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COLONIAL VOLVOCALES (CHLOROPHYTA) FROM THE UPPER DEVONIAN OF POLAND AND THEIR PALAEOENVIRONMENTAL SIGNIFICANCE

Abstract. — First fossil representatives of the modern fresh-water algae from the family Volvocaceae — *Eovolvox silesiensis* gen. et sp. nov. — have been discovered in the Frasnian *Amphipora*-calcisphaere limestone of Upper Silesia, Poland. The abundant appearance of these algae indicates a very low salinity gradient of the depositional environment, probably close to that of modern eutrophic lacustrine conditions. The algae have been preserved due to rapid carbonate permineralization during preburial and/or early burial stage.

INTRODUCTION

Several famous findings of Precambrian microfloras, made during the two last decades (see Schopf, 1970, for summary), evoked a marked revival in exploration of algal microbiotas from the younger, Phanerozoic deposits. The studies, mostly involving chemical method of microflora extraction, have resulted in discovery of numerous representatives of acid-resistant groups as acritarchs and hystrichosphaerids, which are of certain stratigraphic importance but of little value for understanding major steps in evolution, palaeobiology, and ecology of the thallophytes. Remains of microthallophytes with cellular walls built of cellulose, hemicellulose or of other polysaccharides are markedly more scarcely found because of their remarkable susceptibility to bacterial decomposition or chemical hydrolysis. Such remains are so fragile that they may only be studied in thin sections. The cellularly preserved algal microfossils are primarily derived from cherts, where their preservation was facilitated by rapid, early diagenetic, hermetic embedding in siliceous matrix (e.g. Barghoorn & Tyler, 1965; Schopf, 1968; Cloud *et al.*, 1969; Moorman, 1974).

The present author found mass occurrence of colonial Volvocales in fine-grained bituminous limestones. A unique preservation of these microfossils indicates that some carbonate rocks may also be prospective for searching of similar delicate microthallophytes. The forms described here undoubtedly represent the modern family Volvocaceae. They are related to the *Amphipora*-calcisphaere facies widely distributed in the Devonian and lowermost Carboniferous. The well known ecological requirements of modern volvocacean algae and the great similarity between them and the Devonian forms suggest that the fossil forms may be a useful tool in palaeoenvironmental reconstructions. These algae and some other Devonian microfloras described from Germany (Grüss, 1928), Scotland (Croft & George, 1959) and USA. (Baschnagel, 1942; Fairchild *et al.*, 1973; Wicander & Schopf, 1974) give so far the best insight into the Palaeozoic non--calcareous microscopic thallophytes.

The present paper was prepared in the Institute of Palaeozoology (Zakład Paleozoologii) of the Polish Academy of Sciences, Warsaw, (abbreviated as ZPAL) where the collection of thin sections with the algal material studied is housed.

LOCATION AND STRATIGRAPHY

Samples yielding volvocacean algae are derived from Sosnowiec IG-1 borehole localized in the area of Sosnowiec town (Katowice district, Upper Silesia, southern Poland). The core materials of the Devonian were obtained through the courtesy of the Upper Silesian Branch of the Geological Survey of Poland in Sosnowiec.

Volvocacean algae were found in intercalation of fine-grained black bituminous *Amphipora* limestone, 20 cm thick, penetrated by the borehole at the depth of 2385—2395 m (box I). *Amphipora* assemblage is composed of two species, abundant *A. perversiculata* Lec. and markedly scarcer, *A. rudis* Lec., indicative of the Frasnian age (see Lecompte, 1951—52; Zukalová, 1971). The *Amphipora* limestone occur in a thick series of black stromatoporoid limestone. The limestone occurring some 40 m above and below the bituminous intercalation with volvocacean algae yield stromatoporoid species including: *Actinostroma crassepilatum* Lec., *Actinostroma expansum* (Hall & Whitfield), *Actinostroma* aff. *voivojense* Riab., *Ferestromatopora parksi* Stearn, *Tienodictyon tschussovense* (Yav.)

The species give further evidence to the Frasnian age of the algae--bearing deposits (e.g. Lecompte, 1951—52; Stearn, 1966, Kaźmierczak, 1971). Other macrofossils occurring here include some ramose tabulate corals *Scoliopora denticulata* (M. Edwards & Haime) which are, however, lacking in the algal-bearing intercalation.

MATERIAL AND MODE OF PRESERVATION

The volvocacean algae were studied by light microscopy in 17 petrological thin-sections. The algae are fairly common, 10 to 15 specimens per 1 mm^2 of thin section.

All the algal colonies are embedded in calcareous matrix forming coatings distinctly separating them from surrounding deposit. The coatings are usually spheroidal (Pl. XVIII, Fig. 2), and occasionally more irregular in shape (Pl. XX, Fig. 6). The coatings are usually fine-crystalline or even almost amorphous close to the surface of a colony, becoming externally markedly more coarsely crystalline. In several instances the coatings are formed of randomly distributed fine- and coarsely grained calcite, which results in their mottled appearance. The coatings are usually 50—60 μm thick, ranging from 10 to 100 μm in thickness. These calcite-coated volvocacean colonies are therefore grainy (pelletoidal) components of the deposit, achieving a remarkable rock-building importance. This sounds as a paradox, if original highly fragile structure of the algae is taken into account.

Development of the calcite coatings can be explained only in terms of diagenetic precipitation of calcium carbonate around volvocacean colonies. The majority of the colonies do not show any traces of compaction, thus it may be inferred that the process of their mineralization started very shortly after or just after their death and was completed on early-diagenetic burial stage. Therefore these $CaCO_3$-coated colonies seem to represent an evident example of eogenetic microconcretion formation. This example also throws some light on the genesis of certain common calcareous microfossils such as calcisphaeres, the mineral coatings of which may also have been formed post-mortem (more details see Kaźmierczak, in preparation).

The early permineralization of volvocacean coenobia resulted in protection to compaction as well as in an efficient antibacterial screen. It does not follow from above that the preservation of all specimens is excellent. Several specimens display partly destroyed cells possibly due to chemical hydrolysis of cell membranes. Moreover, some cells are deformed by framboidal pyrite often infilling central part of colonies.

The preservational history of the Devonian volvocacean algae may be reconstructed as follows: during preburial stage, dead colonies sinking on the bottom were subjected to rapid permineralization with $CaCO_3$. This process was related to intitial phases of decay of colonies and surrounding mucus. Fast progress of this process was facilitated by an increased pH accompanied by suitably high concentration of Ca^+ ions in water (see experimental estimations given by Berner, 1968; Mitterer; 1971; McCunn, 1972). Reducing conditions (dissolved H_2S) at the precipitation site also facilitated formation of iron sulphides (Berner, 1970) within colonies subjected to mineralization. Plastic deformations of some colonies indicate that their permineralization took place on the shallow burial stage of their preservational history. Distinct calcareous coatings found around all fragments of unidentifiable (?blue-gree) filamentous algae show that the eogenetic permineralization was not limited to the volvocacean colonies but it was rather of universal character.

SYSTEMATIC DESCRIPTION

Division **Chlorophyta**
Class **Chlorophyceae**
Order **Volvocales**
Family **Volvocaceae**
Genus *Eovolvox* gen. nov.

Type species: *Eovolvox silesiensis* sp.nov.
Derivation of the name: *Eo* = Gr. — an early age, *Volvox* — a recent genus of volvocacean algae.

Diagnosis. — Colonies (coenobia) in the form of hollow spheres composed of closely packed ovoid, pyriform or spindle-shaped isomorphic cells arranged in a single layer. External diameter of colonies: 42—135 μm; diameter of cells: 5—27 μm. Colonies contain 44—452 cells (values calculated from diameter and number of cells in ± equatorial sections of colonies).

Comparison with modern colonial forms

Eovolvox displays pattern of colonies typical for Recent representatives of the family Volvocaceae including several well known genera as *Pandorina* Bory, *Eudorina* Ehrenberg, *Volvulina* Playfair, *Pleodorina* Shaw and *Volvox* Linné (for a good review see Pascher, 1927; Pocock, 1933; and Fritsch, 1935).

Eovolvox differs from *Pandorina* in markedly higher number of cells in colonies and in daughter-colonies of gonidial origin. The latter feature distinguishes *Eovolvox* from *Eudorina, Volvulina* and *Pleodorina,* characterized by similar outline of colonies (compare Pl. XIX, Figs 1—2). In last mentioned genera either all cells of a colony (some species of *Eudorina*) or the majority of cells (*Pleodorina*) give rise to new daughter-coenobia. Cells of *Eovolvox* colonies are isomorphic whereas those of the above genera show morphological and functional (somatic and reproductive) polarity in coenobia. However, when comparison concerns only the pattern and size of cells of *Eovolvox* and, e.g., *Eudorina elegans* Ehrenberg (Pl. XIX, Figs 1—2), these forms appear to be very similar each other.

Eovolvox appears close to Recent *Volvox* in high number of cells in a colony and in a few daughter-colonies occurring within parent-colonies. This similarity is emphasized by a distinct sexual dimorphism in

Eovolvox. In the Recent Volvocaceae the sexual dimorphism is most strongly developed just so in some species of the genus *Volvox* (e.g., in *V. aureus* Ehrenberg). *Eovolvox* differs from *Volvox* primarily in larger and more closely spaced cells and in generally smaller size of colonies.

Eovolvox undoubtedly belongs to the family Volvocaceae and it represents a transitional link between the group including the genera *Eudorina, Volvulina* and *Pleodorina* and highly specialized species of *Volvox.*

Fossil structures of supposed volvocacean nature

It is highly possible that a large part of enigmatic microfossils generally termed as calcisphaeres actually represent volvocacean coenobia with obliterated organic structure despite calcification. This is suggested by a remarkable similarity between badly preserved coenobia from the author's collection, particularly when observed under small magnification and some non-radiosphaerid calcisphaeres common in various carbonate facies of Eurasia and North America (e.g. Dervillé, 1950; Baxter, 1960; Flügel & Hötzl, 1971). The problem of volvocacean nature of some calcisphaeres will be treated in a separate paper (Kaźmierczak, in preparation).

A separate paper will be also devoted (Kaźmierczak, in press) to the important problem of presumed affinity between the Devonian volvocacean algae and the Middle Precambrian problematic microfossil *Eosphaera tyleri* Barghoorn from the Gunflint Iron Formation of Canada.

Eovolvox silesiensis sp.nov.
(Pl. XVII, XVIII, XIX Figs 1, 3—4 and Pl. XX)

Holotype: Pl. XVIII, Fig. 1; thin section ZPAL Al. III/8; MIN-8 Microscope stage coordinates 11.3/47.7 (behind and to the right of reference X).

Type locality: subsurface of Sosnowiec town (Katowice district), Upper Silesia, southern Poland.

Type horizon: Frasnian Stage of the Upper Devonian.

Derivation of the name: from Silesia, a geographical region of southern Poland.

Diagnosis: — As for genus.

Variability. — Histograms of frequency distribution of size ranges (Text-fig 1A-C) show a remarkable variability of colonies. Large differences in size of colonies may be attributed to succession of generations of daughter-colonies until a fully developed colony is produced. Such a growth is typical of some colonial Volvocaceae (Chapman, 1964, p. 31).

The correlation coefficient between the external diameter of coenobia and the diameter of cells $r = +0.66$, indicates a moderately positive correlation between the two values. Regarding the degrees of freedom $N-2 = 25$, the coefficient obtained is significant below 1% level (compare Table V in Simpson *et al.*, 1960).

Two more or less distinct morphological subdivisions may be divided on the basis of shape and number of cells in colonies: (1) colonies composed of ovoid to slightly pyriform cells, usually less than 120 and not more than 240 in number (Pl. XVIII, Figs 3—4; Pl. XIX, Figs 1 and 3), and (2)

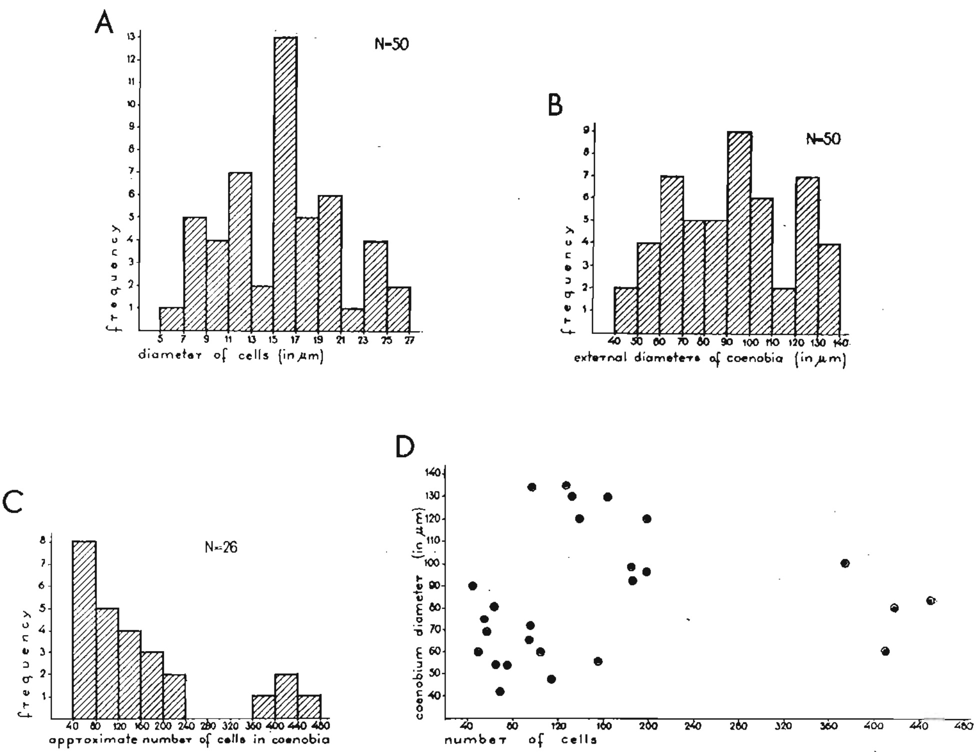

Fig. 1. *Eovolvox silesiensis* gen. et. sp. nov. A, B and C — histograms indicating frequency distribution of size ranges; D — coenobium diameter/number of cells ratio.

colonies composed of strongly elongated, pyriform, or spindle-shaped cells (Pl. XVIII, Fig. 1; Pl. XX, Figs 5—6), over 360 and up to 452 in number. Very well preserved specimens of the latter group (e.g. colony from Pl. XVIII, Fig. 1) display cells with prominent, very thin outgrowths of cell membrane in their external parts. These structures somewhat resemble so called pseudocilla found in colonies of Tetrasporales (e.g., *Gloechaete* Lagerheim) affined to Volvocales, or cell processes known in some Chlorococcales (e.g., *Pediastrum* Meyen). The colonies of type (1) are markedly more common than those of type (2) and contribute about 85% of all analysed specimens.

Taking into account the morphological differentiation in Recent representatives of the family Volvocaceae, e.g. in the common genus *Volvox* (see Pascher, 1927; Pocock, 1933), it may be assumed that *Eovolvox* colonies with ovoid cells may represent female and/or vegetative colonies, and those with spindle-shaped cells may belong to male (antheridial) coenobia.

MODE OF REPRODUCTION

The character of asexual reproduction is well documented in the material studied. Daughter-colonies differing in development were found inside over a dozen colonies. Their occurrence also evidences the volvocacean nature of the studied forms. The number of daughter-colonies varies from 1 to 5 (Pl. XX, Figs 1—3). Parent-coenobia with a single large daughter-colony are the most common. The daughter-colonies vary from 30 to 40 μm in size when they occur in groups, and 30—40 to 90 μm in case of single forms. The largest daughter-colonies may be so large that their cells butt against cells of parent-colony (Pl. XX, Fig. 3). Well--distinct outlines of cells of daughter-colonies indicate that cell membranes were acquired relatively early, before liberation of the new coenebium. In some modern representatives of the genus Volvox the cell membranization is apparently delayed and takes place after liberation (Fritsch, 1935). Early stages of development of daughter-colonies, i.e., formation of gonidia and phialopores, are not preserved in the material studied.

There are no direct evidences for sexual reproduction in the material studied as neither thick-walled cospores nor markedly increased cells corresponding to ova are preserved. However, the dimorphism in *Eovolvox* colonies discussed above may be treated as an equivocal evidence of sexual reproduction (monoecious coenobia). Therefore, the lack of cospores within colonies may indicate fertilization of gametes outside the colonies, i.e., highly advanced heterogamy but not oogamy.

PALAEOECOLOGY AND PALAEOENVIRONMENTAL SIGNIFICANCE

Similarly as all modern spherical colonial Volvocales, *Eovolvox silesiensis* was a motile planktont. Its mass occurrence in the deposit indicates that it presumably was a "water-blooming" form, similarly as its Recent relatives. Traces of filamentous structures commonly found close to or adjoining *Eovolvox* colonies (Pl. XVII, Fig. 2; Pl. XIX, Figs 3—4) show that the colonies were often entangled or interwinned with floating clusters or mats of filamentous algae. Small thickness of the filaments, 5—8 μm, suggests that they most probably represent remains of blue-green algae. It may be assumed that the *Eovolvox* colonies, after a temporary bloom, settled together with algal filaments entangling them on the bottom, where their remains soon underwent a partial or complete permineralization.

The mass occurrence of the representatives of Volvocaceae in the Frasnian *Amphipora*-calcisphaere deposit is of primary importance for the reconstruction of their sedimentary environment, first of all of its salinity gradint. All modern members of the family Volvocaceae, to which *Eovolvox silesiensis* undoubtedly belongs, are exclusively inhabitants of fresh water. They are characterized by rather sharp environmental requirements and primarily live in strongly eutrophized ponds and lakes. It should be noted that the vast majority of other Volvocales are also fresh-water forms (Fritsch, 1935) and unicellular *Dunaliella* Teodoresco from the family Pyramimonadaceae appears to be the only important member of this order living in estuarine and sometimes in marine environments (Wood, 1967).

A very low salinity gradient, close to that of lacustrine facies, is here postulated for the depositional environment of *Eovolvox*-bearing sediment. The sediment also yields fairly numerour, non-abraded sticks of *Amphipora* (with peripheral membrane intact), abundant radiosphaerid calcisphaeres and problematic foraminifera, *Parathurammina* Suleimanov and *Irregularina* Vissarionova, as well as occasional enigmatic fossil *Uraloporella* Korde. Similar Devonian sediments with low diversity biota were usually interpreted as products of restricted shallow marine environment (e.g. Reitlinger, 1957; Klovan, 1964; Wilson, 1967; Stanton, 1967; Read, 1973). Attention should be paid to the fact that the volvocacean algae cooccur with *Amphipora* — one of the most common Devonian fossil, commonly related to more "marine" facies. *Amphipora* should be therefore interpreted as typical euryhaline form, tolerant to salinity changes from hypersaline facies (dolomites) to almost oligohaline facies. So large changes in salinity of the Upper Devonian basin in the area of Upper Silesia were presumably related to sea level fluctuations in the interior of this very shallow Frasnian epeiric sea. For instance, the average water depth estimated for *Amphipora* limestones based on carbonate cycles analysis equals 1 m or less (Read, 1973). In such an epeiric sea the normal diurnal tides would not have occurred and the freshening stopped (Shaw, 1964; Conclusions 2—4). Moreover, even small regressive trends would have resulted in origin of isolated shoals in which a large influx of meteoric water could have resulted in a reduction in salinity down to a critical point, at which forms diagnostic of fresh-water environment could thrieve. In this way an isolated part of the Frasnian basin, inhabited by the volvocacean algae described here, gained its lacustrine ecological status. In the same time, the waters surrounding that lake could have been and most probably have been characterized by more widely open connection with the distant sea by a complex system of deep tidal channels or other drainage systems. In these waters, of course, more "marine" biota might have flourished.

A local low salinity gradient exclusively related to influx of meteoric water was very unbalanced and a rapid inversion to hypersaline or brackish conditions due to evaporation was fairly possible.

The black colour of the deposits bearing volvocacean algae resulted from a marked contribution of kerogenous substance and pyrite, indicating that bottom deposits with algal remains were under slightly reducing conditions.

The intensive permineralization of algal remains was undoubtedly related to highly alkaline pH values at the sediment/water interface, as well as to high content of Ca^{++} ions in water. These feautures are typical of Recent energy-sink eutropic lacustrine environment (e.g. Round, 1965; Bradley & Beard, 1969). Such an environment, often markedly enriched in dissolved organic matter, is especially favourable for modern Volvocaceae, which are recognized as its indicative elements (e.g. for β-mesosaprobic zone — see Fott, 1959, p. 449). The volvocacean algae described in this paper seem to be of similar importance and may serve as a new, highly useful palaeoenvironmental indicator.

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JÓZEF KAŹMIERCZAK

KOLONIJNE VOLVOCALES (CHLOROPHYTA) Z DEWONU GÓRNEGO POLSKI I ICH ZNACZENIE PALEOEKOLOGICZNE

Streszczenie

W bitumicznych wapieniach amfiporowo-kalcysferowych franu z wiercenia Sosonowiec IG-1 (Górny Śląsk) odkryto unikalnie zachowane pierwsze kopalne glony należące do dzisiejszych słodkowodnych zielenic wiciowych z rodziny Volvocaceae (rząd Volvocales). Analiza tafonomiczna wskazuje, że glony te zachowały się dzięki szybkiemu pośmiertnemu otuleniu kolonii w $CaCO_3$. Proces ten rozpoczął się przypuszczalnie już w trakcie ekspozycji gnijących kolonii na dnie zbiornika, a został zakończony we wczesnej fazie pogrzebania. Mineralizacja kolonii związana była z silnie podwyższonym pH strefy przydennej i nasyceniem jonami Ca^{+}.

Odkryte glony, oznaczone jako *Eovolvox silesiensis* gen. et sp. nov., dają się dobrze porównać pod względem morfologicznym z dzisiejszymi Volvocaceae, wykazując szereg cech przejściowych pomiędzy formami z rodzajów *Eudorina, Volvulina* i *Pleodorina* a grupą wysoko wyspecjalizowanych form włączanych do rodzaju *Volvox.*

Masowe występowanie kolonijnych Volvocales w wapieniu amfiporowo-kalcysferowym uznawanym dotychczas za osad morski, wskazuje na bardzo niski stopień zasolenia środowiska sedymentacji, zbliżony do warunków chemicznych dzisiejszych słodkowodnych (oligohalinowych) jezior. Inne cechy wapienia z Volvocales, jak znaczna zawartość kerogenowych substancji organicznych i liczne synsedymentacyjne (framboidalne) ziarna pirytu świadczą, że podobnie jak w przypadku środowisk zasiedlanych masowo przez dzisiejsze Volvocaceae, jeziorny zbiornik frański miał silnie eutroficzny charakter.

ЮЗЕФ КАЗЬМЕРЧАК

КОЛОНИАЛЬНЫЕ VOLVOCALES (CHLOROPHYTA) ИЗ ВЕРХНЕГО ДЕВОНА ПОЛЬШИ И ИХ ПАЛЕОЭКОЛОГИЧЕСКОЕ ЗНАЧЕНИЕ

Резюме

В битуминозных амфипоро-кальцисферовых известняках франского возраста, вскрытых буровой скважиной Сосновец ИГ-1 (Верхняя Силезия), были найдены уникально сохраненные, первые ископаемые водоросли, принадлежащие к современным пресноводным жгутиковым водорослям семейства Volvocaceae (отряд Volvocales). Тафономический анализ показал, что эти водоросли сохранились балгодаря быстрому покрытию колонии карбонатом кальция после ее отмирания. Этот процесс начался, очевидно, уже во время экспозиции разлагавшейся колонии на дне водоема и был завершен во время ранней стадии захоронения. Минерализация колонии была обусловлена сильно повышенным pH и насыщением ионами Ca+ придонной среды.

В морфологическом отношении выявленные водоросли, которые были отнесены к *Eovolvox silesiensis* gen. et sp. nov., во многом напоминают современные Volvocaceae и характеризуются рядом переходных признаков между формами родов *Eudorina, Volvulina* и *Pleodorina* и группой высоко специализированных форм, принадрежащих к роду Volvox.

Массовое распространение колониальных Volvocales в амфипоро-кальцисферовом известняке, который до сих пор считался морским осадком, указывает на весьма слабую соленость среды осадконакопления, напоминающую химические условия современных пресноводных (олигогалинных) озер. Другие признаки известняка с Volvocales, как значительное содержание керогенного органического вещества и наличие синседиментационных зерен пирита, свидетельствуют о том, что франский водоем отличался сильно эвтрофным характером, свойственным современным водоемам с массовым распространением Volvocaceae.

EXPLANATION OF PLATES

Eovolvox silesiensis gen. et sp. nov. in petrographic thin sections from the Late Devonian (Frasnian) *Amphipora*-calcisphaere limestone from Sosonowiec IG-1 borehole, depth 2385—2395 m (I), Sosnowiec (Katowice district), Upper Silesia, southern Poland. Thin section number (Z PAL Al.III) and MIN-8 Microscope stage coordinates are given for each specimen.

Plate XVII

Fig. 1. Volvocaceae-bearing sediment with some of the volvocacean algae shown by arrows. Radiosphaerid calcisphaeres, parathuramminid foraminifera and dark spots of organic substance are also visible. Z PAL Al.III/3.

Fig. 2. Nearly equatorial section of two colonies in heavy calcareous coatings. Considerable differences in cell size of both colonies are clearly visible. Note also a fragmentary filamentous (?) blue-green alga attached to the right colony. Z PAL Al.III/2, 7.8/67.9.

Plate XVIII

Fig. 1. Holotype. Nearly tangential section showing elongated, pyriform cells with thin external outgrowths. Z PAL Al.III/8, 12.9/43.6.

Figs 2 and 4. Nearly equatorial sections of four colonies showing differences in colony and cell diameter as well as character of the calcareous envelopes. Fig. 2 — Z PAL Al.III/3, 6.4/47.8; Fig. 4 — Z PAL Al.III/9, 10.5/55.8.

Fig. 3. Nearly tangential section of a colony composed of globose and ovoid cells surrounded by an amorphous calcareous matrix. Z PAL Al.III/7, 11.9/43.4.

Plate XIX

Fig. 1. Nearly tangential section of a colony with ovoid cells. Z PAL Al.III/7, 11.3/47.7.

Fig. 2. Modern volvocacean alga *Eudorina elegans* Ehrenberg in transmitted light. Note the striking similarity in colony organization (size and shape of cells) between this form and specimens of *Eovolvox silesiensis* gen. et sp. nov. illustrated on Fig. 1 and on Pl. II, Fig. 3. Collected in August from a pond in Łazienki Park, Warszawa.

Fig. 3. Nearly equatorial section of a colony with partially destroyd cells and a filament of (?) blue-green alga attached to the surface. Z PAL Al.III/6, 4.5/42.3.

Fig. 4. A poorly preserved colony entagled in cluster of (?) blue-green algae. Z PAL Al.III/9, 8.2/58.6.

Plate XX

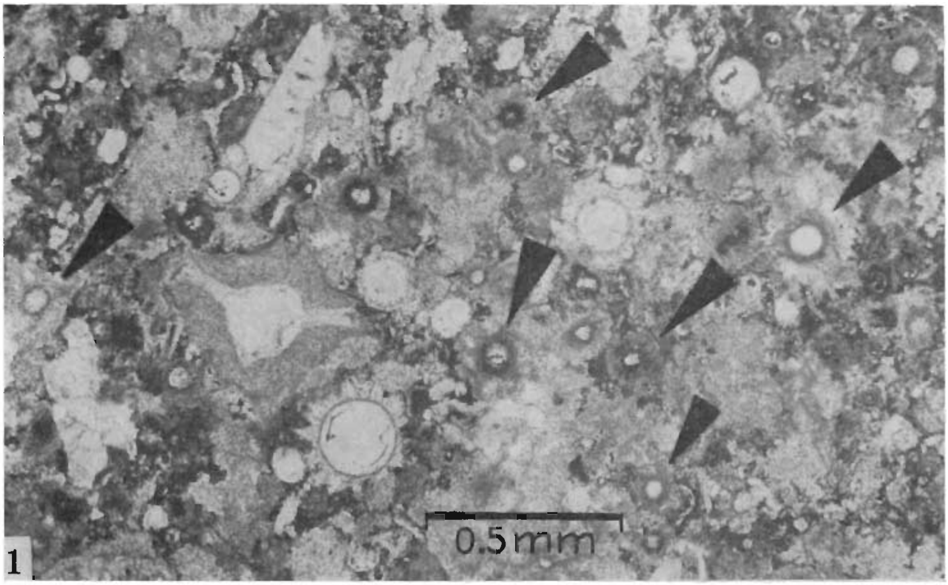
Fig. 1. Section of a parent-colony containing remnants of five daughter-colonies. Z PAL Al.III/1, 15.4/52.5.

Fig. 2. Section of a parent-colony with one big daughter-colony, both strongly pyritized. Z PAL Al.III/2, 9.0/60.2.

Fig. 3. Section of a parent colony with very big completely pyritized daughter-colony. Z PAL Al.III/12, 19.2/65.7.

Fig. 4. Nearly equatorial section of a colony composed of globose cells. Z PAL Al.III/7, 2.9/42.5.

Figs 5 and 6. Nearly equatorial section of colonies composed of pyriform and spindle-shaped cells with external outgrowths. Fig. 5 — Z PAL Al.III/9, 15.5/63.3; Fig. 6 — Z PAL Al.III/4, 5.3/45.9.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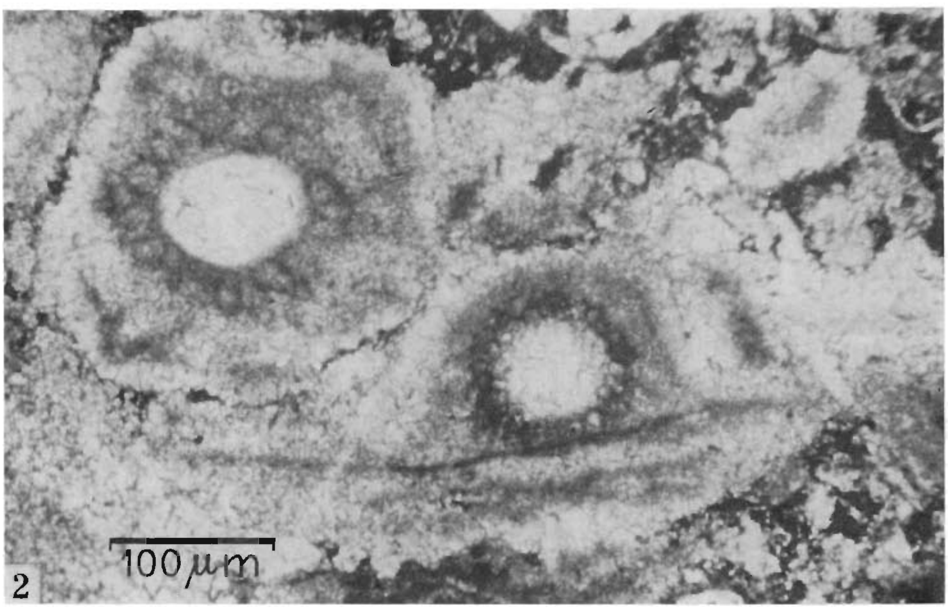
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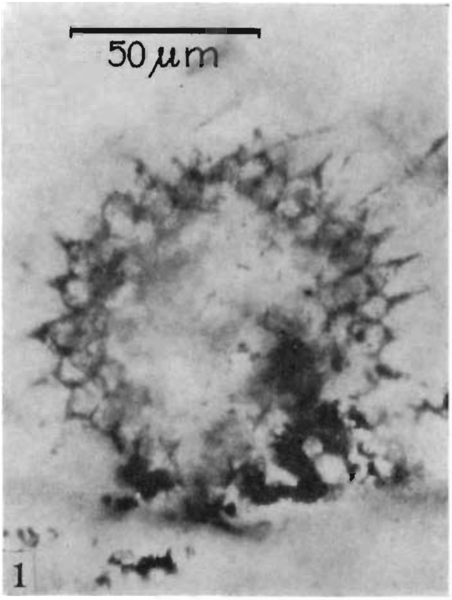
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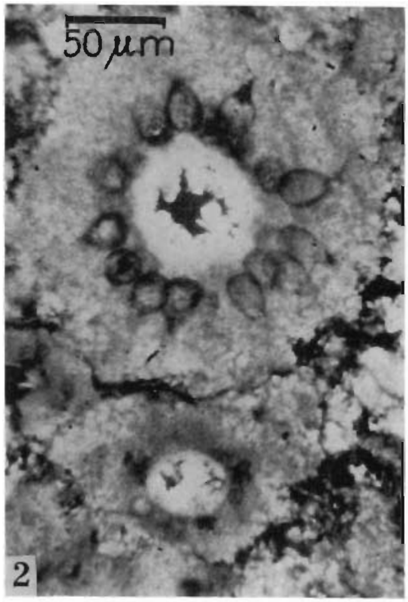
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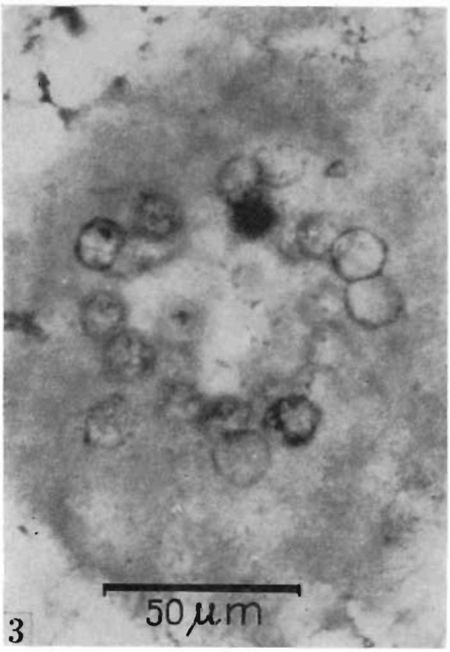
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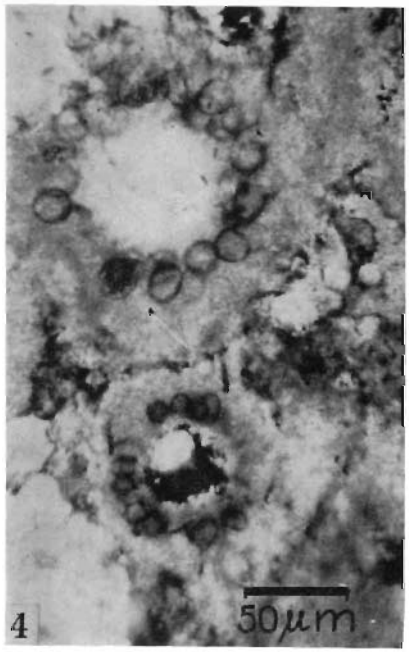
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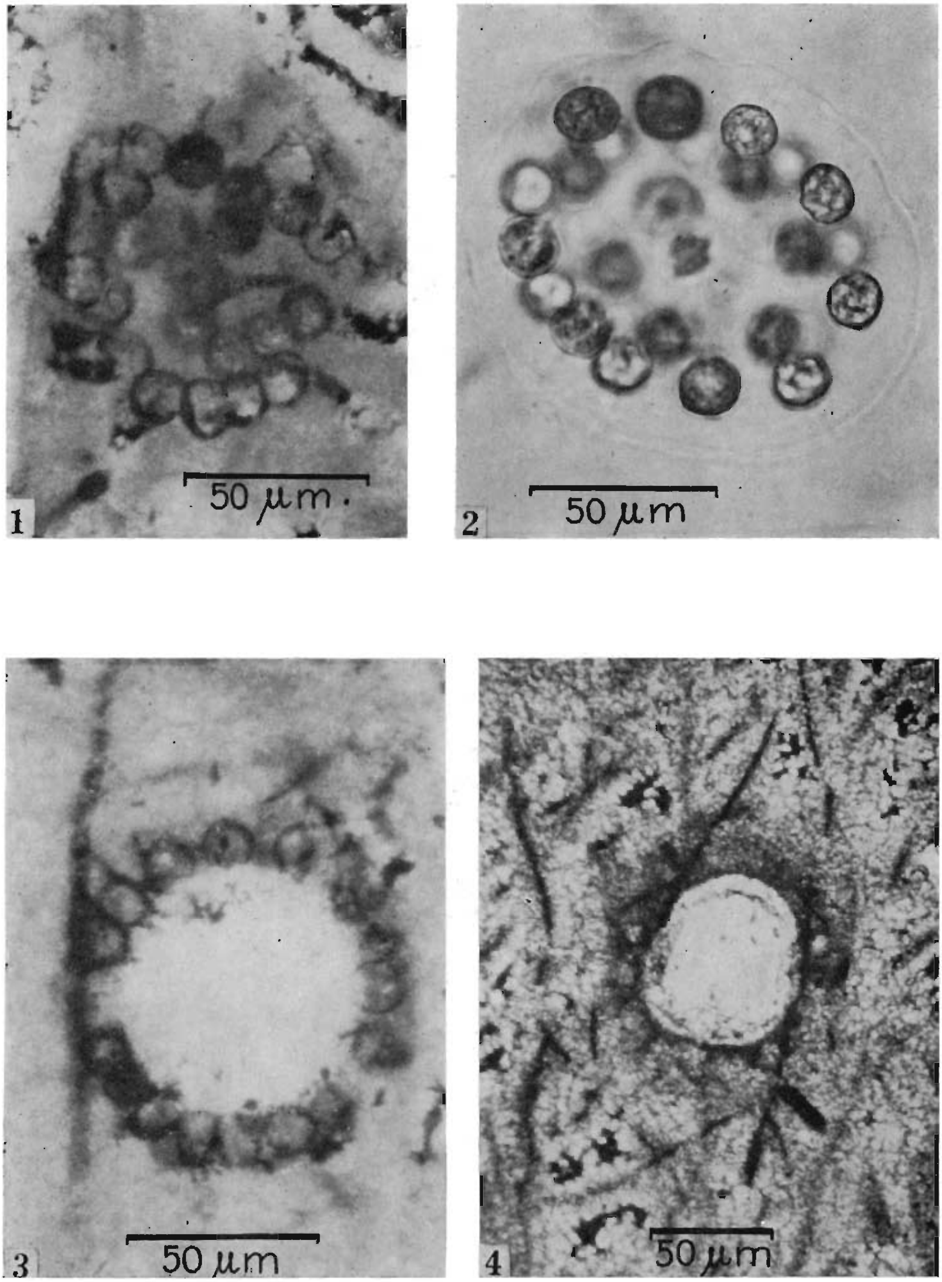
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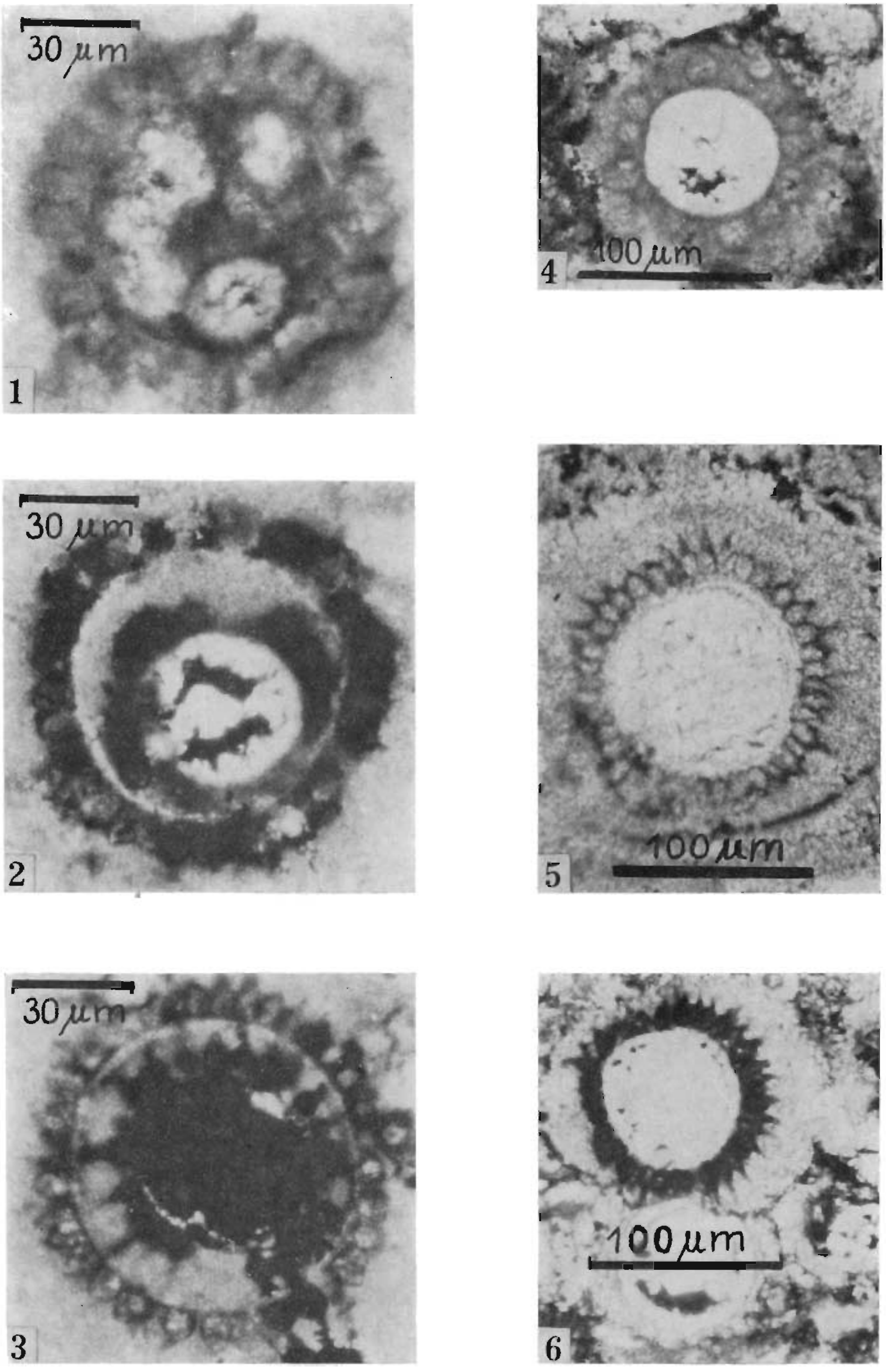
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