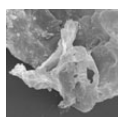


Proterozoic acritarchs from the Precambrian-Cambrian transition in southern Moravia (Měnin-1 borehole, Czech Republic)

MILADA VAVRDOVÁ



Well preserved and varied sphaeromorphs, filamentous trichomes and synaploid organic-walled microfossils occur in fine-grained clastics in the Měnin-1 borehole. Thirty genera with 40 species have been identified, previously known from Meso- and Neoproterozoic sediments. The Proterozoic microfossils are excellently preserved, not affected by post-diagenetic thermal alteration. The Vendian age is documented by the presence of the taxa *Bavlinella faveolata* (Shepeleva) Vidal, 1976, *Chabiosphaera bohémica* Drábek, 1972, *Obruchevella valdaica* (Shepeleva ex Aseeva) Jankauskas *et al.*, 1989, *Podolina minuta* Hermann in Timofeev *et al.*, 1976, and *Primoflagella speciosa* Gnilovskaya, 1983. The palynological residuum contained no acritarch species of Early Cambrian age, although the basal Cambrian *Asteridium tornatum*–*Comasphaeridium velvetum* palynozone was ascertained from 266 m below the level with acritarchs. Thin sections from the Měnin-1 borehole suggest a possible presence of more than 600 m of Vendian sediments. Irrespective of the possible secondary origin of the recovered microfossils, the existence of extensive Proterozoic marine sedimentation within the southern part of the Brunovistulicum is clearly demonstrated. Sediments from the Precambrian-Cambrian transition were not subjected to Cadomian or younger metamorphic processes. • Key words: Vendian, acritarchs, basal clastics, southern Moravia.

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Milada Vavrdová, Academy of Sciences of the Czech Republic, Institute of Geology v.v.i., Rozvojová 269, 165 02 Praha 6, Czech Republic; vavrdova@gli.cas.cz

The eastern part of the Czech Republic is underlain by a distinctive unit with an independent geological history, called either the Moravo-Silesian Terrane (Pharaoh 1999) or the Bruno-Vistulicum (Dudek 1980). The Brunovistulicum, as the easternmost margin of the Bohemian Massif, acted as a stable foreland for both the Variscan and Alpine fold belts according to Kalvoda *et al.* (2003). The eastern part of the unit, buried beneath Carpathian nappes, is relatively undeformed and was not evidently involved in the Variscan orogeny.

The Brunovistulicum has been interpreted alternatively as an integral part of the Fenno-Sarmatian Platform (Suk 1984, Jaworowski & Sikorska 2006), as a Cambrian-docked microplate (Belka *et al.* 2000), or as a part of the late Proterozoic passive margin of the Gondwanan paleocontinent (Finger & Pin 1997, Raumer *et al.* 2003). One of the arguments for the latter assignment is the Brno Massif, a body of igneous and metamorphic rocks, for which Cadomian consolidation and the Pan-African provenance has recently been claimed (Breemen *et al.* 1982, Franke 1995, Nawrocki & Poprawa 2006). However, some

parts of the Brno Massif are much older, at least 725 Ma (Finger *et al.* 1999). A recent sedimentological assessment of the Cambrian siliciclastic sequences from the neighbouring Małopolska Unit and Lysogóry block (Jaworowski & Sikorska 2006) confirms a Baltic affinity and the autochthonous nature of both units, situated south of the Trans-European Suture Zone.

The clastic cover of the Brno massif, informally known as basal clastics, is known from several outcrops in tectonic “zones” (Dvořák 1998) and from more than 100 boreholes drilled by Moravian Oil Industries, Hodonín. The Měnin-1 borehole, situated in the Carpathian Foredeep 17 km SE from Brno, is distinguished by a relatively thick succession of the so-called basal clastics, which underlie the Devonian carbonate complex. The basal clastic member of the Phanerozoic succession attains 1500 m in thickness. Conglomerates, quartzose sandstones and subarkoses with less common pink, reddish and violet siltstones prevail in the succession (Nehyba in Vavrdová *et al.* 2003). Fine-grained pelites are more extensively developed than in other boreholes.

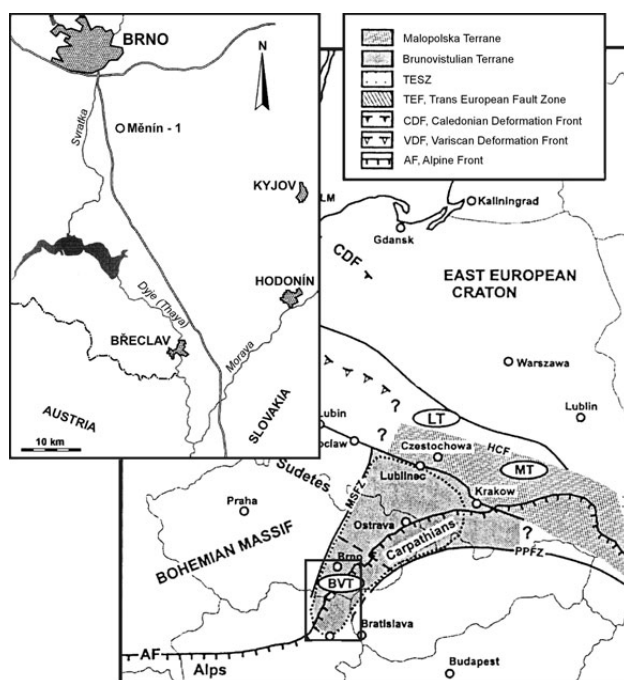


Figure 1. Structural setting of the Brunovistulicum and location of the study area in southern Moravia. Slightly modified after Buřa *et al.* 1997. Abbreviations: BVT – Brunovistulian Terrane, MT – Malopolska Terrane, MSFZ – Moravo-Silesian Fault Zone, PPFZ – Peri-Pienian Fault Zone, CDF – Caledonian Deformation Front.

In places, the thickness of the pelitic sediments exceeds 30 m. The borehole, despite its depth of 2100 m, did not reach the crystalline basement.

The basal clastics, devoid of organic remains and developed in the Old Red Sandstone facies, have been correlated with the Early-Middle Devonian (Chlupáč 1967, Dvořák 1998). The history of palynological research, which has significantly modified the biostratigraphy of the basal clastics, was summarized in Vavrdová (2006). The main objective of the present investigation has been to obtain more information on the age of the massive mudstones in core 27A, from the level 1299 m to 1300.2 m. The sample, assigned originally to the basal Cambrian, contained nearly exclusively pre-Phanerozoic palynomorphs. Although the allochthonous or autochthonous origin of the Ediacaran species above the sediments of the basal Cambrian age (core 29, Vavrdová *et al.* 2003) is still not sufficiently elucidated, the presence of unmetamorphosed ma-

rine sediments in close proximity to the borehole is significant.

Material and methods

Vendian acritarchs were studied mainly as residua produced by chemical leaching of an approx. 20 g rock sample with the use of standard palynological procedures (HCl, HF, HNO₃, sieving). Massive fine-grained grey to greenish-grey pelites from core number 27A (depth 1297–1300 m) were productive in repeated analysis. The limited amount of the available core samples does not allow assessment with the overlying strata. Bedding is not clearly visible, but appears to be nearly horizontal, and cleavage is minor or absent.

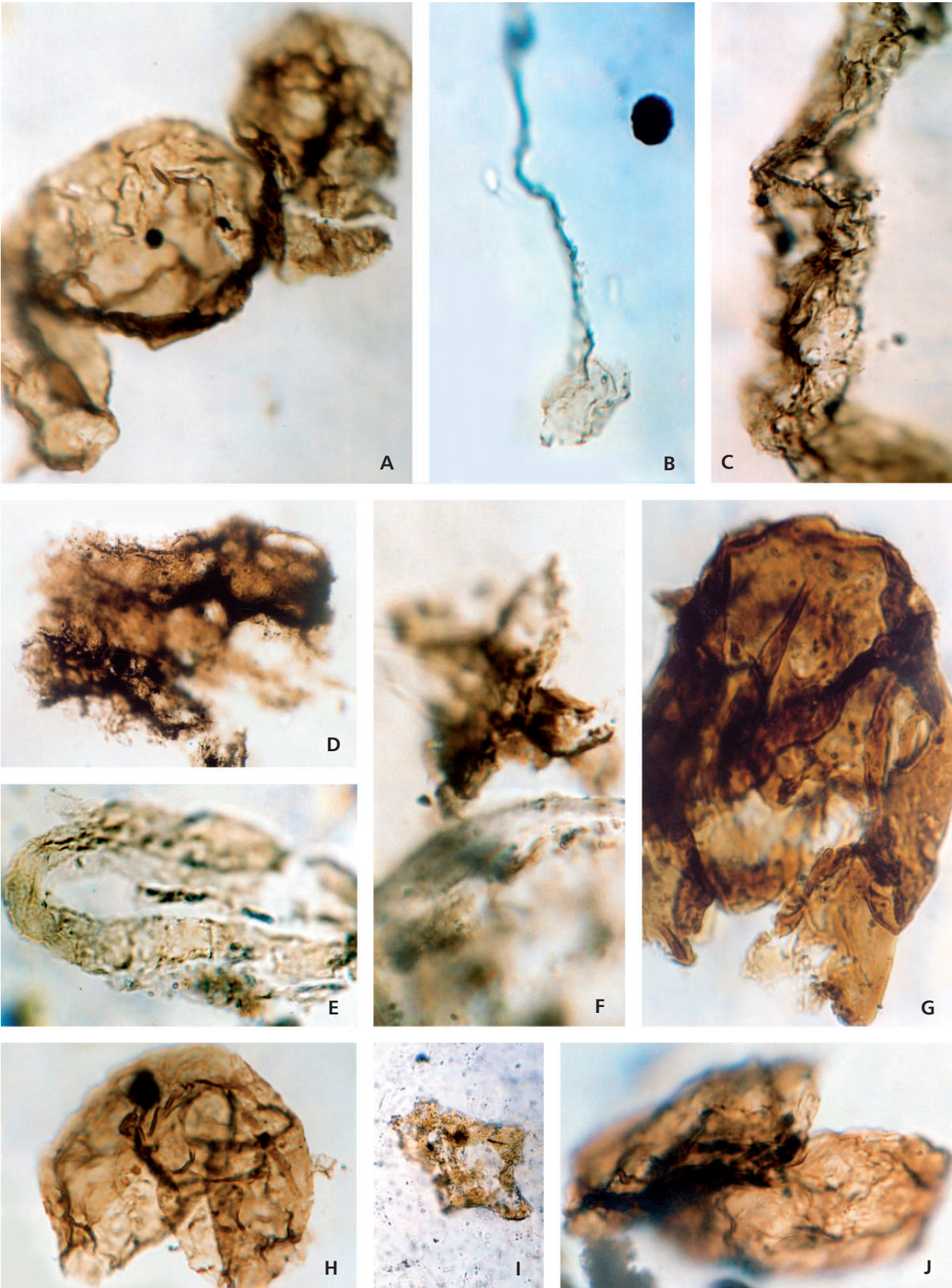
The palynological residuum was mounted in permanent palynological slides. The relatively abundant palynomorphs were coated and observed in the scanning electron microscope (Fig. 3).

Thin-walled specimens display a pale yellow colour (*Archaeotrichion* sp.). The brownish-orange tint of the vesicle wall was observed in conspicuously thick-walled specimens (Fig. 2G). The colour of the recovered microfossils indicates that very low thermal alteration of both sphaeromorphs and filamentous trichomes had occurred, not exceeding 50 °C (*Pellicularia tenera* Jankauskas, 1980, Fig. 2C). The presence of long twisted processes, exceeding several times the size of the main body (*Primoflagella speciosa* Gnilovskaya, 1983, Fig. 2B) documents the partial preservation of the original elasticity of the cell wall.

Palynological analyses have been supplemented with a study of thin sections from core Nos 16 to 34 (depth 473–2100 m). Fragments of Phanerozoic acritarchs have been ascertained in thin sections of rock samples from core Nos 16 (473–477.5 m), 17 (507–512 m), 18 (563–565.5 m), 19 (655–660 m), 21 (856–857.7), 23 (988.5–989.7), and 29 (1565–1566.5 m).

Questionable Vendian leiospheres, acritarchs, filaments and globular colonies were observed in core Nos 24 (1059–1061 m), 25 (1160–1161.5 m), 27 (1299–1300.2 m), 31 (1804.6–1805.8 m), 32 (1899–1900.5 m), 33 (2039–2042 m), and 34 (2097–2100 m). In bright-coloured, oxidized rocks of red, deep-purple and light-green colours, the polymeric wall of the palynomorphs was replaced by limonite or other minerals.

Figure 2. A – *Arctacellularia tetragonalis* (Maithy) Hofmann & Jackson, 1994, size 120 µm. • B – *Primoflagella speciosa* Gnilovskaya, 1983, size 125 µm. • C – *Pellicularia tenera* Jankauskas, 1980, size 210 µm. • D – vase-shaped body, size 195 µm. • E – *Obruchevella valdaica* (Shepeleva) Jankauskas *et al.*, 1989, size 90 µm. • F – *Podolina minuta* (Hermann) Vidal, 1983, size 40 µm. • G – *Valeria tchapomica* (Timofeev) Fensome *et al.*, 1990, size 120 µm. • H – aff. *Shouaioisphaeridium* spp., opened vesicle with three short processes, size 60 µm. • I – *Podolina minuta* (Hermann) Vidal, 1983; thin section No. 1045, depth 2039–2042 m, size 65 µm. • J – *Brevitrichoides bacillaris* (Hermann) Hermann, 1990, size 58 µm. • A, C, E, J – Měnín-1 borehole, sample 27A, depth 1299–1300.2 m. • B, D, F–I – Měnín-1 borehole, sample 27A, depth 1299–1300.2 m (apart from Fig. 2I).



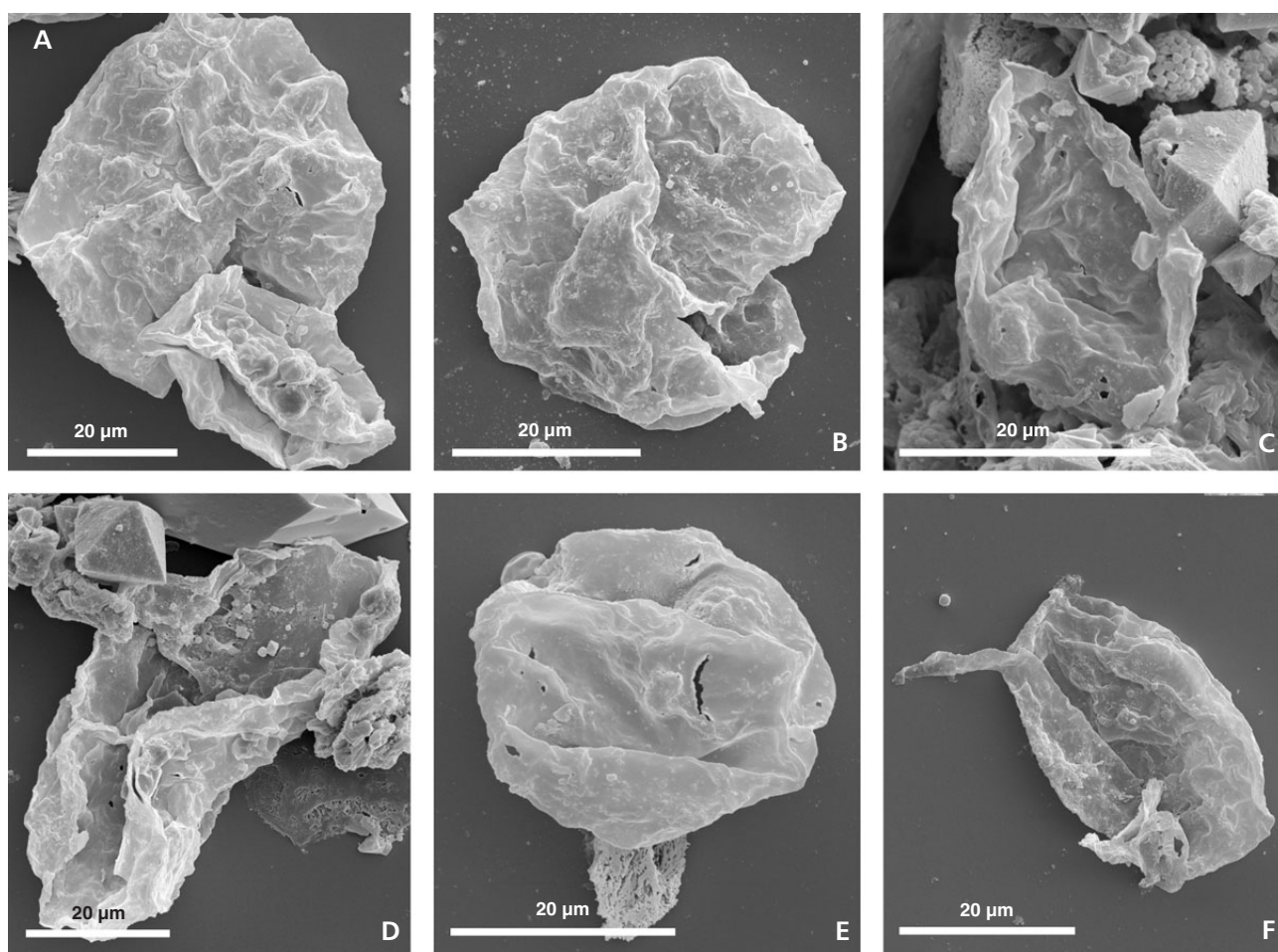


Figure 3. A – *Arctacellularia ellipsoidea* Hermann in Timofeev *et al.*, 1976. • B – *Valeria granulata* (Vidal in Vidal & Sedliecka, 1983) Fensome *et al.*, 1990. • C – *Leiosphaeridia tenuissima* Eisenack, 1958. • D – *Brevitrichoides bashkircus* Jankauskas, 1980. • E – *Leiosphaeridia asperata* (Naumova) Lindgren, 1982. • F – *Primoflagella speciosa* Gnilovskaya, 1983. The Měnín-1 borehole, sample 27A, depth 1299–1300.2 m. SEM images by Vlasta Böhmová.

Palynology

Flattened smooth leiospheres such as *Leiosphaeridia asperata* (Naumova) Lindgren, 1982 (Fig. 3E), *L. crassa* (Naumova) Jankauskas in Jankauskas *et al.*, 1989, *L. tenuissima* Eisenack, 1958 (Fig. 3C), large sphaeromorphs: *Valeria tchapomica* (Timofeev) Fensome *et al.*, 1990 (Fig. 2G), *V. granulata* (Vidal in Vidal & Sedliecka, 1983) Fensome *et al.*, 1990 (Fig. 3B), smooth linear tubes (*Siphonophycus capitaneum* Nyberg & Schopf, 1984, *S. kestron* Schopf, 1968, *S. robustum* (Schopf) Knoll *et al.*, 1991), and coiled spirali-form types (*Obruchevella valdaica* (Shepeleva) Jankauskas *et al.*, 1989, Fig. 2E) dominate the assemblage. Chain-like uniserial aggregates of spheroidal cells are assigned to the species *Arctacellularia ellipsoidea* Hermann in Timofeev *et al.*, 1976 (Fig. 3A), and *A. tetragonala* (Maithy) Hofmann & Jackson, 1994 (Fig. 2A); cylindrical aggregates composed of irregular rows of spherical unicells to the species *Chlorogloeaopsis contexta* (Hermann) Hofmann

& Jackson, 1994 (Fig. 4). Closely arranged threads with parallel orientation (*Polytrichoides lineatus* Hermann, 1974) and other synaploids (*Chabiosphaera bohémica* Drábek, 1972, *Myxocoides* spp., *Satka elongata* Jankauskas, 1979) differentiate the recovered associations from the younger, Phanerozoic palaeocommunities. Irregular colonies of unicells are assigned to the genera *Symplassosphaeridium* spp. and *Synsphaeridium* spp., spindle-like vesicles to the genus *Brevitrichoides* (*B. bashkircus* Jankauskas, 1980, Fig. 3D and *B. bacillaris* (Hermann) Hermann, 1990, Fig. 2J). Spherical and cylindrical aggregates (Fig. 4) can attain the size near the margin of macroscopic remains (up to 1.4 mm), similarly in some of the trichomes (e.g., *Pellicularia tenera* Jankauskas, 1980, Fig. 2C). Sphaeromorphs with a single tubular whip-like protrusion belong to the species *Primoflagella speciosa* Gnilovskaya, 1983 (Fig. 3F).

The assemblage contains densely arranged knots of cyanobacterial trichomes, carbonaceous remains of flat

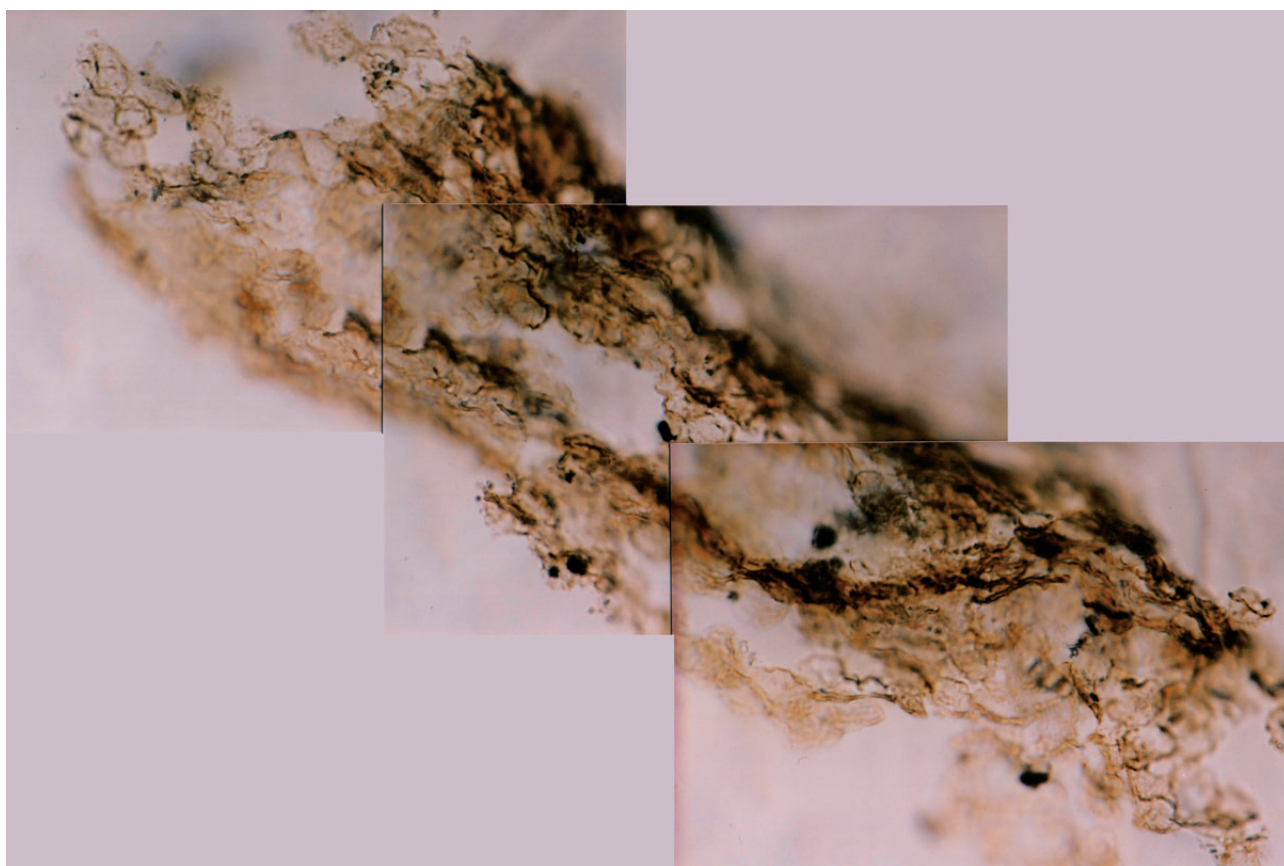


Figure 4. *Chlorogloeopsis contexta* (Hermann) Hofmann & Jackson, 1994, size 280 µm. The Měnin-1 borehole, sample 27A, depth 1299–1300.2 m. Photo by the author.

algal tissues and, rarely, flask-shaped or vase-shaped bodies, smooth or with a conspicuous surface sculpture. A relatively thick-walled vase-shaped body attains a size of 0.2 mm. The surface is decorated with longitudinal striae provided with irregular, semi-circularly perforated and dentate crests (Fig. 2D). The vase-shaped vesicle suggests a possible affinity with metazoans of the genus *Melanocyrrillium*. However, the Moravian specimens differ in the complicate morphology of the surface, which differentiates the taxon from hitherto described forms.

Ribbon-shaped, flattened filaments that form densely entangled masses most probably represent fossil remains of flowing algal islands. Proterozoic acritarchs apparently utilized a different strategy for keeping in surface water masses: large aggregates of unicells (Fig. 4) and filaments kept together with a sticky outer layer, in a similar manner to modern Cyanophyta such as *Microcystis aeruginosa*, or by thin filamentous threads (Fig. 3A).

Stratigraphy

Long-ranging forms of cosmopolitan distribution, which characterize Meso- and Neoproterozoic sediments (Ven-

dian and Late Riphean; Hofmann & Jackson 1994, Mankiewicz 1992, Prasad & Asher 2001, Vidal & Ford 1985, Yin 1991), dominate the recovered palynospectra.

Species *Podolina minuta*, *Octaedrixium truncatum*, *Tanarium tuberosum*, *Tappania tubata*, and abundant filamentous remains are reliable Late Proterozoic markers (Moczyłowska *et al.* 1993; Timofeev 1973; Vidal & Knoll 1983; Vidal & Moczyłowska 1992; Yin 1991, 1997a, b).

The palynological residuum contained no taxa signifying the Phanerozoic, although the sample 265 m below (core No. 29, 1565–1566.5 m) yielded abundant basal Cambrian microfossils [*Asteridium tornatum* (Volkova) Moczyłowska, 1991, *Comasphaeridium molliculum* Moczyłowska & Vidal, 1988; Vavrdová *et al.* 2003]. For this reason, the age of sample 27A was originally determined as basal Cambrian, and the Ediacaran palynomorphs were thought to be allochthonous, recycled from the older strata (Vavrdová 2006). A single specimen of *Asteridium*, reported by Vavrdová 2006, in the sample from the Měnin-1 borehole of the same level (core 27A), is too poorly preserved to give reliable evidence for the younger age. Unfortunately, the patchy, incomplete core material does not allow recognition of the relationship of the

Ediacaran sample to overlying cores. Repeated analyses of mudstones from the interval 1297–1300.2 m accumulated a large amount of pre-Phanerozoic species (see the list below).

Of those recovered, there are 18 in common with palynomorphs described by Hoffmann & Jackson (1994) from shales of Late Riphean age from Baffin Island, Canada (Bylot Supergroup, 1.270–750 Ma) and Riphean microbiota from Siberia (Hermann 1981), southern Urals (Jankauskas 1979), and from the Ganga Basin, India (Prasad & Asher 2001). Therefore, ranges of some acritarch species are either longer than previously thought, or the Moravian basal clastic sequences were fed from even older strata, an equivalent to the older Proterozoic terrigenous successions in the southern part of the East European platform, such as Sławatysze Formation in the Lublin Slope, Poland (Moczyłowska 1995).

Vesicles of acritarchs, identified tentatively in thin sections in the samples not available for palynological analysis, include chains of spherical vesicles of the genus *Arctacellularia* (at depth 1470–1471.5 m), of the species *Podolina minuta* (depth 2039–2040 m; Fig. 2I), and of a fragment of a uniseriate, septate trichome of the genus *Oscillatoropsis* (depth 2097–2100 m).

The composition of the palynological palaeocommunities implies a possible palaeogeographic link with coeval sedimentary accumulations in the Małopolska Block of Poland (Jachowicz 2006), in Svalbard (Knoll & Swett 1987), Greenland (Vidal 1979), Norway (Vidal 1981), central China (Yin 1991, 1997a, b), from the Siberian Platform (Moczyłowska *et al.* 1993), and from the Ganga Basin, India (Prasad & Asher 2001).

Results

Fine-grained siliciclastics from the Měnin-1 borehole (core No. 27A, depth 1299–1300.2 m) yielded diversified, well-preserved acritarchs of Proterozoic age. Thirty genera and 40 species of acritarchs have been identified. The presence of approximately 240 m of Ediacaran-derived sediments within the Early Cambrian succession of Moravia can be explained either as an example of tectonic replacement, of massive recycling from older sequences, or, less probably, as a local survival of a primitive Ediacaran microflora into the basal Cambrian because of reasons unknown. Both the tectonic emplacement of Ediacaran strata and the massive recycling can be considered feasible, although both explanations are difficult to envisage. The high density of palynomorphs in the sample, high variability and their excellent preservation, namely large aggregates (Fig. 4) and coenobia (Vavrdová 2006, Fig. 2J), are not consistent with long transport. The nearly horizontal, little disturbed strata do not signal any significant tectonic deformation.

Although the allochthonous or autochthonous nature here reported of Ediacaran microflora is still not sufficiently elucidated, palynomorphs from the Měnin-1 borehole are nevertheless a valuable evidence for the autonomous position of the Brno Massif at the eastern termination of the Variscides. Evidently, extensive sequences of Late Proterozoic marine siliciclastics existed in the southern part of the Brunovistulicum, which were not subjected to any significant metamorphic processes.

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References

- BELKA, Z., AHRENDT, H., FRANKE, W. & WEMMER, K. 2000. The Baltica-Gondwana suture in Central Europe: evidence from K-Ar ages of detrital muscovites and biogeographical data, 87–102. *In* FRANKE, W., HAAK, V., ONCKEN, O. & TANNER, D. (eds) *Orogenic processes: Quantification and Modelling in the Variscan belt. Geological Society of London, Special Publications* 179.
- BREEMEN, O. VAN, AFTALION, M., BOWES, D.R., DUDEK, A., MÍŠAR, Z., POVONDRA, P. & VRÁNA, S. 1982. Geochronological studies of the Bohemian Massif, Czechoslovakia, and their significance in the evolution of Central Europe. *Transactions of the Royal Society Edinburgh, Earth Sciences* 73, 89–108.
- BULÁ, Z., JACHOWICZ, M. & ŽABA, J. 1997. Principal characteristics of the Upper Silesian Block and Małopolska Block Zone. *Geological Magazine* 134(5), 669–677. DOI 10.1017/S0016756897007462
- CHLUPÁČ, I. 1967. Devonian in Czechoslovakia, 109–126. *In* OSWALD, D.H. (ed.) *International Symposium on the Devonian System, Vol. 1*. Calgary 1967.
- DRÁBEK, K. 1972. *Chabiosphaera bohémica* n. g., n. sp. (Acritarcha) from the Precambrian of central Bohemia. *Věstník Ústředního ústavu geologického* 47, 161–163.
- DUDEK, A. 1980. The crystalline basement block of the Outer Carpathians in Moravia: Bruno-Vistulicum. *Rozpravy Československé akademie věd, Řada matematicko-přírodních věd* 90(8), 1–85.
- DVOŘÁK, J. 1998. Lower Devonian basal clastics – Old Red Formation, Southern Moravia, Czech Republic. *Bulletin of the Czech Geological Survey* 73(1), 55–60.
- EISENACK, A. 1958. Mikrofossilien aus dem Ordovizium des Baltikums. 1. Markasitschicht, *Dictyonema*-Schiefer, Glaukonitsand, Glaukonitkalk. *Senckenbergiana lethaea* 39(5–6), 389–405.

- EISENACK, A. 1965. Mikrofossilien aus dem Silur Gotlands. *Problematica. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 122(3), 257–274.
- FENSOME, R.A., WILLIAMS, G.L., BARRS, M.S., FREEMAN, J.E. & HILL, J.M. 1990. Acritarchs and fossil Prasinophytes: an index to genera, species and intraspecific taxa. *AASP Contributions Series* 25, 1–655.
- FINGER, F. & PIN, C. 1997. Arc-type crustal zoning in the Bruno-Vistulicum, Eastern Czech Republic: a trace of the Late-Proterozoic Euro-Gondwana margin. *Journal of the Czech Geological Society* 42(3), 53.
- FINGER, F., SCHITTER, F., RIEGLER, G. & KRENN, E. 1999. The history of Brunovistulicum: Total-Pb Monazite ages from the metamorphic complex. *Geolines* 8, 21.
- FRANKE, D. 1995. The Caledonian terranes along the southwestern border of the East European Platform – evidence, speculations and open questions, 241–156. In GEE, D.G. & BECKHOLMEN, M. (eds) *The Trans-European suture Zone EUROPROBE in Liblice 1993. Studia Geophysica et Geodetica* 39.
- GARDINER, P.R.R. & VANGUESTAINE, M. 1971. Cambrian and Ordovician microfossils from south-east Ireland and their implications. *Geological Survey of Ireland, Bulletin* 1(2), 163–210.
- GNULOVSKAYA, M.B. 1983. Vendotaenides, 46–55. In URBANEK, A. & ROZANOV, A.Y. (eds) *Upper Precambrian and Cambrian palaeontology of the East-European Platform*. Wydawnictwa geologiczne, Warszawa.
- HERMANN, T.N. 1974. Nachodki masovych skopleniy v rifee, 6–10. In TIMOFEEV, B.V. (ed.) *Mikrofosilii proterozoya i rannego paleozoya SSSR. Paleontologicheskii Zhurnal* 1981(2).
- HERMANN, T.N. 1981. Findings of filamentous algae in the Miroedikcha Formation of the Late Precambrian age. *Paleontologicheskii Zhurnal* 4, 118–122 (in Russian).
- HERMANN, T.N. 1990. *Organicheskii mir milliard let nazad. (Organic world billion year ago.)* 50 pp. Academy of Sciences of the USSR, Institute of Precambrian Geology and Geochronology, Leningrad.
- HOFMANN, H.J. & JACKSON, G.D. 1994. Shale-facies microfossils from the Bylot Supergroup, Baffin Island, Canada. *Journal of Paleontology* 68(4), 1–35.
- JACHOWICZ, M. 2006. Palynological investigation of Precambrian rocks on the Małopolska Block – foreland of the East/European Platform, 28. In BEK, J., BROCKE, R., DAŠKOVÁ, J. & FATKA, O. (eds) *CIMP General Meeting in Prague 2006: Palaeozoic palynology in space and time*. Institut of Geology, Academy of Sciences of the Czech Republic, Prague.
- JANKAUSKAS, T.V. 1978. Plant microfossils from the Riphean deposits of the south Ural. *Doklady Akademii nauk SSSR* 242(4), 913–915.
- JANKAUSKAS, T.V. 1979. Middle Riphean microbotas of the Southern Urals. *Doklady Akademii nauk SSSR* 248(1), 190–193 (in Russian).
- JANKAUSKAS, T.V. 1980. New algae from the Upper Riphean of the Southern Urals and the Ural forelands. *Paleontologicheskii Zhurnal* 4, 107–113.
- JANKAUSKAS, T.V., MIKHAYLOVA, N.S. & HERMANN, T.N. 1989. *Mikrofosilii dokembrija SSSR*. 190 pp. Nauka, Leningrad.
- JAWOROWSKI, K. & SIKORSKA, M. 2006. Lysogóry Unit (Central Poland) versus East European Craton – application of sedimentological data from Cambrian siliciclastic association. *Geological Quarterly* 50(1), 77–88.
- KALVODA, J., LEICHMANN, J., BABEK, O. & MELICHAR, R. 2003. Brunovistulian terrane (Central Europe) and Istanbul zone (NW Turkey): Late Proterozoic and Paleozoic tectonostratigraphic development and Paleogeography. *Geologica Carpathica* 54(3), 139–152.
- KNOLL, A.H. & SWETT, K. 1987. Micropaleontology across the Precambrian-Cambrian boundary in Spitsbergen. *Journal of Paleontology* 61(5), 898–926.
- KNOLL, A.H., SWETT, K. & MARK, J. 1991. Paleobiology of a Neoproterozoic tidal flat/lagoon complex: The Draken Conglomerate Formation, Spitsbergen. *Journal of Palaeontology* 65, 531–570.
- LINDGREN, S. 1982. Algal coenobia and leiospheres from the Upper Riphean of the Turukhansk region, eastern Siberia. *Stockholm Contributions in Geology* 38(3), 35–45.
- LO, S.C. 1980. Microbial fossils from the lower Yudoma suite, earliest Phanerozoic, Eastern Siberia. *Precambrian research* 13, 109–166. DOI 10.1016/0301-9268(80)90002-9
- MANKIEWICZ, C. 1992. *Obruchevella* and other microfossils in the Burgess Shale: preservation and affinity. *Journal of Paleontology* 66(5), 717–729.
- MAITHY, P.K. & SHUKLA, M. 1977. Microbiota from the Suket Shales, Ramapura, Vindhyan System (Late Precambrian), Madhya Pradesh. *The Paleobotanist* 23, 176–188.
- MOCZYDŁOWSKA, M. 1991. Acritarch biostratigraphy of the Lower Cambrian and the Precambrian-Cambrian boundary in south-eastern Poland. *Fossils and Strata* 29, 1–127.
- MOCZYDŁOWSKA, M. 1995. Cambrian microplankton distribution in Iberia and Baltica, and possible palaeogeographic relationship, 117–120. In RODRIGUEZ ALONSO, M.D. & GONZALO CORRAL, J.C. (eds) *XIII Reunion de Geologia del Oeste peninsular. Annual IGCP Project 319–320 Meeting Salamanca, Comunicaciones*.
- MOCZYDŁOWSKA, M. & VIDAL, G. 1988. Early Cambrian acritarchs from Scandinavia and Poland. *Palynology* 12, 1–10.
- MOCZYDŁOWSKA, M., VIDAL, G. & RUDAVSKAYA, V.A. 1993. Neoproterozoic (Vendian) phytoplankton from the Siberian Platform, Yakutia. *Palaeontology* 36(3), 495–521.
- MOORMANN, M.A. 1974. Microbiota of the late Proterozoic Hector Formation, southwestern Alberta, Canada. *Journal of Micropaleontology* 48, 528–539.
- NAWROCKI, J. & POPRAWA, P. 2006. Development of the Trans-European Suture Zone in Poland: from Ediacaran rifting to Early Paleozoic accretion. *Geological Quarterly* 50, 59–76.
- NYBERG, A.V. & SCHOPF, W. 1984. Microfossil in stromatolitic cherts from the Upper Proterozoic Minyar Formation, southern Ural mountains. *Journal of Paleontology* 58, 738–772.
- PRASAD, B. & ASHER, R. 2001. *Acritarch biostratigraphy and lithostratigraphic classification of Proterozoic and Lower Palaeozoic sediments (pre-unconformity sequence) of Ganga basin, India*. 95 pp. Oil and Natural Gas Corporation Ltd., Dehra Dun.
- PHARAOH, T.C. 1999. Palaeozoic terranes and their lithostratigraphic boundaries within the Trans-European Suture Zone (TESZ): a review, 17–41. In THYBO, H., PHARAOH, T. & GUTERCH, A. (eds) *Geophysical investigation of the Trans-European suture zone. Tectonophysics* 314.

- RAUMER, J.F. VON, STAMPFLI, G.M. & BUSSY, F. 2003. Gondwana-derived microcontinents – the constituents of the Variscan and Alpine collisional orogens. *Tectonophysics* 365, 7–22. DOI 10.1016/S0040-1951(03)00015-5
- SCHOPF, J.W. 1968. Microflora of the Bitter Springs Formation, Late Precambrian, central Australia. *Journal of Palaeontology* 42, 651–688.
- SUK, M. Ed. 1984. *Geological history of the territory of the Czech Socialist Republic*. 396 pp. Academia, Geological Survey, Prague.
- SHEPELEVA, E.D. 1974. Stratigraficheskoe raschlenenie vendskikh otlozenij centralnykh rayonov Russkoy platformy po akritarcham, 50–72. In VOZZHENNIKOVA, B.V., TIMOFFEEV, B.V. & SHESHEGOVA, L.I. (eds) *Mikrofosilii SSSR. Transaction of the Institute of the Geology and Geophysics* 81.
- TIMOFFEEV, B.V. 1969. *Spheromorphides of the Proterozoic (Sferomorfidy proterozoya)*. 145 pp. Nauka, Moskva.
- TIMOFFEEV, B.V. 1973. *Microfossils of the Precambrian age from Ukraina*. 58 pp. Akademia nauk SSSR, Izdatelstvo Nauka, Leningrad (in Russian).
- TIMOFFEEV, B.V., HERMANN, T.N. & MIKHAYLOVA, N.S. 1976. *Microfossils from the Precambrian, Cambrian and Ordovician (Mikrofitofosilii dokembryia kembryia i ordovika)*. 107 pp. Nauka, Leningrad.
- VAVRDOVÁ, M. 2006. Two benthic microbial assemblages from the Měnin-1 borehole (Early Cambrian, Czech Republic). *Bulletin of Geosciences* 81(2), 115–122. DOI 10.3140/bull.geosci.2006.02.115
- VAVRDOVÁ, M., MIKULÁŠ, R. & NEHYBA, S. 2003. Lower Cambrian siliciclastic sediments in southern Moravia (Czech Republic) and their paleogeographical constraints. *Geologica Carpathica* 54(2), 67–79.
- VIDAL, G. 1976. Late Precambrian microfossils from the Visingsö beds in southern Sweden. *Fossils and Strata* 9, 1–57.
- VIDAL, G. 1979. Acritarchs from the Upper Proterozoic and Lower Cambrian of East Greenland. *Grønlands geologiske undersøgelse* 134, 1–40.
- VIDAL, G. 1981. Micropaleontology and biostratigraphy of the Upper Proterozoic and Lower Cambrian sequence in East Finnmark, Northern Norway. *Norges geologiske undersøgelse Bulletin* 362, 1–53.
- VIDAL, G. & FORD, T.D. 1985. Microbiotas from the Late Proterozoic Chuar Group (Northern Arizona) and Uinta Group (Utah) and their chronostratigraphic implications. *Precambrian Research* 28, 349–389. DOI 10.1016/0301-9268(85)90038-5
- VIDAL, G. & KNOLL, A.H. 1983. Proterozoic plankton. *Geological Society of America, Memoir* 161, 265–277.
- VIDAL, G. & MOCZYDŁOWSKA, M. 1992. Patterns of phytoplankton radiation across the Precambrian-Cambrian boundary. *Journal of the Geological Society of London* 149, 647–654. DOI 10.1144/gsjgs.149.4.0647
- VIDAL, G. & SEDLIECKA, A. 1983. Planktonic, acid-resistant microfossils from the Upper Proterozoic strata of the Barents Sea region of Varanger Peninsula, East Finnmark, Northern Norway. *Norges geologiske undersøgelse Bulletin* 382, 45–79.
- YIN, L.-M. 1991. Late Proterozoic microfossils from the Tongjiazhuang Formation, Western Shandong, China. *Acta Paleontologica Sinica* 8(3), 253–269.
- YIN, L.-M. 1997a. Precambrian-Cambrian transitional biostratigraphy of the Yangtze Platform. *Bulletin of the National Museum of Natural Science* 10, 217–231.
- YIN, L.-M. 1997b. Acanthomorphic acritarchs from Meso-Neoproterozoic shales of the Ruyang Group, Shanxi, China. *Revue of the Palaeobotany and Palynology* 98, 15–25. DOI 10.1016/S0034-6667(97)00022-5
- ZHANG, Y. 1981. Proterozoic stromatolite microfloras of the Gaoyuzhuang Formation (Early Sinian: Riphean), Hebei, China. *Journal of Paleontology* 55, 485–506.

Appendix – List of species

Archaeotrichion contortum Schopf, 1968; *Arctacellularia ellipsoidea* Hermann in Timofeev *et al.*, 1976 (Fig. 2J); *Arctacellularia tetragonala* (Maithy) Hofmann & Jackson, 1994 (Fig. 2A); *Bavlinella faveolata* (Shepeleva) Vidal, 1976; *Brevitrichoides bacillaris* (Hermann) Hermann, 1990 (Fig. 2E); *Brevitrichoides bashkiricus* Jankauskas, 1980 (Fig. 3D); *Chabiosphaera bohemica* Drábek, 1972; *Chlorogloeaopsis contexta* (Hermann) Hofmann & Jackson, 1994 (Fig. 4); *Eomycetopsis psilata* Maithy & Shukla, 1977; *Karamia* sp.; *Leiosphaeridia asperata* (Naumova) Lindgren, 1982 (Fig. 3E); *Leiosphaeridia crassa* (Naumova) Jankauskas in Jankauskas *et al.*, 1989; *Leiosphaeridia minutissima* (Naumova) Jankauskas in Jankauskas *et al.*, 1989; *Leiosphaeridia tenuissima* Eisenack, 1958 (Fig. 3C); *Myxococcoides staphylidion* Lo, 1980; *Nucellospheeridium minutum* Timofeev, 1966; *Obruchevella valdaica* (Shepeleva ex Aseeva) Jankauskas *et al.*, 1989; *Octaedrixium truncatum* (Rudavskaya) Vidal, 1976; *Oscillatorioopsis psilata* Maithy & Shukla, 1977; *Palaeocalothrix diva-*

ricata Hermann, 1981; *Pellicularia tenera* Jankauskas, 1980, Fig. 2C; *Podolina minuta* Hermann in Timofeev *et al.*, 1976 (Fig. 2F); *Polytrichoides lineatus* Hermann, 1974; *Primoflagella speciosa* Gnilovskaya, 1983 (Fig. 3F); *Protosphaeridium lacatum* Timofeev, 1966; *Satka elongata* Jankauskas, 1979; *Siphonophycus capitaneum* Nyberg & Schopf, 1984; *Siphonophycus kestron* Schopf, 1968; *Siphonophycus inornatum* Zhang, 1981; *Siphonophycus robustum* (Schopf) Knoll *et al.*, 1991; *Sphaerocongregus variabilis* Moorman, 1974; *Synplastosphaeridium tumidulum* Timofeev ex Timofeev, 1969; *Synsphaeridium sorediforme* (Timofeev) Eisenack, 1965; *Stictosphaeridium brayense* Gardiner & Vanguetstaine, 1971; *aff. Tanarium tuberosum* Moczydłowska in Moczydłowska *et al.* 1993; *aff. Tappania tubata* Yin, 1997; *Tasmanites rifejicus* Jankauskas, 1978; *Valeria granulata* (Vidal in Vidal & Sedliecka, 1983) Fensome *et al.*, 1990 (Fig. 3B); *Valeria sinica* (Timofeev) Fensome *et al.*, 1990; *Valeria tschapomica* (Timofeev) Fensome *et al.*, 1990 (Fig. 2G).