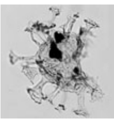
Campanian to Maastrichtian palynofacies and dinoflagellate cysts of the Silesian Unit, Outer Western Carpathians, Czech Republic

PETR SKUPIEN & OMAR MOHAMED



Dinoflagellate cysts are reported from 20 Upper Cretaceous claystone samples from the Godula and Istebna formations of the Silesian unit. Age-assessment of the sediments based on 150 species suggests a Late Campanian to probably earliest Maastrichtian age for the middle and upper part of the Godula Formation and a Early Maastrichtian age for the basal part of the Istebna Formation. Key biotic events are especially the first occurrence datums of *Areoligera senonensis, Cerodinium diebelii, Palaeocystodinium golzowense* and *Trithyrodinium evittii,* and the last occurrence datums of *Odontochitina, Palaeohystrichophora infusorioides, Raeteiaedinium truncigerum, Trihyrodinium suspectum* and *Xenascus ceratioides.* Palynofacies analysis shows deposition in an offshore marine environment subjected to influxes of terrestrial material. Organic matter is dominated by phytoclasts and contains very little amorphous organic material. The succession is also characterized by a low percentage of dinoflagellate cysts and a very low percentage of spores and pollen grains. The presence of thermophilitic dinoflagellate cysts points to a warm-temperate to subtropical climate during Late Campanian to Early Maastrichtian. • Key words: Silesian Unit, Cretaceous, Campanian, Maastrichtian, dinoflagellate cysts, palynofacies, Carpathians.

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The studied sections of marine Upper Cretaceous deposits are situated in the Moravskoslezské Beskydy Mountains, which are part of the Outer Western Carpathians (OWC). Geologically, they belong to Subsilesian and Silesian units of Upper Jurassic to Oligocene hemipelagic and flysch deposits within the OWC nappe system, which overthrusted part of the Carpathian Miocene foredeep and partly on buried Variscides of the Bohemian Massif (Fig. 1). Three fundamentally different facies (developments) are preserved in the present-day structure of the Silesian unit, *i.e*. the Godula facies (basinal setting); the Baška facies (frontal slope setting); and the Kelč facies (continental slope setting).

The Upper Cretaceous comprises dominantly flysch (turbiditic) sediments belonging to the Godula Formation and Istebna Formation (Fig. 2). The dinoflagellate cyst assemblages described in this paper come from the Staré Hamry, Horní Bečva, Zarovjanka and Bílá sections, which belong to the Godula facies. Twenty samples collected for palynology were studied with special emphasis on the dinoflagellate cyst assemblages.

This study builds on earlier investigations by Skupien (1999, 2003), Skupien & Vašíček (2003), Skupien *et al.* (in press), which dealt with the stratigraphic distribution of microplankton species in the Upper Cretaceous of the Silesian unit. Discovery of dinoflagellate cysts in a claystone layer brings new information on age, palaeoenvironment and palaeogeographical position of these deposits.

Geological setting

The studied sections are situated in the Silesian unit of the OWC flysch zone. The Upper Cretaceous includes the uppermost part of the Lhoty Formation, the Mazák Formation, the Godula Formation and the Istebna Formation (Pícha *et al*. 2006). Late Cretaceous (Early Cenomanian; Skupien & Vašíček 2003) sedimentation starts with light gray shales with a few thin intercalations of dark grey shales in the upper Lhoty Formation. The deposits of the

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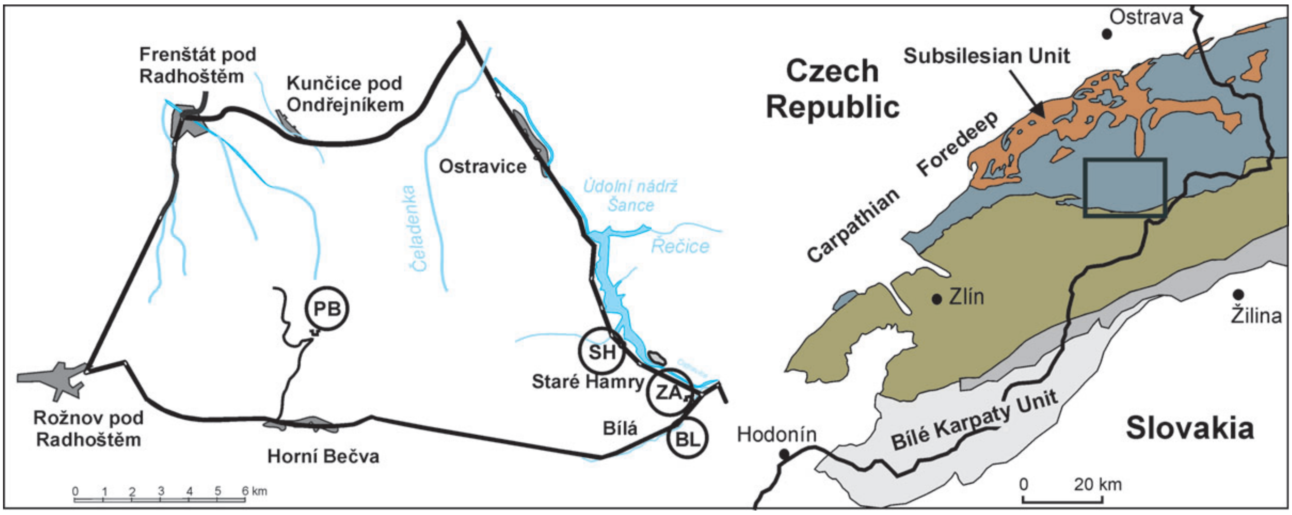


Figure 1. Location map of the studied sections and area in the Outer Western Carpathians. Abbreviations: BL – Bílá section, PB – Horní Bečva section, SH – Staré Hamry section, ZA – Zarovjanka section. Subsilesian Unit and Ždánice Unit, Silesian Unit, Rača Unit, Bystrica Unit, Bílé Karpaty Unit.

Silesian unit have been studied biostratigraphically using mainly foraminifera; Upper Cretaceous macrofauna are absent.

The Upper Cenomanian to lowermost Coniacian Mazák Formation is represented by sequence of variegated (red, red-brown and grey-green) non-calcareous shales, occasionally interbedded with thin, greenish gray quartzose sandstone layers (Roth 1980, Skupien *et al*. in press).

The Turonian to Santonian Godula Formation (Hanzlíková 1972a, Menčík *et al.* 1983) is a typical flysch sequence of alternating sandstones and shales with a variable proportion of these two main lithological components and an overall thickness of more than 3000 m. Lithologically, the formation is subdivided into three parts (Eliáš 2000; Matějka 1949, 1952; Menčík *et al.* 1983): a lower turbiditic facies of thinly bedded glauconitic sandstones and shales (grey, brown-grey, red-grey in colour); middle part with a facies dominated by coarse glauconitic sandstones and conglomerates; and an upper facies of thinly interbedded glauconitic sandstones and shales (grey, green-grey), with coarse sandstones and conglomerates occuring locally.

The Campanian to Maastrichtian to Danian(?) Istebna Formation (Hanzlíková 1972b) developed from the underlying Godula Formation is 1200 m thick and represented by a typical flysch facies of alternating sequences of arkosic sandstones, slump conglomerates, and sand flows (fluxoturbidites) with an equally thick sequence of dark shales.

The Cenomanian–Early Turonian age of the Mazak Formation was established by the concurrent presence of foraminifers *Praeglobotruncana helvetica* (Bolli)*, Praeglobotruncana stephani* (Gandolfi) and *Rotalipora greenhornensis* (Morrow) (Hanzlíková 1973). New data (foraminifera and dinoflagellate cysts) support a Late Cenomanian to earliest Coniacian age (Skupien *et al.* in press). Hanzlíková (1972a) described from the Godula Formation foraminiferal assemblages of Turonian to Santonian age. New observation from the continuous Bystrá section (Skupien & Vašíček 2003, Skupien *et al.* in press) provided foraminiferal and dinoflagellate cyst assemblages of Coniacian to Early Campanian age in the lower part and of Early to Late Campanian age in the middle part of the formation. Early Campanian to Danian foraminiferal zones were described by Hanzlíková (1972b) from the Istebna Formation.

Material

Four sections were sampled (Fig. 1). Sample positions are indicated on Figs 3, 4 and 5.

The Staré Hamry section is situated north-east of Trojačka Hill and on the south-western part of the Šance dam. Eleven samples of grey claystones were taken from exposures along the road from Staré Hamry to Ostravice. The studied section consists of thick flysch sediments of the middle part of the Godula Formation (Figs 2A, 3).

The Horní Bečva section is located in an old quarry on the southern side of Kněhyně Hill and about 700 m north of the town Horní Bečva, situated near a sharp turn on the right-hand side of the road from Horní Bečva to Pustevny. Thinly interbedded glauconitic sandstones and shales (grey, green-grey) of the upper part of the Godula Formation are exposed. Three samples were taken from the middle part of the quarry (Figs 2B, 4).

Two samples from the Zarovjanka section were taken from a quarry near the junction of the Bílá Ostravice and Černá Ostravice rivers, north of Bílá. Arkosic sandstones

Figure 2. Lithology of the studied sections. • A – thick flysch of the middle part of the Godula Formation, Staré Hamry. • B – thin flysch of the upper part of the Godula Formation, Horní Bečva. • C – slump conglomerates of the basal part of the Istebna Formation, Zarovjanka. • D – dark grey shales with occasional sandstone layers of the Istebna Formation, Bílá.

and slump conglomerates of the basal part of the Istebna Formation are exposed. Samples were taken from the grey to dark grey claystones and siltstones in the middle part of the quarry (Figs 2C).

The Bílá section is located in the south-eastern part of the town Bílá, opposite the old church. Four samples were taken from the exposure on the right bank of the river Bílá Ostravice. The sampled part of the section consists of approximately 9 m of dark grey shales with occasional sandstone layers of the Istebna Formation (Figs 2D, 5). Shales are rich in organic matter and pyrite.

Methods

A total of 20 rock samples, mostly recovered from the clay and sandy clay beds, were processed for palynomorphs. After washing and drying, standard processing involved chemical treatment of 15–20 g of sample with HCl to remove the calcareous fraction and with HF to remove silicates, sieving with an 8 μm and 15 μm nylon mesh, and centrifuging to concentrate the residues. Oxidation is not used. Two microscope slides were made from each samples using a residue > 8 μm for palynofacies analysis. Three sli-

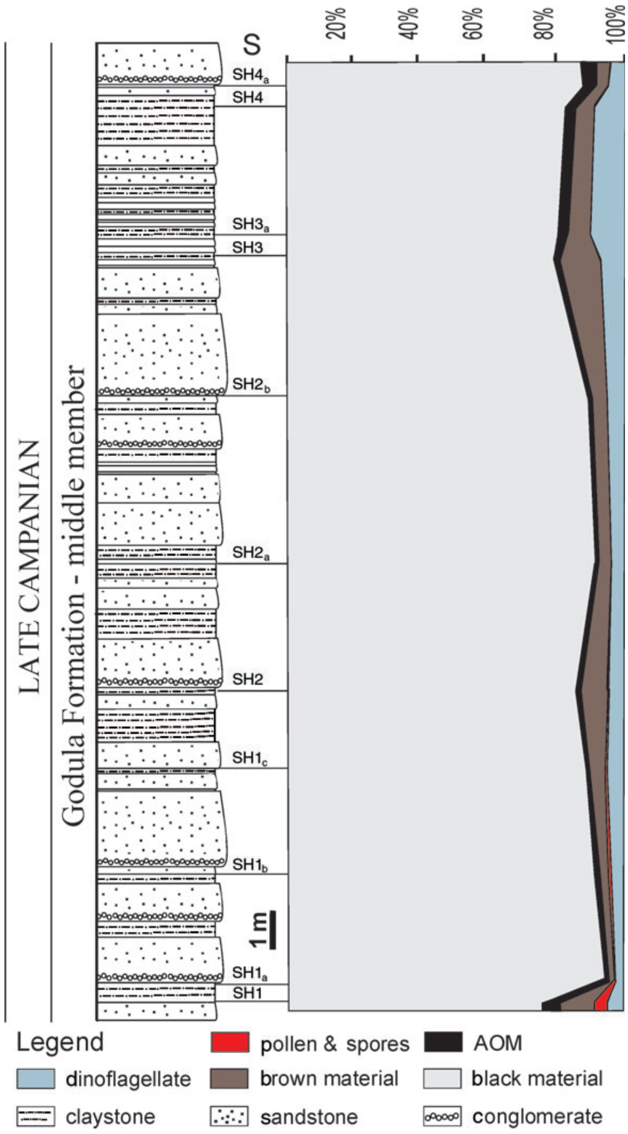


Figure 3. Lithological column with sample position and organic facies composition of the Staré Hamry section. Abbreviation: S – sample.

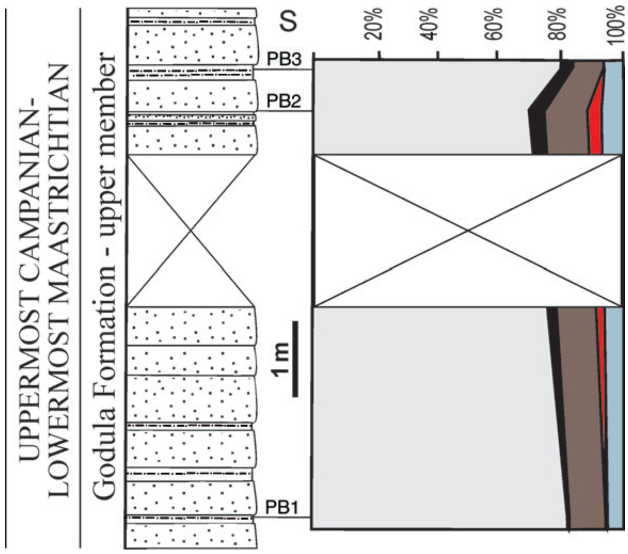


Figure 4. Lithological column with sample position and organic facies composition of the Horní Bečva section.

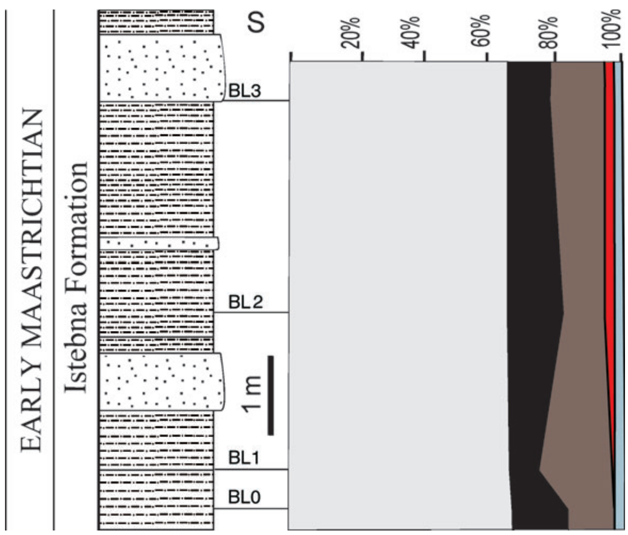


Figure 5. Lithological column with sample position and organic facies composition of the Bílá section.

des were prepared from each sample using a part of the residue >15 μm for dinoflagellate cyst analysis. Whole slides of residues were investigated under a binocular transmitted light microscope to identify and count the palynomorphs and other organic materials. The palynological permanent mounts are stored at the Institute of Geological Engineering at the VŠB – Technical University of Ostrava, Czech Republic. Dinocyst taxa discovered are illustrated and listed in alphabetical order of genus name in an appendix. For dinocyst taxonomy and references to taxa names and authors, please refer to Fensome & Williams (2004) and Fauconnier & Masure (2004).

Palynofacies analysis (counting up to 1000 particles) was based on phytoclasts (brown and black material), amorphous organic material (AOM), spores and pollen grains, dinoflagellate cysts and foraminiferal test linnings. The quantitative study included counting of up to 150 determinable dinoflagellate cysts when possible.

Results

Dinoflagellate cysts have been found in all samples of grey or dark-grey lithofacies. In the present study we identify Late Campanian to Early Maastrichtian dinoflagellate cyst assemblages from the claystone samples (Godula and Istebna formations) in four sections. We also concentrated on the quantitative analysis to interpret the palaeoecology and palaeoenvironment of the studied samples by counting

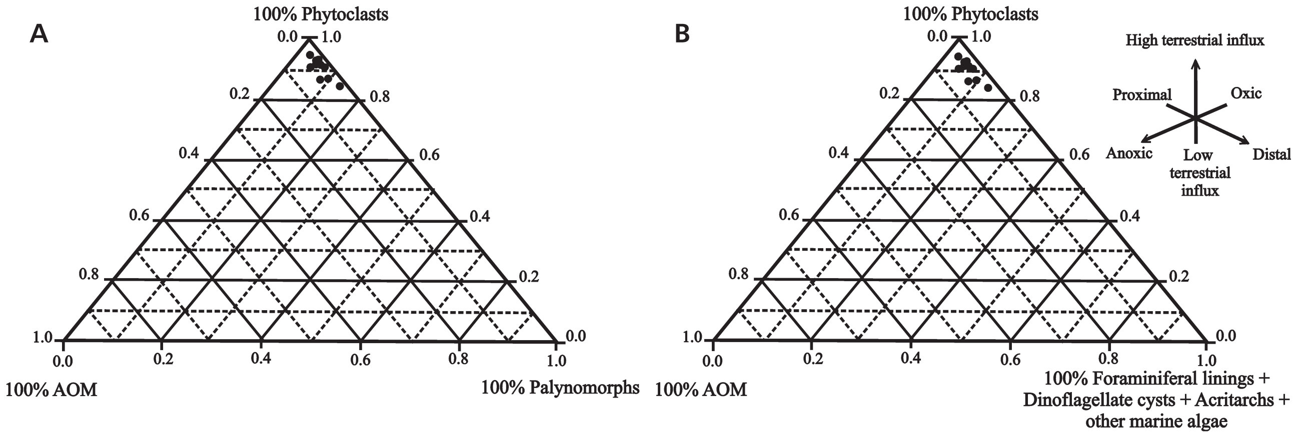


Figure 6. A – AOM-palynomorph (marine and terrestrial) -phytoclast ternary diagram (after Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Staré Hamry section. • B – AOM-phytoclasts-foraminiferal linings/dinoflagellate cysts/acritarchs/other marine algae diagram (modified from Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Staré Hamry section.

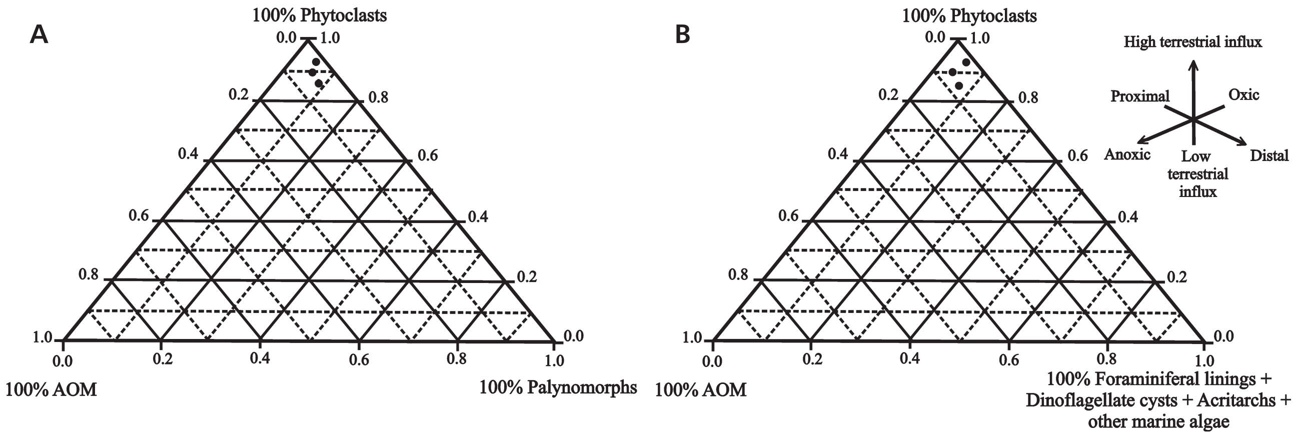


Figure 7. A – AOM-palynomorph (marine and terrestrial)-phytoclast ternary diagram (after Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Horní Bečva section. • B – AOM-phytoclasts-foraminiferal linings/dinoflagellate cysts/acritarchs/other marine algae diagram (modified from Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Horní Bečva section.

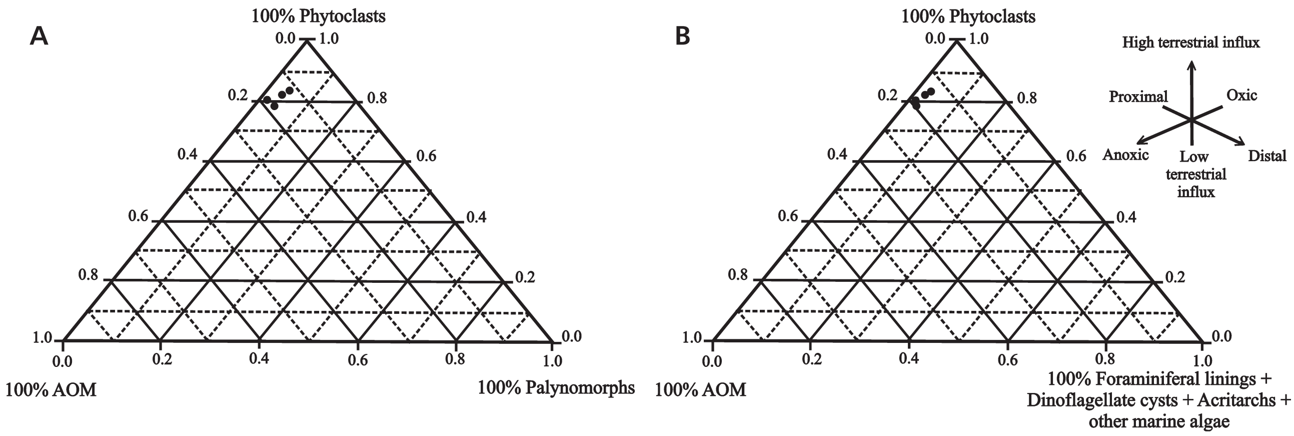


Figure 8. A – OM-palynomorph (marine and terrestrial)-phytoclast ternary diagram (after Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Bílá section. • B – AOM-phytoclasts-foraminiferal linings/dinoflagellate cysts/acritarchs/other marine algae diagram (modified from Tyson 1995) of the relative numerical particle frequency (% of the TSOM) in the Bílá section.

Table 1. Distribution of dinoflagellate cysts in the Staré Hamry section. Numbers refer to counted specimens in the slides.

Age	Late Campanian										
Formation	Godula Formation										
Species / Sample Number	SH1	SH1a	SH1b	SH1c	SH2	SH2a	SH2b	SH3	SH3a	SH4	SH4a
Achomosphaera fenestra			2			3		3	2	3	2
Achomosphaera ramulifera	12	35	30		40	16		20	30	10	16
Achomosphaera sagena										4	
Achomosphaera triangulata	8	43	40	20	46	12		21	17		
Areoligera coronata	16										
Areoligera senonensis			4								
Biconidinium longissimum								2			
Callaiosphaeridium asymmetricum	13		5		17	9					7
Cerebrocysta bartonensis											1
Cerodinium sp.	9										
Chatangiella bondarenkoi	8										
Chatangiella spectabilis					7	8			12		5
Chatangiella tripartita				7		7					
Chatangiella williamsii							6				
Cordosphaeridium sp.						1					
Coronifera oceanica hebospina							5				
Cribroperidinium orthoceras	6		5	4					5		
Cyclonephelium distinctum					7			7		9	
Dinogymnium cf. *sibiricum*	4				2						
Dinogymnium sp.			5								
Downiesphaeridium? *aciculare*		5			3			7		4	
Exochosphaeridium bifidum					10				14		
Exochosphaeridium aff. *bifidum*					4						
Exochosphaeridium multifurcatum	11										
Exochosphaeridium phragmites					7						
Exochosphaeridium sp.		38	40	31		46					
Florentinia aculeata				8		11			25		15
Florentinia cooksoniae				2							
Florentinia deanei	7								6		
Florentinia hypomagna			2								
Florentinia laciniata					5				6		
Florentinia sp.			21								
Glaphyrocysta sp.			1								
Glaphyrocysta texta					2						
Hafriasphaeridium fluens			2								
Hystrichokolpoma proprium				2		1			5		
Hystrichodinium pulchrum	5	7					5				6
Hystrichosphaeridium bowerbankii		11		24	23	13		11	27	21	21
Hystrichosphaeridium salpingophorum						4					
Hystrichosphaeridium tubiferum		12				8	7			6	
Hystrichosphaeridium sp.					5						
Hystrichostrogylon membraniphorum	7				10	8	8				
Isabelidinium belfastense			5			2				1	
Isabelidinium sp.			35			11	11	5	26		
Isabelidinium svartenhukense	4										
Kiokansium polypes				4							
Kleithriasphaeridium loffrense			22					5	15		

Table 1. Continued

Age	Late Campanian										
Formation	Godula Formation										
Species / Sample Number	SH1	SH1a	SH1b	SH1c	SH2	SH2a	SH2b	SH3	SH3a	SH4	SH4a
Kleithriasphaeridium readii								3			
Leberidocysta chlamydata							1				
Multiplicisphaeridium? *cruciatum*									3		
Odontochitina costata					2	9			7		
Odontochitina operculata	23		29	31	21	4		5	17		
Oligosphaeridium albertense	5										
Oligosphaeridium complex		11	15	41	43			5			23
Operculodinium centrocarpum							1				
Palaeohystrichophora infusorioides	5	6		2							
Palaeoperidinium sp.		2									
Palaeotetradinium silicorum									2		
Pervosphaeridium pseudhystrichodinium		19	68	23	18	17					19
Pervosphaeridium truncatum			11	8	15			4			
Phelodinium cf. *kozlowskii*	1										
Phthanoperidinium distinctum								1			
Pterodinium aliferum	1			1				8			1
Pterodinium cingulatum	5		1						1		
Raetiaedinium truncigerum			1								
Senoniasphaera inornata							2				
Senoniasphaera rotundata	6		5								
Spiniferites cf. *bulloideus*			2	2		4	3			1	
Spiniferites crassipellis									1		
Spiniferites membranaceus		2						3			
Spiniferites porosus											2
Spiniferites ramosus	31	23	47	13	31	25	10	31	74	11	31
Spiniferites ramosus brevifurcatus	13	13	16							11	
Spiniferites aff. *ramosus granomembranaceus*				2	12	6	2		14		
Spiniferites aff. *ramosus granosus*				2							
Subtilisphaera sp.						2					
Surculosphaeridium? *longifurcatum*	31	26	49	21	43	32	20	9	31		
Tanyosphaeridium boletus							2		2		
Trithyrodinium evittii								2			
Trithyrodinium sp.									4		
Trithyrodinium suspectum	2				3	2					2
Xenascus ceratioides	9							19	7	14	
Xenascus sp.		22						10			11

the total sedimentary organic material (TSOM), as noted above.

Most residues were characterized by abundant sedimentary organic materials (SOM), dominated by phytoclasts (87–96% in the Staré Hamry section; 85–95% in the Horní Bečva section; 79–83% in the Bílá section) and a small percentage of AOM (1–4% in Staré Hamry section; 1–5% in Horní Bečva section; up to 17% in the Bílá section). The succession is also characterized by a low percentage of dinoflagellate cysts (less than 9%) and a very low percentage of spores and pollen grains (less than 5%). Overall the studied samples show little vertical variation in the palynofacies (Figs 3–5).

Changes in palynofacies types and composition of palynomorph assemblages can provide information to interpret the depositional environments in terms of water depth, sea-water oscillation, temperature variations and terrigenous influx (Lister & Batten 1988, Smelror & Leereveld 1989, Batten 1996). Samples are usually plotted in ternary diagrams. Tyson (1995) suggested the use of

AOM-Palynomorphs-Phytoclasts (APP) ternary plots to characterize marine depositional facies based on SOM (Figs 6–8).

The middle member of the Godula Formation (Staré Hamry section) is characterized by a high percentage of phytoclasts (87–96%, Figs 3, 6), a low percentage of palynomorphs (2–10%) and a very low amount of AOM (1–4%). We found only one foraminifer specimen in every SH1, 1c and 2b sample, which indicates a shallow marine environment with high terrestrial influx. Also, we identified 87 dinoflagellate cysts species (Table 1) and the assemblages of many samples are rich in species such as *Achomosphaera ramulifera, A. triangulata, Cribroperidinium orthoceras, Exochosphaeridium* sp., *Florentinia aculeata, Hystrichosphaeridium bowerbankii, Hystrichosphaeridium pulchrum, Odontochitina operculata, Oligosphaeridium complex, Pervosphaeridium pseudhystrichodinium, Spiniferites ramosus, Surculosphaeridium*? *longifurcatum* and *Xenascus ceratioides.*

In the upper member of the Godula Formation (Horní Bečva section, Table 2) we identified 52 dinoflagellate cyst species. Assemblages are characterized by taxa such as *Chatangiella spectabilis*, *Heterosphaeridium spinaconjunctum*, *Odontochitina operculata*, *Oligosphaeridium asterigerum*, *Palaeohystrichophora infusorioides*, *Spiniferites* cf. *bulloideus*, *Spiniferites porosus*, *Spiniferites ramosus*, *Surculosphaeridium*? *longifurcatum*, *Thalassiphora* sp., *Trithyrodinium evittii*, *Xenascus ceratioides* and *Xenascus sarjeantii.* Samples are characterized by a very high percentage of phytoclasts (85–95%, Figs 4, 7), a low percentage of palynomorphs (5–10%) and very little AOM (1–5%), which indicates a shallow marine environment with high terrestrial influx.

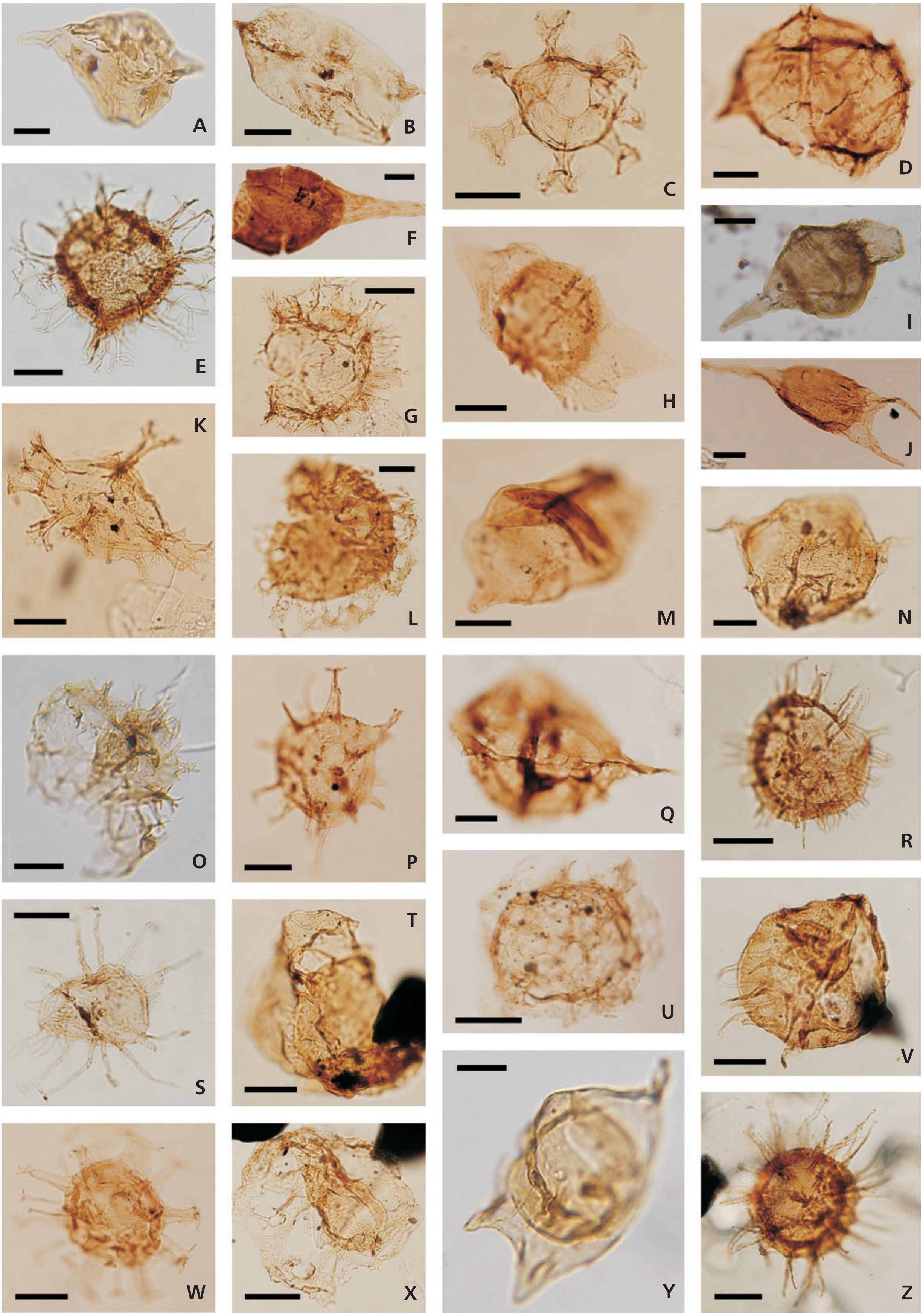
In the Istebna Formation (Bílá section, Table 3), 57 dinoflagellate cyst species have been identified, which are dominated by species as *Achomosphaera fenestra, Areoligera volata, Cerodinium diebelii, Florentinia radiculata, Glaphyrocysta* sp.*, Hystrichosphaeridium pulchrum, Palaeocystodinium golzowense, Palaeoperidinium pyrophorum, Spiniferites ramosus* and *Sumatradinium soucouyantiae.* Samples are characterized by a very high percentage of phytoclasts (79–83%, Figs 5, 8), a very low percentage of palynomorphs (1.5–3.5%) and a slightly higher percentage of AOM (10–17%), which indicates a shallow marine environment with high terrestrial influx and near anoxic conditions.

Discussion

Below we characterize the stratigraphic assignment of the studied sediments according to dinoflagellate cysts (Figs 9–11). Quantitative abundances of dinoflagellate cysts are illustrated in Tables 1, 2 and 3. To determine the age of the strata based on the distribution of dinoflagellate cysts, species ranges were compared with other studies in the Northern Hemisphere (Robaszynski *et al.* 1985, type-Maastrichtian area; Kirsch 1991, southern Germany; Costa & Davey 1992, North Sea; Hoek *et al.* 1996, Israel; Roncaglia & Corradini 1997, Roncaglia 2002, Torricelli & Amore 2003, Italy; Antonescu *et al.* 2001, south-western France). In addition, the oldest and youngest occurrences of dinoflagellate cyst species of Stover *et al.* (1996) and Williams *et al.* (2004) were considered.

The dinoflagellate cyst assemblages of the samples of the middle part of the Godula Formation (Staré Hamry section, Table 1) can be assigned to the Late Campanian. Two interesting markers are the first occurrences of the species *Areoligera senonensis* and *Trithyrodinium evittii*. The first occurrences of *Areoligera senonensis* (sample SH1b in the lower part of the Staré Hamry section) are calibrated in the Late Campanian of the Maastrichtian type area (Robaszynski *et al.* 1985), of southern Germany (Kirsch 1991) and of the northern Apennines (Roncaglia & Corradini 1997). *Trithyrodinium evittii* (sample SH3) has the first occurrence in the latest Campanian of south-west France (Antonescu *et al.* 2001). But the FO of this taxon is usually considered to be a criterion for the earliest Maastrichtian in mid-latitudes (Williams *et al.* 2004). The FO observed in the Silesian unit can thus represent the evolutionary ap-

Figure 9. Taxa discovered; the species name is followed by sample location and England Finder coordinates (for localization of the specimen on the slide). Scale is 20 μm. • A – *Alterbidium acutulum* (Wilson, 1967b) Lentin & Williams, 1985; ZA1, S28/2. • B – *Chatangiella bondarenkoi* Vozzhennikova, 1967; SH1/a, U32/3. • C – *Callaiosphaeridium asymmetricum* (Deflandre & Courteville, 1939) Davey & Williams 1966b; Pb1a, K31/32. • D – *Cribroperidinium orthoceras* (Eisenack, 1958a) Davey 1969a; SH3a/a, K43/2. • E – *Achomosphaera sagena* Davey & Williams, 1966; SH4/a, P42/2. • F – *Biconidinium longissimum* Islam, 1983c; SH3/a, S54/1. • G – *Areoligera senonensis* Lejeune-Carpentier, 1938; SH1b/a, K35/3. • H – *Chatangiella spectabilis* (Alberti, 1959b) Lentin & Williams, 1976; SH4a/a, R44/1. • I – *Cerodinium* sp.; PB1/a, P42/1. • J – *Cerodinium diebelii* (Alberti, 1959b) Lentin & Williams, 1987; ZA1, L42/3. • K – *Achomosphaera fenestra* Kirsch, 1991; BL2/b, S38. • L – *Areoligera volata* Drugg, 1967; BL3/b, R53. • M – *Chatangiella williamsii* Yun, 1981; SH2b/a, P32/4. • N – *Cerodinium* cf. *wardenense* (Williams & Downie, 1966) Lentin & Williams, 1987; BL0a, S41. • O – *Glaphyrocysta* sp.; ZA2/a, D51. • P – *Florentinia aculeate* Kirsch, 1991; SH2a/c, L37. • Q – *Cribroperidinium orthoceras* (Eisenack, 1958a) Davey, 1969a; PB3/a, R39. • R – *Exochosphaeridium bifidum* (Clarke & Verdier, 1967) Clarke *et al.*, 1968; SH3a/a, H47/1. • S – *Hystrichosphaeridium bowerbankii* Davey & Williams, 1966b; SH1c/a, Q32/4. • T – *Glaphyrocysta castelcasiensis castelcasiensis* Corradini, 1973; BL0a, K32. • U – *Cauveridium membraniphorum* (Cookson & Eisenack, 1962b) Fauconnier & Masure, 2004; PB3/a, Z46/1. • V – *Exochosphaeridium phragmites* Davey *et al.*, 1966; SH2/a, D34. • W – *Hystrichosphaeridium salpingophorum* Deflandre, 1935a; SH2a/c, T50. • X – *Glaphyrocysta wilsonii* Kirsch, 1991; BL0b, F43. • Y – *Deflandrea* cf. *phosphoritica* Eisenack, 1938b; ZA1/a, R42/1. • Z – *Exochosphaeridium* sp.; SH1a/a, S41.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pearance of the taxon in the Western Tethys in accordance with the data of Antonescu *et al.* (2001).

Other stratigraphically important dinocyst species found are *Kleithriasphaeridium loffrense, Raeteiaedinium truncigerum, Senoniasphaera rotundata* and *Trihyrodinium suspectum*. The last occurrences of *Kleithriasphaeridium loffrense, Raetiaedinium truncigerum* and *Senoniasphaera rotundata* are Late Campanian (Williams *et al.* 2004). Antonescu *et al.* (2001) reports the LO of *Raetiaedinium truncigerum* slightly above the Campanian/Maastrichtian boundary. In southern Germany the last occurrence of *T. suspectum* is close to the Campanian/Maastrichtian boundary (Kirsch 1991) and in the Northern Hemisphere its total stratigraphical distribution ranges slightly higher into the earliest Maastrichtian (Stover *et al.* 1996, Williams *et al.* 2004).

Co-occurrence of these dinocyst species suggests that sedimentation of the middle part of the studied Godula Formation took place during the Late Campanian. This is in accordance with data from the Bystrá section (Skupien *et al.* in press) where dinoflagellate cyst associations of Middle to Late Campanian age were found, and occurrences of agglutinated foraminifera confirm this age assignment (Skupien *et al.* in press).

Samples of the upper part of the Godula Formation (Horní Bečva section, Table 2) yield diverse Late Cretaceous dinoflagellate cyst assemblages, including the first appearance of *Alterbidinum ulloriaq* and *Palaeocystodinium golzowense* in the Silesian unit. The first occurrences of these species are known from the Early Maastrichtian (Antonescu *et al.* 2001, Kirsch 1991, Roncaglia 2002). *P. golzowense* is the index species for the *P. golzowense* Interval Subzone of Roncaglia & Corradini (1997) in Italy. Only Hoek *et al.* (1996) have described this species from the Late Campanian in Israel.

Several dinocyst species from the Horní Bečva section are long ranging with stratigraphic range tops limited to the earliest Early Maastrichtian (*e.g.*, *Odontochitina costata, Palaeohystrichophora infusorioides, Xenascus ceratioides, X. sarjeantii*; Roncaglia & Corradini 1997, Robaszynski *et al.* 1985, Stover *et al.* 1996, Williams *et al.* 2004).

Consistent with trends in the composition of the dinoflagellate cyst assemblages throughout the studied sections, the section Horní Bečva indicates an age close to the Campanian/Maastrichtian boundary or probably earliest Maastrichtian.

A Late Campanian – earliest Maastrichtian age of the basal part of the Istebna Formation (Zarovjanka section, Table 3) is confirmed by the presence of *Cerodinium diebelii* and *Palaeocystodinium golzowense.* The first occurrence of *C. diebelii* and its related forms (Ypes 2001) is close to the Campanian/Maastrichtian boundary (Antonescu *et al.* 2001, Kirsch 1991, Roncaglia 2002). Williams *et al.* (2004) reported that worldwide total distribution of ranges of *C. diebelii* is earlier in the Campanian. This is also the bed that yielded several specimens of *Cyclonephelium filoreticulatum*, a dinoflagellate cyst described from the Early Maastrichtian (Costa & Davey 1992), and rich occurrence of *Alterbidinium* (*A. acutulum, A. distinctum*), a genus that characterises the Maastrichtian (Antonescu *et al.* 2001). Hence, depending on the range interpretation of *C. filoreticulatum* and *Alterbidinium*, an Early Maastrichtian age of the beginning of the Istebna Formation sedimentation in this area of the Silesian basin can be suggested. The latter interpretation coincides with the absence of taxa such as *Palaeohystrichophora infusorioides, Odontochitina* sp., *Xenascus ceratioides* with last occurrence in the uppermost Campanian. Their last occurrence was observed in the Horní Bečva section.

Dark grey shales of the Istebna Formation (Bílá section, Table 3) represent the Lower Maastrichtian, as indicated by the presence of *Alterbidinium distinctum, Apteodinium deflandrei, Areoligera volata, Hystrichodinium pulchrum, Odontochitina operculata, Trihyrodinium suspectum* and genus *Glaphyrocysta*.

Figure 10. Taxa discovered; the species name is followed by sample location and England Finder coordinates (for localization of the specimen on the slide). Scale is 20 μm. • A – *Hystrichodinium pulchrum* Deflandre, 1935a; SH2b/a, K27/4. • B – *Odontochitina operculata* (O. Wetzel, 1933a) Deflandre & Cookson, 1955; SH2/a, R35. • C – *Kleithriasphaeridium readii* (Davey & Williams, 1966b) Davey & Verdier, 1976; SH3/b, M41. • D – *Operculodinium echigoense* Matsuoka, 1983b; BL1/b, G40/4. • E – *Hystrichosphaeridium*? sp.; SH2/a, N33. • F – *Isabelidinium belfastense* (Cookson & Eisenack, 1961a) Lentin & Williams, 1977a; SH2a/c, O42. • G – *Isabelidinium* cf. *bakeri* (Deflandre & Cookson, 1955) Lentin & Williams, 1977a; PB1/b, T43. • H – *Odontochitina costata* Alberti, 1961; SH2a/c, Q39/4. • I – *Operculodinium divergens* (Eisenack, 1954b) Stover & Evitt, 1978; BL1/a, P42/4. • J – *Florentinia cooksoniae* (Singh, 1971) Duxbury, 1980; SH1c/a, R39. • K – *Hystrichokolpoma proprium* (Marheinecke, 1992) Foucher, 2004; SH2a/c, L38/2. • L – *Odontochitina porifera* Cookson, 1956; PB1/b, G44/4. • M – *Oligosphaeridium albertense* (Pockock, 1962) Davey & Williams, 1969; SH1, S49. • N – *Surculosphaeridium*? *longifurcatum* (Firtion, 1952) Davey *et al.*, 1966; SH1/a, O47/2. • O – *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937b) Yun, 1981; PB1/b, L47/1. • P – *Palaeocystodinium golzowense* Alperti, 1961; BL3/a, K50. • Q – *Palaeocystodinium golzowense* Alperti, 1961; BL0/b, C29/1. • R – *Oligosphaeridium buciniferum* Corradini, 1973; BL0c, Q36/4. • S – *Senoniasphaera rotundata* Clarke & Verdier, 1967; SH1/b, S39. • T – *Pervosphaeridium truncatum* (Davey, 1969a) Below, 1982a; SH3/b, M41. • U – *Pterodinium cingulatum* (O. Wetzel, 1933b) Below, 1981a; SH3a/a, R37. • V – *Palaeoperidinium pyrophorum* (Ehrenberg, 1838) Sarjeant, 1967b; BL0/b, R28. • W – *Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970; BL3/a, D48.• X – *Phelodinium* cf. *kozlowskii* (Górka, 1963) Lindgren, 1984; SH1/b, Q49. • Y – *Palaeotetradinium silicorum* Deflandre, 1936b; SH3a/b, S39/1. • Z – *Palaeohystrichophora infusorioides* Deflandre, 1935; SH1a, H44/45.

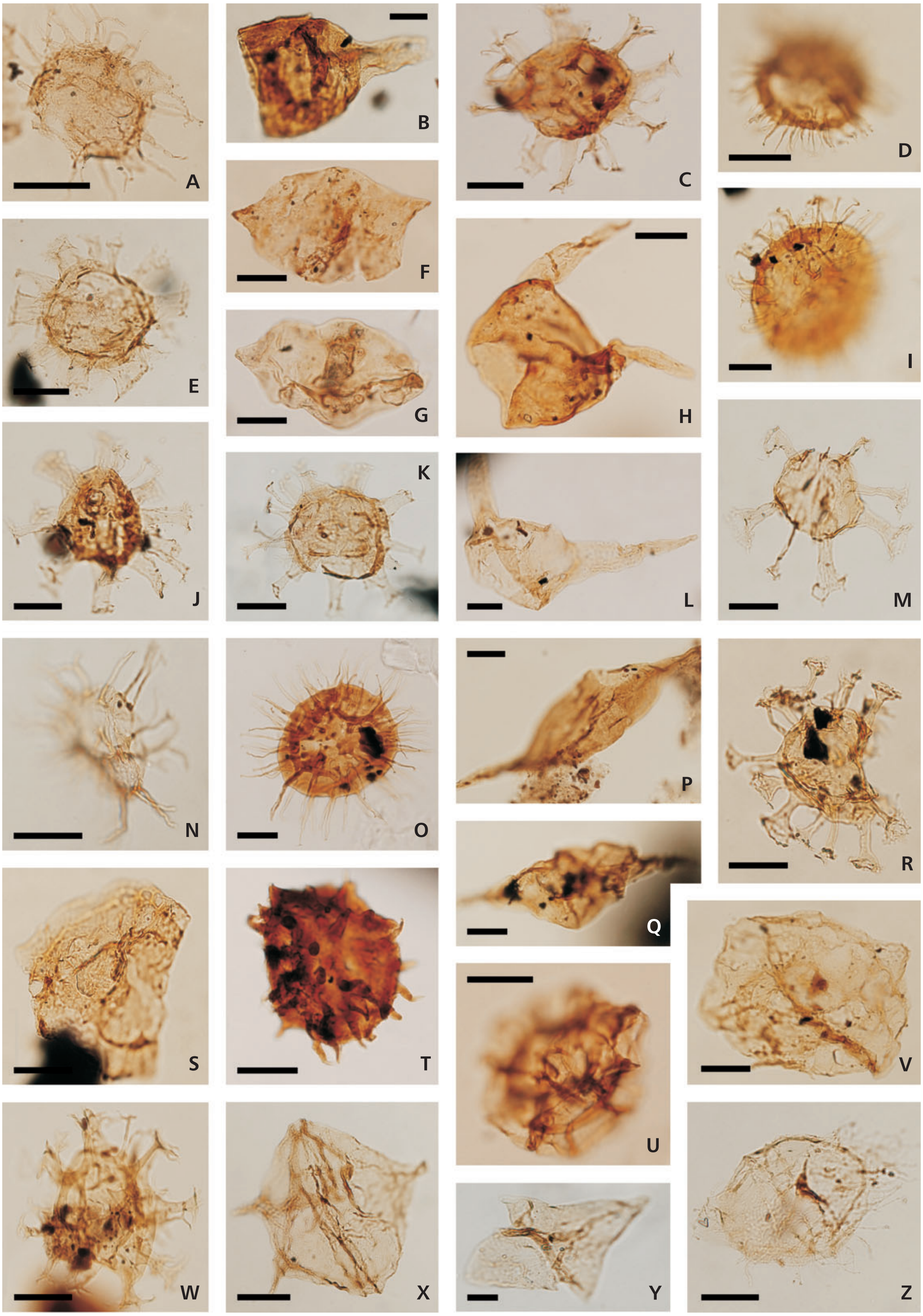
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Table 2. Distribution of dinoflagellate cysts in the Horní Bečva section. Numbers refer to counted specimens in the slides.

Age	Uppermost Campanian-Lowermost Maastrichtian		
Formation	Godula Formation		
Species / Sample Number	PB1	PB2	PB3
Achomosphaera alcicornu	6		
Achomosphaera andalousiensis	6	3	
Achomosphaera ramulifera	32		3
Achomosphaera ramulifera ramosasimilis			16
Achomosphaera triangulata	11	17	18
Alterbidinium ulloriaq	3		
Callaiosphaeridium asymmetricum	11		
Cerodinium sp.	3		12
Chatangiella spectabilis	11	6	
Cordosphaeridium sp.			6
Cribroperidinium cf. *edwardsii*			5
Cauveridium membraniphorum			3
Dapsillidinum duma	2		
Ellipsodinium rugulosum			2
Florentinia aculeata	11		12
Heteraulacacysta porosa	3		
Heterosphaeridium cordiforme	15		
Heterosphaeridium spinaconjunctum	23		24
Hystrichodinium pulchrum	8		5
Isabelidinium cf. *bakeri*	14		
Odontochitina costata		3	4
Odontochitina operculata	7	5	8
Odontochitina porifera	3		
Oligosphaeridium asterigerum	4	3	
Oligosphaeridium poculum	3		
Oligosphaeridium sp.			16
Operculodinium centrocarpum	6		
Palaeocystodinium golzowense			5
Palaeohystrichophora infusorioides	4	4	
Palaeoperidinium pyrophorum			11
Pervosphaeridium pseudhystrichodinium	4		
Pervosphaeridium truncatum			4
Pierceites cf. *schizocystis*	2		
Senoniasphaera inornata	13		19
Spiniferites cf. *bulloideus*	3	4	
Spiniferites porosus		3	2
Spiniferites pseudofurcatus			11
Spiniferites ramosus	23	9	19
Spiniferites ramosus granomembranaceus			14
Spiniferites scabrosus			2
Spiniferites? *velatus*			3
Surculosphaeridium sp.			36
Surculosphaeridium? *longifurcatum*	7	8	5
Tehamadinium sp.			7
Thalassiphora sp.	3	1	
Trithyrodinium evittii	1	1	
Trithyrodinium sp.			13
Trithyrodinium suspectum			1
Xenascus ceratioides	22	7	2
Xenascus perforatus	6		
Xenascus sarjeantii	11	7	15

Alterbidinium distinctum was found in sample BL0. Representatives of the genus *Alterbidinium* have their first occurrence in the Early Maastrichtian (Antonescu *et al.* 2001). *Apteodinium deflandrei* has its last occurrence in the Early Maastrichtian (Roncaglia 2002, Williams *et al.* 2004). *Areoligera volata* was previously reported from the Maastrichtian of south Germany (Kirsch 1991). The highest occurrences of *Hystrichodinium pulchrum* and *Odontochitina operculata* are calibrated in the Early Maastrichtian both in the northern Apennines (Roncaglia 2002, Roncaglia & Corradini 1997) and in the Maastrichtian type-area (Robaszynski *et al.* 1985). The highest occurrence of *Odontochitina* is accepted as a cosmopolitan "event", which has often been reported in the Early Maastrichtian (Wiliams *et al.* 2004). *Trihyrodinium suspectum* has its last occurrence in sample BL0 of the studied sections. Representatives of this species do not range beyond the lowermost Maastrichtian (Williams *et al.* 2004, and others).

In summary, interpretation of our data suggests that sedimentation of the middle and upper parts of the Godula Formation in the studied part of the Silesian basin is Late Campanian in age and was presumably terminated during the earliest Maastrichtian. Based on earlier data (Skupien *et al.* in press), sedimentation of the Godula Formation starts in the Santonian. This is in contradiction with the Turonian to Santonian age suggested by Hanzlíková (1972a) based on agglutinated foraminifera. Similarly, Lemanska & Gedl (2005) interpreted a Late Santonian to Middle Campanian age for the Godula Formation in the Silesian Unit in Poland based on dinoflagellate cysts and foraminifera.

The age of the Istebna Formation was previously interpreted as Campanian to Maastrichtian or Danian(?) (Hanzlíková 1972b). We propose herein a latest Campanian, or possibly Early Maastrichtian age (in comparison with data from Italy, Roncaglia 2002) for the basal sedimentation of the Istebna Formation.

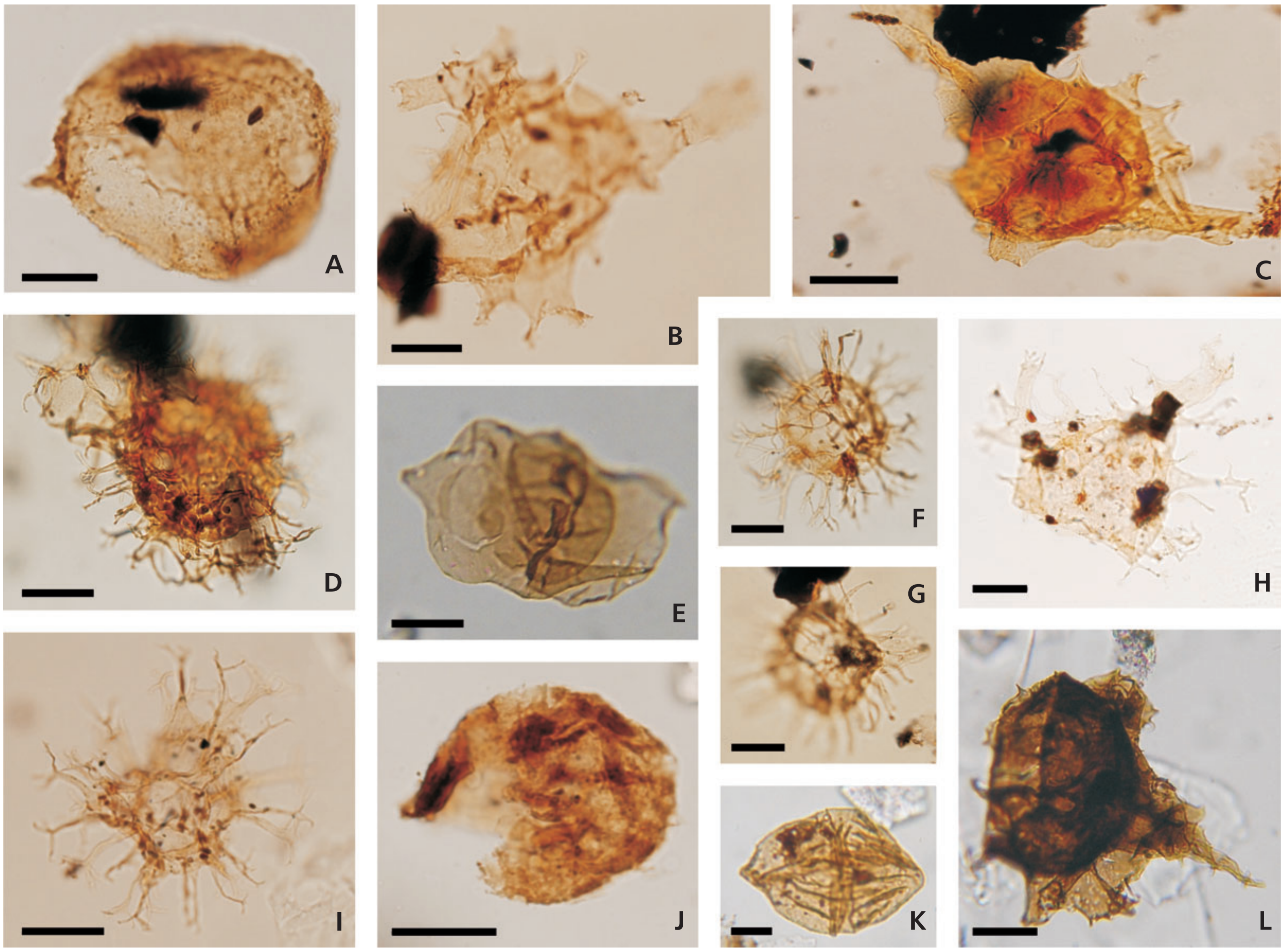

Figure 11. Taxa discovered; the species name is followed by sample location and England Finder coordinates (for localization of the specimen on the slide). Scale is 20 μm. • A – *Tehamadinium* sp.; PB3/a, S38. • B – *Xenascus ceratioides* (Deflandre, 1937b) Lentin & Williams, 1973; SH3a/a, V43/4. • C – *Xenascus* sp.; SH3b, K/L40.• D – *Spiniferites* aff. *ramosus granosus* (Davey & Williams, 1966a) Lentin & Williams, 1973; SH2/a, Q35/4. • E – *Isabelidinium* sp.; SH1b, D35. • F – *Achomosphaera triangulata* (Gerlach, 1961) Davey & Williams, 1969; PB1a, O37/1. • G – *Florentinia radiculata* (Davey & Williams, 1966b) Davey & Verdier, 1973; BL3a, K44/45. • H – *Xenascus sarjeantii* (Corradini, 1973) Stover & Evitt, 1978; PB2/a, S32. • I – *Spiniferites ramosus* (Ehrenberg, 1838) Loeblich & Loeblich, 1966; SH2b/a, D50/1. • J – *Trithyrodinium evittii* Drugg, 1967; PB2/a, F51/3. • K – *Dinogymnium* sp.; SH1b, S32/33. • L – *Xenascus perforatus* (Vozzhennikova, 1967) Yun, 1981; PB1b, U37.

Palaeoenvironmental assessment

The Godula and Istebna Formations represent flysch sedimentation consisting of turbiditic rhythms of relatively coarse-grained clastic material at the base, and fining upwards. Turbiditic material typically originates from the more proximal parts of a flysch basin, *e.g.*, from outer shelf and slope environments. The palynofacies reflect this sedimentation.

Samples are characterized by a very high percentage of phytoclasts (Figs 3–8), a low percentage of palynomorphs (5–10%) and very little AOM (1–5%) which indicates a shallow marine environment with high terrestrial influx. Only in the "black" shales of the Istebna Formation (Bílá section) percentage of AOM is slightly higher (10–17%) and which can indicate anoxic conditions. The studied successions are also characterized by a low percentage of dinoflagellate cysts (less than 9%) and a very low percentage of spores and pollen grains (less than 5%).

Dinoflagellate cyst assemblages in the studied section are dominated by groups, as genera *Achomosphaera, Exochosphaeridium, Oligosphaeridium, Pervosphaeridium, Spiniferites* and *Surculosphaeridium*, that lived in offshore waters. However, their ratio is variable. It is the higher in the samples taken from the middle part of the Godula Formation. The occurrence of typical open oceanic dinoflagellates like *Pterodinium* confirms open marine or oceanic depositional settings.

A general decline in the number of representatives of *Achomosphaera, Spiniferites* and absence of *Pterodinium* in the upper part of the Godula Formation and Istebna Formation might be related to sea-level fall.

High flux of organic matter, which seems to be resedimented from more proximal areas, is indicated by the

Table 3. Distribution of dinoflagellate cysts in the Zarovjanka and Bílá sections. Numbers refer to counted specimens in the slides. Abbreviations: *Glap.* – *Glaphyrocysta*, *Heterosphae.* – *Heterosphaeridium*, *S.* – *Spiniferites, Surculosphae.* – *Surculosphaeridium*.

Age	Early Maastrichtian					
Formation	Istebna Formation					
Species / Sample Number	ZA1	ZA2	BL0	BL1	BL2	BL3
Achomosphaera alcicornu			4			
Achomosphaera fenestra			12		12	13
Alterbidium acutulum	11					
Alterbidinium? *distinctum*	14		2			
Apteodinium deflandrei					2	
Areoligera aff. *tenuicapillata*			18		12	
Areoligera coronata						15
Areoligera guembelii						14
Areoligera volata			26	6	31	18
Cassiculosphaeridium reticulatum	12					
Cauveridium membraniphorum						2
Cerodinium diebelii	12	3		2	1	16
Cerodinium cf. *wardenense*			1			
Chatangiella sp.			2			16
Chatangiella williamsii			2			
Cordosphaeridium sp.					1	
Cyclonephelium filoreticulatum	2					
Deflandrea galeata						6
Deflandrea cf. *phosphoritica*	16					
Florentinia ferox				2		
Florentinia radiculata				1		13
Glap. castelcasiense castelcasiense			10			
Glaphyrocysta sp.		3	27	2		
Glaphyrocysta wilsonii			4			
Heterosphaeridium cordiforme					11	
Heterosphaeridium sp.			42			
Heterosphae. spinaconjunctum						12
Homotryblium cf. *tenuispinosum*	2	1				
Hystrichodinium pulchrum				2		11
Hystrichosphae. conispiniferum				12		
Hystrichosphae. salpingophorum					2	4

Age	Early Maastrichtian					
Formation	Istebna Formation					
Species / Sample Number	ZA1	ZA2	BL0	BL1	BL2	BL3
Hystrichosphaeridium truswelliae					1	
Isabelidinium sp.	14	2				
Kleithriasphaeridium sp.				5		
Odontochitina operculata			2			
Oligosphaeridium buciniferum			14			
Oligosphaeridium complex	35	4				7
Oligosphaeridium sp.					1	
Operculodinium centrocarpum				6		3
Operculodinium cf. *divergens*				7		
Palaeocystodinium bulliforme						1
Palaeocystodinium golzowense	5	1	13	2	2	3
Palaeoperidinium pyrophorum			2	1	3	1
Pervosphaeridium intervelum			5	4	1	4
Phelodinium kozlowskii						x
Phelodinium magnificum				1		
Phelodinium tricuspis						1
Pierceites? *chiemgoviensis*					2	1
Scriniodinium sp.	10		2			
Senoniasphaera inornata				2		
Spiniferites membranaceus						12
Spiniferites pseudofurcatus						1
Spiniferites ramosus			30	6	2	12
S. ramosus granomembranaceus						7
Spiniferites scabrosus						1
Sumatradinium soucouyantiae			1	1		
Surculosphaeridium sp.	35		4			
Surculosphaeridium? *cassospinum*					1	
Surculosphae.? *longifurcatum*		8				
Trithyrodinium sp.			2			
Trithyrodinium suspectum			1			
Xiphophoridium cf. *asteriforme*					1	

occurrence of dinoflagellate cysts (as genera *Areoligera, Odonotochitina*), which inhabit mainly near-shore waters. Representatives of *Odontochitina* are frequent in Godula Formation. Representatives of *Areoligera*, a genus often associated with inshore environments (Brinkhuis 1994), show the highest frequencies in "black" shales of the Istebna Formation. This might indicate less-open oceanic conditions in the Early Maastrichtian possibly related to a long-term sea-level fall from the Campanian into the Early Maastrichtian.

The constant presence of taxa *Cerodinium* and *Trithyrodinium* that indicate tropical conditions (Gedl 2004), indicates rather stable and warm surface waters in the Silesian basin, consistent with the warm temperate or subtropical climate that prevailed during the Late Campanian and Early Maastrichtian.

Conclusions

The palynological study of samples from the Godula and Istebna formations documents the kerogen assemblage and dinoflagellate cysts distribution.

1. Residues are characterized by abundant sedimentary organic materials (SOM), dominated by phytoclasts and containing only a small amount of AOM. The studied successions are also characterized by a low percentage of dinoflagellate cysts (less than 9%) and a very low percentage of spores and pollen grains (less than 5%). The former indicates deposition in an offshore marine environment subjected to high influxes of terrestrial material.

2. Dinoflagellate cysts suggest that sedimentation of the middle part of the studied Godula Formation took place

during the Late Campanian. This is in accordance with data from the Bystrá section (Skupien *et al.* in press) where dinoflagellate cyst associations of Middle to Late Campanian age occur and occurrence of agglutinated foraminifera confirm this age assignment.

3. Sedimentation of the Godula Formation was terminated close to the Campanian/Maastrichtian boundary or probably during the earliest Maastrichtian.

4. The basal part of the Istebna Formation is of Late Campanian – earliest Maastrichtian age.

5. The dark grey shales of the Istebna Formation were deposited in anoxic conditions (slightly higher percentages of AOM) and are of Early Maastrichtian age.

6. A gradual sea-level fall was presumably responsible for a gradual decrease in the frequency of oceanic taxa from Late Campanian to Early Maastrichtian.

7. The presence of *Cerodinium* and *Trithyrodinium* throughout the sections suggests that surface waters were warm.

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Appendix. List of dinocyst taxa encountered in this study

List of dinocyst taxa encountered in this study, arranged in alphabetical order of genus name. The readers are referred to Fensome & Williams (2004) and Fauconnier & Masure (2004) for dinocyst taxonomy and references to taxa. A selection of taxa is depicted on Figs 9–11.

Achomosphaera alcicornu (Eisenack, 1954b) Davey & Williams, 1966
Achomosphaera andalousiensis Jan du Chêne, 1977
Achomosphaera fenestra Kirsch, 1991
Achomosphaera ramulifera (Deflandre, 1937b) Evitt, 1963
Achomosphaera ramulifera ramosasimilis Yun, 1981
Achomosphaera sagena Davey & Williams, 1966
Achomosphaera triangulata (Gerlach, 1961) Davey & Williams, 1969
Alterbidium acutulum (Wilson, 1967b) Lentin & Williams, 1985
Alterbidinium? *distinctum* (Wilson, 1967) Lentin & Williams, 1985
Alterbidinium ulloriaq Nøhr-Hansen, 1996
Apteodinium deflandrei (Clarke & Verdier, 1967) Lucas-Clark, 1987
Areoligera coronata (O. Wetzel, 1933a) Lejeune-Carpentier, 1938
Areoligera guembelii Kirsch, 1991
Areoligera senonensis Lejeune-Carpentier, 1938
Areoligera aff. *tenuicapillata* (O. Wetzel, 1933) Lejeune-Carpentier, 1938
Areoligera volata Drugg, 1967
Biconidinium longissimum Islam, 1983
Callaiosphaeridium asymmetricum (Deflandre & Courteville, 1939) Davey & Williams, 1966
Cassiculosphaeridium reticulatum Davey, 1969
Cauveridium membraniphorum (Cookson & Eisenack, 1962) Fauconnier & Masure, 2004
Cerebrocysta bartonensis Bujak *in* Bujak *et al.*, 1980
Cerodinium diebelii (Alberti, 1959b) Lentin & Williams, 1987

Cerodinium cf. *wardenense* (Williams & Downie, 1966) Lentin & Williams, 1987
Cerodinium sp.
Chatangiella bondarenkoi (Vozzhennikova, 1967) Lentin & Williams, 1976
Chatangiella sp.
Chatangiella spectabilis (Alberti, 1959b) Lentin & Williams, 1976
Chatangiella tripartita (Cookson & Eisenack, 1960a) Lentin & Williams, 1976
Chatangiella williamsii Yun, 1981
Cordosphaeridium sp.
Coronifera oceanica hebospina Yun, 1981
Cribroperidinium cf. *edwardsii* (Cookson & Eisenack, 1958) Davey, 1969
Cribroperidinium orthoceras (Eisenack, 1958a) Davey, 1969
Cyclonephelium distinctum Deflandre & Cookson, 1955
Cyclonephelium floreticulatum (Slimani, 1994) Prine *et al.*, 1999
Dapsillidinum duma (Below, 1982) Lentin & Williams, 1985
Deflandrea galeata (Lejeune-Carpentier, 1942) Lentin & Williams, 1973
Deflandrea cf. *phosphoritica* Eisenack, 1938
Dinogymnium sp.
Dinogymnium cf. *sibiricum* (Vozzhennikova, 1967) Lentin & Williams, 1973
Downiesphaeridium? *aciculare* (Davey, 1969a) Fauconnier & Masure, 2004
Ellipsodinium rugulosum Clarke & Verdier, 1967
Exochosphaeridium aff. *bifidum* (Clarke & Verdier, 1967) Clarke *et al.*, 1968
Exochosphaeridium bifidum (Clarke & Verdier, 1967) Clarke *et al.*, 1968
Exochosphaeridium multifurcatum (Deflandre, 1937b) Fauconnier & Masure, 2004
Exochosphaeridium phragmites Davey *et al.*, 1966
Exochosphaeridium sp.
Florentinia aculeata Kirsch, 1991
Florentinia deanei (Davey & Williams, 1966b) Davey & Verdier, 1973
Florentinia ferox (Deflandre, 1937b) Duxbury, 1980
Florentinia hypomagna Yun, 1981
Florentinia laciniata Davey & Verdier, 1973
Florentinia cooksoniae (Singh, 1971) Duxbury, 1980
Florentinia radiculata (Davey & Williams, 1966) Davey & Verdier, 1973
Florentinia sp.
Glaphyrocysta castelcasiensis castelcasiensis Corradini, 1973
Glaphyrocysta sp.
Glaphyrocysta texta (Bujak, 1976) Stover & Evitt, 1978
Glaphyrocysta wilsonii Kirsch, 1991
Hafniasphaera fluens Hansen, 1977
Heteraulacacysta porosa Bujak *in* Bujak *et al.*, 1980
Heterosphaeridium cordiforme Yun, 1981
Heterosphaeridium sp.
Heterosphaeridium spinaconjunctum Yun, 1981
Homotryblium cf. *tenuispinosum* Davey & Williams, 1966
Hystrichodinium pulchrum Deflandre, 1935
Hystrichokolpoma proprium (Marheinecke, 1992) Foucher, 2004
Hystrichosphaeridium bowerbankii Davey & Williams, 1966
Hystrichosphaeridium conispiniferum Yun, 1981
Hystrichosphaeridium salpingophorum Deflandre, 1935
Hystrichosphaeridium truswelliae Wrenn & Hart, 1988
Hystrichosphaeridium tubiferum (Ehrenberg, 1838) Deflandre, 1937
Hystrichosphaeridium? sp.
Hystrichostrogylon membraniphorum Agelopoulos, 1964
Isabelidinium belfastense (Cookson & Eisenack, 1961) Lentin & Williams, 1977
Isabelidinium cf. *bakeri* (Deflandre & Cookson, 1955) Lentin & Williams, 1977
Isabelidinium sp.
Isabelidinium svartenhukensis Nøhr-Hansen, 1996
Kiokansium polypes (Cookson & Eisenack, 1962) Below, 1982
Kleithriasphaeridium loffrense Davey & Verdier, 1976
Kleithriasphaeridium readii (Davey & Williams, 1966) Davey & Verdier, 1976
Kleithriasphaeridium sp.
Leberidocysta chlamydata (Cookson & Eisenack, 1962b) Stover & Evitt, 1978
Multiplicisphaeridium? *cruciatum* (Wetzel, 1933) Stancliffe & Sarjeant, 1994
Odontochitina costata Alberti, 1961
Odontochitina operculata (O. Wetzel, 1933) Deflandre & Cookson, 1955
Odontochitina porifera Cookson, 1956
Oligosphaeridium albertense (Pockock, 1962) Davey & Williams, 1969
Oligosphaeridium asterigerum (Gocht, 1959) Davey & Williams, 1969
Oligosphaeridium buciniferum Corradini, 1973
Oligosphaeridium complex (White, 1842) Davey & Williams, 1966
Oligosphaeridium poculum Jain, 1977
Oligosphaeridium sp.
Operculodinium centrocarpum (Deflandre & Cookson, 1955) Wall, 1967
Operculodinium cf. *divergens* (Eisenack, 1954b) Stover & Evitt, 1978
Palaeocystodinium bulliforme Ioannides, 1986
Palaeocystodinium golzowense Alperti, 1961
Palaeohystrichophora infusorioides Deflandre, 1935
Palaeoperidinium pyrophorum (Ehrenberg, 1838) Sarjeant, 1967
Palaeoperidinium sp.
Palaeotetradinium silicorum Deflandre, 1936
Pervosphaeridium intervelum Kirsch, 1991
Pervosphaeridium pseudhystricodinium (Deflandre, 1937) Yun, 1981
Pervosphaeridium truncatum (Davey, 1969) Below, 1982
Phelodinium cf. *kozlowskii* (Gorka, 1963) Lindgren, 1984
Phelodinium magnificum (Stanley, 1965) Stover & Evitt, 1978
Phelodinium tricuspe (O. Wetzel, 1933) Stover & Evitt, 1978
Phthanoperidinium distinctum Bujak, 1994
Pierceites? *chiemgoviensis* Kirsch, 1991
Pierceites cf. *schizocystis* Habib & Drugg, 1987
Pterodinium aliferum Eisenack, 1958
Pterodinium cingulatum (O. Wetzel, 1933b) Below, 1981
Pterodinium? *cornutum* Eisenack, 1958

Raetiaedinium truncigerum (Deflandre, 1937) Kirsch, 1991
Scriniodinium? sp.
Senoniasphaera inornata (Drugg, 1970) Stover & Evitt, 1978
Senoniasphaera rotundata Clarke & Verdier, 1967
Spiniferites aff. *ramosus granosus* (Davey & Williams, 1966) Lentin & Williams, 1973
Spiniferites cf. *bulloideus* (Deflandre & Cookson, 1955) Sarjeant, 1970
Spiniferites membranaceus (Rossignol, 1964) Sarjeant, 1970
Spiniferites porosus (Manum & Cookson, 1964) Harland, 1973
Spiniferites pseudofurcatus (Klumpp, 1953) Sarjeant, 1970
Spiniferites ramosus granomembranaceus (Davey & Williams, 1966a) Lentin & Williams, 1973
Spiniferites ramosus (Ehrenberg, 1838) Loeblich & Loeblich, 1966
Spiniferites ramosus brevifurcatus (Eisenack & Cookson, 1974) Lentin & Williams, 1977
Spiniferites scabrosus (Clarke & Verdier, 1967) Lentin & Williams, 1975
Spiniferites? *velatus* (Clarke & Verdier, 1967) Stover & Evitt, 1978
Subtilisphaera sp.
Sumatradinium soucouyantiae de Verteuil & Norris, 1992
Surculosphaeridium sp.
Surculosphaeridium? *cassospinum* Yun, 1981
Surculosphaeridium? *longifurcatum* (Firtion, 1952) Davey *et al.*, 1966
Tehamadinium sp.
Tanyosphaeridium boletus Davey, 1974
Thalassiphora sp.
Trithyrodinium evittii Drugg, 1967
Trithyrodinium sp.
Trithyrodinium suspectum (Manum & Cookson, 1964) Davey, 1969
Xenascus ceratioides (Deflandre, 1937) Lentin & Williams, 1973
Xenascus perforatus (Vozzhennikova, 1967) Yun, 1981
Xenascus sarjeantii (Corradini, 1973) Stover & Evitt, 1978
Xenascus sp.
Xiphophoridium cf. *asteriforme* Yun, 1981