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RADIOLARIA FROM THE UPPER CENOMANIAN–LOWER TURONIAN DEPOSITS OF THE SILESIAN UNIT (POLISH FLYSCH CARPATHIANS)

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Abstract: Upper Cenomanian to lower Turonian deposits of the Silesian Unit of the Polish Flysch Carpathians comprise a characteristic interval of green and black shales with manganese concrections, tuff and bentonites. These strata are not only distinctive lithologically, but also contain a rich radiolarian fauna. Thirty-five species of Radiolaria have been identified. Spherical cryptothoracic and cryptocephalic Nassellaria dominate in the assemblage, especially species such as *Holocryptocanium barbui, H. tuberculatum*, *Hemicryptocapsa prepolyhedra* and *H. polyhedra*. The systematic description of fifteen species belonging to order Spumellaria and twenty species of Nassellaria is presented herein.

Key words: Cretaceous, Flysch Carpathians, Silesian Unit, Radiolaria.

Introduction

"Green Shales with Radiolarians" represent the most distinctive horizon of the mid-Cretaceous of the Flysch Carpathians (Sujkowski & Różycki 1930; Sujkowski 1932; Burtanówna et al. 1933; Książkiewicz 1951; Koszarski 1956; Koszarski et al. 1959; Liszkowa 1962; Liszkowa & Nowak 1962; Bieda et al. 1963; Geroch et al. 1967, 1985; Kotlarczyk 1978, 1988; Gzik 1990).

In the Polish Flysch Carpathians "Green Shales" are present in the Silesian, Sub-Silesian and Skole units (*op. cit.*). The thickness of these deposits changes from dozens of centimetres to several meters. They mainly consist of green shales with intercalations of black, grey and olive, silty or calcareous shales, and sometimes they are intercalated with red shales, green and red cherts and radiolarites. Clastic intercalations are also present in the form of thin layers of fine- and very fine-grained sandstone, sometimes with glauconite. The lower part of this succession includes characteristic layers of ferromanganese concretions and black shales with manganese incrustations, and a few layers of bentonite and tuff which are usually situated just below the layer with ferromanganese concretions. This tuff has been dated as 91.4 ± 4.7 Ma (Van Couvering et al. 1981).

These deposits are the most completely developed within the Silesian Unit of the Polish Flysch Carpathians (Fig. 1). They have been named here "jaspary cherts" following Książkiewicz (1951). Stratigraphically they are situated between the Lgota Beds (thin bedded flysch, the upper part of which can be developed as the Mikuszowice Spongiolites) and the Godula Beds (red shales or sandstone) (Fig. 2).

"Green Shales with Radiolarians" have been a subject of lithological and biostratigraphical studies since the early 1930's. Previous authors dealing with micropaleontological investigations focused their interests on foraminifers as the most useful tool for biostratigraphical purposes (i.e. Lisz-

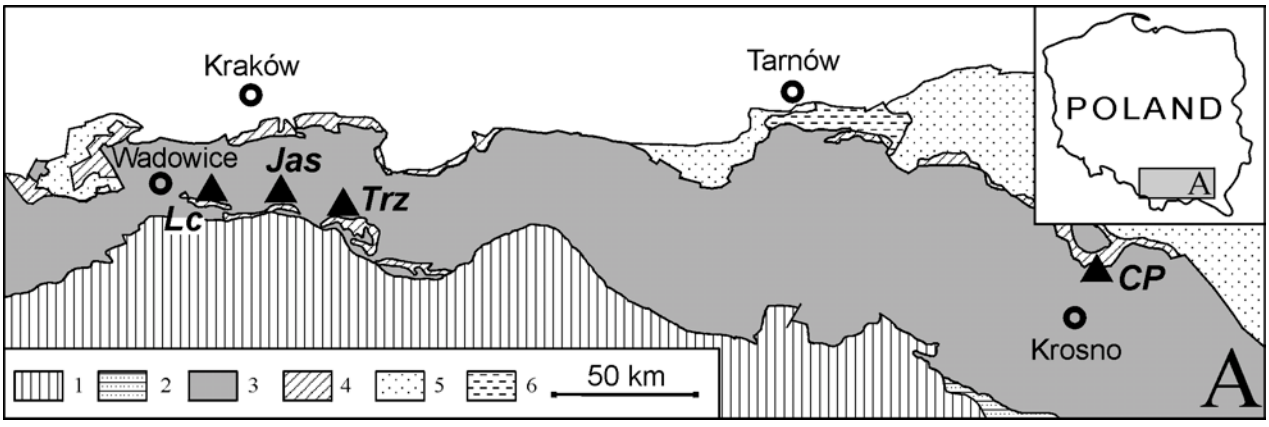

Fig. 1. Location of the sections studied (black triangles) in the geological map of the Outer Western Carpathians (after Żytko et al. (1988) — simplified): 1 — Magura Unit, 2 — Dukla Unit, 3 — Silesian Unit, 4 — Sub-Silesian Unit, 5 — Skole Unit, 6 — post-orogenic Neogene cover. Abbreviations of section names: Lc — Lanckorona, Jas — Barnasiówka-Jasienica, Trz — Trzemeśnia, CP — Czarny Potok.

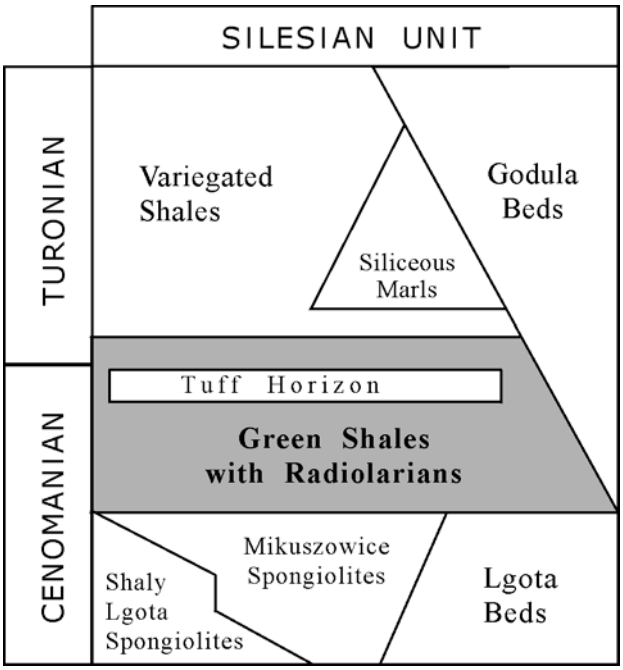

Fig. 2. Lithostratigraphy of the Cenomanian through Turonian deposits in the Silesian Unit (after Ślączka et al. 1993).

kowa 1956, 1962; Liszkowa & Nowak 1962; Bieda et al. 1963; Geroch et al. 1967, 1985), although radiolarians are the most abundant microfauna in these deposits. Górka (1996) has presented the only systematic description of a radiolarian assemblage from the Skole Unit (Polish part of the Flysch Carpathians). A few investigations focus on the radiolarian fauna from comparable deposits in the Ukrainian and the Romanian Carpathians (Sujkowski 1932; Lozyniak 1969, 1975; Dumitrică 1970, 1975). Despite this, the radiolarian fauna has neither been described in detail nor applied in the Polish Flysch Carpathians.

The first systematic investigations of the radiolarian fauna from the "Green Shales" in the Polish part of the Silesian Unit were initiated by the author in the early 1990's (Bąk 1994).

The present paper summarizes the current state of research, with the aim of documenting the radiolarian assemblages from the "Green Shales with Radiolarians".

Geological setting

The Silesian Nappe is one of the Tertiary thrust-sheets of the Outer Western Carpathians (Fig. 1). The exposed part of the Silesian sequence is represented by the Upper Jurassic to Miocene deposits.

During the formation of the Outer Carpathian geosyncline, the Silesian Basin was one of the sedimentary basins, which were created (Książkiewicz 1962). The basin was relatively deep as indicated by the absence of shallow-water sedimentary structures and shallow-water fauna in the autochthonous sediments. During the Cenomanian the basin reached its maximum depth and "Green Shales with Radiolarians" and radiolarites were deposited (Koszarski & Żytko 1965).

Four sections were selected for a detailed study of radiolarian assemblages (Figs. 1, 3).

1. Lanckorona (Lc). This is the type section of radiolarian cherts in the Polish Flysch Carpathians (Książkiewicz 1951; Bieda et al. 1963). It is located between the Lanckorona and Brody settlements, on the northern slope of the Zamkowa Hill along the stream, which is a right tributary of the Cedron creek.

Stratigraphically, the radiolarian-bearing deposits are situated between the Mikuszowice Spongiolites which represent the uppermost part of the Lgota Beds (Albian–Lower Cenomanian) and the Godula Beds (lower Turonian–Senonian) (Książkiewicz 1951). They are represented here by red shales (Figs. 2, 3). The sediments are strongly tectonized due to folding, hence the entire lithological section of the radiolarian-bearing deposits has been reconstructed based on several outcrops along the stream (Gzik 1990). The deposits are about 40 m thick here (Książkiewicz 1951). The oldest sediments of the section are represented by black manganese shale intercalated with thin olive-green silty shale. Manganese shale is up to the 50 cm thick. This interval is followed by tan-coloured siliceous shale, with olive-green, black and rust-coloured shale intercalated.

Olive-green and grey-green shale dominate the younger sediments of the section. Thin black calcareous or siliceous shale and rare thin glauconitic sandstone sporadically intercalate them. There follow laminated cherts (up to 63 %), siliceous marls and non-structural marls. The uppermost part of the deposits investigated is characterized by thin intercalations of cherry-red shales of Godula type.

2. Barnasiówka-Jasienica (Jas). The section is located in the north-eastern part of the quarry situated on the Barnasiówka Range at Jasienica. The lower part of the Radiolaria-bearing deposits is presented here. Green, grey and black shales with frequent thin mudstone and sandstone intercalations are exposed. The shales are spotty in some places. The complex is underlain by the Lgota Beds made of thin-bedded fine-grained grey and dark sandstone with black, shale intercalations.

3. Trzemeśnia (Trz). This section is situated in the village Trzemeśnia, about 10 km east from Myślenice town. The Mikuszowice Spongiolites represents the stratigraphically lower part of this section, which is the uppermost part of the Lgota Beds. There is a sedimentary contact between the Mikuszowice Spongiolites and the overlying radiolarian beds, which consists mainly of green shales, silty or partly siliceous, with thin-bedded very fine-grained sandstone and mudstone intercalations. In this section, "Green Shales" include the bed with ferromanganese concretions as well as a bentonite layer.

4. Czarny Potok (CP). This section is located 13 km north of Krosno town near the Węglówka settlement. It is exposed in the Czarny Potok stream. The upper part of the radiolarian beds and the Lgota red shales are exposed here. The radiolarian beds consist mainly of green and black shales, silty and calcareous with some intercalations of olive shales and very thin beds of fine-grained sandstone and mudstone.

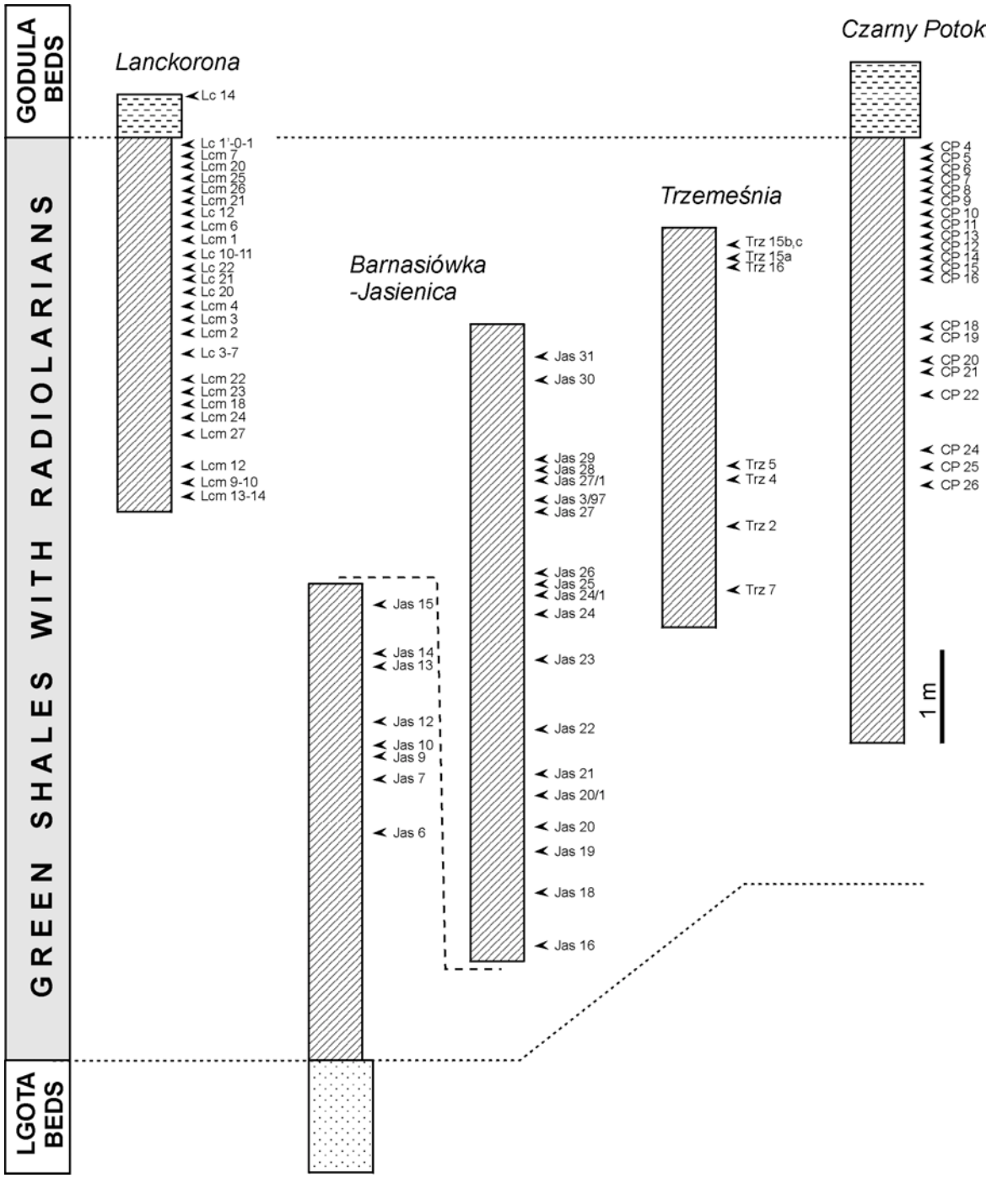

Fig. 3. Lithological columns showing the lithological units and position of radiolarian samples.

Material and methods

The material prepared and studied includes 90 samples of different lithologies, from four sections of the Polish part of the Silesian Unit.

The samples were collected in the sections every 10 to 80 cm (depending on changes in lithology and the quality of exposure). Green, black and olive shales, silty and siliceous are the dominant lithotypes. A few samples were taken from mudstones and marly shales.

Samples of about 1 kg were taken for preparation. Each sample was broken into pieces of 1–2 cm and dried at a temperature of 105 °C. The preparation procedures depended on the lithology of the sample. Mudstones and silty shales were soaked in hot solution of glauberic salt and boiled usually for several days. Than the residue was washed through a 63 μm sieve. Next, the remaining cemented parts of the samples were treated with hydrogen peroxide with addition of chalk (to avoid oxidation of pyrite) for several minutes to one hour, and finally washed again.

In the case of marly shales, radiolarian skeletons were freed by dissolving the rock matrix in hot acetic acid. Then the residue was washed through a 63 μm sieve.

For further cleaning the skeletons were soaked in hydrogen peroxide or boiled in Calgon solution.

The radiolarians were first examined under a binocular microscope. They were picked out manually from the residue (maximum 300 specimens per sample). The best preserved specimens were mounted on Scanning Electron Microscope (SEM) stubs for photography. More than 1000 SEM pictures were taken during the study.

The sample material is deposited in the Institute of Geological Sciences, Jagiellonian University.

Radiolarian assemblage

Thirty five species of Radiolaria have been identified from the samples studied (Figs. 4, 5). Twenty of them belong to the order Nassellaria and fifteen belong to the Spumellaria.

Samples with abundant radiolarians are from black, green and olive shales of "Green Shales with Radiolarians". The fauna is moderately to well-preserved. The poor state of preservation of some radiolarian specimens observed in black shales is due to pyritization processes. Pyrite coatings occur on the spherical radiolarian skeletons. Radiolaria are rare in the remaining deposits (Lgota Beds and Godula Beds).

The assemblage analysed is dominated by spherical cryptothoracic and cryptocephalic Nassellaria, belonging especially to the species *Holocryptocanium barbui* Dumitrică, *Holocryptocanium tuberculatum* Dumitrică, *Hemicryptocapsa prepolyhedra* Dumitrică and *H. polyhedra* Dumitrică. These forms form about 60 to 99 per cent of the specimens. Spumellarians are less common. They consist of 30 to 40 per cent of the radiolarian fauna, and are represented mainly by the genera such as *Pseudoaulophacus*, *Patellula*, *Alievium*, *Crucella* and *Praeconocaryomma*.

Systematic description

The taxonomy used in this paper is that proposed by O'Dogherty (1994). It is supplemented with data given by Dumitrică (1970), Pessagno (1976, 1977), Hollis (1997) and Ožvoldová (1997). All taxa are listed in alphabetical order of the genera. Their distribution in samples is shown in Figs. 4–5.

Order NASSELLARIA Ehrenberg 1875

Genus *Amphipyndax* Foreman 1966
Type species: *Lithostrobus pseudoconulus* Pessagno 1963

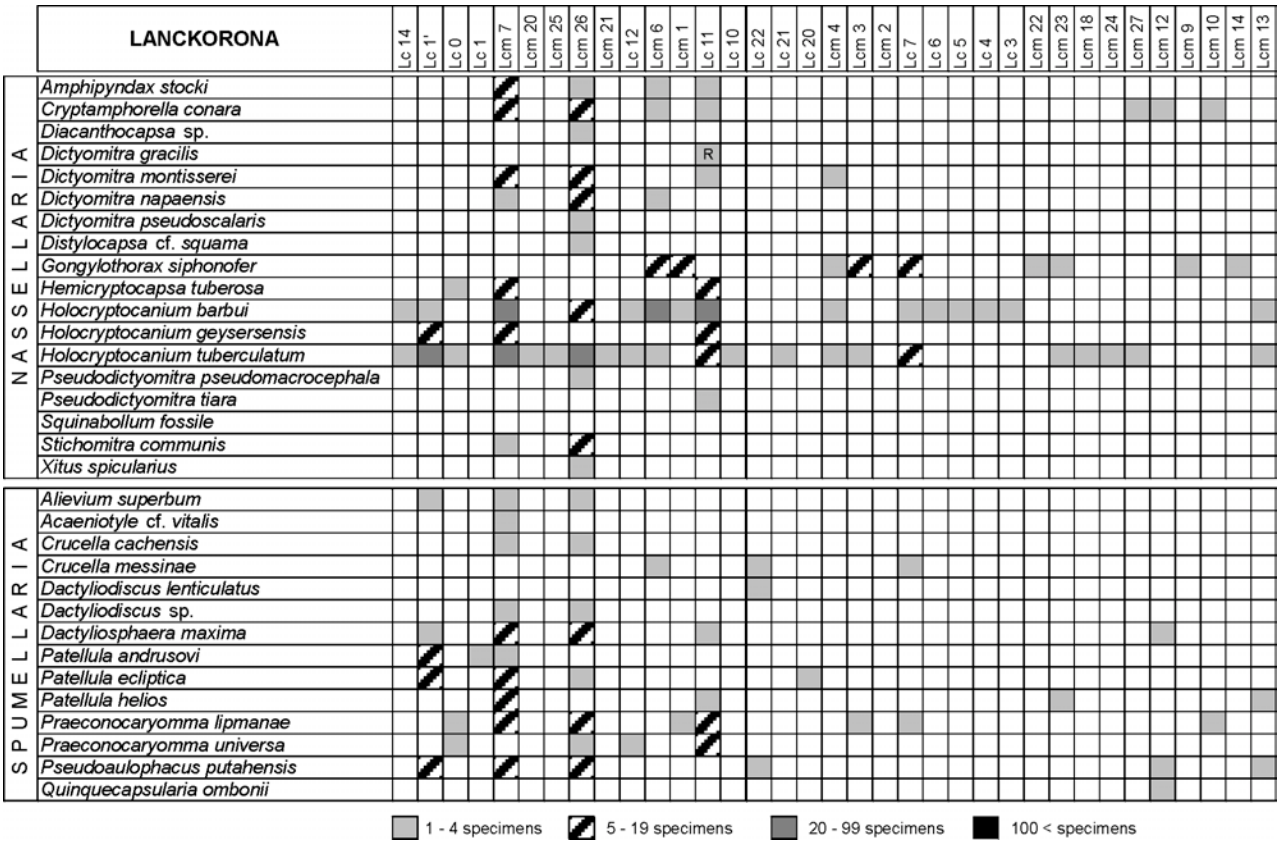

Fig. 4. Frequency of the radiolarian specimens in the Lanckorona (Lc) section. R — species redeposited.

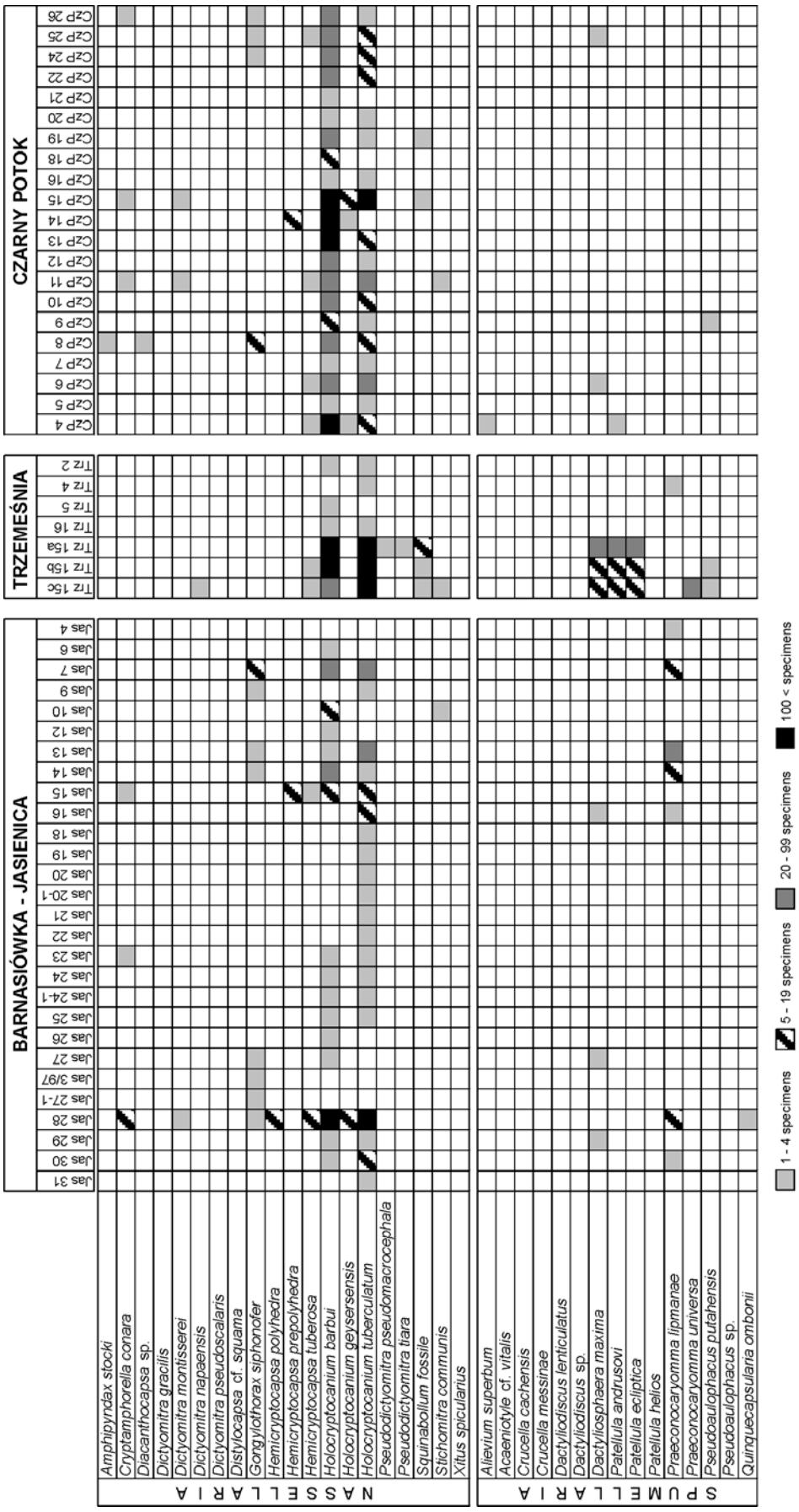

Fig. 5. Frequency of the radiolarian specimens in the Barnasiówka-Jasienica (Jas), Trzemeśnia (Trz) and Czarny Potok (CP) sections.

Amphipyndax stocki (Campbell & Clark)
Plate I: Fig. 14, Plate II: Fig. 3

1944 *Stichocapsa megalocephalia* Campbell & Clark: Campbell & Clark; p. 44, pl. 8, figs. 26, 34.
1944 *Stichocapsa* (?) *stocki* Campbell & Clark: Campbell & Clark; p. 44, pl. 8, figs. 31–33.
1968 *Amphipyndax stocki* (Campbell & Clark): Foreman; p. 78, pl. 8, figs. 12a–c.
1994 *Stichomitra stocki* (Campbell & Clark): O'Dogherty; p. 147, pl. 18, figs. 9–15.
1997 *Amphipyndax stocki* (Campbell & Clark) group: Hollis; p. 66, pl. 15, figs. 5–11.

Material: Two poorly preserved specimens have been found in the material investigated.

Genus *Cryptamphorella* Dumitrică 1970
Type species: *Hemicryptocapsa conara* Foreman 1968
Cryptamphorella conara (Foreman)
Plate II: Figs. 7, 8

1968 *Hemicryptocapsa conara* Foreman: Foreman; p. 35, pl. 4, figs. 11a,b.
1970 *Cryptamphorella conara* (Foreman): Dumitrică; p. 80, pl. 11, figs. 66a–c.

Material: 45 moderately preserved specimens have been found in the material investigated.

Genus *Diacanthocapsa* Squinabol 1903
Type species: *Diacanthocapsa euganea* Squinabol 1903
Diacanthocapsa sp.
Plate II: Fig. 9

Description: Test tricyrtid, spindle shaped. Cephalis small, poreless, partly encased into the thorax, lacking apical horn. Thorax companulate, porous. Abdomen oval, twice larger than thorax. Test lacking a sutural pore.
Material: Two poorly preserved specimens have been found in the material investigated.

Genus *Dictyomitra* Zittel 1876
Type species: *Dictyomitra multicostata* Zittel 1876
Dictyomitra gracilis (Squinabol)
Plate I: Figs. 1, 2

1903 *Sethoconus gracilis* Squinabol: Squinabol; p. 131, pl. 10, fig. 13.
1982 *Mita gracilis* (Squinabol): Taketani; p. 60, pl. 5, figs. 2a–b, pl. 12, fig. 3.
1994 *Dictyomitra gracilis* (Squinabol): O'Dogherty; p. 73, pl. 1, figs. 12–25.

Diagnosis: Test conical, spindle shaped to globose distally. Cephalis sharply pointed distally. Test consists of eight to ten segments. Constrictions between segments weakly marked.
Material: Three well-preserved specimens.

Dictyomitra montisserei (Squinabol)
Plate I: Figs. 3, 4

1903 *Stichophormis Montis Serei* Squinabol: Squinabol; p. 137, pl. 8, fig. 38.
1903 *Stichophormis costata* Squinabol: Squinabol; p.136, pl. 8, fig. 41.
1977 *Archaeodictyomitra sliteri* Pessagno: Pessagno; p. 43, pl. 6, figs. 3, 4, 22, 23, 27.
1994 *Dictyomitra montisserei* (Squinabol): O'Dogherty; p. 77, pl. 3, figs. 1–29.

Diagnosis: Test multi-segmented, slender, and conical to cylindrical toward distal part. Constrictions on segmental divisions weak to well-developed. Test with ten to twelve costae in lateral view.
Material: 30 well-preserved specimens.

Dictyomitra napaensis Pessagno
Plate I: Figs. 6–9

1976 *Dictyomitra napaensis* Pessagno: Pessagno; p. 53, pl. 4, fig. 16, pl. 5, figs. 1, 9.

Diagnosis: Test multi-segmented, conical, with characteristic stiplike outline. Cephalis small, sharply pointed apically. Nine to thirteen costae in lateral view. Costae converging apically.
Material: Twelve well to moderately preserved specimens.

Dictyomitra pseudoscalaris (Tan)
Plate I: Fig. 5

1927 *Stichomitra pseudoscalaris* Tan: Tan; p. 56, pl. 11, fig. 84.

Diagnosis: Test multi-segmented, consists of nine to eleven segments, slender, conical. Cephalis small, sharply pointed. Constrictions on segmental divisions very weak developed, with a single row of pores. Twelve to fourteen costae are present on the visible side of the test.
Material: Only one specimen has been found in the material investigated.

Genus *Distylocapsa* O'Dogherty 1994
Type species: *Distylocapsa nova* Squinabol 1904
Distylocapsa cf. ***squama*** O'Dogherty
Plate II: Fig. 4

1994 *Distylocapsa* cf. *squama* O'Dogherty: O'Dogherty; p. 189, pl. 28, figs. 16–21.

Diagnosis: Test spindle-shaped, with four to five chambers. Weak constrictions developed between post-cephalic segments. Cephalis small, hemispherical with apical horn. Test thick-walled consisting of two lattice layers of pore frames regularly disposed on post-cephalic chambers. Test with a slender terminal spine.
Material: Only one moderately preserved specimen has been found in the material investigated.

Genus *Gongylothorax* Foreman 1968
Type species: *Gongylothorax verbeeki* (Tan) 1927
Gongylothorax siphonofer Dumitrică
Plate II: Fig. 6

1970 *Gongylothorax siphonofer* Dumitrică: Dumitrică; p. 57, pl. I, figs. 3a–b, 4a–c, 5a–b.

Diagnosis: Test dicyrtid. Cephalis spherical, poreless, partly depressed into the thoracic cavity. Thorax spherical, inflated, with numerous conical nodes, which might be only weakly, marked on its surface. Pores are situated on the top of nodes. Aperture narrow. Sutural pore indistinct.
Material: 74 moderately preserved specimens have been found in the material investigated.

Genus *Hemicryptocapsa* Tan 1927
Type species: *Hemicryptocapsa capita* Tan 1927
Hemicryptocapsa polyhedra Dumitrică
Plate III: Fig. 5

1970 *Hemicryptocapsa polyhedra* Dumitrică: Dumitrică; p. 71, pl. 14, figs. 85a–c.

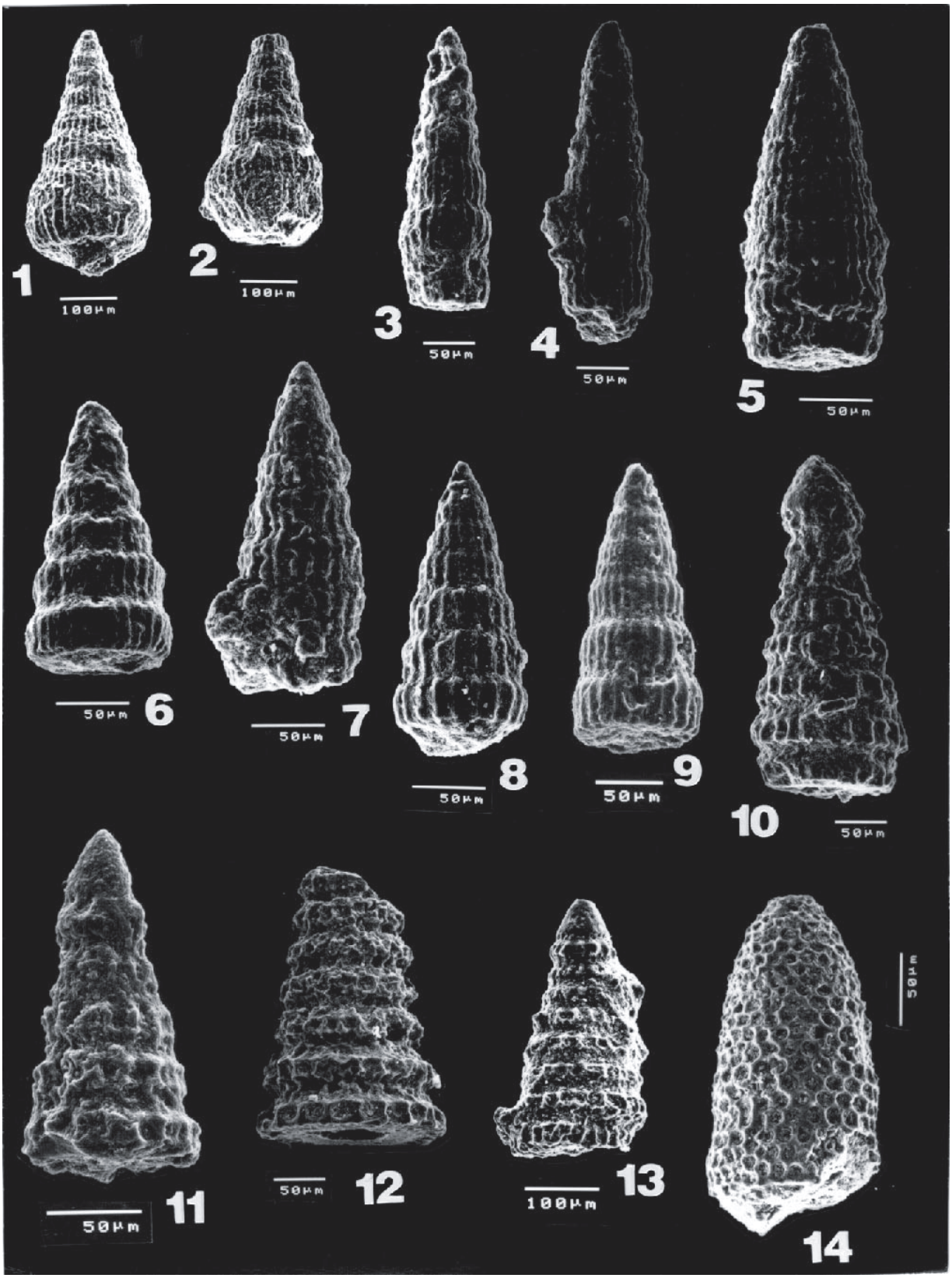

Plate I: Radiolarian microfauna in the Cenomanian/Turonian deposits from the Silesian Unit. **Figs. 1, 2.** *Dictyomitra gracilis* (Squinabol), 1 — Lc-11031; 2 — Lc-11037. **Figs. 3, 4.** *Dictyomitra montisserei* (Squinabol), 3 — Lcm-7037; 4 — Lcm-26030. **Fig. 5.** *Dictyomitra pseudoscalaris* (Tan), Lcm-26025. **Figs. 6–9.** *Dictyomitra napaensis* Pessagno, 6 — Lcm-26015; 7 — Lcm-26002; 8 — Lcm-7015; 9 — Lcm-7003. **Fig. 10.** *Pseudodictyomitra pseudomacrocephala* (Squinabol), Lcm-26033. **Figs. 11–13.** *Pseudodictyomitra tiara* (Holmes), 11 — Lcm-26035; 12 — Tr15A542; 13 — Lc-11025. **Fig. 14.** *Amphipyndax stocki* (Campbell & Clark), CP-803314.

Material: 35 well to moderately preserved specimens have been found in the material investigated.

Hemicryptocapsa prepolyhedra Dumitrică
Plate III: Figs. 6, 7

1970 *Hemicryptocapsa prepolyhedra* Dumitrică: Dumitrică; p. 71, pl. 13, figs. 80–84, pl. 20, fig. 131.

Material: 60 well to moderately preserved specimens have been found in the material investigated.

Hemicryptocapsa tuberosa Dumitrică
Plate II: Figs. 11, 12

1970 *Hemicryptocapsa tuberosa* Dumitrică: Dumitrică; p. 71, pl. 12, fig. 78a, pl. 13, figs. 78b, c, 79a, pl. 21, fig. 135.

Material: 46 well to moderately preserved specimens have been found in the material investigated.

Genus *Holocryptocanium* Dumitrică 1970
Type species: *Holocryptocanium tuberculatum* Dumitrică 1970
Holocryptocanium barbui Dumitrică
Plate II: Figs. 13–15

1970 *Holocryptocanium barbui* Dumitrică: Dumitrică; p. 76, pl. 17, figs. 105–108a,b, pl. 21, fig. 136.

Material: 1750 excellent to poorly preserved specimens have been found in the material investigated.

Holocryptocanium geysersensis Pessagno
Plate III: Fig. 1

1977 *Holocryptocanium geysersensis* Pessagno: Pessagno; p. 41, pl. 6, figs. 19, 25, 26.

Diagnosis: Test three-segmented. Abdomen subspherical, large, thick-walled with small closely spaced, inperforate nodes. Each node surrounded by 5 pores. Abdominal aperture circular, constricted, surrounded by a rise, flattened rim.

Material: 40 moderately to poorly preserved specimens have been found in the material investigated.

Holocryptocanium tuberculatum Dumitrică
Plate III: Figs. 2–4

1970 *Holocryptocanium tuberculatum* Dumitrică: Dumitrică; p. 75, pl. 16, figs. 103a–c, pl. 21, figs. 138a, b.

Material: 1030 excellent to poorly preserved specimens have been found in the material investigated.

Genus *Pseudodictyomitra* Pessagno 1977
Type species: *Pseudodictyomitra pentacolaensis* Pessagno 1977
Pseudodictyomitra pseudomacrocephala (Squinabol)
Plate I: Fig. 10

1903 *Dictyomitra pseudomacrocephala* Squinabol: Squinabol; p. 139, pl. 10, fig. 2.
1977 *Pseudodictyomitra pseudomacrocephala* (Squinabol): Pessagno; p. 51, pl. 8, figs. 10, 11.

Material: Three well preserved specimens have been found in the material investigated.

Pseudodictyomitra tiara (Holmes)
Plate I: Figs. 11–13

1900 *Dictyomitra tiara* Holmes: Holmes; p. 701, pl. 38, fig. 4.
1975 *Dictyomitra tiara* Holmes: Dumitrică; text-fig. 2.9.

Material: Three specimens have been found in the material investigated.

Genus *Squinabollum* Dumitrică 1970
Type species: *Clistophaena fossilis* Squinabol 1903
Squinabollum fossile (Squinabol)
Plate II: Fig. 10

1903 *Clostiphaena fossilis* Squinabol: Squinabol; p. 130, pl. 10, fig. 11.
1970 *Squinabollum fossilis* (Squinabol): Dumitrică; p. 83, pl. 19, figs. 118a–122.

Material: 15 moderately to poorly preserved specimens have been found in the material investigated.

Genus *Stichomitra* Cayeux 1897
Type species: *Stichomitra bertrandi* Cayeux 1897
Stichomitra communis Squinabol
Plate II: Figs. 1, 2

1903 *Stichomitra communis* Squinabol: Squinabol; p. 230, pl. 9, fig. 11.
1994 *Stichomitra communis* Squinabol: O'Dogherty; p. 144, pl. 17, figs. 6–16.

Material: Three specimens.

Genus *Xitus* Pessagno 1977
Type species: *Xitus plenus* Pessagno 1977
Xitus spicularius (Aliev)
Plate II: Fig. 5

1965 *Dictyomitra spicularia* Aliev: Aliev; p. 39, pl. 6, fig. 9, pl. 14, fig. 4.
1977 *Xitus spicularius* (Aliev): Pessagno; p. 56, pl. 9, fig. 7, pl. 10, fig. 5.

Material: Two poorly preserved specimens have been found in the material investigated.

Order SPUMELLARIA Ehrenberg 1875

Genus *Acaeniotyle* Foreman 1973
Type species: *Xiphosphaera umbilicata* Rüst 1898
Acaeniotyle cf. ***vitalis*** O'Dogherty
Plate IV: Figs. 13, 14

1994 *Acaeniotyle vitalis* O'Dogherty: O'Dogherty; p. 287, pl. 51, figs. 1–4.

Remarks: Forms with almost completely broken primary spines protruding out from the cortical shell.

Material: Five moderately to poorly preserved specimens have been found in the material investigated.

Genus *Alievium* Pessagno 1972
Type species: *Theodiscus superbus* Squinabol 1914
Alievium superbum (Squinabol)
Plate IV: Figs. 9–12

?1900 *Trigonocyclia* sp. B: Holmes; p. 698, pl. 27, fig. 24.
1914 *Theodiscus superbus* Squinabol: Squinabol; p. 271, pl. 20, fig. 4.
1975 *Alievium superbum* (Squinabol): Dumitrică; text-fig. 2.

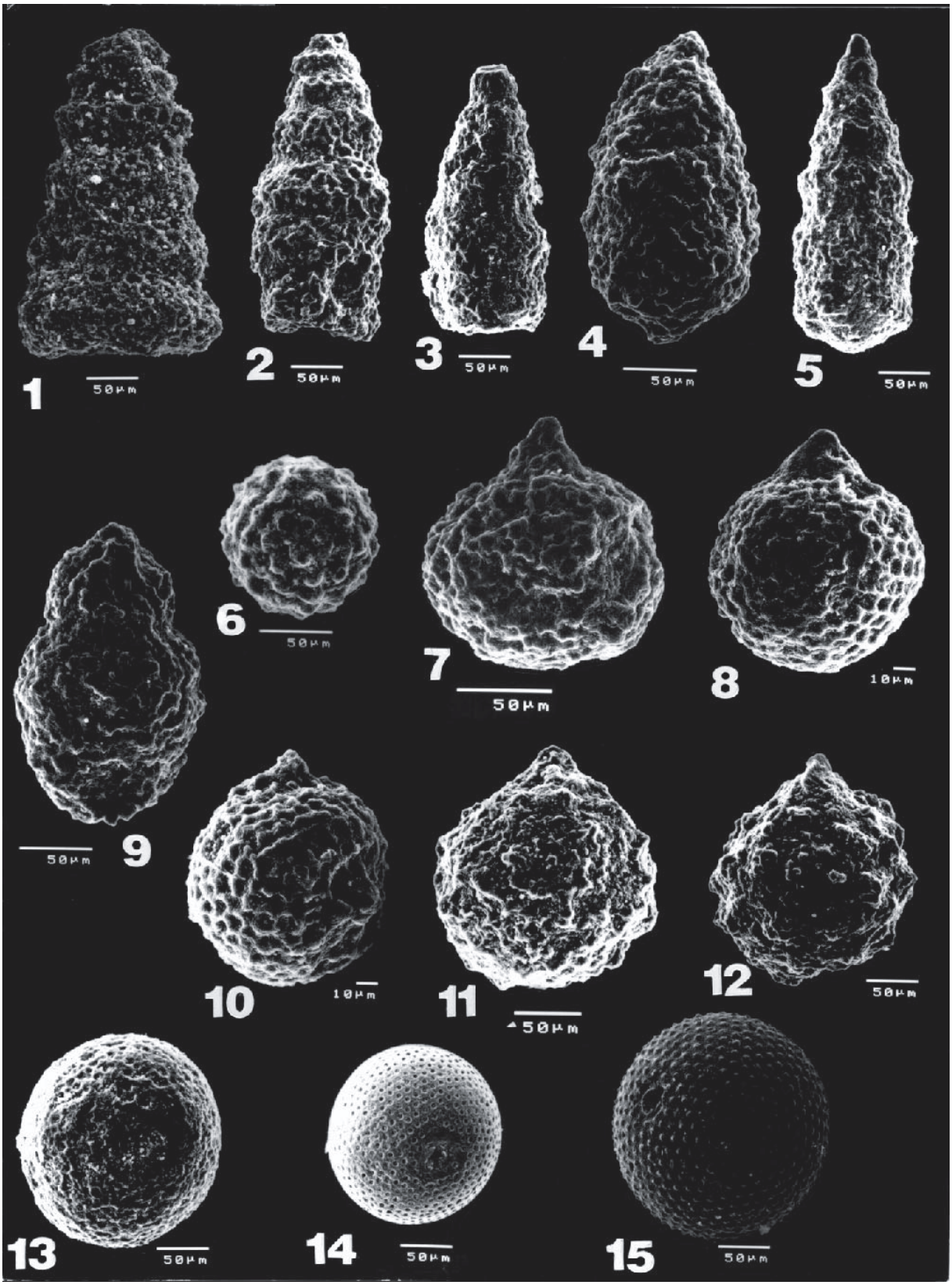

Plate II: Radiolarian microfauna in the Cenomanian/Turonian deposits from the Silesian Unit. **Figs. 1, 2.** *Stichomitra communis* Squinabol, 1 — Tr15B0518; 2 — Lcm-26005. **Fig. 3.** *Amphipyndax stocki* (Campbell & Clark), Lcm-7016. **Fig. 4.** *Distylocapsa* cf. *squama* O'Dogherty, Lcm-26027. **Fig. 5.** *Xitus spicularius* (Aliev), Lcm-7014. **Fig. 6.** *Gongylothorax siphonofer* Dumitrică, Jas-28001. **Figs. 7, 8.** *Cryptamphorella conara* (Foreman), 7 — Lcm-26019; 8 — Lcm-7019. **Fig. 9.** *Diacanthocapsa* sp., Lcm-26031. **Fig. 10.** *Squinabollum fossile* (Squinabol), Lcm-7011. **Figs. 11, 12.** *Hemicryptocapsa tuberosa* Dumitrică, 11 — Lc-0028; 12 — Lc-001. **Figs. 13–15.** *Holocryptocanium barbui* Dumitrică, 13 — Lc-11038; 14 — Tr-15A01; 15 — Tr-15A0543.

Diagnosis: Test triangular in outline, convex. Meshwork of cortical shell composed mostly of triangular pore frames, bearing small raised, spinose nodes. Test has three massive primary spines.

Material: Seven moderately preserved specimens have been found in the material investigated.

Genus *Crucella* Pessagno 1971
Type species: *Crucella messinae* Pessagno 1971
Crucella cachensis Pessagno
Plate III: Fig. 10

1971 *Crucella cachensis* Pessagno: Pessagno; p. 53, pl. 9, figs. 1–3.

Diagnosis: Hagiastrid with test four-rayed. Central area cylindrical with well-developed lacuna. The diameter of the central area is about equal to the length of the rays. Rays slender and cylindrical, terminate in moderately long, massive central spines.

Material: Three moderately preserved specimens have been found in the material investigated.

Crucella messinae Pessagno
Plate III: Fig. 9

1971 *Crucella messinae* Pessagno: Pessagno; p. 56, pl. 6, figs. 1–3.

Diagnosis: Test large, four-rayed without bracchiopyle. Rays approximately equal in length, rectangular to ellipsoidal in cross-section sharply pointed distally. Central area moderately to strongly inflated.

Material: Four moderately to well-preserved specimens have been found in the material investigated.

Genus *Dactyliodiscus* Squinabol 1903
Type species: *Dactyliodiscus cayeuxi* Squinabol 1903
Dactyliodiscus lenticulatus (Jud)
Plate IV: Fig. 8

1994 *Godia lenticulata* Jud: Jud; p. 78, pl. 10, figs. 10–11.
1994 *Dactyliodiscus lenticulatus* (Jud): O'Dogherty; p. 331, pl. 61, figs. 12–15.

Diagnosis: Test large, disc-shaped, circular in outline, flat. Periphery of the test rounded with more than 20 moderately massive spines. Meshwork of the test spongy with numerous small tubercles on its upper and lower part.

Material: Only one well-preserved specimen has been found in the material investigated.

Dactyliodiscus sp.
Plate V: Figs. 6, 7, 11

Description: Test large, disc-shaped, circular in outline, flat. Periphery of the test rounded with variable number of massive spines. Meshwork of the test spongy, consists of hexagonal to irregular pore frames. Meshwork forms on its lower and upper surfaces wide tubercles.

Material: Three moderately preserved specimens have been found in the material investigated.

Genus *Dactyliosphaera* Squinabol 1904
Type species: *Dactyliosphaera silviae* Squinabol 1904
Dactyliosphaera maxima (Pessagno)
Plate IV: Figs. 5–7

1976 *Orbiculiforma maxima* Pessagno: Pessagno; p. 34, pl. 1, figs. 14, 16.
1994 *Dactyliosphaera maxima* (Pessagno): O'Dogherty; p. 338, pl. 63, figs. 5–8.

Diagnosis: Test large, circular in outline, with deep central cavity. Central part of the cavity raised. Meshwork composed of circular to hexagonal pore frames. Periphery of the test is angular with indeterminate number of short spines.

Material: 82 moderately preserved specimens have been found in the material investigated.

Genus *Patellula* Kozlova in Petrushevskaya & Kozlova 1972
Type species: *Stylospongia planoconvexa* Pessagno 1963
Patellula andrusovi Ožvoldová
Plate V: Figs. 1–5

1997 *Patellula andrusovi* Ožvoldová: Sýkora, Ožvoldová & Boorová; p. 260, pl. IV, figs. 1–7, 9, 11.

Material: 64 moderately to well-preserved specimens have been found in the material investigated.

Patellula helios (Squinabol)
Plate IV: Fig. 15

1903 *Stylotrochus helios* Squinabol: Squinabol; p. 124, pl. 10, figs. 23, 23a.
1994 *Patellula helios* (Squinabol): O'Dogherty; p. 327, pl. 60, figs. 19–24.

Remarks: Specimens investigated usually have their spines broken.

Material: 15 moderately preserved specimens have been found in the material investigated.

Patellula ecliptica O'Dogherty
Plate V: Figs. 8–10

1994 *Patellula ecliptica* O'Dogherty: O'Dogherty; p. 329, pl. 61, figs. 1–5.

Remarks: Described specimens usually with broken spines.

Material: 60 moderately to well-preserved specimens have been found in the material investigated.

Genus *Praeconocaryomma* Pessagno 1976
Type species: *Praeconocaryomma universa* Pessagno 1976
Praeconocaryomma lipmanae Pessagno
Plate III: Figs. 11–14

1976 *Praeconocaryomma lipmanae* Pessagno: Pessagno; p. 41, pl. 4, figs. 12, 13.
1994 *Praeconocaryomma* sp.: Bąk; p. 150, pl. 1, fig. b.
1996 *Praeconocaryomma lipmanae* Pessagno: Górka; p. 556, pl. 1, fig. 1.

Remarks: Identified forms have tests spherical with conical, porous mammae. Spines protruding from each mammae, present on holotype illustrated by Pessagno (1976) are not visible in the material investigated, probably because of poor state of specimens preservation.

Material: 100 well to moderately preserved specimens have been found in the material investigated.

Praeconocaryomma universa Pessagno
Plate IV: Figs. 1–4

1976 *Praeconocaryomma universa* Pessagno: Pessagno; p. 42, pl. 6, figs. 14–16.

Diagnosis: Test consists of concentric spheres. Cortical shell of the test with latticed nodes. It comprises circular to elliptical pore

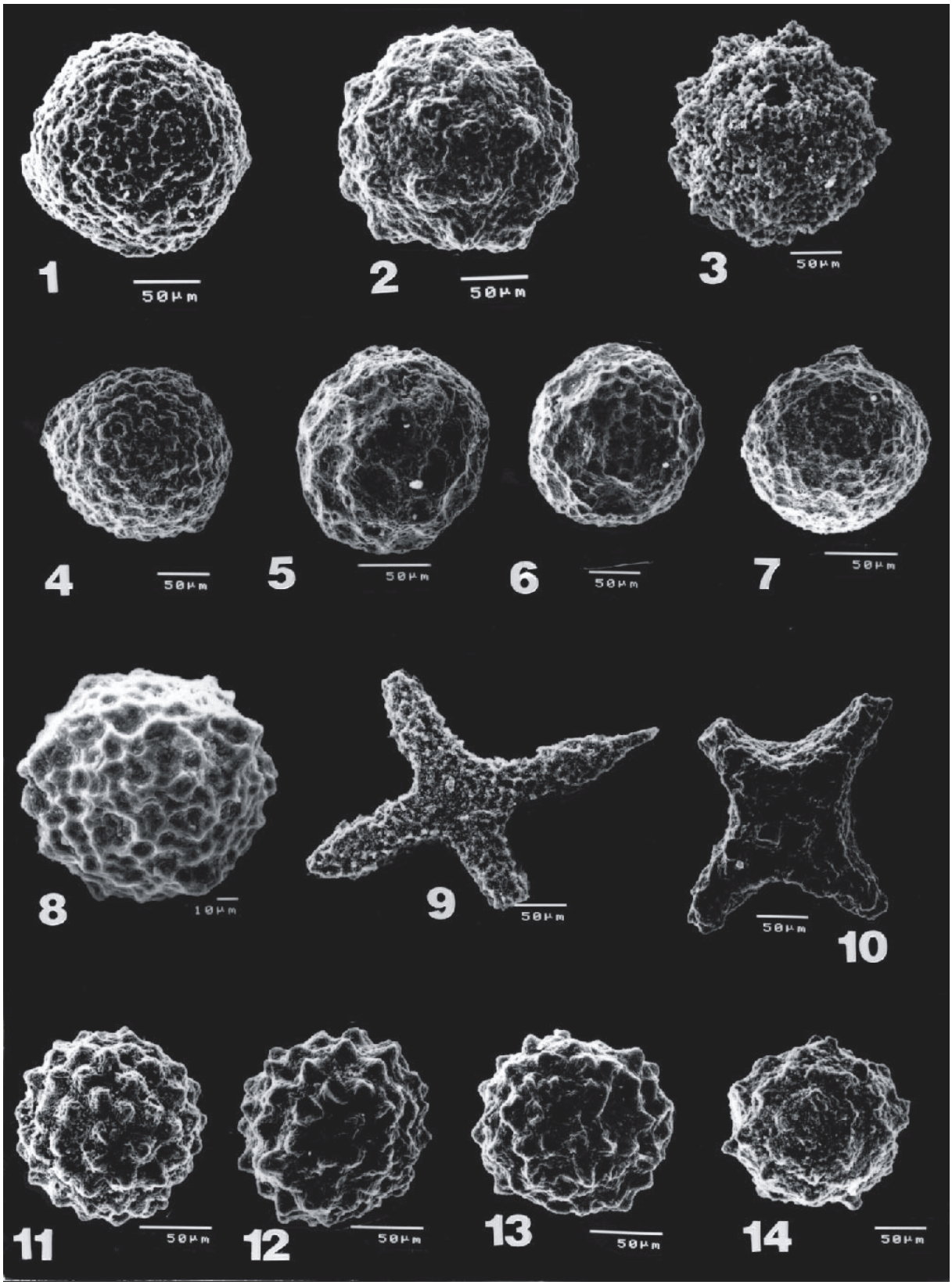

Plate III: Radiolarian microfauna in the Cenomanian/Turonian deposits from the Silesian Unit. **Fig. 1.** *Holocryptocanium geysersensis* Pessagno, Lcm-7021. **Figs. 2–4.** *Holocryptocanium tuberculatum* Dumitrică, 2 — Lcm-7017; 3 — Tr-15A0523; 4 — Jas-1502919. **Fig. 5.** *Hemicryptocapsa polyhedra* Dumitrică, Jas-1502815. **Figs. 6, 7.** *Hemicryptocapsa prepolyhedra* Dumitrică, 6 — CP-1403101; 7 — Jas-1502815. **Fig. 8.** *Quinquecapsularia ombonii* (Squinabol), Jas-2802. **Fig. 9.** *Crucella messinae* Pessagno, Lc-22017. **Fig. 10.** *Crucella cachensis* Pessagno, Lcm-26023. **Figs. 11–14.** *Praeconocaryomma lipmanae* Pessagno, 11 — Jas-1401; 12 — Jas-1402; 13 — Lc-11040; 14 — Jas-14015.

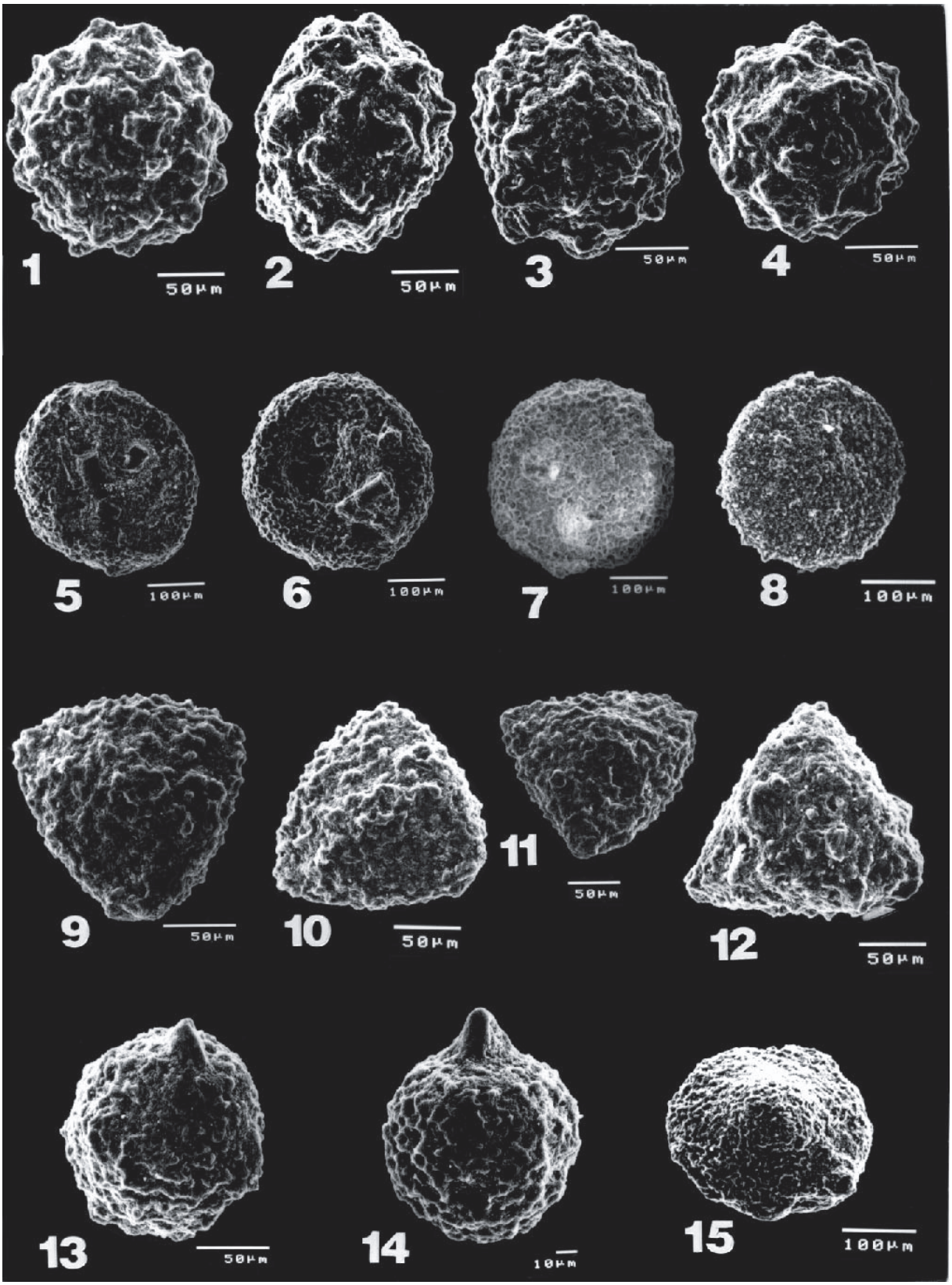

Plate IV: Radiolarian microfauna in the Cenomanian/Turonian deposits from the Silesian Unit. **Figs. 1–4.** *Praeconocaryomma universa* Pessagno, 1 — Lcm-26013; 2 — Lc-0002; 3 — Lcm-26001; 4 — Lcm-26004. **Figs. 5–7.** *Dactyliosphaera maxima* (Pessagno), 5 — Tr-15C08; 6 — Lcm-26012; 7 — Jas-1502. **Fig. 8.** *Dactyliodiscus lenticulatus* (Jud), Lc-22018. **Figs. 9–12.** *Alievium superbum* (Squinabol), 9 — Lcm-26032; 10 — Lcm-26016; 11 — Lcm-26026; 12 — Lcm-7001. **Figs. 13, 14.** *Acaeniotyle* cf. *vitalis* O'Dogherty, 13 — Lcm-7007; 14 — Lcm-7022. **Fig. 15.** *Patellula helios* (Squinabol), Lc-11006.

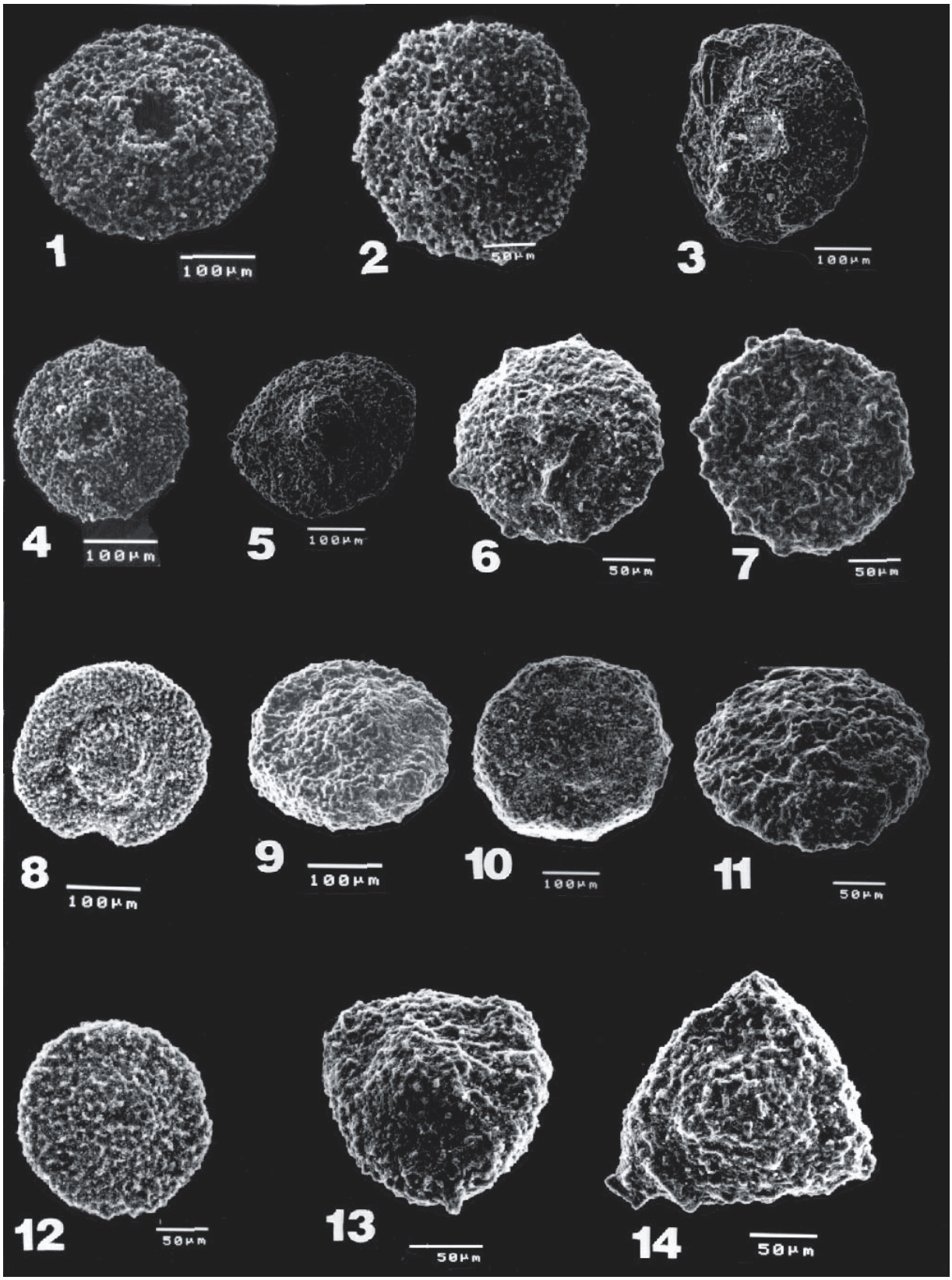

Plate V: Radiolarian microfauna in the Cenomanian/Turonian deposits from the Silesian Unit. **Figs. 1–5.** *Patellula andrusovi* Ožvoldová, 1 — Tr-15A0526; 2 — Tr-15A0538; 3 — Tr-15A0524; 4 — Tr-15A004; 5 — Tr-15A0540. **Figs. 6, 7, 11.** *Dactyliodiscus* sp., 6 — Lcm-7006; 7 — Lcm-26028; 11 — Lcm-26029. **Figs. 8–10.** *Patellula ecliptica* O'Dogherty, 8 — Lc-20012; 9 — Lcm-26010; 10 — Tr-15A009. **Fig. 12.** *Pseudoaulophacus* sp., Lc-22019. **Figs. 13–14.** *Pseudoaulophacus putahensis* Pessagno, 13 — Lcm-7021; 14 — Lcm-7020.

frames of variable size with usually six pores on each node. Triradiate, massive spines, which connect cortical and medullar shells protruding out from the centre of each node.

Remarks: Only poorly preserved forms, with broken spines, have been found in the material investigated.

Material: 37 moderately preserved specimens have been found in the material investigated.

Genus *Pseudoaulophacus* Pessagno 1963
Type species: *Pseudoaulophacus floresensis* Pessagno 1963
Pseudoaulophacus putahensis Pessagno
Plate V: Figs. 13–14

?1900 *Trigonocyclia* sp. A: Holmes; p. 698, pl. 27, fig. 20.
1972 *Pseudoaulophacus putahensis* Pessagno: Pessagno; p. 310, pl. 27, fig. 1.

Remarks: Forms present within deposits investigated posses their tests more subtriangular.

Material: 25 moderately to well-preserved specimens have been found in the material investigated.

Pseudoaulophacus sp.
Plate V: Fig. 12

Remarks: Forms differ from *Pseudoaulophacus putahensis* Pessagno by having only circular outer shape.

Material: Five moderately to well-preserved specimens have been found in the material investigated.

Genius *Quinquecapsularia* Pessagno 1971
Type species: *Quinquecapsularia spinosa* Pessagno 1971
Quinquecapsularia ombonii (Squinabol)
Plate III: Fig. 8

1903 *Hexastylus Ombonii* Squinabol: Squinabol; p. 113, pl. 8, fig. 10.
1904 *Acrosphaera mirabilis* Squinabol: Squinabol; p. 187, pl. 2, fig. 5.
1994 *Quinquecapsularia ombonii* (Squinabol): O'Dogherty; p. 268, pl. 47, figs. 21–24.

Diagnosis: Test spherical with initial skeleton formed by a system of bars forming a pentagonal prism. Cortical shell of the test with broad, irregular to hexagonal pore frames, usually with small, sharp nodes at the pore frame junctions. Several (eight to ten) small, primary spines can be visible around the test.

Material: Five moderately preserved specimens have been found in the material investigated.

Radiolarian correlation

The radiolarian assemblage investigated, including all radiolarians recovered in the mid-Cretaceous deposits of the Silesian Unit has been used for comparison with radiolarian zonal schemes from different regions of the Carpathians and Mediterranean.

The only zonal scheme for the Radiolaria-bearing deposits of the same interval but recognized in the Romanian Carpathians has been proposed by Dumitrică (1975). This author recognized two assemblages*: Holocryptocanium barbui-Holocryptocanium tuberculatum* and *Holocryptocanium nanum -Excentropyloma cenomana* for the Late Cenomanian–earliest Turonian interval. The radiolarian assemblages investigated show great similarities with the associations presented by Dumitrică based on the high frequency of cryptocephalic and cryptothoracic Nassellaria such as *H. barbui, H. tuberculatum, Hemicryptocapsa tuberosa, Cryptamphorella conara* and *Gongylothorax siphonofer*. Moreover, some multi-segmented Nassellaria from genera such as *Dictyomitra, Pseudomacrocephala, Stichomitra, Amphipyndax* and *Xitus* are also present in the radiolarian associations from the Silesian Unit. The upper assemblage of Dumitrică can also be distinguished in the presented material on the basis of the presence of *Alievium superbum* the first occurrence of which delineates the base of the *H. nanum-E. cenomana* assemblage.

The radiolarian assemblage investigated differs from that of Dumitrică (1975) by including a smaller percentage of Nassellaria (only 60–70 %), and more Spumellaria (up to the 30–40 %).

The first radiolarian local zonation for the Cenomanian through Turonian deposits in the Polish part of the Pieniny Klippen Belt was proposed by the author in 1999 (Bąk 1999). Two radiolarian zones (Hemicryptocapsa prepolyhedra and Hemicryptocapsa polyhedra) have been established for the interval investigated. The radiolarian association from the Silesian Unit shows similarities with coeval association in the Pieniny Klippen Belt based on the presence of both index specimens as well as a high percentage of cryptothoracic and cryptocephalic Nassellaria such as *H. barbui, H. tuberculatum, H. tuberosa, C. conara*, and multi-segmented Nassellaria as: *Dictyomitra montisserei, Dictyomitra napaensis, Pseudodictyomitra tiara, Pseudodictyomitra pseudomacrocephala, Stichomitra communis, Amphipyndax stocki* and *Xitus spicularius*. Spumellarian specimens are less frequent in the Pieniny Klippen Belt deposits, but some of the species (i.e. *Dactyliosphaera maxima, Patellula andrusovi*) are the same in both these areas.

The radiolarian assemblage from the Silesian Unit shows great similarities with the earliest Turonian radiolarian fauna presented by Sýkora et al. (1997) from the Czorsztyn Succession of the Pieniny Klippen Belt in the Slovak territory. Many species, especially belonging to Spumellaria are present in both these areas. These are: *Alievium superbum*, *Patellula ecliptica, Patellula andrusovi, Pseudoaulophacus putahensis, Crucella cachensis,* as well as the nassellarians such as *Dictyomitra napaensis, Dictyomitra montisserei, Pseudodictyomitra pseudomacrocephala, Holocryptocanium barbui* and *Cryptamphorella conara*.

The assemblage investigated can also be correlated with the first radiolarian biozonation of mid-Cretaceous deposits for the Mediterranean region proposed by O'Dogherty (1994). This author recognized two radiolarian zones and two subzones for the Late Cenomanian–early Turonian interval. The studied radiolarian assemblage is similar to this zonation for latest Cenomanian (subzone of Silviae Zone), on the basis of co-occurrence of some Nassellaria and Spumellaria species. The Superbum Zone can also be distinguished in the assemblage investigated on the basis of the presence of the index taxon.

Conclusions

The results presented here are based on micropaleontological analysis of 90 samples from four profiles of mid-Cretaceous deposits of the Silesian Unit, in its Polish part. The deposits investigated are very rich in radiolarian fauna. Lithologically, they consist mainly of green shales with black shale intercalations, including a manganese concretions level, bentonites and tuff layer dated as 91.4 ± 4.7 Ma (Van Couvering et al. 1981). These deposits represent characteristic correlating horizon, presents in the whole Carpathian arc.

A systematic search of all different radiolarian morphotypes in the samples investigated proved the diversity of radiolarian fauna. Twelve genera and twenty species from the order Nassellaria, and nine genera and fifteen species from the order Spumellaria have been recognized. The radiolarian assemblage is dominated by spherical cryptothoracic and cryptocephalic Nassellaria, belonging especially to the species *Holocryptocanium barbui* Dumitrică, *H. tuberculatum* Dumitrică, *Hemicryptocapsa tuberosa* Dumitrică, *H. prepolyhedra* Dumitrică and *H. polyhedra* Dumitrică. These forms make up about 60–99 % of radiolarian specimens. The spumellarians are less common. They consist of 30–40 % of the radiolarian association, and are represented mainly by genera such as *Pseudoaulophacus*, *Patellula*, *Alievium*, *Crucella* and *Praeconocaryomma*.

All the radiolarian taxa recorded in the deposits investigated have been used for comparison with the radiolarian zonal schemes used by the previous authors in different areas of Carpathians as well as Mediterranean. The age of the deposits investigated, based on the radiolarian fauna ranges from the Late Cenomanian to early Turonian.

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