



First palynological dating of Miaolingian (Cambrian) strata at the Biskoupky locality (Skryje-Týřovice Basin, Teplá-Barrandian unit)

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Abstract: The Biskoupky locality represents a tectonically delimited relict of Miaolingian sediments within Furongian volcanic rocks of the Křivoklát-Rokycany Volcanic Complex, serving as the southernmost outcrop of the Miaolingian Buchava Formation of the Skryje-Týřovice Basin. Over a century of research focused on this outcrop has produced a well-documented assemblage of comparatively rare remains of skeletal fauna, including species so far restricted to this locality; however, a microfossil analysis has until now never been conducted. Herein, we present the results of a palynological analysis of material from samples of fine-grained siltstone to shale from the Biskoupky locality. The samples yielded moderately well preserved organic-walled microfossils, particularly the acritarch genera *Cristallinium*, *Eliasum*, *Heliosphaeridium*, *Retisphaeridium*, *Solisphaeridium*, *Synsphaeridium*, and multiple species of *Timofeevia*. For the first time in the Skryje-Týřovice Basin, the presence of *Adara?* sp. is documented. The presence of *Timofeevia* here and in previously recorded acritarch assemblages from the Skryje-Týřovice Basin suggests a later-than-expected deposition of the Buchava Formation.

Keywords:

- acritarchs;
- Drumian;
- Miaolingian;
- biostratigraphy;
- Skryje-Týřovice Basin;
- Czech Republic

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Résumé : *Première datation palynologique des strates du Miaolingien (Cambrien) de la localité de Biskoupky (Bassin de Skryje-Týřovice, unité de Teplá-Barrandien).*- La localité de Biskoupky représente un vestige tectoniquement délimité de sédiments miaolingien au sein des volcanites furongiennes du Complexe Volcanique de Křivoklát-Rokycany. Elle constitue l'affleurement le plus méridional de la Formation de Buchava (Miaolingien) dans le Bassin de Skryje-Týřovice. Plus d'un siècle de recherches menées sur cet affleurement ont permis de documenter un assemblage bien conservé de restes relativement rares de faune à squelette, incluant des espèces exclusivement connues de cette localité ; cependant, une analyse des microfossiles n'avait jusqu'à présent jamais été réalisée. Nous présentons ici les résultats d'une analyse palynologique conduite sur des échantillons de siltite à grain fin et de schiste de la localité de Biskoupky. Les échantillons ont livré des microfossiles à paroi organique modérément bien préservés, notamment des acritarches des genres *Cristallinium*, *Eliasum*, *Heliosphaeridium*, *Retisphaeridium*, *Solisphaeridium* et *Synsphaeridium*, ainsi que plusieurs espèces de *Timofeevia*. La présence d'*Adara alea* est documentée pour la première fois dans le Bassin de Skryje-Týřovice. La présence de *Timofeevia*, ici et dans les associations d'acritarches précédemment étudiées dans le Bassin de Skryje-Týřovice, suggère un dépôt plus tardif que prévu pour la Formation de Buchava.

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**Mots-clefs :**

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- Drumien ;
- Miaolingien ;
- biostratigraphie ;
- Bassin de Skryje-Týřovice ;
- République tchèque

1. Introduction

In the Teplá-Barrandian unit (TBU), two major areas with paleontologically dated Cambrian rocks have been known for more than two centuries, the Příbram-Jince and the Skryje-Týřovice basins (e.g., HAVLÍČEK, 1971; GEYER *et al.*, 2008). In the Skryje-Týřovice Basin, the Cambrian volcano-sedimentary sequence (Fig. 1.B-C) rests unconformably on the slightly metamorphosed Neoproterozoic rocks of the Cadomian consolidated basement. Sediments of the Miaolingian Buchava Formation (FATKA *et al.*, 2011b) are capped by Furongian to Early Ordovician tholeiitic and calc-alkaline subaerial basalts, andesites and rhyolites of the Křivoklát-Rokycany Volcanic Complex (HAVLÍČEK, 1971; DROST *et al.*, 2004; GEYER *et al.*, 2008).

The Buchava Formation is represented by a sequence up to 200 metres thick, consisting of conglomerates, sandstones, greywackes, and shales cropping out in the northwestern part of the lower Paleozoic exposures of the Barrandian area (HAVLÍČEK, 1971; GEYER *et al.*, 2008; HAJNÁ *et al.*, 2017). Cambrian sediments have been recognized in a belt approximately 20 km long and up to 2 km wide. The southernmost occurrence of skeletal fauna in the Buchava Formation has been reported from a small outcrop near the village of Biskoupky (Fig. 1.C).

The aim of this contribution is to describe and stratigraphically evaluate the recently discovered moderately well preserved organic-walled microfossils isolated from siltstones to shales of the Buchava Formation at the Biskoupky locality and to put the acritarch record of the Skryje-Týřovice Basin into a regional context.

2. Geological setting

Buchava Formation and its fossil record

In the mid-19th century, marine Cambrian sediments of the Skryje-Týřovice Basin were classified as the "Ginetzer Schichten" (= Jince layers) by LIPOLD and KREJČÍ (1860), based on the presence of the so-called "faune primordiale" of BARRANDE (1852), traditionally assigned to the étage C of Barrande. Since then, numerous stratigraphic schemes have been proposed for the strata. Most recently, the name Buchava Formation has been applied to include all Cambrian sediments in the Skryje-Týřovice Basin by FATKA *et al.* (2011b). These authors recognised three distinct units within the Buchava Formation: the Skryje, Slapnice and Mileč members (Fig. 1.D).

The fossil record of the Buchava Formation has been intensively studied for nearly 180 years (e.g., BARRANDE, 1846, 1852; POMPECKJ, 1896; ŠNAJDR, 1958; BRUTHANSOVÁ *et al.*, 2007). Locally common fossils have been collected from dozens of natural outcrops and excavations, both large and small, in the 19th and 20th centuries (for discussion, see JAHN, 1896; ŠNAJDR, 1958; CHLUPÁČ, 1999; FATKA, 2004; FATKA *et al.*, 2011b; FATKA & HERYNK, 2016). Numerous articulated and disarticulated remains of trilobites and agnostids; strophoran, cinctan, eocrinoid, and ctenocystid echinoderms; hyoliths; brachiopods; and rare bivalved arthropods, wiwaxiids, helcionelloid molluscs, pterobranchs, foraminifera, and ichnofossils have been documented. These fossils have been studied for nearly two hundred years (for a summary, see FATKA, 1990, 2004; MIKULÁŠ, 2000; MALETZ *et al.*, 2005; FATKA *et al.*, 2011a; MIKULÁŠ & FATKA, 2017). In comparison, organic-walled microfossils have been reported only sporadically (KONZALOVÁ, 1974; VAVRDOVÁ, 1976; CHLUPÁČ *et al.*, 1998).

Biostratigraphy

ŠNAJDR (1958) assigned the fossiliferous shales and greywackes to the *Paradoxides* (*Eccapadoxides*) *pusillus* Trilobite Biozone (Fig. 1.E), drawing a direct comparison between these strata and the lower portions of the Jince Formation (Příbram-Jince Basin). Based on the stratigraphically restricted occurrence of brachiopods, HAVLÍČEK (1971) defined the older *Pompeckium kuthani* and the younger *Bohemiella romingeri* biozones (Fig. 1.E). KORDULE (2006) proposed a problematic scheme combining three barren intervals with four assemblage zones of rare ptychopariid and paradoxidid trilobites along with the earlier established trilobite and brachiopod biozones.

The discovery of the trilobite *Mikaparia mutica* (HAWLE & CORDA, 1847) (V. VOKÁČ, personal communication) suggests that the Biskoupky locality belongs to the middle to upper levels of the Buchava Formation (cf. KORDULE, 2006; VOKÁČ & MICKA, 2024). However, other faunal elements typically associated with younger strata of the Buchava Formation are absent. Therefore, the interpretation of the biostratigraphic position of the Biskoupky locality based on macrofossils within the sequence of the Buchava Formation is uncertain.

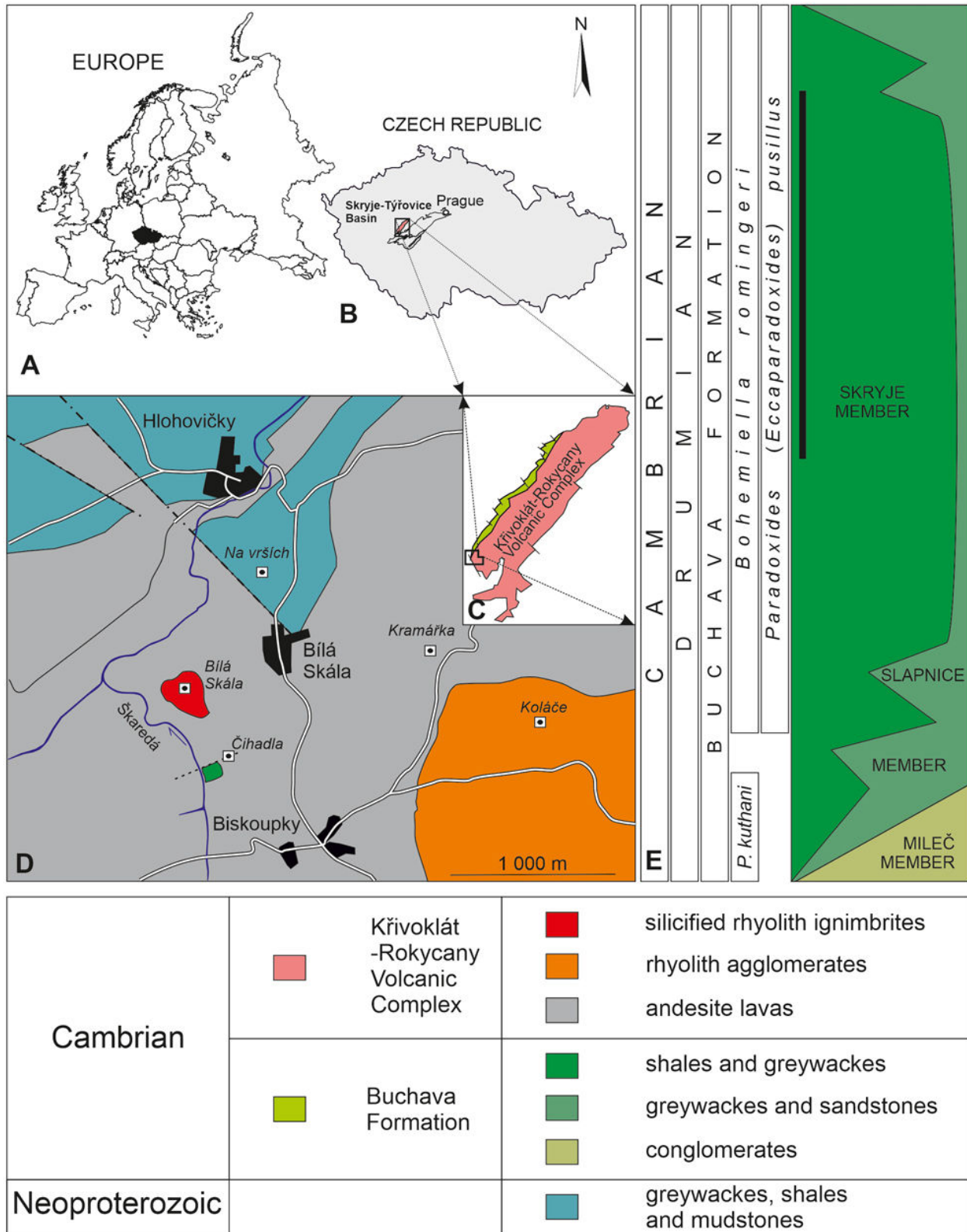


Figure 1: Map showing the location of the outcrop near the village of Biskoupky. A - Position of the Czech Republic in Europe. B - Czech Republic with the Palaeozoic of the Teplá-Barrandian unit and the Skryje-Týřovice area. C - Geological map showing the distribution of the middle Cambrian Buchava Formation and the location of the Biskoupky locality. D - A simplified geological map showing the position of the Biskoupky locality. E - Stratigraphy of the Skryje-Týřovice Basin with a black bar representing the supposed range of *Mikaparia mutica*. Geology modified from VOREL *et al.* (2018); stratigraphy after VOKÁČ (2002) and FATKA *et al.* (2011b).



Organic-walled microfossils (Appendix)

The first report on organic-walled microfossils from the Buchava Formation was published by KONZALOVÁ (1974, p. 47, 49). It was followed by a study of VAVRDOVÁ (1976, p. 61-62), who analysed samples from three outcrops: the Pod hrůškou, Buchava, and Dlouhá hora localities; acritarchs from the Dlouhá hora locality were further discussed by VAVRDOVÁ (1982, p. 146-147). From stratigraphically high levels of the Skryje Shale at the Luh locality, acritarchs were reported by CHLUPÁČ *et al.* (1998, p. 171, interval 6).

The reports generally describe moderately diversified assemblages consisting of *Timofeevia* sp., *Solisphaeridium* spp., small acanthomorphic acritarchs (*Michrhystridium*, *Heliosphaeridium*), and leiospheres. Furthermore, CHLUPÁČ *et al.* (1998) demonstrated the presence of *Eliasum llaniscum* and *Cristallinium cambriense* - two taxa important in Miaolingian biostratigraphy.

The Biskoupky locality

A set of small outcrops is located approximately 850 m NW of the village of Biskoupky. These outcrops are dispersed across the middle portion of a slope above the Škaredá rivulet. The sequence represents an isolated relict of Miaolingian sediments, roughly 100 × 30 m in size, enclosed within grey-blue to purple andesites and rhyolites of the Křivoklát-Rokycany Volcanic Complex. At the Biskoupky locality, the sediments are tectonically bounded by faults, presumed to trend NW and NE (KETTNER, 1923; VOREL *et al.*, 2018). Cleavage overprints the original stratification substantially; however, measurements taken from the outcrops indicate a generally N-S, steeply inclined bedding orientation.

Massive greyish-green siltstones dominate the sequence, forming layers more than 30 cm thick. Within these siltstones, fine to medium-grained, sometimes laminated greywackes and easily disintegrating shales form subordinate layers. The sequence seems to exhibit a generally upward fining trend; however, minor layers of greywackes occasionally occur higher up in the section as well. In the central portion, carbonate-rich concretions are present.

The first fossils from the Biskoupky locality were reported by KNITTL (1913). Subsequent discoveries of skeletal fauna and ichnofossils were reported by SMETANA (1920), V. KRAFT (1928), ŠNAJDR (1958), HAVLÍČEK (1977), J. KRAFT (1982), MERGL and ŠLEHOŘOVÁ (1990), VOKÁČ (1997), MIKULÁŠ (2000), KORDULE (2006), MERGL and ZAMORA (2013), and NOLČOVÁ and MERGL (2016). More recently, VALENT *et al.* (2017, p. 229) briefly summarised all previously published data on skeletal fauna and listed the presence of trilobites (nine genera), agnostids (one species), lingulate brachiopods (two species), rhynchonelliformean brachiopods (one species), echinoderms (two species), helcionelloid molluscs (two species), hyoliths (seven species), indeterminable sponge spicules, and four genera of ichnofossils.

3. Material and methods

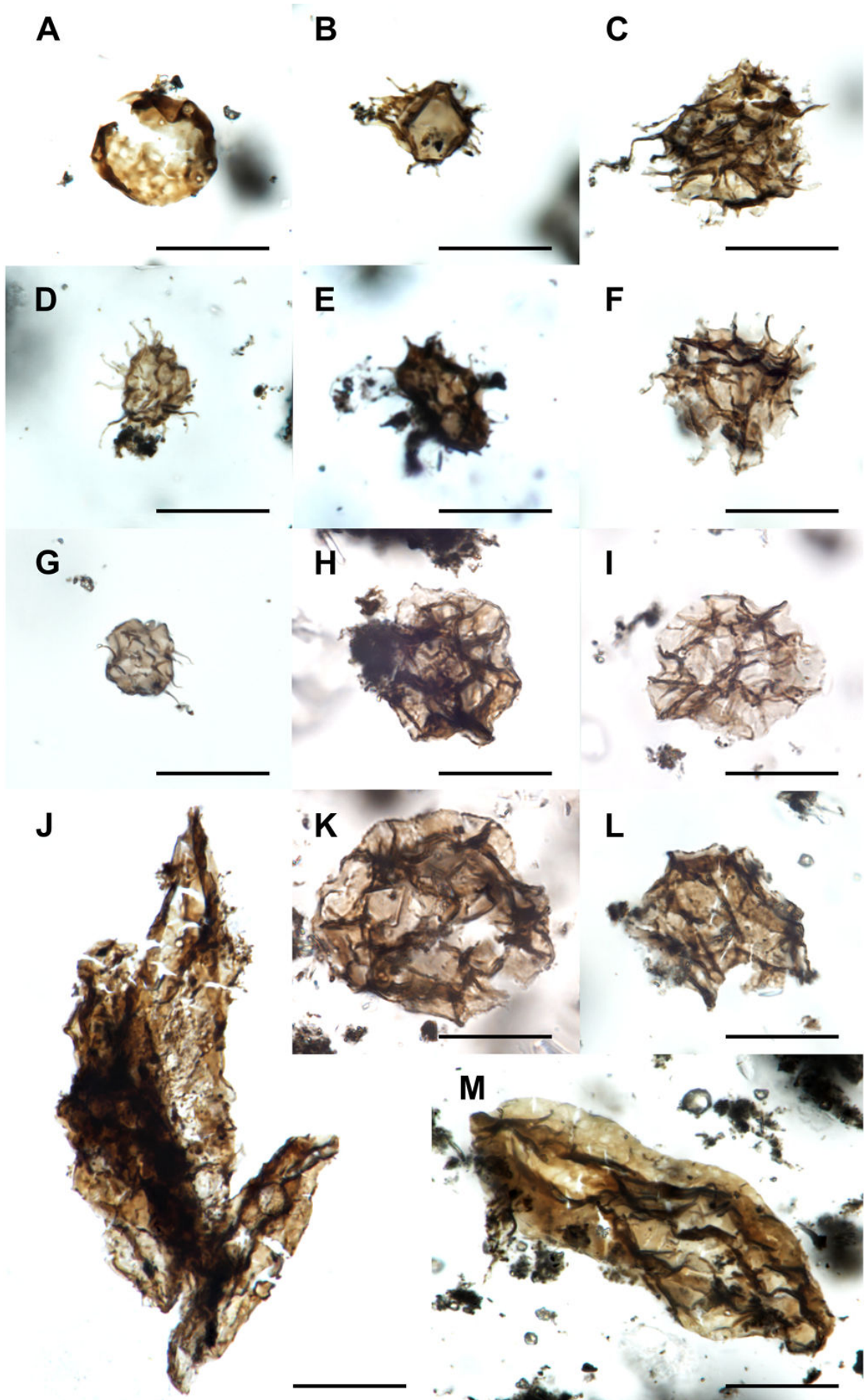
Six samples of fine-grained siltstone to shale (ca. 20-30 g each) were collected. All but one sample (BS-BI-0) were processed using a standard HCl-HF-HCl palynological procedure (e.g., RIDING, 2021). Neither centrifugation nor oxidation were applied. Residues were passed through a 32µm mesh, and the smaller fraction was subsequently filtered through a 10µm mesh. BS-BI-0 was treated only with HF and sieved at 30µm. Part of the smaller fraction was subsequently treated with HCl and heated in order to remove secondary fluorides. The resulting residue was filtered through a 10µm mesh.

Microfossils in the > 32µm fraction were hand-picked by pipette and mounted on slides, fixed by synthetic resin (Entellan), and covered with a cover slip. For the 10-32µm fraction, a drop of residue was mixed with glycerin gel, spread over a slide, and covered with a cover slip. Fossils were documented using an Olympus BX 51 optical microscope. Slides are deposited in the Czech Geological Survey under numbers VKO27 to VKO53.

4. Microfossils

The residues contain isolated acritarchs (see Figs. 2 - 3), acritarch clusters (for comparison, see KOVÁŘ *et al.*, 2023) and a few cyanobacterial filaments. The preservation of individual specimens varies considerably. While processes are generally well-preserved, including multiple levels of branching, a considerable portion of the processes is often broken off. This prevents a precise reconstruction of the original number of processes for the individual specimens and taxa. Central bodies of acritarchs are often plastically deformed due to early diagenetic pyrite growth, making taxonomic determination of many specimens difficult (see Fig. 4). Curiously, specimens of *Eliasum FOMBELLA, 1977, emend. PALACIOS, 2015*, appear to be affected only rarely, which stands in sharp contrast with other taxa. This suggests a biologically and/or morphologically selective pyrite formation within different acritarchs.

► **Figure 2:** Specimens of acritarchs from the Biskoupky locality. A - *Leiosphaeridia minutissima*; B, D - *Heliosphaeridium* cf. *notatum*; C - *Solisphaeridium* sp.; E-F - *Heliosphaeridium* cf. *exile*; G - *Heliosphaeridium* sp.; H-I - *Retisphaeridium dichamerum*; K-L - *Cristallinium cambriense*; J, M - *Eliasum llaniscum*. The scale bar represents 20 µm. England finder (EF) coordinates for individual fossils on slides stored at the Czech Geological Survey (Prague): Specimen A: Slide BS-BI-1-Sc_10 EF:G53/4; Specimen B: Slide BS-BI-9-Sa_10 EF:Q31/2; Specimen C: Slide BS-BI-9-Sa_10 EF:O50/2; Specimen D: Slide BS-BI-1-Sa_10 EF:R39/2; Specimen E: Slide BS-BI-1-Sa_10 EF:E55/3; Specimen F: Slide BS-BI-9-Sa_10 EF:O53/3; Specimen G: Slide BS-BI-9-Sa_10 EF:G44; Specimen H: Slide BS-BI-3-Sb_10 EF:L51/1; Specimen I: Slide BS-BI-1-Sa_10 EF:C29/3; Specimen J: Slide BS-BI-0-Sa_30 EF:R49; Specimen K: Slide BS-BI-1-Sd_10 EF:V43; Specimen L: Slide BS-BI-6-Sb_10 EF:Q49/2; Specimen M: Slide BS-BI-1-Sd_10 EF:Q33/3.



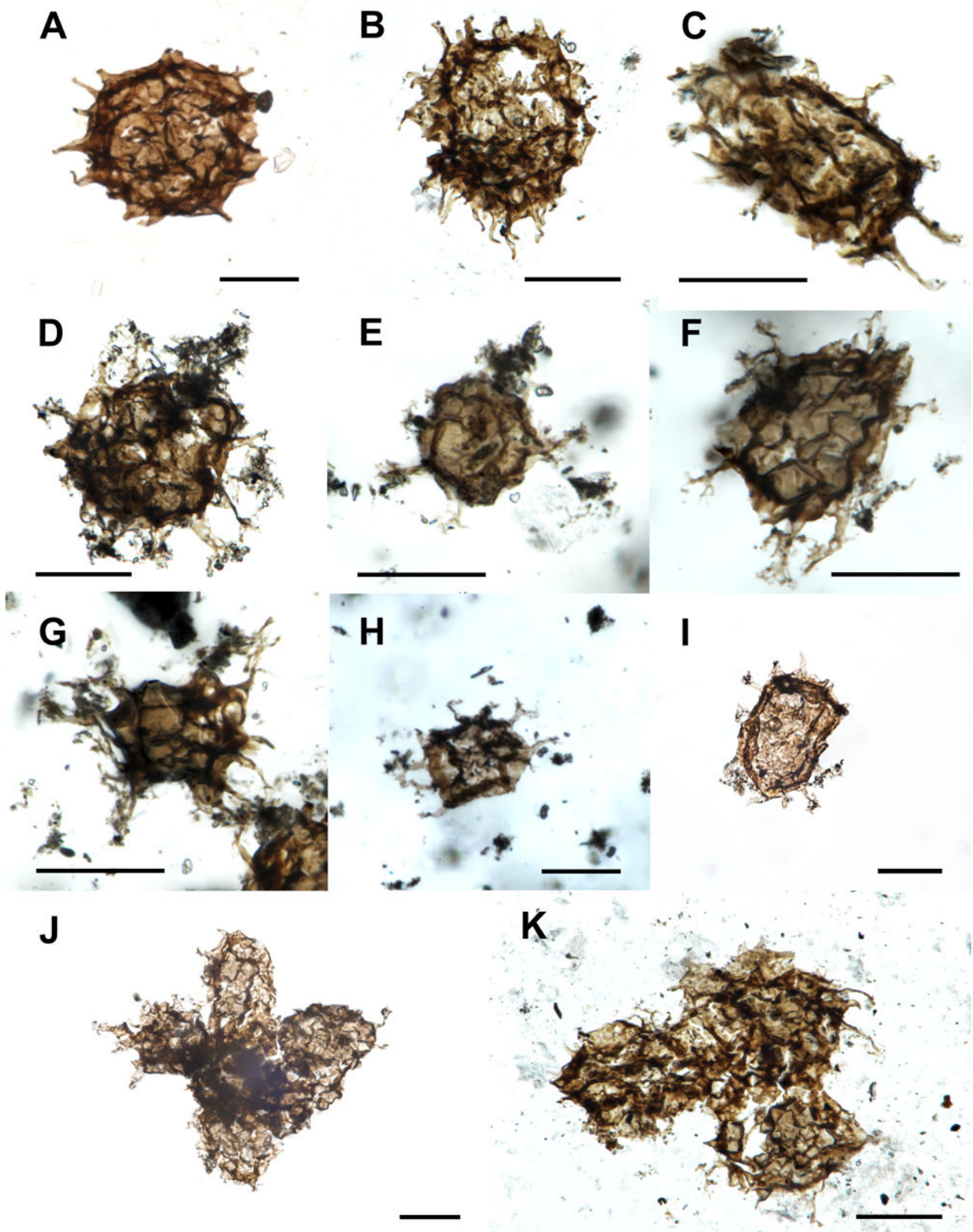


Figure 3: Specimens of acritarchs from the Biskoupky locality. A - *Adara?* sp.; B - acritarch indet.; C - *Timofeevia simplex*; D-F - *Timofeevia lancarae*; G-H - *Timofeevia heteromorpha*; I - *Timofeevia* cf. *raquelinae*; J-K - clusters of *Timofeevia*. The scale bar represents 20 μ m. England finder (EF) coordinates for individual fossils on slides stored at the Czech Geological Survey (Prague): Specimen A: Slide BS-BI-0-Sc_30 EF:H62/3; Specimen B: Slide BS-BI-0-Sb_30 EF:R33/2; Specimen C: Slide BS-BI-1-Sa_10 EF:P51/3; Specimen D: Slide BS-BI-4-Sa_32 EF:H40/4; Specimen E: Slide BS-BI-6-Sc_10 EF:H43; Specimen F: Slide BS-BI-1-Sa_10 EF:J39/2; Specimen G: Slide BS-BI-1-Sd_10 EF:V43/3; Specimen H: Slide BS-BI-1-Sa_10 EF:M53/2; Specimen I: Slide BS-BI-1-Sa_32 EF:G37/2; Specimen J: Slide BS-BI-3-Sb_32 EF:O38/2; Specimen K: Slide BS-BI-0-Sc_30 EF:M63.



In addition to the clearly Miaolingian-aged acritarchs, two specimens of comparatively large, poorly preserved, degraded and highly flattened acritarchs are preserved (see Fig. 4.J-K). These specimens exhibit a clearly distinct mode of preservation differing from the rest of the microfossil assemblage. One of the specimens represents a leiosphere (Fig. 4.J); the other is comparable to the genus *Germinosphaera* MIKHAILOVA, 1986, emend. BUTTERFIELD, 1994 (Fig. 4.K).

5. Sedimentology and petrology

The sequence is primarily composed of siltstones typically lacking internal stratification, though poorly developed laminations may occasionally be observed. This locally develops into up to 1 cm-thick layers of shale. Fragments of irregularly dispersed remains of skeletal fossils occur in the silty sediment and generally are not concentrated in distinct fossiliferous horizons. The character of the sedimentation is thus consistent with distal turbidite deposition dominated by fine-grained material deposited in numerous separate pulses. A coarser fraction of the turbidites is represented by layers of mostly fine-grained greywackes up to several centimetres thick; these locally also preserve current-induced sedimentary structures typical for the upper portions of a Bouma sequence (BOUMA, 1962). The greywackes are made up of quartz grains corresponding in size to the silty to fine sandy fraction, argillized rock clasts and comparatively rare heavy minerals such as zircons, apatite, baryte, rutile, and less frequently also leucoxene and tourmaline. The matrix is composed of clay minerals with secondary Fe minerals associated. The clays are represented mainly by highly crystalline illite, occasionally replaced by chlorite or chlorite aggregates. Despite the relict's position within the volcanic complex, the sediments are not substantially more thermally affected than is common elsewhere within the Skryje-Týřovice Basin.

Organic residues contain a substantial amount of amorphous organic matter and, curiously, a considerable proportion of acritarchs are severely deformed by pyrite ingrowths - both framboidal (e.g., Fig. 4.B-C) and cubical (e.g., Fig. 4.F-G) forms - from inside. The acritarch walls reacted with a high degree of plasticity, replicating both the surface texture and the overall shape of the pyrite grains. This, alongside the degree of crystallinity exhibited by the pyrite grains, suggests a synsedimentary to early diagenetic origin for the pyrite at least partially linked to the decay of organic matter within the acritarchs.

6. Systematic palaeontology

The synonymy lists are not exhaustive and generally only include a limited number of publications that are most important for understanding the taxonomy of the respective species or their occurrence within the Cambrian of the Skryje-Týřovice Basin.

Group Acritarchs EVITT, 1963 (incertae sedis)

Genus *Adara* FOMBELLA, 1977, emend. MARTIN in MARTIN & DEAN, 1981

Type species. *Adara matutina* FOMBELLA, 1977.

Adara? sp. (Fig. 3.A)

Remarks: Only a single specimen tentatively assigned to the genus *Adara* has been observed. The specimen measures 44.3 µm in diameter and bears several tens of conical processes with wide bases and blunt tips, ranging from wide cones to longer, distally more cylindrical processes. The size of the vesicle and the morphology of processes generally resemble those of *A. longispinosa* FATKA, 1989, which has been synonymized with *A. alea* MARTIN in MARTIN & DEAN, 1981, by JACHOWICZ-ZDANOWSKA (2013); however, there are substantially fewer processes in the specimen from Biskoupky. The specimen further resembles an acritarch specimen figured by PALACIOS *et al.* (2021, Fig. 25.B), identified there as *Adara alea*. Numerous other specimens resemble *Adara* to a degree (e.g., Fig. 4.F-G); however, these are in fact often specimens of different acritarchs, likely mostly leiospheres, that have been severely deformed by pyrite.

Genus *Cristallinium* VANGUESTAINE, 1978, emend. PALACIOS in PALACIOS *et al.*, 2022

Type species. *Cristallinium cambriense* (SLAVÍKOVÁ, 1968) VANGUESTAINE, 1978, emend. PALACIOS in PALACIOS *et al.*, 2022 (= *Dictyotidium cambriense* SLAVÍKOVÁ, 1968, p. 201, Pl. II, fig. 1).

Cristallinium cambriense (SLAVÍKOVÁ, 1968) VANGUESTAINE, 1978, emend. PALACIOS in PALACIOS *et al.*, 2022 (Fig. 2.K-L)

- 1968 *Dictyotidium cambriense* n. sp. - SLAVÍKOVÁ, p. 201, Pl. II, figs. 1, 3.
1978 *Cristallinium cambriense* (SLAVÍKOVÁ, 1968) comb. nov. - VANGUESTAINE, p. 271, Pl. II, figs. 16-17; Pl. 3, figs. 16, 26.
1981 *Cristallinium cambriense* - MARTIN in MARTIN & DEAN, p. 17, Pl. 3, figs. 4- 5, 9, 11; Pl. 5, figs. 3, 5, 8, 11.
1998 *Cristallinium cambriense* - CHLUPÁČ *et al.*, p. 171.
2022 *Cristallinium cambriense* emend. - PALACIOS *et al.*, p. 32-33, Fig. 25.B.

Remarks: Only three observed specimens of polygonal acritarchs exhibit a well-developed minute ornamentation along their edges. Distinguishing whether this is the result of taphonomic loss of ornamentation or reflects a genuine rarity of *Cristallinium* is difficult to determine unequivocally. However, specimens of *Cristallinium*, while present, are generally not very abundant in the Cambrian deposits of both the Příbram-Jince and Skryje-Týřovice basins (KOVÁŘ, unpublished data). Specimens herein assigned to *Cristallinium cambriense* range between 30.6 and 43.7 µm (N=3).

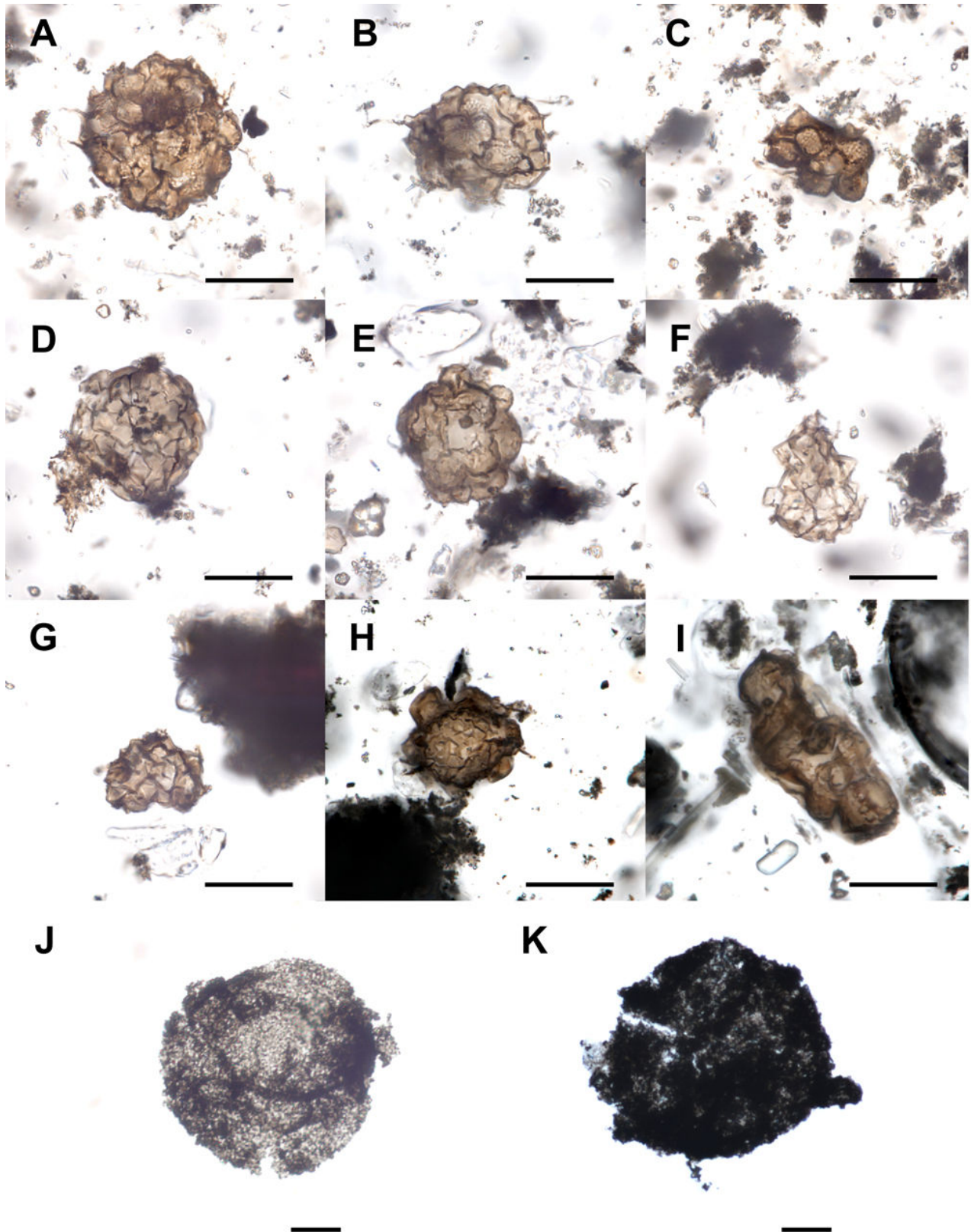


Figure 4: Examples of reworked (J-K) and severely deformed acritarchs (A-I) from the Biskoupky locality. Specimens A, B, C, E are not assigned to any taxon; specimens D, F, G likely represent leiospheres. Specimen I likely belongs to the genus *Eliasum*, however, it could also be a closer undetermined fusiform acritarch. The scale bar represents 20 μm . England finder (EF) coordinates for individual fossils on slides stored at the Czech Geological Survey (Prague): Specimen A: Slide BS-BI-1-Sd_10 EF:N44/2; Specimen B: Slide BS-BI-4-Sb EF:D38; Specimen C: BS-BI-1-Sd_10 EF:E49; Specimen D: BS-BI-1-Sb_10 EF:M33/4; Specimen E: BS-BI-1-Sb_10 EF:E35/1; Specimen F: BS-BI-1-Sa_10 EF:D29/4; Specimen G: BS-BI-1-Sa_10 EF:F27; Specimen H: BS-BI-1-Sd_10 EF:W29/1; Specimen I: BS-BI-1-Sb_10 EF:E29/1; Specimen J: BS-BI-3-Sb_32 EF:N29/3; Specimen K: BS-BI-3-Sa_32 EF:K51/2.

**Genus *Eliasum* FOMBELLA, 1977,
emend. PALACIOS, 2015**Type species. *Eliasum llaniscum* FOMBELLA, 1977.***Eliasum llaniscum* FOMBELLA, 1977
(Fig. 2.J, .M)**1977 *Eliasum llaniscum* n. sp. - FOMBELLA, p. 118, Pl. I, fig. 6.1998 *Eliasum llaniscum* - CHLUPÁČ *et al.*, p. 171.1998 *Eliasum llaniscum* - MOCZYDŁOWSKA, p. 66-68, Fig. 28.A-D.2015 *Eliasum llaniscum* - PALACIOS, Pl. VIII, fig. 1.

Remarks: *Eliasum llaniscum* is a common and easily recognizable component of the microfossil assemblage at the Biskoupky locality. The specimens are mostly comparatively mildly deformed; severe pyrite ingrowths occur only rarely. Complete specimens range from 33.1 to 75.8 μm (N=41; μ =59.2 μm ; σ =14.6) in length and lack surface ornamentation. Apart from isolated specimens, three clusters consisting of two to three specimens have been recovered. No other species of *Eliasum* has been observed; however, a few poorly preserved specimens are assigned to the genus only tentatively and could belong to an undetermined fusiform acritarch genus instead, as these specimens lack discernible longitudinal ridges (e.g., Fig. 4.I).

**Genus *Germinosphaera* MIKHAILOVA, 1986,
emend. BUTTERFIELD, 1994**Type species. *Germinosphaera bispinosa* MIKHAILOVA, 1986.***Germinosphaera?* sp.
(Fig. 4.K)**

Remarks: A single, poorly preserved specimen measures approximately 98.5 μm in diameter. At least two processes are present; however, they are broken off near their bases. The width of the processes at their base corresponds to 11.8 and 12.8 μm , respectively. Its preservation is distinct from that of the Miaolingian acritarchs preserved in the sample, indicating it is possibly reworked material.

Genus *Heliosphaeridium* MOCZYDŁOWSKA, 1991Type species. *Heliosphaeridium dissimulare* (VOLKOVA, 1969) MOCZYDŁOWSKA, 1991.

Material: A total of 35 specimens were examined. However, the majority of specimens have all but a few processes broken off, and many specimens are damaged, severely limiting the possibility of species-level determination.

***Heliosphaeridium* cf. *notatum*
(VOLKOVA, 1969) MOCZYDŁOWSKA, 1991
(Fig. 2.B, .D)**cf. 1969 *Micrhystridium notatum* n.sp. - VOLKOVA, p. 228, Pl. 51, figs. 16-19 (*non vidi*).cf. 1991 *Heliosphaeridium notatum* (VOLKOVA 1969) comb. nov. - MOCZYDŁOWSKA, p. 58.cf. 1998 *Heliosphaeridium notatum* - MOCZYDŁOWSKA, p. 77-79, Figs. 31.L, 33.A-L.cf. 2013 *Ammonidium notatum* comb. nov. - JACHOWICZ-ZDANOWSKA, p. 47-48, Pl. XXII, figs. 13-15, 17-24.

Remarks: Subspherical to oval acritarchs with processes bearing funnel-shaped endings. In one

specimen, short branching is observed in the distal parts of the processes. Central body size ranges from 12.8 to 16.8 μm (N=4). Considerable variability in process length is evident both among specimens and within a single specimen (cf. MOCZYDŁOWSKA, 1998); the processes range from 2 to 8.3 μm .

***Heliosphaeridium* cf. *exile*
MOCZYDŁOWSKA, 1998
(Fig. 2.E-F)**cf. 1998 *Heliosphaeridium exile* sp. n. - MOCZYDŁOWSKA, p. 75, Pl. 32, fig. G.

Remarks: Subspherical to oval acritarchs with short processes that have acute tips and conical bases. The size of the central body ranges from 16.1 to 25.9 μm (N=5). Locally, the wall appears concave between processes, though this is difficult to ascertain due to deformations of the central body. Approximately 10-15 processes are visible on the observed surface; in contrast, *H. lanceolatum* (VANGUESTAINE, 1974) MOCZYDŁOWSKA, 1998, typically bears 20-40 processes.

***Heliosphaeridium* sp.
(Fig. 2.G)**

Remarks: These are subspherical to oval acritarchs with slightly conical to hair-like processes ending in sharp tips. The central body size ranges from 14.8 to 23.4 μm (N=5), and process lengths are variable, ranging from 2.4 to 8.1 μm .

Genus *Leiosphaeridia* EISENACK, 1958Type species. *Leiosphaeridia baltica* EISENACK, 1958.***Leiosphaeridia minutissima* NAUMOVA, 1949,
emend. JANKAUSKAS in JANKAUSKAS *et al.*, 1989
(Fig. 2.A)**1949 *Leiotriletes minutissimus* sp. n. - NAUMOVA, p. 52-53, Tab. 1, figs. 1-2, Tab. 2, figs. 1-2.1989 *Leiosphaeridia minutissima* (NAUMOVA, 1949) emend., comb. nov. - JANKAUSKAS *et al.*, p. 79-80, Pl. IX, figs. 1-4, 11.

Remarks: Numerous specimens can be assigned to *Leiosphaeridia* with various certainty levels. The diameter ranges from 12.5 to 65.7 μm (N=64; μ =29.8 μm ; σ =10.6). These specimens are often deformed by pyrite ingrowths, which, in some cases, causes them to resemble other genera, especially *Adara* (see, e.g., Fig. 4.G). A similar deformation is also common in specimens of other genera (e.g., *Solisphaeridium* or *Timofeevia*) in our material. In some specimens, the severe deformation prevents an unequivocal differentiation between *Leiosphaeridia* and *Retisphaeridium*.

***Leiosphaeridia* sp.
(Fig. 4.J)**

Remarks: A single, poorly preserved specimen of *Leiosphaeridia*. The specimen is oval in outline (likely deformed), measuring approximately 108.6 μm in maximal length. The preservation suggests that the specimen is reworked, as is the case with the specimen of *Germinosphaera?* sp.

**Genus *Retisphaeridium* STAPLIN *et al.*, 1965, emend. PALACIOS in PALACIOS *et al.*, 2022**

Type species. *Retisphaeridium dichamerum* STAPLIN *et al.*, 1965, emend. PALACIOS in PALACIOS *et al.*, 2022.

***Retisphaeridium dichamerum* STAPLIN *et al.*, 1965, emend. PALACIOS in PALACIOS *et al.*, 2022 (Fig. 2.H-I)**

1965 *Retisphaeridium dichamerum* sp. n. - STAPLIN *et al.*, p. 187-188, Pl. 19, figs. 1-7.

1982 *Retisphaeridium dichamerum* - DOWNIE, p. 279, Figs. 11 o-p.

2022 *Retisphaeridium dichamerum* STAPLIN *et al.*, 1965, emend. - PALACIOS *et al.*, p. 36, Figs. 13.A-F.

Remarks: A range of taphomorphs ranging from specimens clearly exhibiting their original subspherical form to those resembling *Cymatiosphaera* (see DOWNIE, 1982; PALACIOS *et al.*, 2022). Complete specimens range from 12.7 to 50.7 μm (N=31; μ =33.6; σ =7.99) in diameter and have approximately 13-18 fields on the observed side. However, the exact number of fields is difficult to ascertain in many specimens due to their deformation and/or degradation. Further spherical to subspherical acritarch specimens, severely deformed by pyrite, could also belong to the genus; however, these specimens could also be placed into *Leiosphaeridia* or other sphaeromorph taxa.

Genus *Solisphaeridium* STAPLIN *et al.*, 1965, emend. MOCZYDŁOWSKA, 1998

Type species *Solisphaeridium stimulierum* (DEFLANDRE, 1938) STAPLIN *et al.*, 1965.

***Solisphaeridium* spp. (Fig. 2.C)**

Remarks: Originally spherical acritarchs with processes. The size of the central body ranges from 24.7 to 52.7 μm (N=36). The processes are primarily slender, cylindrical to hairlike, though more rarely conical, reaching up to 18.9 μm . The majority of processes are broken off, which hampers more precise determination. However, most of our specimens are generally comparable to *Solisphaeridium flexipilosum* SLAVÍKOVÁ, 1968.

Genus *Synsphaeridium* EISENACK, 1965

Type species. *Synsphaeridium gotlandicum* EISENACK, 1965.

***Synsphaeridium?* sp.**

Remarks: Two clusters of closely packed leio-sphere-like objects consisting of three and six spheres, respectively. The individual spheres are approximately 10 μm in diameter.

Genus *Timofeevia* VANGUESTAINE, 1978

Type species. *Multiplicisphaeridium lancarae* CRAMER & DIÉZ, 1972.

Remarks: As with other acritarchs in the studied material, a large portion of the specimens is substantially degraded and/or affected by pyrite ingrowths, obscuring the original outline of the central body. Curiously, processes tend to be

comparatively well-preserved, exhibiting up to several levels of branching. *Timofeevia* occurs both individually and in clusters. We follow the species classification developed by PALACIOS (2015) and PALACIOS *et al.* (2022), though a revision of the species co-occurring in the *T. lancarae* Zone is warranted.

***Timofeevia heteromorpha* PALACIOS, 2015 (Fig. 3.G-H)**

2015 *Timofeevia heteromorpha* sp. nov. - PALACIOS, p. 94-96, Pl. XI, figs. 1-6.

2022 *Timofeevia heteromorpha* - PALACIOS *et al.*, Fig. 26.F.

Remarks: Polygonal to subspherical acritarchs, unless secondarily deformed by pyrite. The size of the central body ranges from 18.6 to 46 μm (N=20). Processes conical to subcylindrical, ranging from simple to branched in up to three orders. Process length varies from 3.1 to 13.5 μm .

***Timofeevia lancarae* (CRAMER & DIÉZ, 1972) VANGUESTAINE, 1978 (Fig. 3.D-F)**

1972 *Multiplicisphaeridium lancarae* sp. n. - CRAMER & DIÉZ, p. 42, Pl. 1, figs 1-4, 6, 8.

1978 *Timofeevia lancarae* (CRAMER & DIÉZ) nov. comb. - VANGUESTAINE, p. 272.

2015 *Timofeevia lancarae* - PALACIOS, p. 96-98, Pl. XII, figs. 1-6.

Remarks: Polygonal to subspherical acritarchs, unless secondarily deformed by pyrite. The size of the central body ranges from 17.8 to 47.8 μm (N=42; μ =30.6 μm ; σ =6.5). Processes conical, often with broad bases. Processes usually branch several times in their distal portions, forming pinae: process length is variable, ranging from 3.6 to 13.5 μm .

***Timofeevia cf. raquelinae* (CRAMER & DIÉZ, 1972) CRAMER & DIÉZ, 1979 (Fig. 3.I)**

cf. 1972 *Multiplicisphaeridium raquelinae* (New Species). - CRAMER & DIÉZ, p. 43-44, Pl. 1, fig. 7.

cf. 1979 *Timofeevia raquelinae* - CRAMER & DIÉZ, p. 58.

Remarks: Polygonal to subspherical acritarchs, unless secondarily deformed by pyrite. The size of the central body ranges from 26.9 to 39.8 μm (N=4). Processes conical to subcylindrical, with pointed or manate endings, rarely extending into short branches. Process length varies from 3.6 to 9.8 μm . The specimens are similar to those figured by PALACIOS (2015). The presence of *T. raquelinae* has also been reported by VAVRDOVÁ (1982); however, no specimens were figured.

***Timofeevia simplex* PALACIOS, 2015 (Fig. 3.C)**

2015 *Timofeevia simplex* sp. n. - PALACIOS, p. 98, Pl. XIII, figs. 1-4.

Remarks: Polygonal to subspherical acritarchs, unless secondarily deformed by pyrite. The size of the central body ranges from 24 to 41.5 μm (N=14). Processes conical or hair-like with conical bases and pointed tips, and only rarely do the tips branch dichotomously. The process length varies considerably from 3.7 to 10.8 μm .



7. Discussion

Reworked acritarchs

Apart from Miaolingian acritarchs, two reworked acritarchs were documented. These can be distinguished by their very poor, highly flattened preservation and the comparatively darker colouration of the wall. One of the reworked acritarchs likely represents a large leiosphere (Fig. 4.J), while the second specimen is tentatively assigned to the genus *Germinosphaera* (Fig. 4.K). Comparable fossils have been reported from Proterozoic sequences of the Teplá-Barrandian Unit (e.g., FATKA & GABRIEL, 1991).

The reworked acritarchs and analyses of heavy minerals indicate that the source material is derived from weakly metamorphosed sedimentary and magmatic rocks of the Cadomian basement. This is in accordance with the data of DROST *et al.* (2004). The sedimentary rocks incorporated into the Cadomian basement span a prolonged timespan, demonstrated to include fossiliferous sequences of both Proterozoic and Cambrian age (see KONZALOVÁ, 1974; HAJNÁ *et al.*, 2017). Both Proterozoic and "early" Cambrian Cadomian rocks lie relatively close to the Skryje-Týřovice Basin, making them likely sources for the clastic material within the basin. Unfortunately, the current stratigraphic utility of the reworked microfossils is quite limited. Nevertheless, their presence suggests that at least part of the clastic material at the Biskoupky locality more likely originates from the Neoproterozoic rather than the Cambrian sequences. Additional material could prove useful for clarifying the provenance of sediments within the Příbram-Jince and Skryje-Týřovice basins.

Age of the Cambrian sequence

The acritarch record from the Biskoupky locality consists of a distinct assemblage including abundant specimens of *Eliasum llaniscum*, *Retisphaeridium dichamerum*, multiple species of *Timofeevia* and *Heliosphaeridium*, as well as *Solisphaeridium* sp. and rare specimens of *Cristallinium cambriense*. Our findings generally agree with records from other localities within the Skryje-Týřovice Basin (KONZALOVÁ, 1974; VAVRDOVÁ, 1976, 1982; CHLUPÁČ *et al.*, 1998; KOVÁŘ & FATKA, 2024). Noteworthy is the presence of *Adara?*; *Adara* is commonly found across European peri-Gondwana and Baltica (see summary in PALACIOS *et al.*, 2022) and is notably present in the Příbram-Jince Basin of the TBU (FATKA, 1989; KOVÁŘ & FATKA, 2025). However, *Adara* has not previously been observed in the Skryje-Týřovice Basin (see Section 2.2 and KOVÁŘ & FATKA, 2024). Whether the conspicuous lack of *Adara* in other successions is due to the age of the successions, unknown ecological or paleobiogeographic constraints, or insufficient sampling cannot be determined at this time. Unfortunately the single specimen is insufficient for any further interpretations.

In the Příbram-Jince Basin, *Timofeevia* first appears within the *Onymagnostus hybridus* Biozone

(see FATKA, 1989; KOVÁŘ *et al.*, 2023; KOVÁŘ & FATKA, 2025). However, based on the macrofossil content, the rocks of the Skryje-Týřovice Basin have been compared to the *P. (Eccaparadoxides) pussilus* Biozone, which partly underlies the *O. hybridus* Biozone in the Jince Formation with an only relatively short overlap. The acritarch record, therefore, suggests that the *P. (Eccaparadoxides) pussilus* biozones of the Příbram-Jince and Skryje-Týřovice basins might not be directly correlatable and that the studied sections within the Skryje-Týřovice Basin are likely younger than previously expected (cf. e.g., ŠNAJDR, 1958; HAVLÍČEK, 1971; KORDULE, 2006). More generally, the acritarch assemblage at the Biskoupky locality closely resembles those of the *T. lancarae* Zone described by PALACIOS *et al.* (2022), which has been suggested to span the late Drumian to early Guzhangian. If accepted, this age range would contradict the age indicated by the trilobites due to the occurrence of "*Paradoxides*" *hicksii* in the Skryje-Týřovice Basin (see VANĚK *et al.*, 1999), a trilobite species characteristic of the lower half of the Drumian (compare FLETCHER, 2007; GEYER, 2019). Further analyses of both macrofossil and microfossil records of the Skryje-Týřovice Basin is necessary in order to explain these discrepancies.

8. Conclusions

(1) Organic-walled microfossils are reported from the southernmost occurrence of the Buchava Formation in the Skryje-Týřovice Basin for the first time. The acritarchs include, most notably, *Eliasum llaniscum*, *Retisphaeridium dichamerum*, *Solisphaeridium* sp., multiple species of *Timofeevia* and *Heliosphaeridium*, and rare specimens of *Cristallinium cambriense*. Notably, *Adara?* sp. is described for the first time from the basin.

(2) The assemblage closely matches with assemblages of the *Timofeevia lancarae* Zone described by PALACIOS *et al.* (2022) and its analogues in peri-Gondwana and Baltica.

(3) The stratigraphic interpretation based on the microfossil record differs slightly from the biostratigraphy based on macrofossils (especially trilobites).

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Appendix

Table of reports on acritarchs from the Skryje-Týřovice Basin with acritarch taxa reported.

KONZALOVÁ (1974, p. 47, 49)

- *Acanthodiacrodium* cf. *miconatum* TIMOFEEV
- cf. *Acanthodiacrodium tuberculatum* (DOWNIE) MARTIN
- *Acanthodiacrodium* sp.
- *Archaeohystrichosphaeridium* *ianischewskyi* TIMOFEEV (belongs to the genus *Timofeevia* - after VANGUESTAINE, 1978, p. 272)
- *Archaeohystrichosphaeridium* cf. *pentagonum* TIMOFEEV (invalid species - after COLTHURST & SMITH, 1977, p. 148)
- *Dictyotidium cambriense* SLAVÍKOVÁ (= *Cristallinium cambriense* - after VANGUESTAINE, 1978, p. 270)
- *Micrhystridium pallidum* VOLKOVA
- *Micrhystridium* cf. *dissimilare* VOLKOVA (belongs to the genus *Heliosphaeridium* - after MOCZYDŁOWSKA, 1991, p. 58)
- cf. *Micrhystridium* sp.
- *Poikilofusa* sp.
- *Solisphaeridium* sp.
- *Vulcanisphaera* sp.

VAVRDOVÁ (1976, p. 61-62)

- *Baltisphaeridium ornatum* VOLKOVA
- *Baltisphaeridium* sp.
- *Cymatiogalea minor* (TIMOFEEV) comb. nov.
- *Cymatiosphaera crameri* SLAVÍKOVÁ
- *Dactylofusa simplex* COMBAZ
- *Micrhystridium dissimilare* VOLKOVA (= belongs to the genus *Heliosphaeridium* - after MOCZYDŁOWSKA, 1991, p. 58)
- *Micrhystridium obscurum* (= belongs to the genus *Heliosphaeridium* - after MOCZYDŁOWSKA, 1991, p. 60)
- *Micrhystridium shimetonense* DOWNIE
- *Micrhystridium tornatum* VOLKOVA
- *Multiplicisphaeridium lancarae* CRAMER & DIÉZ (= *Timofeevia lancarae* - after VANGUESTAINE, 1978, p. 272)
- *Multiplicisphaeridium martae* CRAMER & DIÉZ
- *Solisphaeridium multiflexipilosum* SLAVÍKOVÁ
- *Staplinia cambriense* (SLAVÍKOVÁ) VANGUESTAINE (= *Cristallinium cambriense* - after VANGUESTAINE, 1978, p. 270)
- ?*Veryhachium* sp.
- small-sized and thin-walled leiospheres

VAVRDOVÁ (1982, p. 146-147)

- *Acanthodiacrodium*
- *Cristallinium*
- *Eliasum*
- *Leiosphaeridia*
- *Lophosphaeridium*
- *Leio-*, *Dactylofusa*
- *Micrhystridium*
- *Timofeevia*
- *Timofeevia lancarae*
- *Timofeevia martae* (= *Multiplicisphaeridium martae*)
- *Timofeevia raquelinae*

CHLUPÁČ *et al.* (1998, p. 171)

- *Cristallinium cambriense* (SLAVÍKOVÁ, 1968) VANGUESTAINE, 1978
- *Eliasum* cf. *Ilaniscum* FOMBELLA, 1977
- *Leiosphaeridia* sp.
- *Micrhystridium* sp.
- *Timofeevia* sp. cf. *T. lancarae* (CRAMER & DIÉZ, 1972) VANGUESTAINE, 1978