Benthic microfossils from the Teplá–Barrandian Late Proterozoic (Blovice Formation, Czech Republic)

Bentické mikrofosilie z tepelsko–barrandienského pozdního proterozoika (blovické souvrství, Česká republika) (Czech summary)

(2 text-figs., 4 plates)

MILADA VAVRDOVÁ

Geological Institute, Academy of Sciences of the Czech Republic, Rozvojová 135, 165 00 Praha 6, Czech Republic

Dark carbonaceous cherts from the Blovice Formation (Kralupy–Zbraslav Group, Teplá–Barrandian Late Proterozoic) contain planktonic and benthic types of silicified microbiota, organo-sedimentary textures and structures and other evidence of locally preserved sequences which originated in near-shore, littoral environment. Microfossils were studied in 200 thin sections, as palynological residua and by SEM rock-surface observation. Three successive generations of silicites can be distinguished, based on both mat-forming benthic and planktonic microfossils. Depositional environment includes subtidal shelves, oolitic shoals, hypersaline lagoons and supratidal algal marshes. Silicified stromatolitic algal breccias, oolitic limestones and silicified biostromes and presumed layered evaporites have been investigated. Agglomerations of coccoid, filamentous, colonial and vase-shaped microfossils are described.

Key words: Late Proterozoic, Blovice Formation, stromatolites, silicified biota, palaeoecology

Introduction

The present paper is an attempt to summarize the most frequent fossil remains from the older part of sedimentary sequences of the Late Proterozoic age in the Teplá–Barrandian region.

Procaryotic cyanobacteria are distinguished by a remarkable evolutionary conservatism (Schopf 1992) and by a constraint to specific lithological facies. Permineralized stromatolitic build-ups and algal crusts are generally preserved in situ and consequently represent suitable tool for a determination of microfacies, palaeogeographical reconstructions and basinal analysis. Coastal algal communities have been described in numerous reports and studies. Among the most frequently quoted are descriptions of microbial coastal zones established on dominant types of mat-forming cyanobacterial organisms, known from the modern microbial coastal communities from Andros Island, Bahamas (Monty 1967, Monty – Hardie 1976), from Persian gulf (Abu Dhabi sabkha, Kendall – Skipwith 1968) and from evaporitic flats on the Pacific coast of Mexico (Horodyski – Vonder Haar 1975, Horodyski 1977). The best known example of modern stromatolitic bioherms represents Hamelin pool, the barred hypersaline embayment in Shark Bay, Western Australia (Playford – Cockbain 1976).

Exceptionally well preserved Neoproterozoic assemblages found in chert nodules in the Draken Conglomerate Formation, Spitsbergen (Knoll et al. 1991) have shown a possibility to utilize a close analogy in morphology, abundance and variability of Neoproterozoic and modern allochthonous and mat-forming cyanobacteria for paleoenvironmental deductions. Several biofacies can be distinguished, which span the high energy, storm-influenced outer shelf, barred basins, microbial barriers, and evaporitic flats. Supratidal zone covered with leathery microbial algal mats is not a negligible biofacies: on the eastern coast of Andros Island (Bahamas), coastal saline marshes represent 4 to 8 km wide belt extending up to 60 km, forming the most extensive unit in the coastal ecosystem (Monty 1967).

Apart from the characteristic dominating cyanobacterial forms involved in the construction of stromatolitic crusts, other phenomena like sediment/fossil ratio, a degree of diversity of microbial communities and presence of evaporitic minerals characterize the original sedimentary setting (Fairchild et al. 1991, Knoll et al. 1991).

The research has been partially financed by the Ministry of the Environment, Prague. The reference material is stored in the Collections of Geological Institute of Academy of Sciences, Czech Republic, Prague.

Geological situation

The predominantly flyschoid Neoproterozoic Štěchovice Group is preceded by the Kralupy–Zbraslav Group with more variegated lithological development. Blovice Formation represents the lower part of the unit, comprising at least 5 thousands meters thick volcano-sedimentary complex of greywackeous, aleuritic and argillitic rocks associated locally with spilitized tholeiitic and calc-alkaline lavas and pyroclastics. Abundant lenses of dark carbonaceous cherts (phtanites, lydites) and rare limestones distinguish the lower part of the Barrandian Late Proterozoic sequences. Cherts are massive or brecciated, usually pyritic, often with well-developed regular lamination and microlamination. More than 500 outcrops of lydites have been recognized so far (Mrázek, oral communication). Extensive accumulations of dark shales rich in pyrite are concentrated along the central volcanic belt, in the broad environment of Plzeň. Rare limestones (massive, finely laminated, oolitic, stromatolitic) occur as lensoid bodies about 200–300 m in length. Recrystallized oolitic fragments form small intraclasts in sparitic limestones. Twinned calcite crystals overprint both nuclei and highly ordered cortex of oolites (Černice and Oplot near Přeštice, Pl. III, fig. 4).

In the eastern part of the studied area the relatively low degree metamorphosed successions grade into metasediments of Stříbro–Plasy belt and than into strongly degraded monotonous facies of the Teplá Upland.

Sedimentological facies analysis (Holubec 1988) allows to distinguish several lithological cycles from basal greywackes to graphitoid shales. Lithofacies are arranged linearly and symmetrically within the Barrandian Late Proterozoic basin. The Rabštejn Group in the eastern limb represents according to Holubec the oldest stratigraphical unit.

Acritarchs significant for the biostratigraphic correlation (late Riphean to Early Vendian) have been recorded by Fatka and Gabriel (1991) from the locality Dlouhá skála near Příkosice (9 km south of Rokycany).

Microfossils from the lydites enabled the correlation of the Blovice formation with the lower part of French Brioverian (Pacltová 1977, Konzalová 1981, Chauvel – Mansuy 1991).

Predominantly deep sea origin is generally presumed for the Teplá–Barandian Late Proterozoic complex, although indications of locally preserved littoral sedimentation are increasing. According to Kukal (1985), clastic sequences of subsiding Proterozoic basin are predominantly of intrabasinal origin. The differentiated basinal relief can be presumed in the vicinity of volcanic belts, where depressions with anoxic regime, evaporitic flats, sabkhas and carbonate build-ups were formed. Coastal lithofacies were exposed to complex processes which included mineralization, leaching, compaction and subsequent silicification. The main source of silica were (in presumed absence of silica-secreting organisms) hydrothermal vents and silica-rich brines from underlaying lavas and pyroclastics.

Jaspilitic iron ores and silicites with bleached vanadiferous patches (Kříbek et al. 1993) indicate according to Kříbek diagenetic processes connected with algal activities in coarsely brecciated laminated silicites at the locality Kokšín near Nové Mitrovice (Pl. I, figs. 1, 2). Vavrdová (1994) distinguished three informal generations of cherts and limestones, based on predominating allochthonous and mat-forming cyanobacterial species. Within each of the "generation", biofacies indicating subtidal and intertidal environment can be recognized. Supratidal algal crusts were most frequently encountered at localitites in the Stříbro–Plasy belt.

List of fossiliferous localities

Nižbor Anticline (Křivoklát upland): (*Huroniospora psilata* Barghoorn 1965 – *Gunflintia minuta* Barghoorn 1965).

1. Broumy near Kublov, the abandoned quarry 1.8 km S of the village Broumy, variegated fossiliferous cherts.

2. Černá skalka, Podmokly near Kladno, outcrops of variegated cherts in the dust road 1 km NE from the village.

Blovice Anticline (*Eomicrocoleus crassus* Horodyski et Donaldson, 1980 – *Protoleiosphaeridium laccatum* Timofeev) Fensome et al. 1990.

3. Černice, southern Plzeň. Outcrop in a right bank of river Úslava. Laminated limestones with stromatolitic textures, graphitoid shales with lenses of oolitic limestones.

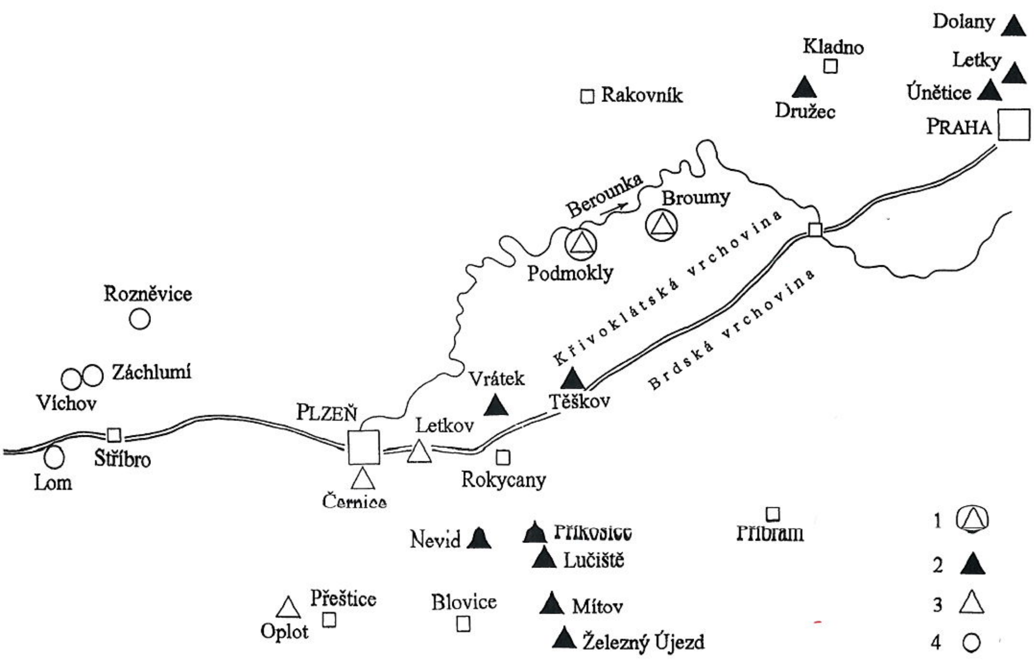

Fig. 1. Selected localities of fossiliferous silicites, stromatolites and limestones. *1* – Nižbor Anticline, silicites of the first generation; *2* – Main volcanic belt, silicites of the second generation; *3* – limestones; *4* – Stříbro–Plasy belt, silicites of the third generation.

4. Černice, southern Plzeň, city sewage excavation 200 m from the bank of river Úslava, depth 21 m. Graphitoid shales with lenses of white limestone with scattered oolites.

5. Dlouhá skála, outcrops 800 m NE from the village Příkosice (8 km south of Rokycany). Domal stromatolites, stiriolites (geysirites) and silicified oolitic and pisolitic structures.

6. Dolany near Kralupy, outcrops in a dust road 100 m SW of the village. Dark grey to black silicites with microlamination and silicified black shales.

7. Kokšín near Spálené Poříčí, rock debris in a dust road on the southern slope of the hill. Unsorted chaotic breccias with clasts of laminated silicites.

8. Lučiště near Blovice. Abandoned quarry 1 km north of the village Lučiště. Stromatolitic textures (LLH-type of domical nodular stromatolites), silicified evaporitic minerals.

9. Oplot near Přeštice. Abandoned limestone quarry 4 km west of the village. Oolitic limestones with degraded stromatolitic layers.

10. Teškov near Zbiroh; massive black nodules of amorphous silicites with degraded cellular trichomes. Isolated phtanitic boulder 300 m N of the village.

Stříbro anticline (*Siphonophycus kestron* Schopf, 1968 – *Myxococcoides cantabrigiensis* Knoll, 1982).

11. Rozněvice near Pernárec, rock debris on the slope edge, 1.2 km W of the village. Finely laminated carbonaceous silicites and silicified shales.

12. Záchlumí near Stříbro. Outcrops at the forest margin 0.5 km W of the village. Carbonaceous silicites with stromatolitic textures.

Micropaleontology

Fine-grained cherts represent a suitable medium for a preservation of even fragile organic remains. Microfossils in lydites have been known since 1925 and 1927, when Ignác Rodič described and illustrated both unicells (as *Sphaerosomatites* Rothpletz) and larger forms, presumed to represent radiolarians. Micropaleontological investigation of silicified (Vavrdová 1966, Pacltová 1970, 1972) and colonial (Drábek 1972, Pacltová 1977, Konzalová 1973, 1981) microorganisms proved the possibility to correlate Blovice Formation with the lower part of French Briovérian (Chauvel – Mansuy 1991).

Paleontological investigations included: A) spherical (coccoid) microfossils, acritarchs with acid-resistant envelopes and cellular agglomerations; B) nematoclasts and filamentous mats, multicellular filamentous nodules, degraded trichomes; C) vase-shaped microfossils (possible heterotropic protists).

A) Spherical types (unicells, sphaeromorphic acritarchs and spherical colonial forms)

Most frequent types of fossil remains encountered in the Blovice Formation are simple small spheres (diameter 3 to 15 μm; 600 specimens measured) with smooth or psilate wall. Unicells form in places agglomerations of several hundreds of specimen's (locality 1). Resistant polymeric outer wall, if preserved, reveal fractures and deformations after framboidal pyrite.

A classification of unicells is hindered by frequent secondary deformations of originally elastic vesicle wall and presumed presence of various stages of a life cycle of procaryotic microorganisms. Several genera and species have been defined, with closely similar morphology: *Caryosphaeroides* Schopf, 1968 (Pl. II, fig. 2), *Glenobotrydion* Schopf, 1968; *Huroniospora* Barghoorn, 1965 and *Sphaerophycus* Schopf, 1968. Priority, however, belongs to *Palaeocryptidium cayeuxi* Deflandre, 1955 (Pl. II, fig. 1), found at each of the investigated localities. Less frequent are forms with minor irregular sculpture (*Favososphaeridium variabilis* Cloud et Germs 1971), forms with double wall (*Glenobotrydion* Schopf, 1968) and relatively small (6–22 μm) forms with regular morus-like apppearance (Pl. IV, figs. 1, 2). These are partly conspecific with species *Sphaerocongregus variabilis* Moorman (1974), and *Bohemipora pragensis* Pacltová 1972. Identical microfossils have been assigned to the species *Nevidia sphaerocellaria* Vavrdová 1966 and *N. multicellaria* Vavrdová 1966 (Pl. II, figs. 1, 3).

Relatively large multicellular colonies of the species *Myxococcoides cantabrigiensis* Knoll 1982 occur either as mat-dwellers in cherts with stromatolitic textures (Vavrdová 1994, Pl. IV, fig. 3), or in silicified shales. Individual cells are closely packed in regular ovoidal bodies upto 260 μm in size. Oval carbonaceous discs about 300 μm to 1 mm in size (aff. *Chuaria* and *Tawuia*) have been ascertained in micritic limestones (Oplot near Přeštice, Pl. II, fig. 6) and in dark cherts rich in organic matter (Záchlumí near Stříbro).

B) Filamentous types

Filamentous types are preserved rarely as organic-walled nematoclasts. Exceptionally, uniseriate cellular trichomes with barrel-shaped to ellipsoidal cells (*Oscillatoriopsis* spp.) have been encountered in amorphous, cryptocrystalline cherty concretions (locality Těškov near Zbiroh).

Mineralized sheats of trichomes were ascertained in thin sections of metalydites from the Stříbro–Plasy metamorpphic belt (*Siphonophycus kestron* Schopf 1968, *S. capitaneum* Nyberg et Schopf 1984 and *S. inornatum* Zhang 1981). Silicites from the Zbiroh anticline contain limonitized filaments of *Gunflintia minuta* Barghoorn 1955 (Pl. IV, fig. 4). Prostrate filamentous mats, forming cohesive bituminous films, are comon in oolitic limestones (Černice *Eomicrocoleus crassus* Horodyski et Donaldson 1980 (Pl. II, fig. 5), in cherts with stromatolitic textures (Záchlumí near Stříbro, Vavrdová 1994, Pl. IV, fig. 5) and in silicified shales (Dolany near Prague).

Degraded algal trichomes disintegrated into 15 loosely attached ring-like segments were observed at the loca-

Fig. 2. Nodular colony of filamentous trichomes with cellular structure (aff. *Rivularia*). Locality: Rozněvice near Stříbro, x1000.

lity Rozněvice near Stříbro, in silicites with well-developed microlamination. Overall length of trichome attains 300 μm, width 40–50 μm. In the same thin section, hemispherical nodules preserved as compact masses of radial filaments have been detected (Text-fig. 2; Pl. IV, fig. 6). Nodules are preserved in vertical section, with regular concetric segmentation of filaments by horizontal cellular walls, giving the closely packed tissue regular zonation. Size of the specimen attains 300 μm, individual cells 1 to 3 μm. The botanical affinities of ascertained fossil remains are inevitably uncertain. Larger hemispherical nodules with similar structure are formed by crustose benthic algae, especially red algae in reefal facies. First bangiophyte red alga has been found in silicified carbonates from the Hunting Formation (Knoll 1992). Small size of the Barrandian specimens indicate a procaryotic affinity of nodular tissues, most probably colonial cyanobacteria such as the modern colonies of *Rivularia polyotis* (after Geitler 1960, *in* Voronova – Radionova 1976).

C) Vase-shaped microfossils

Permineralized microfossils with elongate vase-shaped, flask-shaped or barrel-shaped lorica and oral aperture were especially common in thin sections of silicites from the Stříbro–Plasy metamorphic belt.

Fossils are rarely preserved as organic-walled bodies. More often, the wall is impregnated by iron oxides and sulphides. Very frequently fossils are enclosed in a chamber filled by very finely fibrose quartz (Pl. IV, fig. 5). Size of specimens range from 60 to 120 μm, rarely up to 260 μm.

Vase-shaped microfossils are known from various biotopes of Neoproterozoic benthic and off-shore communities 700–800 Ma old. Best known examples are those observed in phosphate nodules in southern Sweden (Knoll – Vidal 1980). They are believed to represent heterotrohic loricate protists, apparently related to tintinnids.

Biosedimentary textures and paleoecology

Some of the laminated Late Proterozoic silicites from the outcrops between Blovice, Rokycany and Plzeň show structures and textures, which Pouba (1973) and Pacltova and Pouba (1975) denoted as stromatolitic, representing silicified bioherms of procaryotic microorganisms. Stromatolitic crusts are usually brecciated (Pl. I, figs. 1, 2), modified by processes connected with leaching, diagenesis, compaction, dolomitization and later mobilization of organic matter. Two main types of biosedimentary textures can be distinguished: horizontal biostromes and nodular laterally linked hemispheroids (genus *Coleniella* Korolyuk). SEM observation of silicite fragments revealed the abiogenic nature of some of the microlaminites as well as presence of laminites, the origin of which is closely connected with microbial activities.

The stromatolitic textures are supported by other geochemical, geological and mineralogical evidence, such as finds of solid bitumens in the interpillow fillings of silitic andesitic basalts (Mítov near Spálené Poříčí, Kříbek et al. 1993) and sulphur isotope analysis indicating a bacteriogenic reduction of sulphates in barred hypersaline basins (Hladíková in Mrázek et al. 1990). Further evidence include quartzose pseudomorphs: silicified rhomboedra with preserved relict cleavage (Kříbek 1992) and silicified dolomite and evaporites at the locality Lučiště near Spálené Poříčí (Pl. III, fig. 3). Oolitic and pisolitic sequences indicate a proximity to a shore line.

More than 40 sites in which black fossiliferous cherts are genetically connected with layered evaporites, dolomitization, oolitic sequences and intratidal stromatolites have been reported so far. Among the best known are: 3.46 Ga old North Pole chert (Pilbara Craton, western Australia, Barley 1993), 2 Ga old Pokegama Quartzite, SE Minnessota (Cloud – Licari 1972), 2 Ga old Gunflint Iron Formation, Ontario (Awramik – Barghoorn 1977), 1.9 Ga Kasegalik Group, Belcher Supergroup, Arctic Canada (Hofman 1976), 1.2 Ga old Uluksan Group, Baffin Island (Hofman – Jackson 1991) and Dismal Lakes group, Northwest Territories (1.2 Ga, Horodyski – Donaldson 1980).

The following biofacies can be distinguished in the Barrandian Late Proterozoic:

1. Subtidal fragmented facies (mikrosparitic limestones with intraclasts of oolitic limestones, in which allochthonous microfossils dominate (fragments of trichomes, unicells, rare acritarchs). Pl. II, fig. 4. Characteristic locality: Černice near Plzeň.

2. Reefal facies: limestones and silicified carbonates with high-relief stromatolites, algolites with vertically oriented trichomes (Pl. III, fig. 1), dolomitized sequences (Pl. II, fig. 3). Quartzose pseudomorphs with relict cleavage and elongated crystals with dentulous edgesand silicified lenses presumed to be replaced sulphates (Skoček – Vavrdová 1994). Characteristic locality: Příkosice near Rokycany; Dlouhá skála.

3. Lagoonal pelitic facies with framboidal pyrite, vase-shaped microfossils (*Melanocyrillium*) and colonial forms (*Chabiosphaera* sp., *Myxococcoides* sp.) black carbonaceous muds rich in organic sludge. Pl. IV, fig. 5. Characteristic locality: Záchlumí near Stříbro, site "Na šachtách".

4. Intertidal zone with low-relief stromatolites (LLH type of mats), silicified limestones and limestones with in-situ preserved microbial mats (multiserial filaments of *Eomicrocoleus* spp., Pl. II, fig. 5). Characteristic locality: Lučiště near Spálené Poříčí.

5. Supratidal algal marshes and evaporitic flats with horizontal stromatolitic crusts (robust filamentous forms of cyanobacteria: *Siphonophycus kestron* Schopf, 1968; *S. capitaneum* Nyberg et Schopf, 1984). Mineralized mats of cyanobacterial sheats prevail in investigated thin-sections. Characteristic locality: Záchlumí near Stříbro.

Summary

Microfossils recovered from silicites, silicified shales and limestones from 18 localities in Blovice Formation allow to distinguish three generations of microfossils within the lower part of the Kralupy–Zbraslav Group. Over 200 thin sections were studied, in which coccoidal cyanobacteria, rare planktic acritarchs and filamentous mats and possible heterotrophic protists have been ascertained. Reconstruction of sedimentary environment based on recovered microfossils indicate communities tied to off-shore facies (with allochthonous, planktic forms), anoxic bottom sludges (facies with *Melanocyrillium*), shallow plateau (oolitic shoals) and evaporitic coastal plains and marshes (microbial crusts and stromatolitic build-ups).

Submitted March 15, 1999

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Bentické mikrofosilie z tepelsko–barrandienského pozdního proterozoika (blovické souvrství, Česká republika)

V proterozoických sedimentech blovického souvrství zbraslavsko–kralupské skupiny byly zjištěny různé typy bentických mikrofosilií, které dokládají jejich vznik v mělkovodním prostředí. Mikrofosilie spolu s dalšími indikátory povahy fosilního sedimentačního prostředí jako jsou oolitické vápence, silicifikované evapority, fosilní bitumeny a biosedimentární stromatolitické textury a struktury umožnily získat nové poznatky pro paleogeografii Barrandienského mladšího paleozoika. Mikrofosilie byly studovány převážně ve výbrusech, na povrchu fragmentů ve skenovém mikroskopu a v menší míře jako palynologická residua. Buližníky Zbirožska a Kralupska obsahují převážně aglomerace primitivních vláknitých a sférických mikroorganismů, zatímco v metalyditech stříbrsko–plasského pruhu jsou časté supratidální řasové krusty a povlaky, koloniální mikroorganismy a vázovité mikrofosilie interpretované jako lorikátní heterotrofní prvoci.

Explanation of plates

Plate I

1, 2. Chaotic silicified breccias of laminated silicites. Locality Kokšín near Spálené Poříčí (Approximately one third of the original size).
Photos by Ing. A. Langrová, J. Brožek and the author

Plate II

1. Dispersed unicells in laminated silicite/evaporite; rock surface SEM. Density of unicells 30 specimens per 0.01 mm. Locality Dolany near Kralupy.
2. Trasparent unicells (*Huroniospora psilata* Barghoorn, 1955 = aff. *Caryosphaeroides* sp.) in thin section of peloidal silicite. Small pyrite crystals and organic blobs are visible inside of cells. Locality Broumy near Kublov. x1000.
3. Multiunit aggregates (*Nevidia multicellaria* Vavrdová). Rock surface of laminated silicite. Locality Dolany.
4. Recrystallized ooids in intraclasts. Limestone from the locality Černice, southern Plzeň. Thin section 6573, coordinates 3x110.6. x300.
5. *Eomicrocoleus crassus* Horodyski et Donaldson. Thin section 6573, coord. 121.1x4.5. Locality Černice near Plzeň. x330.
6. Degraded carbonaceous body (aff. *Chuaria*). Locality Oplot near Přeštice. x330.

Plate III

1. Vertical trichomes resembling the modern cyanobacterial species *Scytonema myochrous* (*Girvanella* type). Locality Dlouhá skála near Příkosice, thin section 8354, x300.
2. “Oolitic” structure of stiriolites from the locality Dlouhá skála near Příkosice, thin section 8354, coordinates 11.2x115.3. x100.
3. Silicified pseudomorphs of dolomite (rhombohedral crystals with preserved relict cleavage fractures). Locality Lučiště near Spálené Poříčí. x25.
4. Recrystallized ooids with partially preserved highly ordered cortex. Thin section 6573, coord. 9.6x114.8. Locality Černice near Plzeň. x330.

Plate IV

1–3. Unicells in silicified chert with well developed microlamination. Locality Dolany near Kralupy. SEM observation. 1 – x2000, 2 – *Nevidia multicellaria* Vavrdova, x6500, 3 – replacive microlamination, x600.
4. *Gunflintia minuta* Barghoorn, 1965; thin trichomes in thin section of peloidal chert from the locality Broumy near Kublov. x1000.
5. Permineralized lorica of vase-shaped microfossil (*Melanocyrilium*) in a cavity filled with fibrous quartz. Thin section 4/1, coord. 17.1x120. Locality Záchlumí near Stříbro. x330.
6. Nodular colonies of filamentous microbial trichomes (aff. *Rivularia*). Thin section Roz-1, coord. 8.2x106.4. Size 300 μm. Locality Rozněvice near Stříbro. x330.

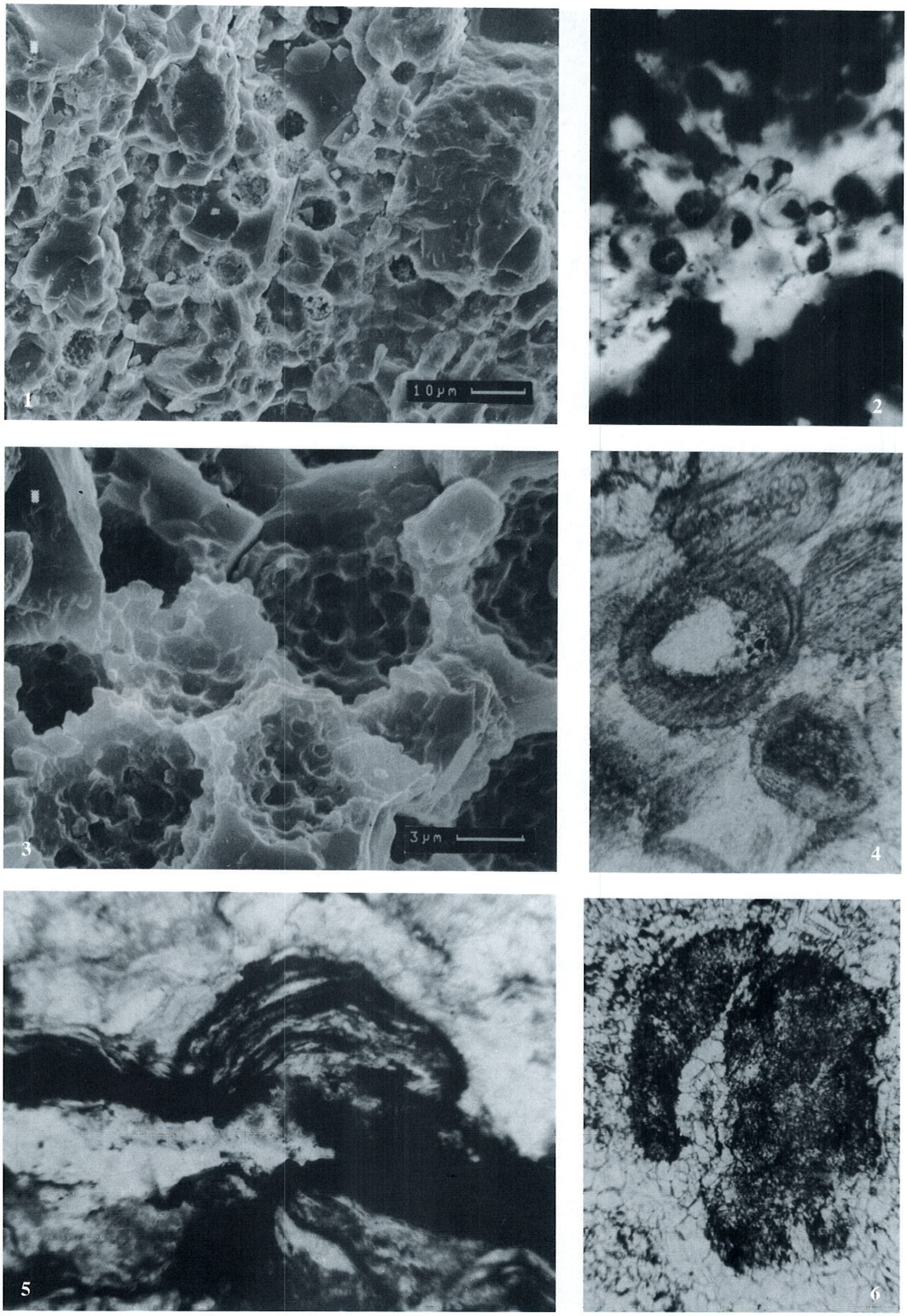
M. Vavrdová: Benthic microfossils from the Teplá–Barrandian Late Proterozoic (Blovice Formation, Czech Republic) (Pl. I)

1

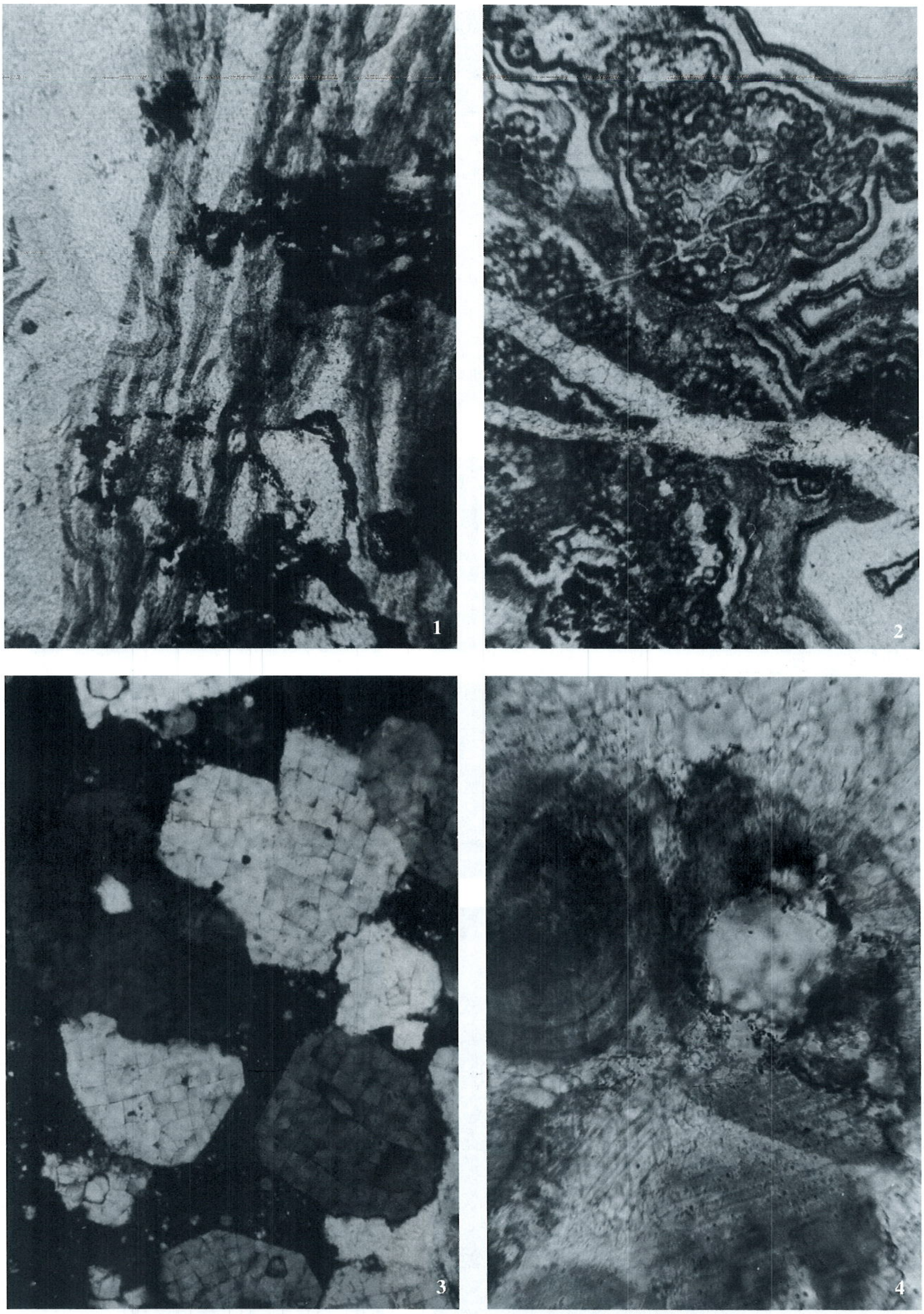
2

For explanation see p. 48

M. Vavrdová: Benthic microfossils from the Teplá–Barrandian Late Proterozoic (Blovice Formation, Czech Republic) (Pl. II)



M. Vavrdová: Benthic microfossils from the Teplá–Barrandian Late Proterozoic (Blovice Formation, Czech Republic) (Pl. III)



M. Vavrdová: Benthic microfossils from the Teplá–Barrandian Late Proterozoic (Blovice Formation, Czech Republic) (Pl. IV)