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1992 ACTA UNIVERSITATIS CAROLINAE - GEOLOGICA Nos 3-4 PAG. 385-419

Appeared February, 1995

TRACE FOSSILS FROM THE KLABAVA FORMATION (EARLY ORDOVICIAN), CZECHOSLOVAKIA

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Abstract: Previous palaeographical conclusions on early developmental stages of the Prague Basin are supported by trace fossils found in the Klabava Formation (Arenigian), Central Bohemia. Monotonous assemblages of *Bergaueria* and *Zoophycos* occur close to the presumed coastline. Clay shales were being deposited in the central depression of the Prague Basin, yielding assemblages of trace fossils dominated by fodinichnia (*Phycodes, Glockerichnus, Ancorichnus, Taenidium*) and subordinate specimens of pascichnia (*Cochlichnus, Megagrapton, Gordia*) and domichnia (*Arenicolites, Palaeophycus*). One new trace fossil, *Phycodes noha,* is described herein.

Key Words: Early Ordovician, Czechoslovakia, Prague Basin, Trace fossils.

INTRODUCTION

This paper gives a systematic description of trace fossils of early Ordovician age from the Klabava Formation (Arenigian, central Bohemia).

Knowledge of trace fossils from the Klabava Formation remains much sketcheier than that of macro- and microfossils, as is usual in the entire early Paleozic of Bohemia. No material from old collections is available (except three specimens from Professor Bouček's collection, Geological Institute, Czechoslovak Academy of Sciences, Prague). Literary data are almost lacking. The material described in this paper is partly from my own collections and largely from new collections made by Dr. P. Kraft (Faculty of Natural Science, Charles University, Prague) to whom I am grateful for making specimens available for study. Dr. R. W. Frey (The University of Georgia) kindly critically read the manuscript.

PREVIOUS WORK

The Klabava Formation which consists chiefly of clay shales in many places admixed with silt, is poorly exposed. All specimens examined in this study are from wide areas surrounding the town of Rokycany in the

southwest part of the Prague Basin. No material from the eastern part of the basin was available for study, nor was it possible to acquire such material at the present time. Most published data on the Klabava Formation come from the southwest part of the Prague Basin. Locality data, together with lists of faunas, were given in papers by KLOUČEK (1924), HORNÝ and CHLUPÁČ (1951), and J. KRAFT (1977), for example. Palaeontology of the Klabava Formation was studied by BOUČEK (1944, 1956, 1973 – graptolites), KRAFT (1975, 1977 – graptolites), MAREK (1961); PŘIBYL and VANĚK

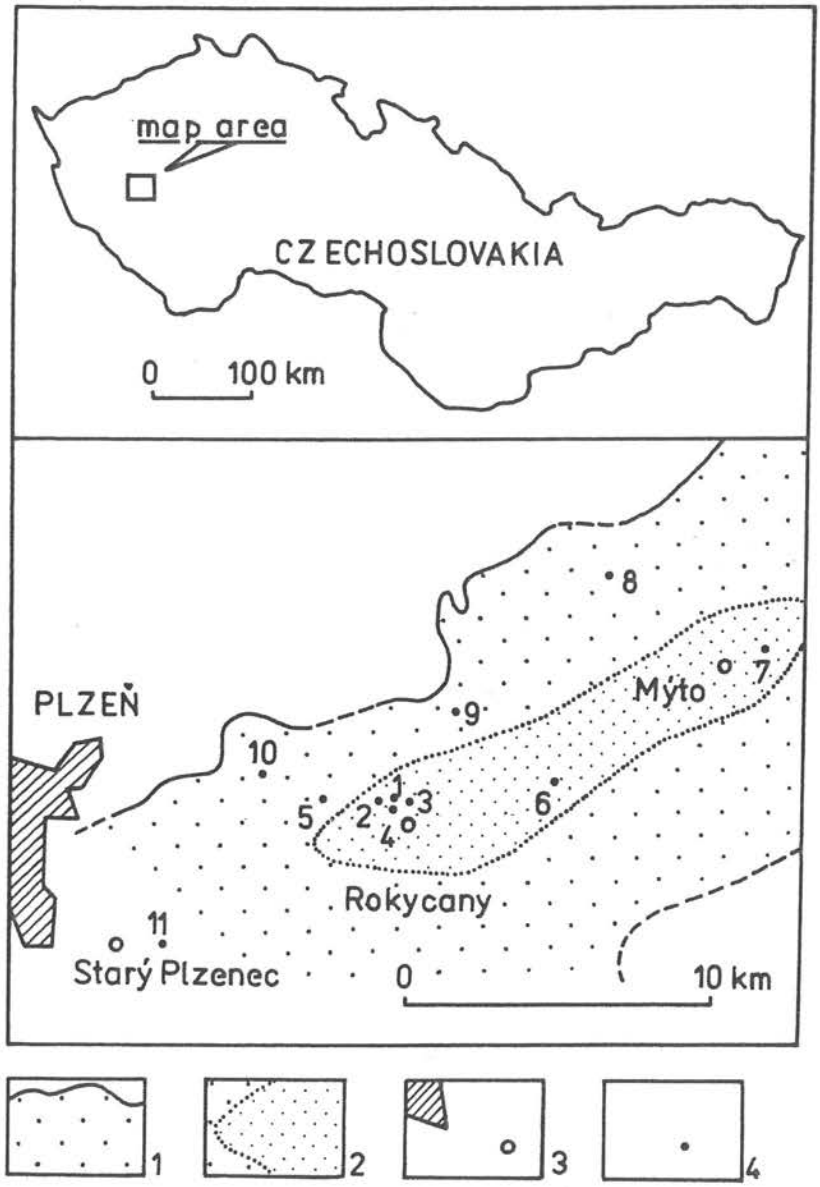


Fig. 1 Index map of collecting localities. Key: 1. presumed extent of Prague Basin in Arenig (after HAVLÍČEK, 1981); 2. area where thickness of the Klabava Formation is higher than 300 m, corresponding to the central depression of the Prague Basin (after HAVLÍČEK, 1981); 3. towns; 4. localities: 1. Rokycany-Stráň (Quarry); 2. Rokycany-Stráň (Valcha); 3. Rokyca-

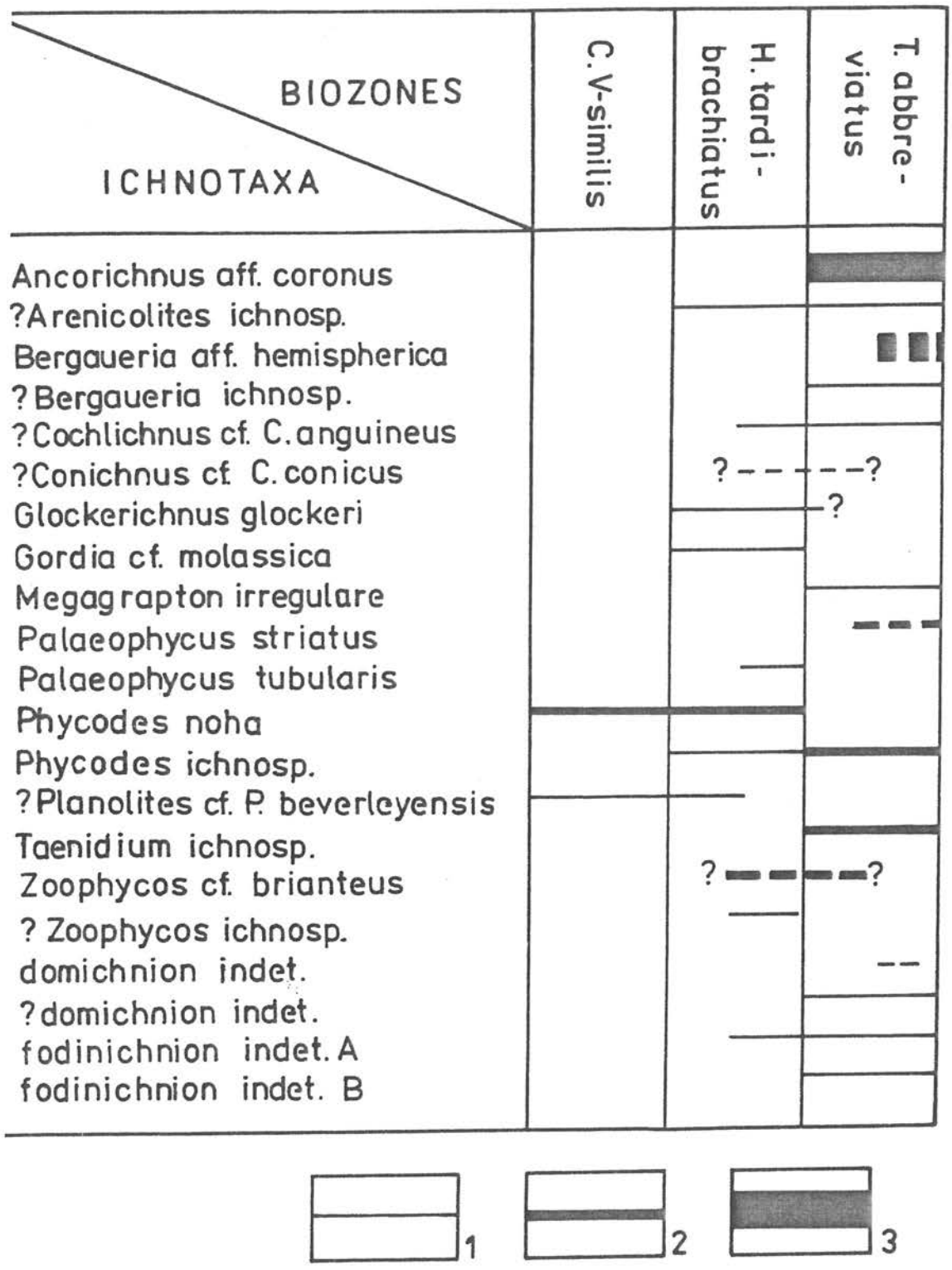


Fig. 2 Stratigraphical distribution of trace fossils in the Klabava Formation. The inter-

(1965, 1968); PEK (1977) – trilobites, HAVLÍČEK (1977, 1982) – brachiopods, P. KRAFT and MERGL (1989) – worms, PARIS and MERGL (1984); VAVRDOVÁ (1972, 1973) – acritarchs. Sedimentological studies were carried out by KUKAL (1959).

Papers dealing with the palaeogeography of the Prague Basin and the development of its benthic communities were published by HAVLÍČEK (1981, 1982). He considered that the Prague Basin, which was highly dissected in Arenig time, has a relatively deep central depression elongated in a southwest to norheast direction with steep slopes and nearshore flats (Fig. 1). Both the landmass and supply area lay northwest and southeast of the basin. The shale facies of the Klabava Formation originated in the central part of the basin. Marginal parts consists predominantly of clastics and volcanoclastics.

The biostratigraphical scheme of the Klabava Formation drawn earlier is based on epiplanktonic praptolites. They were divided BOUČEK (1973) and KRAFT (1977) into three biozones: the *Corymbograptus V-similis* Zone (oldest), *Hologratpus tardiobrachiatus* Zone, and *Tetragraptus abbreviatus* Zone (Fig. 2).

LIST OF LOCALITIES

The situation of the localities and their position in the Prague Basin are depicted on Fig. 1.

1. Rokycany - Stráň (Quarry). Yellowish, yellow-brown, brown, and grey clay shales (*T. abbreviatus* Zone) showing kaolinitic weathering effects. Locality data and content were given by HORNÝ and CHLUPÁČ (1951) and KRAFT (1977). The following trace fossils were found: ?repichnia ichnogen. indet., *Phycodes* ichnosp., ?*Cochlichnus* cf. *C. anguineus, Megagrapton irregulare,* and *Bergaueria* ichnosp.

2. Rokycany - Stráň (Valcha). Greyish-green clay shales containing megascopically visible scales of clastic mica (*H. tardibrachiatus* Zone). The locality was decribed by KRAFT (1977). Trace fossils are represented by *Phycodes noha* ichnosp. nov., *Gordia* cf. *molassica,* and ?*Arenicolites* ichnosp.

3. Rokycany - Stráň (Nad koupalištěm). Greyish-green clay shales (*H. tardibrachius* Zone). The locality position was given by KRAFT (1975, 1977). Trace fossils include *Phycodes noha* and *Glockerichnus glockeri.*

4. Rokycany - Stráň (Rokle). Grey and greyish-green clay shales (*H. tardibrachiatus* Zone). The locality position was given by HORNÝ and CHLUPÁČ (1951) and KRAFT (1975, 1977). Trace fossils are represented only by ?*Planolites*cf. *P. beverleyensis.*

5. Klabava - U starého hradu. Greyish-green clay shales (*T. abbreviatus* Zone). The position and faunal content of this classical locality were described mainly by HOLUB (1911), MAREK (1961), and KRAFT (1975, 1977). Trace fossils include *Ancorichnus* aff. *coronus, Taenidium* ichnosp., and fodinichnia ichnogen. indet. A.

6. Svojkovice - Zavírka. Greyish-green clay shales of the earliest *C. V-similis* Zone (KRAFT, 1977). Trace fossils discovered include abundant specimens of *Phycodes noha* followed by *Planolites* ichnosp.

. Mýto. Greyish-blue to greyish-green clay shales in the middle part of the *T. abbreiatus* ne, grading upwards into tuffs and tuffites (KLOUČEK, 1924; KRAFT, 1977). Trace fossils lude *Ancorichnus* aff. *coronus,* found in especial abundance, followed by *Taenidium* nosp., ?*Arenicolites* ichnosp., and fodinichnia ichnogen. indet. B.

. Těškov - well no. I. Greyish-green clay shales (H. *tardibrachiatus* Zone). For locality ition see KRAFT (1988). *Phycodes* ichnosp. was found.

. Volduchy - well. Grey clay shales in the topmost part of the *H. tardibrachiatus* Zone, countered by the well drilled at the road leading from Osek to Volduchy. Trace fossils lude ?*Cochlichnus* cf. *C. anguineus,* ?*Zoophycos* ichnosp., fodinichnia ichnogen. indet. and *Palaeophycus tubularis.*

0. Ejpovice. Extensive exposure at the site of a former iron ore opencast mine. The per part of the Klabava Formation consists of various rocks, mainly tuffite shales bearing *Nocturnellia nocturna* community in a thick layer (HAVLÍČEK 1982). Several thin layers ematite-chamosite oolitic iron ore can be seen at the top. The main ore horizon (Šárka mation) exposed above was subject to exploitation.

oophycos cf. *brianteus* and ?*Conichnus* cf. *C. conicus* were found in clay shales nixed with tuffite. *Bergaueria* aff. *hemispherica* and *Palaeophycus striatus* occur at the most part of the Klabava Formation overlying the *Nocturnellia* horizon. The form covered in the *Nocturnellia* horizon is described herewith as domichnia ichnogen. et nosp. indet.

1. Sedlec near Starý Plzenec. This is a locality of the old collections of Professor B. Bou-, containing *Ancorichnus* aff. *coronus* and *Glockerichnus glockeri.* The place of collec- and the biozone are not precisely known.

SYSTEMATIC ICHNOLOGY

Ancorichnus HEINBERG, 1974
Ancorichnus aff. *coronus* FREY *et al.,* 1984
Pl. VII, fig. 1; Pl. IX, fig. 1

terial: More than 100 specimens (full reliefs in clay shales). Mýto, Klabava - U starého du and Sedlec at Starý Plzenec.

Description: Straight, gently curved or sinuous, unbranched, horintal traces. Burrows are oval in section; the original circular section s changed during compaction of the clay shales. Burrows are thinlled, sharply separated from, and darker than, the surrounding shales. burrow lining is clearly visible. Trace fill contains characteristic escentic or cupshaped menisci, the thickness and colour of which do t differ from the burrow walls. Menisci usually number 6 to 12 per 1 cm burrow length. This pattern is locally obscured by suboval granules ughly 0.5 mm in grain size and perhaps of fecal provenance. Burrow

Remarks: The burrows of similar morphology were placed by many authors to the ichnogenus *Muensteria* STERNBERG, 1833 (KSIĄŻKIEWICZ 1977; PICKERILL *et al.* 1984, 1987; McCANN and PICKERILL 1988). The new concept of the systematic of meniscate burrows was given by FREY *et al.* (1984) and by D'ALESSANDRO and BROMLEY (1987). Because of the presence of the wall lining, I suspect that the specimens from the Klabava Formation belong to the ichnogenus *Ancorichnus* HEINBERG. *A. coronus* FREY *et al.*, 1984, described from the Miocene of Nebraska, shows the wall lining and menisci of the same arrangement and shape but thicker. Thus, the specimens from the Klabava Formation are indicated as *A.* aff. *coronus.*

Arenicolites SALTER, 1857
?*Arenicolites* ichnosp.
Pl. III, fig. 2; Pl. VII, fig. 4

Material: Five specimens from greyish-green clay shales at Mýto and Rokycany - Stráň (Valcha).

Description: Paired sections of tubes perpendicular to bedding. Material filling the tubes is darker than that of rock wall. Wall lining not developed. In one case (Pl. VII, fig. 4) tubes are filled with abundant chitinozoans. This specimen has tubes suboval in section and 9 to 13 mm in diametr; tube centers are 26 mm apart. Specimens from Mýto are considerably smaller in size.

Remarks: These specimens probably represent burrow of *Arenicolites.* This ichnogenus is represented by simple U-shaped burrows of various sizes (HÄNTZSCHEL 1975; CRIMES *et al.* 1977; BJERSTEDT 1988) occuring in various environments from the Proterozoic to the present.

Bergaueria PRANTL, 1946
Bergaueria aff. *hemispherica* CRIMES *et al.*, 1977
Pl. X, figs 1 – 6, 8

Material: More than 100 burrows, mostly extracted freely from topmost layers of the Klabava Formation and the base of the Šárka Formation, Ejpovice. Oolitic iron ores and tuffite shales.

Description: Burrows circular in section, perpendicular or nearly perpendicular to bedding planes, ranging in diameter from 5 to 15 mm and fill depth or length ranging between 3 and 10 mm. Diameter /depth ratio is highly variable, ranging from 5:1 to 1:1. Burrow surface smooth. In one case only (P. X, figs 2, 8) a circular protuberance can be observed on the lower surface of the trace. Most specimens display a slight inscrease in burrow diameter from the top to the base; the latter is hemispherical, an in

some is flattened primarily or diagenetically. Many burrows are filled with hematite-chamosite ooids.

Remarks: Close affinities of these specimens to *B. hemispherca* are based on criteria given by PEMBERTON *et al.* (1988), who also pointed to relationships of *B. hemispherica* with other ichnogeneric representatives, namely *B. perata* PRANTL, 1946, *B. radiata* ALPERT, 1973, and *B. langi* (HALLAM, 1960). *B. hemispherica* differs from *B. perata* in the absence of the shallow central depression at the end of the burrow fill. Specimens described by CRIMES *et al.* (1977) from the Lower Cambrian of Spain attain much larger sizes (maximum 47 mm) than those reported from the Klabava and Šárka Formations. Another difference lies in that there is no increase in the diameter of the Spanish specimens from the orifice toward the base.

Bergaueria was interpreted by PEMBERTON *et al.* (1988) as a domichnion or cubichnion of anemores.

?*Bergaueria* ichnosp.
Pl. VI, fig. 3

Material: One specimen from clay shale at Rokycany - Stráň (Quarry).

Description: Vertical trace nearly oval in section and 40 mm in diameter. It is filled with material somewhat darker than the wall rock, containing about 5 % oval clay pellets up to 3 mm in size which are impossible to determine in greater details as to their origin and which do not occur in the neighbouring rock. Original vertical proportions of the specimen are unknown; data on the shape of its base and orifice are also lacking.

Remarks: What little that is known about the morphology of this trace suggests a close parallel to plug-shaped trace fossils, particularly those represented in the Bohemian Ordovician by *Bergaueria* PRANTL, 1946. Consideration must also be given to *Conichnus* MYANILL, 1966 or *Dolopichnus* ALPERT and MOORE, 1975. A survey of plug-shaped trace fossils was given by PEMBERTON *et al.* (1988).

Cochlichnus HITCHCOCK, 1858
?*Cochlichnus* cf. *C. anguineus* HITCHCOCK, 1858
Pl. VI, fig. 2

Material: Two specimens from clay shales of the Klabava Formation. Rokycany - Stráň (Quarry) and Volduchy - well.

Description: Smooth, indistictly sinuous horizontal burrows. Width 1.5 to 2 mm. Single "wawes" about 25 mm long. Burrows lack lined walls.

Remarks: *C. anguineus* was described by such workers as PICKERILL *et al.* (1987), PICKERILL (1981), MCCANN and PICKERILL (1988), and

KSIĄŻKIEWICZ (1977). Specimens described in these papers are more sinuous to meandering than those known from the Klabava Formation. *Cochlichnus* has been reported from rocks of various ages and compositions. It represents a feeding trace.

Conichnus MYANILL, 1966
?*Conichnus* cf. *C. conicus* MYANILL, 1966
Pl.XI, fig. 2

Material: One specimen from tuffite siltstone. Upper part of Klabava Formation. Ejpovice.

Description: Large conical burrow, circular in section, perpendicular to bedding plane. Neither orifice nor base have been preserved so that original depth cannot be determined. Preserved burrow fill 35 mm high. Burrow diameter 65 or 55 mm at other end of preserved part; the trace therefore becomes narrower toward one end. Burrow wall 1.5 to 3 mm thick is clearly seen in section. The trace has the same composition as surrounding material.

Remarks: Incomplete preservation of the specimen makes its taxonomic assignment difficult. The specimen most likely belongs to plug-shaped trace fossils described in a comprehensive paper by PEMBERTON *et al.* (1988). Its tentative placement in *Conichnus* is based on large size and a conical shape of the preserved part. The possibility cannot be ruled out, however, that it is attributable to some allied ichnogenera such as *Bergaueria* or *Dolopichnus.*

Glockerichnus PICKERILL, 1982
Glockerichnus glockeri (KSIĄŻKIEWICZ, 1968)
Pl. IV, fig. 2; Pl. V, figs 5, 6

Material: Two specimens from green clay shales. Rokycany - Stráň (Nad koupalištěm) and Sedlec near Starý Plzenec.

Description: Stellate traces (full reliefs, strongly compressed horizontally in clay shales). Single "stars" consist of numerous straight arms diverging from one point. The amrs are nearly uniform in length except those going a little beyond the circular or oval outline of the trace. They form dense clusters having no unsorted sediment between therm. In one case, only, the arms are filled with material considerably darker than the surrounding clay shales, whereas in the other case the fill is only slightly darker.

Many indistinct boundaries occur between the "arms", which represent feeding probes. Two known specimens consist of 32 or 42 arms, but this number is influenced by a subjective assessement of the separate position of such feeding probes. Traces are 75 or 90 mm in diameter.

Remarks: Taxonomic assignment of the trace follows criteria by SIĄŻKIEWICZ (1977) and PICKERILL (1982). *Glockerichnus* has been escribed from Ordovician to recent deposits, especially in deep-water /sh sedimentary environments (PICKERILL 1987, PICKERILL *et al.* 1987, cCANN and PICKERILL 1988, KSIĄŻKIEWICZ 1977).

Gordia EMMONS, 1844
Gordia cf. *molassica* (HEER, 1865)
Pl. VIII, fig. 1

aterial: More than 10 specimens found one one bedding plane. Clay shales. Rokycany - ráň (Valcha).

Description: Horizontal trails, simple, smooth, not branched, filled ith materil showing no structural pattern. Many parts of traces intersect ıe another; some undulate and meander irregularly. Fill is generally of e same grainsize and colour as wall rock; the parallel arrangement of ica scales makes the fill lustrous when properly illuminated. Trails range width from 0.6 to 2 mm.

Remarks: The morphologically simple ichnogenus *Gordia* is difficult subdivide in further detail; trace fossil species have been described . g., KSIĄŻKIEWICZ 1977, PICKERILL 1981, McCANN and PICKERILL 1988, ıt similar species, such as *G. molassica* and *G. marina,* may be syno- /ms (PICKERILL 1981). Traces of *Gordia* from the Klabava Formation ırrespond in shape and size to specimens identified by KSIĄŻKIEWICZ 977) as *G. molassica.*

Gordia is known from the Proterozoic to recent. It can be regarded as trace left by an animal feeding on sediment. In the Proterozoic (CRIMES)87) and Lower Cambrian (FREY and PEMBERTON, 1984) it represents shallow-water trace fossil; beginning with the Late Ordovician it has ;en reported from deep-water, flysch type sediments (BENTON 1982, CKERILL *et al.* 1987, PIKERILL 1987); in Mesozoic time it predominanted flysch rocks (KSIĄŻKIEWICZ 1977; McCANN and PICKERILL 1988). Spe- mens resembling *Gordia* ichnosp. were recorded by PICKERILL *et al.* 984) from the typical *Cruziana* ichnofacies of the Arenig of Spain.

Megagrapton KSIĄŻKIEWICZ, 1968
Megagrapton irregulare KSIĄŻKIEWICZ, 1968
Text fig. 3

aterial: Two specimens (full reliefs of horizontal networks. Clay shales. Rokycany - ráň (Quarry).

Description: The specimen figured herein consists of an irregular

shales. Consequently, the trace is poorly visible. Burrows are moreorless invariable in width (about 2 mm) and branch at approximaely uniform intervals of 10 to 15 mm. Branches include an angle ranging between 80 and 140°. Areas intervening between branches are straight of gently curved. The other specimen comes from the same locality and represents only a fragment with two branches.

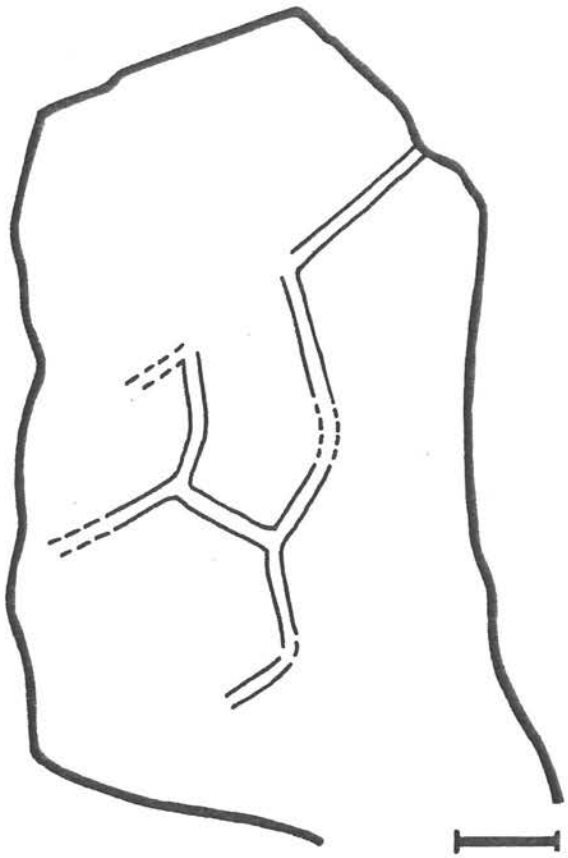


Fig. 3 Megagrapton irregulare KSIĄŻKIEWICZ, 1968 (schematic drawing). District Museum, Rokycany, inv. no. I 171. Locality: Rokycany-Stráň (Quarry). Bar = 1 cm.

Remarks: Specimens of *M. irregulare* are assigned in agreement with criteria by KSIĄŻKEWICZ (1977), who recorded the taxon from the Senonian to Oligocene of Poland. In younger geological periods *Megagrapton* represented the *Nereites* ichnofacies. (FREY and PEMBERTON 1984). It also was reported by BENTON (1982) from the Paleozoic, particularly in Upper Ordovician turbidites of Scotland, and by BJERSTEDT (1988) from the Early Mississippian of the Appalachians (outer shelf).

Palaeophycus HALL, 1847
Palaeophycus striatus HALL, 1852
Pl. XI, fig. 1

Material: About 20 specimens, mostly studied in situ, from uppermost layers of the Klabava Formation. Shale containing ooids alternates with tuffite shale devoid of ooids. Ejpovice.

Description: Oval, probably secondarily flattened burrows, some bifurcating and straight. Their surface is covered with fine, continuous, quite parallel grooves. There are about seven grooves in 5 mm of burrow width. Width of burrows ranges from 5 to 10 mm and remains invariable within one burrow. Length of preserved parts of burrows 30 cm or more. Very thin, clay lining seen in sections. There is no difference in colour and grain size between burrow fill and wall rock.

Remarks: This specimen is clearly identical with *P. striatus* as revised by PEMBERTON and FREY (1982).

Palaeophycus tubularis HALL, 1847
Pl. V, fig. 4

Material: One specimen (full relief) from grey clay shale. Volduchy-well.

Description: Tunnel arched, smooth, horizontal, not branched with very thin but distinct wall lining darker than wall rock. Tunnel oval in section, probably circular prior to diagenesis of clay shale. Trace diameter is essentially invariable throughout its course and attains a value of about 6.5 mm. Total length 10.5 mm. Fill much like that of wall rock.

Remarks: This specimen is amenable with the description and figures of *P. tubularis* given by PEMBERTON and FREY (1982), who give a revision of all representatives of *Palaeophycus* and *Planolites.* Tunnels of *Palaephycus* were permanently inhabited, mostly by predators.

Phycodes RICHTER, 1850
Phycodes noha ichnosp. nov.
Pl. 1, fig. 1; Pl. II, fig. 3; Pl. III, figs 3, 4; Pl. VII, fig. 3; Pl. VIII, fig. 2; Text fig. 4 A, C, D, H, I

Holotype: Specimen figured as Pl. VII, fig. 3, and Textfig. 4 A. District Museum, Rokycany, inv. no. I 165.

Type Horizon and Locality: Ordovician, Arenigian, Stage, Klabava Formation, *Corymbograptus V-similis* Zone; Svojkovice - Závírka.

Material: Ten specimens from clay shales of *C. V-similis* and *T. abbreviatus* Zones. Svojkovice-Závírka, Rokycany - Stráň (Valcha), Nad koupalištěm).

Description: Horizontal, perhaps secondarily flattened passages diverging like fans from a straight, simple, higherorder tunnel. Where such a tunnel was not developed, the passages diverge from a single point. In some, proximal parts of the fan-shaped passages form a compact flat body a approximately triangular in plan view (Pl. I, fig. 1). Well-preserved or completely developed specimens consists of 4 to 14 passages in fanlike arrangement. The terminations of passages are finger or pestleshaped. Some specimens have passages somewhat uniform in width and length (holotype, Textfig. 4A), but in some the converse is true (Textfig. 4H, I).

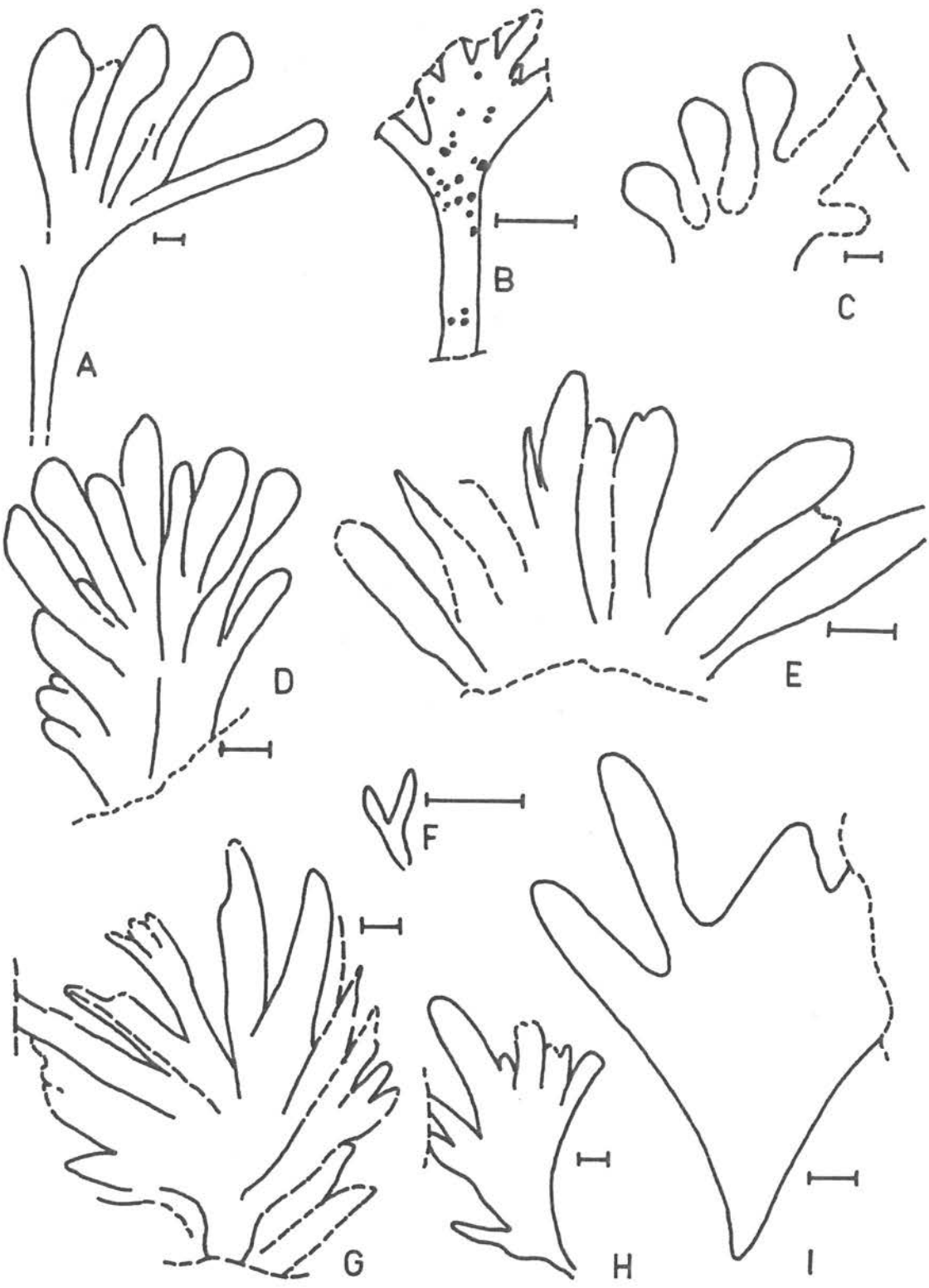


Fig. 4 Several finds of Phycodes from the Klabava Formation (schematic drawings). A, C, D, H, I: Phycodes noha ichnosp. nov.; A, I 165 (holotype). Locality: Svojkovice-Závírka; C, I 168. Svojkovice-Závírka; D, I 174. Rokycany-Stráň (Nad koupalištěm); H, I 153. Rokycany-Stráň (Quarry); I, I 150. Svojkovice-Závírka. B, E, G: Phycodes ichnosp.; B, I 173. Rokycany-Stráň (Quarry); E, I 160. Rokycany-Stráň (Quarry)l G, P2-L 29109. Sedlec near Starý Plzenec. F: ?Phycodes ichnosp.; 10657. Těškov. Bars = 1 cm; for explaining the inv. numbers see explanations of plates.

The angle included by marginal passages in fairy complete specimens ranges from 70 to 90°.

Total length of the holotype is 160 mm; width of passages 8 to 17 mm. Other specimens mostly attain rather smaller sizes (Textfig. 4).

The trace is filled with a fine-grained clay material usually differing in colour from wall rock. Some specimens are filled with abundant chitinozoans found sparsely in the surrounding shale (Pl. III, fig. 3; Pl. VII, fig. 3; Pl. VIII, fig. 2).

Remarks: The ichnogeneric assignment of *P. noha* follows the new concept of FILLION and PICKERILL (1990). *P. noha* differs from *P. palmatus* (HALL, 1852) in having some burrows with pestle-shaped terminations. Proximal parts of the passages form in some a compact triangular body. However, the species is highly variable in morphology and its distinctions from other taxa are so subtle that further discoveries may require refined diagnosis.

Phycodes ichnosp.

Pl. II, fig. 1; Pl. IV, fig. 1; Pl. VI, fig. 1; Text-fig 4 B, E, F, G

Material: Four specimens from clay shales (upper part of the Klabava Formation). Rokycany - Stráň (Quarry) and Sedlec near Starý Plzenec (one specimen from Prof. Bouček's collection). One questionable specimen from Těškov middle part of *H. tardibrachiatus* Zone).

Description: Specimens of *Phycodes* from the latest biozone of the Klabava Formation (*T. abbreviatus* Zone) differ slightly from those described as *P. noha* ichnosp. nov. Differences are as follows: (1) burrows do not end by pestle-shaped terminations; their ends are finger-shaped or sharp; (2) single traces consists of as many as 20 feeding probes; and (3) the angle included by lateral burrows ranges up to 120°.

The specimen from Těškov, which represents a bifurcating burrow with sharp ends and filled with chitinozoans (Pl. II, fig. 1), is assigned to *Phycodes* ichnosp. with caution.

Remarks: Infrequent specimens of variable morphology are difficult to attribute with certainty to any existing species of *Phycodes*, but it is very likely that *Phycodes* from the *T. abbreviatus* Zone may be distinguished from specimens of that ichnogenus described from the *H. tardibrachiatus* and *C. V-similis* Zones as *P. noha*.

Planolites NICHOLSON, 1873
?*Planolites* cf. *P. beverleyensis* (BILLINGS 1862)

Pl. VIII, fig. 4

Material: A group of traces (more than 15 burrows) in one sample of clay shale. Rokycany - Stráň (Rokle).

Description: A cluster of gently curved, extremely flattened burrows without lined walls filled with a material essentially darker than surrounding clay shale. All burrows about 5 mm wide. Preserved areas as much as 70 mm long. Burrows intersect each other especially in the central part of the cluster assuming the appearance of a radially arranged structure.

Remarks: Assuming that the burrows were flattened secondarily, it is possible to refer them to *Planolites,* particularly *P. beverleyensis* (BILLINGS, 1862) on the basis of size, morphology and fill. All representatives of the ichnogenus have been revised by PEMBERTON and FREY (1982). It is left for further consideration to what degree the radial arrangement of clustered burrows is incidental and whether it should be taken into account in taxonomic assignment. No doubt the specimens are fodinichnia.

Taenidium HEER, 1877
Taenidium ichnosp.
Pl. III, fig. 2; Pl. V, fig. 2; Pl. VII, figs 1, 2; Pl. VIII, fig. 3

Material: Ten specimens (horizontaly flattened burrow fills). Mýto.

Description: Horizontal burrows without wall lining but with a homogenous meniscus fill darker than wall rock. Many show the pestle-shaped terminations, in some indicating a change to vertical direction. These burrows were found in strata yielding abundant *Ancorichnus* aff. *coronus.*

Remarks: Because of the joint occurence and the same diameter of burrows, the tracemaker of the trace described above is probably identical with that of *A.* aff. *coronus.* The assignment of the trace fossil to *Taenidium* follows the works of D'ALESSANDRO and BROMLEY (1987), and FREY and HOWARD (1990).

Zoophycos MASSALONGO, 1855
Zoophycos cf. *brianteus* (VILLA, 1844)
Pl. XII, fig. 1

Material: Five specimens from reddish-brown clay shales admixed with tuffite. Ejpovice. They were studied only in situ, except the figured specimen, which was collected.

Description: Low conical, wide forms of *Zoophycos.* Spirally developed ridges regarded as first-order lamellae are seen on the helicoidal plane of the spreite. There are about 3 mm and up to 12 mm apart in the central part of disc and in marginal parts, respectively. Lamellae of lower

of the clay shale. Total diameter of discs of measured specimens ranges from 8 to 30 cm.

Remarks: Most specimens of *Zoophycos* are described in the literature without a trace fossil species designation. Tentative placement of the specimens from Ejpovice in *Z. brianteus* follows the practice of KSIĄŻKIEWICZ (1977), who referred all helicoidal forms to this species.

The environmental significance of *Zoophycos* is a very serious problem. Most recent work on *Zoophycos* ichnospecies comes from Mesozoic and Cenozoic material. But, as pointed by FREY and PEMBERTON (1984), the significance of Paleozoic ichnospecies differs from that of post-Paleozoic ichnospecies. Much of the data on post-Paleozoic forms simply does not apply to Paleozoic forms. An example of coastal occurences of Paleozoic *Zoophycos* was given by OSGOOD and SZMUC (1972).

?*Zoophycos* ichnosp.
Pl. V, fig. 3

Material: One specimen from grey clay shale. Volduchy-well.

Description: Trace parallel to stratification, consisting of fine ridges and grooves probably expressing the morphology of a spreite on a rock fracture. The ridges and grooves are 1 to 2 mm wide and extend in an arc with indications of a fan-like arrangement.

Remarks: The specimen likely represents part of a spreite of *Zoophycos*.

domichnion ichnogen. et ichnosp. indet.
Pl. X, fig. 7

Material: One specimen from base of Nocturnellia horizon (carbonate tuffite with great numbers of brachiopod valves). Upper part of Klabava Formation. Ejpovice.

Description: Straight horizontal tunnel (full relief) 1.5 mm wide and 9 mm long. Its surface is gently undulated by an irregular, very shallow constriction and swelling. It is terminated on one side by a flat, approximately triangular element 3.3 mm long and 0.3 mm vide; the other side ends in a simple circular opening width lined walls 0.2 to 0.4 mm thick extending along its periphery.

Remarks: This single specimen displays simple morphology and can be hardly given taxonomic assignment. Wall linings typically occur in dwelling structures, as noted by many authors (FREY and PEMBERTON, 1984). The broad termination on one side of the tunnel is reminiscent of *Bifungites* GUTSCHICK and LAMBORN 1975), but this resemblance seems only incidental (since *Bifungites*, for example, lacks lined walls). This specimen is the only trace fossil known to me from the *Nocturnellia* horizon.

?domichnion ichnogen. et ichnosp. indet.
Pl. II, fig. 2; Pl. III, fig. 1

Material: Two specimens from yellowishbrown clay shales. Rokycany-Stráň (Quarry).

Description: Broad tunnels of trails filled with material slightly darker than the wall rock. This fill contains fossilized rhabdosomes of graptolites attaining various size and mostly showing a very good state of preservation. Maximum width or broader and narrower traces 83 and 11 mm respectively. Length of both specimens is controlled by the size of the sample collected. Neighbouring rocks contain no or only rare graptolite fossils.

Remarks: The good preservation of the fossils of graptolites in the fill suggests that the tunnels were filled passively and hence were originally hollow. It suggests that the structure might have been a domichnion of indeterminable animal.

fodinichnion ichnogen. et ichnosp. indet. A
Pl. VI, fig. 2; Pl. VIII, fig. 3

Material: Two specimens from clay shales. Volduchy-well and Klabava - U starého hradu.

Description: Trails or tunnels highly variable in width, filled with crushed organic material (chitinozoans, inarticulate brachiopods, fragmentary graptolites), most single components of which range from 0.2 to 1 mm in size. Broader and narrower traces are 18 to 30 mm and 22 mm wide respectively. In both cases their length is limited by the size of the rock sample.

Remarks: Unlike the traces described herein as ?domichnion ichnogen. et ichnosp. indet., the specimens under consideration are filled with minute, mechanically disturbed faunal fragments. This fill may possibly be explained by the fact that is passed through the animal's digestive tract; the feeding structure may have been refilled, or coprolites are involved. Nor can the possibility be excluded that mechanically damaged valves were washed down into trails and grooves on the bottom, that is, a passively filled domichnion or repichnion.

fodinichnion ichnogen. et ichnosp. indet. B
Pl. V, fig. 1; Textfig. 5

Material: Three from clay shales. Mýto.

Description: Short, horizontaly curved burrows, strikingly swollen at irregular intervals. Preserved parts 15 to 30 mm long. Burrows outside and within swollen areas 3 to 4 mm and 7 to 7.5 mm vide,, respectively. They are filled with material darker than the wall rock.

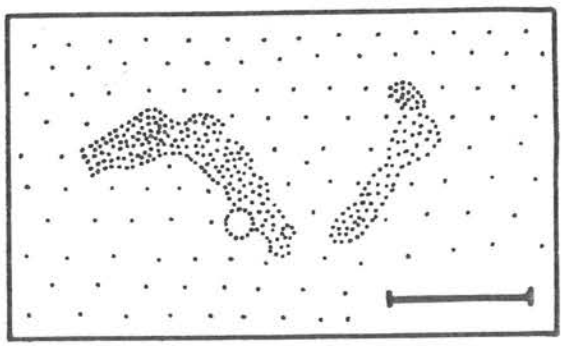


Fig. 5 Fodinichnion ichnogen. et ichnosp. indet. B (schematic drawing). District Museum, Rokycany, inv. no. I 172. Locality: Mýto. Bar = 2 cm.

Remarks: Traces may have been left by animals feeding on sediment, ıt their taxonomic assignment is problematic in view of the low fre- ıency of occurence and the imperfect preservation of the specimens.

SIGNIFICANCE OF TRACE FOSSIL ASSEMBLAGES

The pattern of trace fossil assemblages recovered in this study is in good :cord with paleogeographical conclusions reached by HAVLÍČEK (1981,)82), confirming generally their environmental validity and giving ıpport to other paleontological or sedimentological data. On the ;sumption that the elongated Prague basin had a central depression with :latively steep slopes and nearshore flat, it is reasonable to expect ;sential differences existing between trace fossil assemblages from the .arginal flats and central depression. This difference is in full agreement ith data so far available. A nearshore environment is suggested by the jpovice locality, absolutely dominated by *Bergaueria* or elsewhere *oophycos. Bergaueria,* interpreted as domichnial or cubichnial urrows f anemones, is regarted by MILLER and KNOX (1985) and other authors ; a shallow-water trace fossil. The occurence of *Zoophycos,* discussed reviously, is common in various Paleozoic nearshore settings (OSGOOD ıd SZMUC, 1972).

Taxa of the trace fossil assemblages inhabiting the shale facies of the labava Formation are relatively frequent in occurence but remain diffi- ılt to assign to one of the known recurrent ichnofacies (e. g., FREY *et al.*)90), because ichnotaxa characteristic of single ichnofacies are lacking. feature typical of these assemblages is the striking predominance of

One can make the preliminary statement that differences exist in the occurence of trace fossils within single biozones of the Klabava Formation (Textfig. 2). *Phycodes noha* clearly predominates in the earliest zone referred to as *Corymbograptus V-similis,* partibularly at the Závírka locality. This fossil can be regarded as a particular subsurface feeding structure; its tracemaker was feeding on organic matter distributed in its substrate. Tracemakers of fodinichnia mostly exploited sediment, too. Fodinichnia known from the clay shales in Upper Ordovician strata of the Prague Basin are represented virtually only by *Chondrites* (MIKULÁŠ 1989) characteristically occuring in rocks representing the most adverse environmental conditions. This ichnogenus compatible with low-oxygen conditions at the bottom and in sediment with environmental conditions unfavourable for the development of benthic organisms (e. g., SAVRDA and BOTTJER 1989, and EKDALE 1989). This of course is not the case with regard to the shales of the Klabava Formation. In this instance, one expects normal oxygen supply to the bottom and sediment, together with a sufficient supply of nutrients from the nearshore flats.

The *Hologaptus tardibrachiatus* Zone (Stráň - Valcha, Nad koupalištěm, Rokle, Volduchy, Těškov) contains additional taxa indicating the development of forms feeding on sediment, such as the tracemakers of ?*Planolites* cf. *P. beverleyensis, Glockerichnus glockeri,* and ?*Zoophycos* ichnosp. The domichnia (?*Arenocolites, Palaeophycus tubularis*) more likely represent suspension feeders or carnivores (FREY and PEMBERTON 1984). Pascichnia (*Gordia* cf. *molassica,* ?*Cochlichnus*) also occur. The trace *Ancorichnus* predominates over *Phycodes* in the *Tetragraptus abbreviatus* Zone, but otherwise the trace fossil composition remains almost invariable. *Magagrapton,* which is a trace left by a surface feeding pascichnial form, occurs sporadically in this zone, too.

The ratio in numbers of individual ethological groups of traces, together with the absence of ichnotaxa indicating nonoptimum ecologic conditions, suggests deposition of the clay shales of the Klabava Formation in an invariable environment showing slight dynamic effects, at no great distance from primary sources of organic matter, and having normal O_2 content in both water and sediment. This habitat matches conditions believed to have existed at an early development stage of the central depression of the Prague Basin.

Manuscript received, February 7, 1992

ICHNOFOSILIE KLABAVSKÉHO SOUVRSTVÍ (SPODNÍ ORDOVIK, ČECHY)

RADEK MIKULÁŠ

Předložená práce obsahuje systematické zpracování nálezů ichnofosilií z klabavského uvrství českého spodního ordoviku (arenig).

Podobně jako v celém českém spodním paleozoiku, je stupeň poznání ichnofosilií v kla-vském souvrství nízký, na rozdíl od fosilních živočichů a mikrofosilií. Není tedy k dispo-ci žádný starší sbírkový materiál (s výjimkou tří nálezů ze sbírky prof. B. Boučka), rovněž erární údaje téměř chybějí. Zpracovaný materiál pochází z menší části z vlastních terén-ch prací a z celké části z nových sběrů dr. P. Krafta (Přírodovědecká fakulta UK, Praha), muž jsem zavázán za umožnění jeho studia.

Detailněji zaměřených prací dotýkajících se klabavského souvrství nebo jeho paleonto-gického obsahu bylo již publikováno několik; nelze tedy očekávat zásadní přínos ichno-gie pro poznání prostředí vzniku, stratigrafické a faciální členění, resp. vytvoření zcela ových koncepcí. Nicméně jsou ichnologické poznatky bezpochyby materiálem pro vše-ny komplexněji pojaté práce o klabavském souvrství v budoucnu. Nelze opomenout ani ilezy neobvyklých stop a tedy přínos pro systematiku ichnofosilií.

Práce, zaměřené na paleogeografii pražské pánve a na vývoj benthických společenstev iblikoval HAVLÍČEK (1981, 1982). Podle jeho výzkumu měla pražská pánev v arenigu lmi členitý tvar, relativně hlubokou centrální depresi JZ - SV směru se strmými svahy příbřežní plošiny. Pevnina a současně snosová oblast byla jak na SZ, tak na JV od pánve; lková šířka pánve nepřesahovala v okolí Rokycan 15 km. Břidličná facie klabavského uvrství vznikala v centrální části pánve; v okrajových částech je větší podíl hruběji klas-ických a vulkanoklastických sedimentů, oolitických Fe-rud aj.

Charakter nalezených ichnospolečenstev dobře odpovídá těmto paleogeografickým věrům. Zároveň tím rámcově potvrzuje jejich platnost, podobně jako další paleontolo-cké, případně sedimentologické výzkumy. Při představě protáhlé členité pánve se středo-u depresí s relativně strmými svahy a s příbřežními plošinami je nutno očekávat zásadní zdíl mezi ichnospolečenstvy plošin a centrální deprese, což odpovídá zjištěným poznat-im. Příbřežní prostředí reprezentuje lokalita Ejpovice, na které zcela převládající složku oří ichnorod *Bergaueria*, resp. v jiné poloze *Zoophycos*, *Bergaueria*, interpretovaná jako oupata a stopy po odpočinku sasanek, je podle MILLERA a KNOXE (1985) a dalších autorů íbřežní, mělkovodní ichnofosilií. Pokud jde o ichnorod *Zoophycos*, škála jeho výskytu je lmi pestrá (viz údaje v systematické části práce).

Ichnospolečenstva břidličné facie klabavského souvrství je i přes relativní četnost xonů obtížné zařadit k některé z rekurentních ichnofacií (jejich moderní definici viz práci FREYE - PEMBERTONA - SAUNDERSE 1990), protože ichnotaxony charakteristické pro dnotlivé ichnofacie chybějí. Charakteristickým rysem těchto ichnospolečenstev je razná převaha fodinichnií, tj. stop po požírání sedimentu (*Ancorichnus*, *Glockerichnus*, *ycodes*). Daleko méně jsou zastoupena domichnia (doupata) - ?*Arenicolites* a pascich-a (povrchové potravní struktury) - *Cochlichnus*, *Megagrapton*, *Gordia*.

Předběžně lze konstatovat rozdíly ve výskytu ichnofosilií v jednotlivých biozónách kla-vského souvrství. V nejstarší zóně *Corymbograptus V-similis* (lokalita Závírka) zcela

kých souvrství pražské pánve jsou fodinichnia redukována prakticky pouze na ichnorod *Chondrites* (viz MIKULÁŠ 1988), který je charakteristický výskytem v nejrůznějších typech prostředí; převládající složkou se stává v podmínkách nepříznivých pro rozvoj benthických organismů z důvodu nízkého obsahu kyslíku při dně a v sedimentu (EKDALE 1989 aj.). To však není případ jílových břidlic klabavského souvrství; lze tedy předpokládat normální kyslíkové podmínky při dně i uvnitř sedimentu a dostatečný přínos živin z příbřežních plošin.

V zóně *Hologaptus tardibrachiatus* (střední polohy klabavského souvrství - lokality Stráň - Valcha, Nad koupalištěm, rokle, Volduchy, Těškov) přibývají další taxony, svědčící pro rozvoj požíračů substrátu: ?*Planolites* cf. *P. beverleyensis, Glockerichnus glockeri,* ?*Zoophycos* ichnosp. Objevují se i domichnia (*Arenicolites, Palaeophycus tubularis*) a pascichnia (*Gordia* cf. *molassica,* ?*Cochlichnus*). V nejvyšší zóně *Tetragraptus abbreviatus* je převládající stopou nikoliv *Phycodes,* ale *Ancorichnus,* jinak je složení obdobné. Přibývají nálezy ichnorodu *Megagrapton,* který je stopou povrchové pastvy (pascichnia).

Poměr jednotlivých etologických skupin stop a nepřítomnost ichnotaxonů poukazujících na ekologickou „tíseň" (*Chondrites, Zoophycos* – viz FREY a PEMBERTON 1984 aj.) svědčí pro sedimentaci jílových břidlic klabavského souvrství ve stálém prostředí, s nevelkou dynamikou, nepříliš vzdáleném od primárních zdrojů potravy, s normálním obsahem O_2 ve vodě i v sedimentu. Toto prostředí odpovídá podmínkám, které lze předpokládat v raném stádiu vývoje pražské pánve v její centrální depresi.

Je zřejmé, že dalšími terénními pracemi by bylo možné představu o ichnologickém obsahu klabavského souvrství ještě dále zpřesňovat.

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EXPLANATION OF PLATES

The figured material is deposited in the National Museum, Prague (inv. numbers with abbreviation P2-L) and in the District Museum, Rokycany (inv. numbers without this abbreviation). Photos by the author.

Pl. I.
Phycodes noha ichnosp. nov.; x 1.1: inv. no. I 150. Locality: Svojkovice-Závírka.

Pl. II.
1: ?*Phycodes* ichnosp.; x 2.5; 10657. Těškov-well no. I.
2: ?repichnion ichnogen. et ichnosp. indet.; x 2.0; 19437. Rokycany-Stráň (Quarry).
3.: *Phycodes noha* ichnosp. nov.; x 1.1; I 151. Svojkovice-Závírka.

Pl. III.
1: ?~~rep~~ichnion ichnogen. et ichnosp. indet.; x 0.7; 19940. Rokycany-Stráň (Quarry).
2: *Taenidium* ichnosp.; x 0.6; I 152. Mýto.
3, 4: *Phycodes* ~~*noha*~~ ichnosp. ~~nov.~~; feeding traces with chitinozoans in the fill; 3 - x 0.7; I 153; 4 - x 2.2; I 154. Rokycany-Stráň (Quarry).

Pl. IV.
1: *Phycodes* ichnosp.; x 0.9; P2-L 29109. Sedlec near Starý Plzenec (collections by Prof. B. Bouček).
2: *Glockerichnus glockeri* (KSIĄŻKIEWICZ, 1968); x 1.3; P2-L 29096. Sedlec near Starý Plzenec (coll. by Prof. B. Bouček).

Pl. V.
1: fodinichnion ichnogen. et ichnosp. indet. B; x 0.8; I 155. Mýto.
2: ?*Taenidium* ichnosp.; x 0.8; I 156. Mýto.
3: ?*Zoophycos* ichnosp.; x 0.8; I 157 C. Volduchy-well.
4: *Palaeophycus tubularis* HALL, 1847; x 0.8; I 158. Volduchy-well.
5, 6: *Glockerichnus glockeri* (KSIĄŻKIEWICZ, 1968); the same specimen as negative and positive; x 0.8; I 159. Rokycany-Stráň (Nad koupalištěm).

Pl. VI.
1: *Phycodes* ichnosp.; x 0.8; I 160. Rokycany-Stráň (Quarry).
2: ?*Cochlichnus* cf. *C. anguineus* HITCHCOCK, 1858, and fodinichnion ichnogen. et ichnosp. ident. A; x 0.6; I 157 A, B. Volduchy-well.
3: ?*Bergaueria* ichnosp.; x 0.8; I 161. Rokycany-Stráň (Quarry).
4: Trail or tunnel filled by tuffaceous material; x 0.8; I 162. Mýto.

Pl. VII.
1: *Ancorichnus* aff. *coronus* FREY *et al.*, 1984, and *Taenidium* ichnosp.; x 0.8; I 163. Mýto.
2: *Taenidium* ichnosp.; x 0.8; I 164. Mýto.
3: *Phycodes noha* ichnosp. nov.; holotype; x 0.7; I 165. Svojkovice-Závírka.
4: ?*Arenicolites* ichnosp.; x 1.2; I 166. Rokycany-Stráň (Valcha).

Pl. VIII.
1: *Gordia* cf. *molassica* (HEER, 1865); x 1.2; I 167. Rokycany-Stráň (Valcha).
2: *Phycodes noha* ichnosp. nov.; x 0.8; I 168. Svojkovice-Závírka.
3: fodinichnion ichnogen. et ichnosp. indet. A, and *Taenidium* ichnosp.; x 0.8; I 169. Klabava - U starého hradu.
4: ?*Planolites* cf. *P. beverleyensis* (BILLINGS, 1862); x 0.8; I 170. Rokycany-Stráň (Rokle).

Pl. IX.
Ancorichnus aff. *coronus* FREY *et al.*, 1984; x 1.0; P2-L 29097. Sedlec near Starý Plzenec (coll. by Prof. B. Bouček).

Pl. X.
1–6, 8: *Bergaueria* aff. *hemispherica* CRIMES *et al.*, 1977; 1 - x 5.0; P2-L 29104; 2 - x 4.2; P2-L 29102; 3 - x 3.5; P2-L 29100; 4 - x 3.0, P2-L 29101; 5 - x 5.3; P2-L 20103; 6 - x 3.2, P2-L 29099; 8 - x 4.0; P2-L 29102 (the same specimen as on fig. 2). Ejpovice.
7: domichnion ichnogen. et ichnosp. indet.; x 3.8; P2-L 29105. Ejpovice.

Pl. XI.
1: *Palaeophycus striatus* HALL, 1852; x 4.0; P2-L 29106. Ejpovice.
2: ?*Conichnus* cf. *C. conicus* MYANILL, 1966; x 0.8; P2-L 29107. Ejpovice.

Pl. XII.
Zoophycos cf. *brianteus* (VILLA, 1844); x 0.9; P2-L 29108. Ejpovice.



Plate I.

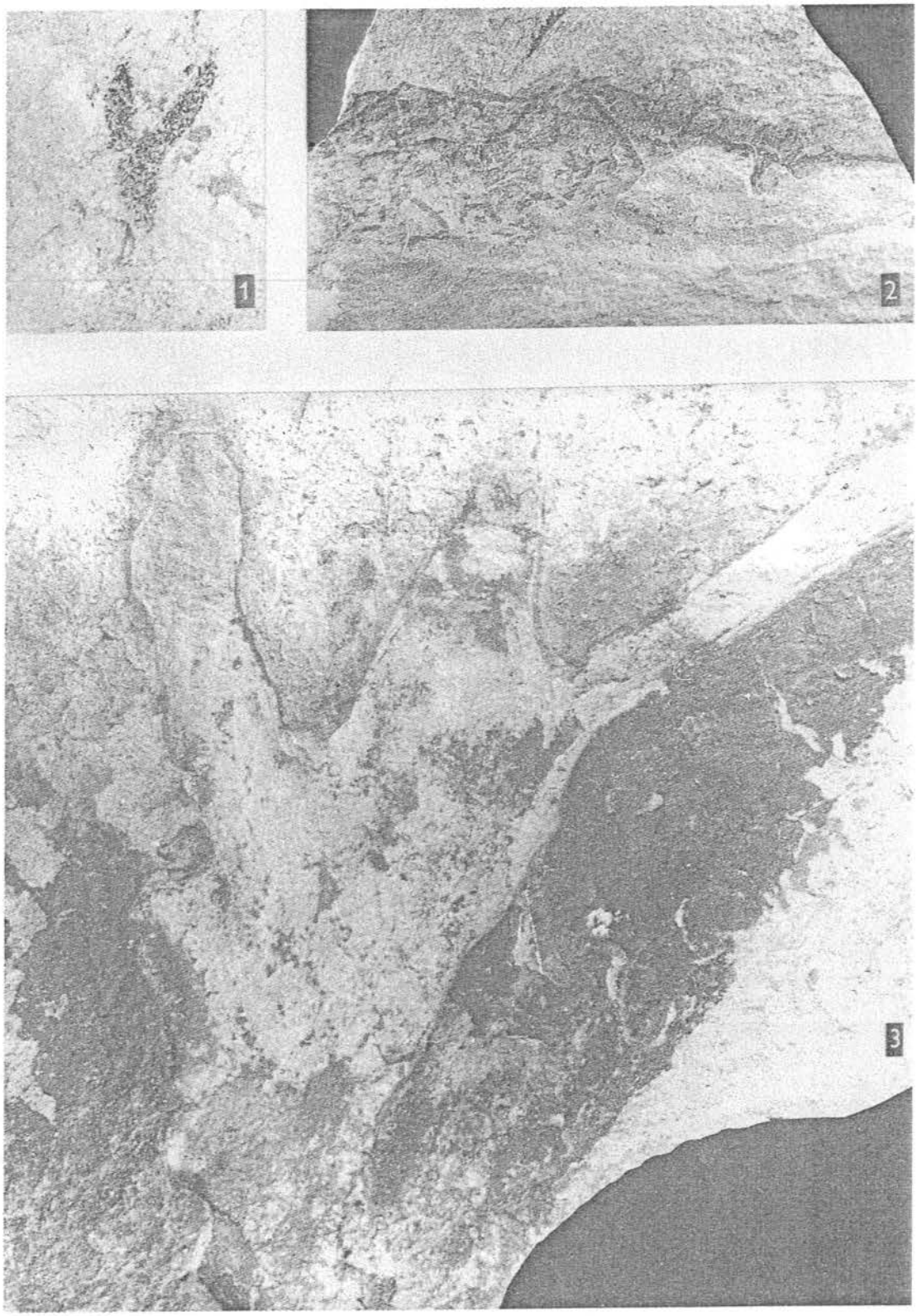


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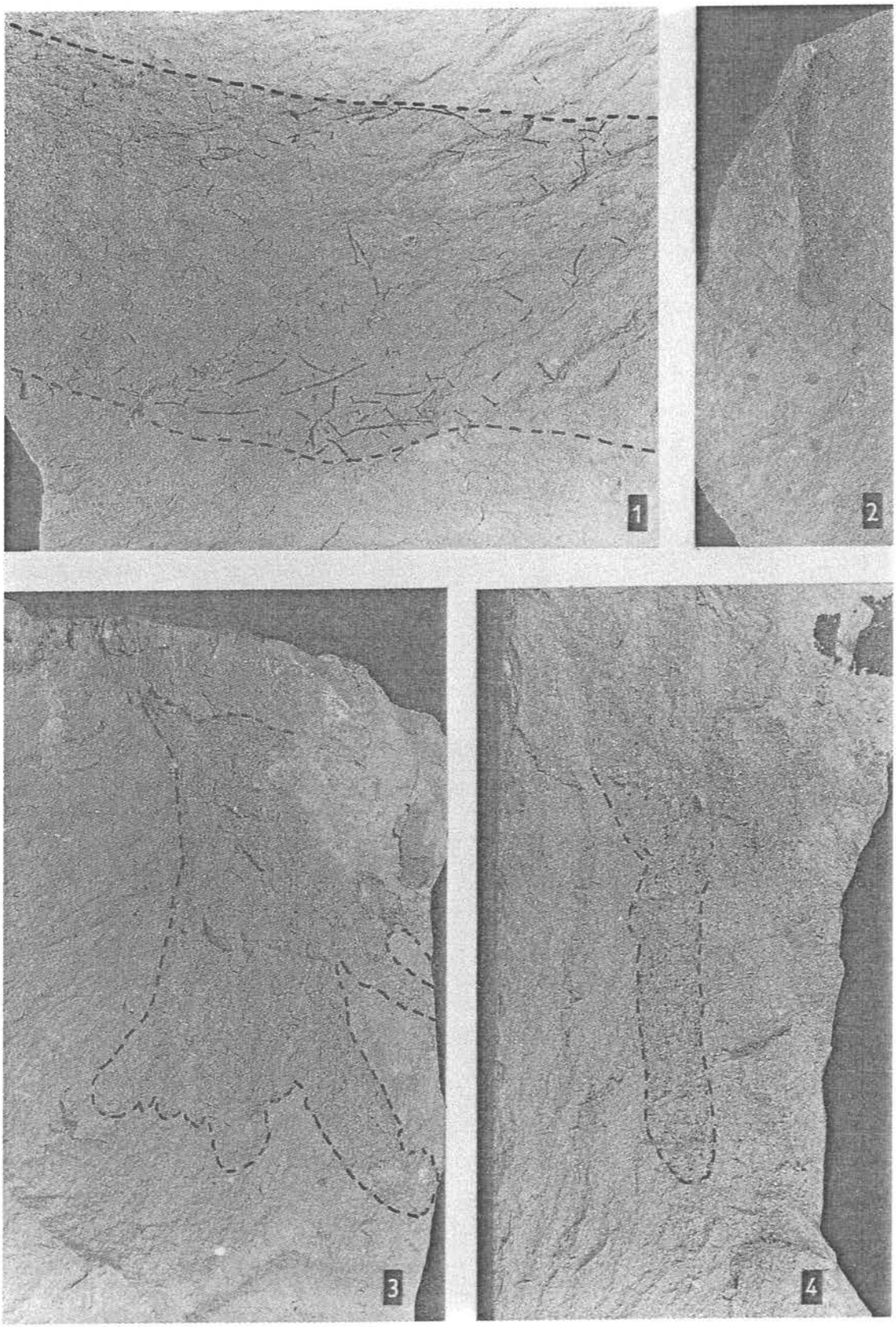


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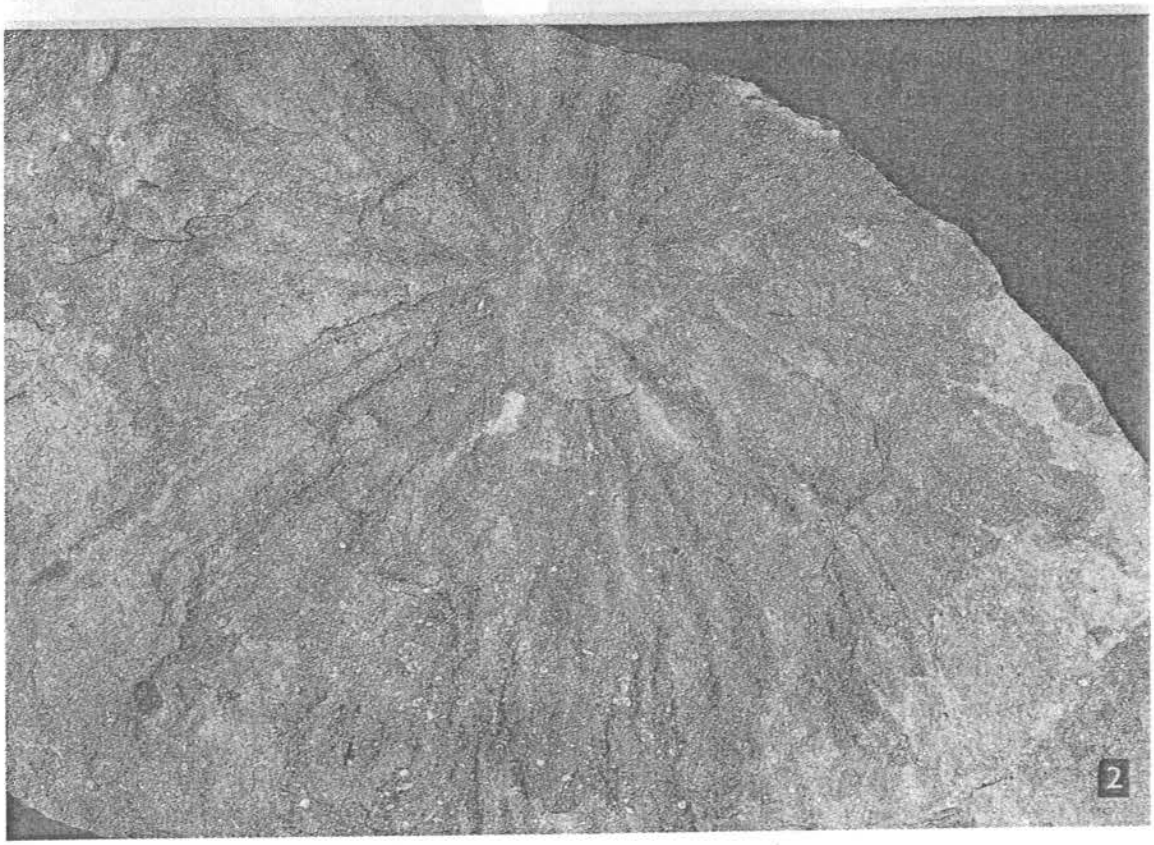


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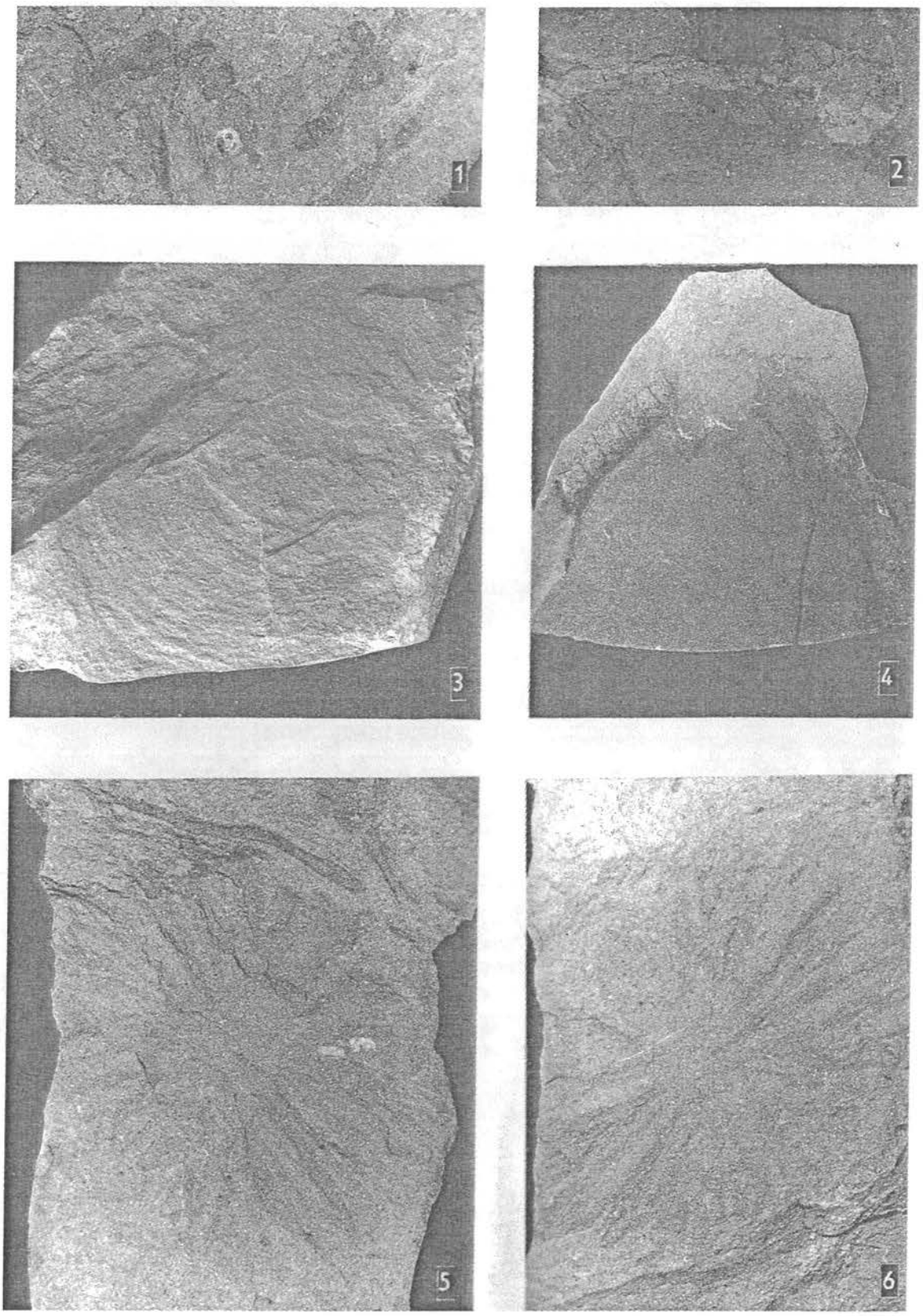


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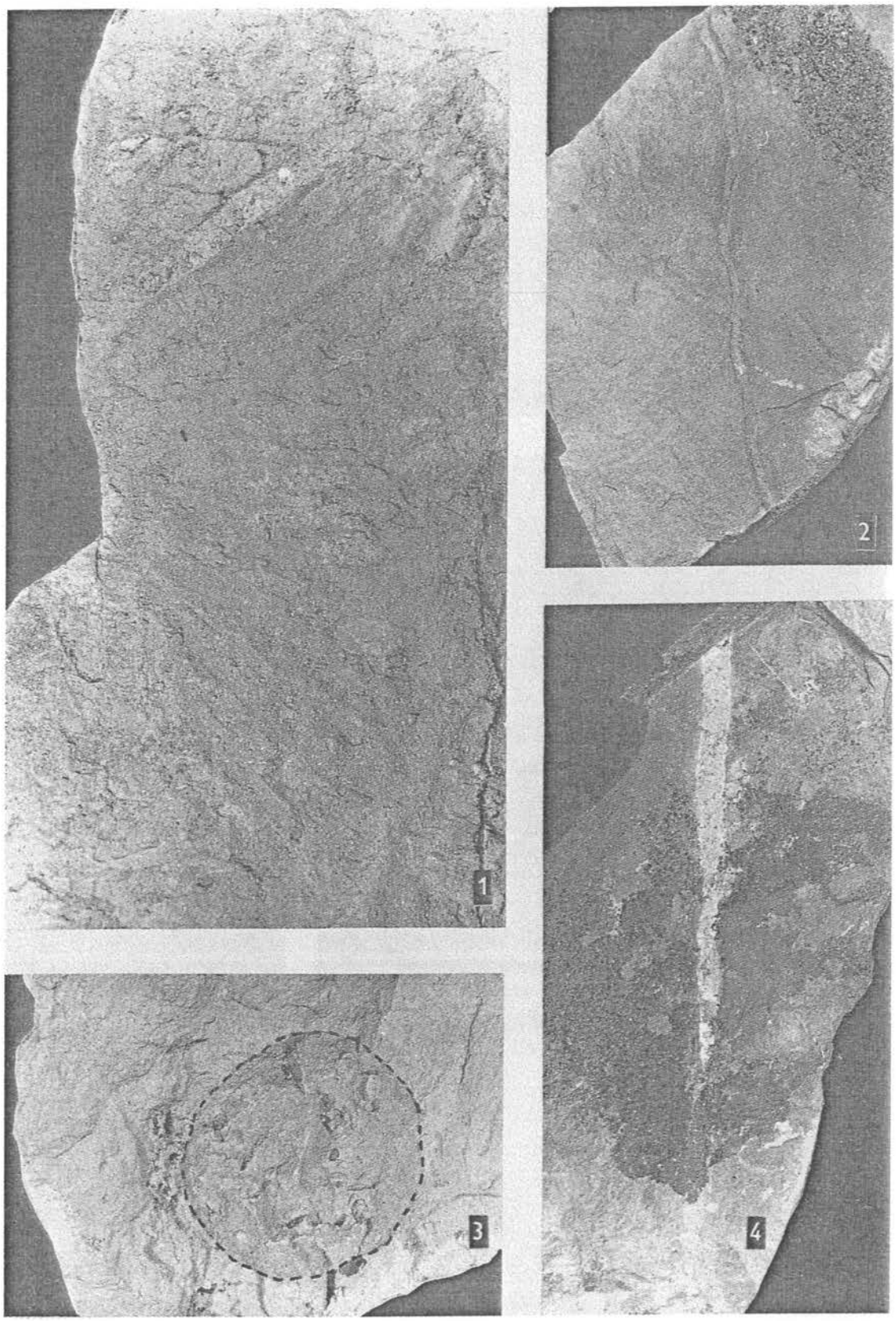


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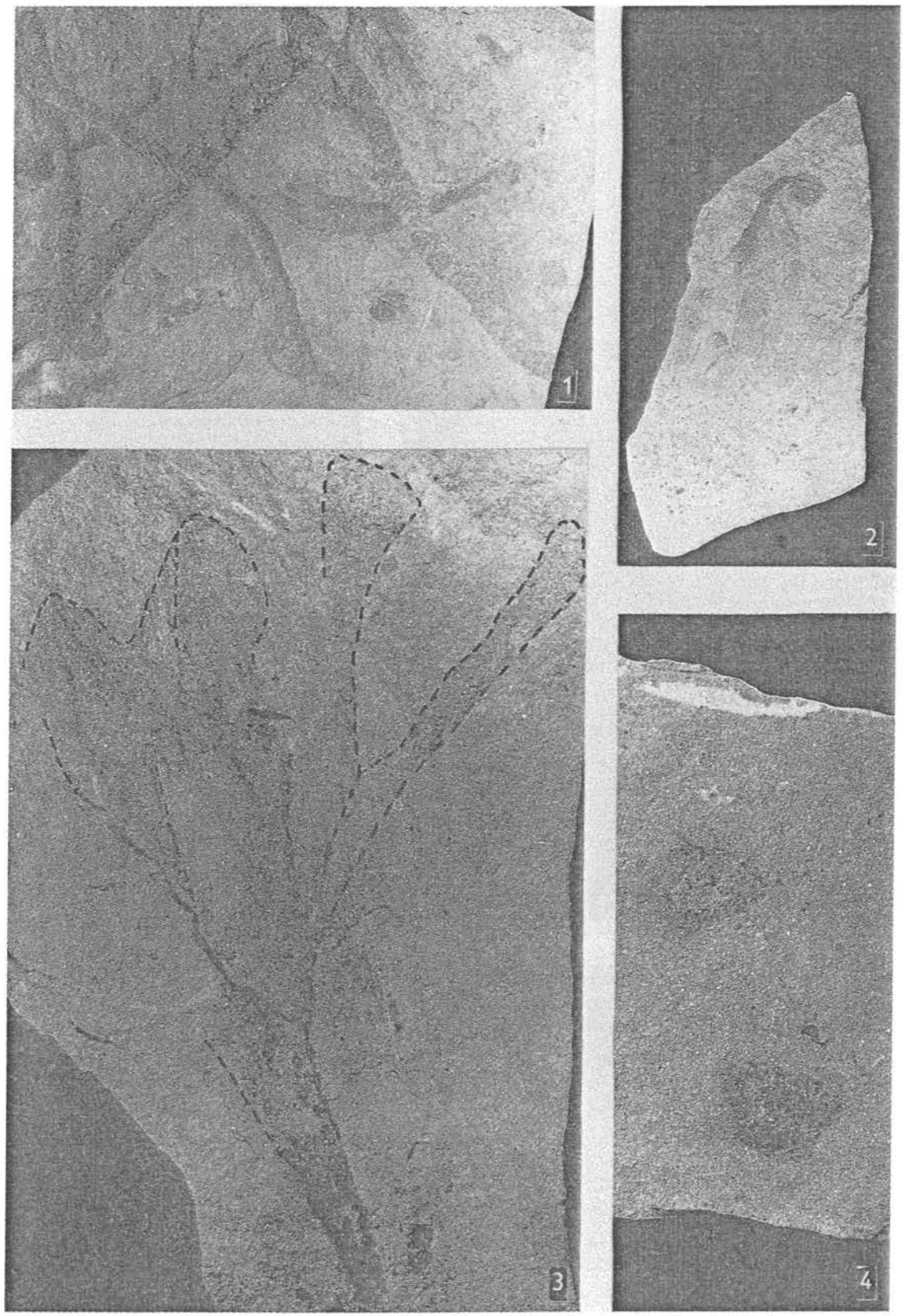


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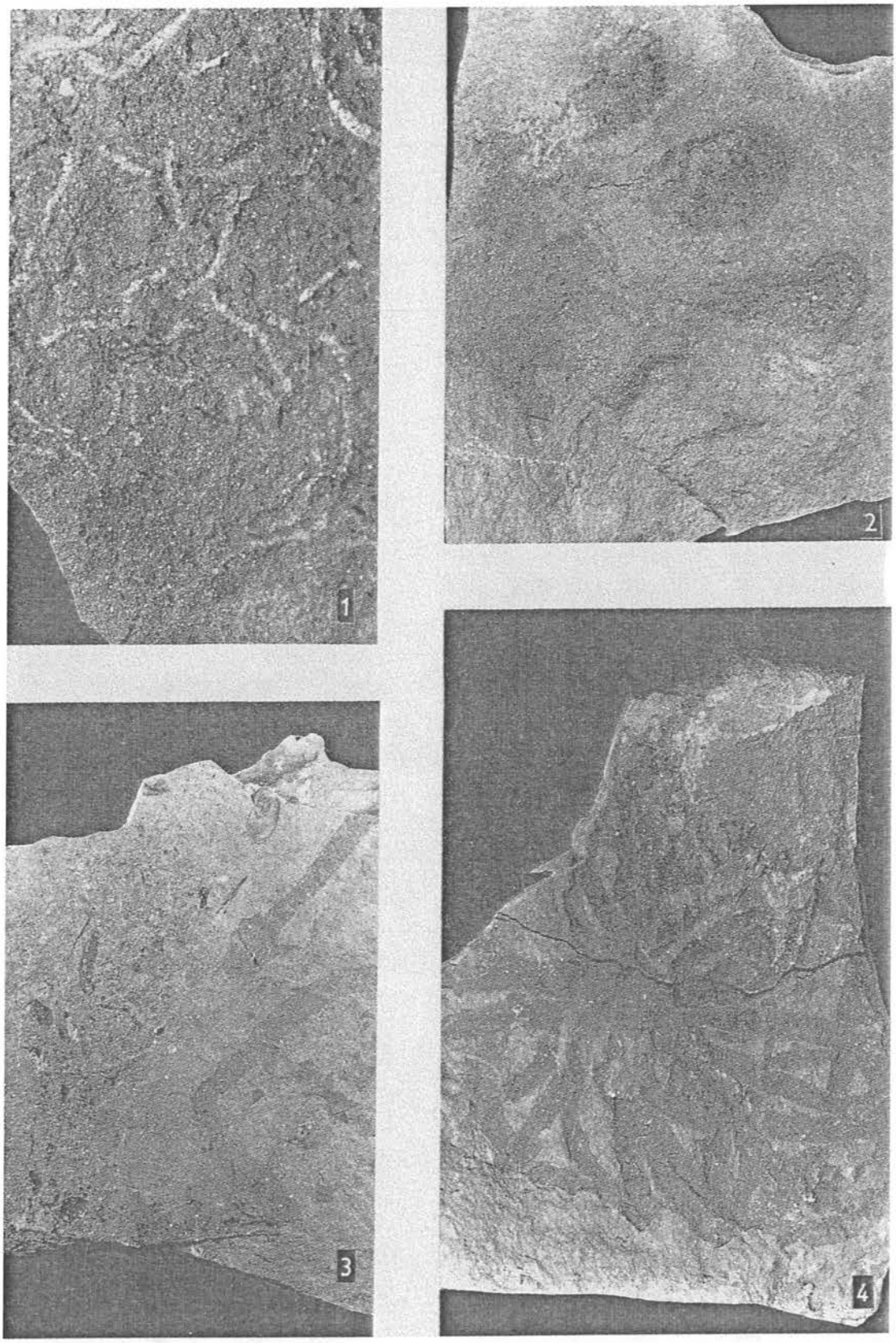

1
2
3
4



Plate IX.

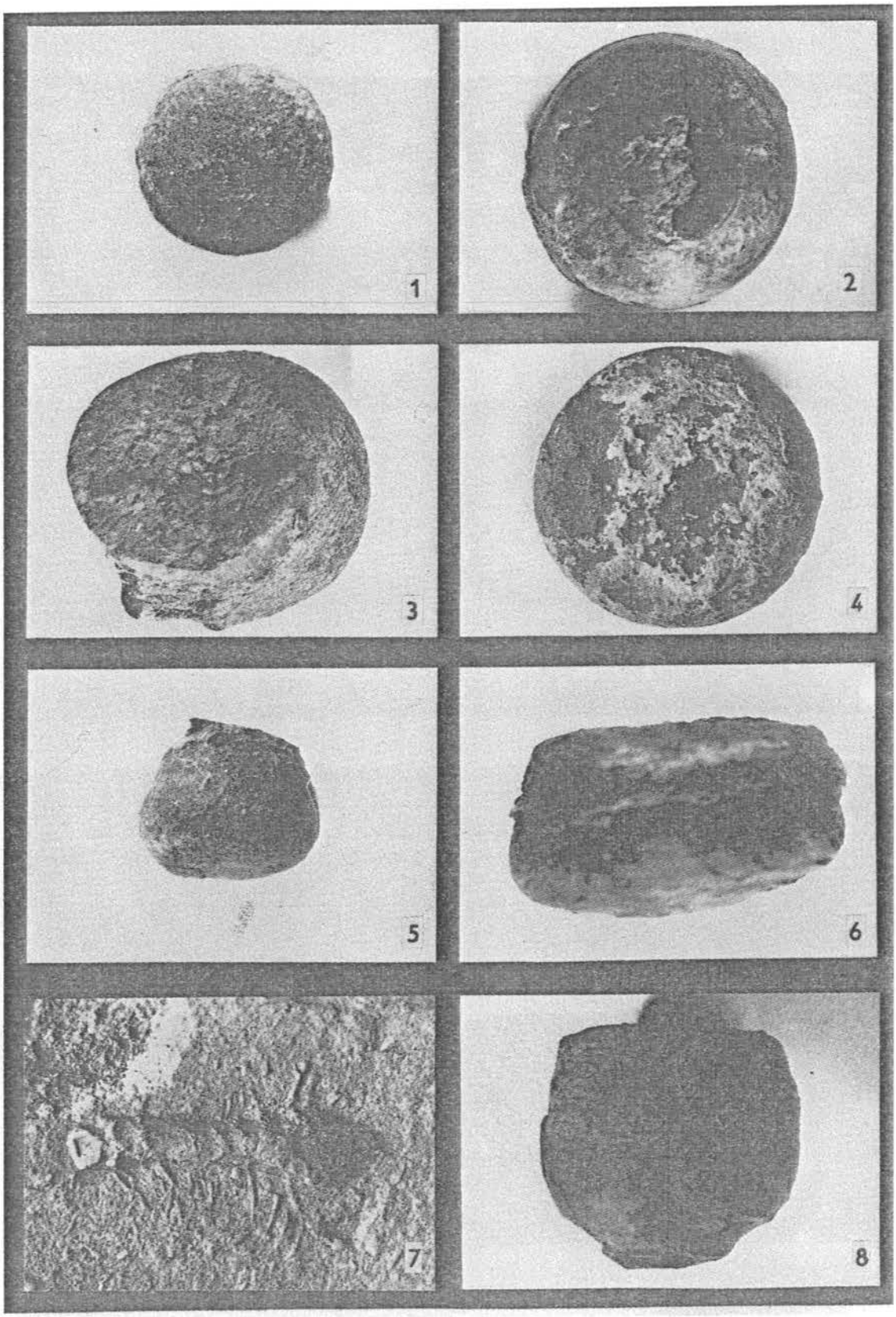
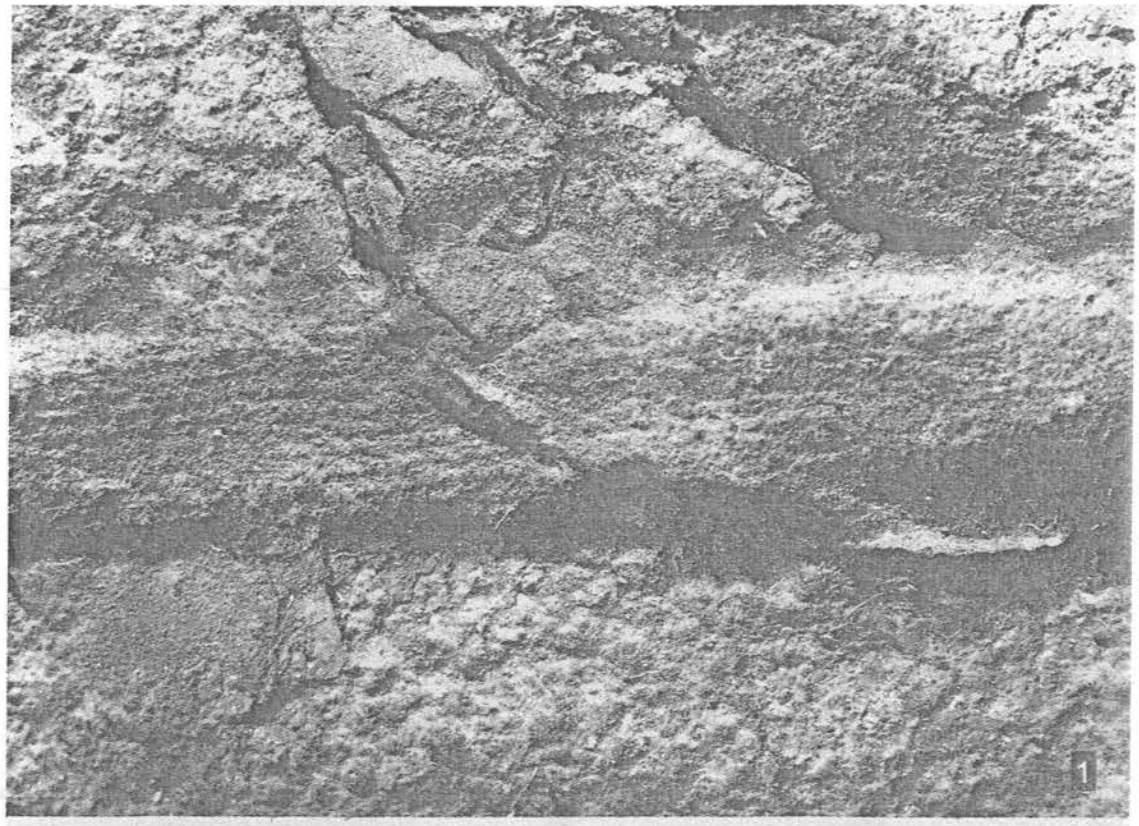


Plate X.



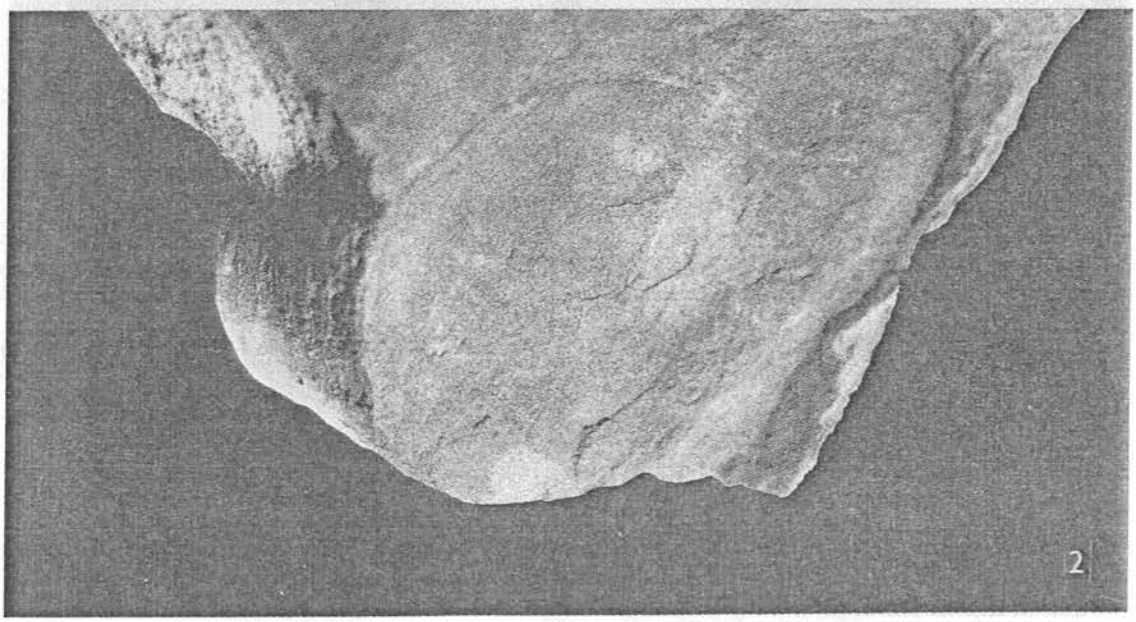


Plate XI.



Plate XII.