphichnus lineatus* CRIMES, LEGG, MARCOS and ARBOLEYA; PřFUK, ×1.2. Locality: Řeporyje.
2, 5. "*Asteriacites*" sp.; 2 — PřFUK, ×1.1. 5 — PřFUK, ×2.4. Locality: Řeporyje.
3, 7. "*Scolicia*" sp.; 3 — PřFUK ,×0.7. Locality: Praha-Michle, Bohdalec Hill. 7 — P2-L 28732, ×1.0. Locality: Praha-Podolí, Pod Pekařkou Street.
4. ?*Cruziana* sp.; P2-L 28770, ×2.0. Locality: Praha-Braník, Vysoká cesta Street.
6. *Taphrhelminthopsis* sp.; PřFUK, ×1.2. Locality: Praha-Michle, Bohdalec Hill.

Pl. IX

1, 2, 3. *Scalarituba michlensis* ichnosp. nov.; 1 — P2-L 28738, ×3.5. 2 — P2-L 28777, ×3.6. 3 — P2-L 28759, ×4.3. Locality: Praha-Michle, Tyršův vrch Hill.
4. An inorganic structure described by Fritsch (1908) as "*Crossochorda*"; P2-L 28689, ×0.9. Locality: Praha-Michle, Tyršův vrch Hill.

Pl. X

1. *Interruptida* ichnogen. et ichnosp. indet. A (on the right) and *Asteriacites lumbricalis* VON SCHLOTHEIM; P2-L 28733, ×1.0. Locality: Praha-Michle, Tyršův vrch Hill.
2, 8. ?*Scalarituba* sp.; 2 — P2-L 28776 b, ×4.7. 8 — P2-L 28778, ×3.2. Locality: Praha-Michle, Tyršův vrch Hill.
3. *Arthraria* sp. B; P2-L 28724, ×2.2. Locality: Praha-Michle, Tyršův vrch Hill.
4, 5. "*Arthrophycus*" sp.; 4 — P2-L 28778, ×3.5. 5 — P2-L 28776 d, ×4.5. Locality: Praha-Michle, Tyršův vrch Hill.
6. *Curvolithus multiplex* FRITSCH; P2-L 28804, ×1.8. Locality: Praha-Michle, Kapitol Hill.
7. ?*Rusophycus* cf. *cryptolithi* OSGOOD; P2-L 28776 a, ×6.0. Locality: Praha-Michle, Tyršův vrch Hill.
9: *Phycodes* sp.; P2-L 28776 c, ×2.5. Locality: Praha-Michle, Tyršův vrch Hill.

Pl. XI

1, 3, 4, 5. "*Monomorphichnus*" sp.; 1 — PřFUK, ×1.1. Locality: Bohdalec Hill (Praha-Michle).
3 — P2-L 28806, ×1.1. Locality: Praha-Michle, Reitknechtka. 4 — P2-L 28766, ×1.2. Locality: Praha-Michle, U plynárny Street. 5 — P2-L 28725, ×0.9. Locality: Praha-Michle, Reitknechtka.
2. *Crustolithida* ichnogen. et ichnosp. indet. B; L 28802 ×1.1. Locality: Praha-Běchovice.
6. *Treptichnus* sp.; PřFUK, ×1.1. Locality: Praha-Michle, Bohdalec Hill.
7. *Podichnacea* ichnogen. et ichnosp. indet.; P-2 (without inventary number), ×1.6. Locality: Řeporyje.
8. *Cilindrotomaculum* cf. *melendezi* GUTIÉRREZ MARCO; P2-L 28788, ×2.2. Locality: Praha 5-Nová Ves.

Pl. XII

1. *Planolites* sp. C; P2-L 28735, ×0.9. Locality: Praha-Michle, Reitknechtka.
2. Inorganic structure ("*Aspidiaria silurica*" VLČEK); P2-L 28752, ×1.4. Locality Praha-Braník, Vysoká cesta Street.
3, 4. *Asteriacites lumbricalis* VON SCHLOTHEIM; 3 — a specimen with preserved grooves in the middle of the arms, P2-L 28781, ×2.7. Locality: Praha-Braník, Nad strouhou. 4 — a specimen with smooth surface, P2-L 28769, ×2.2. Locality: Karlova Huť.

Pl. XIII

1. *Isopodichnus* sp.; P2-L 28773, ×3.2. Locality: Praha-Michle, Tyršův vrch Hill.
2. ?*Cruziana* sp.; P2-L 27729, ×1.5. Locality: Řeporyje.
3. "*Spongolithus*" *strobilifer* FRITSCH; P2-L 27725, ×2.2. Locality: Řeporyje.
4. *Gyrochorte* sp.; P2-L 28763, ×2.2. Locality: Praha-Braník, Nad strouhou Street.
5. *Interruptida* ichnogen. et ichnosp. indet. B; P2-L 28743, ×1.1. Locality: Hlásná Třebaň.
6. ?*Beaconichnus* sp.; PřFUK, ×1.0. Locality: Řeporyje.

Pl. XIV

1. "*Arthrophycus*" *corrugatus* (FRITSCH); P2-L 7798, ×0.5. Locality: Praha-Řeporyje.
3. *Monocraterion* sp.; P2-L 28762, ×1.7. Locality: Praha-Hodkovičky.

3, 8. *Bifungites* sp.; 3 — × 2.8. 8 — × 3.2. Locality: Levín.
4. ?*Lockeia* sp. and *Asteriacites lumbricalis* VON SCHLOTHEIM; P2-L 28745, × 1.7. Locality: Zdice-Slavíky.
5. *Crustolithida* ichnogen. et ichnosp. indet. A; P2-L 28730, × 1.1. Locality: Hlásná Třebaň.
6. *Rhizocorallium* sp.; P2-L 7808, × 0.8. Locality: Řeporyje.
7. *Arenicolites* sp. B; P2-L 28761, × 1.6. Locality: Levín.

Pl. XV

1. *Taphrhelminthopsis* sp.; P2-L 27704, × 1.8. Locality: Řeporyje.
2, 5. *Curvolithus gregarius* FRITSCH; 2 — P2-L 28746, × 1.4. Locality: Levín. 5 — P2-L 7536, × 1.0. Locality: Řeporyje.
3. *Curvolithus multiplex* FRITSCH; P2-L 7573, × 1.6. Locality: Řeporyje.
4. "*Palaeoscia*" sp.; P2-L 27726, × 1.0. Locality: Řeporyje.

Pl. XVI

1. *Interruptida* ichnogen. et ichnosp. indet. C; P2-L 28763, × 2.5. Locality: Praha-Braník, Nad strouhou Street.
2. *Torrowangea* sp.; P2-L 28740, × 1.2. Locality: Praha-Michle, Tyršův vrch Hill.
3. *Gordia vermicularis* (FRITSCH); P2-L 7765, × 1.6. Locality: Řeporyje.
4. *Protopaleodictyon* sp., P2-L 28731, × 2.0. Locality: Hlásná Třebaň.
5. *Dictyonida* ichnogen. et ichnosp. indet. A; P2-L 28737, × 1.7. Locality: Hlásná Třebaň.
6, 7. *Dictyonida* ichnogen. et ichnosp. indet. B; 6 — P2-L 28792, × 2.3. 7 — P2-L 28797, × 1.4. Locality: Libomyšl-Želkovice.

Ichnofosilie v kosovském souvrství českého svrchního ordoviku

(*Résumé anglického textu*)

RADEK MIKULÁŠ

Předloženo 22. dubna 1990

Hojné nálezy ichnofosilií z rytmicky vyvinutých partií kosovského souvrství jsou už dlouho známy, ale byly popisovány naposledy FRITSCHEM (1908). Nové sběry L. Marka a vlastní sběry z 26 odkryvů kosovského souvrství, spolu s Fritschovým materiálem, umožnily popsat 56 ichnodruhů. Charakter nalézaných společenstev fosilních stop se mění od skolithové ichnofacie (nálezy *Monocraterion* sp., charakterizující mělkovodní prostředí ve vyšších, hrubozrnných polohách souvrství) až po smíšené společenstvo kruzianové a nereitové ichnofacie ve středních, rytmicky vyvinutých polohách (*Planolites, Protopaleodictyon, Torrowangea, Asteriacites, Monomorphichnus, ?Beaconichnus, Isopodichnus, Cruziana* aj.). Změny společenstev jsou v souladu s představou o eustatických změnách v tomto období, publikovanou ŠTORCHEM (1986).

V práci jsou stanoveny nové ichnorody a ichnodruhy: *Monofungites* ichnogen. nov. s druhem *M. udubuensis* ichnosp. nov., *Scalarituba michlensis* ichnosp. nov. Řada ichnodruhů je s ohledem na malou četnost výskytu a problematičnost nálezů ponechána v otevřené nomenklatuře.

Ископаемые следы в косовской свите верхнего ордовика Чехии

В косовской свите были установлены различные ихноценозы (всего 56 видов ископаемых следов). Их характер меняется от ихнофации *Skolithos* по смешанное сообщество ихнофаций *Cruziana* и *Nereites*. Изменения ихноценозов соответствуют полагаемым эвстатическим изменениям в течение образования косовской свиты. В представленной работе определен новый род *Monofungites* и несколько новых видов ископаемых следов. Ряд ихнотаксонов приводится впервые из палеозоя Чехии.

Přeložil A. Kříž