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Trace fossils of the Moravice Formation from the southern Nízký Jeseník Mts. (Lower Carboniferous, Culm facies; Moravia, Czech Republic)

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Abstract. The Moravice Formation provides a facies association of extremely diverse turbidites comprised of facies types A, B, C, D and E. These occur in several 10–100 m cycles that become finer and thinner upwards, and alternate with thick successions of laminite. These are interpreted as channel-fill cycles alternating with overbank sediments deposited in inner- to middle-fan environments. A second, overlying facies association is comprised of thick successions of laminite and beds of facies D and C, alternating with sandstone lenses that range in thickness from several tens to about one hundred metres, and are composed of facies C and B. The second facies association was deposited as sandstone lobe and lobe-fringe sediments in an outer-fan environment. The ichnoassemblages of the first facies association are dominated by *Dictyodora liebeana*, which is accompanied by *Chondrites* isp., *Phycosiphon incertum*, *Planolites beverleyensis*, *Planolites* isp., *Spirodesmos archimedeus* and rare occurrences of *Cosmorhaphe* isp., *Chondrites* cf. *intricatus*, *Falcichnites lophoctenoides*, *Pilichnus* isp., *Protopalaeodictyon* isp. and *Zoophycos* isp. The second facies association occurs at the margins of greywacke lenses and contains *Diplocraterion* isp., *Rhizocorallium* isp., *Dictyodora liebeana*, *Cosmorhaphe* isp. and *Paleodictyon* isp.

Key words: ichnofossils, Lower Carboniferous, Culm facies, Czech Republic

Introduction and summary of previous work

The Culm facies, named after the English Culm Measures, represents a specific variety of flysch sediments that are characteristic of sedimentary basins bordering active margins of the Variscan orogeny. These facies are indicative of a rapid influx of clastic material (e.g., Kumpera 1983). In Europe, regions with flysch facies include southern England, Ireland, the Massif Central in France, Schwarzwald, the Rhenish Slate Mts., the Harz Mts., and the Moravian-Silesian Zone. Due to the relatively large aerial extent of the Culm facies, numerous studies of its trace fossils have been published (see Stur 1875, Patteisky 1929, Stepanek and Geyer 1989, and Pek 1986 for further literature sources).

The modern systematic evaluation and depiction of the trace fossils from the Moravian-Silesian Zone has been hampered by several unfortunate circumstances. I. Pek and co-authors published several brief papers in the 1970s (Pek and Zapletal 1975, Pek et al. 1978, Lang et al. 1979), but Pek's more recent ichnotaxonomic considerations are preserved only in manuscript form (Pek 1986). Catastrophic flooding in 1997 destroyed most of the ichnofossil collections, and thus prevented the publication of a large work. I. Pek died in 1998, and only a preliminary draft of his paper (Pek and Zapletal 1998) exists. Though ichnofossils from the eastern part of the Moravian-Silesian Lower Carboniferous owned by private collectors have recently been studied, the sites from which these samples were collected are not well documented. Therefore, the authors of the present work have decided to report on the systematic ichnology of the southern Nízký Jeseník Mts. (Fig. 1). Finding from other areas of the Moravian-Silesian

Figure 1. Sketch map of the Nízký Jeseník area showing the position of the studied localities. Numbers correspond with their description in the text.

Culmian will be published after revisiting the localities cited by previous authors.

Geological setting

The Culm sediments of the Moravian-Silesian region are preserved in an elongated, SW-NE to SSW-NNE-trending structure on the eastern margin of the Bohemian Massif. Two Culm basins are generally recognized in the Moravian-Silesian Zone: the Drahany Basin and the Nízký Jeseník Basin. The fill of the Drahany Basin has been lithostratigraphically subdivided into three formations: the Protivanov Formation of early to late Viséan age (Peγ to Peδ Zone), the Rozstání Formation of late Viséan age (Peδ to *Goniatites* Goα Zone), and the Myslejovice Formation of late Viséan age (Goα to Goγ Zone), each consisting of several members. The lithostratigraphic succession of the Nízký Jeseník Basin has been subdivided into four formations: the Andělská Hora Formation of early Viséan to middle Viséan age (Peγ Zone), the Horní Benešov Formation of middle to late Viséan age (Peγ to Goα Zone), the Moravice Formation of late Viséan age (Goα2–3 to Goβmu Subzone), and the Hradec-Kyjovice Formation ranging from the late Viséan to the lowermost part of the Namurian (Goβspi Subzone to E1 Zone) (Kumpera 1983, Dvořák 1994).

The Moravice Formation covers the most extensive outcrop area of all formations within the Nízký Jeseník Basin. It is comprised of a ca 2500 m thick succession of fine-grained sandstones, siltstones, and mudstones, alternating with prominent sandstone and small conglomerate strata. The facies patterns of the Moravice Formation are very complex. The following basic types have been identified and classified by Mutti et al. (1975) and Pickering et al. (1989):

1. Massive and/or normally graded conglomerates and pebbly sandstones, several metres thick, of facies type A.
2. Beds of massive, coarse- to medium-grained sandstone of facies type B, several tens of centimetres to several metres thick, sometimes featuring coarse-tail grading, repeated grading or parallel stratification, and some bearing prominent rip-up clasts of black mudstone.
3. Beds of fine- to medium-grained sandstone of facies type C, from several to tens of centimetres thick, with T_a, $T_{a,b}$ and $T_{a,b,c}$ Bouma sequences, frequent parallel lamination, ripple-cross lamination and convolute lamination.
4. Beds or irregular lenses of massive or faintly normally graded, fine-grained sandstone and siltstone of facies type D, several mm to about 20 cm thick, often with parallel lamination and/or ripple-cross lamination.
5. Structureless or bioturbated black mudstones of facies type E.

A zebra-striped alternation pattern of generally light-coloured beds and laminae of facies D with the black mudstones of facies E is the most common feature of the fine-grained flysch deposits in all Culm-facies formations, and is commonly referred to as "laminite" (Lombard 1963, Zapletal 1971). The observed lithofacies characteristics, sedimentary structures (such as erosional bases, flute casts, tool marks, Bouma sequences), and facies stacking patterns reflect deposition from high-density turbidity currents (facies A and B), low-density turbidity currents (facies C and D), and possibly also debris flows (certain beds of facies A). The fine-grained facies D may have been deposited by bottom currents. Sediments of facies type E were presumably deposited from hypopycnal inflows (Mulder and Alexander 2001), pelagic suspensions, and as the uppermost divisions of Bouma sequences.

Detailed mapping of the facies of the Moravice Formation allowed the identification of two distinct facies associations in this turbidite succession. The first is extremely diverse, being comprised of facies types A, B, C, D and E in several 10–100 m thick asymmetric cycles that become finer and thinner upwards, and that alternate with thick successions of laminite. These cycles are interpreted as channel-fill cycles alternating with overbank sediments, deposited in the inner- to middle-fan environments. The second, overlying facies association is comprised of thick successions of laminite and beds of facies D and C, alternating with sandstone lenses of facies C and B, which range in thickness from several tens to about one hundred metres. The second facies association was deposited as sandstone lobes and lobe-fringe sediments in the outer-fan environment. As envisaged from the present facies characteristics and supported by the paleocurrent and clastic provenance data (Kumpera 1983, Hartley and Otava 2001), the Moravice Formation evolved as a longitudinal, predominantly fine-grained turbidite system within a remnant foreland basin.

In the southern part of the preserved basin fill, the ichnoassemblages of the first facies association are dominated by *Dictyodora liebeana*. This ichnotaxon is accompanied by *Chondrites* isp., *Phycosiphon incertum*, *Planolites beverleyensis*, *Planolites* isp. and rare occurrences of *Cosmorhaphe*, *Chondrites* cf. *intricatus*, *Falcichnites lophoctenoides*, *Pilichnus* isp., *Protopaleodictyon* isp. and *Zoophycos* isp. (emended after Zapletal and Pek 1997). The second facies association in the upper part of the Moravice Formation occurs at the margins of greywacke lenses and contains *Diplocraterion* isp., *Rhizocorallium* isp., *Dictyodora liebeana*, *Cosmorhaphe* isp. and *Paleodictyon* isp.

List of localities

1. **Domašov – quarry driveway.** This locality was described by Pek (1986) as No. 165. The exposed rocks consist of rhythmically deposited flysch, in sequences ranging from 5 to 10 cm, fining upwards. Although Pek (1986) documented the trace fossil *Spirodesmos archimedeus*, recent investigations have revealed only a sole specimen of *Dictyodora liebeana*.
2. **Domašov – Railway Quarry.** The abandoned Railway Quarry was numbered as locality 152 by Pek (1986). The ichnology of this locality has not yet been described, though Pek and Zapletal (1998) noted irregular knobs

of biogenic origin. The quarry exposes a single megacycle, starting with several-metre thick layers of greywacke, some of which contain gravelites. The cycle fines upwards to include ichnofossiliferous siltstones and shales in which *Dictyodora liebeana* is frequent, while *Nereites missouriensis*, *Pilichnus* and *Falcichnites lophoctenoides* are rare.

3. **"Bělský mlýn" Quarry.** Pek (1986) designated this locality as No. 149. The succession of strata starts with a 14 m thick interval of laminated shales with thin, laterally discontinuous laminae of fine-grained greywacke. The fauna (molluscs *Posidina* sp., goniatites *Nomismoceras* sp.) and flora (*Archaeocalamites scrobiculatus*, *Lepidodendron* sp., *Stigmaria* sp. and *Cardiopteris frondosa*) mark the oldest faunal horizon of the Moravice Formation. Trace fossils at this locality include *Chondrites* isp., *Dioctyodora liebeana*, and *Phycosiphon incertum* (Pek and Zapletal 1998, new collections).
4. **Malý Rabštýn.** This locality, cited by Pek as No. 151 (Pek 1986), contains a rich and diverse ichnoassemblage (Pek and Zapletal 1998, new collections). The natural cliffs reveal graded, bedded conglomerates at the base. These become finer upwards, and are overlaid by siltstones and claystones. The fauna is represented by goniatites and hyolithids. Rare floral remains of *Archaeocalamites*, *Lepidodendron* and *Archaeopteridium* have also been recorded. Among the trace fossils, *Dictyodora liebeana* and *Planolites beverleyensis* are most common, while *Phycosiphon* isp., *Zoophycos* isp. and graphoglyptids were found less frequently.
5. **Small quarries above the hiking path.** These outcrops resulted from the quarrying of roofing slates that overlie the succession of the Malý Rabštýn locality. The outcrops are composed of shales containing several-millimetre thick laminae of silty, clayey and greywacke composition. The ichnofossils *Dictyodora liebeana* and *Chondrites* cf. *intricatus* have been found at this locality.
6. **Small outcrop near the road from Domašov to Jívová**. This site consists of fine- to medium-grained greywackes bearing the trace fossils *Spirodesmos* isp. (Pek 1986) and *Dictyodora liebeana*.
7. **Olšovec.** This site is in an old abandoned bench quarry about 3 km north of the town of Hranice. The uppermost part of the Moravice Formation is exposed in this quarry. At the lower, flooded bench of the quarry, a sequence of thick-bedded greywacke is exposed. The overlying strata are composed of shales, silty shales, and siltstones with minor intercalations of greywacke. A relatively rare but diverse macrofauna occurs in the fine-grained rocks, including *Posidonia becheri*, *P. corrugata, Dolorthoceras striolatum*, *Hibernioceras kajlovicense*, and crinoids (Prokop and Pek 1998). Trace fossils, namely *Nereites missouriensis*, *Furculosus* isp., *Diplocraterion parallelum*, *Dictyodora liebeana*, *Protopaleodictyon* isp. and *Chondrites* isp., are very frequent (cf. Pek and Zapletal 1998).

Systematic ichnology

Ichnogenus *Chondrites* Sternberg 1833

Chondrites cf. *intricatus* (Brongniart 1828)
Plate I, figs 1, 2; Plate II, figs 1–3

Material: Several dozen specimens from the localities of Olšovec, the Domašov Railway Quarry, the "Bělský mlýn" Quarry, Malý Rabštýn, and the quarries above the hiking path.

Description: Systems of tunnels branching out at sharp angles, like roots. The lengths of the tunnels are 8–10 mm, and their widths range from 0.8 to 1.0 mm. They are subcircular to elliptical in cross section, preserved either as convex hyporeliefs or filled with material differing from the host rock; the fill is usually lighter and of coarser grain size.

Remarks: Morphology of the specimens resembles *C. intricatus* as depicted by Uchman (1995) in Plate 3, fig. 4.

Chondrites isp.
Plate I, figs 3, 4

Material: Two specimens from the Malý Rabštýn locality.

Description: Root-like branching preserved as semicircular, smooth, convex hyporeliefs. The tunnels branch at angles of 30–90°. The lengths of the specimens are 35 mm and 40 mm; the width of the branches ranges from 1.5–2.5 mm.

Remarks: These specimens resemble incompletely preserved systems of large forms of the ichnogenus *Chondrites* (e.g., *Ch. targionii*, cf. Fu 1991). However, the full morphology of the systems cannot be distinguished.

Ichnogenus *Cosmorhaphe* Fuchs 1895

?*Cosmorhaphe* isp.
Plate III, fig. 3

Material: A dozen specimens from the Malý Rabštýn and Olšovec localities.

Description: Unbranched, smooth, horizontally meandering, tape-like traces showing two orders of meanders. The widths of the traces are up to 5 mm, and their lengths up to 50 cm.

Remarks: The presence of the ichnogenus *Cosmorhaphe* in the Culm deposits remains unclear. Pfeiffer (1968) and Pek and Zapletal (1975) interpreted two-order meandering traces on the soles of turbidite beds or on the bedding planes of shales as surface feeding traces, which they subsequently classified as *Cosmorhaphe*. Conversely, Uchman (1998) excluded *C. timida* Pfeiffer and *C. kettneri* Pek and Zapletal from the ichnogenus *Cosmorhaphe*. The same author (Uchman personal communication 2000) considers the meandering traces from the Culm facies to represent basal parts or horizontal sections of systems of *Dictyodora*.

In our opinion, it is probable that numerous trace fossils determined previously as *Cosmorhaphe* represent the basal parts of *Dictyodora*, though some specimens (see Plate III, fig. 3) show no vertical aspect and can thus be reasonably interpreted only as horizontal trails. Resolution of this problem will require revising the type material of Pfeiffer (1968).

Ichnogenus *Dictyodora* Weiss 1884

Dictyodora liebeana (Geinitz 1867)
Plate II, fig. 4; Plate III, figs 1, 2, 4; Plate IV, figs 1–4; Plate VI, fig. 2

1959 *Dictyodora liebeana* (Geinitz), Pfeiffer, p. 425, pl. 1, figs 1–3, pl. II, figs 4, 6, 7, pl. III, figs 8, 10, 11
1989 *Dictyodora liebeana* (Geinitz), Stepanek and Geyer, p. 16, pl. 1, figs 6–8, pl. 2, figs 9–16, text-fig. 4

The two above-quoted papers contain a detailed synonymy, which is supplemented here:

1975 *Dictyodora sudetica* Roemer; Kapler, p. 87
1978 *Dictyodora sudetica* (Roemer); Pek, Zapletal and Lang, p. 255, pl. IV, figs 1–3
1978 *Crossopodia moravica* Patteisky; Pek Zapletal and Lang, p. 256, pl. III, fig. 1
1979 *Crossopodia moravica* Pateisky; Lang, Pek and Zapletal, p. 70, pl. VI, fig. 2
1979 *Dictyodora sudetica* (Roemer); Lang, Pek and Zapletal, p. 81, pl. VIII, figs 3, 4, text-fig. 3
1987 *Dictyodora liebeana* (Geinitz); Zapletal and Pek, p. 48 (ff)

Material: Approximately one hundred specimens have been collected and hundreds of observations of this trace in the field (mostly horizontal cross sections of the spreiten structure) exist from all the above-listed localities.

Description: Complex three-dimensional spreiten structures, of conical or helicoidal shape, composed of two distinct parts. The spreite is usually poorly visible; among the few specimens from the Moravice Formation, the sample depicted by Pek (1986, Plate 15, figs 1, 2) clearly shows the inner spreiten structure. The basal part is made up of broad meanders, is tripartite, and 8–15 mm wide. The middle portion is ca 1–2 mm wide; attached on both sides are flat stripes 3–6 mm wide. The spreite part lies over the basal part, is gathered in folds and inclined. The spreite is 1–2 mm wide on average; the height in this material is mostly indeterminable. The diameter of the whole cone-shaped structure is sometimes fairly large (maximum estimated diameter 50 cm). The horizontal cross sections of the spreite are the most common finds; in such cases, the trace has the character of variously shaped asymmetrical (Plate IV, fig. 2), and less often nearly symmetrical (Plate II, fig. 4), meanders; complex meanders (third-order at maximum; cf. Plate III, fig. 4) also occur.

Remarks: *D. libeana* represents a complex feeding-trace of worm-like endobionta (Benton 1982, Stepanek and Geyer 1989). In the Moravian-Silesian region, *D. liebeana* is the most common ichnofossil and has the widest stratigraphical and geographical range of all encountered trace fossils. In some localities it represents the only ichnotaxon, which holds especially for the Upper Viséan formations of the entire region. *D. liebeana* is typical for fine-grained, distal sediments with a rich clay fraction. It is most often found in sediments of the "roofing slate" type and in fine laminite with intercalations of fine-grained greywacke. In the region described here, it has not yet been found in the sandy sediments of the typical proximal turbidite facies; nor has any link between *D. liebeana* and the presence of some specific communities of other ichnofossils been observed.

Ichnogenus *Diplocraterion* Torell 1870

Diplocraterion paralellum Torell 1870
Plate X, fig. 1

Material: Several dozen specimens (full reliefs) from the Olšovec locality.

Description: Vertical U-shaped tubes having a spreiten structure between limbs. The spreite may be poorly preserved or obscured by cleavage (see Plate X, fig. 1); well-preserved examples of the spreiten structures were given by Pek (1986, Plate 27, figs 1, 5; Plate 28, figs 3–5, 7). The tubes, up to 15 mm in diameter, are smooth and unlined; the distance between openings is usually 30–50 mm. The depth of these traces may reach several decimetres (cf. Pek 1986). Cross-sections on bedding planes are encountered more often than complete specimens. These occur in a dumbbell-like structure, having two circular sections of the vertical tubes joined by a lamina of reworked material (i.e. spreite).

Remarks: For descriptions, relations, and figures of the ichnogenus and particular ichnospecies see Fürsich (1974), Häntzschel (1975), Crimes et al. (1977), Bjerstedt (1988), and Fillion and Pickerill (1990). According to these authors, *Diplocraterion* is the dwelling burrow of suspension feeders that are characteristic of settings with strong wave and current energy.

In the Culm deposits of the Moravian-Silesia region, the systematic ichnology of the U-shaped tubes presents a complicated problem. Four related ichnogenera are considered valid at present: *Diplocraterion*, having a vertical "U" and spreite; *Arenicolites*, showing a vertical U-structure without spreite; *Rhizocorallium*, composed of a sub-horizontal spreiten U-structure; and *Furculosus*, showing a sub-horizontal or oblique "U" without spreite. Whereas the four forms can easily be distinguished in most trace fossil assemblages, the specimens from our study area show possible transitional forms, although the size of the tunnels is the same for all morphotypes. We therefore conclude that they are the result of the same tracemaker and represent similar behaviour. The presence or absence of spreite can easily be explained by sedimentary and erosional processes and/or by the growth of the tracemaker. However, the organism's motivation for making horizontal, oblique, or vertical structures is unclear. It may have been influenced by mechanical properties or chemical composition of the substrate during its colonization.

Ichnogenus *Falcichnites* Stepanek and Geyer 1989

Falcichnites lophoctenoides Stepanek and Geyer 1989
Plate V, fig. 1

Material: Sole specimen from the Domašov Railway Quarry locality.

Description: Five rows of shallow bars (convex hyporeliefs and full reliefs) on a bedding plane of shale. The bars are oriented obliquely to the direction of the rows, and are densely spaced, 3–5 mm long and approximately 2 mm in maximum width. The rows are 20–30 mm long, closely spaced, and subparallel. The material filling the bars (where preserved) is darker and finer relative to the surrounding rock.

Remarks: The ichnotaxon *Falcichnites lophoctenoides* Stepanek and Geyer, 1989 was previously known only from the Culm of Frankenwaldes. It can be regarded as a transitional form between graphoglyptids and spreiten structures (cf. Stepanek and Geyer 1989 for further discussion and interpretation).

Ichnogenus *Furculosus* Roniewicz and Pienkowski 1977

Furculosus isp.
Plate X, figs 2–4

Material: Several dozen specimens (full reliefs) from the Olšovec locality.

Description: Horizontal or subhorizontal U-shaped tubes showing no spreiten structure. The tubes are circular in outline, smooth, unlined, and up to 15 mm in diameter. The distance between limbs is usually 25–50 mm.

Remarks: For descriptions, relations, and figures see Roniewicz and Pienkowski (1977). For general remarks see the discussion on the ichnogenus *Diplocraterion*.

Ichnogenus *Nereites* MacLeay 1839

Nereites missouriensis (Weller, 1889)
Plate VII, figs 1, 3, 4

See Uchman (1995) for a detailed synonymy, supplemented here by the following:

1978 *Phyllodocites jacksoni* (Emmons) Pek, Zapletal and Lang, p. 259, pl. 2, figs 1–4
1979 *Phyllodocites jacksoni* (Emmons) Lang, Pek and Zapletal, p. 65, pl. 8, fig. 1, text-fig. 2
1987 *Phyllodocites jacksoni* (Emmons) Zapletal and Pek, p. 51

Material: Dozens of collected samples and approximately one hundred field observations.

Description: Horizontal, irregularly curved, slightly meandering, less often J-shaped or asymmetrically spiralling traces. The trails consist of a ribbon-like, obliquely segmented or meniscate median parts, which are enveloped by lateral leaf-shaped lobes of reworked sediment. The material in the latter is usually coarser than the surrounding rock. Rarely, the surface of the leaf-like lateral lobes have indistinct, fan-like grooves. The length of the trace reaches as much as 250 mm, and the widths of "ribbons" are 1.5 to 6.5 mm. Numerous preservational variants of the traces exist, including those preserving only the median, meniscate-filled string (Plate VII, fig. 3). In convex hyporelief, the rows of knobs may be attributable to the ichnospecies (cf. Uchman 1995; see Plate VII, fig. 4 of the present paper).

Ichnogenus *Paleodictyon* Meneghini 1850

Paleodictyon strozzii Meneghini 1850

Material: Five specimens from the Olšovec locality were reported by Pek (1986), but are unavailable after the floods of 1997.

Description: Small paleodictyonids with mesh sizes of 2–6 mm, and strings 0.2–1.0 mm in diameter (cf. Uchman 1995).

Ichnogenus *Phycosiphon* Fischer-Ooster 1858

Phycosiphon incertum Fischer-Ooster 1858
Plate VI, figs 1, 3

Synonymy: See Stepanek and Geyer (1989), and the following supplements

1979 *Phycosiphon incertum* Fischer-Ooster; Lang, Pek and Zapletal, p. 68, pl. V, fig. 1, text-fig. 4
1979 *Cosmorhaphe timida* Pfeiffer; Lang, Pek and Zapletal, p. 70
1987 *Cosmorhaphe timida* Pfeiffer; Zapletal and Pek, p. 55
1994 *Phycosiphon incertum* Fischer-Ooster; Wetzel and Bromley, p. 1396, figs 1, 2, 4–6
1994 *Anconichnus horizontalis* Kern; Wetzel and Bromley, p. 1396, fig. 3
1995 *Phycosiphon incertum* Fischer-Ooster; Uchman, p. 25, pl. 8, figs 7, 8

Material: Eight specimens collected, and several dozen in situ observations from the Malý Rabštýn locality.

Description: Small, protrusive spreiten-structures, parallel to the bedding plane, consisting of U-shaped tubes winding as a system of lobes. Between the arms of the tubes (especially in the distal parts of the lobes) irregular spreite can sometimes be observed. The diameters of the tubes vary around 1mm. The material filling the tubes is usually more highly carbonaceous than the host substrate.

Remarks: Stepanek and Geyer (1989) regarded *Cosmorhaphe timida* Pfeiffer 1969 to be a minor, subjective synonym of *Phycosiphon incertum*. We agree with their decision, and classify the material from the Moravian-Silesian region presented in previous reports (e.g., Pek 1986) as *C. timida*, with the ichnospecies *P. incertum* Fischer-Ooster. Wetzel and Bromley (1994) also classify *Anconichnus horizontalis* Kern as a synonym of *P. incertum*.

This ichnospecies represents the work of a eurybathic, opportunistic sediment feeder. It is mostly found in facies rich in shales ("roofing slates"), less often in shale intercalations within thin greywacke beds.

Ichnogenus *Pilichnus* Uchman 1999

Pilichnus isp.

Material: Five samples from the Domašov-Railway Quarry and Olšovec localities.

Description: A system of horizontal, straight, curved to irregularly winding, branched strings without wall lining, preserved in full relief on parting surfaces. The strings are 0.3–0.6 mm wide. They are filled with a darker argillaceous substance. Their dichotomous, Y-shaped branches are characteristic.

Remarks: Systems of these shapes have usually been interpreted as fragments of the essentially radial, regular trace fossil *Chondrites*. However, as these systems represent the deep tier, there is no reason to assume that the traces are incomplete. We therefore accept the systematic solution proposed by Uchman (1999), who established a new ichnogenus *Pilichnus* for irregular *Chondrites*-like traces.

Ichnogenus *Planolites* Nicholson 1873
Planolites beverleyensis (Billings 1862)

Plate VI, fig. 4; Plate VII, fig. 2

Synonymy: See Pemberton and Frey (1982) and the following supplements.

1995 *Planolites beverleyensis* (Billings 1862); Uchman, p. 134, pl. 3, figs 2, 8
1987 *Planolites beverleyensis* (Billings); Zapletal and Pek, p. 48

Material: About 50 specimens collected or observed in the field from the Malý Rabštýn and Olšovec localities.

Description: Approximately horizontal, unbranched cylindrical traces, mostly straight or gently curved, less often irregularly sinuous. They are found solitarily or form irregular, contorted clusters, with the traces often overlapping. The traces are circular or elliptical in cross section, and range from 5–8 mm in diameter. The lengths of the preserved trace sections go up to 100 mm. The trace surfaces are smooth. The casts are structureless, the majority of which are filled with the same material that comprises the host sediment. Less often, the cast consists of coarser material with a higher proportion of sand.

Remarks: *P. beverleyensis* is a eurybathic trace, fairly widespread from late Proterozoic to modern times (cf. Pemberton and Frey 1982).

Planolites isp.
Plate X, fig. 5

Material: Five specimens from the Olšovec locality.

Description: Horizontal, straight, unbranched cylindrical traces, circular or elliptical in cross section, 15–20 mm in diameter. The lengths of the preserved trace sections reach 100 mm. The trace surfaces are smooth. The casts are structureless, and filled with coarse-grained sediment.

Ichnogenus *Protopaleodictyon* Książkiewicz 1958

Protopaleodictyon isp.
Plate V, figs 2, 3; Plate VIII, figs 1–4

Material: Twenty specimens and about 50 field observations at the Olšovec and Malý Rabštýn localities.

Description: Large-sized graphoglyptid traces. Burrows are irregular to angular, and meandering, creating closed and open networks. The strings are 2.0–3.5 cm in diameter (cf. Uchman 1995).

Remarks: These traces are the most common graphoglyptids of the Culmian facies of the Moravian-Silesian Region (cf. Pek 1986).

Ichnogenus *Rhizocorallium* Zenker 1836

Rhizocorallium isp.
Plate IX, figs 3, 4

Material: Eight specimens (full reliefs) from the Malý Rabštýn and Olšovec localities.

Description: Horizontal to subhorizontal U-shaped tubes with variably prominent spreiten structures. The tubes are circular in outline, smooth, unlined, and up to 15 mm in diameter. The distance between the limbs is usually 30–60 mm.

Remarks: For description, relations, and figures see Fürsich (1974). For general remarks see the discussion on the ichnogenus *Diplocraterion*.

Ichnogenus *Urohelminthoida* Sacco 1888

?*Urohelminthoida* isp.
Plate IX, fig. 1

Material: Two specimens several *in situ* observations from the Olšovec locality.

Description: Thread-like grooves forming broad meanders with tail-like appendages at each turn. The width of the grooves is 4–5 mm, while that of the meanders ranges from 10–14 mm. The length of appendages goes up to 25 mm.

Remarks: *Urohelminthoida* is typical for turbidite sequences, especially for Mesozoic and Cenozoic Nereites ichnofacies (e.g., Frey and Pemberton 1984).

Ichnogenus *Zoophycos* Massalongo 1855

Zoophycos isp.
Plate IX, fig. 2

Material: Two specimens from the Malý Rabštýn locality.

Description: Subhorizontal irregular, lobate spreiten-structures, observable on bedding planes. The distances between the spreite lamellae range between 1.5–2.5 mm. The diameters of the entire structures reach up to 15 cm.

Remarks: *Zoophycos* occurs in Paleozoic shallow-water sediments (Ekdale and Lewis 1991), and is usually related to environments with low physical energy and specific ecological stress, which are most often dysoxic environments (e.g., Olivero 2003 and references therein).

Sedimentological conclusions

The trace fossils in our study area of the Moravice Formation occur chiefly in the fine-grained sediments of the upper parts of individual sedimentary megacycles, while the coarse-grained, clastic rocks of the lower parts of megacycles are very seldom bioturbated. The preservation of traces is imperfect due to the cleavage of the rocks, which often affects the morphologic details. Assessing the ichnofabric index is also hampered by the cleavage structures (Mikuláš et al. 2002). In spite of these limitations, observations from our study area confirm the opinion of Zapletal and Pek (1997) that the richest ichnofossil associations occur in the proximity of larger greywacke bodies. *Dictyodora liebeana* is ubiquitous; it was characterized by Pek (1986) as the trace of an r-strategy sediment and/or suspension feeder.

Empirical data on trace fossil associations (Table 1) demonstrate that *Planolites* and *Phycosiphon* seldom occur with graphoglyptids, and that *Pilichnus* occupied the same substrates (probably also the same tiers) as *Chondrites* and *Dictyodora*. Most of the ichnotaxa are too rare to give statistically relevant data. The significance of these associations is not clear; we suspect that a "metamorphic filter" preferentially preserved full reliefs and destroyed minute hyporeliefs.

Generally, trace fossils from the Moravice Formation represent a diverse ichnoassemblage in the Culm facies (see Stepanek and Geyer 1989). The Culm facies as a whole resembles Mesozoic and Cenozoic flysches in many aspects (Uchman 2001 and references therein), but both the density and diversity of the traces are much lower in the former. More detailed comparisons of the Culm facies and the younger flysches will be given by the present authors following the study of large, newly obtained collections from the eastern part of the Moravian Culm area.

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Table 1. Trace fossil association data for 18 ichnospecies recorded in the Culm facies of the southern Nízký Jeseník Mts. Joint occurrence = occurrence on the same beds or bedding planes; tiering is not taken into consideration

ICHNOTAXA	*Dictyodora liebeana*	*Planolites beverleyensis*	*Planolites* isp.	*Phycosiphon incertum*	*Zoophycos* isp.	*Chondrites* isp.	*Chondrites* cf. *intricatus*	*Falcichnites lophoctenoides*	*Pilichnus* isp.	*Protopaleodictyon* isp.	*Paleodictyon* isp.	*Cosmorhaphe timida*	*Cosmorhaphe* isp.	*Rhizocorallium* isp.	*Diplocraterion* isp.	*Nereites* isp.	*Urohelminthoidea* isp.	*Furculosus* isp.
Dictyodora liebeana	■	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Planolites beverleyensis	•	■	•	•	•	•	•			•		•		•				
Planolites isp.	•	•	■	•	•	•		•	•	•		•		•				
Phycosiphon incertum	•	•	•	■	•	•				•		•		•				
Zoophycos isp.	•	•	•	•	■	•				•		•		•				
Chondrites isp.	•	•	•	•	•	■		•	•	•		•		•	•	•	•	•
Chondrites cf. *intricatus*	•	•					■											
Falcichnites lophoctenoides	•		•			•		■	•									
Pilichnus isp.	•		•			•		•	■									
Protopaleodictyon isp.	•	•	•	•	•	•				■		•		•				
Paleodictyon isp.	•										■			•	•	•	•	•
Cosmorhaphe timida	•	•	•	•	•	•				•		■		•				
Cosmorhaphe isp.	•												■		•	•	•	•
Rhizocorallium isp.	•	•	•	•	•	•				•	•	•		■	•	•	•	•
Diplocraterion isp.	•					•					•		•	•	■	•	•	•
Nereites isp.	•					•					•		•	•	•	■	•	•
Urohelminthoidea isp.	•					•					•		•	•	•	•	■	•
Furculosus isp.	•					•					•		•	•	•	•	•	■

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Explanation of plates

The specimens are housed in the paleontological collection of Palacký University, Olomouc. Inventory numbers will be added and published in a subsequent paper. Photos by Josef Brožek and Radek Mikuláš. Scale bars = 2 cm.

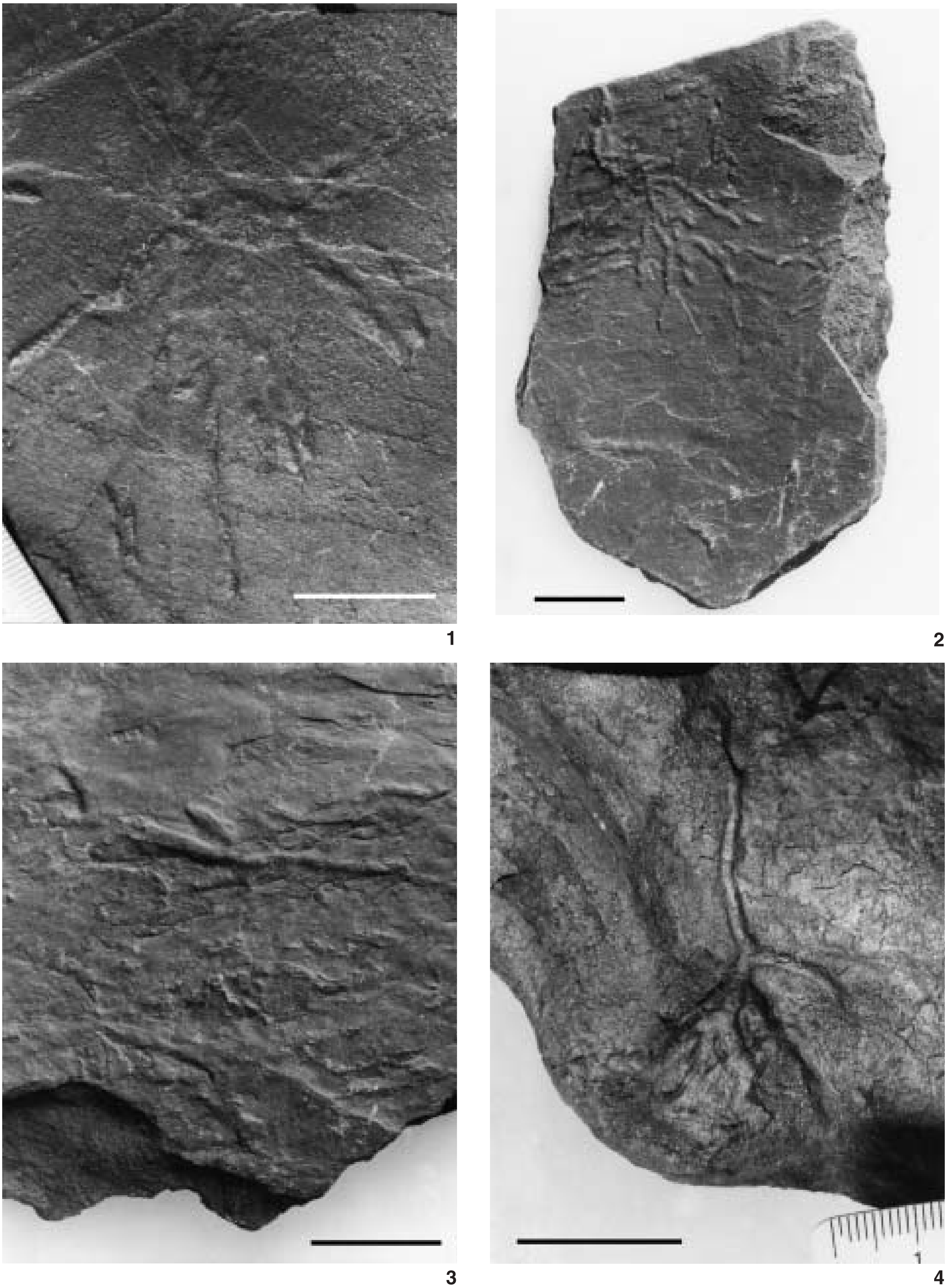

Plate I
1, 2 – *Chondrites* cf. *intricatus* (Brongniart 1828). 3, 4 – *Chondrites* isp. Malý Rabštýn locality.

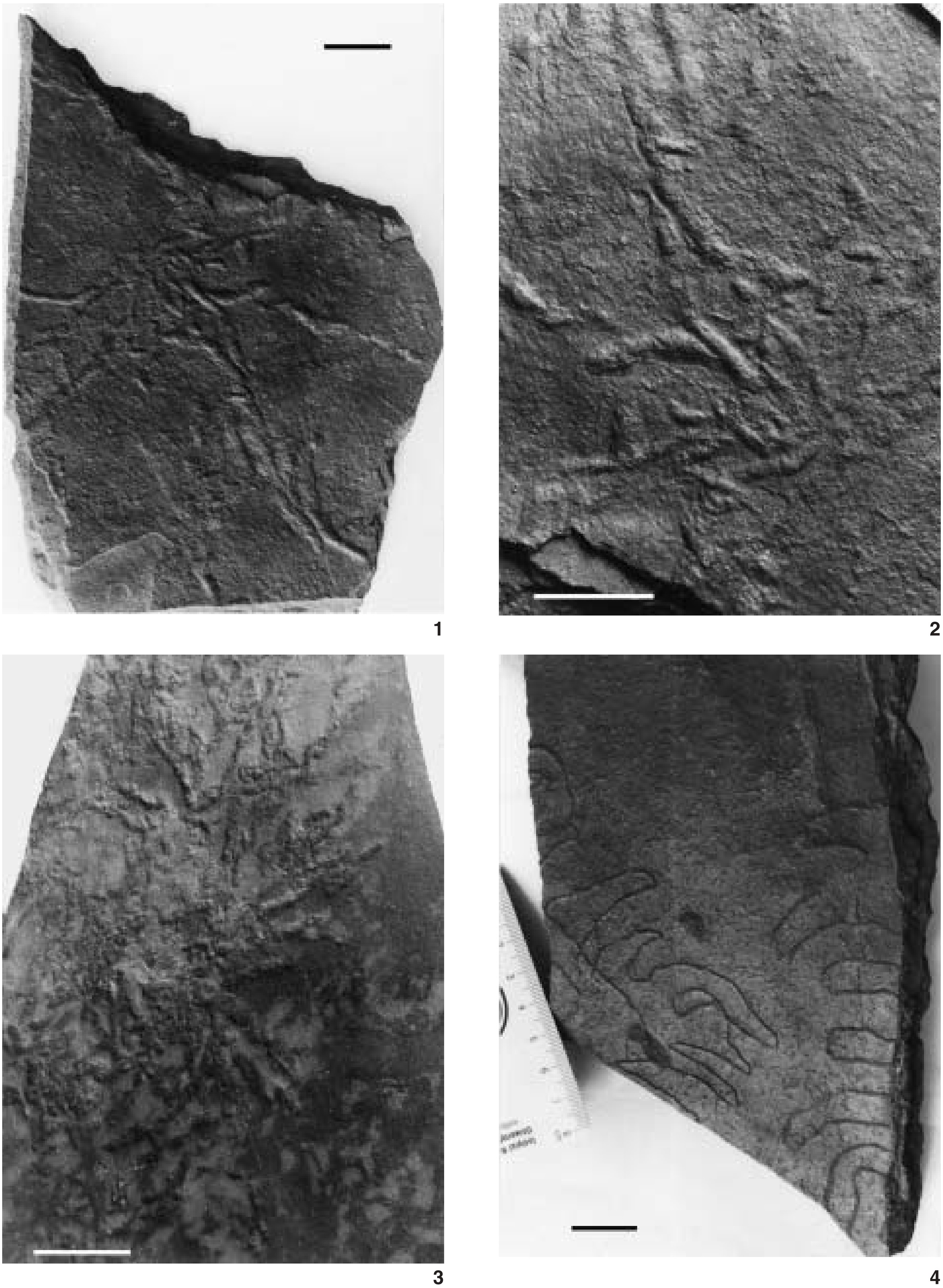

Plate II
1–3 – *Chondrites* cf. *intricatus* (Brongniart 1828). 4 – *Dictyodora liebeana* (Geinitz 1867). Malý Rabštýn locality.

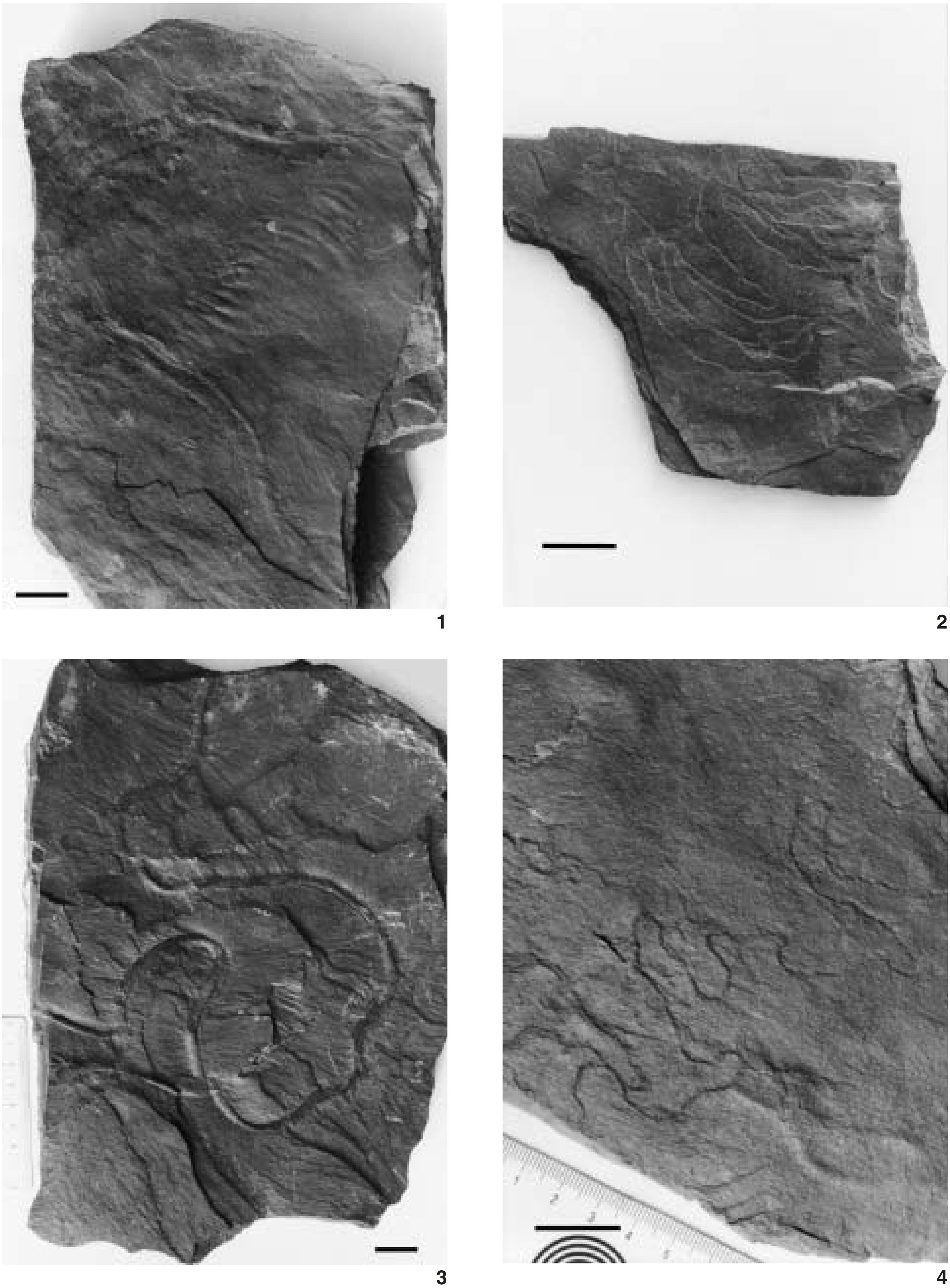

Plate III
1, 2, 4 – *Dictyodora liebeana* (Geinitz 1867), Malý Rabštýn locality. 3 – ?*Cosmorhaphe* isp. Malý Rabštýn locality.

1

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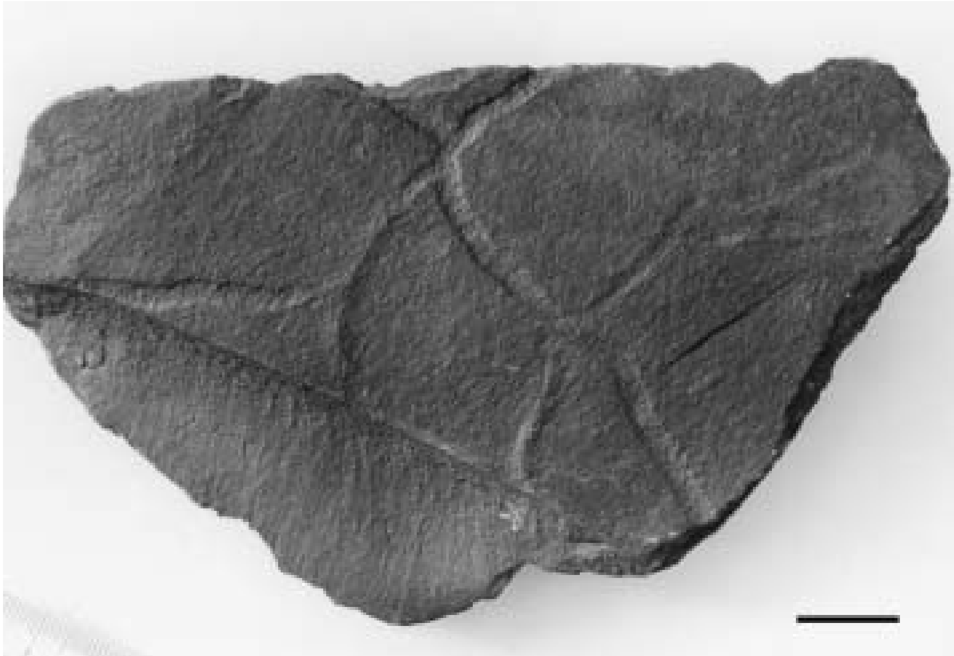
Plate IV
1–4 – *Dictyodora liebeana* (Geinitz 1867), Malý Rabštýn locality.

1

2



3

Plate V

1 – *Falcichnites lophoctenoides* Stepanek and Geyer 1989, Domašov – Railway Quarry. 2, 3 – *Protopaleodictyon* isp., Malý Rabštýn locality.

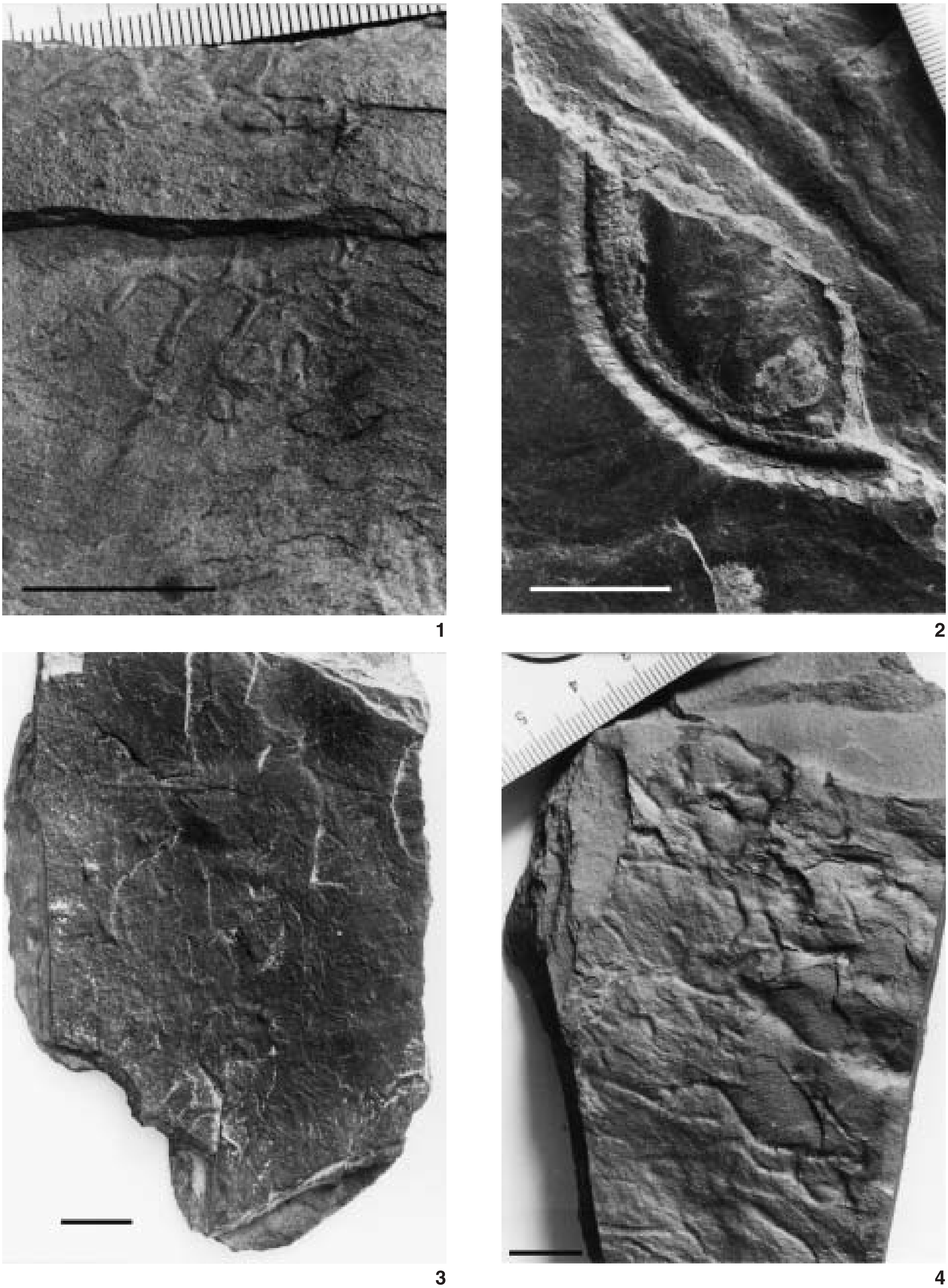


Plate VI
1, 3 – *Phycosiphon incertum* Fischer-Ooster 1858, Malý Rabštýn locality. 2 – *Dictyodora liebeana* (Geinitz 1867), Olšovec locality. 4 – *Planolites beverleyensis* (Billings 1862), Malý Rabštýn locality.

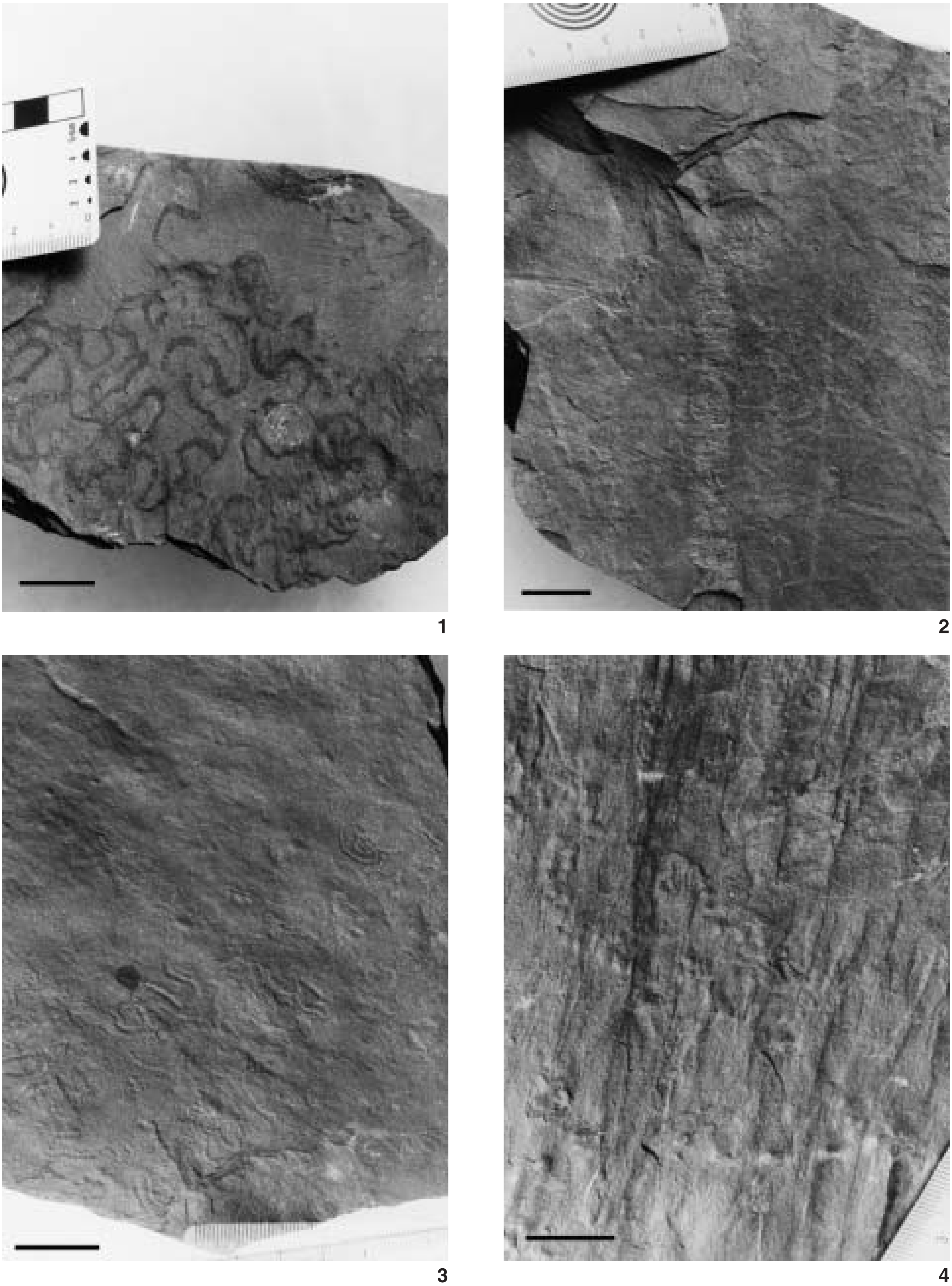


Plate VII
1, 3, 4 – *Nereites missouriensis* (Weller 1889), Olšovec locality. 2 – *Planolites beverleyensis* (Billings 1862), Olšovec locality.

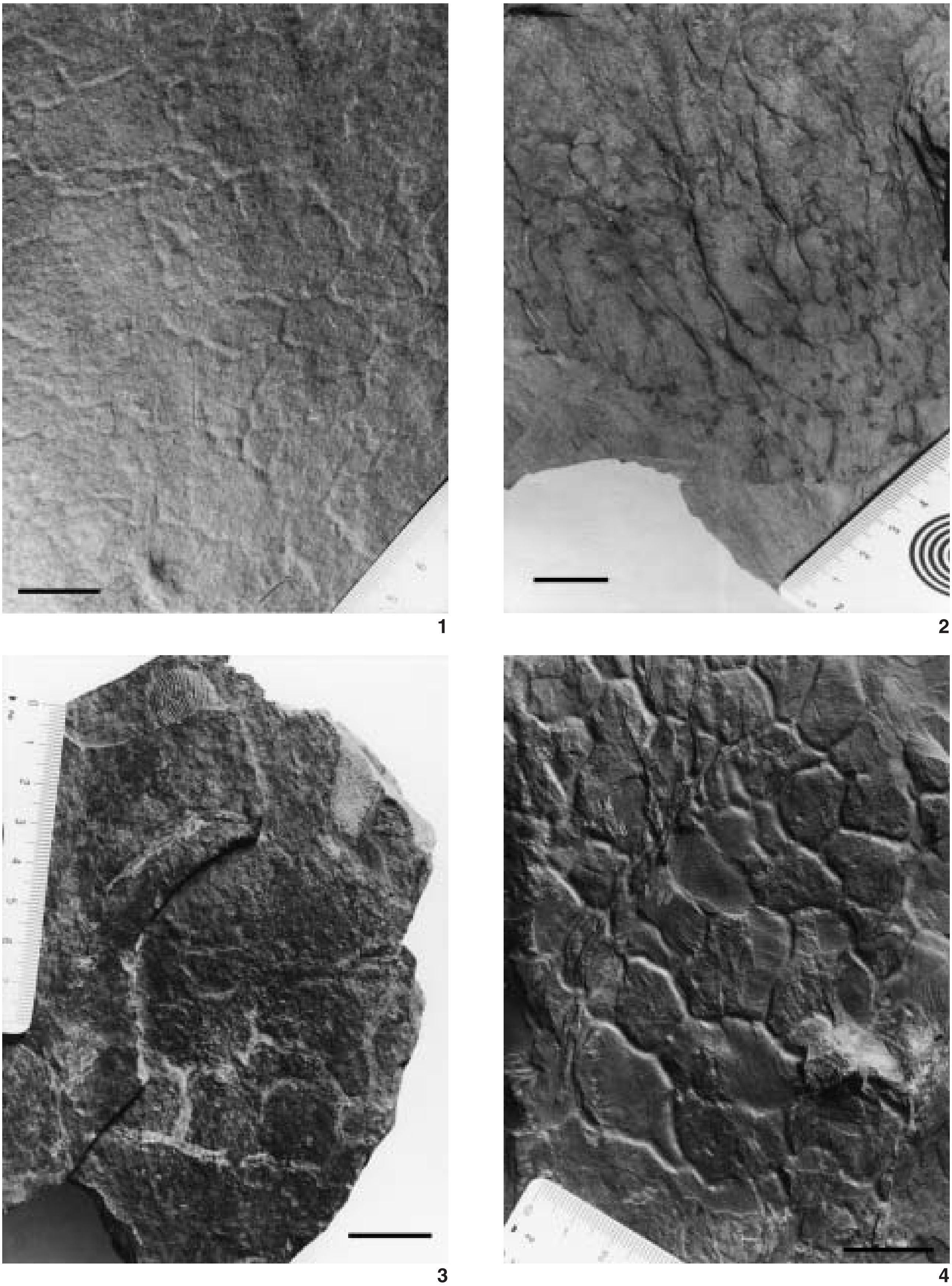
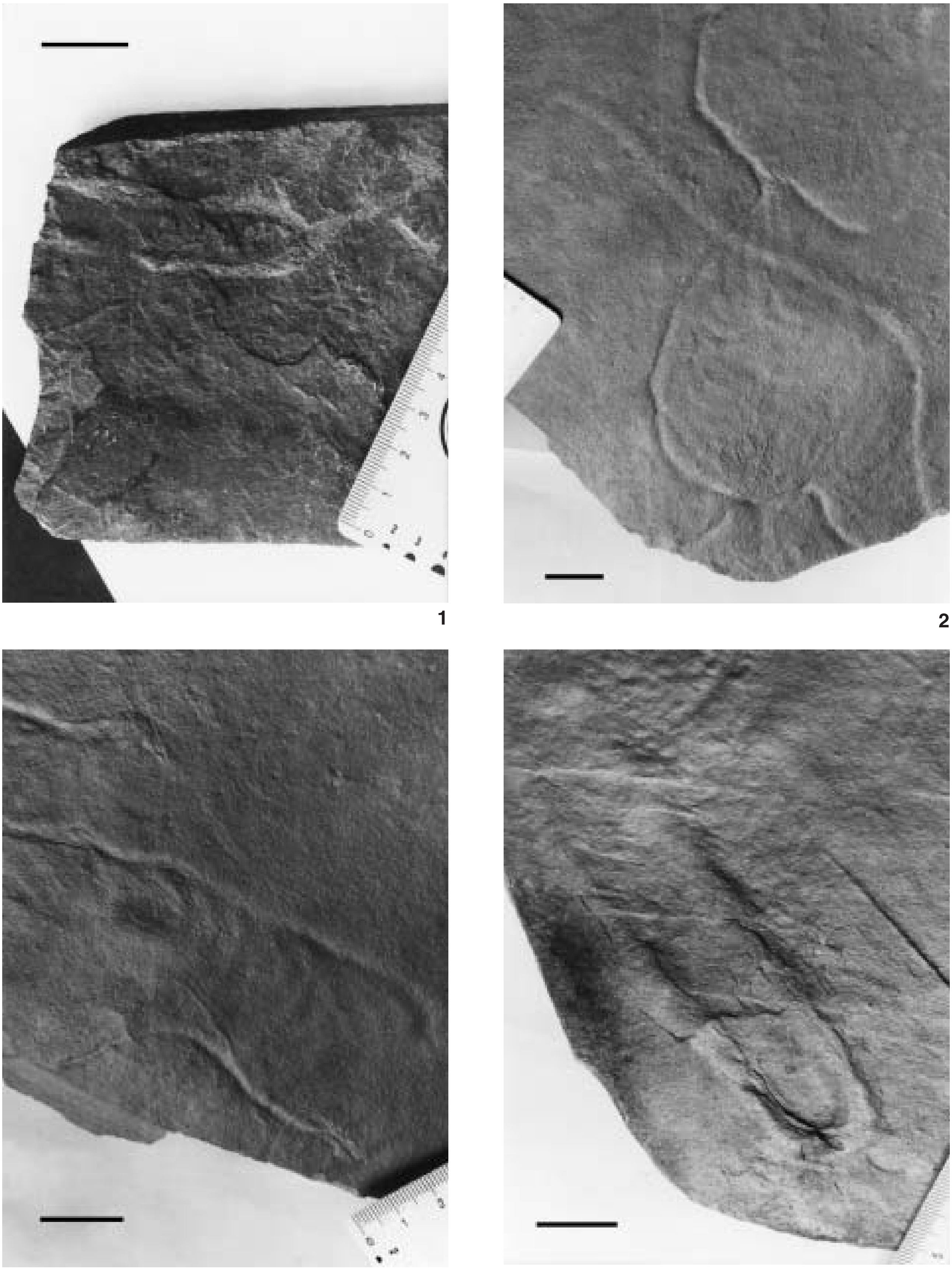


Plate VIII
1–4 – *Protopaleodictyon* isp., 1–3 – Malý Rabštýn locality, 4 – Olšovec locality.



1 2 3 4

Plate IX
1 – *Urohelminthoida* isp., Olšovec locality. 2 – *Zoophycos* isp., horizontal view, spreite and its marginal tubes, Malý Rabštýn locality. 3, 4 – *Rhizocorallium* isp., 3 – Malý Rabštýn locality, 4 – Olšovec locality.

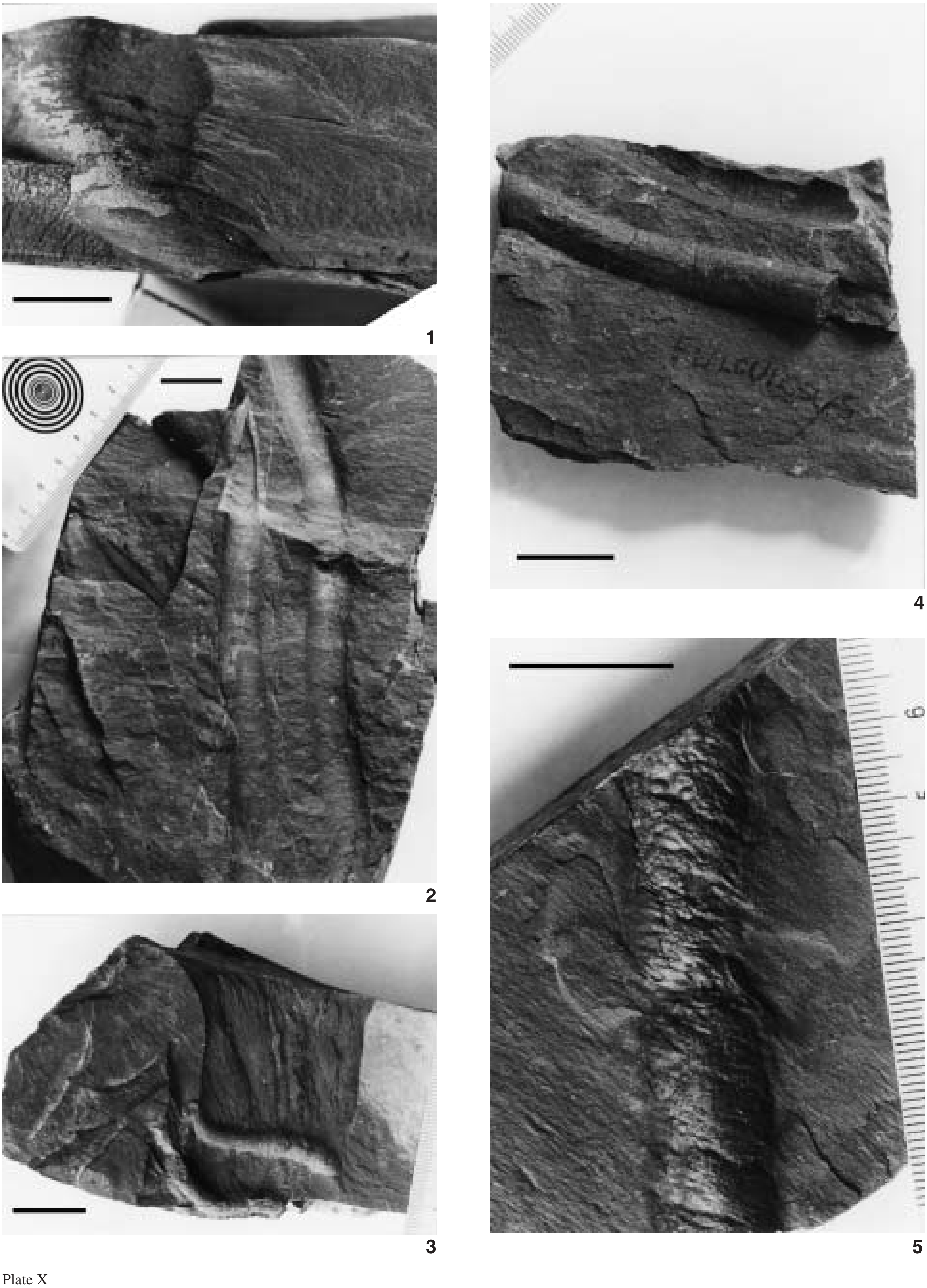


Plate X
1 – *Diplocraterion paralellum* Torell 1870, oblique view of one of the "limbs" (left) and the plane of the spreite (middle). 2–4 – *Furculosus* isp. 5 – *Planolites* isp. Olšovec locality.