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## The nature and systematic position of the microfossils *Globochaete alpina* Lombard, 1945

**ABSTRACT:** Well preserved aciniform associations of *Globochaete alpina* Lombard discovered within Upper Visean limestones of the Lublin Coal Basin, eastern Poland, allow to recognize the relationship of these microfossils to the present-day green algae of the family Chlorosphaeraceae. The revision of the whole genus *Globochaete* is undertaken, and the species *Nostocites vesiculosa* Maslov is regarded as a subjective synonymy of *Globochaete alpina* Lombard.

### INTRODUCTION

The microfossil *Globochaete alpina* Lombard, 1945, commonly interpreted as a calcified zoospore of green algae, has long been described from primarily Mesozoic and Tertiary carbonates developed in both pelagic and extreme shallow marine environments (cf. Mišik 1959, 1979; Lefeld & Radwański 1960; Zawidzka 1972; Borza 1975; Flügel 1978). A few reports concern also Paleozoic occurrences in the Silurian of Algeria, Devonian of Morocco and Dinantian of France (Durand Delga 1956), Devonian of Czechoslovakia (Biely & Kullmanova 1979), Silurian through Carboniferous of the Soviet Union (Linetskaya & Muromtseva 1973, Muromtseva 1979), Carboniferous of Afghanistan (Vachard 1980), and Permian of Mexico (Tellez-Giron & Trejo 1974).

The specimens discussed in this paper come from the Upper Visean limestones with *Calcifolium* pierced by the borehole Podedwórze 2 in the north-eastern part of the Lublin Coal Basin, eastern Poland; location of the borehole and stratigraphic setting of the limestones are presented elsewhere (Skompski 1980, Skompski & Soboń-Podgórska 1980).

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MORPHOLOGICAL TYPES OF *GLOBOCHAETE ALPINA* LOMBARD

Lombard (1945) defined *Globochaete* as hemispherical or spherical cells, preserved in diverse stages of division, single or joined in linear associations, commonly affixed epiphytically to concavo-convex fragments of algae, or of other undetermined organisms. The cells are filled with radial calcite which effects in a black cross under the crossed nicols. The size of the cells ranges widely from 40 $\mu$  to 100 $\mu$ , or even to 200 $\mu$  as noted by the subsequent authors. A lengthy, but not comprehensive description offered by Lombard (1945) was supplemented by sketch-drawings of *Globochaete* in the stage of partition and germination, in the mature epiphytic stage, and in the final senile stage. These sketches are evidently simplified when compared to the earlier study (Lombard 1937) which presented *Globochaete* as "Organism D". The partition of the unicells was well illustrated by Colom (1955). Both Lombard and Colom did not present any associated forms with a larger number of unicells, and such very structures were recognized later, e.g. by Mišik (1959, 1979), Zawidzka (1972), Borza (1975) and recently, under the name *Globochaete gregaria*, by Schäfer & Senowbari-Daryan (1980). A variety of the associated forms are the spherical specimens composed of well arranged *Globochaete*, and illustrated by Tellez-Giron & Trejo (1974), who doubted about the zoospore nature of *Globochaete*.

The investigated Visean specimens from the Lublin Coal Basin represent mostly associations of a greater number of *Globochaete*, and called here the aciniform associations which vary into the spherical, enveloped forms (empty inside), circular in sections (Pl. 2, Figs 1—2), and globular forms with their interior filled (Pl. 1, Fig. 2; probably also Pl. 1, Fig. 1). Moreover, recorded are the linear associations (Pl. 3, Fig. 1), whereas the unicells and epiphytic cells are absent.

The hitherto presented descriptions and illustrations of *Globochaete*, as well as the investigated material allows to distinguish the following types of morphologies (see Text-fig. 1) observable in the thin sections of *Globochaete*:

- A — unicellular type: all the single forms, and cells during partition, usually into 2 or 4;
- B — linear association: all the chain-like ("rosary-beaded"; "chapelet" of Lombard, 1945) groups which might have developed due to one-dimensional partition of the cells;
- C — epiphytic cells: all the single or grouped cells attached to organic remains, commonly of the algal origin. As these cells are usually affixed to the concave side of the epiphyse (for exceptions see Pl. 3, Fig. 2; and Bronnimann 1955, Text-fig. 60); Zawidzka (1972) suggested their nature as the remnants of vegetative cells with affixed zoospores;
- D — aciniform association: the cells grouped into the grapes, the external envelope of which may be the only one preserved.

Additionally, as the fifth type, the endophytic cells are to be distinguished, viz. those presented by Linetskaya & Muromtseva (1973), who recognized *Globochaete* inside the thallus of the alga *Beresella*; an obscure photo does not allow to verify that record.

The above "section"-types correspond to the four morphological types of the occurrence of *Globochaete*. It should however be noted that a two-dimensional image from thin sections is not always recognizable to a certainty as to its three-dimensional shape.

#### SYNONYMY OF *GLOBOCHAETE ALPINA* LOMBARD

Within the genus *Globochaete*, the five species have hitherto been recognized, viz. *G. alpina* Lombard, 1945; *G. tatrica* Radwański, 1968; *G. spinosa* Dragastan, 1971; *G. hronica* Borza, 1975; and *G. gregaria* Schäfer & Senowbari-Daryan, 1980. The last three of these species should evidently be revised, as the criteria of their distinction are either unclear or simply wrong. Highly similar to some *Globochaete* are also the microfossils *Nostocites vesiculosa* Maslov discussed beneath.

The species *Globochaete tatrica* Radwański, 1968, described for the first time from the Rhaetian of the Tatra Mts (Radwański 1968), has subsequently been

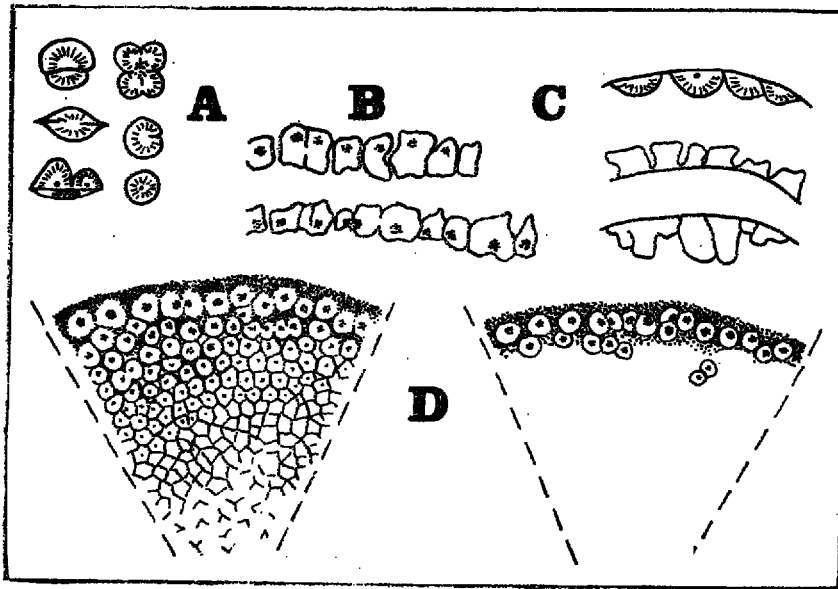


Fig. 1. Morphological types of *Globochaete alpina* Lombard

A — single cells (after Colom 1955), B — linear association of cells (after Mišik 1959, Linetskaya & Muromtseva 1973), C — epiphytic cells (after Bronnimann 1955, Bonet 1956, Mišik 1959), D — aciniform association of cells: solid form (at left) and superficial form (at right)

accepted and recorded both from the Rhaetian of the Tatra Mts and of the Alps (Flügel 1972, 1978; Gaździcki 1974; Schäfer & Senowbari-Daryan 1980), as well as from the stratigraphically wide ranging deposits (Carnian through Neocomian) of Slovakia (Borza 1975, Mišik 1979).

The species *Globochaete spinosa* Dragastan, 1971, recognized in the Jurassic-Cretaceous deposits of Romania, does not display the requested generic features, and was already denied by Mišik (1979).

A feature diagnostic of *Globochaete hronica* Borza, 1975, was a large, conical depression, filled with micrite inside the cell. However, only in some sections this structure is recognizable as a depression; in most cases, the holotype including it is a dark spot inside the cell. Such a spot varying in size (see Pl. 3, Fig. 6), is also characteristic of *G. alpina* and may even appear at the edge of the cell, as illustrated by Borza (1975, Pl. 1, Fig. 8). Consequently, there are no specific features distinguishing the species *hronica* which therefore is rejected. It is to note that the taxonomic value of the dark spot is doubtful, as this structure, its size, shape, and location within the cells are supposedly resulting only from fossilization and diagenesis, similarly as in some bluegreen algae (see Golubić & Hofmann 1976).

The species *Globochaete gregaria* Schäfer & Senowbari-Daryan, 1980, was established due to "... diameters of single spores between 150 and 180 microns, modus of division of the spores in rosettes, and aggregatelike appearance of numerous spores" (Schäfer & Senowbari-Daryan 1980, p. 100). Included into synonymy by Schäfer & Senowbari-Daryan (1980) were the gregarious specimens of *Globochaete alpina* described by Zawidzka (1972). As stated above, the cell diameter in *Globochaete alpina* ranges from 40 to 200 $\mu$ , the type of association is a morphotype not a specific feature, and the diverse modes of partition (the rosette-like including) appear within the same composite specimen. Usually, the cells situated nearer to the centre of an aciniform association are more densely spaced and, contrary to the outer cells, they display a rather polygonal outline (see Pl. 3, Fig. 5). Consequently all the specimens described as *G. gregaria* are to be included into *G. alpina*, the same as those specimens presented correctly under this very name by Zawidzka (1972).

Concerning the species *Nostocites vesiculosa* Maslov, 1929, it was established for arched or contorted, chain-like aggregates composed of loosely spaced cells, about 45 $\mu$  in diameter (see Text-fig. 2) The generic name was coined up by Mas-

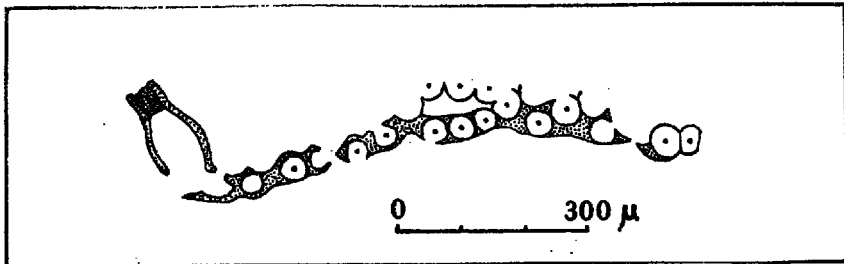


Fig. 2. *Nostocites vesiculosa* Maslov (after Maslov 1929)

lov (1929) to announce the relationship with the bluegreen algae of the genus *Nostoc*, the view being rejected by Maslov himself in a later paper (Maslov 1956). Formerly, Maslov (1929) distinguished within the genus *Nostocites* the two species, viz. *N. vesiculosa* and *N. problematica*. The latter species was subsequently suggested by Maslov (1956) to consist of foraminiferal fragments, but nevertheless,

it was accepted and illustrated by Johnson (1963), Rich (1974), and Brenckle (1977). An attribution of that taxon to either foraminifers or to problematic algae was offered by Mamet & Roux (1978), who also presented the first photographs of *Nostocites vesiculosa*, taking them however for an aciniform association, nor for a linear one. The size and type of the cell arrangements of the specimens described both by Maslov (1929, 1956, 1963), and by Mamet & Roux (1978), clearly shows that these are the Carboniferous representatives of *Globochaete alpina*, type B and D distinguished in this paper. The name *Nostocites vesiculosa* is therefore regarded by the present Author as a subjective synonymy.

To the Carboniferous occurrences of *Globochaete alpina* should also be included the specimens described as *Litostroma* sp. by Jansa, Mamet & Roux (1978, Pl. 1, Fig. 11 and ? 10). Their cell size (40–80 $\mu$ ), mode of partition, and shape of cells are more similar to *Globochaete alpina* (especially to such forms as illustrated in Pl. 3, Figs 3 and 7 of this paper; see also suggestions by Vachard 1980) than to any forms of the genus *Litostroma* Mamay, 1959.

#### RELATION OF GLOBOCHAETE ALPINA TO RECENT ALGAE

The taxonomic features important in Recent algae, are hardly recognizable in *Globochaete* in its most advanced stages which display some resemblances to the palmelloid and gleocystid stages of green algae. Commonly accepted is the opinion expressed by Lombard (1945) that *Globochaete*, recognized by Lombard only in unicellar and chain-like forms, has a nature of green-algal zoospores, certainly related to the Protococcaceae group of the order Chaetophorales and the best analogies were suggested with the zoospores of the genus *Dicranochaete*. Tellez-Giron & Trejo (1974) believed however that the composite forms evidence a more complicated nature of the mother plant. On the other hand, Linetskaya & Muromtseva (1973) were of the opinion that *Globochaete* were the zoospores of various algae coming from diverse facies and stratigraphic ages.

Both the investigated material (Pls 1–3) and analyzed references allow to recognize that the best analogies of *Globochaete* appear not only in zoosporic but also in vegetative forms of the two ordines of the green algae, namely in the Chlorococcales and in the Chaetophorales (systematics according to Fritsch, 1961). Taking into account the modes of partition, cell size and morphologies, the best pronounced similarities are recognizable in the family Chlorosphaeraceae (cf. Herndon 1968) of the Chaetophorales, which includes i. a. such genera as *Chlorosphaeropsis* (? = *Chlorosphaera*) Vischer, 1933, *Planophila* Gerneck, 1907, and *Chloroplana* Hollerbach, 1936. All these genera are represented by unicells or associations and coenobia, sometimes of the chain-like outline (see Text-fig. 3). The cells, ranging in size from a few to over 50 $\mu$ , are embraced by a cell wall; usually their the best readable element is the chromatophor, cup-like or ovoid in shape. All the

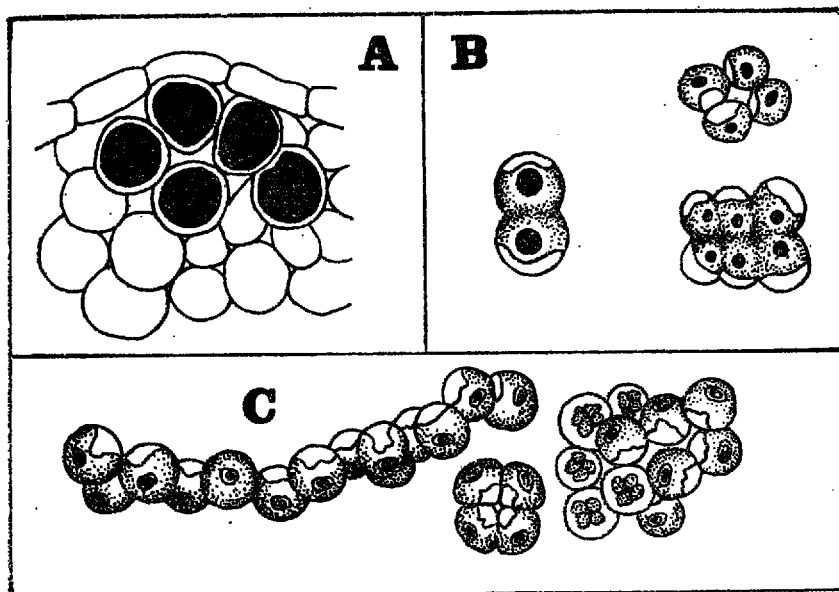


Fig. 3. Morphological types of algae of the family Chlorosphaeraceae  
 A — *Chlorosphaera alismatis* Klebs (after Artari; taken from Fritsch 1961), B — *Planophila asymmetrica* Gerneck (after Gerneck 1907), C — *Chloroplana terricola* Hollerbach (after Hollerbach 1936).

Chlorosphaeraceae reproduce either by separation or by biflagellate zoospores (the latter of less than  $8\mu$  in diameter). It seems therefore doubtful that the unicells of *Globochaete*, the same as those in diverse stages of partition, were the zoospores (their size attains  $200\mu$  in *G. alpina*, and  $500\mu$  in *G. tatrica*). Hardly believable is also Lombard's interpretation of some convexities of the cells as the germinating flagellas (cf. Lombard 1945, Text-fig. 1).

The Chlorosphaeraceae display also all the morphological types distinguishable in *Globochaete* (compare Text-fig. 3 and Pls 1—3). The recent representatives of that family live either free, without any relation to a substrate, or epi- and endophytically. As an example, the genus *Chlorosphaeropsis* lives as an endophyte in leaves of many water plants, and as an epiphyte of the duckweeds.

#### REMARKS ON CALCIFICATION OF GLOBOCHAETE

The investigated Carboniferous *Globochaete* commonly occur in association with diverse calcifying algae, e. g. with *Calcifolium* of the family Codiaceae in the Visean and Namurian deposits (see Linetskaya & Muromtseva 1973, Skompski 1980), with *Donezella* and *Beresella*

(problematic Dasycladaceae) in the other Namurian deposits (see Linetskaya & Muromtseva 1973; Maslov 1929 in regard with *Nostocites vesiculosa*). A similar situation there also exists in the Middle and Upper Jurassic stromatolitic structures (see Lefeld & Radwański 1960, Radwański & Szulczewski 1966; Szulczewski 1968). The *Globochaete* itself, if its attribution to the Chlorosphaeraceae is substantial, did not belong to the calcifying algae. Its preservation in a calcified form must therefore be regarded as a result of fossilization, i. e. of diagenetic processes, as it was already suggested by Lombard (1945).

The first stage of calcification certainly realized in the covering and enveloping of the *Globochaete* grapes by a thin layer of micrite. This process was supposedly similar to that acting in present-day bluegreen algal mats, and was a result both of biochemical precipitation, and of physical trapping and binding of calcareous ooze by the mucilaginous cover of *Globochaete* cells. The thickness of the micritic layer may be estimated as about 10 $\mu$  (see Pl. 1, Figs 1—2 and Pl. 3, Fig. 4). The settling of this envelope became the termination of the photosynthesis and the beginning of organic decay. Under favorable conditions, for example when buried by the sediments, either the *Globochaete* cells or more or less complete aciniform associations, have undergone successive calcification by secretion (cf. Pl. 1, Fig. 2), or disintegrate. If the latter case happened, usually only the outermost cells remained in a calcified state (cf. Pl. 2, Fig. 2; also the specimens illustrated by Tellez-Gironi & Trejo 1974), whereas an emptied *Globochaete*-bearing sphere might suffer from contortion and collapsing (cf. Pl. 2, Fig. 1) during further advances of diagenesis.

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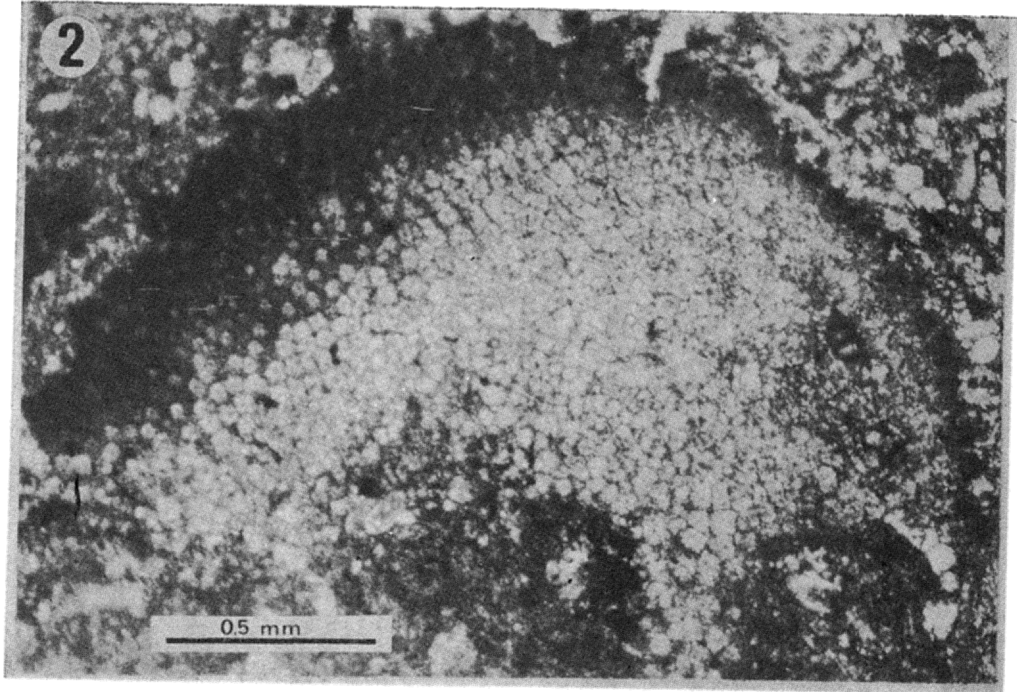
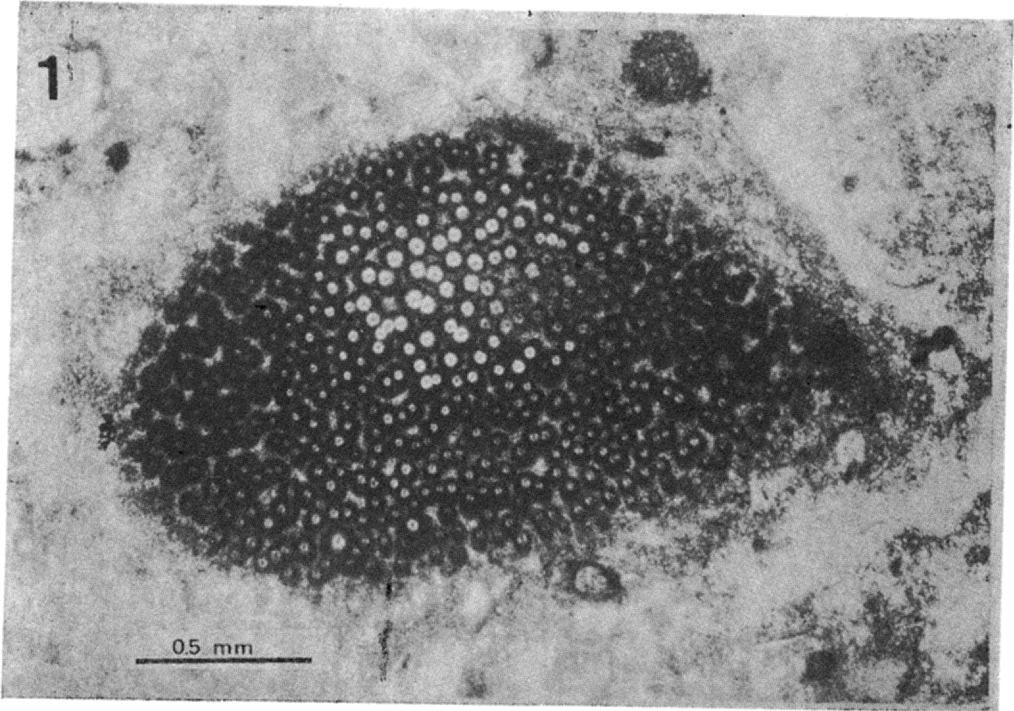
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**BUDOWA I POZYCJA SYSTEMATYCZNA  
GLOBOCHAETE ALPINA LOMBARD**

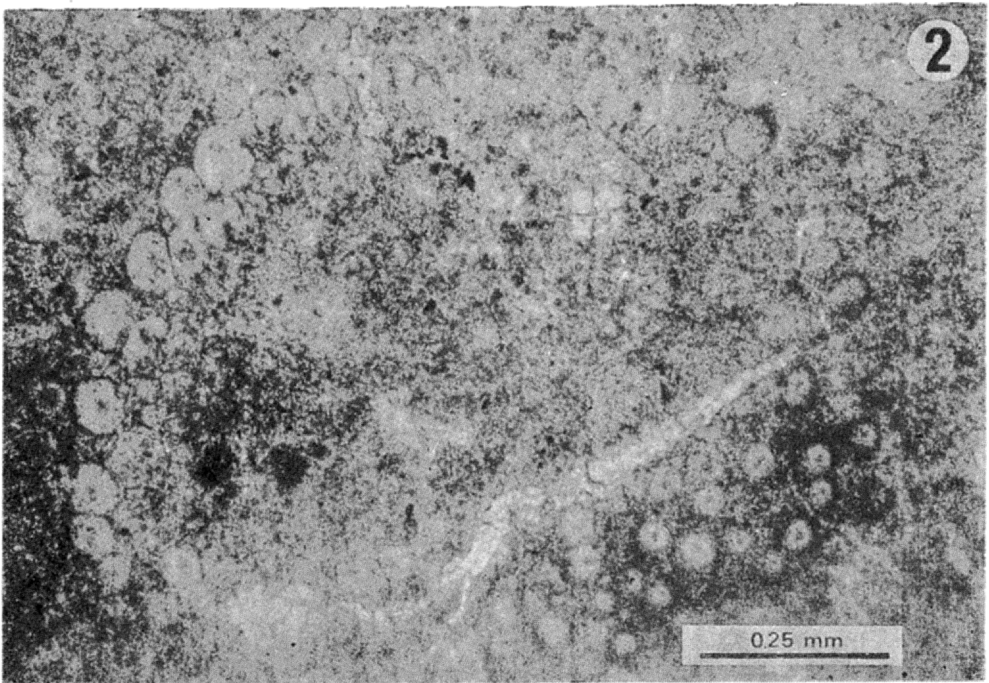
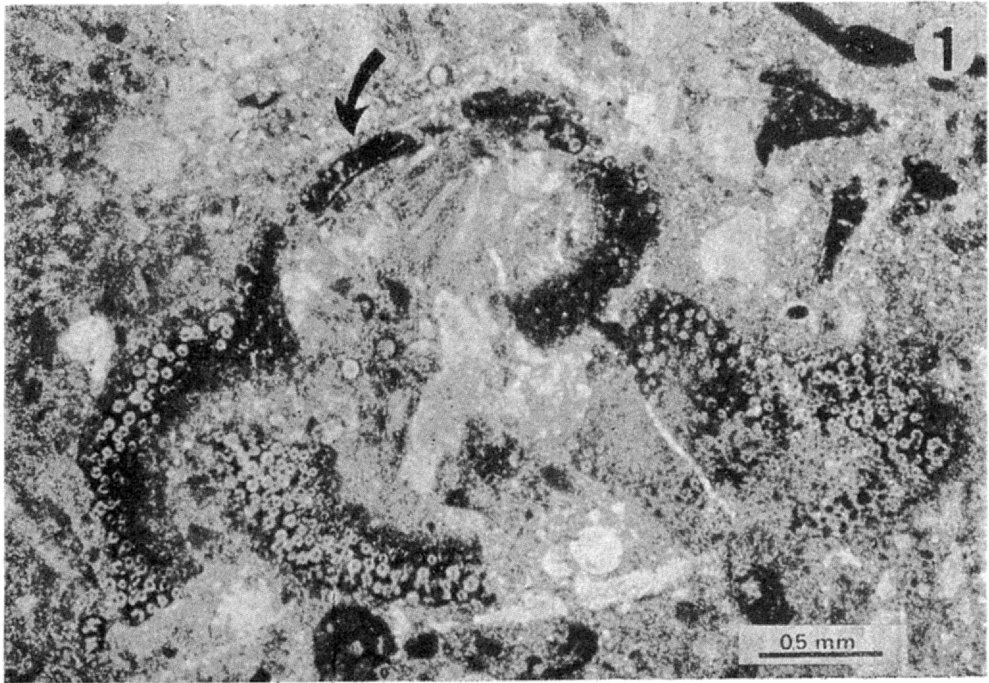
(Streszczenie)

Przedmiotem pracy jest rewizja kosmopolitycznych mikroorganizmów *Globochaete alpina* Lombard, dokonana w oparciu o materiał pochodzący z górnowizeńskich wapieni Lubelskiego Zagłębia Węglowego. Stan zachowania badanego materiału (patrz pl. 1—3) pozwolił na usystematyzowanie dotychczas znanych postaci morfologicznych w obrębie tego gatunku (patrz fig. 1). Porównanie ze współczesnymi formami nie potwierdziło poglądu o zoosporowej naturze *Globochaete*, lecz wskazało na pokrewieństwo tego rodzaju z postaciami vegetatywnymi glonów należących do rodziny Chlorosphaeraceae (patrz fig. 3). Występowanie różnych stadiów zachowania pozwoliło ponadto na odtworzenie przebiegu procesu kalcyfikacji *Globochaete*. Podobieństwo do innych kopalnych form glonowych umożliwiło uznanie gatunków *Globochaete gregaria* Schäfer & Senowbari-Daryan, *Globochaete hronica* Borza oraz *Nostocites vesiculosa* Maslov (patrz fig. 2) za synonimy *Globochaete alpina* Lombard.

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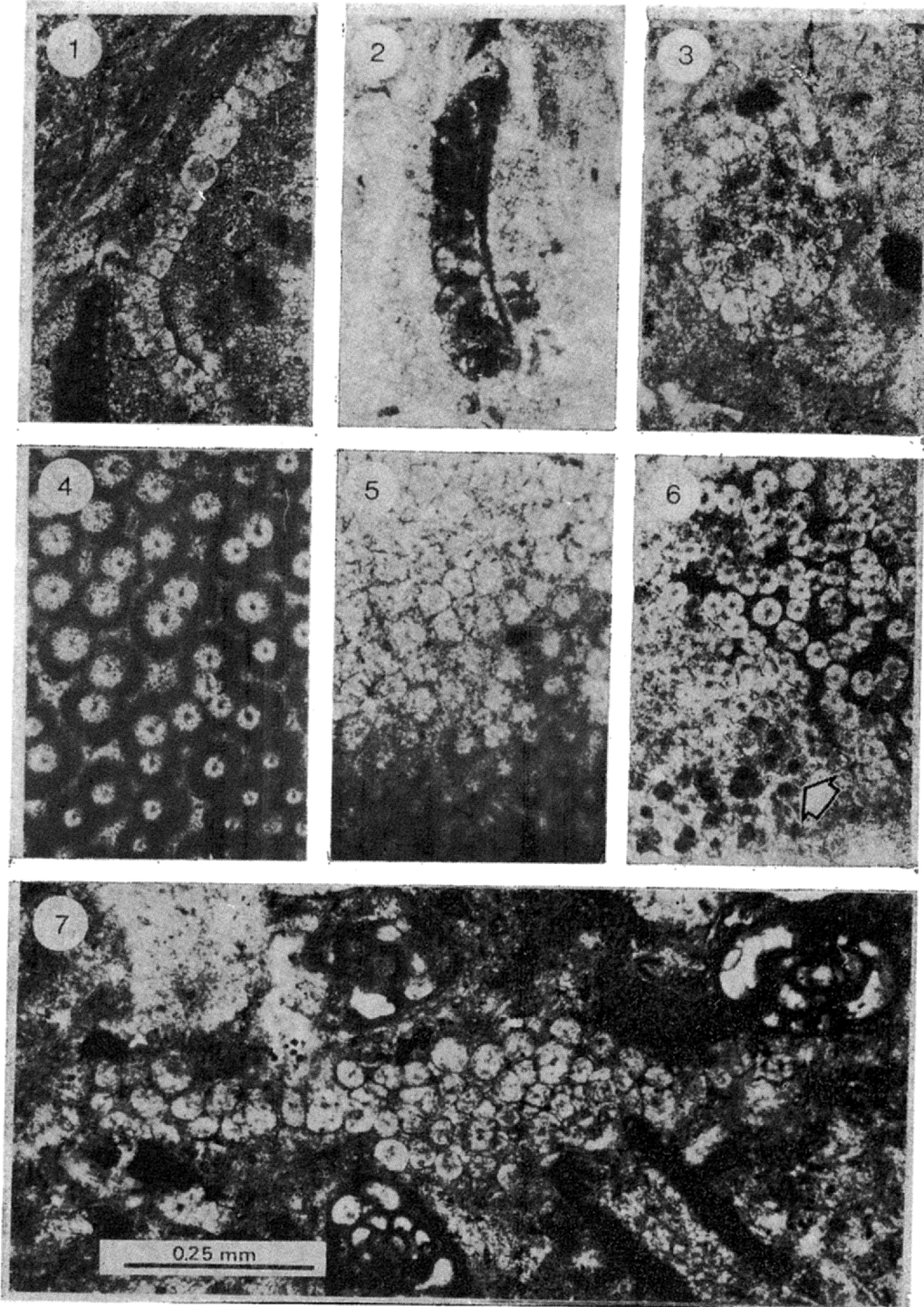


1 — Aciniform association of *Globochaete alpina* Lombard; tangential section  
2 — Aciniform association of *Globochaete alpina* Lombard; transverse section



1 — Aciniform association of *Globochaete alpina* Lombard; superficial form with a thick, multilayered external cover, torn out during lithification; arrowed is the fragment magnified in Pl. 3, Fig. 2

2 — Aciniform association of *Globochaete alpina* Lombard; superficial form with one-layered external cover, displaying both transverse (at left) and tangential section (at bottom right)



Linear and aciniform associations of *Globochaete alpina* Lombard

1 — Linear association (fragment of *Calcifolium okense* at bottom left); 2 — pseudoepiphytic fragment of that presented in Pl. 2, Fig. 1; 3 — transverse section of small aciniform association; 4 — fragment of that presented in Pl. 1, Fig. 1, with partition of cells; 5 — fragment of that presented in Pl. 1, Fig. 2; 6 — fragment of that presented in Pl. 2, Fig. 1 (arrowed are cells with great central spots); 7 — transverse section of larger aciniform association