THE COLONIAL ROCK-FORMING MICROFOSSILS OF THE BOHEMIAN UPPER PROTEROZOIC (CZECHOSLOVAKIA), 'BOHEMIPORA PRAGENSIS' n.g., n.sp.

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Abstract. Large amounts of well preserved microfossils have been reported from the cherts of the Upper Proterozoic of the Bohemian Massif (Middle Europe). They resemble those described by Cayeux (1894) from the Upper Proterozoic (Brioverian) of Bretagne (France). It is shown, unlike the views of Cayeux and his followers (Deflandre, 1955, and Graindor 1957), that the observed structures did not belong to individuals but to colonies of filamentous prokaryotic organisms, most probably blue-green algae (Cyanophyta). These produced specific crystal-like mineral aggregation round each filament. Scanning microscope examination has revealed that the individual facets of these mineral crystals were perforated by the openings through which the thread-like bodies of these primitive organisms protruded. It is shown that these microorganisms were attached to the cells of other, bigger microorganisms and enveloped them. Some of these substrate organisms might have been eukaryotic algae. The thecae gradually accumulated around the cells of these carrier organisms and after death the colonies disintegrated to constitute the main component of the sediment. The microfossils described are just a major component of a complicated fossil assemblage comprising coccoid and filamentous blue-green algae and bacteria. There are indications that several eukaryotic species might also have been present.

The following new taxa are described: *Thecophytales,* new order, *Cayeuxidae* (Graindor) family emend., *Bohemipora* n. gen., *B. pragensis* n.sp.

1. Preface

The described microfossils from the Upper Proterozoic cherts of the Bohemian Massif (Praha, locality Šárka – Barrandian) correspond closely to those discovered by Cayeux (1894) and have been widely discussed by other French authors (Deflandre in 1948, 1955, 1957, 1960, 1968 and Graindor in 1957a, b) from the Upper Proterozoic of France. Their morphological structure and biological classification have been a subject of sharp scientific controversy for more than 80 years.

Similar microfossils from the cherts of the same period from a nearby locality on the outskirts of Praha were first described by Rodić (1925, 1931). He compared them with Sphaerosomatites described earlier by Rothpletz (1880) from Saxonian Silurian, and assigned them to *Radiolaria.* Koutek (1936) dealt with this subject in the same way and called these cherts radiolarites. Rodić does not quote the earlier work of Cayeux (1894), however, who identified similar microfossils from the French Proterozoic (Brioverian) as Radiolaria. Since then Deflandre (1955) revised the original thin sections of Cayeux and rejected their qualification as *Radiolaria.* He created a new artificial genus Palaeo-

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cryptidium Deflandre and, unlike Cayeux, refused to admit the possibility that they had any mineral thecae. On the other hand, Graindor (1957a, b), who found the same organisms in the Brioverian in Normandy claimed that they had inorganic skeletons. The author (Pacltová, 1972) suggested that they were related to the French specimens of *Palaeocryptidium* Deflandre on the basis of the original illustrations by Cayeux (1894), observing the presence in both of them of organic and inorganic structures. The original study was based only on optical microscopic observations of thin sections, which did not allow a deep comprehension of either the organic or the inorganic structure of the organisms. It is concluded that the main reason for scientific misunderstandings had been their too limited dimensions, which were at the limits of the discriminating power of the optic microscope. Other reasons were the complexity of the given assemblage with a number of different species unusual in that period and, last but not least, differences in their state of preservation and the degree of decomposition of their bodies in the moment of fossilization.

Thanks to the kind assistance of the director and staff of the National Museum in Paris, the author had occasion to compare her specimens with those from Bretagne discovered by Cayeux and discussed by Deflandre in a thin section preserved in the mentioned collections under the name *Palaeocryptidium cayeuxi.* Unfortunately she was not able to obtain the materials of Graindor, collected in the corresponding formation of Normandy, which the last-mentioned identified with Cayeux's specimens from Bretagne and described as four different species, a new genus (*Cayeuxipora*) and a new family (*Cayeuxidae*).

The comparison has clearly shown the identity of the material described by both authors with the new paleontological evidence from Bohemia, and the presence in all of them of an inorganic structure as claimed by Graindor, the presence of which was rejected by Deflandre. Unlike Graindor's view, however, it is not internal skeleton of spherical individuals, but a surface covering of tiny filamentous colonial microorganisms. Unlike the original view of Cayeux, they have nothing in common with *Radiolaria.* They lived in abundant biocenosis with a number of other species of different groups, probably both prokaryotic and eukaryotic.

In the present study, the author briefly describes the given fossil assemblage with a detailed discussion of her own view on the character of the mentioned microfossils based on their detailed examination in the light microscope and in the transmission and scanning electron microscope.

2. Age Determination of the Upper Proterozoic of the Bohemian Massif

Although several attempts were made to determine the absolute age of the Proterozoic rocks in the Bohemian Massif, its stratigraphic assignment and that of its base and the overlayer cannot be viewed as reliable owing to the complicated tectonics and a number of metamorphic processes which it underwent. Kettner (1917) suggested a local stratigraphic subdivision of the Czech Proterozoic (formerly referred to as Algonkium)

based on the time span of Spilitic volcanism which took place in that period into the Prespilitic, Spilitic, and Postspilitic group. Only one analysis is available concerning the absolute age of the Spilitic group. It was done by the K-Ar method from a whole sample of metabasalt metamorphosed in the prehnite-pumpellyite facies. The age has been determined to be 647 m.y.

3. Material and Methods

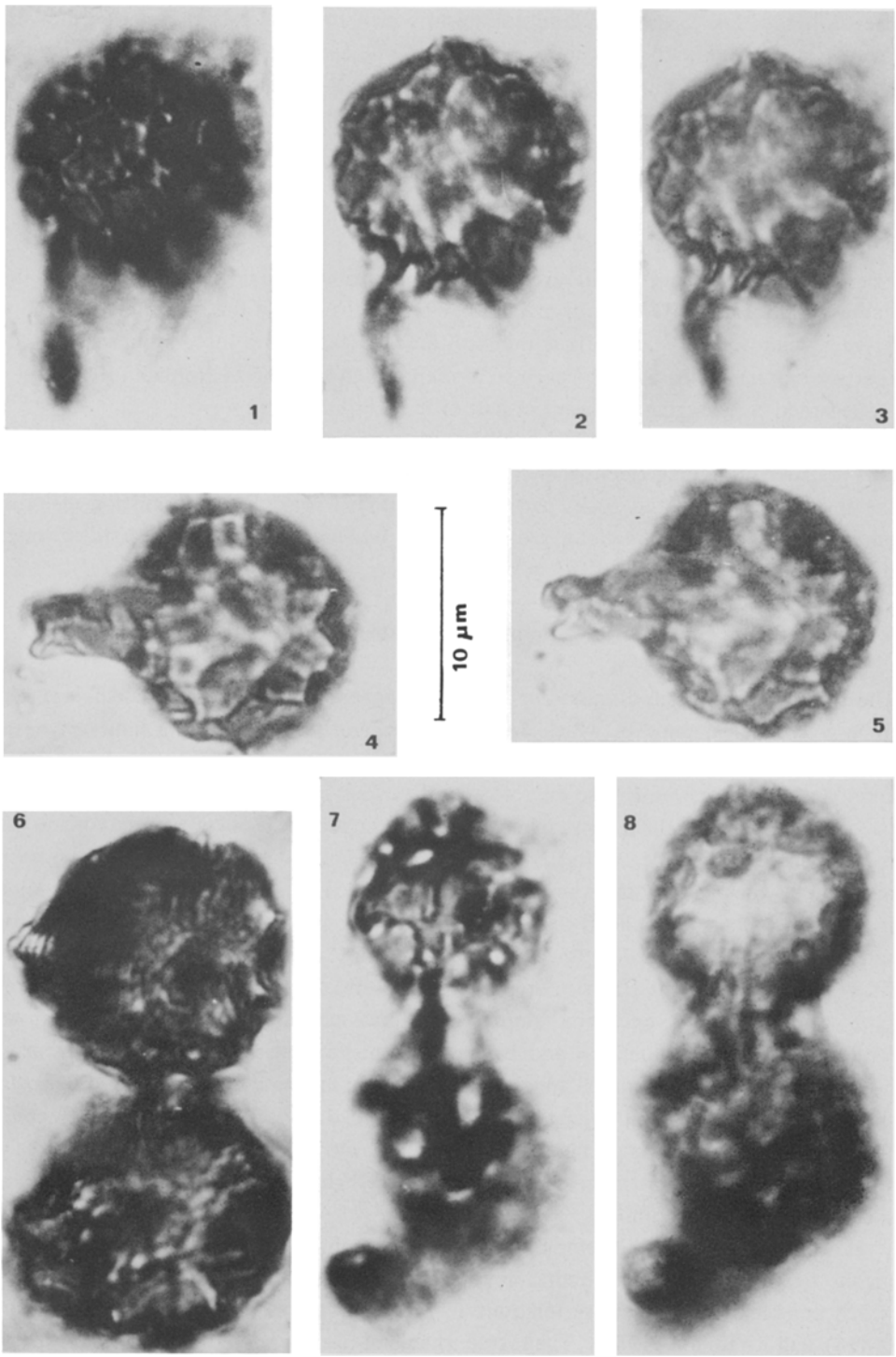
Paleontological evidence of the discussed microfossils was obtained in the cherts of the Praha-Šárka locality (NW suburb of Praha), which is the base of the Barrandian limb. For detailed microscopic examination, thin sections and slides with maceration residues, of cherts from the Praha-Šárka locality were prepared. According to Röhlich (1945), they are regarded as belonging to the upper part of the Prespilitic group.

For light microscope examination, thin sections and slides of maceration residues were also prepared. Scanning electron microscopy (SEM) observations were made partly with the break surface of the rock, partly with grounded rock. For transmission electron microscopy (TEM) examinations, grounded chert was used suspended in redistilled water or macerated in HF as for the light microscope.

4. Characteristics of the Microfossil Assemblage of the Praha-Šárka Cherts

The colonial microfossils discussed in the present paper are just part of an assemblage rich in various species, some of which are of a size scarcely surpassing the limits of optic microscope power. In thin sections of gray-black cherts with microscopic lamination, abundant assemblage of diverse microfossils of various size has been observed. The most conspicuous among them are spherical hollow structures of either gray-black or red-brown colour. Some of them seem to have been covered with a distinct surface membrane, whereas the others seem to be composed of minute rod-shaped components. Either type occurs prevailingly in separated aggregations. Among them another type of sphere appears, which seems to be composed of tiny radial threads with conspicuous fluorescence in UV-light. The size of all these structures ranges from 8 to 18 μm. Another type of microfossils occurring among the above-mentioned ones are filamentous structures of varying thickness and length. The thickest ones appear to be thinwalled hollow and sometimes ramified tubes of about 10 μm in diameter. The thinnest ones, on the other hand, are long, fine, highly UV luminescent threads each composed of three to five thinner, cordlike tangled filaments formed of chains of tiny constricted cells scarcely visible at the highest light microscope power. In UV light, manifold fragments of mineral skeletons are also discernible.

However, the most characteristic among all the observed microfossils are the tiny, highly refractive crystal-like bodies covering many of the above-mentioned structures, which are very similar in close relations to the observations (and pictures) of Cayeux (1894) and Graindor (1957). Their true character can be determined only by SEM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examination (Figures 3 and 4). It shows that the crystal-like structures are mineral thecae produced by filamentous microorganisms each protruding from a small opening in the middle of the crystal faces. They undoubtedly belong to some prokaryotic algae (*Cyanophyta?*). Their detailed description follows.

5. Systematical Description and Biological Relationships

Division *Cyanophyta* (?)
Class *Cyanophyceae* (?)
Order *Thecophytales* new order

Diagnosis: Colonial, epiphytic filamentous *Cyanophyta* (?), producing a mineral theca round each uniserial filament.

Etymology: Cyanophyta growing in thecae.

Discussion: The relation to the genus *Sphaerocongregus* Moorman (1974) are to be cleared. The author does not mention the presence of inorganic thecae, which seems to be evident from her microphotographs.

A. FAMILY 'CAYEUXIDAE' (GRAINDOR) EMEND.

Diagnosis: Thecophytales with siliceous crystals with round openings from which short, septate, uniserial, unbranched, tongue-like filaments protrude.

Discussion: According to Graindor (1957): "... the family includes micoorganisms with a siliceous skeleton". Graindor mentions two genera (*Cayeuxipora*) = *Palaeocryptidium* Deflandre (1955) and *Cayeuxistylus.*

B. GENUS 'BOHEMIPORA', N.GEN.

Synonyms: Cayeuxipora Graindor, 1957 part.
Cayeuxistylus Graindor 1957 part.
Palaeocryptidium Deflandre 1955 part.

Type species: Bohemipora pragensis, n.sp.

Diagnosis: Cayeuxidae forming polymorphic colonies epiphytic on various substrate organisms accepting the shape of their cells: spherical, oval, tubular, etc. Dimensions of individual filament ca. 5 μm in length, 0.2–0.4 μm in diameter. Size of the colony ca. 10 μm in diameter.

Fig. 1. Proterozoic rockforming microfossils from Praha-Šárka locality – *Bohemipora pragensis,* n. sp. Epiphytic colonies on varisphaerical substrate organisms. Thin section, light microscope, transmitted light. x 3000. 1–3: Three different optical levels of a substrate organism cell covered with the epiphytic colony of *B. pragensis,* n.sp. showing the polygonal crystalic fields. 3–4: Similar structures with distinct tube-like projection covered by the crystalic thecae. 6: Two adjacent substrate organism cells covered by the epiphytic colony. 7–8: Two sphaeres seemingly interconnected by a mineralized projection.

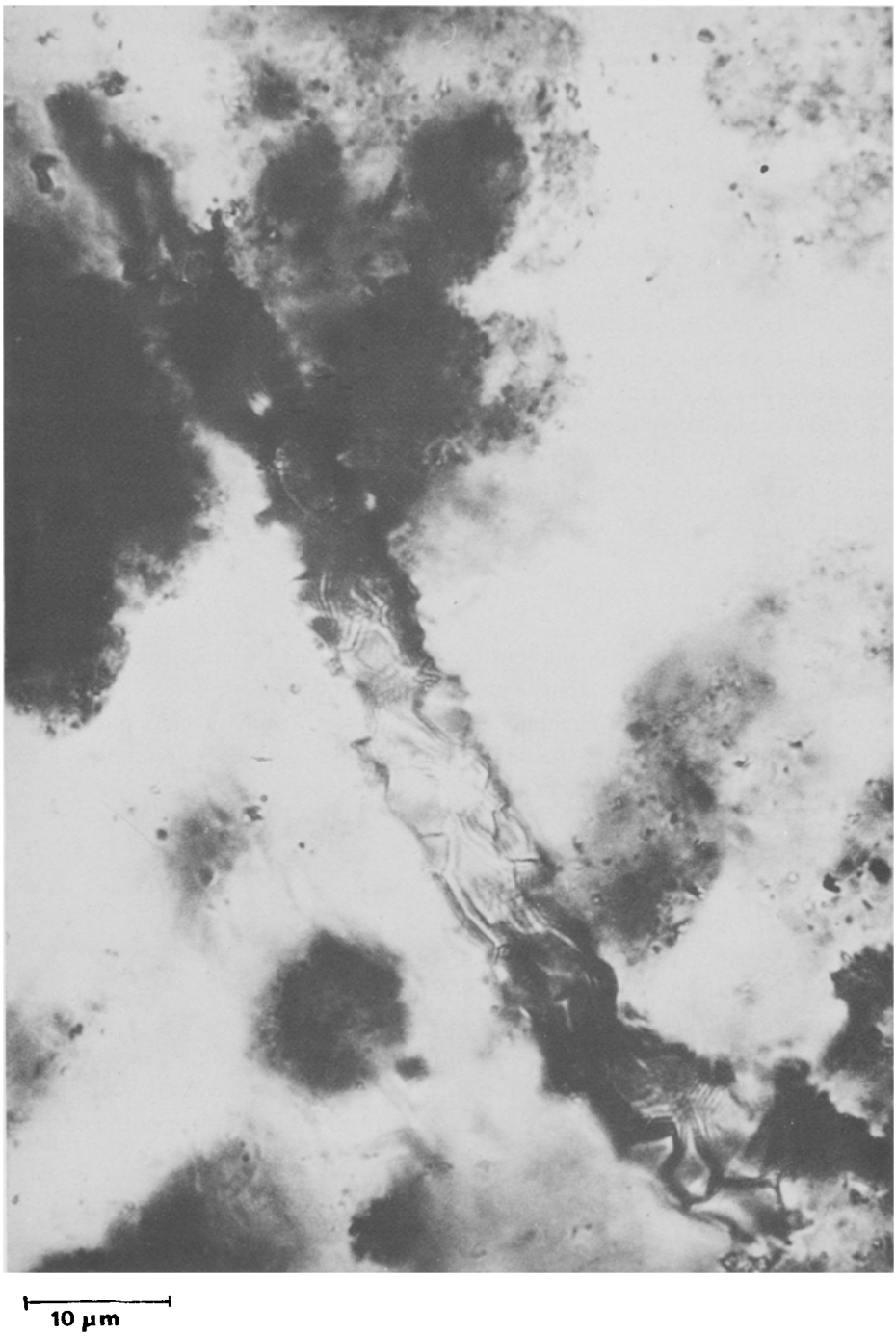

Fig. 2. A longitudinal filamentous structure covered by the colony of *B. pragensis*, n.sp. showing the polygonal fields of the microcrystals. × 2000.

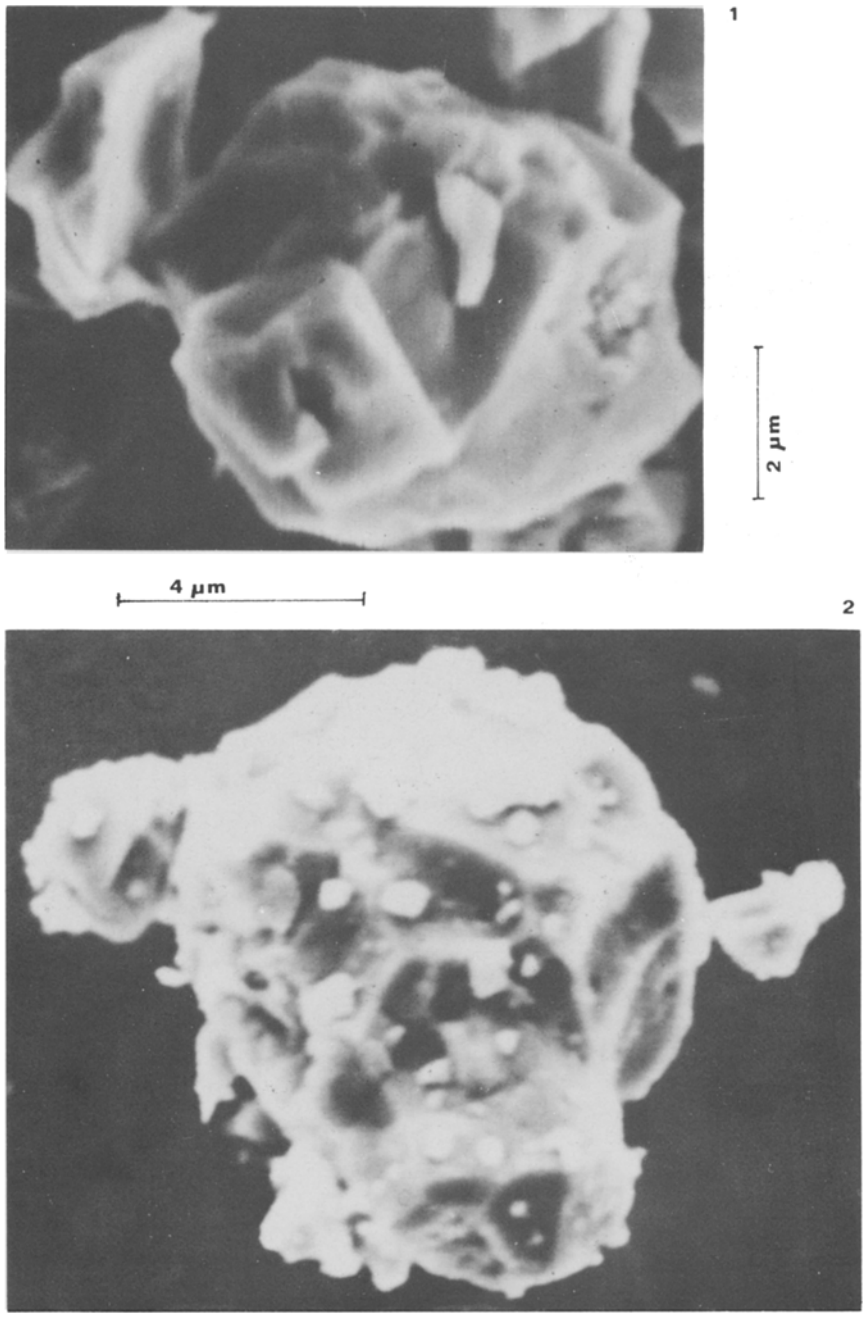

Fig. 3. SEM micrographs of the microfossils like in Figures 1 and 2 from the powdered chert. 1: A colony of *B. pragensis*, n.sp. with perforated microcrystals and one distinct tongue-like protruding organic filament. 2: Another colony at lower power, but without the openings and distinct filaments.

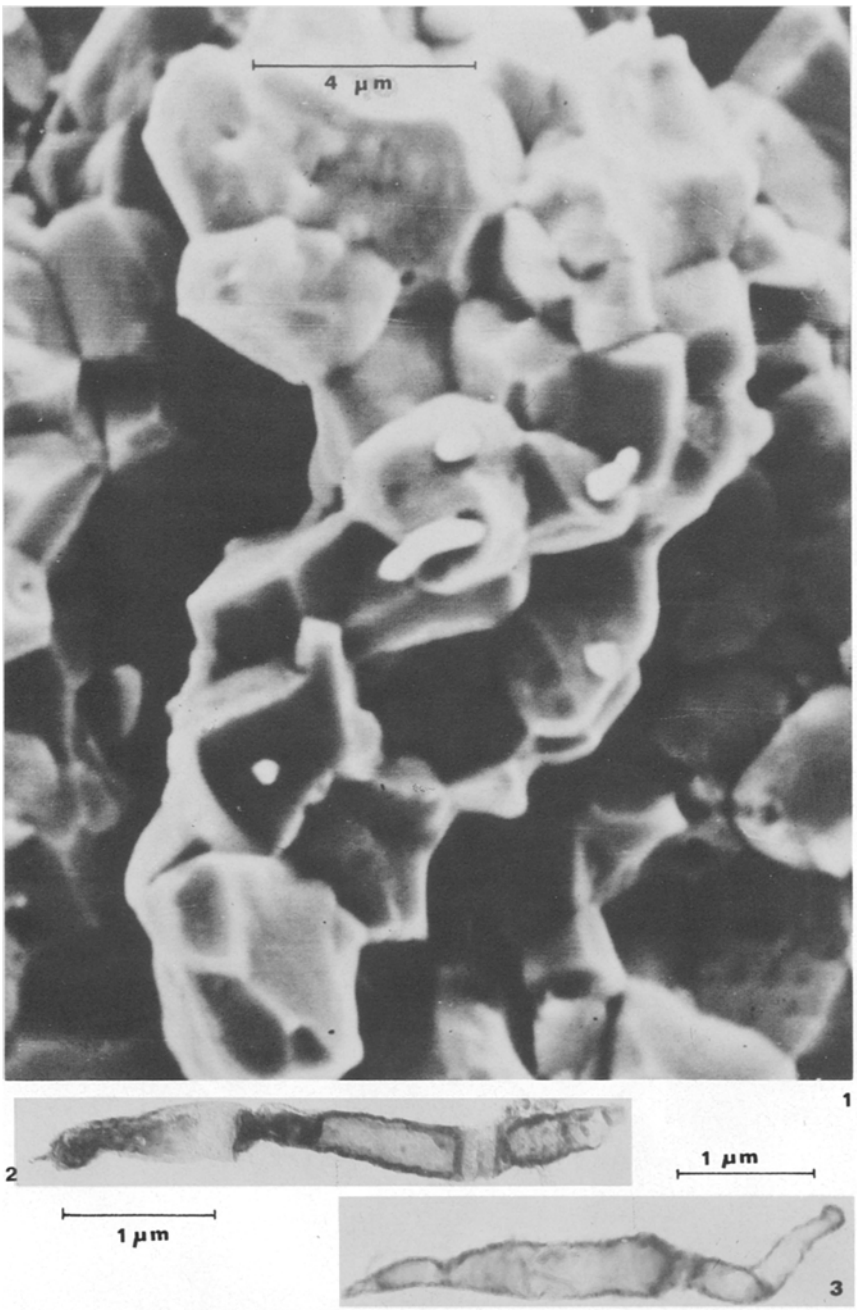

Fig. 4. SEM micrograph of a colony of *Bohemipora pragensis*, n.sp. from a freshly fractured rock chip showing the perforated microcrystals with several distinct filaments – the holotype (1). TEM micrographs of two filaments corresponding most probably to the filaments in the above SEM micrographs (2, 3).

Ethymology: Refers to the locality. Country: Bohemia, place: Praha.

Discussion: Although the microfossils dealt by Deflandre (1955) are closely related to those described by Graindor (1957) and the evidence discussed here, Deflandre's description, not respecting the mineral component (see further below), is valid for the corresponding substrate organisms species. On the other hand, the Graindor's description of *Cayeuxipora* viewing both the organic and inorganic components as one individual is to be accepted as synonymous to *Palaeocryptidium.*

C. SPECIES 'BOHEMIPORA PRAGENSIS' N.SP.

Diagnosis: Colonial filamentous (Figures 1–8) microfossils preserved with inorganic thecae in the shape of microcrystals which lay tightly pressed each against the adjacent ones (Figures 5 and 8). They are most probably formed of SiO_2 (Pacltová, 1974). The crystalline structures resembling a tetragonal or cubic system awaits a detailed crystallographic examination. The shape of the colony as a whole is spherical in most cases with various processes, being rather polymorphic, however, and formed of tubes ca. 10 μm in diameter in some cases (Figures 2 and 8). In agreement with the observations of Graindor (1957), the colony looks like a sphere with polygonal surface structure. In

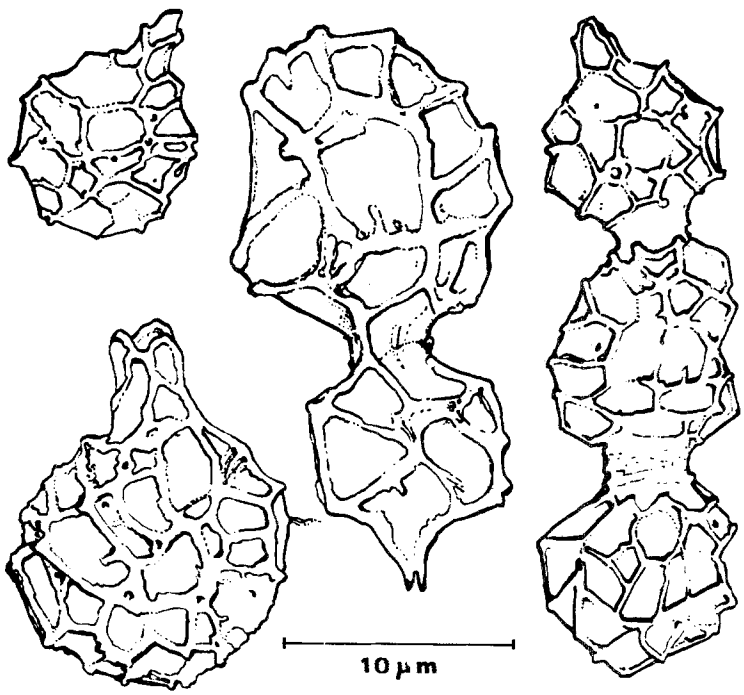

Fig. 5. Drawings of several colonies of *B. pragensis*, n.sp., showing variability in shape and in the crystalic fields. (The openings in the crystals are scarcely visible in the light microscope.)

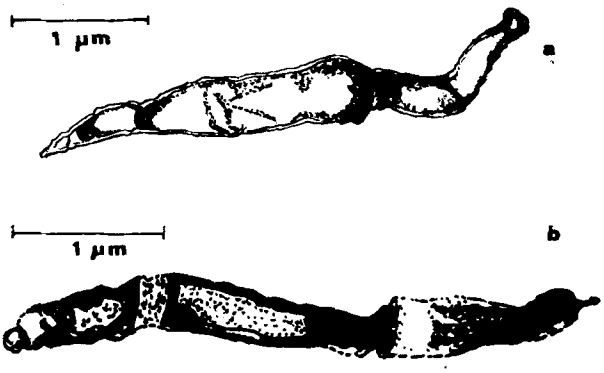

Fig. 6. Drawing of two filaments of *B. pragensis*, n.sp. in TEM, as shown in micrographs in Figure 4.

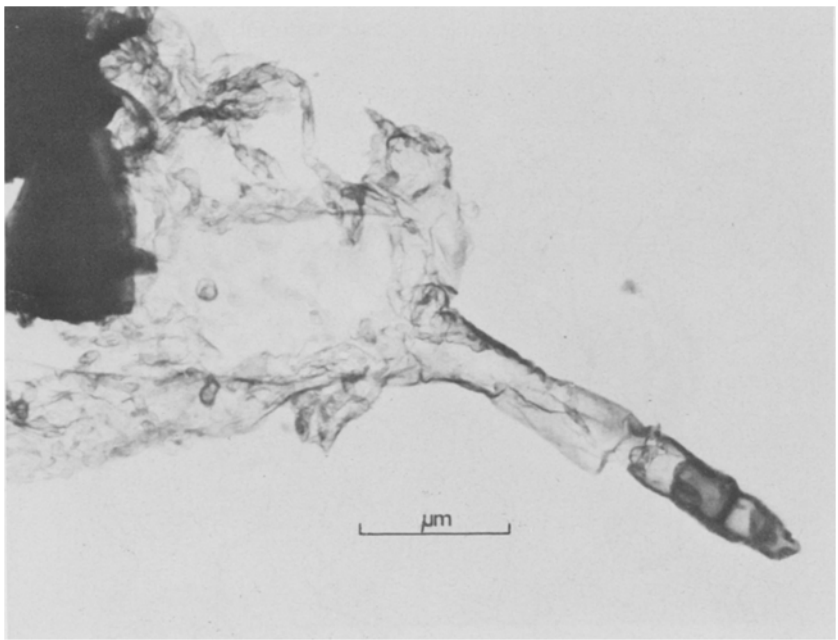

Fig. 7. *Bohemipora pragensis*, n.sp., organic residue after hydrofluoric acid maceration, observed in TEM. Four different microorganisms can be distinguished: a filament of *B. pragensis*, 5 µm in length, composed of cylindrical cells, clearly discernible at the terminal end. Note the part of the surface sheath typical for blue-green algae in about the middle of the filament (1). Part of the substrate organism, probably sphaerical originally, to the surface of which the filament was attached (2). Several tiny chains of little oval cells, 0.1 µm in length (3), and a few coccoid structures of about the same size (4). The last two mentioned structures were probably bacteria decomposing the substrate algal cell, or, may be, a developmental stage of a blue-green alga. x 20 000.

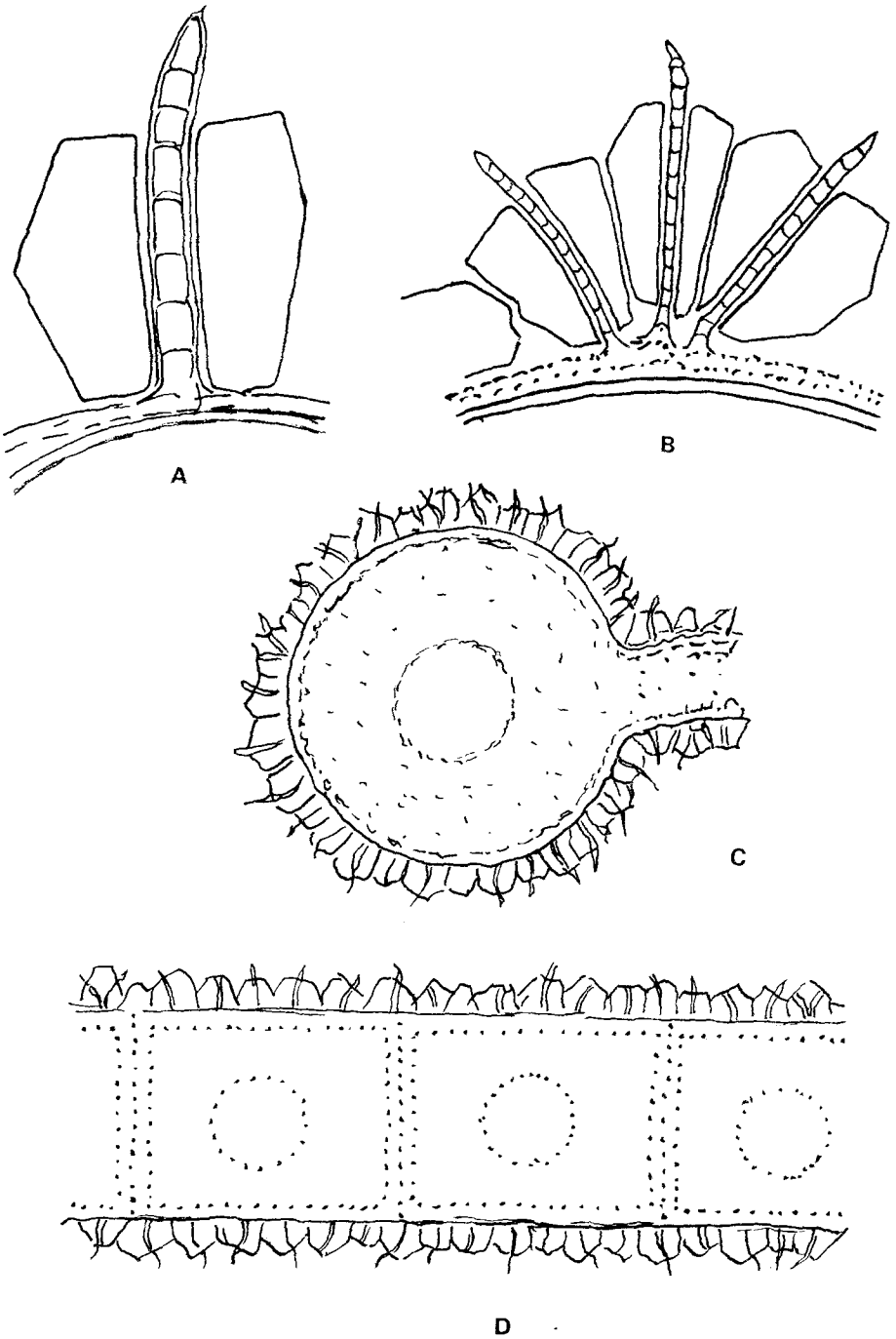

Fig. 8 Hypothetical reconstruction of a filament with the crystalline theca (a), a group of filaments with thecae (b) and two types of colonies of *Bohemipora pragensis*, n.sp. on eukaryotic cells in longitudinal sections, (c,d).

the middle of each polygon a short uniserial tongue-like thread arises, or a round opening is left (Figure 8). The size of the colony varies from 4 to 20 μm.

Description: Electron microscopy confirmed the colonial character of the microfossil. Each filamentous individual is preserved with an inorganic skeleton in the shape of a microcrystal, being in close connection with the surrounding crystals. From the central opening in most of the crystal faces the terminal part of a uniserial unbranched filament protrudes. TEM observation shows the cellular structure of the threads found in maceration residues either freely, or connected with broken parts of the substrate fossils (Figure 7). Each filament is formed of 8 to 12 or more cylindrical cells of varying length, which decrease in both length and diameter towards the terminal end, the end cell being round-tipped in most cases. The length of the whole filament is about 6 μm, its part protruding from the crystal scarcely surpassing 2 μm. The diameter of the cells is between 0.2 and 0.4 μm.

Holotype: Three adjacent individuals of crystals with protruding tongue-like filaments observed by SEM in part of the colony on the surface of a freshly fractured rock chip of the locality Praha-Šárka. Deposited in the collections of the Department of Paleontology, Charles University, Praha (Figure 4).

Paratypes: All other specimens of the same locality discussed, and shown in the pictures (Figures 1–8).

Type locality: Praha-Šárka, Upper Proterozoic cherts.

6. Conclusions

From what has been said above it follows that the microfossils with an inorganic skeleton first observed by Cayeux (1894) in the Upper Proterozoic of Bretagne and by Graindor (1957a, b) in the rocks of the corresponding period in Normandy and by Rodić (1925, 1931) in the Upper Proterozoic of Bohemia (Č.S.S.R.), are not individual organisms but colonies (large systems of individuals) formed of minute uniserial threads, preserved each with its own cover in form of a siliceous microcrystal. The closely packed microcrystals on the cell surface of various other, larger fossil micro-organisms create the impression of a continous body, thereby causing the above error.

The study of the most manifold organisms forming the fossil assemblage in which the colonial species is found reveals that they belong in reality to a number of different species, undoubtedly both prokaryotic and eukaryotic, fossilized in the living state and in various degrees of decomposition of their bodies, which formed the Proterozoic association. The largest of them became the substrate for the colonies of the studied species. The following questions remain to be answered: were the filaments of *Bohemipora* attached to living organisms or to their dead bodies; was the substrate organism just a suitable mechanical support, or did it serve as food for the epiphytic colony, or, perhaps, stand in a symbiotic relation with it? The size and structure of the colonies e.g. (the mentioned sheaths of the filaments) suggest that they belonged to *Cyanophyta.* From the ecological point of view, the species belonged in all probability to

the stenoekent organisms, presuming the presence specific of a medium, in the given case the vicinity of thermal effusions connected with submarine volcanic activity.

The author concludes that, from the point of view of the nomenclature, the species name *Palaeocryptidium cayeuxi* Deflandre (1955) (= *Cayeuxipora* Graindor, 1957) is to be preserved. It should be limited, however, to one specific substrate organism species, as follows from the description and figure of Deflandre (1955), who rejected the presence of an inorganic skeleton. His objections to the presence of mineral thecae in the microfossils described by Cayeux (1894) and Graindor (1957) are, of course, unfounded. Even in the figure (photograph) of his selected holotype from the Cayeux material, two adjacent bodies are clearly visible with the surface structure characteristic for the crystalline thecae of the colonial species described here. In agreement with Deflandre (1957) also the genus name (*Palaeocryptidium*) in Vavrdová's (1968) paper concerns the substrate organisms.

The inorganic character of these structures was clearly recognized by Graindor (1957) who identified the microfossils of Cayeux from Bretagne with his own findings from Normandy. He, however, agreed with Cayeux in regarding the colonies together with their substrate organisms, as individuals with a mineral meshlike surface skeleton. According to the different shape of the substrate organisms, he described four different species, belonging to two different genera.

In Graindor's description of the genus *Cayeuxipora* two different organisms are included. Thus the large spherical substrate organism, being an algal cell, most probably eukaryotic, or, perhaps, several such species, and the colony of the much smaller species on its surface. The latter, however, is regarded by Graindor as just a 'mineral skeleton' of the former one. The genus *Cayeuxipora* is thus a synonym of the genus *Palaeocryptidium* Deflandre. The description of the family *Cayeuxidae* Graindor, on the other hand, is so broad that it may also be related to the colonial microorganisms described here (even if it was not so in the view of Graindor), so that the name can be preserved in the new sense, with the new type genus and type species *Bohemipora pragensis*. The validity of the four species of *Palaeocryptidium* (=*Cayeuxipora*) described by Graindor (1957) as well as that of his genus *Cayeuxistylus*, will be verified by further research.

The mineral components of the fossils and their abundance in the studied rocks (Proterozoic cherts) seems to justify their classification as rockforming species. Figure 4 shows the amount of the crystals with typical openings also outside the living colony, which are no doubt remnants of earlier, disintegrated colonies which later became a main component of the sediment and thus a substantial part of the given rock (Šárka cherts).

Rich evidence has been accumulated especially from TEM studies which seems to justify together with the French findings the assumption that the corresponding complicated assemblage of the various microorganism species, both prokaryotic and eukaryotic, was a characteristic ecosystem of the youngest Upper Proterozoic. We have only reached the very beginning of the research on this so complicated and interesting problem, however, as revealed by the studies of Schopf (1968, 1974, etc), Schopf and Blacic (1971) Cloud (1968, etc.), Muir (1974, etc.) and their followers.

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