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

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Well preserved and varied sphaeromorphs, filamentous trichomes and synaploid organic-walled microfossils occur in fine-grained clastics in the Měnín-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 Bavinella faveolata (Shepeleva) Vidal, 1976, Chabiosphaera bohemia Drábek, 1972, Obruchella valida (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 palynzone was ascertained from 266 m below the level with acritarchs. Thin sections from the Měnín-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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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 Fennosarmatian Platform (Suk 1984, Jaworowski & Sikorska 2006), as a Cambrian-docked microplate (Belka et al. 2000), or as part of the late Proterozoic passive margin of the Gondwana 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 Malopolska 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” (Dvořáčik 1998) and from more than 100 boreholes drilled by Moravian Oil Industries, Hodonín. The Měnín-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.
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 marine 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).

Thick-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 Gnolovskaya, 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.
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 spiraliform types (*Obruchevella valdatica* (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 *Chlorogloeopsis contexta* (Hermann) Hofmann & Jackson, 1994 (Fig. 4). Closely arranged threads with parallel orientation (*Polytrichoides lineatus* Hermann, 1974) and other synaploids (*Chabiosphaera bohemica* Drábek, 1972, *Myxoccoides* spp., *Satka elongata* Jankauskas, 1979) differentiate the recovered associations from the younger, Phanerozoic palaeocommunities. Irregular colonies of unicells are assigned to the genera *Symplassospheridium* spp. and *Synsphaeridium* spp., spindle-like vesicles to the genus *Brevitrichoides* (*B. bashkiricus* 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
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 Melanocyrillium. 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**


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) Moczydłowska, 1991, Conasphaeridium molliculum Moczydłowska & Vidal, 1988; Vavrčová 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 (Vavrčová 2006). A single specimen of Asteridium, reported by Vavrčová 2006, in the sample from the Měnín-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 Slawanysze Formation in the Lublin Slope, Poland (Moczydłowska 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 *Oscillatoriopsis* (depth 2097–2100 m).

The composition of the palynological palaeocommunities implies a possible palaeogeographic link with coeval sedimentary accumulations in the Malopolska 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 (Moczydłowska et al. 1993), and from the Ganga Basin, India (Prasad & Asher 2001).

**Results**

Fine-grained siliciclastics from the Měnín-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. 2I), 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 Měnín-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.

**Acknowledgements**

The research reported here is a part of the research programme of the Institute of Geology AS CR v.v.i., No. AVOZ 30130516. The samples were processed by A. Tichá in the laboratories of the Czech Geological Survey, Praha-Barrandov. The Moravian Oil Mines Company enabled access to the core material and thin sections. The manuscript benefited from the helpful criticism and corrections of O. Fatka and an anonymous reviewer.

**References**


Appendix – List of species

Archaeotrichion contorum Schopf, 1968; Arctacellularia ellipsoidae Hermann in Timofeev et al., 1976 (Fig. 2J); Arctacellularia tetragonala (Maithy) Hofmann & Jackson, 1994 (Fig. 2A); Bavelinella faveolata (Shepeleva) Vidal, 1976; Brevitrichoideae bacillaris (Hermann) Hermann, 1990 (Fig. 2E); Brevitrichoidei bshkhiricus Jankauskas, 1980 (Fig. 3D); Chabiosphaera bohemicv Drábek, 1972; Chlorogloeopsis contexta (Hermann) Hofmann & Jackson, 1994 (Fig. 4); Eomyctecopsis psilata Maithy & Shukla, 1977; Karanmia 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 tenissima Eisenack, 1958 (Fig. 3C); Mycococcioides stephylidion Lo, 1980; Nucellophycidae minutum Timofeev, 1966; Obruchevella valdaica (Shepeleva ex Aseeva) Jankauskas et al., 1989; Octaedarix trunatum (Rudavskaya) Vidal, 1976; Oscilatoriosis 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); Polystrochoides lineatus Hermann, 1974; Primoflagella speciosa Gnilovskaya, 1983 (Fig. 3F); Protosphaeridium lacatum Timofeev, 1966; Satka elongata Jankauskas, 1979; Siphonophycus capitanum Nyberg & Schopf, 1984; Siphonophycus kestron Schopf, 1968; Siphonophycus inornatum Zhang, 1981; Siphonophycus robustum (Schopf) Knoll et al., 1991; Sphaerocereus variabilis Moorman, 1974; Symplasosphaeridium tumidulum Timofeev ex Timofeev, 1969; Synsphaeridium sordiforme (Timofeev) Eisenack, 1965; Stictosphaeridium rayense Gardiner & Vanguetaine, 1971; aff. Tanarium tuberosum Moczydlska in Moczydlska et al. 1993; aff. Tappania tubata Yin, 1997; Tasmanites rifejicus Jankauskas, 1978; Valeria granulata (Vidal in Vidal & Sedieicka, 1983 Fensome et al., 1990 (Fig. 3B); Valeria sinica (Timofeev) Fensome et al., 1990; Valeria tschapomica (Timofeev) Fensome et al., 1990 (Fig. 2G).