

Rugosa (Anthozoa) from the Serpukhovian (Lower Carboniferous) of the Upper Silesian Coal Basin

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ABSTRACT:

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Two species, *Antiphyllum* sp. nov. 1 and *Zaphrufimia* sp. nov. 1, the first corals found in Štur horizon of the upper Malinowickie Beds, Upper Pendleian (E₁), are here described. Additional study of the subspecies of *Zaphrufimia disjuncta* show them to be more similar than previously thought. Although they occur mainly in the Enna and Barbara horizons, one specimen of *Z. d. serotina* comes from the Gabriela horizon. Biozone *Zaphrufimia disjuncta disjuncta*/Z. *d. praematura* is proposed for the Enna and Barbara horizons. The subzone of *Zaphrufimia/Triadufimia* of that Biozone, defined by the presence of *Triadufimia* gen. nov., is restricted to the Enna horizon. As confirmed by the occurrence of *Cravenoceratoides edalensis*, the new subzone roughly corresponds to the E2b1 ammonite Zone. An *Antiphyllum/Ostravaia/Variaxon* assemblage Zone is proposed for the coral assemblage of the Gaebler horizon. *Cravenoceratoides nitidus* present in the Roemer band (I^b) shows it to correlate with the E2b2 ammonite Zone. Comparison with other European regions suggests possible faunal exchange between those areas and the Upper Silesian Coal Basin in Serpukhovian time.

Key words: Upper Silesian Coal Basin; Serpukhovian; Rugosa; Taxonomy; Relationships; Succession.

INTRODUCTION

The two authors are responsible for different chapters of the paper. The senior author is responsible for the entire systematic part, including authorship of the new taxa, for the summary of the Upper Silesian Coal Basin (USCB) rugose coral succession, including its zonation, and for all illustrations and tables corresponding to those parts of the paper. He also is co-responsible for placing the position of particular Beds within the Serpukhovian part of the stratigraphic column. The present paper concludes a series of his ear-

lier papers (Fedorowski 2009a, 2010, 2012a, b) devoted to the late Serpukhovian Rugosa from the USCB. All these papers, including the present one, deal with all specimens of rugose corals known to the senior author from the USCB. These specimens were either investigated for the first time (Fedorowski 2012a, and herein) or were described by earlier authors (Schwarzbach 1937; Schindewolf 1942, 1944, 1952; Matl 1971; Řehoř and Řehořová 1959, 1972; Weyer 1974, 1977) and revised by Fedorowski (*ibid.*). Additional information is included in the ‘Material and Methods’ chapter below.

The junior author is responsible for the geological setting, including remarks on the sedimentary environments of the marine 'horizons' yielding rugose corals, and for all other remarks on the geology of the USCB as well as for the illustrations related to those parts of the paper. Most specimens investigated here indicated on Table 1 were provided by her. Both authors are responsible for the introduction, the material and methods, the history of the investigation, and the references.

All corals investigated were derived from both named and numbered 'marine horizons', referred to herein as horizons; their numbers and term 'marine' are omitted; e.g., Štur horizon (for Štur XVI marine 'horizon'). In the stratigraphic order the following horizons were recognized: Štur (XVI), Franciszka (X), Enna (VII), Barbara (V), Gabriela (IV), Gaebler (I) and a marine band of the latter named Roemer (I^b).

TERMINOLOGY AND ABBREVIATIONS

The term *primary septa*, applied in the species descriptions in this and some earlier papers of the senior author, refers to the innermost parts of septa, secreted prior to secretion of their sclerenchymal sheets. Although secreted in a continuous manner, those two parts of septa differ in their microstructure and diagenetic alterations. The *primary septa* are the only parts of septa proper for the study of their microstructure. They commonly bear a neutral term *middle dark lines*.

Letters 'd' and 'n', used in diagnoses and/or descriptions of species, refer to a corallite diameter and the number of septa, respectively.

HISTORY OF THE INVESTIGATION

The Upper Silesian Coal Basin is situated in southern Poland and the north-eastern Czech Republic (Text-fig. 1), where it is known as the Ostrava-Karvina Coal Basin. Geological investigations, including the stratigraphy and palaeontology of the Paralic Series in Silesia date back to the second half of nineteenth century. They include studies on Serpukhovian siliciclastic sediments with coal seams and fossiliferous marine intercalations in outcrops of the western part of the USCB. Schütze (1865) introduced the first stratigraphy in the Rybnik area (SW margin of Polish part of the USCB). Štur (1875) studied and named the Ostrava Beds in the Czech part of the basin. Several names, such as Marginal Group (Michael 1904), Marginal Beds (Gaebler 1909), or Paralic Series (Kotas

and Malczyk 1972) were introduced for those deposits in the twentieth century. The latter name is most popular and is applied herein.

More sophisticated studies of the fossiliferous intercalations of the western USCB were conducted by Gaebler (1909) and Michael (1913), who published monographs on the Carboniferous stratigraphy based on palaeontological and lithological investigation in all of the coal mines and boreholes in the Rybnik area. Klebelsberg (1922) characterized the faunal composition of marine 'horizons'. Petrascheck (1928) described faunal 'horizons' in the Ostrava region and correlated lithostratigraphic units in that area with those of the Rybnik area. Niemczyk (1928) drew up a composite lithostratigraphic profile of the Gliwice Coal Mine and correlated it with that of the Ostrava area. Faunal horizons of the Ostrava area were further described by Patteisky and Folprecht (1928) and Patteisky (1936), who also established the E₁ and E₂ goniatite zones in the Ostrava Beds. Makowski (1931) correlated the lithostratigraphy of the Rybnik area with that of the Ostrava area and the western part of the USCB and discussed the faunal content of the 'horizons' in terms of sea level oscillations (Makowski 1937). Schwarzbach (1937) described several taxa of corals, bellerophonitids, brachiopods, goniatitids, trilobites and other fossils. Schwarzbach and Reichelt (1940) described the lower Marginal Beds succession and its faunal 'horizons' in the Gliwice area.

The faunal composition of marine horizons in the eastern and central part of the USCB were examined by Karczewski (1904), Cramer (1910), Wirth (1931) and Doktorowicz-Hrebniński (1935). The last author introduced the informal lithostratigraphic units, such as the Malinowice Beds, Sarnów Beds, Flora Beds and Grodziec Beds.

Strong development of mining after the Second World War resulted in a rapid increase of geological data. Marine faunas were investigated by Přibyl (1951), Vasiček (1957), Řehoř and Řehořová (1959, 1972), Matl (1971), Bojkowski (1972, 1978, 1979), Krzoska (1982), Musiał and Tabor (1964, 1982, 2001), Dopita (1997), and Machłajewska (2002, 2005). Most groups of fossils were treated in these papers, but special attention was given to taxa of the most frequently occurring, i.e., pelecypods, gastropods, brachiopods, and goniatitids, the most important stratigraphically. Unfortunately, goniatitids are rare and scarce in the Serpukovian strata of the USCB. That paucity or lack of other index fossils (Foraminifera and Conodonta) in the Paralic Series has created numerous difficulties in establishing the stratigraphy of the USCB. The currently

accepted stratigraphical division is discussed in the Geological Setting chapter.

Rugose coral investigations are restricted to only a few papers because of the scarcity of these fossils, difficulties in their identification, requiring laborious methods of preparation, and their low stratigraphic value as postulated by many stratigraphers. This last statement has been shown to be incorrect as indicated by the value of corals in determining local stratigraphy as well as that within provinces (e.g., Sando and Bamber 1985; Poty and Hannay 1994; Poty *et al.* 2006; Fedorowski *et al.* 2007). Here an attempt is made to establish the rugose coral biozones for the USCB (see below). Unfortunately, the Serpukhovian Rugosa of the USCB were superficially treated in most early papers. Weigner (1937) mentioned rugose corals in his restudy of Cramer's (1910) collection of the Gołonóg Sandstones fauna. Schwarzbach (1937) illustrated and briefly described three species (*Zaphrentis* aff. *postuma* Smith, ?*Zaphrentis* aff. *postuma* Smith, and *Zaphrentis* sp. a) on the basis of his rich collection. His paper was the first in which the rugose corals were illustrated. The lack of appreciation of the value of the Rugosa was continued by stratigraphers into the second part of the 20th Century despite the comprehensive redescription by Schindewolf (1942, 1952) of Schwarzbach's (1937) material, his introduction of nine new species, belonging to five genera (one new; see Table 3) and his introductory recapitulation of the stratigraphic succession of the species described by him (Schindewolf 1952, fig. 1). Following Schindewolf's (1952) taxonomy, Řehoř and Řehořová (1959, 1972) illustrated and briefly described three species from the Czech part of the USCB. Most of their identifications were corrected by Fedorowski (2012a, and herein). Matl (1971) illustrated and incorrectly identified one species (see Table 3). Bojkowski (1972) only mentioned the rugose coral species described by Schindewolf (1952). Only Weyer (1974, 1977) continued revision of the specimens collected by Schwarzbach (1937), that were either omitted by Schindewolf (1942, 1944, 1952) in his studies, or misinterpreted by him. Weyer's (1974) reorientation, redescription and reillustration of *Antiphyllum inopinatum* Schindewolf, 1952 allowed the correct identification of some corals traditionally included in the genus *Claviphyllum* McCoy, 1849. The same is true for Weyer's (1977) rejection of the name *Fasciculophyllum* Dybowski, 1873, applied by Schindewolf (1952) to some USCB corals. All of Weyer's (1974, 1977) suggestions are not followed either here or in the earlier papers by the senior author (Fedorowski 2009a, 2010, 2012a, b),

but several taxonomic and stratigraphic corrections were important and fully accepted.

Fedorowski (*ibid.*) revised all specimens known to him of the Rugosa from the Serpukhovian strata of the USCB in Czech, German and Polish museums. He introduced several new taxa at the species, genus and subfamily level. Thus, the remarks in the concluding part of this paper are based on new descriptions and revisions with only a few references to the older papers, summarized in Table 3.

MATERIAL AND METHODS

Most of the specimens described in this paper were collected by Dr. Tadeusz Krzoska in the 70s and, subsequently, by the junior author (Table 1). She was able to examine the lithology and to collect fossils in the Sośnica coal mine. Only a few of these corals were mentioned in her Ph.D. thesis (Machłajewska 2005). The collection is supplemented with specimens collected by Dr. Łucja Musiał (Table 2) and kindly lent by the State Geological Institute, Upper Silesian Branch, Sosnowiec for this study. Both collections form the basis for the systematic descriptions, all taphonomic and part of the stratigraphic considerations in the present paper. Unfortunately, mature parts and calices of most of the specimens have been partly damaged by compression. As a result, subspecies status of some specimens included in *Zaphrurifimia disjuncta* (Carruthers, 1910) is uncertain. This damage also has made identifications of some specimens at the genus and species level impossible. Thus, out of the total 90 specimens collected and investigated in the present article, 18 were left unidentified.

Most specimens were re-crystallized and/or dolomitized. All were cut with an ultra-thin (0.05 mm) wire, thin sectioned and peeled. Digital photographs with the Olympus professional microscope combined with a computer program were taken of the thin sections, peels and/or polished surfaces. When necessary, drawings were made on some photographs to provide more clarity.

DEPOSITORY

Specimens borrowed from the Polish Geological Institute are housed in the Upper Silesian Branch in Sosnowiec with the acronym OG. Specimens collected by the junior author are deposited in the Institute of Geology of the Adam Mickiewicz University, in Poznań, with the acronym SUT; collection numbers: SUT-K-1-19, SUT-LC-1-35, SUT-S-1-17.

Name species/subspecies	Mine name	Ditch name & depth/meters	'Horizon'	Number of specimen Akronym SUT
<i>Zaphrufimia disjuncta disjuncta</i>	Knurów	G5W. Level 550	Enna	K-1 – K-8
	Ludwik-Concordia	West. Level 430		LC-9
	Ludwik-Concordia	West. Level 430		LC-10 – LC-22
	Sośnica	BP3z. Level 550	Barbara	S-23 – S-27
<i>Zaphrufimia disjuncta praematura</i>	Knurów	G5W. Level 550	Enna	K-29, K-30
	Ludwik-Concordia	West. Level 430		LC-31 – LC-39
	Sośnica	BP3z. Level 550	Barbara	S-40 – S-42
<i>Zaphrufimia disjuncta serotina</i>	Knurów	G5W. Level 550	Enna	K-43
	Ludwik-Concordia	West. Level 430		LC-44
	Ludwik-Concordia	West. Level 430		LC-45
	Sośnica	BP3z. Level 550	Barbara	S-47, S-48
	Ludwik-Concordia	BP3z. Level 550	Gabriela	LC-46
<i>Triadufimia coepta</i>	Knurów	G5W. Level 550	Enna	K-49 – K-51
	Ludwik-Concordia	West. Level 430		LC-52, LC-53
	Sośnica	BP3z. Level 550	Barbara	S-54, S-55
<i>Triadufimia</i> sp. n. 1	Knurów	G5W. Level 550	Enna	K-56
<i>Triadufimia</i> sp. n. 2	Ludwik-Concordia	West. Level 430	Enna	K-57

Table 1. The rugose coral species collected from ditches made in the Ludwik-Concordia, Knurów and Sośnica coal mines at levels as indicated

Name species/subspecies	Number collection/specimen	Drilling name	Depth	Horizon
<i>Zaphrufimia disjuncta disjuncta</i> (Carruthers 1910)	119/28	Brzeszcze 32	1101.8 m	Barbara (V)
	183/332	Grodziec 342	314.0 m	
	184/236	Czeladź 19	366.2 m	
	461/247	Piasek IG1	1794.1 m	
<i>Zaphrufimia disjuncta praematura</i> (Schindewolf, 1952)	119/5	Brzeszcze 32	1101.8 m	
	119/33		1102.0 m	
	183/218	Wełnowiec IG1	307.2 m	
	183/324	Grodziec 342	313.85 m	
	183/330		315.0 m	
	183/492	Grodziec 344	376.5 m	
	461/249	Piasek IG1	1794.8 m	
<i>Zaphrufimia disjuncta serotina</i> (Schindewolf, 1952)	183/432	Grodziec 343	196.8 m	
<i>Zaphrufimia</i> sp. n. 1	461/152a, b	Łąka IG1	1771.0 m	Štur (XVII)
? <i>Antiphyllum</i> sp. n. 1	482/142	Leńcze IG1	1357.1 m	Štur (XVII)

Table 2. The rugose coral species collected from drilling cores

GEOLOGICAL SETTING

The Upper Silesian Coal Basin (USCB), triangular in shape (Text-fig. 2), is primarily located in southwestern Poland. However, it continues into the north-eastern Czech Republic (Text-fig. 1) where it is known as the Ostrava-Karvina Coal Basin. The deepest basement of the USCB consists of the crystalline rocks of the Precambrian Upper Silesia Block. This block is discordantly covered by Lower and partly Middle Cambrian and Ordovician siliciclastic deposits. These Lower Paleozoic rocks were later uplifted and mostly eroded. The Devonian and Car-

boniferous strata, discordantly overlying rudiments of the Lower Palaeozoic rocks or resting directly on the crystalline basement, belong to the Variscan foredeep tectonic structure. An Early Devonian transgression led to the accumulation of conglomerates and sandstones. These clastic deposits were succeeded by Middle and Upper Devonian shallow-water limestones, which accumulated in a shelf basin (Bojkowski 1978) carbonate platform (Bełka 1985). The total thickness of the Devonian deposits reaches 1000 m.

Continuous deposition across the Devonian/Carboniferous boundary is not documented in the USCB.

Condensed sequences or gaps, the result of the Bretonian tectonic phase, was recognized by Belka (1985). The oldest Carboniferous (Tournaisian and Lower Viséan) deposits (mudstones, wackstones, grainstones) occur exclusively in the NE and NW margins of the basin. They accumulated on the Devonian carbonate platform, which was more deeply depressed on the west side. This platform underwent slow subsidence, which resulted in a slow rate of deposition, but differences in sediment type depended on the depth of the platform in any given area (Bojkowski 1978).

Sedimentary conditions changed in the Late Viséan due to an early Sudetic phase of the Variscan orogeny. Deposits became more differentiated due to the rapid sinking of the western part of carbonate platform and simultaneous uplift in the east. The latter area was broken into blocks and mostly eroded. Conglomerates, sandstones, and mudstones replaced the more fine-grained older deposits. The axis of sedimentation shifted from the west to the east during the Namurian (Belka 1985).

The Viséan and Lower Serpukhovian siliciclastic deposits, up to 1500 m thick, are interpreted as representing a flysch facies. They form an informal lithostratigraphic unit called “flysch association” (Kotas 1982) with a generally western provenance of detrital material (Paszkowski *et al.* 1995). The top of this sequence, belonging to the Lower *Eumorphoceras* Zone, consists of the Malinowickie Beds that yield the oldest marine faunal horizon (Štur), described below. The higher Serpukhovian, Bashkirian and Moscovian strata (Text-figs 2, 3) represent a foredeep molasse deposition. These strata form an informal lithostratigraphic unit, the “molasse association” (Kotas 1982). Within the molasse as-

sociation numerous coal seams occur and its lower, Serpukhovian part, contains several marine intercalations (marine horizons as referred further to herein) (Text-fig. 4).

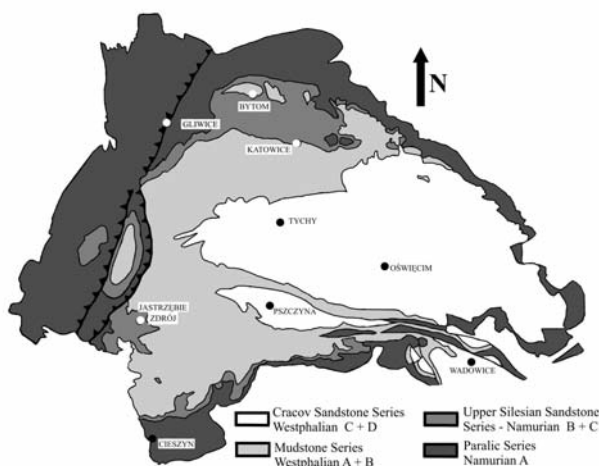
The middle and upper part of the Serpukhovian succession, called the ‘Paralic Series’, consists of claystones, mudstones, sandstones and coal seams, characteristic of a paralic basin with cyclic marine and non-marine sedimentation. The higher part of the Carboniferous succession comprises terrestrial and limnic sediments of the Namurian B+C (Upper Silesian Sandstone Series), through the Westphalian A+B (Mudstone Series) to the Westphalian C+D (Cracow Sandstone Series) (Text-fig. 3). During this latter time the USCB underwent a second phase of flexural foredeep development in front of the northeastward advancing Moravian-Silesian Belt (Narkiewicz 2007).

The marine horizons of the Paralic Series yield various fossils, described by many authors (Štur 1875; Petrascheck 1910; Klebelsberg 1912; Sušta 1926, 1928; Patteisky and Folprecht 1928; Niemczyk 1929; Schwarzbach 1937; Schwarzbach and Reichelt 1940; Schindewolf 1942, 1944, 1952; Řehoř and Řehořova 1959, 1972; Matl 1971; Weyer 1974, 1977; Fedorowski 2009a, 2010, 2012a, b). These horizons are essential for stratigraphic correlation. The wide range in the composition of fossil assemblages in these horizons reflects the diversity of paleoenvironmental conditions in the Serpukhovian history of the basin.

The Paralic Series (Text-fig. 4) reaches a maximum thickness of more than 4000 m in western part of the basin where it is subdivided into four informal lithostratigraphic units: the Petřkovice Beds, Hrušov Beds, Jaklovec Beds and Poruba Beds in Czech, and named Pietrzkowice



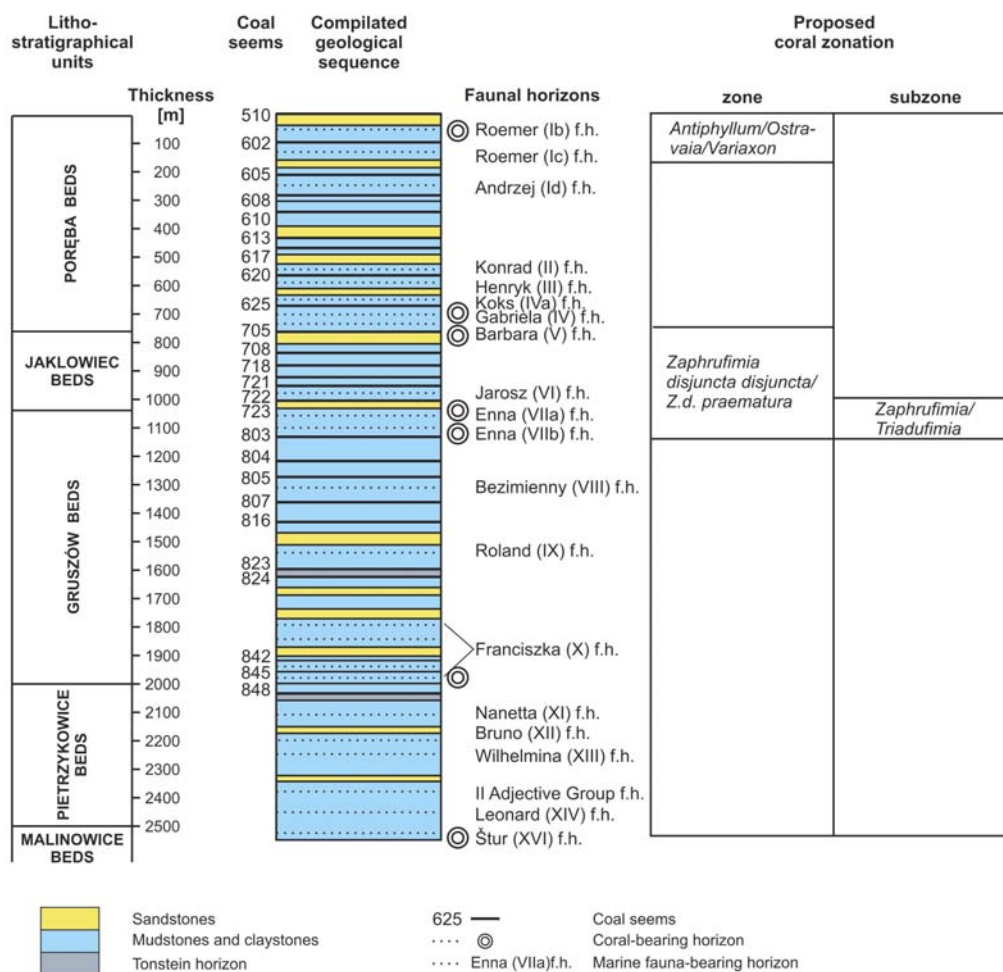
Text-fig. 1. General map of Poland and Czech Republic with the study area roughly indicated by dashed quadrangle



Text-fig. 2. The simplified map of the Polish part of the Upper Silesian Coal Basin. Names of stages used in traditional sense (After Jura 2001, simplified)

ma	CHRONOSTRATIGRAPHY				AMMONOID BIOSTRATIGRAPHY		REGIONAL LITHOSTRATIGRAPHY		THICKNESS [UP TO IN M]				
	Global			Regional									
310	PENNSYLVANIAN	MOSCOWIAN	BOLSOVIAN	WESTFALIAN	D	Anthracoeras	A	CRACOW SANDSTONE SERIES	LIBIAŻ BEDS	400			
											ŁAZISKA BEDS	675	
									DUCKMANTIAN	B			Gastrioceras
315		LANGSETTIAN	A	G ₁	ZAŁĘŻE BEDS	79							
							YEADONIAN	Upper			R ₂	RUDA BEDS	
					MARSDENIAN	Middle			R ₁	SADDLE BEDS			250
320		KINDERSCOUTIAN	Lower	Homoceras									
							ALPORTIAN	Eumorphoceras			E ₂	PARALIC SERIES	
					CHOKIERIAN	E ₁			CULM	MALINOWICE BEDS			800
325		ARNSBERGIAN	PENDLEIAN										
	MISSISSIPPIAN			SERPUKHOVIAN									
					SANDSTONES AND CONGLOMERATES PREDOMINATED OVER THE MUDSTONES AND CLAYSTONES, WITH COAL SEAMS								
		MUDSTONES AND CLAYSTONES PREDOMINATED OVER THE SANDSTONES, WITH COAL SEAMS											
	"Culm" deposits												

RUGOSA FROM THE LOWER CARBONIFEROUS OF UPPER SILESIA



Text-fig. 4. Columnar section of the Paralic Series, Upper Silesian Coal Basin (after Bojkowski 1962; Kotas and Malczyk 1972; Machłajewska 2005; simplified) with the rugose corals biozonation

Beds, Gruszów Beds, Jaklowiec Beds and Poręba Beds in Polish. They represent upper E₁ and entire E₂ zones of Pendleian and Arnsbergian stages. The thickness of individual lithostratigraphical units and the number of marine intercalations decrease towards the eastern side of the basin. Also, the taxonomic content of the fauna present in these intercalations becomes impoverished in the same direction. In the Polish part of the USCB rugose corals were identified in six of the marine horizons:

The Štur horizon occurs near the top of the Malinowickie Beds, i.e., below the base of the 'Paralic Series'. Bojkowski (1972) correlated it with the 'Gołonóg sandstones', first described by Cramer (1910) and investigated afterwards by Doktorowicz-Hrebniński (1935) and Weigner (1937). The Štur horizon contains a rich marine faunal assemblage with numerous spiriferid brachiopods, locally occurring in masses in mudstones and calcareous sandstones. Cramer (1910) and Musiał and

Tabor (1982) mentioned coral occurrences, but did not identify species or genera. Two species, left in open nomenclature were described for the first time in the present paper (see Tables 2, 3).

The Franciszka horizon is situated in the lower part of the Hrušov (Gruszów) Beds. It consists of one to four marine bands, yielding lamellibranchs, brachiopods and snails. The position of the single rugose coral described from that horizon was not specified.

The top of the double Enna horizon (lower and upper band) forms the boundary between the Hrušov (Gruszów) Beds and the Jaklovec (Jaklowiec) Beds. In terms of the fauna this horizon contains one of the richest and most diverse faunas with numerous lamellibranchs, snails, cephalopods, brachiopods, large numbers of crinoids ossicles and less frequent Trilobita and Rugosa. *Cravenoceratoides edalensis* documents placement of these beds in subzone E2b (see Table 3 for corals).

Species/subspecies name here accepted	Name/s applied by earlier author/s	Author, date	Horizon name, number
? <i>Antiphyllum</i> sp. nov. 1	As in column 1	Fedorowski, this paper	Štur, XVI
<i>Zaphrufimia</i> sp. nov. 1	As in column 1	Fedorowski, this paper	Štur, XVI
<i>e.p. Variaxon radians</i>	<i>e.p. Fasciculophyllum repressum</i>	Schindewolf, 1952	Not mentioned
	? <i>Lophophyllidium repressum</i>	Weyer, 1977	Franciszka, X
	As in column 1. Perhaps new species	Fedorowski, 2010	Franciszka, X
<i>Zaphrufimia disjuncta</i> <i>disjuncta</i>	<i>Zaphrentis disjuncta</i>	Carruthers, 1910	Arnsbergian, E ₂ Zone
	<i>Plerophyllum (Ufimia) schwarzbachi schwarzbachi</i>	Schindewolf, 1952	Enna, VII
	<i>Ufimia schwarzbachi</i> (Schindewolf, 1942)	Řehoř and Řehořova, 1972	
	<i>Ufimia schwarzbachi schwarzbachi</i> Schindewolf, 1942	Weyer, 1977	Enna, VII Barbara, V
	Renamed as in column 1	Fedorowski, 2012a and this paper	
<i>Zaphrufimia disjuncta</i> <i>praematura</i>	<i>Plerophyllum (Ufimia) schwarzbachi praematura</i>	Schindewolf, 1952	?Enna, VII. Not mentioned
	<i>Ufimia schwarzbachi praematura</i> Schindewolf, 1952	Weyer, 1977	Uncertain. ?Enna, VII
	Renamed as in column 1	Fedorowski, 2012a and this paper	Enna, VII Barbara, V
<i>Zaphrufimia disjuncta</i> <i>serotina</i>	<i>Plerophyllum (Ufimia) schwarzbachi serotina</i>	Schindewolf, 1952	?Enna, VII. Not mentioned
	<i>Ufimia schwarzbachi serotina</i> Schindewolf, 1952	Weyer, 1977	Barbara, V
	Renamed as in column 1	Fedorowski, 2012a and this paper	Enna, VII, Barbara V, Gabriela, IV
<i>Zaphrentites</i> sp. or <i>Zaphrufimia</i> sp.	As in column 1	Fedorowski 2012a	Enna, VII
<i>Triadufimia coepta</i> sp. nov.	As in column 1	Fedorowski, this paper	
<i>Triadufimia</i> sp. n. 1	As in column 1	Fedorowski, this paper	
<i>Triadufimia</i> sp. n. 2	As in column 1	Fedorowski, this paper	
<i>Antiphyllum inopinatum</i>	As in column 1	Schindewolf, 1952	Roemer, I ^b
	<i>Claviphyllum inopinatum</i> (Schindewolf, 1952)	Weyer, 1974; 1977	
	As in column 1	Fedorowski, 2012b	
<i>Antiphyllum ?inopinatum</i>	<i>Claviphyllum magnificum</i>	Schindewolf, 1952	
	<i>Claviphyllum magnificum</i> Schindewolf, 1952	Weyer, 1977	
	As in column 1	Fedorowski, 2012b	
<i>Antiphyllum (Antiphyllites)</i> <i>pauperculus</i> (Schindewolf, 1952)	<i>Claviphyllum pauperculum</i>	Schindewolf, 1952	
	<i>Claviphyllum pauperculum</i> Schindewolf, 1952	Weyer, 1977	
	As in column 1	Fedorowski, 2012b	
<i>?Antiphyllum (?Antiphyllites)</i> <i>simplex</i> (Schindewolf, 1952)	<i>Fasciculophyllum simplex</i>	Schindewolf, 1952	
	<i>Rotiphyllum simplex</i> (Schindewolf, 1952)	Weyer, 1977	
	As in column 1	Fedorowski, 2012b; perhaps new genus	
<i>?Antiphyllum (?Antiphyllites)</i> sp. 1	As in column 1	Fedorowski, 2012b	

Table 3. Species and subspecies described so far from the Upper Silesian Coal Basin in Poland and Czech Republic

? <i>Antiphyllum</i> (? <i>Antiphyllites</i>) sp. 2	As in column 1	Fedorowski, 2012b	
<i>Silesamplus tripus</i>	<i>Fasciculophyllum tripus</i>	Schindewolf, 1952	
	<i>Rotiphyllum</i> ? <i>tripus</i> Schindewolf, 1952	Weyer, 1977	
	As in column 1	Fedorowski, 2009	
<i>Effigies silesiacus</i> (Schindewolf, 1952)	<i>Pentaphyllum</i> (<i>Tachylasma</i>) <i>silesiacum</i>	Schindewolf, 1952	
	<i>Tachylasma silesiacum</i> (Schindewolf, 1952)	Weyer, 1977	
	As in column 1	Fedorowski, 2012b	
<i>Variaxon repressus</i> (Schindewolf, 1952)	<i>Fasciculophyllum repressum</i>	Schindewolf, 1952	
	<i>Claviphyllum pauperculum</i> Schindewolf	Matl, 1971	
	? <i>Rotiphyllum repressum</i> (Schindewolf, 1952)	Fedorowski, 2001	
	As in column 1	Fedorowski, 2010	
<i>Variaxon radians</i>	<i>Lophophyllidium</i> ? <i>repressum</i> (Schindewolf, 1952)	Weyer, 1977	
	As in column 1	Fedorowski, 2010; Czech specimens	
<i>Ostravaia silesiaca</i>	<i>Claviphyllum pauperculum</i> Schindew. 1952	Řehoř and Řehořová, 1972	
	As in column 1	Fedorowski, 2010	
? <i>Ostravaia</i> sp. 1	As in column 1	Fedorowski, 2010	
? <i>Ostravaia</i> sp. 2	As in column 1	Fedorowski, 2010	
<i>Zaphrentites</i> aff. <i>praecarruthersi</i> (Hudson, 1941)	As in column 1	Weyer 1974	

Table 3. Cont. Species and subspecies described so far from the Upper Silesian Coal Basin in Poland and Czech Republic.

The Barbara horizon ended sedimentation of the Jaklovec (Jaklowiec) Beds. It consists of one to five marine bands comprising rich lamellibranchs, snails and brachiopods, and less frequent scaphopods, bryozoans and corals (see Table 3 for corals).

The Gabriela horizon occurs in the lower part of the Poruba (Poręba) Beds. Its paleontological character differs significantly from that of other the horizons described above. It is only up to 10 m thick and yields an impoverished fauna of lamellibranchs, sparse snails, brachiopods, and locally, crinoid ossicles. Corals are known from a single specimen identified here as *Zaphrufimia disjuncta serotina*. This is the first identification of a rugose coral from this horizon.

The Gaebler horizon developed in the upper part of the Poruba (Poręba) Beds. It consists of several bands of marine intercalations from which Roemer (I^b) is the most important as it yields the index fossils *Cravenocera toides nitidus* (Phillips) and *Eumorphoceras bisulcatum leitrimense* Yates as well as the richest and taxonomically most diverse fauna, including rugose corals. Pectinid lamellibranchs, snails, brachiopods and cephalopods predominate. Crinoids, trilobites and corals are less frequent, but are more differentiated here than in any of the remaining marine horizons (see Table 3 for corals).

SYSTEMATIC PALAEONTOLOGY

Subclass Rugosa Milne Edwards and Haime, 1855

Order Stauriida Verrill, 1865

Suborder Stereolasmatina HILL, 1981

Family Stereophrentidae Fomichev, 1953

Subfamily Zaphrufimiinae subfam. nov.

DIAGNOSIS: Stereophrentidae with ufimoid arrangement of major septa in mature growth stage; minor septa either equally underdeveloped or contratingent if next to counter septum; tabularium generally uniform, biform-like tabulae may appear in some septal loculi; microstructure of septa finely trabecular.

REMARKS: Fedorowski (2012a) has previously suggested the possibility of a separate subfamily status of his new genus *Zaphrufimia*. This supposition was based on the zaphrentoid neanic growth stage and the ufimoid arrangement of major septa in the mature growth stage of this genus. While the latter character does not appear in the other Stereophrentidae Fomichev, 1953, it is homeomorphic to the Permian Plerophyllidae Koker, 1924. A new subfamily was not formally introduced at

that time for the single genus. The new genus *Triadufimia*, however, has allowed formal introduction of the new Subfamily Zaphrufimiinae. The latter genus closely resembles *Zaphrufimia* in all the main ontogenetic, morphological and microstructural details, except for the development of the minor septa contratingent to the counter septum. This clearly qualitative character suggests a separate generic status of its bearers as discussed below in the remarks on *Triadufimia*. The two genera, whereas similar to each other and probably were derived from the same ancestral taxon, are different from the other members of the family, which allows the distinction at the subfamily level. A recent study on the Viséan and Serpukhovian rugose corals from Spain documenting an occurrence of both of these genera in this area (Fedorowski, in preparation) supports this position.

GENERA INCLUDED: *Zaphrufimia* Fedorowski, 2012; *Triadufimia* gen. nov.

Genus *Zaphrufimia* Fedorowski, 2012

EMENDED DIAGNOSIS: Zaphrufimiinae with cardinal septum on concave corallite side and with ufimioid differentiation of major septa in maturity; minor septa equally underdeveloped; bifurc-like tabulae may appear in some septal loculi late in ontogeny.

REMARKS: The diagnosis of *Zaphrufimia* was emended in order to distinguish this genus from the new genus *Triadufimia*. Both genera display similar arrangements of major septa, but only the new one possesses elongated and contratingent minor septa adjacent to the counter septum. A detailed article on *Zaphrufimia* published recently by Fedorowski (2012a), allows us to reduce descriptions of individual subspecies and to restrict them to the characters weakly exposed or absent from the specimens described earlier.

Zaphrufimia disjuncta (Carruthers, 1910)

DIAGNOSIS: *Zaphrufimia* with n:d values 18:5.5 mm to 28:11.5 mm when measured immediately above calice floor; amplexoid counter septum slightly shortened; most succeeding major septa shorten regularly within individual quadrants; stereocolumn long-lasting; minor septa equally developed, recognizable late in ontogeny (after Fedorowski 2012a, supplemented).

REMARKS: This species and its subspecies were discussed in detail by Fedorowski (2012a) who restudied

the lectotype of *Zaphrentis disjuncta* Carruthers, 1910 chosen by Hudson (1941, p. 293). He also re-studied and re-illustrated the holotype and other type material of *Ufimia schwarzbachi* Schindewolf, 1942, described several specimens derived from the Czech side of the USCB, and proposed the synonymy of the two taxa mentioned. This position is followed here as in the diagnosis, supplemented by the indication of equal development of all minor septa.

Zaphrufimia disjuncta disjuncta (Carruthers, 1910) (Plate 1; Text-fig. 5)

1910. *Zaphrentis disjuncta* Carruthers, p. 534, pl. 37, fig. 7a–e.
2012a. *Zaphrufimia disjuncta disjuncta* (Carruthers, 1910);
Fedorowski, p. 127, pls 1, 2, pl. 3, figs 1–10, text-figs
2–4, text-fig. 5A–M, (?) Q–W (*cum synonymicum*).

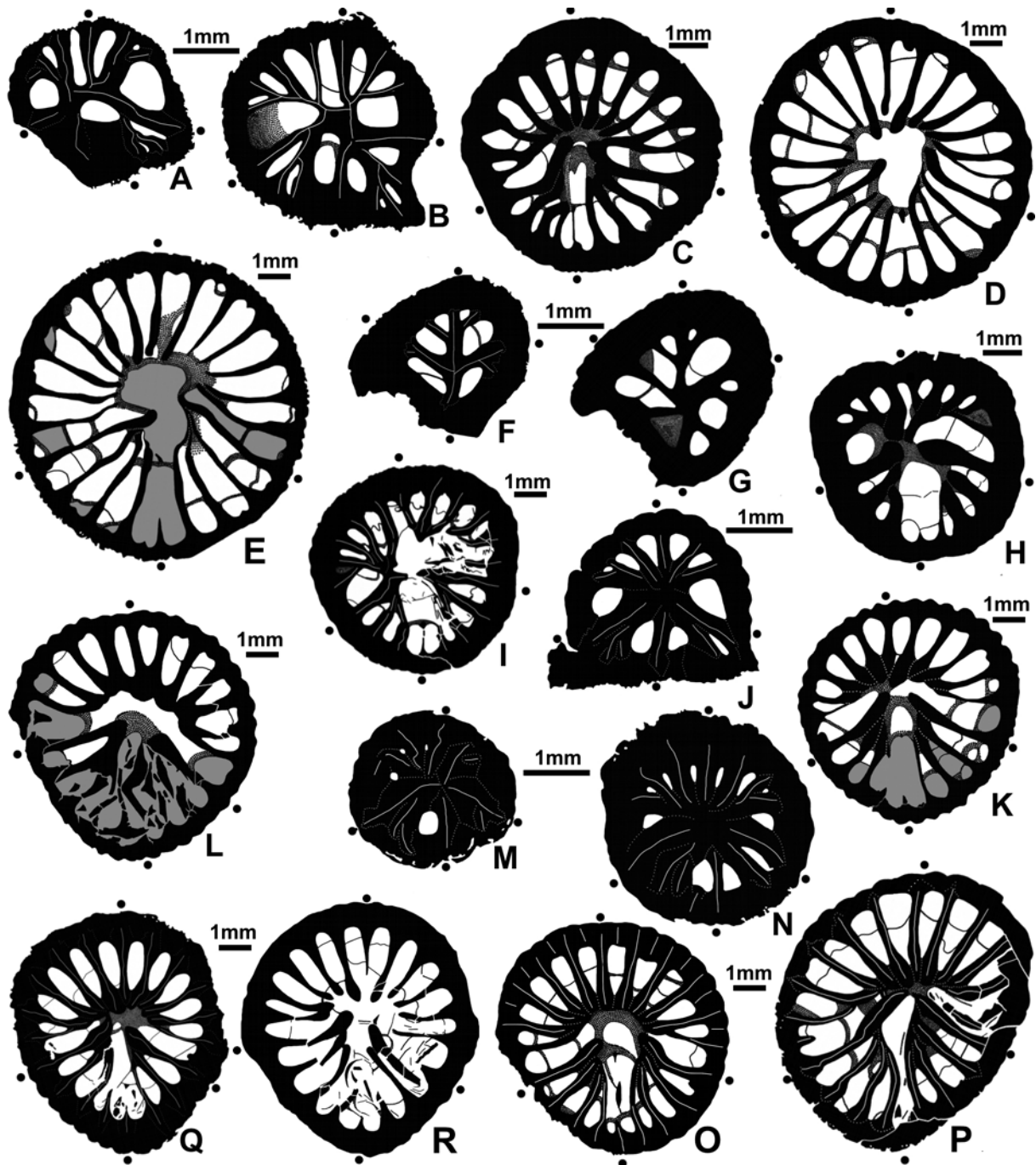
MATERIAL: Thirty one specimens; nine were included with some restrictions as they were either slightly crushed or preserved in the immature growth stages. The neanic growth stage is preserved in most specimens, but the brephic growth stage is missing from all. The mature skeletons in most specimens are slightly crushed by compression; the damage is more advanced where the major septa are thin. Almost all calices are flattened. The microstructure of septa is recrystallized to various extents; strongly in most specimens. 60 thin sections, 52 peels and some polished surfaces were available for the study.

DIAGNOSIS: *Zaphrufimia disjuncta* with n:d values 20:7.2 – 22:8.0 (?10.0) mm near calice floor; zaphrufimioid morphology reached at n:d values 18–20:3.5–5.6 mm (after Fedorowski 2012a, p. 127).

DESCRIPTION OF INTRASPECIFIC VARIATION: The detailed description of this subspecies (Fedorowski 2012a) allows us to discuss the intraspecific variation rather than giving a detailed description of individual growth stages and their characteristics. The best preserved and most complete specimen in the collection (Pl. 1, Fig. 3a–g; Text-fig. 5A–E) closely resembles the lectotype in its shape, its n:d values and the morphology of the early mature and mature growth stages. The smoother external surface in the specimen studied here (Pl. 1, Fig. 3a) may be a result of corrosion. The minor septa, slightly better developed in the lectotype, are the main difference between these two specimens. The neanic growth stage of the corallite described here (Pl. 1, Fig. 3c, d; Text-fig. 5A, B) more closely resembles the holotype of '*Ufimia*'

schwarzbachi schwarzbachi Schindewolf, 1952 rather than the lectotype of '*Zaphrentis*' *disjuncta*. The transverse sections made near or just above the calice floor of some specimens (Pl. 1, Figs 1f, 2) show an inter-

mediate morphology between the holotype of '*U.*' *schwarzbachi schwarzbachi* and the lectotype of '*Zaphrentis*' *disjuncta*, supporting the proposed synonymy.



Text-fig. 5. *Zaphrufimia disjuncta disjuncta* (Carruthers, 1910). A-E – specimen SUT-S-25; A, B – neanic growth stage, C – late neanic/early mature growth stage, D, E – mature growth stage (B, C – polished surfaces). F-I – specimen SUT-LC-15; F, G – neanic growth stage, H – late neanic/early mature growth stage, I – Early mature growth stage (G, H – peels). J-L – specimen SUT-LC-27; J – neanic growth stage, K, L – successive cuts of early mature growth stage (K – peel). M-P – specimen SUT-S-22; M, N – neanic growth stage, O, P – successive cuts of early mature growth stage (O – peel). Q, R – specimen SUT-K-7. Successive cuts of early mature and mature growth stages. Note. Transverse thin sections, except when stated. Protosepta and alar septa marked by dots. Cardinal protoseptum at the bottom of figures. Scale bars between two pictures correspond to both; bar at upper right of a picture corresponds to that picture only. For occurrences see descriptions of species

Several specimens resemble *Z. disjuncta serotina* as they possess a well accentuated alar fossulae, and thicker, more rhopaloid major septa in the counter quadrants which remain longer in the lateral contiguity than those in the cardinal quadrants (Pl. 1, Fig. 4; Text-figs 5K, L, O–Q). However, these specimens reach their zaphrufimoid morphology with comparatively small n:d values and this is the main criterion established by Schindewolf (1952) and followed by Fedorowski (2012a) for distinguishing the subspecies of *Z. disjuncta*.

In contrast to the afore discussed corallites, there are specimens with a slightly smaller n:d values than the one diagnosed for *Z. disjuncta disjuncta*, e.g., 19:6.6 mm (Text-fig. 5H, I). The illustrated specimen displays the arrangement of the major septa atypical for the neanic growth stage (Text-fig. 5F, G). Moreover, it reached the mature morphology later than *Z. d. praematura* but slightly earlier than most specimens of *Z. disjuncta*, and thus may be treated as intermediate between these two subspecies.

The arrangements of major septa in the premature parts of several specimens differ considerably from one another and from those accepted as typical for the Rugosa. That variability is observed in all subspecies of *Z. disjuncta* (Pl. 1, Figs 1a–e, 3c,d; Pl. 2, Figs 1b–d, 3a; Pl. 3, Figs 1a, b, 2a, 3a–c, 4a–c; Text-figs 5A, B, F, G, J, M, N; 6A; 7A, B, D, F, G) and is discussed separately in the concluding part of the species description.

DISCUSSION: Most specimens of the collection studied fit with the n:d values established by Fedorowski (2012a, text-fig. 2) for *Z. d. disjuncta*, but some have values which are intermediate between *Z. d. disjuncta* and *Z. d. praematura* (Schindewolf, 1952). They were included here in *Z. d. disjuncta*, but their occurrence suggests similarity between these subspecies more clearly than was established on the basis of a smaller number of specimens. The intermediate specimens leading towards both *Z. d. serotina* and *Z. d. praematura* may suggest the extreme intraspecific variability of *Z. disjuncta*, informally accepted by Weyer (1977), who did not use the subspecies' names. This option was rejected by Fedorowski both in his earlier study (2012a) and in this paper, but it should not be excluded from consideration.

OCCURRENCE: Scotland: Orchard Limestone, Serpukhovian (Arnsbergian, E2a). Czech Republic, the Ostrava-Karvina part of the USCB, Enna horizon, Serpukhovian (Arnsbergian, E2b1). The Polish part of the USCB, Mines: Knurów, Ludwik-Concordia, Sośnica. Boreholes: Czeladź 19, Grodziec 342, Piasek IG 1 (See Tables 1–3 for details).

Zaphrufimia disjuncta serotina (Schindewolf, 1952)
(Plate 2; Text-fig. 6)

1952. *Plerophyllum (Ufimia) schwarzbachii serotinum* Schindewolf, p. 216 (key to subspecies), text-fig. 23; pl. 1, fig. 10; pl. 2, fig. 8a–c.

2012a *Zaphrufimia disjuncta serotina* (Schindewolf 1952); Fedorowski, p. 132, pl. 3, figs 11–21, pl. 4, pl. 5, figs 1–32 (?); text-figs 2, 5N–P (?), 6, 7A–H, M–Z (?) (cum synonymicum)

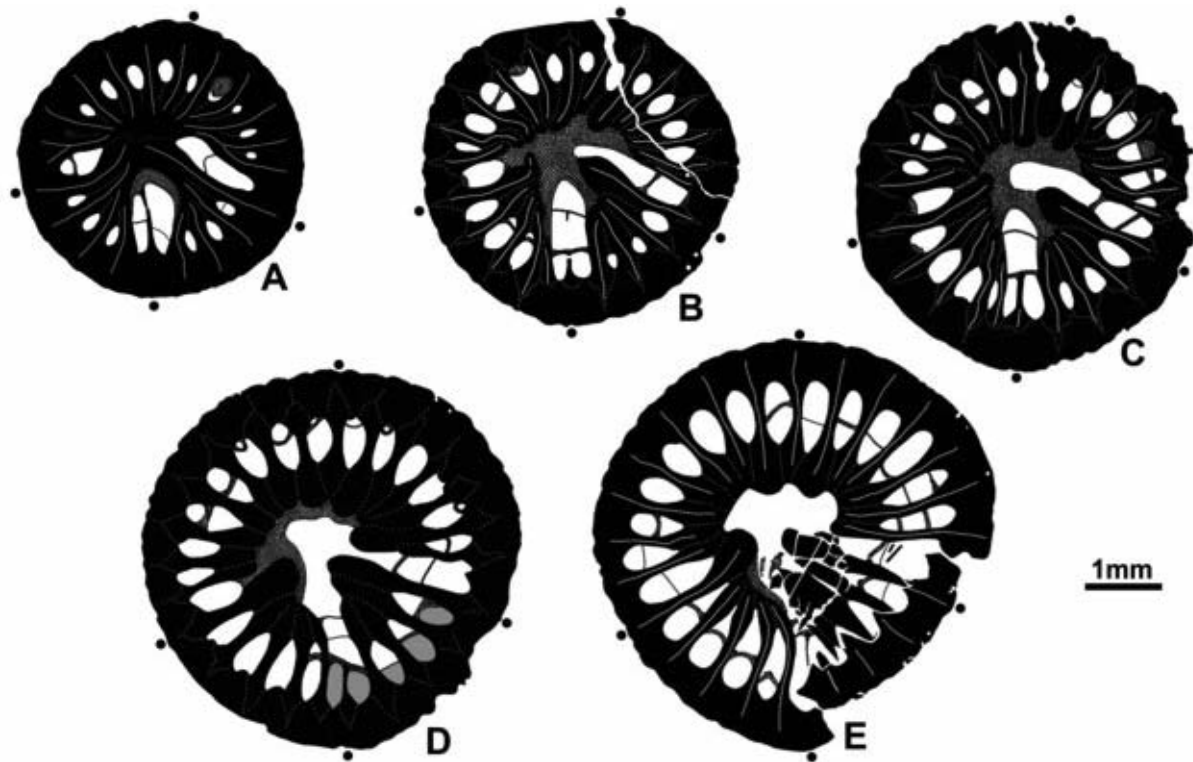
MATERIAL: Seven specimens with various parts of the neanic growth stage preserved and all calices crushed to some extent. The macro-morphology of the mature parts of growth is well preserved, but the microstructure is diagenetically altered. 23 thin sections, 17 peels and some polished surfaces were available for the study.

DIAGNOSIS: *Zaphrufimia disjuncta* with n:d values 24:9.0 mm – 28:11.2 mm near calice floor; zaphrufimoid morphology reached with n:d value 22–23:7.5–9.0 mm (after Fedorowski 2012a, p. 134).

DESCRIPTION OF INTRASPECIFIC VARIATION: Most specimens in the collection studied here demonstrate the arrangement and morphology of major septa comparable to the late neanic/early mature growth stages of the specimens included in this subspecies by Fedorowski (2012a). The major septa in counter quadrants of some specimens are either non-rhopaloid or slightly rhopaloid and arranged in a zaphrentoid manner (Pl. 2, Fig. 1e–g). In other specimens the rhopaloid inner margins of major septa remain in the lateral contiguity for a long period of growth (Pl. 2, Fig. 2b; Text-fig. 6D, E). The n:d values at that growth stage in both groups correspond to those established for the subspecies by Fedorowski (2012a) or are slightly smaller (21–22: 6.5–7.5 mm).

The arrangement of major septa in the early neanic growth stage varies slightly between specimens and is irregular in some (Pl. 2, Fig. 1b,c). This changed in the late neanic growth stage when it becomes regular and similar from one specimen to another (Pl. 2, Fig. 1d–f; Text-fig. 6A), closely resembling the lectotype and most specimens of the subspecies described so far. The same is true for: a) shallow septal furrows and wide, almost flat interseptal ridges with very shallow depressions of 'hyposepta' of Weyer (1980) (Pl. 2, Fig. 1a) and b) major septa easily recognizable in the thickness of the external wall beginning in early maturity (Pl. 2, Fig. 2a, b).

One large specimen, with n:d value in the lower part of the calice 28:10.0 × 12.6 mm (Pl. 2, Fig. 3d), resem-



Text-fig. 6. *Zaphrufimia disjuncta serotina* (Schindewolf, 1952). Specimen SUT-LC-46; A – late neanic growth stage, B-D – successive cuts of early mature growth stage (D – polished surface), E – mature, but not advanced growth stage. Scale bar corresponds to all figures. See Note following description of Text-fig. 1 for further explanations

bles in its character the largest specimens of the subspecies. However, it differs from all the other *Z. d. serotina* specimens in that its major septa are thin, long, slightly rhopaloid, almost radially arranged beneath the calice floor (Pl. 2, Fig. 3b, c) and long in the lower part of the calice; furthermore, there is a long-lasting axial stereocolumn, the alar septa almost equal in length to the remaining major septa, and a comparatively long counter septum up to and including the calice floor (Pl. 2, Fig. 3d). Only its zaphrentoid neanic growth stage (Pl. 2, Fig. 3a) is comparable to the other specimens of the subspecies. Therefore, it may represent a new species.

REMARKS: The distinction between *Z. d. serotina* and the nominative subspecies has already been demonstrated by Fedorowski (2012a, text-fig. 2) as small. The zaphrufimoid arrangement of septa is achieved by the largest specimens of the nominative subspecies the n:d values of which overlaps the smallest n:d values of *Z. d. serotina*. When all the n:d values of the specimens of both subspecies described here are taken into account the similarity is increased. The n:d values of most specimens studied in this paper fall into the overlapping part of Fedorowski's (2012) diagram. Such a distribution may suggest a single maximum summit of a Gauss'

curve and a synonymy of both subspecies. Unfortunately, the small number of specimens studied makes a truthful statistical test impossible.

OCCURRENCE: Czech Republic, the Ostrava-Karvina part of the USCB, the Enna horizon, Serpukhovian (Arnsbergian, E2b1). The Polish part of the USCB, mines: Knurów, Ludwik-Concordia, Sośnica. Borehole: Grodziec 343 (see Tables 1–3 for details).

Zaphrufimia disjuncta praematura (Schindewolf, 1952)
(Plate 3; Text-fig. 7)

partim 1943. *Plerophyllum* (*Ufimia*) *schwarzbachi* Schindewolf, p. 666, text-fig. 22a, b.

1952. *Plerophyllum* (*Ufimia*) *schwarzbachi praematurum* Schindewolf, p. 216, text-figs 21, 22.

2012a. *Zaphrufimia disjuncta praematura* (Schindewolf, 1952); Fedorowski, p. 138, pl. 6, figs 1–17, text-figs 2, 8.

MATERIAL: Twenty two specimens, eight of which were included in this subspecies conditionally – as ei-

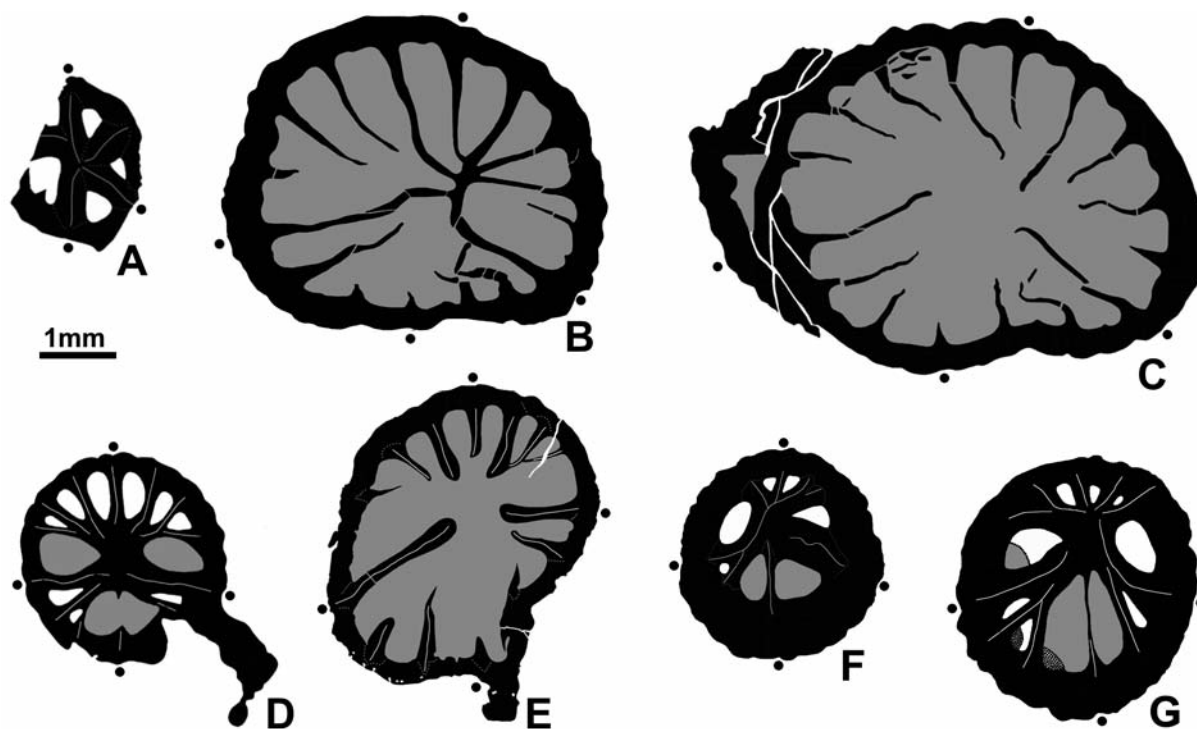
ther being immature corallites or with skeletons damaged too much to allow a confident identification. Most corallites possess almost complete neanic growth stages, whereas their calices are generally flattened. 31 thin sections 28 peels and some polished surfaces were available for study.

DIAGNOSIS: *Zaphrufimia disjuncta* with n:d values 16-17:5.5 mm near calice floor; zaphrufimioid morphology reached with n:d values 14-15:4.0-4.5 mm (after Fedorowski 2012a, p. 138).

DESCRIPTION OF INTRASPECIFIC VARIATION: Specimens included here in *Z. d. praematura* widen the intraspecific variation of this subspecies in the morphology and to a lesser extent in the n:d value. The morphology in the lower parts of the calices of some specimens closely resembles that of the nominative subspecies (Pl. 3, Fig. 1d, e vs Pl. 1, Fig. 2). The specimen illustrated passed the thick septal neanic growth stage (Pl. 3, Fig. 1a, b; Text-fig. 7A) followed by the thin septal late neanic/early mature growth stage developed near or just above the calice floor (Pl. 3, Fig. 1c; Text-fig. 7B). The morphology of that growth stage differs considerably from all the specimens investigated so far in adequate detail. Most of its major septa, including the

alar and counter-lateral septa remain connected axially and only the alar septa can be accepted as dominant. Most specimens (e.g. Pl. 3, Figs 3d, e) resemble the thick septal specimens included in this subspecies by Fedorowski (2012a). The main difference between these two groups is the stronger development of the alar septa in the specimens investigated here. One corallite reached its zaphrufimioid morphology early in the ontogeny as indicated by its shape, external and internal morphology (Pl. 3, Fig. 2b, d). Nevertheless, it passed all the growth stages quickly in a manner typical for the genus, species and subspecies (Pl. 3, Fig. 2a,b; Text-fig. 7D) and reached the morphology comparable to the holotype, except for the shorter major septa in cardinal and counter quadrants and a smaller diameter (Pl. 3, Fig. 2c; Text-fig. 7E). Some specimens are strongly deformed in the early neanic arrangement of major septa (Pl. 3, Fig. 4a, b). Besides, the specimen illustrated possesses a cardinal septum intersecting the cardinal fossula above the calice floor (Pl. 3, Fig. 4c; Text-fig. 7F, G, shadowed).

The microstructure of septa is almost completely destroyed by diagenesis. The remnants in the broken middle lines (Pl. 3, Fig. 4d) may correspond to the diagenetically altered trabeculae, but this cannot be asserted



Text-fig. 7. *Zaphrufimia disjuncta praematura* (Schindewolf, 1952). A-C – specimen SUT-LC-32; A – early neanic growth stage, B – late neanic/early mature growth stage (peel), C – mature growth stage. D, E – specimen SUT-S-40; D – late neanic/early mature growth stage, E – mature growth stage (polished surfaces). F, G – specimen SUT-LC-31; F – neanic growth stage, G – late neanic/early mature growth stage (peel). Scale bar between A and D corresponds to all figures.

See Note following description of Text-fig. 1 for further explanations

DISCUSSION: The increase in morphological variation did not change the general concept of the subspecies discussed, although the specimen described at the beginning of the preceding subchapter may be accepted as indicative for the closer relationship with the nominative subspecies than suggested by Fedorowski (2012a). On the other hand, one specimen (Pl. 3, Fig. 2a-d; Text-fig. 7D, E) may suggest an occurrence of a group of specimens with n:d values smaller from those established earlier in *Z. d. praematura*. Should they be distinguished in another subspecies or do they only expand the concept of the species remains an open question.

OCCURRENCE: Czech Republic, the Ostrava-Karvina part of the USCB, Enna horizon, Serpukhovian (Arnsbergian, E2b1). The Polish part of the USCB, Mines: Knurów, Ludwik-Concordia, Sośnica. Boreholes: Brzeszcze IG 32, Grodziec 342, Grodziec 344, Piasek IG 1, Welnowiec IG 1 (see Tables 1–3 for details).

Zaphrufimia sp. nov. 1
(Text-fig. 8)

MATERIAL: Two incomplete specimens, Nos. 461/152A, B embedded in a rock next to one another. All cuts are oblique; thus, the larger diameters resulting from the obliqueness of sections were omitted. Both specimens were diagenetically altered; one strongly as documented by its twisted and recrystallized major septa. One thin section, three peels and some polished surfaces were available for study.

DESCRIPTION: The specimens discussed here differ in several details. The better preserved specimen 461/152A is described more precisely. In the earliest growth stage investigated (Text-fig. 8A), with the n:d value of 20:4.2 mm, each counter quadrant of septa includes only one more major septa than the corresponding cardinal quadrant. All the major septa are thickened so as to meet each other laterally. The cardinal septum forms the only exception, being strongly shortened and thin, but both this septum and the cardinal fossula were sectioned above the calice floor. Thus, the true length of the cardinal septum, i.e. its extension axially along the calice floor, remains unknown. The strongly thickened counter septum is shorter than the counter-lateral major septa. The alar and the counter-lateral major septa are the longest in their quadrants of septa, whereas the remaining major septa shorten regularly within each quadrant in the sequence of their insertion. All the interseptal loculi are very narrow, some infilled with sclerenchyme.

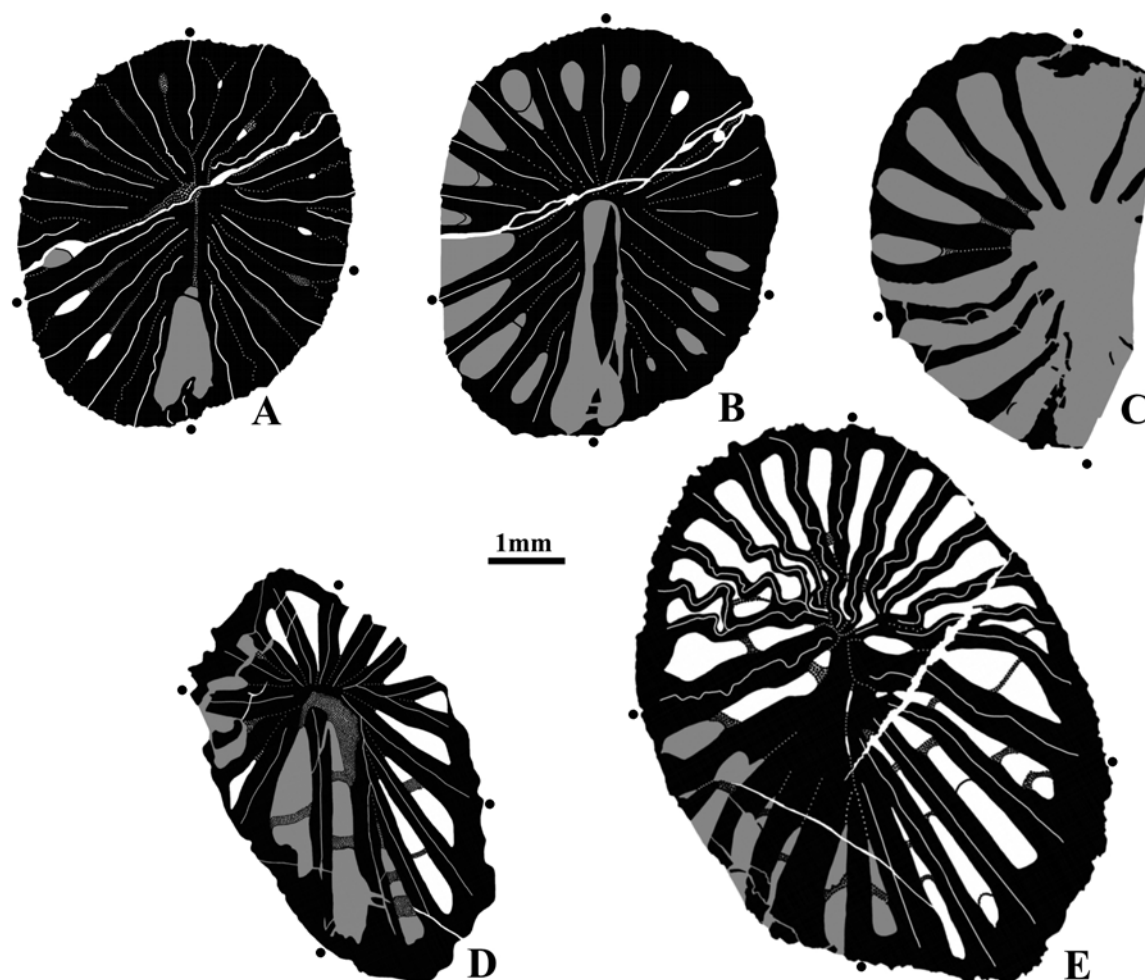
The newly inserted major septa are laterally contiguous with their predecessors. The cardinal fossula widens laterally, extending approximately 2/3 of the corallite radius. The minor septa are absent from both the corallite lumen and its external wall.

The arrangement, length and number of major septa in the corallite's polished section, (Text-fig. 8B) exposed approximately 1.2 mm above the previously described thin section, remain similar. Only the diameter increased slightly (n:d value 20:4.5 mm), the cardinal fossula extends to the corallite axis, and the peripheral parts of the major septa thinned, widening the interseptal loculi. However, most of these widened loculi were sectioned above the calice floor (Text-fig. 8B, shadowed). The fairly rapid thinning of the major septa takes place approximately 1.5 mm above the polished section described, i.e. in the peel taken from the lower part of the calice (Text-fig. 8C). The minor septa are not developed yet. The higher part of the calice is missing.

The second specimen, No. 461/152B, lacks the calice. Its ontogenetically most advanced growth stage preserved is larger and possesses more numerous major septa than the previously described corallite (n:d value 24:5.5 mm), but the arrangement of its septa is similar. This is especially well shown in the cardinal quadrants where the major septa are thick and the alar septa with their length and thickness dominate (Text-fig. 8E). In the ontogenetically earliest growth stage of this specimen studied (Text-fig. 8D), the arrangement of the slightly thickened major septa is rotiphylloid, the cardinal septum intersects the cardinal fossula, the counter septum equals the counter-lateral major septa in length, and the alar major septa do not dominate. The infilling of most septal loculi in this section with a strange fabric may have resulted from the partial damage of the corallite and is not taken into account. The main differences between the corallites described here may suggest either wide intraspecific variability or different taxonomic positions.

DISCUSSION: The n:d value of the smaller specimen resembles that in small corallites of *Zaphrufimia disjuncta*, but its major septa differ in the clearly bilateral symmetry, with non-rhopaloid alar septa and lacking alar pseudofossulae. The zaphrufimioid morphology is easily recognizable only above the calice floor (Text-fig. 8C).

The bilateral arrangement of the major septa in the ontogenetically most advanced growth stage of the second specimen studied is similar to the first one. All its major septa remain axially united, suggesting an immature growth stage. Its zaphrufimioid arrangement of the major septa is weakly accentuated. The ontogenetically late achievement of this morphology and the clearly bilateral arrangement of the non-rhopaloid ma-



Text-fig. 8. *Zaphrufimia* sp. nov. 1. A-C – specimen 461/152a; A, B – immature growth stage, C – lower part of calice (B, C – peels). D, E – specimen 461/152b; D – neanic growth stage (polished surface), E – late neanic/early mature growth stage (peel). Scale bar in the middle corresponds to all figures. See *Note* following description of Text-fig. 1 for further explanations

major septa are the features distinguishing the specimens described above from *Z. disjuncta*.

OCCURRENCE: Polish part of the USCB; Łąka IG-1 borehole. (See Tables 2, 3 for details).

Triadufimia gen. nov.

TYPE SPECIES: *Triadufimia coepta* sp. nov.

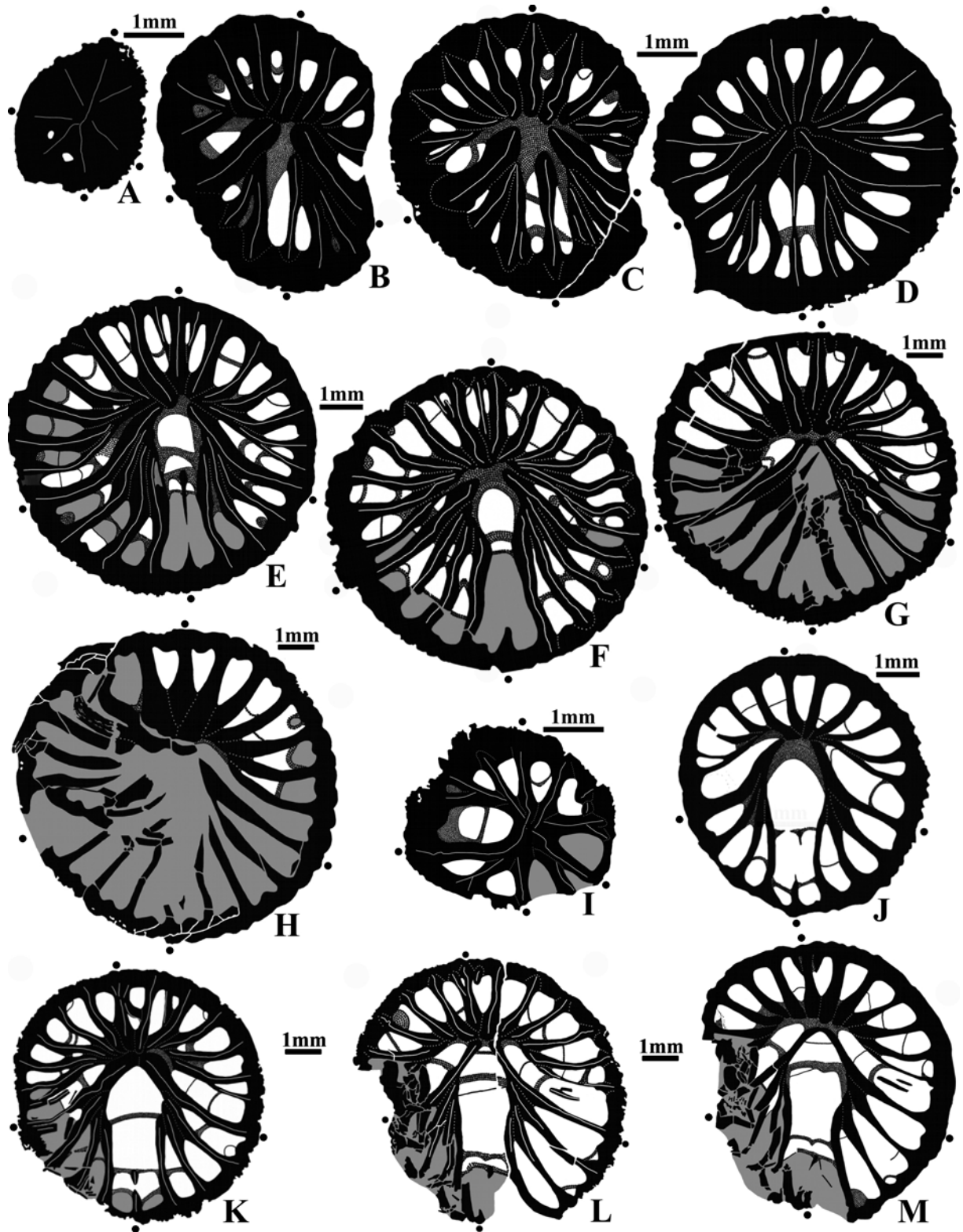
DERIVATION OF NAME: Composed of *lat.* “triada” – triad and the generic name “*Ufimia*”. Named for the arrangement of the major septa similar to *Ufimia* Stuckenberg, 1895 and development of a triad formed by the counter septum and the counter-lateral minor septa.

SPECIES ASSIGNED: *Triadufimia coepta* sp. nov., *Triadufimia* sp. nov. 1, *Triadufimia* sp. nov. 2.

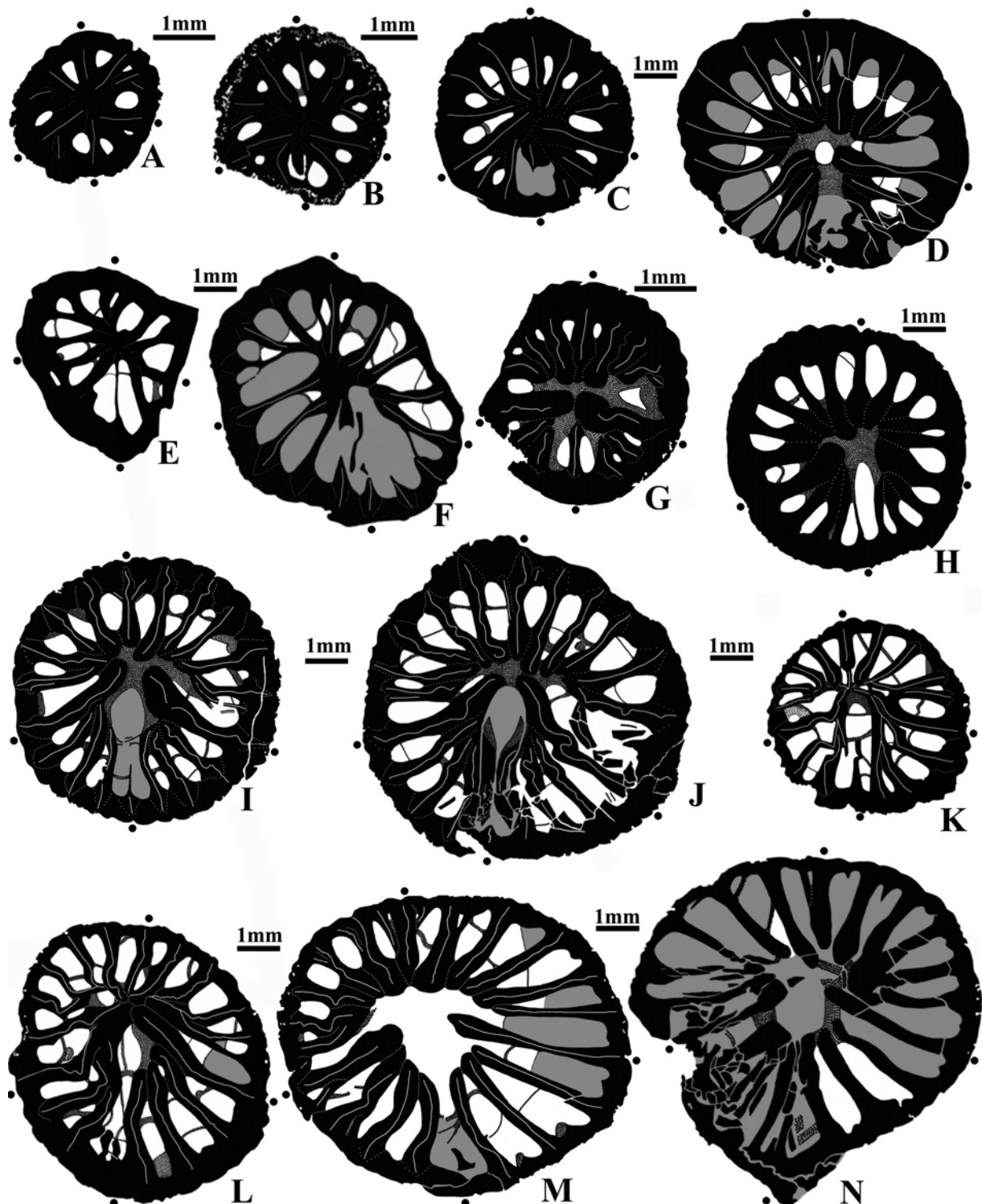
DIAGNOSIS: *Zaphrufimiinae* with triad.

DISCUSSION: The appearance of a triad, an undoubtedly qualitative character, allows an easy discrimination of *Triadufimia* from *Zaphrufimia*. However, this new character appears late in ontogeny and is weakly accentuated in some specimens. The differences in the morphology of corallites included here in *T. coepta* sp. nov. (see description below) may extend the intraspecific variation, but they were grouped under the same species name because only nine specimens are present in the collection.

The position of *Triadufimia* within the family Stereophrentidae Fomichev, 1953 may be considered questionable. However, it is placed here because of the phylogenetic relationship of *Triadufimia* to *Zaphrentites* and *Zaphrufimia* which is much more probable than to any genus of the Family Plerophyllidae Koker, 1924 or Tachylasmatidae Grabau, 1928 – both yielding corals



Text-fig. 9. *Triadufimia coepta* sp. nov. A-H – holotype, specimen SUT-K-51; A – early neanic growth stage, B-D – neanic growth stage, E-H – mature growth stage (A, B, E – polished surfaces). I-M – paratype, specimen SUT-LC-53; I – neanic growth stage, J – late neanic/early mature growth stage, K-M – mature growth stage (J, M – peels). See *Note* following description of Text-fig. 1 for further explanations



Text-fig. 10. *Triadufimia coepta* sp. nov., paratypes. A-D – specimen SUT-K-50; A-C – early to late neanic growth stage, D – mature growth stage (polished surface). E-F – specimen SUT-S-55; E – neanic growth stage, F – late neanic/ early mature growth stage (polished surfaces). G-J – specimen SUT-K-49; early to late mature growth stage (H – peel). K-N – specimen SUT-S-54; K – late neanic growth stage, L – late neanic/early mature growth stage, M, N – mature growth stage.

See Note following description of Text-fig. 1 for further explanations

with a similar arrangement of major septa at maturity. This predicted relationship allows a reference to a comprehensive discussion on *Zaphrufimia* by Fedorowski (2012a), who eliminated the latter genus from the Family Plerophyllidae. The early zaphrentoid ontogeny eliminates *Triadufimia* and all bearers of this character from the Family Tachylasmatidae (see Fedorowski 2009b for data).

The simultaneous existence of *Zaphrufimia* and *Triadufimia* in the USCB may suggest its direct derivation from local representatives of *Zaphrufimia*. Such a suggestion is further supported by different levels of development of the triad in individual specimens from the USCB included here in *Triadufimia*. However, typical *Triadufimia* occurs in the Lower Viséan (Pe γ, δ) strata of northern Spain (Fedorowski, in preparation). The triad in the Spanish species is well developed and appears in the early mature growth stage. These two remote occurrences established so far allow *Triadufimia* to be accepted as an independent genus. The land-sea relationships in the Viséan evidently allowed an easy spreading of *Triadufimia* within the Western European Province of Fedorowski (1981). The two genera, *Zaphrufimia* and *Zaphrentes*, can be pointed out as ancestral for *Triadufimia* – with the former being more probable as it already possessed ufimoid features.

Triadufimia coepta sp. nov.

(Plates 4, 5; Text-figs 9, 10)

HOLOTYPE: SUT-K-51

TYPE LOCALITY: Knurów Mine

TYPE HORIZON: Enna horizon, Serpukhovian (Arnsbergian) ammonoid zone E_{2b}, lowermost

ETYMOLOGY: *Lat. coeptus, a, um* – the outset – after first recognition of the triad in the *Ufimia*-like, early Carboniferous rugose corals.

MATERIAL: Seven specimens with early (but not the earliest) growth stages preserved. The calices are preserved but crushed by compression in most corallites. The skeletons of the neanic and mature growth stages are generally well preserved, although the major septa in cardinal quadrants were crushed in the advanced mature growth stages of some. The microstructure of septa is almost completely re-crystallized in most specimens but recognizable in fragments of some.

DIAGNOSIS: *Triadufimia* with n:d value 22-24:8.0-9.0 mm near calice floor; triad short-lasting, developed close to calice floor, may persist slightly above it.

DESCRIPTION OF THE HOLOTYPE: The corallite is widely horn-shaped (Pl. 4, Fig. 1k); growth lines grouped in bands; septal grooves shallow and wide; flat inter-septal ridges with shallow grooves of “hyposepta” of Weyer (1980) (Pl. 4, Fig. 1l). The earliest neanic growth stage preserved (n:d value 7:2.0 × 2.5 mm; Text-fig. 9A) is almost completely infilled by sclerenchyme. The primary major septa are connected in an almost classic way. Only the cardinal septum prolonged into the axial septum under some angle. In the further corallite growth (Pl. 4, Fig. 1a, b; Text-fig. 9B–D) the thickened major septa are rotiphylloidally arranged and connected by a strong sclerenchymal cover in the corallite axis. The middle dark lines (the primary septa) approach each other adaxially but are rarely united. The direct connection of these primary septa is best developed in the counter quadrants. The rhopaloid cardinal septum intersects the deep cardinal fossula. The shape of that fossula depends on both the strength of the axial column and the insertion of new major septa. Thus, it may narrow axially (Pl. 4, Fig. 1a; Text-fig. 9B), be parallel-walled (Pl. 4, Fig. 1b; Text-fig. 9C), triangular (Pl. 4, Fig. 1d), and key-hole (Text-fig. 9D). The counter septum is commonly undistinguishable in its length and thickness from the counter-lateral septa. The alar septa, clearly dominating at this growth stage, are the thickest and longest of all major septa. The minor septa, including those adjacent to the counter septum, remain undistinguishable in the thickness of the corallite wall and absent from its lumen.

The arrangement of major septa in the early to late mature growth stages (Pl. 4, Fig. 1c–g; Text-fig. 9E–H) resembles that in the late neanic growth stage. The major septa of counter quadrants, shorter and more numerous than these of cardinal quadrants, remain united adaxially by sclerenchymal cover and form an arch open towards the cardinal quadrants of major septa. This arch remains present well above the calice floor (Text-fig. 9H). The alar septa remain dominating in length. A slight, but obvious shortening of the counter septum and an advanced shortening of the cardinal septum are the most important changes. The cardinal fossula remains deep, extending beyond the corallite axis.

The minor septa appear in the corallite lumen at the beginning of the mature growth stage (Pl. 4, Fig. 1c). Most of them are hardly distinguishable, but those forming the triad and one contratingent minor septum attached to the left counter-lateral septum are long, reaching more than two-thirds of the counter septum

in length (Pl. 4, Fig. 1c, d; Text-fig. 9E). This morphology lasts for approximately 1.7 mm of mature corallite growth. The left minor septum of the triad is then strongly elongated for a short time of the corallite growth (Pl. 4, Fig. 1e, h; Text-fig. 9F), whereas the right one is biformly reduced at the same time. In the further corallite growth both the left minor septum of the triad and the minor septum contratingent to the counter-lateral septum became reduced to the knobs on the inner margin of the external wall (Pl. 4, Fig. 1f, g; Text-fig. 9G, H).

INTRASPECIFIC VARIABILITY: All of the well preserved specimens show a rotiphylloid-zaphrentoid arrangement of septa in the neanic growth stage, deformed in several corallites by extrinsic factors, such as attachment to the substrate. The length of this growth stage varies. One corallite (Text-fig. 10G) achieved a zaphrufimioid arrangement of major septa with a comparatively small diameter (n:d value $15:3.4 \times 3.7$ mm). Its major septa are strongly rhopaloidally thickened and its axial area is filled with heavy sclerenchyme. Both protosepta are slightly shortened, although the cardinal septum reaches the axial sclerenchymal cover of the inner limit of the narrow cardinal fossula. The minor septa, including the triad, are absent from the corallite lumen here and in the 1.2 mm of its further growth (Text-fig. 10H). They appeared in the mature growth stage (Text-fig. 10I, J) in the form of underdeveloped and short-lasting bodies.

A similar underdevelopment of minor septa within the triad is observed in another corallite (Pl. 5, Fig. 3a-c; Text-fig. 9I-M). Its morphology is the opposite of the previously described corallite in the sense that its major septa are thin and weakly rhopaloid. It retained the classic zaphrentoid arrangement of major septa up to n:d value of $20:6.0$ mm (Text-fig. 9J), with the cardinal protoseptum at that growth stage already strongly shortened. The general morphology of both paratypes discussed here is closely comparable to that of the holotype despite the different thickening of their skeletal elements.

One specimen in the collection is intermediate in the neanic morphology (Text-fig. 10A-C) and the sclerenchymal cover between the previously described two and is most distant in the arrangement of major septa from the holotype. Moreover, the length of its septa in the counter quadrants is almost equal to these in the cardinal quadrants in maturity, and its alar pseudofossulae are less clearly developed (Text-fig. 10D). However, its triad is much more distinctly developed than the triads in the paratypes described beforehand, which is a similarity it shares with the holotype.

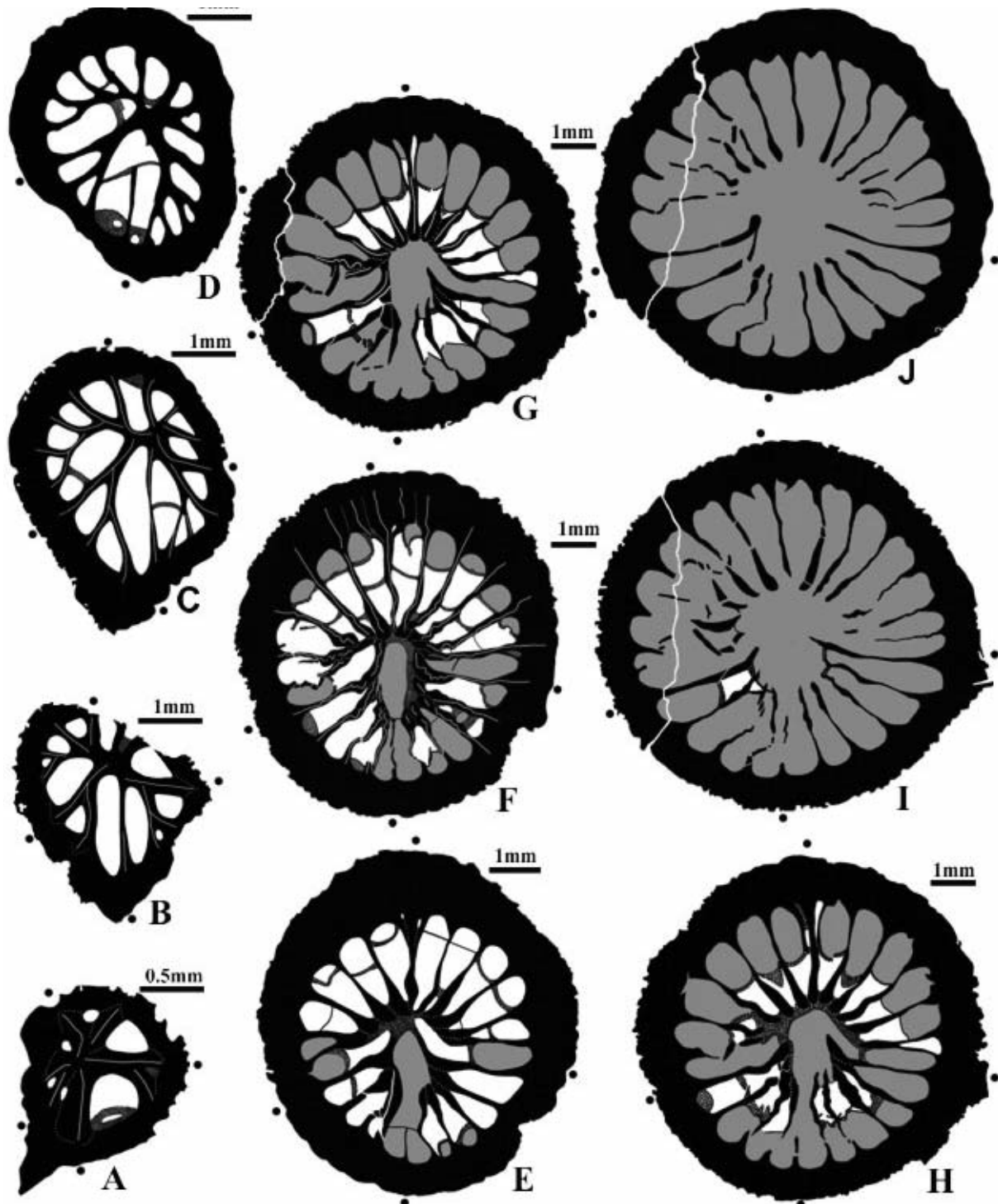
The two remaining paratypes included in the species discussed here differ from each other and from the remaining corallites (including the holotype). The first one (Pl. 5, Fig. 1a, b); has an almost smooth surface of the external wall with septal grooves absent or hardly distinguishable when present and the growth striae dominating. Its inner morphology (Pl. 5, Fig. 1c-e; Text-fig. 10E, F) retained an immature character with zaphrentoidally arranged major septa, not yet shortened counter septum, and only one alar septum developed better than the other major septa. However, its cardinal septum is shortened already and the calice is very deep. Despite the juvenile arrangement of major septa, the triad in this specimen is clearly developed (Pl. 5, Fig. 1e; Text-fig. 10F).

The second specimen (Pl. 5, Fig. 2a-c; Text-fig. 10K-N) possesses a zaphrentoid arrangement of major septa in the early growth stage and a cardinal septum shortened earlier in the corallite growth (Pl. 5, Fig. 2b; Text-fig. 10K, L) than in the holotype and in most of the paratypes. Its alar septa dominate already at this early growth stage, whereas the counter septum is indistinguishable from the counter-lateral septa in its length and thickness. The minor septa adjacent to the counter septum appear early in ontogeny and in sequence, not simultaneously (Text-fig. 10L, M). The later inserted minor septum is better developed than the other one and lasts longer, being clearly recognizable in the calice (Text-fig. 10N). It is the only corallite in the collection with several contratingent minor septa present. Two of them occur in the left cardinal quadrant (Text-fig. 10M, left). The remaining minor septa, short and free, are recognizable in all septal loculi. The wide axial area free from septa, present beneath the calice floor, is another distinguishing character of this corallite. However, the general arrangement of its major septa resembles that of the holotype, with those of the counter quadrants rhopaloidally thickened, laterally contiguous in their inner margins, and shorter than those of the cardinal quadrants. Thus, the corallite is considered to be morphologically the most advanced representative of *T. coepta* found so far.

MICROSTRUCTURE AND DIAGENESIS: The original microstructure of septa is absent in all investigated corallites. This diagenetic deformation resulted mostly from re-crystallization and compaction with rare substitution of calcite with dolomite. The remnants of the trabeculae-like structures (Pl. 4, Fig. 1h, j, m; Pl. 5, Fig. 3d) occur in some fragments of the septa. They are commonly wider than the more strongly deformed parts of the primary septa, present as "dark lines" in the same septa. The enlargement is interpreted here as growth of

the inorganic crystalline fibrils based on the organic stencil of trabeculae. This suspected inorganic widening is never very advanced, but the possibility of its occurrence means the bodies cannot be measured accurately.

OCCURRENCE: Polish part of the USCB. Knurów, Ludwik-Concordia and Sośnica Mines, Serpukhovian (Arnsbergian E_{2b}, lowermost). (See Tables 1, 3 for details).



Text-fig. 11. *Triadufimia* sp. nov. 1. Specimen SUT-K-7B; A-D – neanic growth stage, E-H – early to late mature growth stage, I, J – lower and middle part of calice (7D – peel, 7H, I – polished surfaces). See *Note* following description of Text-fig. 1 for further explanations

Triadufimia sp. nov. 1
(Pl. 6, Figs 1a–f; Text-fig. 11)

MATERIAL: One, well preserved corallite SUT-K-56 with most of the neanic growth stage and the calice preserved, but the microstructure of septa completely destroyed by diagenesis. Six thin sections and three peels were available for the study.

DESCRIPTION: The earliest neanic growth stage preserved with the n:d value of $7:1.3 \times 1.5$ mm (Text-fig. 11A) is deformed by the lateral attachment to the substrate, demonstrated by the underdevelopment of its left alar and counter-lateral septa. The six first major septa extend to the corallite axis and are united there by sclerenchyme. The deformation of the left quadrants of septa disappears during the further corallite growth (Pl. 6, Fig. 1a; Text-fig. 11B–D), with the n:d value of the most advanced neanic growth stage studied $17:4.6 \times 3.6$ mm. Most of the neanic growth stage closely resembles the morphology of *Rotiphyllum omaliusi* (Milne Edwards and Haime, 1851) in the arrangement of the major septa, which are successively shorter towards the cardinal fossula, and the distinct alar pseudofossulae. The cardinal septum intersects the cardinal fossula during the entire neanic growth stage, as indicated by its intercept attached to the inner right border of the cardinal fossula (Text-fig. 11D). The cardinal fossula extends in that growth stage beyond the corallite axis, but its shape varies from parallel-walled to expanded in the middle part to constricted adaxially (Text-fig. 11B–D respectively). The counter septum is hardly distinguishable from the counter-lateral septa. The ‘dark lines’ of the protosepta and some major septa are disconnected. The minor septa, including those adjacent to the counter protoseptum, remain absent from both the corallite lumen and the thick external wall during the entire neanic growth stage.

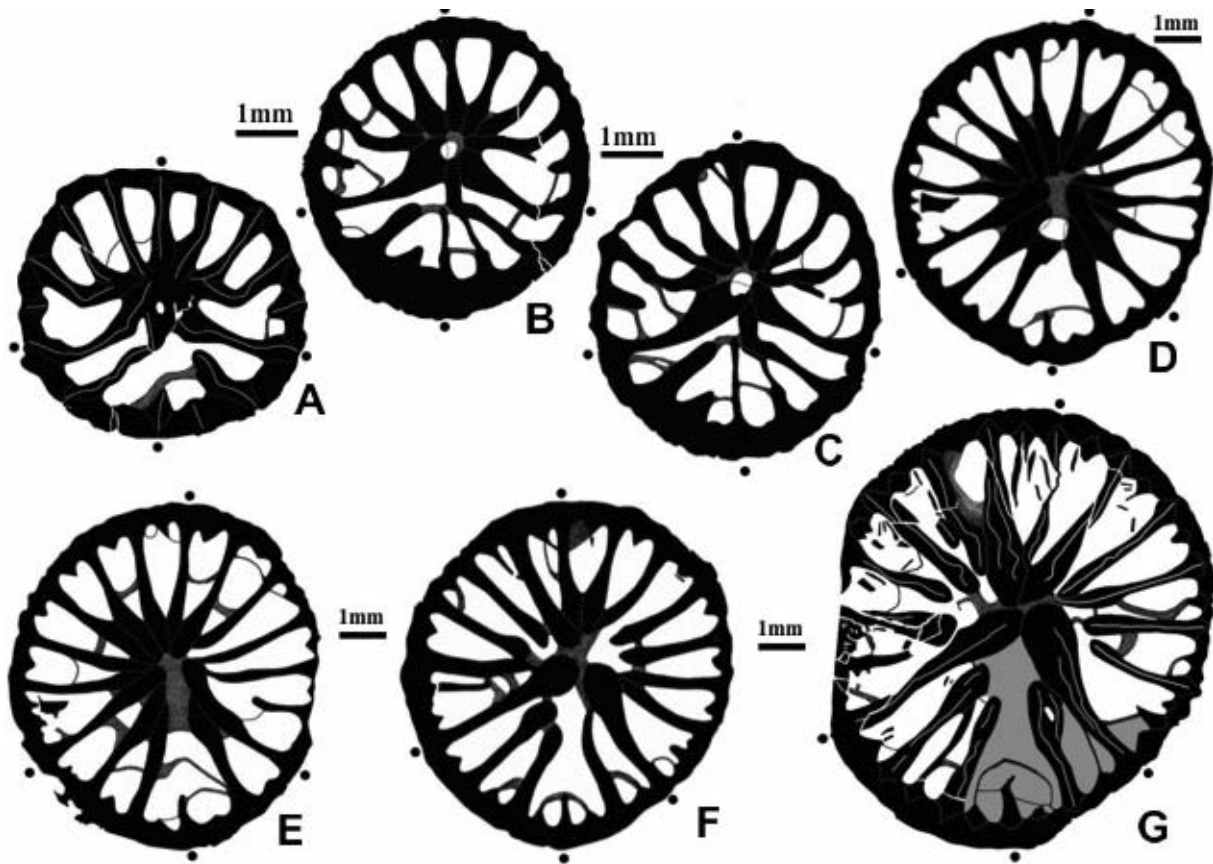
The zaphrentoid arrangement of major septa remains unchanged throughout most of the corallite mature growth stage, including the lower part of the calice (Pl. 6, Fig. 1b–e; Text-fig. 11E–H). In the ontogenetically earliest growth stage of the series mentioned, with the n:d value of $21:6.4 \times 7.0$ mm only the cardinal fossula and the peripheral parts of the alar pseudofossulae are sectioned above the calice floor (shadowed), indicating the deepest depressions of the tabula in these septal loculi. Such a shape of the tabula allows one to consider the loculi adjacent to the alar septa as true fossulae. Most of the major septa became slightly rhopaloidally thickened since the early mature growth stage (Pl. 6, Fig. 1b; Text-fig. 11E). Their differentiation in length within individual quadrants remains similar to that in the earlier growth stages, i.e. they shorten towards the cardinal sep-

tum and the alar septa in accordance with their insertion. However, the major septa in the counter quadrants are generally longer than the ones in the cardinal quadrants, which is the opposite of what occurred in the neanic growth stage. The cardinal septum is thin and distinctly shortened, whereas the counter septum is almost equal in length to the counter-lateral septa. Only the alar septa are clearly elongated, reaching the inner margins of the counter-lateral septa or the major septa adjacent to the latter. That way the alar fossulae are closed and isolated from the corallite axial depression. The cardinal fossulae irregularly key-hole in shape during the mature growth stage (Pl. 6, Fig. 1b–e, Text-fig. 11E–H). It extends behind the corallite axis.

The n:d value increases very slightly in the series of sections described reaching $22:6.0 \times 7.0$ mm in the ontogenetically most advanced growth stage, sectioned below the calice floor in the inner parts of most septal loculi, including the triad (Pl. 6, Fig. 1e; Text-fig. 11H, white). In addition to the characteristics described above, the following important features of the mature growth stage should be pointed out: (1) The appearance of the triad. The minor septa of the triad appear as short, hardly distinguishable bodies, almost completely laterally contiguous to the counter protoseptum (Pl. 6, Fig. 1b, 1c; Text-fig. 11E, F). They were elongated for a short period of the corallite growth (Pl. 6, Fig. 1d–f; Text-fig. 11G, H), reaching nearly half the length of the counter septum, but became strongly reduced immediately after this apogee, retaining as free, thorn-like bodies attached to the corallite wall (Text-fig. 11I, J). (2) Minor septa other than those of the triad are absent from the corallite lumen and from the comparatively thick external wall along most part of the mature corallite growth. Low and hardly recognizable protrusions corresponding to these septa may appear on the inner side of the external wall within some septal loculi of the counter quadrants, in the middle part of the calice (Text-fig. 11I, J). (3) The corallite floor is elevated around the axial depression (Text-fig. 11F–H, white), i.e. around the inner part of the fossula. This higher elevation extends to the septal loculi between the minor septa and the counter protoseptum.

The ufimoid differentiation in length of the major septa is achieved with the n:d ratio of $22:7.7$ mm (Text-fig. 11I) well above the calice floor, i.e., it is clearly recognizable only above the circum-fossula elevation of septa described in the preceding paragraph. The alar septa remain dominant in length, and the counter-lateral septa become longer than the counter septum, but mainly thanks to a slight shortening and thinning of the latter.

The microstructure of septa was diagenetically altered to the extent which makes it impossible to reliably decipher its original type.



Text-fig. 12. *Triadufimia* sp. nov. 2. Specimen SUT-LC-57; A-C – neanic growth stage, D-F – early mature growth stage, G – mature growth stage (B-E – peels). See Note following description of Text-fig. 1 for further explanations

DISCUSSION: The specimen described bears all the diagnostic characters of *Triadufimia* although the ufimioid differentiation in length of the major septa appears only in its calice. It differs from the holotype and the paratypes of *T. coepta* in various ways: its major septa in the counter quadrants are longer than those in the cardinal quadrants; its calice floor forms long-lasting circumaxial elevation; all its minor septa apart from the ones forming the triad are underdeveloped; its cardinal septum is shortened early in the ontogeny; and the external wall is much thicker in comparison to the corallite diameter in the holotype and the paratypes of *T. coepta*. Such a set of differences precludes its identification as *T. coepta*, whereas an inadequate representation precludes its formal identification as named new species.

OCCURRENCE: Polish side of the USCB. Knurów Mine, Enna horizon, Serpukhovian (Arnsbergian E_{2b}, lowermost).

Triadufimia sp. nov. 2
(Pl. 6, Fig. 2a-f; Text-fig. 12)

MATERIAL: One corallite SUT-LC-57. Ontogenetically earliest growth stages missing; macro-morphology of advanced neanic and early mature growth stages well preserved, but entire skeleton recrystallized; hole in corallite axial part (Pl. 6, Fig. 2a,b; Text-fig. 12A-D) – result of dissolution; calice strongly crushed by compression.

DESCRIPTION: The earliest neanic growth stage preserved (Pl. 6, Fig. 2a; Text-fig. 12A), with the n:d value of 14:4.7 mm, exposes a mixture of zaphrentoid and zaphrufimioid features. The expression of the zaphrentoid arrangement of major septa in the counter quadrants is documented by the lateral contiguity of their inner margins and the connection of the middle dark lines (primary septa) of some, whereas the strong rhopaloid thickening and the long length of the alar septa, are zaphrufimioid features. The strongly shortened cardinal septum is arched by a thick tabula imitating a septum by having a comparatively thick basal crystalline layer (Pl. 6, Fig. 2a, lower). The counter septum is almost as long as the counter lateral septa, but the inner margins of the latter are thicker and bent towards it. The irregular arrangement of major septa in the cardinal quadrants

made it difficult to establish the shape of the cardinal septal fossula. Section of only one tabula suggests its rather shallow depression.

In the slightly more advanced neanic growth stage, with the n:d value of $16:4.7 \times 5.2$ mm (Pl. 6, Fig. 2b; Text-fig. 12B, C), the arrangement of the major septa remains similar to the preceding one. The main differences are: more strongly accentuated rhopaloid character of septa – the alars in particular, and more clearly bordered cardinal fossula. The cardinal septum is longer in this stage than in the preceding one, but this may be the result of its amplexoid character. Its inner margin extends to the inner margin of the widely triangular cardinal fossula, which reaches two-thirds corallite radius.

It is as early as in this growth stage that an ephemeral triad appeared (Pl. 6, Fig. 2b, 2c; Text-fig. 12B, C, upper). One counter lateral minor septum of this triad is clearly isolated from the counter-lateral protoseptum, whereas the second one remains in the lateral contiguity with its peripheral part. Other minor septa remain absent at this growth stage both from the corallite lumen and the thickness of the external wall.

In the early mature growth stage (Pl. 6, Fig. 2d; Text-fig. 12D–F) the arrangement of the major septa became clearly bilateral with a strongly shortened cardinal septum and slightly shortened counter septum. The alar septa remain dominant, but their thickness and rhopaloid shape change slightly from section to section. The remaining major septa are strongly rhopaloid at the beginning of the mature growth stage (Pl. 6, Fig. 2d; Text-fig. 12D). Their inner margins are laterally contiguous and join the axial sclerenchyme. Their thinning in the course of the corallite growth is parallel to the reduction of the sclerenchyme (Text-fig. 12E, F). Their number in the counter quadrants increases faster than that in the cardinal quadrants. Thus, they eventually almost double the number of major septa in the cardinal quadrants. Also, the cardinal quadrants septa occupy only slightly more than one-third of the corallite lumen.

Near the end of the early mature growth stage (Text-fig. 13F), the axial sclerenchyme joins only the strongly rhopaloid alar septa and much thinner counter-lateral septa and the counter septum. The cardinal fossula is bordered by all major septa of the cardinal quadrants, three in the left quadrant and two in the right one. Short septal bodies adjacent to the cardinal septum may be either the last pair of the major septa or the minor septa. All the unquestionable minor septa started extending into the corallite lumen at the beginning of the early mature growth stage (Pl. 6, Fig. 2d; Text-fig. 12D–F). Two minor septa form a triad and one is attached to the left counter-lateral septum at the end of that growth stage (Text-fig. 12F). The microstructure of the bodies iden-

tified here as possible elongated minor septa is diagenetically damaged, and they may represent sections of tabulae.

The counter quadrants of the fully mature growth stage (Text-fig. 12G) occupy two-thirds of the corallite volume and consist of twice as many major septa as the cardinal quadrants. The alar and counter-lateral septa are long and very strongly rhopaloid; they dominate over all the remaining major septa and closely approach the corallite axis, with only little sclerenchyme secreted between some of them. The remaining major septa are rhopaloid and slightly differentiated in length out of the sequence of the insertion. This differentiation is best shown in the left counter quadrant of septa. The short cardinal septum intersects less than a quarter of length of the cardinal fossula which retains its triangular shape, achieved earlier. The last pair of the very short, wedge-shaped major septa at the periphery of the cardinal fossula resemble minor septa. The counter septum is much thinner and distinctly shorter than the counter-lateral septa, but it intersects the entire loculum formed by those septa. The minor septa enter the corallite lumen in all septal loculi cut both beneath and above the calice floor (the latter shadowed). These adjacent to the counter septum are long and probably form the triad (Pl. 6, Fig. 2e; Text-fig. 12G). Unfortunately, they were broken by compression, making their contratingent position uncertain. Sections of a few tabulae at the periphery (Text-fig. 12G, right) may suggest a slight biformity of the tabularium.

MICROSTRUCTURE AND DIAGENESIS: The advanced diagenesis (recrystallization in particular) precludes a reliable recognition of the original microstructure of septa. Some best preserved parts of the major septa (Pl. 6, Fig. 2f) suggest possibly finely trabecular microstructure. Bunches of crystalline fibrils within the 'middle dark line' (the primary septum) may correspond to individual trabeculae, although most of them are directed obliquely, not radially from the centre.

DISCUSSION: The position of the specimen described within *Triadufimia*, although probable, leaves some doubts. The triad appeared in the late neanic growth stage is an ephemeral feature, whereas the minor septa alongside the counter septum were broken by compression at maturity. However, there are undoubted bases of minor septa embedded in the external wall between the counter protoseptum and counter-lateral septa. Also, the blades of these minor septa are long. The left one reaches almost two-thirds the length of the counter septum (Pl. 6, Fig. 2e). Assuming this generic position at least probable, the morphology of the specimen dis-

cussed differs from both *Triadufimia coepta* and *Triadufimia* sp. nov. 1 in all growth stages. The following characteristics clearly separate the specimen discussed here from both taxa mentioned above: the morphology of the mature growth stage with the alar and counter-lateral septa strongly dominating and meeting at the corallite axis, other major septa differentiated in length out of the order of their insertion, and strongly dominant counter quadrants in both their volume and the number of septa. A very early shortening of the cardinal septum in ontogeny is an additional distinguishing feature. As in the case of *Triadufimia* sp. nov. 1, a formal name is not proposed for the specimen described. However, the scarcity of corals in the Serpukhovian strata in general and the Upper Silesian Coal Basin in particular, makes the description of this specimen rational.

OCCURRENCE: Polish part of the USCB. Ludwik-Concordia Mine, Enna horizon, Serpukhovian (Arnsbergian, E_{2b}, lowermost).

Family Antiphyllidae Ilina, 1970
Genus *Antiphyllum* Schindewolf, 1952

TYPE SPECIES: *Antiphyllum inopinatum* Schindewolf, 1952

REMARKS: Weyer (1974) re-described and re-illustrated the holotype and the only specimen included by Schindewolf (1952) in his new species and genus *Antiphyllum inopinatum*. Weyer's revision proves that Schindewolf (1952, text-fig. 19a–d) misoriented the specimen; correcting the mistake (Weyer 1974, p. 350) meant that he was able to propose the synonymy of *Antiphyllum* with *Claviphyllum* Hudson, 1942. However, the type species of the latter genus, i.e., *Cyathopsis eruca* McCoy, 1851 possesses contrasting minor septa. Thus, Weyer (2005) modified his original idea and began to consider *Antiphyllum* an independent genus. Unfortunately, he only mentioned this briefly in the text and did not make a formal revision. Fedorowski (2012b) reinvestigated all the specimens from the USCB potentially belonging to *Antiphyllum* and discussed possible relatives of this genus and fully accepted Weyer's (1974) revision of the holotype. However, my opinion (Fedorowski 2012, p. 3–5) on the relationships of specimens identified by Schindewolf as *Claviphyllum* differs from Weyer's (*Ibid.*) and is followed here.

?*Antiphyllum* sp. nov. 1
(Text-fig. 13)

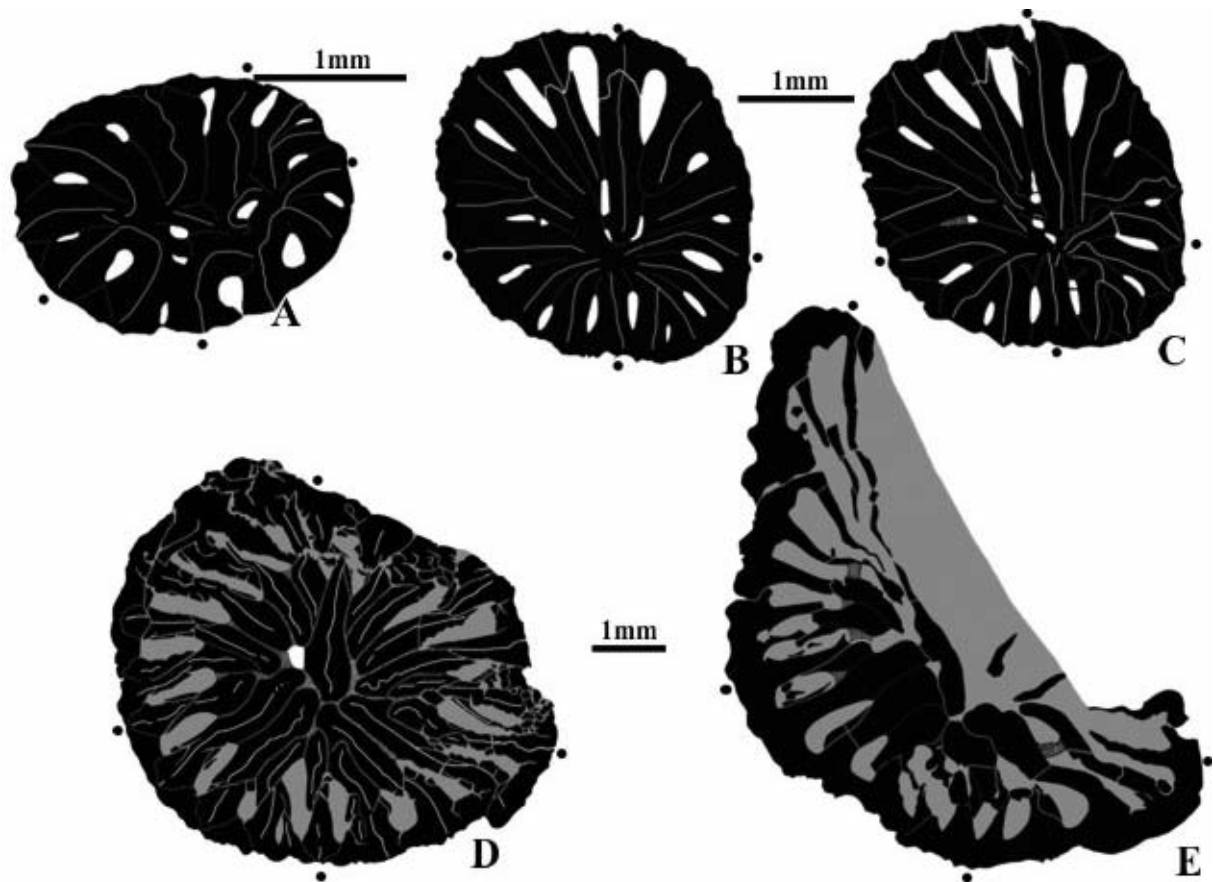
MATERIAL: One specimen 482/142 with most of neanic growth stage preserved, but with mature growth stage affected by the compaction. Four thin sections and three peels were available for the study.

DESCRIPTION: In the earliest neanic growth stage preserved, with the n:d value of $12:2.2 \times 1.7$ mm (Text-fig. 13A), the strongly thickened major septa are irregularly arranged with the cardinal and counter septa hardly recognizable, but both long. The 'middle dark line' of the counter septum joins the 'middle dark line' of one counter-lateral septa. Also, several other 'middle dark lines' of septa (the primary septa) are united. Two skeletal bodies, septal in their microstructure, are located in the corallite middle part. The genesis of these ephemeral bodies is unknown, and they are absent from the next transverse section.

The morphology of the ontogenetically more advanced neanic growth stage (Text-fig. 13B, C), with the n:d value of $15:2.8 \times 2.6$ mm is much more regular despite being slightly obliquely sectioned. The cardinal septum approaches or reaches the inner margins of the zaphrentoidally arranged, completely developed major septa of the cardinal quadrants. Thus, it should be described as long, but not dominating in contrast to the elongated counter septum which strongly dominates beginning at this growth stage. The alar septa are the longest septa in the cardinal quadrants. All the major septa remain strongly thickened, but not rhopaloid. Minor septa are absent from both the corallite lumen and its external wall.

The mature growth stage (Text-fig. 13D) with the n:d value of $24:5.5$ mm (diameter slightly reduced by compression) is illustrated by the section made just above the calice floor. All the major septa are rhopaloid, closely approaching the strongly rhopaloid counter septum, the inner margin of which occupies the axial part of the corallite. The shortened cardinal septum, reaching only two-thirds corallite diameter in length, extends to the inner limit of the cardinal fossula, bordered by three pairs of major septa. The arrangement of major septa is regular, with the alar and the counter lateral septa comparatively short, whereas the middle septa of quadrants are the longest and thickest. Minor septa remain either absent or were not traced because the corallite underwent some damage by compression in its peripheral area.

DISCUSSION: The specimen described bears all the typical features of the genus *Claviphyllum*, except for the contrasting minor septa, characteristic for the type species of this genus, i.e., *Cyathopsis? eruca* McCoy, 1851. The latter character is important enough for the distinction between species on the genus level. Thus,



Text-fig. 13. ? *Antiphyllum* sp. nov. 1. Specimen 482/142; A-C – early to late neanic growth stage, D – mature growth stage, E – middle (?) part of calice. Scale bar between D and E corresponds to all figures. See *Note* following description of Text-fig. 1 for further explanations

specimens with short or absent minor septa in the corallite lumen, such as *Claviphyllum hillae* Hudson and Fox, 1942 or the specimen described here may belong to *Antiphyllum* Schindewolf, 1952. This question is discussed more thoroughly in a separate paper (Fedorowski 2012b).

The early growth stages of the corallite described resemble the comparable growth stages of '*Claviphyllum*' *magnificum* Schindewolf, 1952 and several corallites included by that author in '*Claviphyllum*' *pauperculum* Schindewolf, 1952. It differs from these species in possessing the alar septa clearly shortened, and in the regular arrangement and strong rhopaloid thickening of the remaining major septa. It resembles '*C.*' *pauperculum* in size and in the n:d value, but it is much smaller than '*C.*' *magnificum*.

OCCURRENCE: Polish part of the USCB; Leńcze IG-1 borehole, depth 1357.1 m; Štur horizon, Serpukhovian (upper Pendleian, E₁).

SUMMARY OF THE USCB RUGOSE CORALS SUCCESSION.

The Sudetic phase of the Variscan Orogeny resulted in strong environmental changes in several areas of Poland and dramatic changes in terms of the rugose coral faunas. The Upper Asbian and Brigantian faunas flourished in shallow waters of the present Holy Cross Mountains, the Sudetes, the Cracow upland and some other Polish areas, but disappeared permanently shortly after the end of the *Goniatites crenistria* Biozone. In contrast to those areas, USCB Upper Viséan and Lower Serpukhovian sedimentation was dominated by marine clastic deposits (see Geological Setting above). Such facies made rugose coral settlement impossible. Only the last phase of that sedimentary cycle, terminating the Upper Malinowickie Beds, namely the Štur, appeared acceptable for rare corals to develop (see above and below). That 'horizon' was located by Czech geologists near the base of the Pendleian (e.g., Řehoř and Ře-

hořova 1972, p. 14), but was placed near the top of the Pendleian in the more recent Polish compendium (Musiał and Tabor 2001). We did not follow here either of those two suggestions (Text-fig. 4).

Stratigraphy of the lower part of the Paralic Series, i.e., that following the Malinowickie Beds, is inadequately supported as well. Thus, controversies in the chronostratigraphic position of individual 'beds' and marine 'horizons' remain. In general, Czech scientists tend to lower while Polish scientists tend to elevate their positions. As a result, the Franciszka and Enna horizons are situated by Řehoř and Řehořova (1972) in Pendleian, whereas Bojkowski (1972, 1979) considered them Arnsbergian. Bojkowski's (1979) finding of *Cravenoceratoides edalensis* (Bisat) in the Enna horizon speaks in favour of the lowermost Middle Arnsbergian age for that 'horizon'. Both authors of the present paper accept that age for the Enna despite the earlier opinion of the senior author (Fedorowski 2012b), who followed Czech scientist's idea in placing the Enna in the upper Pendleian. This change of mind stems mostly from comparison of the USCB strata to the revised correlation of the Carboniferous strata in Britain (Waters and Condon 2012; Waters *et al.* 2011) which was not published when Fedorowski's paper was submitted to the *Palaeontographica* in 2010 (published 2012a). Thus, in view of our new data, we accept the lowermost (E2b1) position of the Enna within the Middle Arnsbergian, suggested by *Cravenoceratoides edalensis*, which was placed by Waters *et al.* (2011, fig. 6) at the very bottom of the E2b Zone.

The E2b1 position of the Enna suggests the E2a position of the Franciszka horizon. The latter is not characterized by an index ammonoid, but its appearance six 'horizons' above the Štur, accepted as high Pendleian, and three 'horizons' below the Enna horizon, discussed above, support that suggestion. A single rugose coral specimen found in the Franciszka horizon cannot help in solving that question despite its primitive characteristics (see Fedorowski 2010).

Both Polish and Czech scientists accepted the Barbara horizon as Arnsbergian. We follow that opinion although a more precise stratigraphic position of that marine 'horizon' is not documented by index fossils. Its position between the Enna horizon, characterized by *C. edalensis*, and the upper Roemer horizon marine band (1^b) of the Gaebler, characterized by *C. nitidus* can, however, be confirmed by rugose corals as possibly the upper part of *C. edalensis* Zone (see below).

The rugose coral fauna of the Roemer marine band is well characterized by the index fossil *C. nitidus*, but that is not true for the entire Gaebler horizon. Also, rugose corals are absent from the lower Gaebler, being

well represented only in the Roemer band where they are the richest and the youngest in the Serpukhovian strata of the USCB (Table 3 and below). Rugose corals are absent from Polish territory above that horizon and up to the Upper Bashkirian (Westphalian A or B) strata (Fedorowski, in preparation).

All Serpukhovian rugose coral faunas known from the USCB were either introduced by the marine transgressions from areas other than Poland (see above), or evolved in the basin during periods of transgressions. All species and most genera, except for *Zaphrufimia* and *Antiphyllum* (= *Ufimia* and *Claviphyllum*, respectively, in Fedorowski 1968, 1981) are new to Polish and Czech territories. Only those two genera and probably *Ostravaia* Fedorowski, 2010 are common to other taxa from such areas as Britain (Carruthers 1910; Hill 1938-1941; Hudson 1941, 1944a, b; Hudson and Fox 1942), the Cantabrian Mountains in northern Spain (Kullmann 1966, 1968; Rodríguez 1984), the Donets Basin in the Ukraine (Vassilyuk 1960; Fedorowski, in preparation) and the Moscow Basin in Russia (Kabakovich 1952). Names applied by the various authors cited differ, but the morphology of their specimens are comparable to genera mentioned. The partly endemic status of the USCB rugose coral fauna may be due to severe conditions of a more inland location of the area, compared to the areas listed above. Such a location is suggested by the absence of limestones, which are replaced in the USCB by mudstones and coarser grained clastic deposits.

Detailed analysis of the rugose coral faunas derived from individual coral-bearing marine horizon allows some suggestions concerning their relationships and stratigraphic occurrence.

The Štur horizon yields the stratigraphically oldest rugose corals present in the USCB. These corals are named and described here for the first time. Three specimens were found by Dr. Łucja Musiał in two drilling cores and were kindly provided by her for this study: One specimen, collected from the Leńcze IG-1 borehole, is identified as ?*Antiphyllum* sp. nov. 1. Two specimens, found in the Łąka IG-1 borehole, are identified as *Zaphrufimia* sp. nov. 1 (Table 2). All three specimens are too poorly preserved to help in phylogenetic reconstructions of their lineages, or for comparison to other areas, but their occurrence in the genera known from younger strata of the USCB may aid in recognition of species in or close to the basin. Also, their presence in the USCB proves a temporary return in the late Pendleian of conditions suitable for rugose corals. Their morphologies, which differ from the younger species of their genera, may help to identify the Štur horizon.

The next oldest rugose coral species in the USCB is represented by a single specimen found in the Książenice (Knieczenitz in German) borehole near Szczygłowiec, in the Franciszka horizon of the lower Gruszkowskie (Hrušov) Beds. The corallite mentioned was briefly described by Schindewolf (1952, p. 189) as *Fasciculophyllum repressum*, then renamed *Lophophyllidium? repressum* and illustrated by Weyer (1977, pl. 2, figs 4-13) and recently included by Fedorowski (2010) in his new genus and species *Variaxon radians*. The primitive characteristics of that corallite only slightly agree with the diagnosis of the higher Middle Arnsbergian representatives of *V. radians*, derived from the Roemer I^b marine band (Table 3), and may represent a new, primitive species of the genus *Variaxon*, not established by Fedorowski (2010), nor herein, due to the scarcity of the material. Unfortunately, the authors were not able to discover more specimens from the Franciszka horizon. Thus, inadequate material prevents precise correlation of the Franciszka horizon and the possibility of a coral zonation for both the Štur and the Franciszka horizons.

The stratigraphic position of the Enna horizon is discussed above. Rugose corals in those deposits distinguish the Enna horizon from both the underlying and overlying marine horizons. The most important data, established in the present paper, are as follows:

1. Representatives of the new genus *Triadufimia* are restricted to the Enna horizon. Although only nine specimens are available, they may represent three different species. The distinct morphologies of the two specimens left in the open nomenclature support that supposition.
2. All subspecies of *Zaphrufimia disjuncta* occur in both the Enna and the Barbara horizons, whereas only one specimen of *Z. d. serotina* has been collected from the Gabriela horizons. This distribution allows a slightly different treatment of two older horizons (see next chapter). The abundance of *Z. d. praematura* (Tables 1–3) requires special attention. It points to a bias resulting from restricted collecting opportunities in mining areas and to a patchy distribution of the Rugosa within the horizons. *Z. d. praematura* was originally represented by a single specimen of uncertain stratigraphic position (Schindewolf 1944, 1952; Weyer 1977). New collections (Fedorowski 2012a and here) make it the second most abundant after the nominative subspecies, and documents its almost equal frequency in both the Enna and the Barbara horizons.

Earlier authors differed in their approach to specimens included by Fedorowski (2012a) in *Zaphrufimia disjuncta*. Schindewolf (1952) introduced two sub-

species in addition to his „*Pterophyllum*“ („*Ufimia*“) *schwarzbachi* introduced ten years earlier. Fedorowski (*ibid.*) followed Schindewolf's (1952) idea in general, but not his genus and species identification. Weyer (1977) maintained that *Ufimia schwarzbachi* was a single highly variable species. The present investigated specimens complicate recognition of subspecies, but does not indicate that they should be abandoned, altogether. Their close similarity is here explained as an early step in speciation.

All data accumulated so far allows a distinction in the geographic distribution and stratigraphic range between the nominative subspecies and *Z. d. praematura* and *Z. d. serotina*. Carruthers (1910) described ‘*Zaphrentis*’ *disjuncta*, i.e., the nominative subspecies *Zaphrufimia disjuncta disjuncta*, from the Orchard Limestone in the British Isles. The biostratigraphic position of that limestone was established by Ramsbottom *et al.* (1978) and confirmed by Waters *et al.* (2011) as the base of the Arnsbergian (E2a). Thus, the entire lower Arnsbergian had passed before the nominative subspecies arrived in the USCB. In contrast, *Z. d. praematura* and *Z. d. serotina* are so far unknown beyond the USCB, whereas all three subspecies are present in the Enna horizons and either absent from or not yet found in the older horizons. The existing data are not precise enough to determine whether all of the subspecies arrived in the USCB simultaneously or successively. Thus, two scenarios, both based on the stratigraphically oldest position of the nominative subspecies, are possible: either the subspecies *Z. d. praematura* and *Z. d. serotina* evolved from the nominative subspecies somewhere outside the USCB and all three immigrated together, or the two subspecies evolved in the USCB area very close to the beginning of Enna horizon deposition. Regardless of which scenario is correct, all three subspecies emigrated together with the marine regression to an unknown refuge, and returned to the USCB during the Barbara transgression.

All sources taken in mind (Schindewolf 1942, 1944, 1952; Weyer 1974, 1977; Fedorowski 2012a, and this paper) leave no doubt that *Zaphrufimia disjuncta s.l.* is more abundant in the Enna horizon than in the Barbara horizon and that the rugose coral fauna is most varied in the Enna horizon, and least varied in the Gabriela horizon. Thus, the following scenario is proposed: Corals migrated to the USCB area possibly from the south, as already postulated by Fedorowski (1981) and supported by Rodriguez *et al.* (1986). They may, or may not have undergone local speciation in the USCB area during the Enna horizon high stand. The terrestrial or brackish phase of the sedimentary cycle drove them away from the USCB to an unknown refuge. *Zaphrufimia disjuncta s.l.* was able to return with the Barbara horizon trans-

gression, whereas *Triadufimia* was not. Following the Barbara horizon transgression, the next unfavourable phase drove away most representatives of *Zaphrufimia disjuncta* s.l. Only *Z. d. serotina* survived and returned to the Gabriela horizon in highly reduced numbers. That short and infrequent occurrence was the limit of the *Zaphrufimia disjuncta* s.l. in the USCB area.

In terms of the lithostratigraphy, the history of coral occurrences described comprises the Upper Gruszowskie (Hrušov), the Jaklowice (Jakloviec) and the lower Poręba (Poruba) Beds. Although these beds total more than a thousand meters of sediments, they do not necessarily represent a long period of time, since molasse sedimentation can be relatively rapid.

Corals have not yet been found in the marine intercalations between the Gabriela and Gaebler horizons, i.e., from the lower Porębskie (Poruba) Beds younger than Gabriela horizon. The coral fauna appearing in the Gaebler horizon, and in the upper Roemer band in particular, is the most abundant and diversified rugose coral fauna in the USCB. It contrasts strongly with underlying faunas discussed above (Table 3), and was the last Carboniferous rugose coral fauna in Poland described so far.

Five genera and one subgenus, represented by eight species from Upper Roemer marine band (I^b) were described in detail by Schindewolf (1952) and Fedorowski (2010, 2012a, b) (Table 1). Four specimens, left in open nomenclature, represent at least three new genera in addition to the named ones. Most of these species are presently unknown from other areas. The situation is different at generic level. *Antiphyllum*, which includes some species identified as *Claviphyllum*, is known from several areas (see above). Some species identified by Hudson (1944) as „*Permia*“ may belong to *Ostravaia*. Therefore the coral fauna cannot be considered as truly endemic. However, the assemblage of the Roemer differs clearly from both the older rugose corals assemblage of the USCB and from the other Upper Serpukhovian (Arnsbergian) faunas in Europe.

BIOZONATION

The rugose corals of the USCB are sufficiently diverse and stratigraphically restricted to allow a local coral biozonation to be proposed (Text-fig. 4), despite their restricted representation. Unfortunately, such a biozonation applies to only three marine horizon out of the total 6 present in the succession. Also, it is only in part adjusted to the index fossils zonation, and cannot be expanded beyond the USCB. However, it may help in the correlation of the Paralic Series within the Basin.

The scarcity of the rugose corals in Štur and Franciszka horizons does not allow a zonation.

The *Zaphrufimia disjuncta disjuncta*/Z. d. *prae-matura* rugose coral Zone is here proposed to characterize both the Enna and the Barbara horizons. Occurrences of the rugose coral specimens within particular beds of those horizons cannot be established and comparison between occurrences in particular mines and drilling cores cannot exceed a level of the entire horizon. Thus, the base of the zone is here taken as the beginning of the marine sediment accumulation of the Enna horizon, whereas its top ends with the last bed of the marine beds of Barbara horizon.

The goniatitid index fossil *Cravenoceratoides edalensis* only occurs in the Enna horizon. In addition, the Enna horizon may be distinguished from the Barbara horizon by the co-occurrence of the coral genera *Zaphrufimia* and *Triadufimia*. This allows us to introduce a *Zaphrufimia-Triadufimia* subzone as an approximate equivalent of the E2b1 ammonite zone. A separate subzone for the Barbara horizon is not proposed. It is situated either in the upper *C. edalensis* or in the lower part of the overlying *C. nitidus* zone. Only the three subspecies of the rugose coral *Z. disjuncta* occur in the Barbara horizon.

Rugose corals were not found in III and II (Text-fig. 3) marine horizons and only one specimen of *Zaphrufimia disjuncta serotina* was found in Gabriela horizon. Thus, that part of the succession cannot be zoned on the basis of rugose corals. Furthermore, corals were not found in the lower part of the Gaebler horizon. They re-appeared only in the Roemer band, i.e., in the middle of that ‘horizon’. Only one specimen, included by Schindewolf (1952) in a new species *Claviphyllum magnificum* and re-identified by Fedorowski (2012b) as *Antiphyllum inopinatum*, has been found in the Roemer I^{b,c} marine beds. Other specimens have been found, perhaps from the Roemer I^b beds. The stratigraphic positions of such specimens, however, are not certain. Thus, both the Roemer I^{b,c} and Roemer I^b corals are united to form the *Antiphyllum-Ostravaia-Variaxon* assemblage zone. Corals accompany the goniatite *Cravenoceratoides nitidus* (Phillips) in the Roemer I^b. Thus, the position of the assemblage coral zone within the Middle Arnsbergian E2b2 goniatite subzone is well established. Faunal analysis suggests a comparatively wide distribution of the genera of this assemblage zone. However, local recognition only is proposed for the zone.

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PLATE 1

Zaphrufimia disjuncta disjuncta (Carruthers, 1910)

- 1 – Specimen 183/332; 1a-e – early to late neanic growth stage, 1f – mature growth stage (1e, f – peels).
- 2 – Specimen SUT-K-5; Mature growth stage immediately above calice floor (peel).
- 3 – Specimen SUT-S-25; 3a – side view, 3b – uppermost part of calice wall with both major and minor septa developed, 3c, d – neanic growth stage, 3e – late neanic/early mature growth stage, 3f, g – mature growth stage (3b, d, e polished surfaces).
- 4 – Specimen SUT-LC-20; mature growth stage.

Note. Transverse thin sections, except when stated. Protosepta and alar septa marked by dots. Cardinal protoseptum at the bottom of figures. Scale bars between two pictures correspond to both; bar at upper right of a picture corresponds to that picture only. For occurrences see descriptions of species

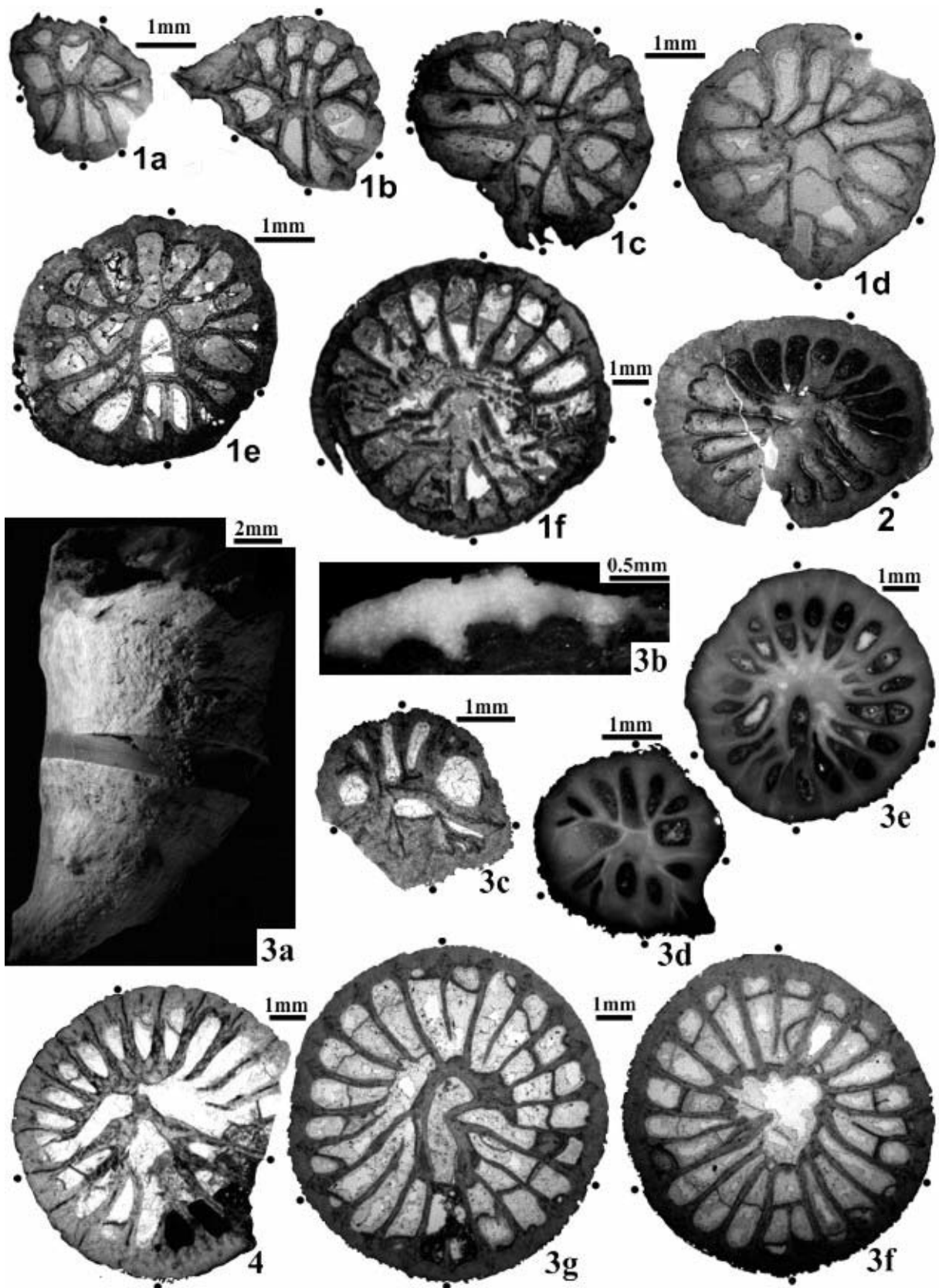


PLATE 2

- 1, 2** – *Zaphrufimia disjuncta serotina* (Schindewolf, 1952). 1 – Specimen SUT-S-47; 1a – side view, 1b-d – neanic growth stage, 1e-g – long lasting late neanic/early mature growth stage (1d, e polished surfaces). 2 – Specimen SUT-LC-46; 2a – late neanic/early mature growth stage, 2b – early mature growth stage.
- 3** – *Zaphrufimia ?disjuncta serotina* (Schindewolf, 1952). Specimen 183/43; 3a – neanic growth stage, 3b – late neanic growth stage, 3c – early mature growth stage, 3d – mature growth stage immediately above calice floor (3a, b – peels).

See *Note* following description of Plate 1 for further explanations

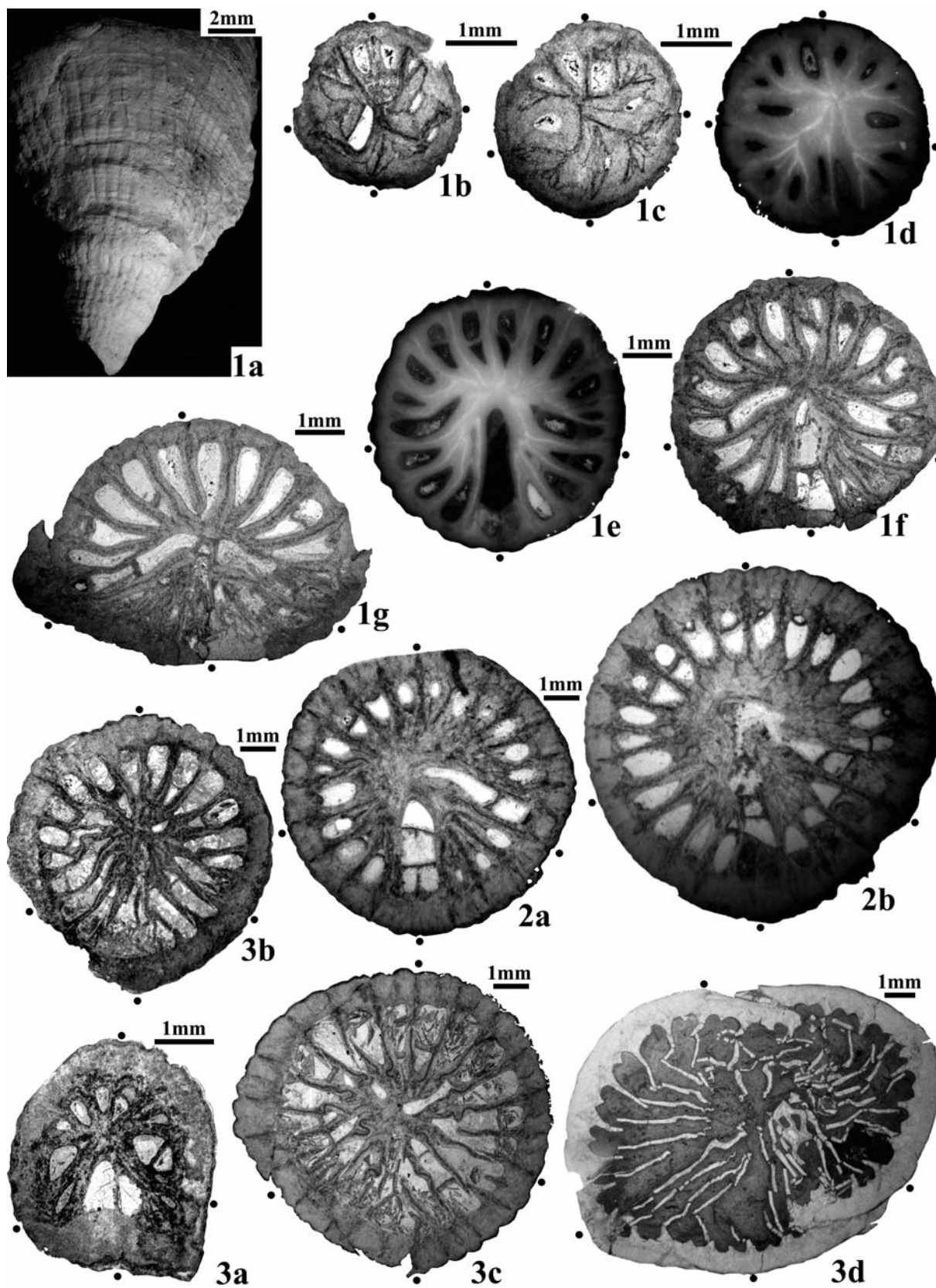


PLATE 3

Zaphrufimia disjuncta praematura (Schindewolf, 1952)

- 1 – Specimen SUT-LC-32; 1a, b – neanic growth stage, 1c – late neanic/early mature growth stage, 1d, e – mature growth stage; successive cuts through calice (1c, e – peels).
- 2 – Specimen SUT-S-40; 2a – neanic growth stage, 2b – late neanic/early mature growth stage, 2c – mature growth stage (2a-c polished surfaces), 2d – external view from cardinal protoseptum side.
- 3 – Specimen 119_5; 3a-c – early to late neanic growth stage, 3d, e – early mature growth stage.
- 4 – Specimen SUT-S-9.23; 4a – early neanic growth stage, 4b late neanic growth stage, 4c – late neanic/early mature growth stage.

See *Note* following description of Plate 1 for further explanations

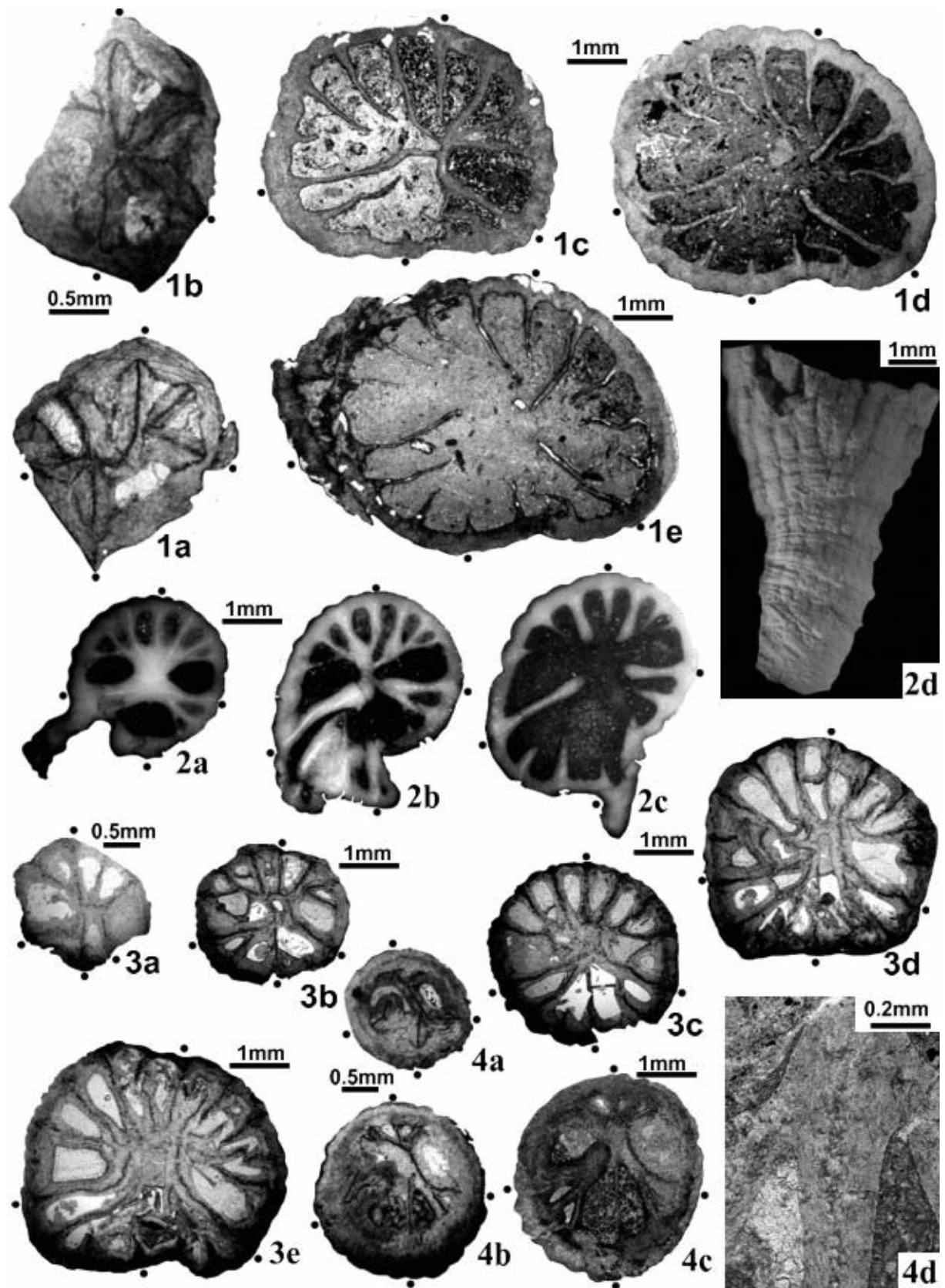


PLATE 4

Triadufimia coepta sp. nov.

Holotype; specimen SUT-K-51; 1a, b – neanic growth stage, 1c-g – mature growth stage, 1h, i – enlarged from 1e, d, respectively, to better illustrate the triad, 1j, m – remnants of trabeculae in primary major septa (enlarged from 1e), 1k, l – external view; l enlarged to show bands of growth striae and “hyposepta” of Weyer (1980) (d, i – polished surfaces).

See *Note* following description of Plate 1 for further explanations

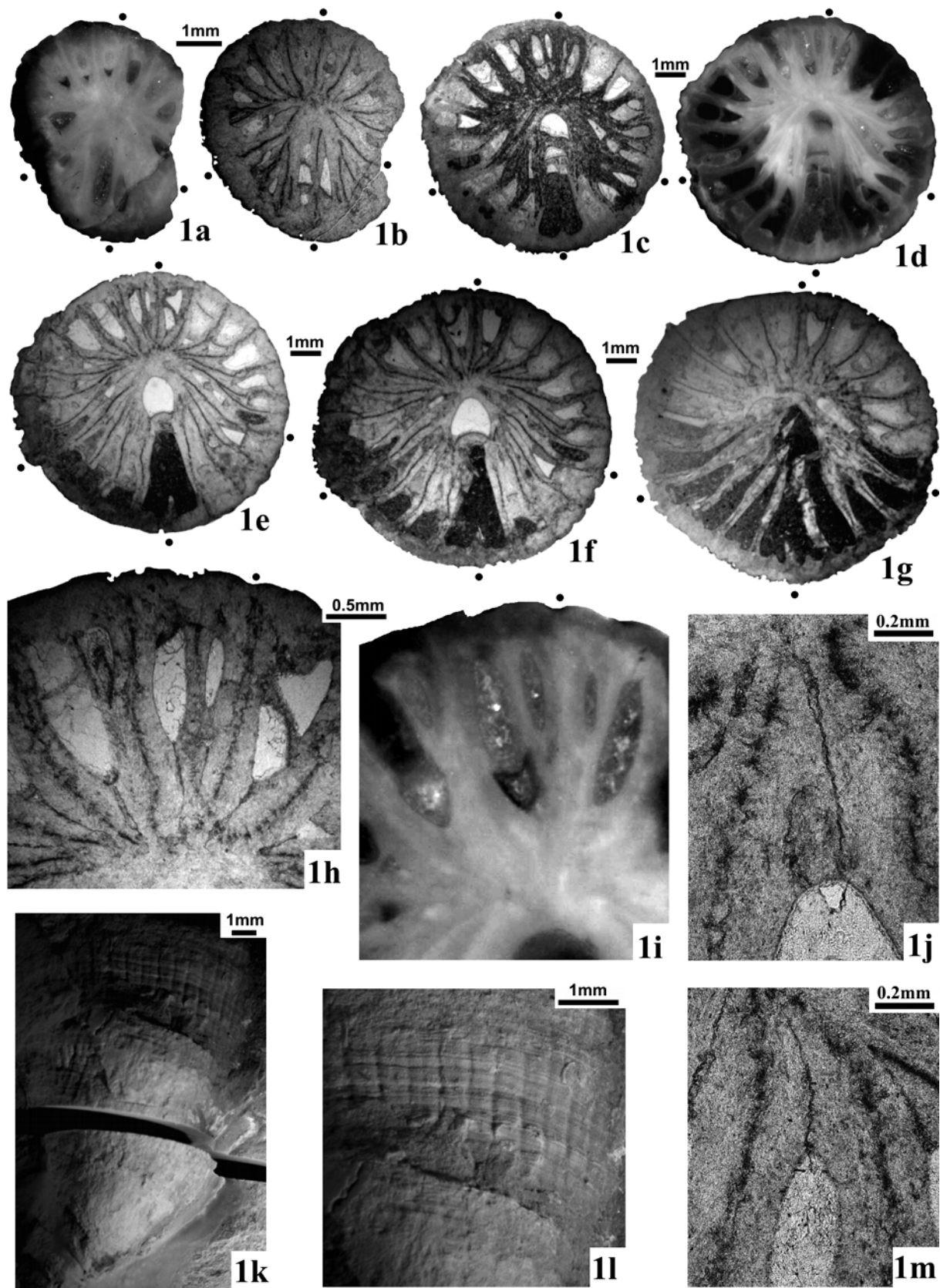


PLATE 5

Triadufimia coepta sp. nov.

- 1 – Paratype, specimen SUT-S-55; 1a – side view, 1b – fragment of 1a enlarged to demonstrate growth striae and an almost total absence of septal furrows, 1c, d – neanic growth stage, 1e – late neanic/ early mature growth stage (1c-e – polished surfaces).
- 2 – Paratype, specimen SUT-S-54; 2a – fragment of 2c enlarged to demonstrate triad and contratingent minor septum at right counter-lateral septum, 2b – late neanic growth stage, 2c – mature growth stage.
- 3 – Paratype, specimen SUT-LC-53; 3a – neanic growth stage, 3b – late neanic/early mature growth stage, 3c – fragment of 3b enlarged to demonstrate triad and minor septum-looke structure next to right major septum, 3d – remnants of trabeculae in parts of primary septa.

See *Note* following description of Plate 1 for further explanations

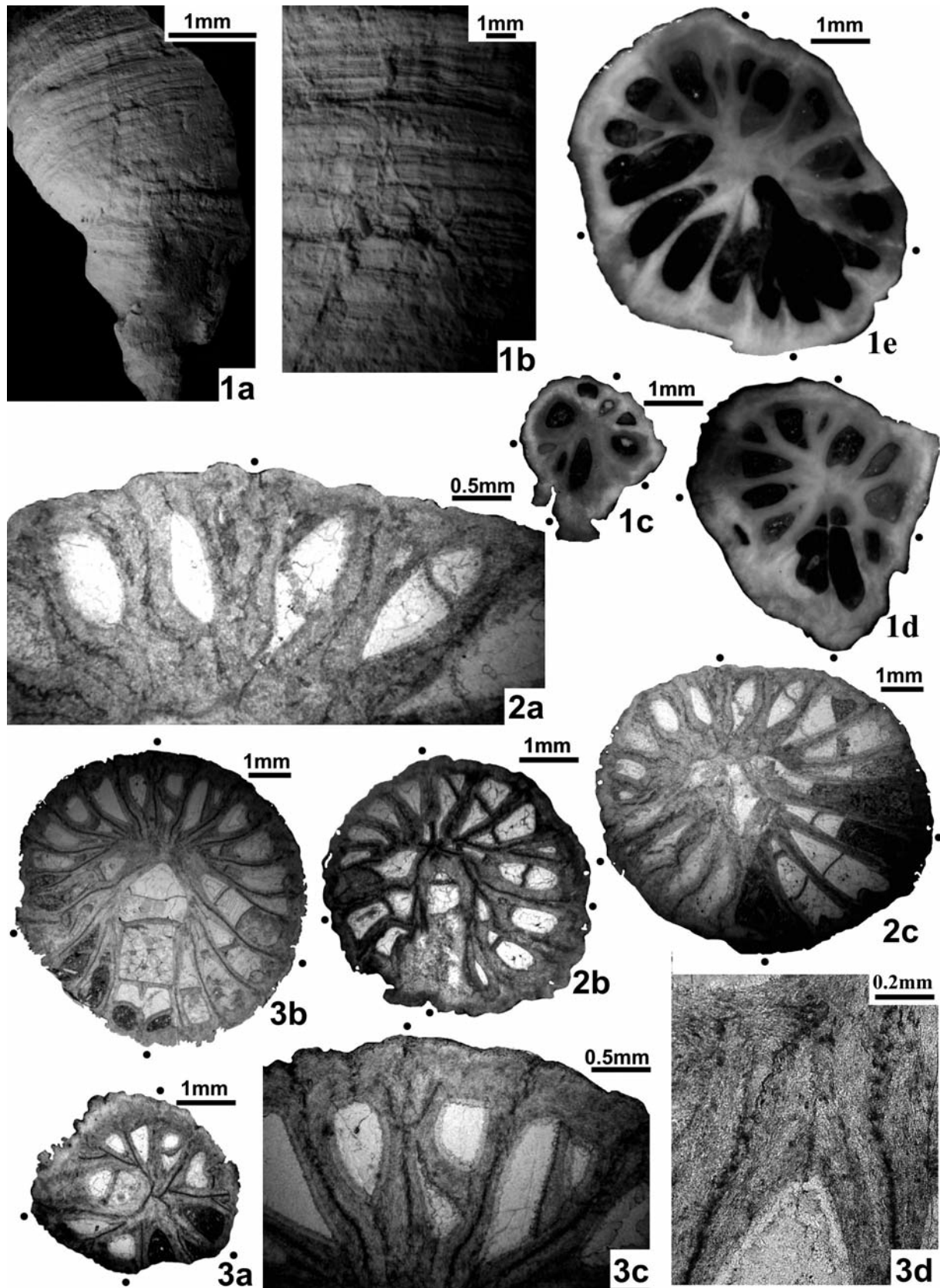


PLATE 6

1 – *Triadufimia* sp. nov. 1; specimen SUT-K-56; 1a – neanic growth stage, 1b-1e – mature growth stage, 1f – fragment of 1e enlarged to demonstrate the triad (1b, d – polished surfaces).

2 – *Triadufimia* sp. nov. 2; specimen SUT-LVC-57; 2a, b – neanic growth stage, 2c – fragment of 2b enlarged to demonstrate ephemic appearance of contratingent minor septum at counter septum (2b, c – peels), 2d – late neanic/early mature growth stage (polished surface), 2e – enlarged fragment of mature growth stage demonstrating long minor septum (left) at counter septum, 2f – diagenetically altered microstructure of major septum.

See *Note* following description of Plate 1 for further explanations

