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RADIOLARIAN FAUNAS FROM THE LATE CALLOVIAN AND EARLY OXFORDIAN DEPOSITS OF THE KRAKÓW–WIELUŃ UPLAND, SOUTH POLAND

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Abstract: This paper presents the result of research on radiolarian faunas from the Upper Callovian and Lower Oxfordian deposits of the Kraków–Wieluń Upland (South Poland). The studied material comes from boreholes Wodna 1, Trzebionka 2 and Trzebionka 3, and from outcrops at Górka near Trzebinia and Grojec. Two radiolarian assemblages, differing markedly in their species contents, I and II, have been identified. Assemblage I occurs in the Upper Callovian deposits. It has been found within *Q. lamberti* ammonitic Zone. In the number of specimens this association is dominated by the spherical, oval and conical forms of the Nassellaria group. Assemblage II is associated with the Lower Oxfordian deposits and it is characterised by the dominance of spongy radiolarians belonging to the Spumellaria group. Assemblage II has been found within *Q. mariae* and *C. cordatum* ammonitic zones. A correlation with the Tethyan radiolarian zones indicates that both assemblages can be assigned to U.A.Z. 8 (Late Callovian trough Early Oxfordian age). The radiolarians show features of Tethyan faunas which spread over epicontinental seas when communication with the Tethys Ocean opened. A change in the character of the radiolarian assemblage in the Lower Oxfordian suggests boreal influences as well as gradual shallowing of the basin.

Key words: Radiolaria, Upper Callovian, Lower Oxfordian, Kraków–Wieluń Upland, biostratigraphy, palaeoecology, palaeogeography.

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INTRODUCTION

This paper shows the results of investigation of radiolarian assemblages from the Upper Callovian and the Lower Oxfordian deposits of the Kraków–Wieluń Upland (South Poland). The rock material was derived from boreholes and outcrops located in the southwestern part of the area near Chrzanów and Krzeszowice (Fig. 1).

Many authors have noted the occurrence of abundant radiolarians in the Jurassic sediments of the Kraków area. The presence of radiolarians in the Lower Oxfordian deposits of the Kraków region was mentioned for the first time by Wiśniowski (1888). The occurrence of radiolarians in the Upper Callovian and Lower Oxfordian deposits of the Kraków area was cited by Bielecka (1956, 1960) from the Chrzanów and Krzeszowice area. Smoleń (1998) distinguished a horizon with radiolarians in the Lower Oxfordian (*C. cordatum* Zone) deposits in the area between Częstochowa and Zawiercie. That paper also contains considerations on palaeogeography and origin of the radiolarian assemblages in the epicontinental basin of the Kraków–Wieluń Upland. A radiolarian assemblage described by Górka & Bąk (2000) from the Zalas quarry near Kraków also comes from the Lower Oxfordian deposits (*C. cordatum* Zone). The characteristics of the radiolarian species, given in that paper, have been used for biostratigraphical and palaeoecological considerations. The occurrence of radiolarians in the Lower Oxfordian deposits of the Zalas area was also mentioned by Barwicz-Piskorz (1989) and Tarkowski (1985).

The most abundant radiolarian assemblages used in the investigations were found in the Wodna 1, Trzebionka 2 and Trzebionka 3 boreholes, as well as in outcrops at Górka, near Trzebinia (Chrzanów region) and at Grojec, southwest of Krzeszowice (Fig. 1B). Less abundant assemblages have been noted in the exposures situated north of Krzeszowice, such as Czatkowice, Paczółtowice and Racławice.

The analysed material gave rise to biostratigraphical, palaeoecological and palaeogeographical considerations on the distribution of the radiolarian assemblages in Jurassic epicontinental deposits of the Kraków–Wieluń Upland.

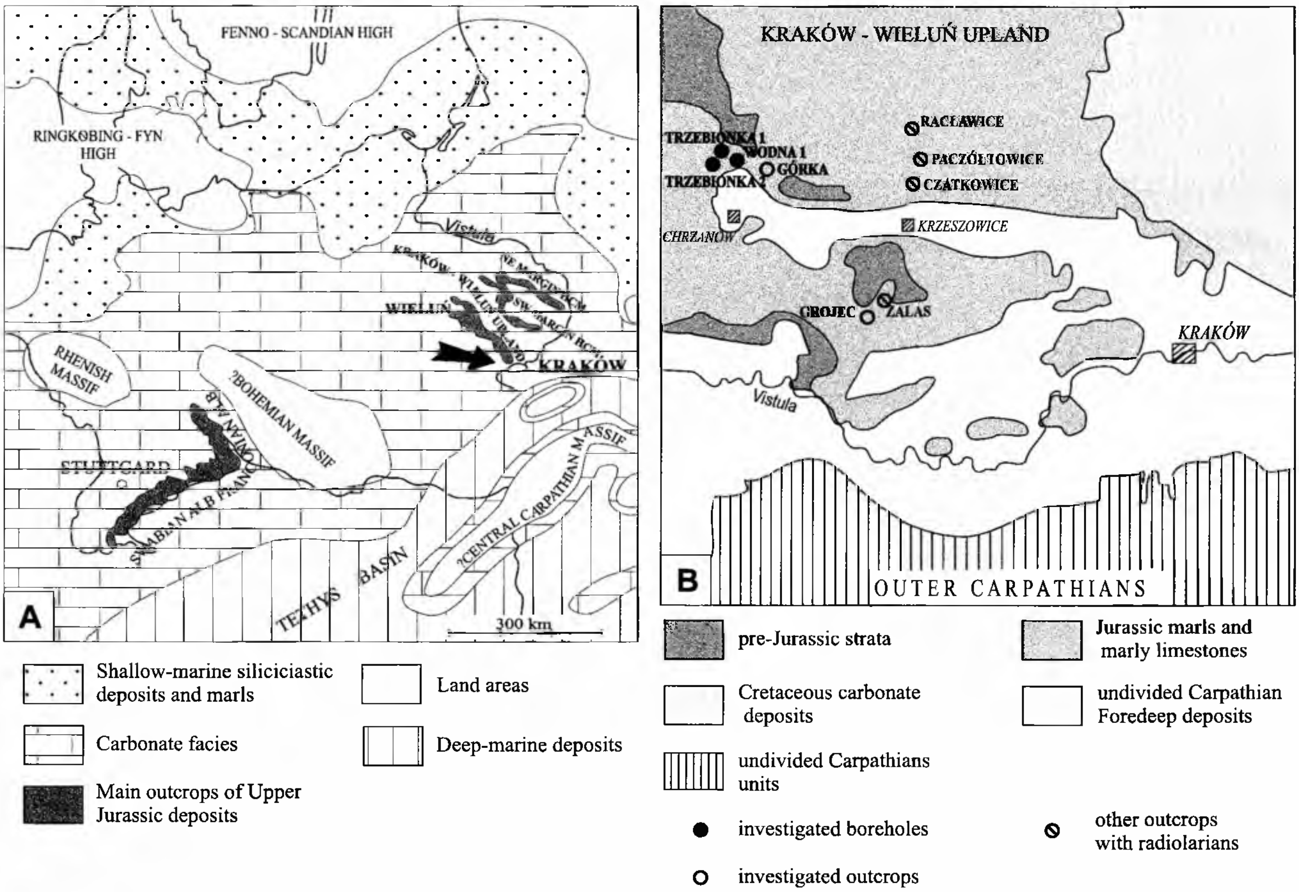

Fig. 1. **A.** Main outcrops of Upper Jurassic deposits related to palaeogeographical map of the central part of northern, stable Tethyan shelf in the Oxfordian (after Ziegler, 1990; modified). **B.** Location of the boreholes and outcrops in the Chrzanów and Krzeszowice area of the Kraków–Wieluń Upland (geological map after Żytko *et al.*, 1988; simplified)

GEOLOGICAL SETTING

Initial lithostratigraphical, biostratigraphical and palaeontological investigations of the Kraków–Wieluń Upland were conducted by Siemiradzki (1891), Wójcik (1910) and Wiśniowski (1890). A detailed stratigraphical and sedimentological analysis of the studied deposits has been given by Różycki (1953). Macrofaunal biostratigraphy (*sensu* Różycki, 1953) was established by Malinowska (1958, 1991) and foraminiferal biostratigraphy – by Bielecka (1956, 1960) for the Chrzanów region, and by Wiśniowski (1890) for the Grojec area. The biostratigraphy of the studied deposits is based on the standard ammonitic zones (Fig. 2).

The uppermost Callovian deposits (*Q. lamberti* Zone) are represented by grey, clayey marls with glauconite, approximately 9 m thick in the vicinity of Chrzanów (Fig. 3). They contain numerous ammonites accompanied by belemnites, bivalves, fragments of echinoids, sponge spicules, foraminifers, rare ostracods and abundant radiolarians. The Upper Callovian deposits are overlain with continuity by the Lower Oxfordian rocks. The *Q. mariae* Zone is composed of clayey marls with glauconite, 3–6 m in thickness. These deposits contain guide ammonites and sponge spicules, foraminifers, skeletal fragments of echinoids and rare radiolarians. Grey, clayey marls of the lowermost Oxfordian pass

STAGE	ZONE
LOWER OXFORDIAN	*Cardioceras cordatum*
	Quenstedtoceras mariae
UPPER CALLOVIAN	*Quenstedtoceras lamberti*

Fig. 2. Standard ammonite zonation of the Upper Callovian and Lower Oxfordian

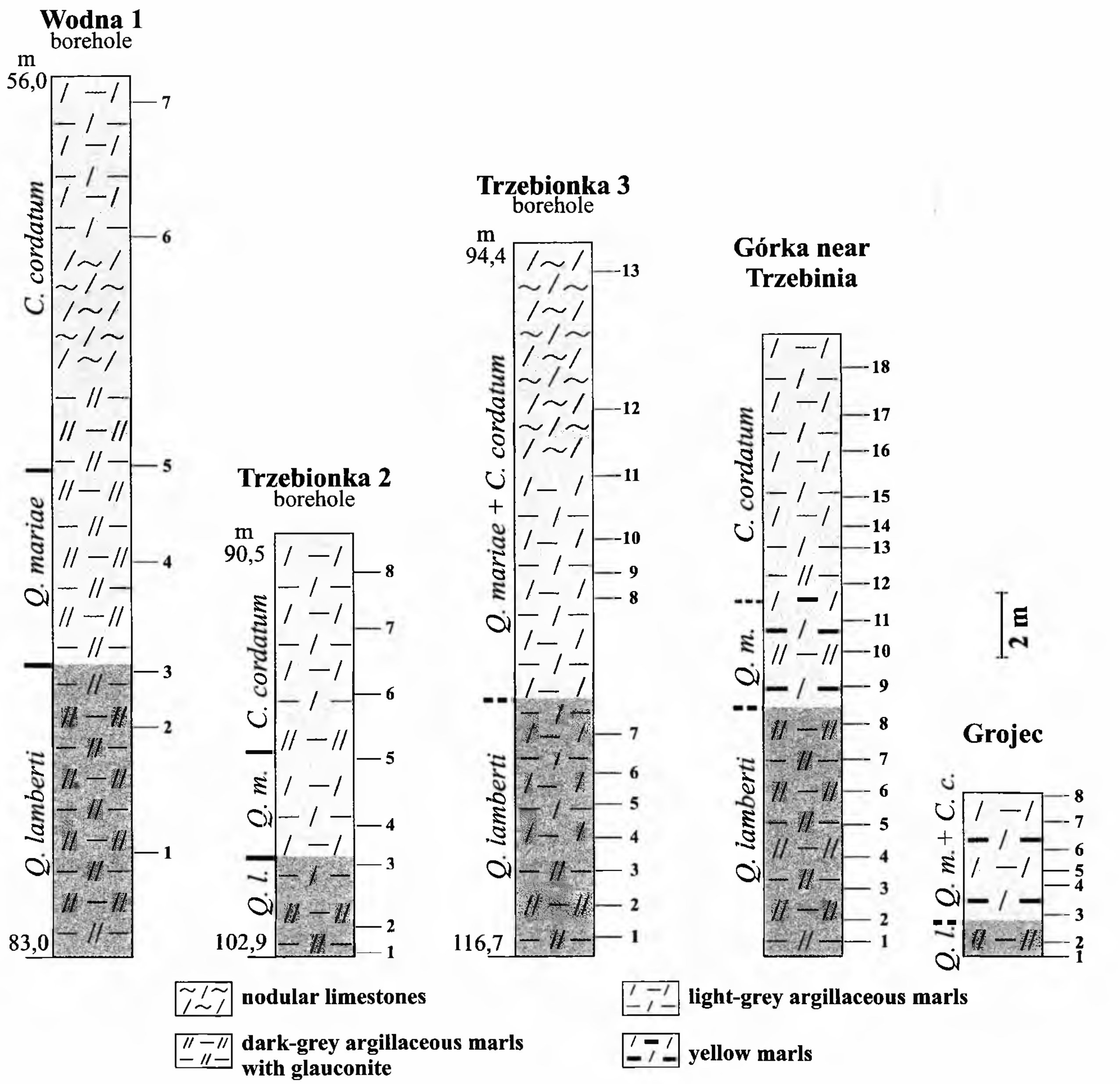

Fig. 3. Lithostratigraphical profiles of the studied sections in the Kraków–Wieluń Upland (after Malinowska, 1991; Różycki, 1953), with the positions of the radiolarian samples. *Q. l* – *Quenstedtoceras lamberti* Zone (grey background of signatures); *Q. m* – *Quenstedtoceras mariae* Zone; *C. c* – *Cardioceras cordatum* Zone. Scale bar – the same for all profiles

upwards into light-grey marls, marly limestones and nodular limestones (Fig. 3) of the upper part of the *C. cordatum* Zone (Lower Oxfordian), containing numerous ammonites and sponge spicules, accompanied by radiolarians and foraminifers with a typical Tethyan species of *Globuligerina oxfordiana* (Grigelis).

Deposits of the *Q. lamberti* Zone (Upper Callovian) and the lowermost *Q. mariae* Zone (Lower Oxfordian) in the vicinity of Krzeszowice (Grojec outcrop) are highly condensed to arourid 3 m in thickness (Fig. 3). The Upper Callovian is represented by grey, clayey marls with phosphorites, containing ammonites, foraminifers, ostracods, skeletal fragments of echinoids and radiolarians. These rocks are overlain by Lower Oxfordian yellow marls with phosphorites and rare fossils. Light-grey marls, locally with glauconite, interbedded with nodular limestones and marly limestones, representing the *C. cordatum* Zone occur in the highest part of the section (Fig. 3). These rocks contain abundant ammonites, foraminifers, sponge spicules and fragments of other macrofauna. The light-grey marls have yielded plenty of radiolarians.

METHODS

Material for this study was taken from archived samples collected by Bielecka for the study of foraminifers (Bielecka, 1960). Fifty-four samples from three boreholes and two outcrops were used for the study of the radiolarian assemblages. Seven samples were studied from borehole

Stratigraphy / Radiolarian taxa	UPPER CALLOVIAN	LOWER OXFORDIAN
	Q. lamberti	*Q. mariae + C. cordatum*
	Assemblage I	Assemblage II
Gongylothorax sp. aff. *G. favosus* Dumitrica	—	
Zhamoidellum ventricosum Dumitrica	—	– (in part)
Zhamoidellum sp.	—	
Stichocapsa convexa Yao	—	
Stichocapsa sp.	—	– (in part)
Sethocapsa sp.	—	
Williriedellum cf. *carpathicum* Dumitrica	—	
?*Williriedellum* sp.	—	
Tricolocapsa undulata (Heitzer)	—	– (in part)
Tricolocapsa sp.	—	– (in part)
Triactoma blakei (Pessagno)	—	—
Podobursa cf. *triacantha* (Fischli)	—	
Podobursa sp. A	—	
Orbiculiforma sp.	—	—
Emiluvia cf. *orea* Baumgartner	—	
Praeconocaryomma sp.	—	—
Archaeodictyomitra (?) *amabilis* Aita	—	
Acaeniotyle sp.	—	
Obesacapsula morroensis Pessagno	—	– (in part)
Higumastra cf. *wintereri* Baumgartner	—	
Transhsuum maxwelli gr. (Pessagno)	—	—
Transhsuum brevicostatum (Ozvoldova)	—	
Radiolaria gen. et sp. indet.	—	
Archaeocenosphaera sp.	—	—
Archaeospongoprunum imlayi Pessagno		—
Tripocylia sp.		—
Triactoma sp.		—
Podobursa sp. B		—
Paronaella mulleri Pessagno		—
Paronaella sp. A		—
Paronaella sp. B		—
Paronaella cf. *pygmaea* Baumgartner		—
Angulobracchia sp.		—
Crucella theokaftensis Baumgartner		—
Mirifusus sp.		—
Stichomitra sp.		—
Homoeoparonaella (?) *gigantea* Baumgartner		—
Emiluvia sp.		—
Higumastra sp.		—
Podocapsa amphitreptera Foreman		—

Fig. 4. Distribution of the radiolarian species in samples studied

Wodna 1, eight from borehole Trzebionka 2 and thirteen from borehole Trzebionka 3. Eighteen samples were taken from outcrop Górka near Trzebinia and eight from Grojec outcrop (Fig. 3). Bielecka (1960) gives a detailed description of methods. Radiolarians were separated together with other microfauna (foraminifers, ostracodes, sponge spicules) after disintegration of rocks using Glauber's salt and sieving trough 0.1 mm mesh. Data on the occurrence of foraminifers, ostracodes and sponge spicules used in this paper may be found in Bielecka (1960; tables XI, XII and XIII) and in Wiśniowski (1890). The radiolarians studied here have been selected from the residuum left after selecting foraminifers. The samples are stored at the Micropaleontology Archive of the Polish Geological Institute in Warsaw.

RADIOLARIAN ASSEMBLAGES

Forty species of radiolaria have been determined in the studied material (Fig. 4). The radiolarian tests reveal mechanical damage (broken spicules) and traces of recrystallization and are calcified to a variable degree which renders their precise taxonomic identification impossible in many cases. Two radiolarian assemblages (assemblage I and II) have been distinguished on the grounds of vertical distribution of radiolarians in the studied sections. They differ significantly in their species compositions (Figs 5–9). Assemblage I occurs in Upper Callovian grey argillaceous marls with glauconite (*Q. lamberti* Zone). This assemblage was found in all samples from the studied boreholes and outcrops, both in the Chrzanów area (boreholes Wodna 1,

Samples / RADIOLARIA	UPPER CALLOVIAN							LOWER OXFORDIAN										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NASSELLARIA																		
Gongylothorax sp. aff. *G. favosus*	▬	▬	▬	▬	▬	—	—											
Zhamoidellum ventricosum	▬	▬	▬	▬	▬	—	—	—	•	•								
Zhamoidellum sp.	—	—	—	—	—	—												
Stichocapsa convexa	▬	▬	▬	▬	▬	▬	•											
Stichocapsa sp.	—	—	—	—	—	—	—	-	—	—	—							
Williriedellum cf. *carpathicum*	▬	▬	—	—	▬	▬												
Williriedellum sp.	—	—	—	—	•	•	•											
Tricolocapsa undulata	—	—	—	—	—	—	—	-	—	—	—							
Tricolocapsa sp.	•		•	•				•			•							
Archaeodictyomitra (?) *amabilis*		•				•												
Transhsuum maxwell gr.	—	—	—	—	—	—	—	•	•	•	•				•		•	
Transhsuum brevicostatum	▬	▬	▬	▬	▬	▬	—											
Podobursa ct. *triacantha*	—	•	•	•		•	•											
Podobursa sp. A	•	•	•	•	•	•	•											
Podobursa sp. B											•	•			•	•	•	
Podocapsa amphitreptera																		
Obesacapsula morroensis					•	•												
Mirifusus sp.																		
Stichomitra sp.																		
Sethocapsa sp.																		
SPUMELLARIA																		
Orbiculiforma sp.	▬	▬	▬	—	—	▬	—	•	•	•	•	•			—	—	—	
Higumastra cf. *wintereri*	•					•												
Higumastra sp.																		
Triactoma blakei	—	—	—	—	•	—									•		—	
Triactoma sp.								•	•						•		•	
Archeocenosphaera sp.	—	•		•	•	•		—	—	•	—	•			—	—	—	•
Acaeniotyle sp.	•																	
Praeconocaryomma sp.	—	—	—	—	•	—		•							•		•	
Tripocylia sp.															•		•	
Paronaella mulleri																		
Paronaella sp. A								•	•									
Paronaella sp. B								•	•							•	•	•
Paronaella cf. *pygmaea*								•										
Angulobracchia sp.																		
Crucella theokaftensis																		
Emiluvia cf. *orea*	•	•																
Homoeoparonaella (?) *gigantea*																		
Archaeopongoprunum imlayi																		
Emiluvia sp.																•	•	
Radiolaria gen. et sp. ident.						•												

number of the specimens: ▬ 21 - 40; — 6 - 20; • 1 - 5

Fig. 5. Occurrence and frequency of the radiolarian species at Górka near Trzebinia outcrop

Trzebionka 2, Trzebionka 3 and outcrop Górka near Trzebinia) and in the Krzeszowice area (outcrop Grojec). Number of specimens in individual sections vary from about 50 to about 400 specimens per sample. The richest associations have been found in outcrop Górka near Trzebina (samples 1–7; Fig. 5). Samples from boreholes Wodna 1, Trzebionka 2 and Trzebionka 3 include similar radiolarian associations, both in number of specimens and in species composition (Figs 6–8). A smaller amount of radiolarians has been found only in outcrop Grojec (samples 1, 2; Fig. 9).

Assemblage I is mostly composed of spherical, oval, conical and discoidal radiolarians (Figs. 10–12). Eighty percent of them belong to the suborder Nassellaria, represented by species of six families and ten genera: Williriedellidae (genera: *Williriedellum*, *Zhamoidellum*, *Tricolocapsa*), Archaeodictyomitridae (genera: *Archaeodictyomitra*, *Transhsuum*), Theoperidae (genus *Stichocapsa*), Amphipyndacidae (genus *Podobursa*), Sethocapsidae (genera: *Gongylothorax, Sethocapsa*) and Spongocapsulidae (genus *Obesacapsula*). Three families and seven genera have been identified amongst Spumellaria (20% of all specimens). The greatest number of specimens belongs to family Orbiculiformidae, most of them to genus *Orbiculiforma* and single individuals to genera *Higumastra* and *Emiluvia*. From Spumellaria, families Xiphostylidae (genera: *Triactoma, Archaeocenosphaera*) and Leugeonidae (genera: *Acaeniotyle*, *Praeconocaryomma*) were observed. Assemblage I is characterised by occurrence of many individuals (about 40 in sample) of the following species: *Stichcapsa convexa* Yao, *Williriedellum* cf. *carpathicum* Dumitrica, *Zhamoidellum ventricosum* Dumitrica, *Gongylothorax* sp. aff. *G. favosus* Dumitrica and *Transhsuum brevicostatum* (Ozvoldova) (Figs 5–8).

Assemblage II is associated with the deposits of ammonitic zones *Q. mariae* and *C. cordatum* (Lower Oxfordian). The most numerous associations of assemblage II

Samples / RADIOLARIA	UPPER CALLOVIAN			LOWER OXFORDIAN				
	1	2	3	4	5	6	7	8
NASSELLARIA								
Gongylothorax sp. aff. *G. favosus*	▬	▬	▬					
Zhamoidellum ventricosum	▬	▬	—	—				
Zhamoidellum sp.	—	—	—					
Stichocapsa convexa	▬	▬	—					
Stichocapsa sp.	—	—	—	—				
Williriedellum cf. *carpathicum*	▬	▬	—					
Williriedellum sp.	—	—	—					
Tricolocapsa undulata	—	—	—	—	•	•		
Tricolocapsa sp.	•				•			
Archaeodictyomitra (?) *amabilis*								
Transhsuum maxwell gr.	—	•	•	•	•	•	•	•
Transhsuum brevicostatum	▬	—	•					
Podobursa ct. *triacantha*	•	•						
Podobursa sp. A	•		•					
Podobursa sp. B				•	•	•		
Podocapsa amphitreptera								
Obesacapsula morroensis								
Mirifusus sp.								
Stichomitra sp.					•	•		
Sethocapsa sp.	•							
SPUMELLARIA								
Orbiculiforma sp.	▬	▬	—	—	•	•		
Higumastra cf. *wintereri*								
Higumastra sp.					•			
Triactoma blakei	—	•	—	•	•	•	•	
Triactoma sp.						•	•	•
Archeocenosphaera sp.	—	—	—	—	•			
Acaeniotyle sp.								
Praeconocaryomma sp.	—	—	—	•				
Tripocylia sp.						•	•	
Paronaella mulleri								
Paronaella sp. A						•	•	
Paronaella sp. B								
Paronaella cf. *pygmaea*						•	•	
Angulobracchia sp.								
Crucella theokaftensis							•	•
Emiluvia cf. *orea*								
Homoeoparonaella (?) *gigantea*					•			
Archaeopongoprunum imlayi					•			
Emiluvia sp.					•		•	•
number of the specimens	▬ 21 - 40; — 6 - 20; • 1 - 5							

Fig. 6. Occurrence and frequency of the radiolarian species at Trzebionka 2 borehole

Samples / RADIOLARIA	UPPER CALLOVIAN			LOWER OXFORDIAN			
	1	2	3	4	5	6	7
NASSELLARIA							
Gongylothorax sp. aff. *G. favosus*	▬	—	—				
Zhamoidellum ventricosum	▬	—	▬				
Zhamoidellum sp.	—	•	•	•	•		
Stichocapsa convexa	▬	—	•				
Stichocapsa sp.	—	•	—	•	•		
Williriedellum cf. *carpathicum*	▬	—	—				
Williriedellum sp.	—	•	•				
Tricolocapsa undulata	—	•	—	•	•		
Tricolocapsa sp.	•	•	•				
Archaeodictyomitra (?) *amabilis*							
Transhsuum maxwell gr.	—	•	—	•	•		
Transhsuum brevicostatum	▬	—	—				
Podobursa ct. *triacantha*	—	•	—				
Podobursa sp. A	•	•	•				
Podobursa sp. B				•	•		
Podocapsa amphitreptera					•		
Obesacapsula morroensis							
Mirifusus sp.							
Stichomitra sp.					•		
Sethocapsa sp.	•						
SPUMELLARIA							
Orbiculiforma sp.	▬	—	—	•	•		•
Higumastra cf. *wintereri*							
Higumastra sp.							•
Triactoma blakei	—	•	—				
Triactoma sp.					•		
Archeocenosphaera sp.	—		•	•	•		•
Acaeniotyle sp.							
Praeconocaryomma sp.	—	—	—	•	•		
Tripocylia sp.					•		
Paronaella mulleri							
Paronaella sp. A					•		
Paronaella sp. B				•			
Paronaella cf. *pygmaea*							
Angulobracchia sp.							
Crucella theokaftensis					•		•
Emiluvia cf. *orea*	•						
Homoeoparonaella (?) *gigantea*					•		
Archaeopongoprunum imlayi					•		
Emiluvia sp.					•		•
number of the specimens	▬ 21 - 40; — 6 - 20; • 1 - 5						

Fig. 7. Occurrence and frequency of the radiolarian species at Wodna 1 borehole

have been found near Krzeszowice, in outcrop Grojec. Numbers of specimens per sample vary from about 40 (samples 4–6; Fig. 9) to about 300 (samples 3, 7, 8; Fig. 9). In the Chrzanów area (boreholes Wodna 1, Trzebionka 2, Trzebionka 3) number of specimens in individual samples are small (from a few to about 100), similarly as in outcrop Górka near Trzebinia (Figs 5–8).

This assemblage contains mostly specimens of spongy radiolarians, multi-rayed and discoidal in shape, of which 70% belongs to the suborder Spumellaria (Fig. 13). Amongst Spumellaria, there are species belonging to 6 families and 12 genera: Xiphostylidae (genera: *Tripocylia*, *Archaeocenosphaera*, *Triactoma*), Orbiculiformidae (genera: *Orbiculiforma*, *Crucella*, *Emiluvia*, *Higumastra*), Sponguridae (genus *Archaeospongoprunum*), Tritrabidae (genus *Homoeoparonaella*), Leugeonidae (genus *Praeconocaryomma*) and Patulibracchidae (genera: *Paronaella*, *Angulobracchia*). Suborder Nassellaria is represented by 6 families and 9 genera: Williriedellidae (genera: *Zhamoidellum*, *Tricolocapsa*), Theoperidae (genus *Stichocapsa*), Parvicingulidae (genus *Mirifusus*), Amphipyndacidae (genera: *Podobursa, Podocapsa*), Spongocapsulidae (genus: *Obesacapsula*) and Archaeodictyomitridae (genera: *Transhsuum, Stichomitra)*. The most commonly represented species are *Paronaella mulleri* Pessagno (Fig. 13A), *Crucella theokaftensis* Baumgartner (Fig. 13J) and others belonging to the genera *Paronaella*, *Higumastra*, *Tripocylia*, *Podobursa* and *Orbiculiforma* (Fig. 13).

AGE OF THE RADIOLARIAN ASSEMBLAGES

Assemblage I was identified in deposits dated by ammonites as the uppermost Upper Callovian, *Q. lamberti* Zone. This zone was documented in the Wodna 1 and Trze-

Samples / RADIOLARIA	UPPER CALLOVIAN							LOWER OXFORDIAN					
	1	2	3	4	5	6	7	8	9	10	11	12	13
NASSELLARIA													
Gongylothorax sp. aff. *G. favosus*	▬	▬	▬	—	▬	—	—						
Zhamoidellum ventricosum	▬	▬	—	—	—	—	—		•	•			
Zhamoidellum sp.	—	—	—	—	—	•	•						
Stichocapsa convexa	▬	▬	▬	▬	—	—	•						
Stichocapsa sp.	—	—	—	—	•	•	•	•	•	•	•		
Williriedellum cf. *carpathicum*	▬	▬	—	—	•	•							
Williriedellum sp.	—	—	—	•	—	—	•						
Tricolocapsa undulata	—	—	—	—	•	•	—	•		—	•		
Tricolocapsa sp.	•			•									
Archaeodictyomitra (?) *amabilis*				•									
Transhsuum maxwell gr.	—	—	—	—	•	—	•	•			•		•
Transhsuum brevicostatum	—	—	—	—	—	—	—						
Podobursa ct. *triacantha*	•	•	•	•	•	•	•						
Podobursa sp. A	•	•		•		•							
Podobursa sp. B										•	•		
Podocapsa amphitreptera									•		•		
Obesacapsula morroensis						•							
Mirifusus sp.													
Stichomitra sp.									•	•			
Sethocapsa sp.													
SPUMELLARIA													
Orbiculiforma sp.	▬	▬	▬	—	▬	—	—	—	•	—	—		•
Higumastra cf. *wintereri*						•							
Higumastra sp.													
Triactoma blakei	—	—	—	•	—	•							
Triactoma sp.									•	•	•		
Archeocenosphaera sp.	—	•		•	•	•	•	•	•	•			•
Acaeniotyle sp.	•												
Praeconocaryomma sp.	•	•		•	•	•	•	•	•				
Tripocylia sp.									•	•			
Paronaella mulleri													
Paronaella sp. A								•	•				
Paronaella sp. B									•	•	•		
Paronaella cf. *pygmaea*													
Angulobracchia sp.													
Crucella theokaftensis											•		
Emiluvia cf. *orea*		•											
Homoeoparonaella (?) *gigantea*										•			
Archaeopongoprunum imlayi													
Emiluvia sp.									•	•			•
Radiolaria gen. et sp. ident.													
number of the specimens	▬ 21 - 40; — 6 - 20; • 1 - 5												

Fig. 8. Occurrence and frequency of the radiolarian species at Trzebionka 3 borehole

bionka 2 boreholes (Malinowska, 1991). Assemblage I was also encountered in the lower part of the *Quenstedtoceras* Beds in the Trzebionka 3 borehole and at the Górka outcrop. At the Grojec outcrop, assemblage I occurs only in the lowermost part of the section, within grey clayey marls of the *Q. lamberti* Zone.

Assemblage II belongs to the Lower Oxfordian on the basis of the correlations with the *Q. mariae* and *C. cordatum* ammonite zones, documented in the Wodna 1 and Trzebionka 2 boreholes (Malinowska, 1991) and at the Grojec outcrop (Różycki, 1953). The most numerous specimens within assemblage II have been observed in light-grey marls of the *C. cordatum* Zone at the Grojec outcrop. Assemblage II is similar to assemblages described from the other Lower Oxfordian sites in Southern Poland. Górka & Bąk (2000) identified a similar radiolarian assemblage in deposits of the *C. cordatum* Zone (*cordatum* Subzone) at Zalas (Kraków Upland). Almost identical radiolarian assemblage from the deposits of the *cordatum* Zone of the boreholes drilled in the Częstochowa – Zawiercie region was also cited by Smoleń (1998).

The studied radiolarian assemblages could be also correlated with the Unitary Association Zones (U.A.Z.), established for the Tethyan Province (Baumgartner *et al.*, 1995). Such a correlation is somewhat difficult due to both, a small number of species in the samples studied by the present author and strong calcification of the radiolarian tests which makes the taxonomical identification difficult. Radiolarian assemblages I and II include the forms occurring within the U.A.Z. 8, dated as the Middle Callovian through the Early Oxfordian. Assemblage I differs significantly from assemblage II in its species contents.

Archaeodictyomitra (?) *amabilis* Aita (Fig. 12F) that occurs only in assemblage I, is known from the Middle Jurassic of the Tethys (U.A.Z. 7 according to Baumgartner *et al.*, 1995 correlated with the Late Bathonian through Early

Samples / RADIOLARIA	UPPER CALLOVIAN		LOWER OXFORDIAN					
	1	2	3	4	5	6	7	8
NASSELLARIA								
Gongylothorax sp. aff. *G. favosus*	—	—						
Zhamoidellum ventricosum	—	—	•					
Zhamoidellum sp.	•	•						
Stichocapsa convexa	•	•						
Stichocapsa sp.			•				•	•
Williriedellum cf. *carpathicum*	—	—						
Williriedellum sp.								
Tricolocapsa undulata	•	•	•					
Tricolocapsa sp.		•	•				•	•
Archaeodictyomitra (?) *amabilis*								
Transhsuum maxwell gr.	•	•	—	•	•		—	
Transhsuum brevicostatum	—	—						
Podobursa ct. *triacantha*	•							
Podobursa sp. A	•							
Podobursa sp. B					•		—	—
Podocapsa amphitreptera			•			•	•	•
Obesacapsula morroensis			•					
Mirifusus sp.			•					
Stichomitra sp.			•	•			•	•
Sethocapsa sp.		•						
SPUMELLARIA								
Orbiculiforma sp.	—	—	▬	—	•	•	▬	▬
Higumastra cf. *wintereri*								
Higumastra sp.			▬	•	•	•	▬	▬
Triactoma blakei	•		—				—	—
Triactoma sp.			—	•	•		—	—
Archeocenosphaera sp.	—	—	—	—	—	•	—	—
Acaeniotyle sp.								
Praeconocaryomma sp.	•	•	—	•			•	•
Tripocylia sp.			—	•		•	—	—
Paronaella mulleri			—				▬	▬
Paronaella sp. A			—		•	•	•	—
Paronaella sp. B			—			•	—	•
Paronaella cf. *pygmaea*			—	•	•		•	•
Angulobracchia sp.			•	•			•	•
Crucella theokaftensis			▬	•		•	▬	▬
Emiluvia cf. *orea*								
Homoeoparonaella (?) *gigantea*			•				•	•
Archaeopongoprunum imlayi			•				•	•
Emiluvia sp.			—				—	—
number of the specimens	▬ 21 - 40; — 6 - 20; • 1 - 5							

Fig. 9. Occurrence and frequency of the radiolarian species at Grojec outcrop

Callovian). Other species of this assemblage include: *Zhamoidellum ventricosum* Dumitrica (Fig. 10F) and *Williriedellum carpathicum* Dumitrica (Fig. 10I), which for the first time appear in the U.A.Z. 8 (Middle Callovian through Early Oxfordian). The coexistence of these species proves the Callovian age of assemblage I. Similar associations of spherical and conical Nassellaria have been most frequently observed in radiolarite deposits and beds with radiolarians of the Tethyan Province, which correspond to the U.A.Z. 7 and the lower part of the U.A.Z. 8. They have been described from the Western Carpathians of Slovakia (Aubrecht & Ožvoldová, 1994; Ožvoldová, 1992; Ožvoldová, 1998; Mock *et al.*, 1998; Polák & Ondrejičková, 1993; Rakús & Ožvoldová, 1999).

Similar radiolarian assemblages are also known from radiolarites of Romania (Dumitrica, 1970), Austria (Ožvoldová & Faupl, 1993) and northern Greece (Danelian *et al.*, 1996). A few species have also been noted in radiolarites of the Pieniny Klippen Belt of Poland (Widz, 1991; Birkenmajer & Widz, 1995).

In terms of species composition, assemblage II is most similar to the assemblages cited from the Tethys and representing the upper part of the U.A.Z. 8 and the U.A.Z. 9 (Middle Oxfordian) and U.A.Z. 10 (Upper Oxfordian through Lower Kimmeridgian). Such assemblages have been identified in radiolarians-rich deposits of the Western Carpathians of Slovakia (e.g., Mišik *et al.*, 1991; Ožvoldová *et al.*, 2000; Schlögl *et. al.*, 2000). In Poland, they are known from the Pieniny Klippen Belt (Widz, 1991; Birkenmajer & Widz, 1995).

The well documented stratigraphic position of both radiolarian assemblages allows to state that radiolarian assemblage I is characteristic of the Middle Jurassic, whereas assemblage II is typical of the Oxfordian (Upper Jurassic). It confirms the results of investigations made by Ožvoldová (Ožvoldová *et al.*, 2000) who observed (probably in Lower Oxfordian deposits), a change in the character of radiolarian faunas within the Tethyan U.A.Z. 8.

PALAEOECOLOGICAL AND PALAEOGEOGRAPHICAL REMARKS

At the Late Jurassic, the Kraków–Wieluń area was covered by an epicontinental sea with carbonate sedimentation (Fig. 1A). The uppermost Callovian (*Q. lamberti* Zone) and Lower Oxfordian (*Q. mariae* Zone) are represented by argillaceous marls. In the *C. cordatum* Zone, the effects of elevation differences on the basin floor and facies diversity are observed (Matyszkiewicz, 1999). Generally, the "*normal facies*" (marls, marly limestones and bedded limestones) and "*microbolitic facies*" – "*sponge megafacies*" are distinguished in the Oxfordian of the Kraków–Wieluń region. The epicontinental basin was connected with the Tethyan and Atlantic Oceans. This communication was established as a result of Mesozoic rifting along the northern edge of the Western Tethys (Golonka *et. al.*, 2000). According to those authors, smaller oceanic-type basins were formed at that time in the northern part of the Tethys. A very distinct change in lithology, followed by development of pelagic microfacies, with abundant radiolarians and globuligerinids (Wierzbowski *et.al.*, 1999), is observed at the Upper Callovian/Lower Oxfordian transition. The opening of new connections between the Tethys and epicontinental seas caused a change in water circulation and wide migration of Tethyan planktonic faunas onto the shallow-water epicontinental areas.

Radiolarian assemblages described in this paper from the area of the Kraków–Wieluń Upland are useful for palaeogeographical analyses. Marked differences in species composition between assemblage I, occurring in the Upper Callovian, and assemblage II, in the Lower Oxfordian, allow for additional conclusions on parameters of the marine palaeoenvironment.

Distribution of radiolaria in Middle and Late Jurassic times was closely related to climatic zones, providing for provincialism within this group. Four provinces have been distinguished in the Northern Hemisphere, characterised by

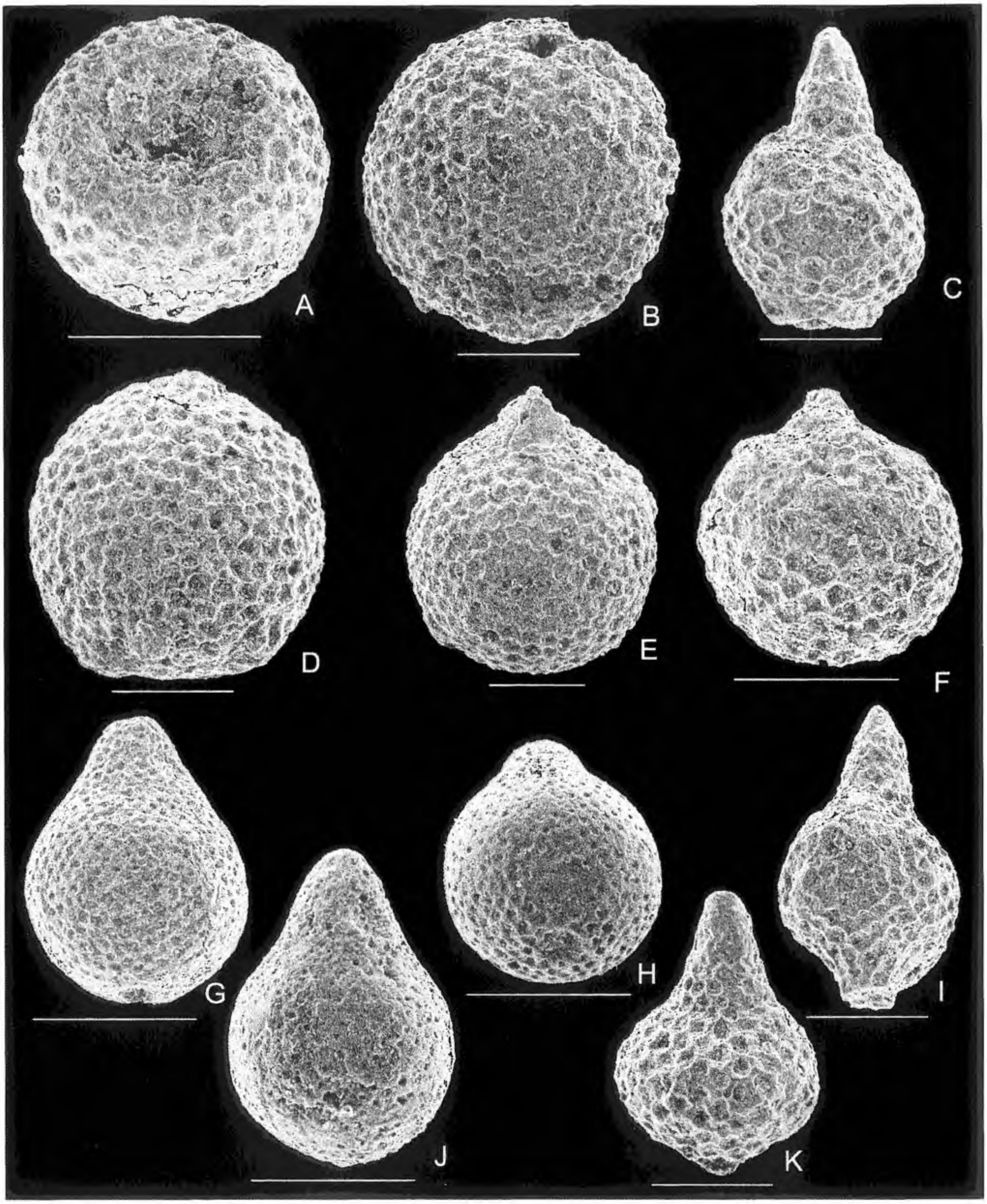

Fig. 10. Upper Callovian radiolarians from the Górka near Trzebinia outrcrop (Kraków–Wieluń Upland) – assemblage I. **A, B** – *Gongylothorax* sp. aff. *G. favosus* Dumitrica (sample 3); **C** – ?*Williriedellum* sp. (sample 4); **D** – *Gongylothorax* sp. aff. *G. favosus* Dumitrica (sample 3); **E** – *Zhamoidellum* sp. (sample 6); **F** – *Zhamoidellum ventricosum* Dumitrica (sample 4); **G, H** – *Stichocapsa convexa* Yao (sample 2); **I** – *Williriedellum* cf. *carpathicum* Dumitrica (sample 2); **J** – *Stichocapsa convexa* Yao (sample 2); **K** – *Stichocapsa* sp. (sample 2). Scale bar – 100 μ

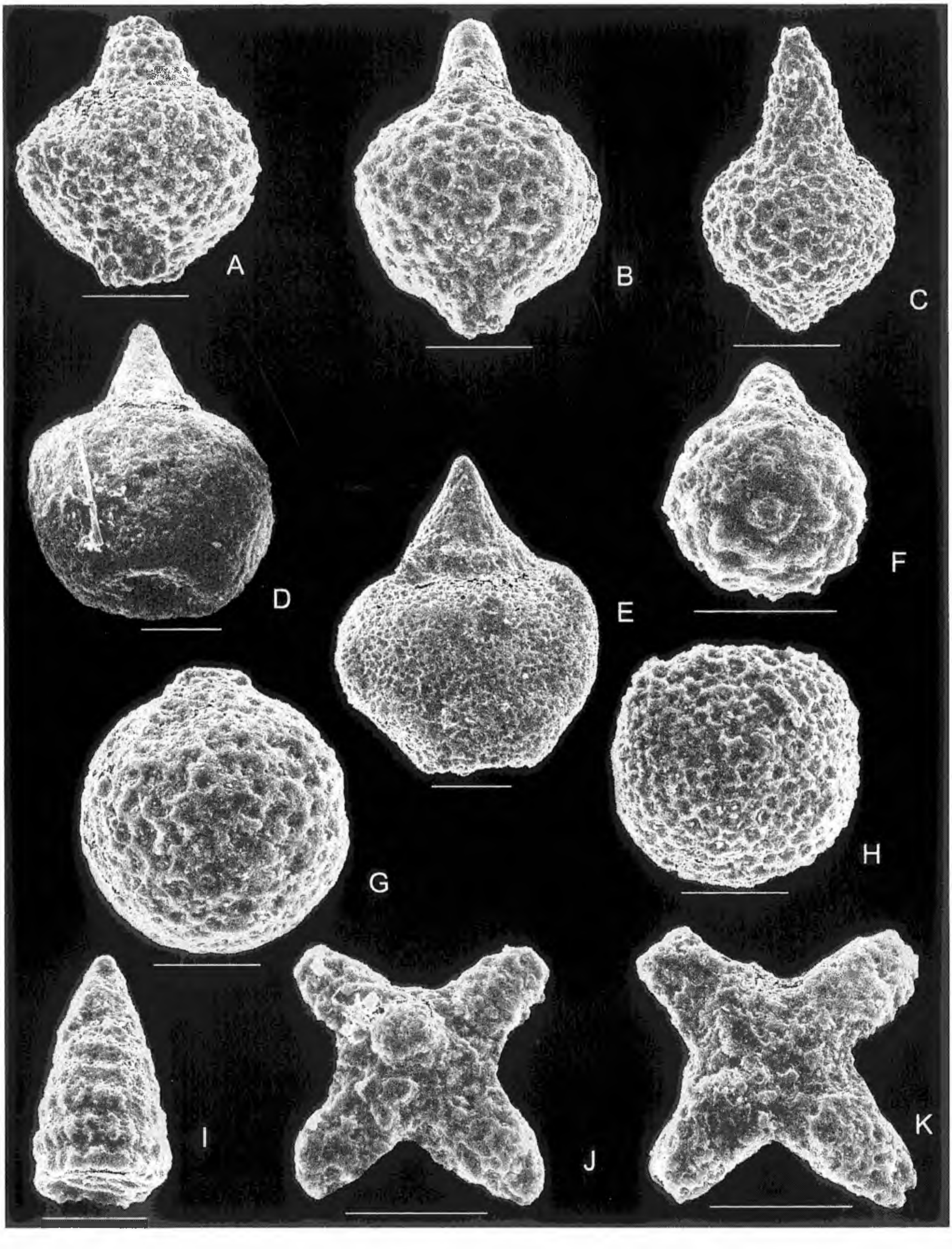

Fig. 11. Upper Callovian radiolarians from the Trzebionka 3 and Wodna 1 boreholes (Kraków–Wieluń Upland) – assemblage I. **A, B** – *Podobursa* cf. *triacantha* (Fischli) (Wodna 1, sample 1); **C** – *Stichocapsa* sp. (Wodna 1, sample 3); **D, E** – *Obesacapsula morroensis* Pessagno (Trzebionka 3, sample 6); **F** – *Tricolocapsa undulata* (Heitzer) (Wodna 1, sample 1); **G** – *Zhamoidellum ventricosum* Dumitrica (Trzebionka 3, sample 2); **H** – *Archaeocenosphaera* sp. (Wodna 1, sample 1); **I** – *Transhsuum maxwelli* gr (Pessagno) (Trzebionka 3, sample 6); **J, H** – *Higumastra* cf. *wintereri* Baumgartner (Trzebionka 3, sample 6). Scale bar – 100 µm

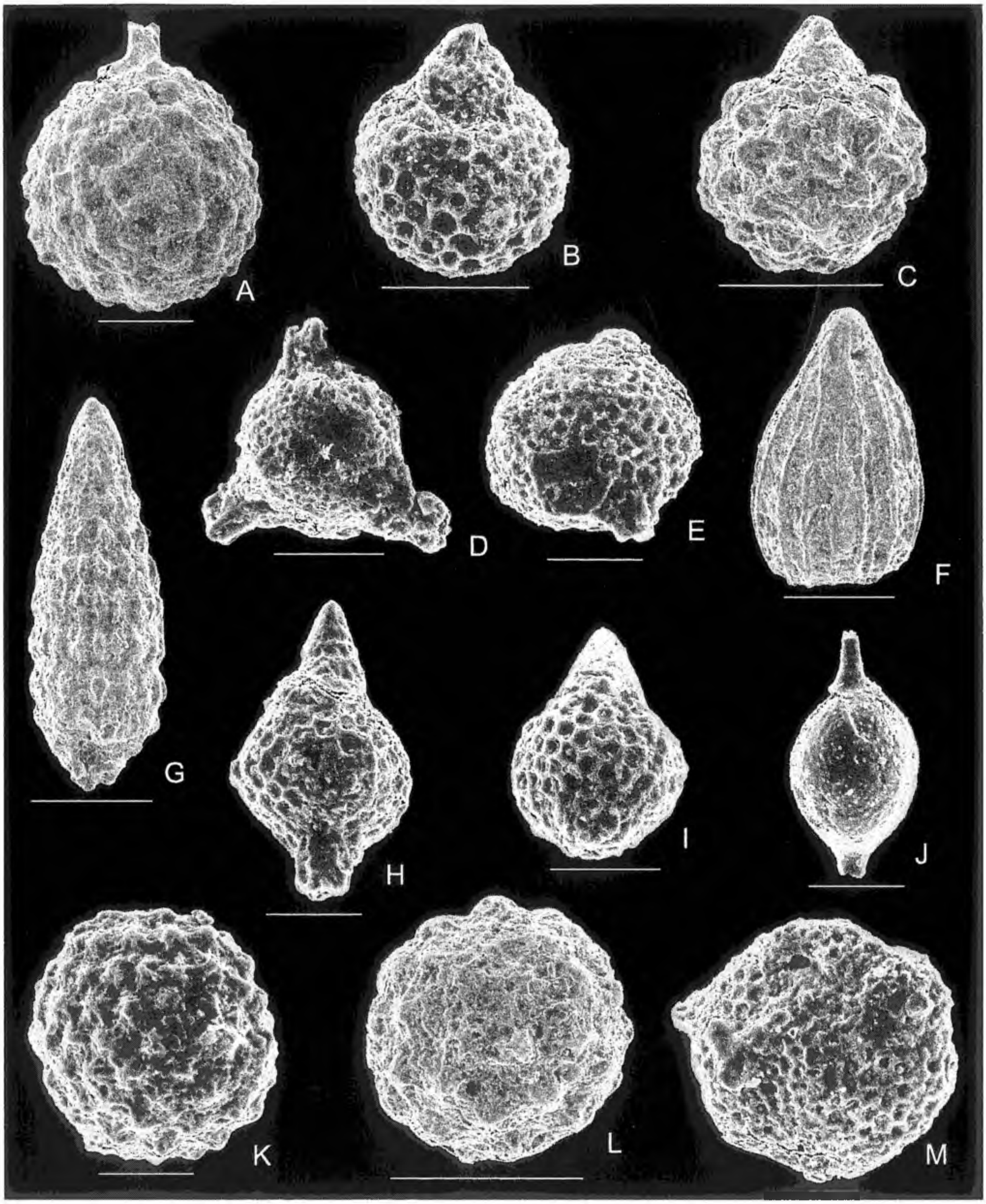

Fig. 12. Upper Callovian radiolarians from the Górka near Trzebinia outrop and from the Trzebionka 3 borehole (Kraków–Wieluń Upland) – assemblage I. **A** – *Emiluvia* cf. *orea* Baumgartner (Górka outcrop, sample 2); **B** – *Tricolocapsa* sp. (Górka outcrop, sample 4); **C** – *Tricolocapsa undulata* (Heitzer) (Trzebionka 3, sample 3); **D** – *Triactoma blakei* (Pessagno) (Trzebionka 3, sample 3); **E** – *Triactoma blakei* (Pessagno) (Górka outcrop, sample 1); **F** – *Archaeodictyomitra* (?) *amabilis* Aita (Trzebionka 3, sample 4); **G** – *Transhsuum brevicostatum* (Ozvoldova) (Górka outcrop, sample 3); **H** – *Podobursa* sp. A (Górka outcrop, sample 4); **I** – *Stichocapsa* sp. (Górka outcrop, sample 6); **J** – Radiolaria gen. et sp. Indet. (Górka outcrop, sample 6); **K, L** – *Praeconocaryomma* sp. (Trzebionka 3, sample 2); **M** – *Orbiculiforma* sp. (Trzebionka 3, sample 3). Scale bar – 100 μm

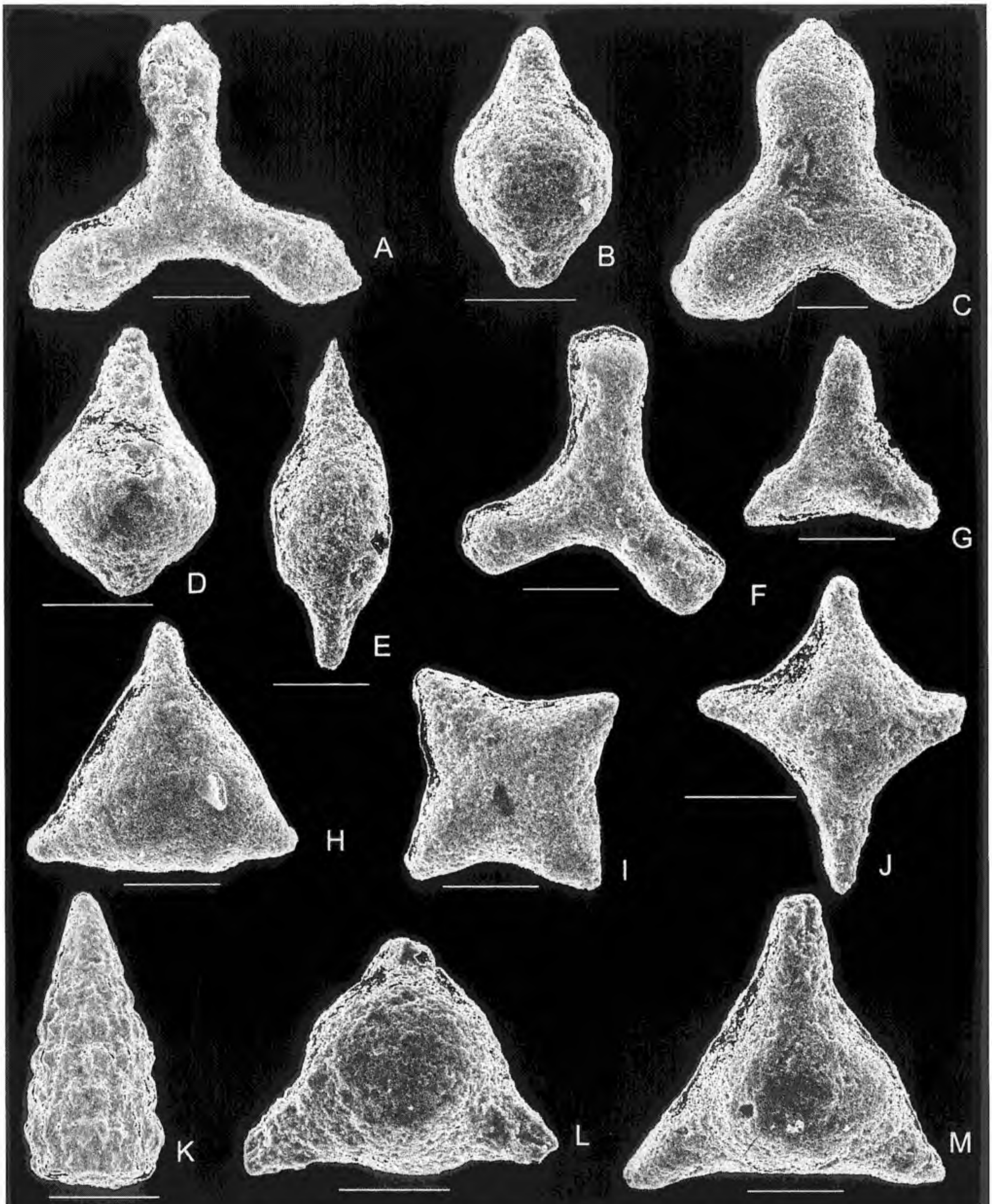

Fig. 13. Lower Oxfordian radiolarians from the Grojec outcrop (Kraków–Wieluń Upland) – assemblage II. **A** – *Paronaella mulleri* Pessagno (sample 7); **B** – *Mirifusus* sp. (sample 3); **C** – *Homoeoparonaella* (?) *gigantea* Baumgartner (sample 7); **D** – *Podobursa* sp. B (sample 3); **E** – *Archaeospongoprunum imlayi* Pessagno (sample 3); **F** – *Angulobracchia* sp. (sample 8); **G** – *Paronaella* cf. *pygmaea* Baumgartner (sample 8); **H** – *Paronaella* sp. A (sample 9); **I** – *Higumastra* sp. (sample 3); **J** – *Crucella theokaftensis* Baumgartner (sample 3); **K** – *Transhsum maxwelli* gr. (Pessagno) (sample 7); **L, M** – *Tripocylia* sp. (sample 7). Scale bar – 100 μm

the presence or lack of the representatives of family Pantanellidae and genera *Parvicingula* and *Praeparvicingula* (Pessagno & Bloom, 1986). These are the Central Tethyan, Northern Tethyan, Southern Boreal and Northern Boreal provinces. In Central Tethyan Province pantanellids are numerous, and representatives of genera *Parvicingula* and *Praeparvicingula* are absent. The Northern Tethyan Province is characterised by the presence of pantanellids and genus *Parvicingula*. In the Southern Boreal Province, pantanellids are infrequent and numerous are *Parvicingula*, while in the Nothern Boreal Province pantanellids are absent and genus *Parvicingula* has abundant representatives.

Assemblage I, distinguished in the studied Upper Callovian sediments, features numerous specimens of nassellarids from families Williriedellidae (genera: *Williriedellum*, *Zhamoidellum*, *Tricolocapsa*), Theoperidae (genus *Stichocapsa*), Sethocapsidae (geneus: *Gongylothorax*), which are numerous in the Central and Northern Tethyan provinces (Baumgartner *et al.*, 1995). This assemblage, however, lacks pantanellids and the parvicingulids of the "*Ristola*" type (genera *Ristola* and *Mirifusus*) which best characterise the Central Tethyan Province (Pessagno & Bloom, 1986; Hull, 1995). Completely absent are also representatives of genera *Parvicingula* and *Praeparvicingula*, characteristic of the areaes situated at high latitudes, where mixed Tethyan-Boreal assemblages are present (Pessagno & Bloom, 1986; Kiessling, 1999). Assemblages I is closest in species composition to coeval assemblages of Northern Tethyan Province described from the West Carpathians in the present-day territory of Slovakia (see preceding chapter). The cryptocephalic and cryptothoracic nassellarians of families Williriedelidae (genera: *Williriedellum*, *Zhamoidellum*, *Tricolocapsa*) and Sethocapsidae (genus *Gongylothorax*) are indicative for Jurassic warm waters at low latitudes, where they lived in deeper zones of open seas (Pessagno & Bloom, 1986; Kiessling, 1999), similarly as in modern assemblages where nassellarians are numerous in warm seas and oceans of tropical and subtropical zones, as an element of deep-dwelling fauna (Casey, 1993).

It may be thus supposed that assemblage I was living in Late Callovian time in sea areas at the margin of the open ocean, in deep neritic or bathyal zones. The basin depth at that time is best indicated by benthic organisms found in sediment together with radiolarian tests. In the assemblages from the studied boreholes and outcrops Bielecka (1960) described rich assemblages of benthic foraminifers (about 40 species), among which dominate representatives of families Vaginulinidae (genera: *Lenticulina*, *Astacolus*, *Planularia*, *Marginulina*) and Nodosariidae (genera: *Dentalina*, *Nodosaria*, *Citharina*). According to literature data, similar foraminiferal assemblages are characteristic of the outer shelf zone to the depth of *ca.* 200 m and sublittoral environment (Gordon, 1970; Stam,1986; Murray, 1991; Olszewska & Wieczorek, 1988). Some genera listed by Bielecka, such as *Lenticulina*, *Dentalina*, *Nodosaria* and *Ophthalmidium*, are also found on continental slopes in typical bathyal zone (Gradstein, 1983).

In assemblage II, in Lower Oxfordian sediments, prevail representatives of suborder Spumellaria with spongy structure of test, especially representatives of families Orbiculiformidae (genera: *Orbiculiforma*, *Crucella*, *Emiluvia*, *Higumastra*) and Patulibracchidae (genera: *Paronaella*, *Angulobracchia*). Spongy spumellaria were cosmopolitan in Early Oxfordian time. They are numerous in sediments from the West Carpathians (e.g., Mišik *et al.*, 1991; Ožvoldová *et al.*, 2000; Schlögl *et. al.*, 2000), but they are also numerous in sediments of the more northern areas, belonging to the Boreal Province (Hull, 1997; Kiessling, 1999). Assemblages II includes also other species from Boreal Province, such as *Archaeospongoprunum imlayi* Pessagno (Fig. 13E) and *Podocapsa amphitreptera* Foreman (Hull, 1995). Totally absent are representatives of typical boreal fauna, that is genera *Parvicingula* and *Praeparvicingula*. On the other hand, assemblage II includes also typical forms of Tethyan nassellarians, e.g. genus *Mirifusus* (single specimens) and representatives of Williriedelidae (genera: *Zhamoidellum*, *Tricolocapsa*) and Theoperidae (genus *Stichocapsa*).

The Lower Oxfordian radiolarian assemblage from the Zalas quarry, similar to assemblage II described in this paper, was identified as boreal fauna with the Tethyan elements by Górka & Bąk (2000). Those authors observed quantitative predominance of representatives of the suborder Spumellaria and spongy forms, as well as the lack of the genera *Mirifusus* and *Ristola*, typical of the Tethyan Province. In my opinion, due to considerable calcification and poor state of preservation of radiolarian tests, accurate taxonomical identification of the specimens is often difficult. Moreover, a small number of genera, resulting probably from transportation-related sorting, means that the lack of the genera mentioned above may be accidental. Genus *Mirifusus* occurs in the Lower Oxfordian assemblage II (Fig. 9) and in the coeval radiolarian assemblage identified in boreholes drilled in the Częstochowa–Zawiercie area (Smoleń, 1998).

Because of proximity to the Tethys and the fact that most radiolarians found in Lower Oxfordian deposits of the Kraków–Wieluń Upland are widespread all over the Central Tethyan and Northern Tethyan Province (Baumgarter *et. al.*,1995), assemblage II can be considered to represent a Northern Tethyan Province association with boreal elements.

Predominance of spongy spumellarians over nassellarians in assemblage II may be related to an Early Oxfordian change in seawater temperature and salinity, caused by mixing of warm Tethyan waters with cold waters from boreal areas. Distribution of spongy spumellarians in modern seas indicates that they are cosmopolitan forms, especially frequent in basins with variable salinity and temperature, preferring shallower environments (Anderson *et al.*, 1989; Blueford & King, 1983; Casey, 1993).

Assemblage II lakcs also representatives of family Pantanellidae which prefer deeper sea zones, more removed from shore. In outcrop Grojec, in *Q. mariae* Zone still occur single deep-dwelling Williriedellidae (genera: *Zhamoidellum*, *Tricolocapsa*) and genus *Mirifusus* (sample 3; Fig. 9), whereas in *C. cordatum* Zone (samples 7 & 8; Fig. 9) increases the predominance of spongy spumellarians that preferred shallower environments. The increase in frequence of spumellarians relative to nassellarians, observed in the

Northern Tethyan Province in Callovian to Late Oxfordian time, has been interpreted as an effect of gradual shallowing of the marine basin (Kiessling, 1996; Ožvoldová *et al.*, 2000). The data presented above indicate that in Early Oxfordian time assemblage II inhabited sublittoral environment of neritic zone. The radiolarian tests in the studied Lower Oxfordian sediments occur together with lithistid sponge spicules, whose amounts increase in the *C. cordatum* Zone (Bielecka, 1960). Sponges, locally forming bioherms, developed in deeper neritic zones to the depths of *ca.* 200 m (Trammer, 1982). Similar depths are indicated by rich assemblages of benthic foraminifers described from the studied sediments (Bielecka, 1960). According to Bielecka, the foraminiferal assemblages in the *Q. mariae* Zone are similar in species composition to the Upper Callovian associations. They are dominated by representatives of genera *Lenticulina*, *Astacolus* and *Epistomina*. In the *C. cordatum* Zone, the foraminiferal assemblage is dominated by genera *Ophthalmidium*, *Spirillina*, *Trocholina* and *Paalzowella*, which are typical of the deeper neritic zones and sponge facies in epicontinental Oxfordian basins (Gradstein, 1983).

The radiolarian assemblages I and II distinguished in the studied sediments are markedly impoverished in species and specimens relative to the Tethyan assemblages. Radiolarian tests are often poorly preserved and bear traces of mechanical damage and recrystallization. These characteristics indicate transport and mechanical sorting. Baumgartner (1987) turns attention to the transport of radiolarians, noting that radiolarians, which made up the main mass the Tethys Ocean plankton could be brought by sea currents to shallower shelf zones. The presence of numerous radiolarians in shelf zones is also known today in areas of upwelling, e.g. at the coasts of California (Casey, 1993).

The palaeogeographical position of the studied area at Late Jurassic time (northern shelf of the Tethys Ocean) suggests that it could be an area where upwellings introduced plankton to shelf zones. Apart from radiolarians, such circulation is indicated in the Lower Oxfordian sediments of the Kraków–Wieluń Upland by the presence of the planktonic foraminifer *Globuligerina oxfordiana* (Grigelis). The extension of this Tethyan foraminifer onto the shelf area has been attributed to the action of upwelling (Riegraf, 1987).

The influence of upwelling in the studied area may be also indicated by the presence of phosphorite concretions and abundant glauconite in the Upper Callovian and lowermost Oxfordian sediments (Różycki, 1953). Palaeoclimatic maps by Golonka and Krobicki (2001) indicate that in Late Jurassic times the pattern of wind directions induced water mass circulation that favoured upwelling in the Northern Tethys.

CONCLUSIONS

Two radiolarian assemblages, differing markedly in their species contents, I and II, have been identified in Callovian and Oxfordian deposits in the boreholes and outcrops in the southwestern part of the Kraków–Wieluń Upland. The radiolarians show feature of Tethyan faunas which spread over epicontinental seas when communication with the Tethys Ocean opened. A correlation with the ammonite zones *Quenstedtoceras lamberti*, *Quenstedtoceras mariae* and *Cardioceras cordatum* shows that radiolarian assemblage I is Late Callovian and assemblage II is Early Oxfordian in age. A correlation with Tethyan radiolarian zones indicates that both assemblages can be assigned to the U.A.Z. 8, comprising the Middle Callovian–Early Oxfordian, according to Baumgartner *et al.* (1995). Assemblage I is characteristic for the lower part of the U.A.Z. 8 (Upper Callovian deposits). Assemblage II represents the upper part of the U.A.Z. 8 (Lower Oxfordian deposits). Radiolarian assemblage I is dominated by nassellarians, spherical, oval, conical and discoidal in shape. It contains Tethyan species (Baumgartner *et al.*, 1995), characteristic for the Northern Tethyan Radiolarian Province with common occurrence of families Williriedelidae (genera: *Williriedellum*, *Zhamoidellum*, *Tricolocapsa*), Archaeodictyomitridae (genus: *Transhsuum*), Theoperidae (genus *Stichocapsa*), and Sethocapsidae (genus *Gongylothorax*). Assemblage I includes predominantly warm-water species which preferred open-marine environments, in deeper neritic or bathyal zones.

The Early Oxfordian assemblage II is dominated by spongy spumellarians, multi-rayed and discoidal in shape. The assemblage includes common cosmopolitan forms of families Orbiculiformidae (genera: *Orbiculiforma*, *Crucella*, *Emiluvia*, *Higumastra*) and Patulibracchidae (genera: *Paronaella*, *Angulobracchia*). The typical Tethyan species, such as *Mirifusus*, *Zhamoidellum*, *Tricolocapsa*, *Stichocapsa* are also present. This mixed cold- and warm-water assemblage shows features of the Northern Tethyan faunas with influences of boreal realm. The character of radiolarian assemblage II suggests changes in the palaeoenvironmental conditions as well as gradual shallowing of the Kraków–Wieluń Upland basin in the Early Oxfordian.

The palaeogeographical position of the studied area at Late Jurassic time (northern shelf of the Tethys Ocean) suggests that it could be an area where upwelling introduced plankton to shelf zones.

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Streszczenie

PROMIENICE W OSADACH GÓRNEGO KELOWEJU I DOLNEGO OKSFORDU WYŻYNY KRAKOWSKO-WIELUŃSKIEJ

Jolanta Smoleń

W artykule przedstawiono wyniki badań zespołów promienic występujących w utworach keloweju górnego i oksfordu dolnego na obszarze Wyżyny Krakowsko – Wieluńskiej w rejonie Chrzanowa (wiercenia: Wodna 1, Trzebionka 2 i Trzebionka 3 oraz odsłonięcie Górka koło Trzebini), a także w rejonie Krzeszowic (odsłonięcie Grojec) (Fig 1).

Szczegółową analizę sedymentologiczną i stratygrafię tego rejonu opracowali Różycki (1953) i Malinowska (1991). W niniejszym opracowaniu, dla badanych osadów zastosowano standardową biozonację amonitową (Fig. 2). Osady najwyższego keloweju (poziom *Q. lamberti*) wykształcone są tu w postaci ciemnoszarych margli ilastych z glaukonitem. W najniższym oksfordzie dolnym (poziom *Q. mariae*) są to margle ilaste, szare i kolorowe (żółte i brunatne z fosforytami) przechodzące w jaśniejsze margle i wapienie margliste poziomu *C. cordatum* (Fig. 3). Wyżej wymienione osady zawierają amonity, belemnity, fragmenty makrofauny oraz mikrofaunę (otwornice, promienice, małżoraczki oraz igły gąbek).

Materiał do badań, pochodzi z prób archiwalnych, pobranych przez Bielecką do badań zespołu otwornic (Bielecka, 1960). W niniejszym opracowaniu wykorzystano 54 próby z wyżej wymienionych wierceń i odsłonięć (Fig. 3).

Z badanych próbek oznaczono 40 gatunków promienic. Na podstawie pionowego rozmieszczenia gatunków w badanych profilach wydzielono dwa zespoły promienic (zespół I i II; Fig. 4).

Zespół I opisano z osadów poziomu *Q. lamberti* keloweju górnego. Przeważają w nim promienice o kształtach kulistych, owalnych i stożkowych (Fig. 10–12), należące w 80% do podrzędu Nassellaria, który reprezentują gatunki z 10 rodzajów: *Williriedellum*, *Zhamoidellum*, *Tricolocapsa*, *Archaeodictyomitra*, *Transhsuum*, *Stichocapsa*, *Podobursa*, *Gongylothorax*, *Sethocapsa* i *Obesacapsula*. Spumellarie reprezentowane są w zespole I przez gatunki należące do 7 rodzajów: *Orbiculiforma*, *Higumastra*, *Emiluvia*, *Triactoma*, *Archaeocenosphaera*, *Acaeniotyle* i *Praeconocaryomma*. Ilość osobników promienic zespołu I w poszczególnych profilach waha się od około 50 do około 400 egzemplarzy w próbce (Fig. 5–9), przy czym najliczniejszą asocjację zespołu I odnotowano w rejonie Chrzanowa. We wszystkich badanych profilach, zespól I jest najliczniej reprezentowany przez *Stichocapsa convexa* Yao, *Williriedellum* cf. *carpathicum* Dumitrica, *Zhamoidellum ventricosum* Dumitrica i *Transhsuum brevicostatum* (Ozvoldova).

Zespół II promienic wyróżniono w utworach należących do poziomów *Q. mariae* i *C. cordatum* oksfordu dolnego. Charakteryzuje go przewaga form o gąbczastej strukturze pancerzyka, budowie wieloramiennej i dyskoidalnej (Fig. 13), należących w 70% do podrzędu Spumellaria, który reprezentowany jest przez gatunki z 12 rodzajów: *Tripocylia*, *Archaeocenosphaera*, *Triactoma*, *Orbiculiforma*, *Crucella*, *Emiluvia*, *Higumastra*, *Archaeospongoprunum*, *Homoeoparonaella*, *Praeconocaryomma*, *Paronaella* i *Angulobracchia*. Podrząd Nassellaria reprezentowany jest w zespole II przez gatunki należące do 9 rodzajów: *Zhamoidellum*, *Tricolocapsa*, *Stichocapsa*, *Mirifusus*, *Podobursa*, *Podocapsa*, *Obesacapsula*, *Transhsuum* i *Stichomitra*. Najliczniejszą asocjację zespołu II (od około 40 do około 300 osobników w próbie) stwierdzono w odsłonięciu Grojec, w rejonie Krzeszowic (Fig. 9). Cechą charakterystyczną zespołu II jest liczne występowanie *Paronaella* *mulleri* Pessagno, *Crucella theokaftensis* Baumgartner oraz innych gatnków należących do rodzaju *Paronaella*, *Higumastra*, *Tripocylia*, *Podobursa* i *Orbiculiforma* (Fig. 9).

Wiek badanych zespołów promienic określono na późny kelowej i wczesny oksford na podstawie korelacji z poziomami amonitowymi *Q. lamberti*, *Q. mariae* i *C. cordatum*. Korelacja z tetydzkimi zonacjami opartymi o promienice (Baumgartner *et al.*, 1995) wskazuje na przynależność zespół I i II do zony 8 (U.A.Z. 8), której wiek przyjmuje się na środkowy kelowej – wczesny oksford. Dobrze udokumentowana stratygraficznie pozycja obu zespołów pozwala stwierdzić, że zespół I jest charakterystyczny dla niższej części tetydzkiej zony 8 (osady jury środkowej), a zespół II reprezentuje wyższą część tej zony i jest charakterystyczny dla osadów dolnego oksfordu.

Badane zespoły promienic zawierają cechy przydatne do analizy paleogeograficznej. Zróżnicowanie gatunkowe jakie odnotowano pomiędzy wyróżnionymi zespołami I i II pozwala na sprecyzowanie dodatkowych wniosków dotyczących środowiska morskiego.

Zespół I wyróżniony w osadach poziomu *Q. lamberti* (kelowej górny) charakteryzuje znaczna ilościowa przewaga gatunków z podrzędu Nassellaria (80% zespołu), w szczególności przedstawicieli rodziny Williriedellidae i Sethocapsidae, które w okresie jurajskim najliczniej występowały w Oceanie Tetydy (Baumgartner *et al.*, 1995). Jednakże w zespole I brak jest przedstawicieli rodziny Pantanallidae oraz parvicingulidów typu "Ristola" (rodzaj *Ristola* i *Mirifusus*), które najlepiej charakteryzują rejon Centralnej Tetydy (Pessagno i Bloom, 1986; Hull, 1995). Całkowity brak jest również przedstawicieli rodzaju *Parvicingula* i *Praeparvicingula* charakterystycznych dla obszarów wysokich szerokości geograficznych (Pessagno i Bloom, 1986; Kiessling,1999). Zepół I jest najbardziej zbliżony gatunkowo do równowiekowych zespołów opisanych z rejonu Karpat Zachodnich na obszarze dzisiejszej Słowacji z Prowincji Tetydy Północnej. Obecność w zespole I licznych nassellarii z rodziny Williriedellidae (rodzaje: *Williriedellum*, *Zhamoidellum* i *Tricolocapsa*) i Sethocapsidae (rodzaj *Gongylothorax*) wskazuje na to, iż zespół ten zajmował w okresie późnego keloweju obszary morza na granicy otwartego oceanu, w obrębie strefy głęboko nerytycznej lub batialnej. Wyżej wymienione rodzaje promienic były w okresie jurajskim wskaźnikowe dla wód ciepłych, niskich szerokości geograficznych żyjących w głębszych strefach otwartego morza (Pessagno i Bloom, 1986; Kiessling, 1999), podobnie jak ma to miejsce w zespołach współczesnych (Casey, 1993).

W zespole II promienic, wyróżnionym w niniejszej pracy w osadach oksfordu dolnego, przewagę zyskują przedstawiciele podrzędu Spumellaria o gąbczastej budowie pancerzyka, a w szczególności rodziny Orbiculiformidae (rodzaje: *Orbiculiforma*, *Crucella*, *Emiluvia*, *Higumastra*) i Patulibracchidae (rodzaje: *Paronaella* i *Angulobracchia*). We wczesnym oksfordzie gąbczaste spumelarie należą do gatunków kosmopolitycznych. Są one licznie znajdowane w osadach Karpat Zachodnich (np. Ožvoldová *et al.*, 2000; Schlögl *et. al.*, 2000), ale również licznie występują w prowincji borealnej (Hull, 1997; Kiessling, 1999). W zespole II obecne są typowe formy tetydzkie jak np. rodzaj *Mirifusus*, *Zhamoidellum*, *Tricolocapsa* i inne oraz gatunki notowane także w prowincji borealnej jak *Archaeospongoprunum imlayi* Pessagno i *Podocapsa amphitreptera* Foreman (Hull, 1995). Całkowity brak jest natomiast przedstawicieli fauny typowej tylko dla obszarów borealnych, to jest rodzajów *Parvicingula* i *Praeparvicingula*. Zespół II reprezentuje zatem typ fauny mieszanej, borealno-tetydzkiej, charakterystycznej dla stref średnich szerokości geograficznych między Oceanem Tetydy a morzami borealnymi.

Ilościowa dominacja gąbczastych spumelarii nad przedstawicielami nasselarii w zespole II może wskazywać na zmianę temperatury i zasolenia morza wczesnooksfordzkiego, spowodowaną mieszaniem się ciepłych wód z obszaru Tetydy i chłodnych z obszarów borealnych. Rozprzestrzenienie gąbczastych spumelarii we współczesnych morzach pokazuje, iż są to formy kosmopolityczne, szczególnie częste w zbiornikach o zmiennym zasoleniu i zróżnicowanej temperaturze wody, preferujące płytsze środowiska życia (Andeson *et al.*, 1989; Blueford & King, 1983; Casey, 1993).

Wzrost liczebności promienic z podrzędu Spumellaria w stosunku do ilości nasselarii w okresie od keloweju do końca późnej jury obserwowany w prowincji Tetydy Północnej został zinterpretowany jako jako efekt stopniowego spłycania zbiornika morskiego (Kiessling, 1996). Powyższe dane wskazują na to, iż zespół II zamieszkiwał w okresie wczesnego oksfordu środowiska sublitoralne, północnego szelfu Oceanu Tetydy, w którym zaznaczały się wpływy borealne.

Zespoły promienic I i II, wyróżnione w badanych osadach Wyżyny Krakowsko – Wieluńskiej, zawierają w większości gatunki tetydzkie, które rozprzestrzeniły się na obszary mórz epikontynentalnych wskutek otwarcia połączeń z Oceanem Tetydy (Golonka *et. al.*, 2000; Wierzbowski *et. al.*, 1999). Zespoły te są znacznie uszczuplone pod względem ilości wyróżnionych w nich gatunków i osobników w stosunku do obszarów Tetydy. Pancerzyki promienic są często słabo zachowane i noszą cechy uszkodzeń mechanicznych i rekrystalizacji. Cechy te wskazują na transport i wysortowanie mechaniczne. Fakt rozprzestrzenienia się promienic na obszary szelfowe można przypisać działalności prądu wznoszącego (*upwelling*). Zjawisko obecności dużej ilości promienic w strefach szelfowych znane jest współcześnie w rejonie występowania prądów wznoszących np. u wybrzeży Kalifornii (Casey, 1993). Na występowanie takich prądów w obszarze Północnej Tetydy wskazują Golonka i Krobicki (2001), według których w okresie późnej jury układ kierunków wiatrów powodował cyrkulację mas wody sprzyjającą ich powstawaniu. O istnieniu prądów wznoszących na badanym obszarze może świadczyć także obecność w osadach konkrecji fosforytowych i dużej ilości glaukonitu.