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Dinoflagellate study of the Lower Cretaceous deposits in the Pieniny Klippen Belt (Rochovica section, Slovak Western Carpathians)

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Abstract. One of the most complete and best documented sections, namely the Rochovica section, was selected for the first detailed palynological study of Lower Cretaceous sediments of the Pieniny Klippen Belt. The greatest attention was given, from not only the biostratigraphical but also the palaeoecological point of view, to the assemblages of non-calcareous dinoflagellates. Based on dinoflagellates, the age of the studied sediments corresponds to the Upper Barremian–Albian. Quantitative composition of the palynomorph assemblage reflects open-sea conditions with higher supply of terrigenous material during the Barremian and the Early Aptian as well as a marked supply of nutrients during the Early Aptian. Generally, a rise in the sea level in the Barremian–Albian period is obvious (oceanic types of dinocysts are present).

Key words: Lower Cretaceous, dinoflagellate, palynomorpha, palaeoecology, palaeoclimatology, Western Carpathians, Pieniny Klippen Belt

Introduction

The submitted study presents the first integrated palynological results concerning the Lower Cretaceous sediments of the Pieniny Klippen Belt. Attention was paid to one of the most complete sections situated NNE of Žilina (Fig. 1), about 3.5 km from this town, on the southeastern slope of Rochovica Hill (640 m above sea level), along the right bank of the Kysuca River. The section belongs to the Kysuca development of the Pieniny Klippen Belt.

Upper Tithonian–Upper Albian deposits are exposed in the cut of the road leading from the village of Vranie to the village of Rudinka (R–section), a part of the exposure (Hauterivian–Lower Aptian) is observed on the right bank of the Kysuca River (K–section in Michalík et al. 1999), too.

Lately, it was Lintnerová (1999), Michalík et al. (1999, 2001), Vašíček et al. (1992, 1994), Houša et al. (1999) and others who have been concerned with Jurassic–Cretaceous deposits of this locality.

Upper Tithonian–Barremian rocks pertain to the Pieniny Limestone Formation. The formation is composed of white and light grey limestones (Maiolica type) with chert beds. The Tithonian–Berriasian part was dated on the basis of calpionellids, calcareous dinoflagellates and calcareous nannoplankton. According to Michalík et al. (1999), the Berriasian limestones with cherts prove deepening of the sedimentary basin. The Upper Valanginian deposits are represented by rhythmically alternating limestone and marlstone beds. The Valanginian–Hauterivian succession was stratigraphically dated, in addition to the microfauna, partly on the basis of ammonite and aptychi assemblages. The Vranie Member as a higher member of the Pieniny Limestone Formation is of Barremian age. Lithologically, this member represents light grey clayey spotted limestones with intercalations of calciturbidites with high content of benthic organisms.

The Pieniny Limestone Formation is overlain by the Koňhora Formation represented by black to dark brown clays with abundant meroleims (coalified remains of plants) and pyrite. These dark clays rich in C_{org} are connected with the 1a OAE (the Selli Event, Lintnerová 1999).

The Late Aptian was the beginning of the sedimentation of spotted limestones with intercalations of dark clays assigned to the Brodno Formation. This formation is overlain by the Late Albian red pelagic marls of the Rudina Formation.

The first preliminary palynological results were presented in a detailed multidisciplinary (biological, chemical and sedimentological) study of Barremian to Albian sediments by Michalík et al. (1999).

Material and methods

Samples for the palynological study were taken from all accessible and unweathered pelitic intercalations of the Vranie Member (Pieniny Limestone Formation; Valanginian–Barremian); dark pelites of the Koňhora Formation (Aptian), intercalations of the Brodno Formation and red pelites of the Rudina Formation (Albian) were sampled in more detail.

The samples were processed by a standard palynological technique, i.e. by dissolution in HCl and HF with subsequent sieving on polyethylene sieves of the mesh size of 20 µm. Specimens with separated dinocysts are deposited in the Institute of Geological Engineering at VŠB – Technical University of Ostrava. For suitable samples, qualitative observation was supplemented by quantitative analysis.

The quantitative study includes two steps:

I. Counting of the whole assemblage of up to 150 palynomorphs; this step includes the recognition of four

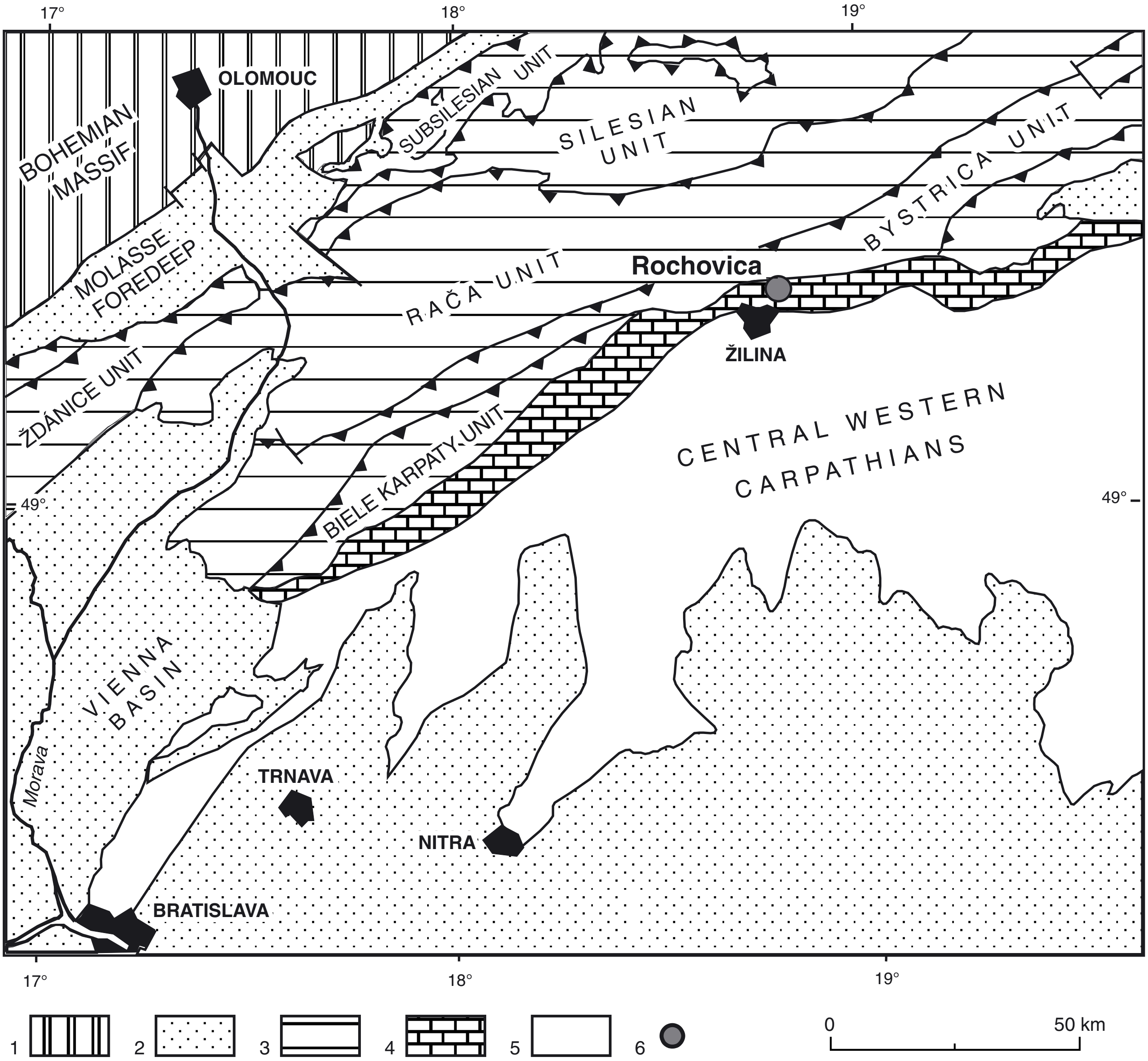

Fig. 1. Principal tectonic units of the Western Carpathians (after Vašíček et al. 1994) and position of the locality of Rochovica. 1 – Bohemian Massif, 2 – Neogene cover, 3 – Outer Western Carpathians, 4 – Pieniny Klippen Belt, 5 – Central Western Carpathians, 6 – locality.

broad palynomorph categories (Fig. 3): dinoflagellate cysts, foraminiferal linings (inner walls of foraminifers), bisaccate pollen, other pollen and spores (sporomorphs excluding bisaccates).

II. Counting of up to 250 determinable dinoflagellate cysts when possible. Dinoflagellate cysts were grouped into six palaeoenvironmentally significant groups (Fig. 4) (modified after Wilpshaar and Leereveld 1994, Leereveld 1995):

Varying salinity group (restricted shallow marine). The regular dominance of the group may be the result of freshwater influx and nutrient supply (Leereveld 1995). Freshwater and nutrient influx implies increased runoff, possibly resulting from increased precipitation. This group comprises representatives of genera *Muderongia*, *Odontochitina* and *Subtilisphaera*.

Littoral group (*Canningia, Circulodinium, Pseudoceratium*).

Inner neritic group (*Cribroperidinium, Apteodinium*).

Neritic I group (*Spiniferites* and morphologically closely related taxa).

Neritic II group (*Florentinia*, *Kleithriasphaeridium*, *Oligosphaeridium*).

Oceanic group (*Hapsocysta*, *Pterodinium*). The oceanic group is the only autochthonous group (not transported from the shelf, but living in the oligotrophic pelagic water) in the studied type of sediments.

Four methods were used to interpret palynological assemblage fluctuations in terms of environmental changes: a) the ratio of marine palynomorphs (acritarchs, dinoflagellate cysts, foraminiferal linings) to land-derived palynomorphs (pollen and spores); b) changes in relative abundance of palaeoenvironmental dinocyst groups; c) dominance ratio expressed as the number of specimens of the most abundant genus plus the number of specimens of the second more frequent genus to the total number of determinable dinoflagellate cysts; d) diversity expressed as the number of genera found in each sample. Warm-water and cold-water species were recognized according to Leereveld (1995).

Stratigraphic evaluation

The text below gives the characteristics of the stratigraphic assignment of the sediments studied according to dinoflagellates. The designation of samples is in accordance with the designation of beds in outcrops. The qualitative abundance of dinocysts is illustrated in Tab. 1 and Fig. 2.

No sufficient amount of material necessary for the analysis of dinoflagellates was obtained from the lowermost part of the section (Valanginian–Hauterivian, Vranie Member of the Pieniny Limestone Formation). Most pelitic intercalations in this part are weathered; as for the available specimens, merely a negligible part of them is positive. The lowermost samples analysed are R157.1 and R157.5. The assemblage is very poor. The species of *Achomosphaera neptunii, Cometodinium whitei, Cyclonephelium distinctum, Dingodinium albertii, Endoscrinium campanula, Muderongia tabulata* and *Systematophora* sp. were determined. This assemblage only suggests that the part concerned is not older than the uppermost Lower Berriasian (Leereveld 1995).

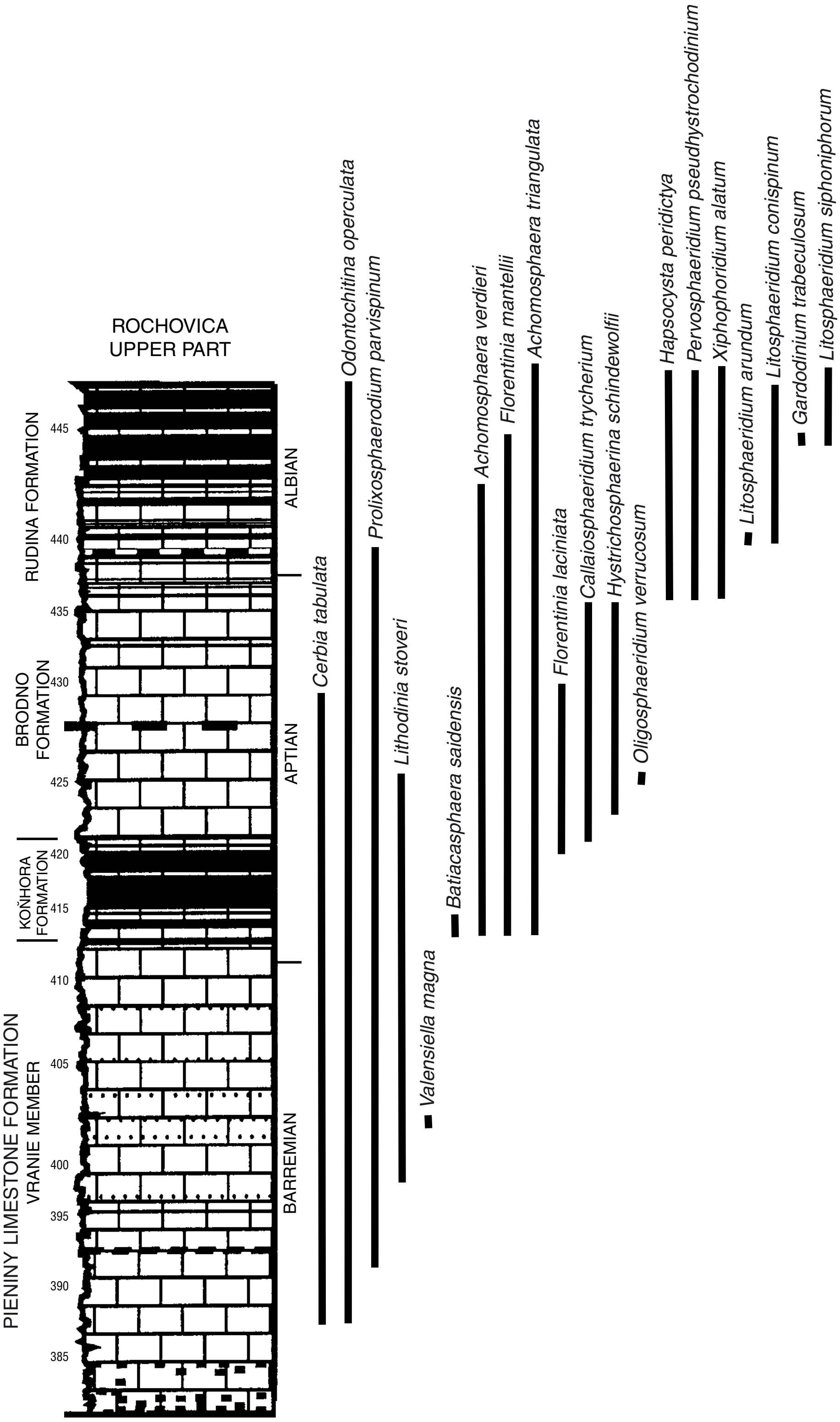

Fig. 2. Ranges of selected stratigraphically important dinoflagellate cysts (section after Michalík et al. 1999)

In sample R162.1, a poor assemblage appears again, being represented by the species of *Cometodinium whitei, Dapsilidinium warrenii, Endoscrinium campanula, Eyrea nebulosa, Muderongia tabulata, Oligosphaeridium complex, Prolixosphaeridium* sp., *Spiniferites* sp. According to the presence of *O. complex* and *Spiniferites* sp. it is possible to say that this part belongs to the Lower Valanginian (from the ammonite *Pertransiens* Zone) or to a younger

Tab. 1. Qualitative distribution of dinoflagellate cyst taxa in the Rochovica section.

Stratigraphy		BARREMIAN							APTIAN													ALBIAN							
		Upper							Lower					Middle				Upper				Lower-Middle						Upper	
Samples	Taxa	385,5	392	397	399	401,8	405	408,5	413,8	415	416	417	418	419	421	422,5	423	425	425,5	429,2	435,1	438,5	440	441	443	444	445	446	446,5
1	*Cymososphaeridium validum*	■																											
2	*Cyclonephelium intonsum*	■			■																								
3	*Gonyaulacysta* sp.	■	■	■	■	■			■																				
4	*Cyclonephelium* sp.	■	■	■							■	■				■	■			■									
5	*Cerbia tabulata*	■			■	■	■		■		■	■	■	■	■	■	■	■	■	■									
6	*Oligosphaeridium asterigerum*	■	■	■			■	■	■	■					■	■	■					■	■						
7	*Kiokansium polypes*	■								■	■	■												■			■		
8	*Oligosphaeridium complex*	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■				■
9	*Spiniferites ramosus*	■		■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■		
10	*Odontochitina operculata*	■					■		■	■	■	■	■	■		■	■			■	■		■	■		■	■	■	■
11	*Dapsilidinium* sp.		■																										
12	*Oligosphaeridium* cf. *vasiformum*		■																										
13	*Surculosphaeridium belowii*		■																										
14	*Tenua hystrix*		■	■																									
15	*Tanyosphaeridium isocalamus*		■										■			■													
16	*Circulodinium distinctum*		■																■	■									
17	*Circulodinium brevispinosum*		■	■							■											■							
18	*Cribroperdinum* sp.		■	■															■			■							
19	*Dapsilidinium multispinosum*		■	■	■	■	■		■			■					■		■	■		■	■						
20	*Prolixosphaeridium parvispinum*		■		■											■	■		■				■						
21	*Oligosphaeridium poculum*		■	■																		■	■					■	
22	*Spiniferites* sp.		■		■														■			■	■	■	■			■	■
23	*Gonyaulacysta cretacea*			■		■																■							
24	*Kleithriasphaeridium eoinodes*			■			■		■	■	■		■	■		■	■					■	■			■	■	■	■
25	*Protoellipsodinium spinosum*			■		■			■		■					■	■		■										■
26	*Protoellipsodinium longispinosum*				■																								
27	*Muderongia tabulata*				■																								
28	*Lithodinia stoveri*				■	■												■											
29	*Exochosphaeridium muelleri*				■			■	■	■	■	■	■	■	■	■	■		■				■		■	■			■
30	*Batiacasphaera* sp.					■																							
31	*Occisucysta duxburyi*					■																							
32	*Valensiella magna*					■																							
33	*Hystrichodinium voigtii*					■						■																	
34	*Ctenidodinium elegantulum*					■					■					■													
35	*Hystrichodinium pulchrum*					■										■													
36	*Coronifera oceanica*					■			■	■				■	■						■								
37	*Tehamadinium* sp.					■																			■				
38	*Cometodinium whitei*					■				■	■					■					■	■	■		■	■	■	■	
39	*Callaiosphaeridium asymmetricum*						■		■	■											■								
40	*Achomosphaera neptunii*						■		■	■		■	■	■		■				■									
41	*Pterodinium aliferum*							■																					
42	*Cribroperidinium edwardsii*							■			■	■	■																
43	*Endoscrinium campanula*							■										■					■		■	■	■		
44	*Achomosphaera ramulifera*							■							■			■					■			■	■	■	■
45	*Dinogymnium* sp.								■																				
46	*Batiacasphaera saidensis*								■	■																			
47	*Florentinia cooksoniae*								■	■												■							
48	*Circulodinium vermiculatum*								■		■		■												■				
49	*Achomosphaera verdieri*								■	■	■	■	■	■	■	■				■			■	■	■				
50	*Florentinia mantellii*								■		■			■		■											■		
51	*Achomosphaera triangulata*								■	■		■			■			■			■		■			■	■	■	■
52	*Cassiculosphaeridia reticulata*									■																			
53	*Protoellipsodinium touile*									■																			
54	*Cribroperidinium cooksoniae*									■	■																		
55	*Tehamadinium tenuiceras*									■			■																
56	*Kleithriasphaeridium corrugatum*									■		■		■															
57	*Coronifera tubulosa*									■					■														
58	*Cyclonephelium brevispinatum*									■							■		■										
59	*Surculosphaeridium* sp.										■																		
60	*Cyclonephelium inconspicuum*										■	■	■																
61	*Subtilisphaera* sp.											■																	

Tab. 1. continued

	Stratigraphy	**BARREMIAN**							**APTIAN**													**ALBIAN**							
		Upper							**Lower**					**Middle**				**Upper**				**Lower-Middle**						**Upper**	
Samples	**Taxa**	385,5	392	397	399	401,8	405	408,5	413,8	415	416	417	418	419	421	422,5	423	425	425,5	429,2	435,1	438,5	440	441	443	444	445	446	446,5
62	*Palaeoperidinium cretaceum*											x	x			x				x									
63	*Cepadinium ventriosum*												x																
64	*Cribroperidinium orthoceras*												x																
65	*Exochosphaeridium bifidum*												x																
66	*Florentinia laciniata*													x		x				x									
67	*Callaiosphaeridium trycherium*														x			x			x								
68	*Dissiliodinium globolus*														x														
69	*Florentinia radiculata*														x														
70	*Trabeculidinium quinquetrum*														x														
71	*Spiniferites ramosus reticulatus*														x		x												
72	*Bourkidinium granulatum*															x													
73	*Protoellipsodinium clavulum*															x													
74	*Subtilisphaera perlucida*															x													
75	*Tanyosphaeridium boletus*															x													
76	*Apteodinium granulatum*															x	x	x											
77	*Hystrichosphaerina schindewolfii*															x					x								
78	*Pterodinium cingulatum*															x	x		x										x
79	*Fromea amphora*																x												
80	*Spiniferites ? dentatus*																x												
81	*Wallodinium krutzschii*																x					x							
82	*Cribroperidinium auctificium*																	x											
83	*Oligosphaeridium verrucosum*																	x											
84	*Systematophora cretacea*																	x				x							
85	*Spiniferites lenzii*																		x										
86	*Spiniferites ancoriferus*																			x									
87	*Systematophora silybum*																			x									
88	*Muderongia* cf. *staurota*																				x								
89	*Hapsocysta peridictya*																				x			x		x	x	x	x
90	*Pervosphaeridium pseudhystrichodinium*																				x		x	x			x	x	x
91	*Xiphophoridium alatum*																				x		x			x			x
92	*Dapsilidinium duma*																					x							
93	*Oligosphaeridium pulcherrimum*																					x							
94	*Florentinia stellata*																						x						
95	*Hapsocysta dictyota*																						x						
96	*Litosphaeridium arundum*																						x						
97	*Pseudoceratium palymorphum*																						x						
98	*Surculosphaeridium longifurcatum*																						x						
99	*Stephodinium coronatum*																						x	x					
100	*Adnatosphaeridium tutulosum*																						x	x		x			
101	*Litosphaeridium conispinum*																						x			x	x	x	
102	*Hystrichostrongylon membraniphorum*																							x	x				
103	*Dinogymnium albertii*																								x				
104	*Protoellipsodinium seghire*																								x				
105	*Tanyosphaeridium* sp.																								x				
106	*Muderongia* sp.																								x			x	
107	*Leberidocysta* sp.																										x		
108	*Gardodinium trabeculosum*																										x		
109	*Litosphaeridium siphoniphorum*																										x	x	x
110	*Codoniella campanula*																											x	
111	*Hystrichosphaeridium bowerbankii*																											x	x

stage. Palynological data from some of the three above mentioned samples are in accord with the former results (Vašíček et al. 1992). Based on calpionellids, this part pertains to the Lower Valanginian (calpionellid *Calpionellites major* Zone), which corresponds to the ammonite *Campylotoxus* Zone.

Above a rather long interval, from which no specimens from pelitic intercalations were taken, the first sample analysed is sample R341.1. A poor assemblage of dinocysts consists of the species *Bourkidinium* sp., *Cometodinium whitei, Ctenidodinium elegantulum, Dapsilidinium warrenii, Muderongia* cf. *australis, M. macwhaei, Oligosphaeridium complex* and *Spiniferites ramosus*. According to the presence of *Bourkidinium* sp., *O. complex* and *S. ramosus,* it is possible to consider the Valanginian–Hauterivian without any closer assignation (Leereveld

1995). As indicated by calcareous nannoplankton and aptychi, it is the uppermost part of the Lower Hauterivian and the Upper Hauterivian, respectively (Vašíček and Skupien 2002).

Most of the samples were taken from pelitic intercalations of the uppermost part of the Pieniny Limestone Formation, namely from 385.5 m (see Tab. 1). From this sample to the Rudina Formation (446.5 m), not only qualitative but also quantitative compositions of the dinoflagellate assemblages and the whole palynospectrum were observed.

The assemblages of the lowermost sample are not markedly rich. In spite of this, the lowermost sample marks the first appearance of stratigraphically significant species *Cerbia tabulata, Odontochitina operculata* and *Prolixosphaeridium parvispinum.* Last occurrences of *Muderongia tabulata* and *Valensiella magna* lie somewhat higher. If the three above mentioned species first appeared in the observed horizon (R385.5 m), it could be considered the base of the Upper Barremian (Leereveld 1995, Wilpshaar 1995), as suggested by the find of the ammonite *Costidiscus recticostatus* (d'Orbigny) in Bed 389 (Vašíček and Skupien 2002). On the contrary, the last occurrences of *M. tabulata* and *V. magna* lie in the uppermost Barremian.

The last samples that can be still assigned to the Pieniny Limestone Formation (R405 and 408.5) provided Barremian–Aptian without any closer assignment. According to Michalík et al. (1999), it is still the Barremian. A change can be seen in Bed 413.5: it marks the first appearance of the species of *Achomosphaera triangulata, A. verdieri, Batiacasphaera saidensis* and *Florentinia mantelii* typical of the Aptian and younger sediments. Similar assemblages of dinoflagellates are known from the Aptian of the Silesian Unit of the Outer Western Carpathians (Skupien 1997, Skupien and Vašíček 2002).

It is the pelitic Koňhora Formation (samples R415–420) that was documented in more detail. The dinoflagellate assemblage of sample R415 is fairly similar to that of the above mentioned sample. As for the stratigraphically significant species, *Coronifera tubulosa,* typical for the Aptian, first appeared here.

The presence of the species of *Callaiosphaeridium trycherium* and *Florentinia laciniata* may suggest the Middle Aptian age for the interval of samples R419–421 (Verdier 1974, Below 1982, 1984).

Species *Oligosphaeridium verrucosum* known merely from the Upper Aptian, e.g. from NW Africa (Below 1984), Spain (Masure 1988) and the Silesian Unit of the Outer Western Carpathians (Skupien and Vašíček 2002), was found in the dinocysts assemblage of sample R425. This is accompanied by the last occurrences of stratigraphically significant dinocysts: *Subtilisphaera perlucida* in sample R422.5, *Lithodinia stoveri* in sample R425.5, *Achomosphaera neptunii* and *Cerbia tabulata* in sample R429.2 and *Hystrichosphaerina schindewolfii* in sample R435.1. All the species listed above occurred in the Upper Aptian or at the Aptian/Albian boundary for the last time (Davey and Verdier 1974, Leereveld 1995, Stover et al. 1996). These data correspond to the previous results of the study of calcareous nannoplankton (Michalík et al. 1999).

The dinoflagellate assemblage of sample R435.1 can be assigned to the uppermost Aptian – the Lower Albian. Neither typical Aptian representatives nor index dinocysts for the Lower Albian are present. Two interesting markers are the first occurrences of the species *Hapsocysta peridictya* and *Xiphophoridium alatum*. *H. peridictya* is known from the Aptian/Albian boundary deposits of the Bay of Biscay (Davey 1979). However, Prössl (1990) described it from NW Germany from sediments not older than the Lower Albian. *Xiphophoridium alatum* is mostly regarded an Albian species; e.g. Monteil (in Stover et al. 1996) described it from the Upper Albian. Prössl (1990) reported it from the Middle Albian, but it also appeared in the uppermost Aptian in SE France (Vink 1995). The Upper Aptian age can be suggested on the basis of calcareous nannoplankton, too (Michalík et al. 1999).

Judged by the dinoflagellates, sample R440 can be most probably ranked to the Lower Albian. Based on calcareous nannoplankton, this boundary lies already from position 437 upwards. Here, the assemblages change significantly by enrichment in species *Adnatosphaeridium tutulosum, H. dictyota, Litosphaeridium arundum, L. conispinum, Surculosphaeridium longifurcatum* and other species representing a part of typical Albian dinoflagellate assemblages. *L. arundum*, the first occurrence of which has been generally reported from the Lower Albian, is the stratigraphically most significant (Verdier 1974, Van Erve et al. 1980, Leereveld 1995). However, according to Verdier (1974), for example, *S. longifurcatum* appeared in the Middle Albian for the first time. This would correspond to the data of Prössl (1990) who described the occurrence of *L. arundum* in the uppermost part of the Lower Albian to the lowermost part of the Upper Albian. This indicates that the Aptian/Albian boundary can be placed probably much lower in the section (between sample R435.1 and sample 440) and Bed 440 pertains to the Middle Albian. Moreover, one cannot exclude that sample R435.1 already belongs, with regard to the common occurrence of *H. peridictya* and *X. alatum*, to the Albian.

Another significant change occurs in sample R446. Species *Litosphaeridium siphoniphorum* first appears here and forms a substantial part of the assemblage together with *H. peridictya, Litosphaeridium conispinum* and *Pervosphaeridium pseudhystrichodinium*. Its first occurrence was confined to the upper part of the Upper Albian ammonite *M. inflatum* Zone (Davey and Verdier 1973, Prössl 1990, Leereveld 1995). Simultaneously, the sample contains *Gardodinium trabeculosum*, the last occurrence of which has been reported from SE France from the Lower Albian (Van Erve et al. 1980, Leereveld 1995), but Monteil (in Stover et al. 1996) described it from the lower part of the Upper Albian. With respect to the fact that no species characteristic of the higher part of the Upper Albian have been found (Davey and Verdier 1973, Foucher 1981, Leereveld 1995, assemblages well known from the Silesian Unit of the Outer Western Carpathians – Skupien 1997, 1999), it is possible to connect this part with the ammonite *M. inflatum* Zone.

Remarks to palaeoecology and palaeoclimatology

With regard to the quality of preservation of palynomorphs and their number, only some samples were suitable for the quantitative evaluation of the stratigraphic interval studied.

Palynological study of the upper (Barremian–Albian) part of the Rochovica section was carried out in order to investigate dinocyst and palynomorph fluctuations. Intercalations of dark shales in the Vranie Member of the Pieniny Limestone Formation, black shales of the Koňhora Formation, intercalations of the Brodno Formation and marls of the Rudina Formation (Figs 3, 4) were studied palynologically.

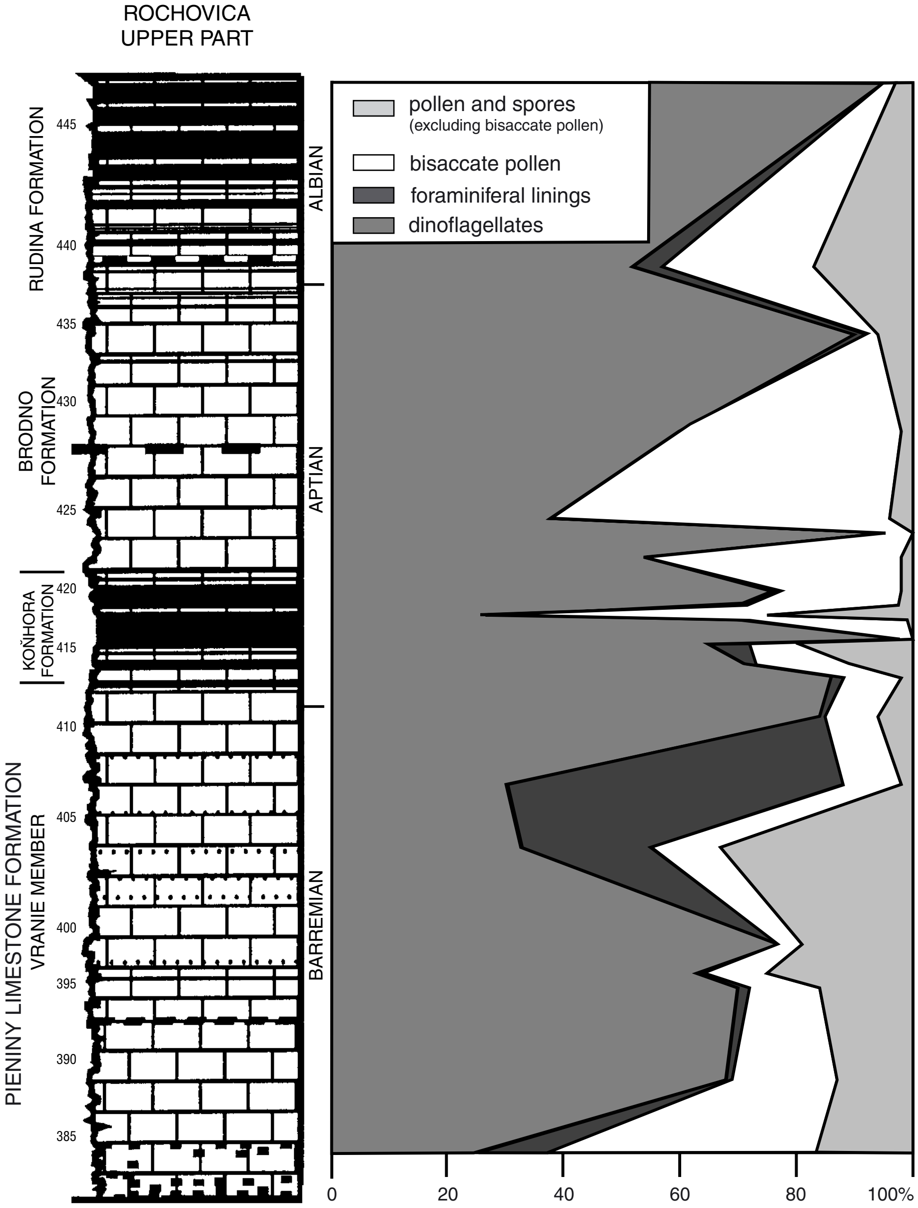

Fig. 3. Relative abundance of palynomorphs in the Rochovica section.

Barremian palynomorph assemblage of the Vranie Member contains a higher proportion of land-derived sporomorphs than the rest of the studied section. The decrease in relative abundance of pollen and spores is important, coinciding with an increased abundance of foraminiferal linings (typical of marine coastal and neritic environments). Neritic (genus *Oligosphaeridium*) dinocysts tend to prevail higher up in the section. The presence of deep-water (oceanic *Pterodinium*) dinocysts in the uppermost Barremian reflects an open marine palaeoenvironment influenced by turbidite transport of land-derived and nearshore remnants. The abundance of genera *Gonyaulacysta* and *Occisucysta* (constituting a substantial proportion of the remaining dinocysts) increases at the same level (samples 399, 401.8).

Early Aptian palynomorph assemblage of the Koňhora Formation contains a lower proportion of land-derived material. The majority of palaeoecologically significant dinocysts (*Cerbia, Circulodinium, Muderongia* and *Odontochitina*) belong to littoral and brackish groups. Neritic dinocysts are also present (*Achomosphaera* and *Spiniferites* prevail, belonging to the neritic I group) but oceanic taxa are absent. This palynofacies characterizes relatively shallow marine environment with mixed of nearshore dinocysts with eutrophic and less saline surface waters. The black shales contain large amounts of terrestrial phytoclasts (brown wood particles dominant in the lower part, black wood particles dominant in the upper part of the Koňhora Formation) and bisaccate pollen grains.

The occurrence of typical open oceanic dinocysts like *Hapsocysta* and *Pterodinium* in the overlying Brodno and Rudina formations confirms open marine or oceanic depositional settings. The rest of the dinocysts pose a mixture

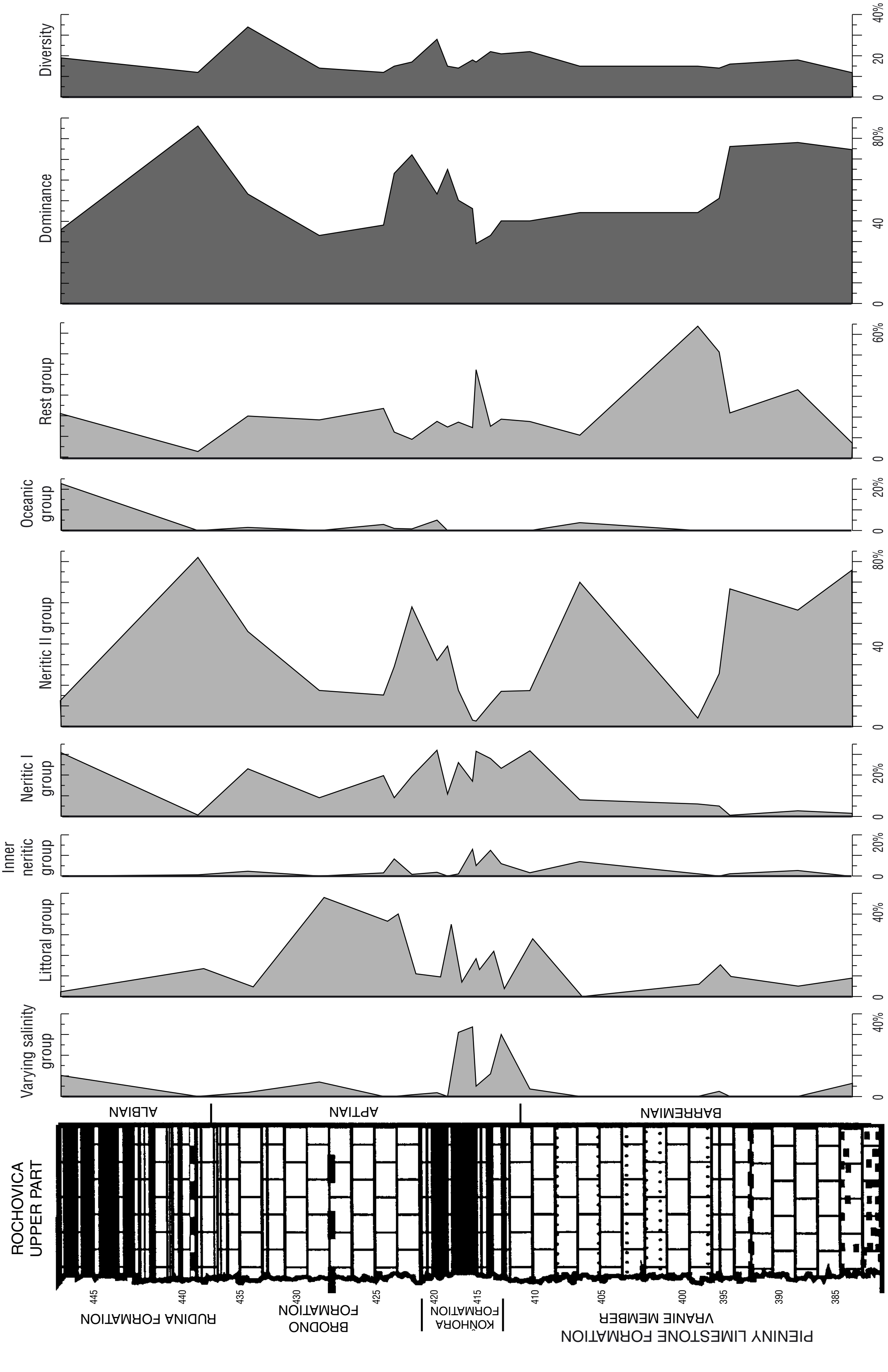

Fig. 4. Relative abundance of dinocyst palaeoenvironmental groups.

from shallower zones. Especially the proportion of oceanic dinocysts increases gradually, reaching a maximum in the uppermost part of the pelagic Rudina Formation indicating a higher proportion of pelagic sedimentation. The oceanic group might be explained by a sea-level highstand.

Dinocyst assemblages in the Rochovica sediments (from Barremian to Albian) comprise almost entirely warm-water forms indicating relatively high surface temperatures. Only two samples (421, 422.5) contain several species (*Hystrichodinium pulchrum, Hystrichosphaerina schindewolfii*) which can be classified as cold-water ones. This may imply a temporary drop in sea-surface temperature, although there is very weak evidence to support this suggestion.

Conclusion

The age of the studied formations based on the dinocyst ranges, is Upper Barremian–Upper Albian.

Dinocyst assemblages of Barremian age suggest a neritic (more likely outer) palaeoenvironment.

Early Aptian assemblages of the Koňhora Formation are characteristic of shallow marine conditions with mixing of dinocysts from the nearshore environment with eutrophic and less saline surface waters. This was caused by increased precipitation on land, resulting in enhanced freshwater and nutrient supply to coastal waters and enhanced organic particle transport to the shelf margin.

Albian dinocyst assemblages are characteristic of rather open marine palaeoenvironment influenced by land-derived material. The slightly elevated abundance of the oceanic group in the uppermost Albian can be regarded to represent increasing influence of oceanic water masses in response to a second-order rise in sea level (eustatic curve of Haq et al. 1988).

A trend towards progressive deepening of the palaeoenvironment during the studied time interval can be postulated, most likely as a result of a combination of tectonic subsidence and eustatic sea-level rise.

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Plate I ⇒

The species name is followed by the size of the specimens, preparation slide number, sample location and England Finder coordinates (for the localization of specimen in slide).

1. *Circulodinium brevispinosum* (Pocock 1962) Jansonius 1986; body width 88 µm, R397/a, T31/32.
2, 3. *Gonyaulacysta* sp.; length 97 µm, R401.8/a, H33/34.
4, 5. *Lithodinia stoveri* (Millioud 1969) Gocht 1976; length 67 µm, R401.8/a, K38/39.
6. *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1854; central body length 42 µm, R401.8/a, M26/4.
7. *Kleithriasphaeridium eoinodes* (Eisenack 1958) Davey 1974; length 70 µm, R415/a, R/S35.
8. *Oligosphaeridium* sp.; diameter 90 µm, R397/c, O40/41.
9. *Achomosphaera* sp.; length 70 µm, R415/b, F45/4.
10. *Protoellipsodinium touile* Below 1981; length 50 µm, R415/b, F45.
11, 12. *Tehamadinium tenuiceras* (Eisenack 1958) Jan du Chêne et al. 1986; length 90 µm, R415/c, T40.
13. *Odontochitina operculata* (O. Wetzel 1933) Deflandre and Cookson 1955; length 140 µm, R415/a, Q47.

Plate II ⇒ ⇒

1, 2. *Cribroperidinium edwardsii* (Cookson and Eisenack 1958) Davey 1969; length 98 µm, R416/a, P39.
3. *Oligosphaeridium complex* (White 1842) Davey and Williams 1969; diameter 85 µm, R418/b, F37/1.
4. *Cassiculosphaeridia reticulata* Davey 1974; width 80 µm, R401.8/d, B33.
5. *Coronifera oceanica* Cookson and Eisenack 1958; length 72 µm, R422.5/a, K33/1.
6. *Coronifera tubulosa* Cookson and Eisenack 1974; length 70 µm, R421/c, V31.
7. *Exochosphaeridium muelleri* Yun 1981; diameter 70 µm, R418/b, V33.
8. *Callaiosphaeridium trycherium* (Deflandre and Courteville 1939) Davey and Williams 1966; diameter 73 µm, R422.5/c, N28.
9. *Florentinia mantellii* (Davey and Williams 1966) Davey and Verdier 1973; length 79 µm, R421/c, R34.
10. *Achomosphaera neptunii* (Eisenack 1958) Davey and Williams 1966; length 78 µm, R422.5/a, R35
11. *Florentinia cooksoniae* (C. Singh 1971) Duxbury 1980; width 47 µm, R415/a, F45.
12. *Gonyaulacysta cretacea* (Neale and Sarjeant 1962) Sarjeant 1969; length 62 µm, R401.8/a, P39/2.
13. *Ctenidodinium elegantulum* Millioud 1969; length 68 µm, R422.5/b, P32.

Plate III ⇒ ⇒ ⇒

1. *Wallodinium krutzschii* (Alberti 1961) Habib 1972; length 98 µm, R422.5/b, V32.
2. *Circulodinium distinctum* (Deflandre and Cookson 1955) Jansonius 1986; length 90 µm, R422.5/b, F40.
3. *Circulodinium brevispinosum* (Pocock 1962) Jansonius 1986; width 80 µm, R423/c, O47/2.
4. *Cyclonephelium intonsum* Duxbury 1983; length 55 µm, R423/a, Q32/1.
5. *Apteodinium granulatum* Eisenack 1958; length 120 µm, R423/a, T28.
6, 7. *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963; length 55 µm, R423/a, H38/2.
8. *Florentinia laciniata* Davey and Verdier 1973; length 70 µm, R435.1/a, J31/3.
9. *Prolixosphaeridium parvispinum* (Deflandre 1937) Davey et al 1969; length 81 µm, R425/c, R35.
10. *Lithodinia* sp.; width 110 µm, R425/c, K36/3.
11. *Cleistosphaeridium multispinosum* (Singh 1964) Brideaux 1971; diameter 52 µm, R422.5, G35
12, 13. *Kiokansium polypes* (Cookson and Eisenack, 1962) Below 1982; length 85 µm, R435.1/b, S44.
14. *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1854; length 70 µm, R435.1/c, R29/4.

Plate IV ⇒ ⇒ ⇒ ⇒

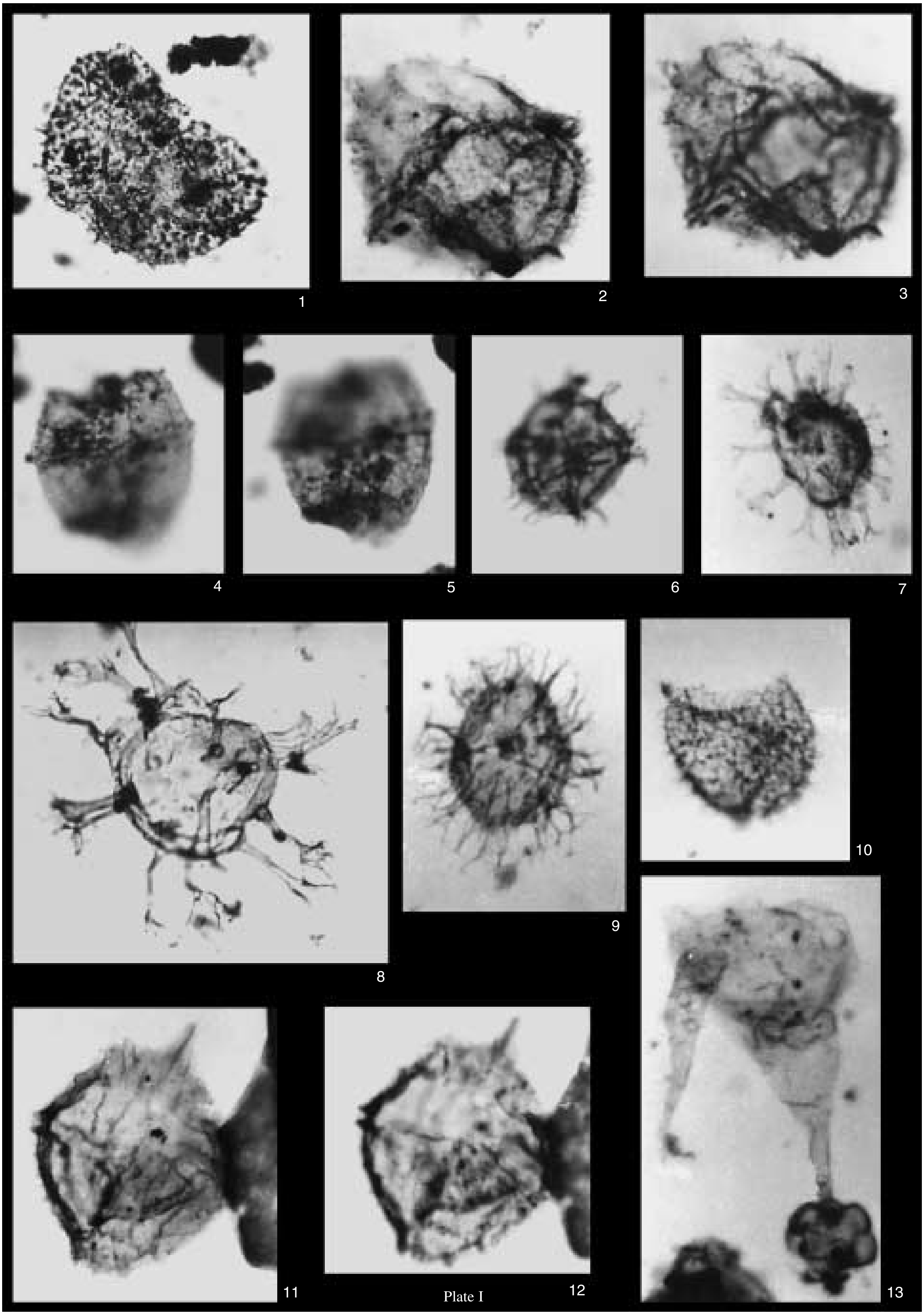
1, 2, 3. *Hapsocysta peridictya* (Eisenack and Cookson 1960) Davey 1979; diameter 68 µm, R435.1/c, R36/3.
4. *Coronifera oceanica* Cookson and Eisenack 1958; length 72 µm, R435.1/c, F44.
5, 6. *Oligosphaeridium complex* (White 1842) Davey and Williams 1969; diameter 82 µm, R435.1/d, G42.
7. *Spiniferites* sp.; length 72 µm, R435.1/d, K/L41.
8. *Florentinia laciniata* Davey and Verdier 1973; length 78 µm, R435.1/e, X32.
9, 12. *Achomosphaera triangulata* (Gerlach 1961) Davey and Williams 1969; length 81 µm, R435.1/d, H38.
10, 11. *Pseudoceratium polymorphum* (Eisenack 1958) Bint 1986; width 83 µm, R435.1/d, R35.

Plate V ⇒ ⇒ ⇒ ⇒ ⇒

1. *Surculosphaeridium*? *longifurcatum* (Firtion 1952) Davey et al. 1966; diameter 84 µm, R440/b, H43.
2. *Xiphophoridium alatum* (Cookson and Eisenack 1962) Sarjeant 1966; length 74 µm, R440/b, I35.
3. *Kleithriasphaeridium eoinodes* (Eisenack 1958) Davey 1974; length 72 µm, R440/b, K36.
4. *Litosphaeridium siphoniphorum* (Cookson and Eisenack 1958) Davey and Williams 1966; diameter 52 µm, R445/b, L38.
5. *Hystrichosphaerina schindewolfii* Alberti 1961; diameter 71 µm, R435.1/b, T46/47.
6. *Exochosphaeridium muelleri* Yun 1981; length 70 µm, R440/b, K24.
7. *Litosphaeridium arundum* (Eisenack and Cookson 1960) Davey 1979; diameter 74 µm, R440/b, O27.
8, 9. *Endoscrinium campanula* (Gocht 1959) Vozzhennikova 1967; length 72 µm, R440/b, K33/34.
10, 11. *Pterodinium cingulatum* (O. Wetzel 1933) Below 1981; length 62 µm, R440/b, J38.
12. *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963; length 82 µm, R440/b, K38.

Plate VI ⇒ ⇒ ⇒ ⇒ ⇒ ⇒

1, 2. *Litosphaeridium conispinum* Davey and Verdier 1973; diameter 52 µm, R440/b, V31.
3. *Exochosphaeridium phragmites* Davey et al. 1966; length 69 µm, R440/b, M38.
4, 8. *Hapsocysta peridictya* (Eisenack and Cookson 1960) Davey 1979; diameter 71 (m, R435.1/b, Q49.
5, 6. *Adnatosphaeridium tutulosum* (Cookson and Eisenack 1960) Morgan 1980; diameter 65 µm, R440/b, P35.
7. *Hystrichostrogylon membraniphorum* Agelopoulos 1964; length 65 µm, R443/b, T35.
9. spore; diameter 53 µm, R440/b, K36.
10. *Cometodinium*? *whitei* (Deflandre and Courteville 1939) Stover and Evitt 1978; inner body diameter 35 µm, R440/b, O36.
11. *Pervosphaeridium pseudhystrichodinium* (Deflandre 1937) Yun 1981; length 82 µm, R445/d, P27/28.
12. bisaccate pollen grain, width 65 µm, R397, H35.
13. foraminiferal lining; diameter 78 µm, R385.5/a, K41.



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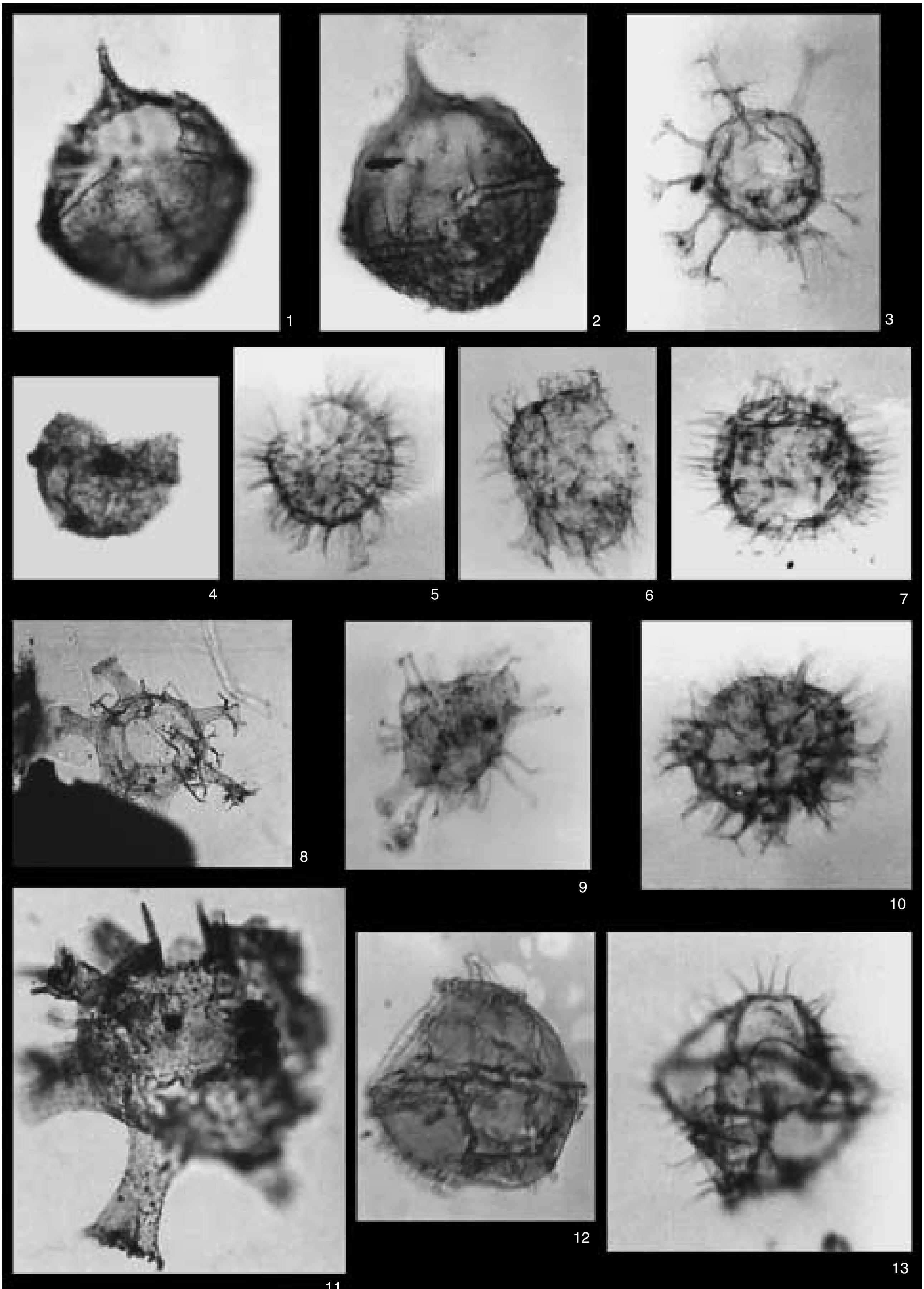

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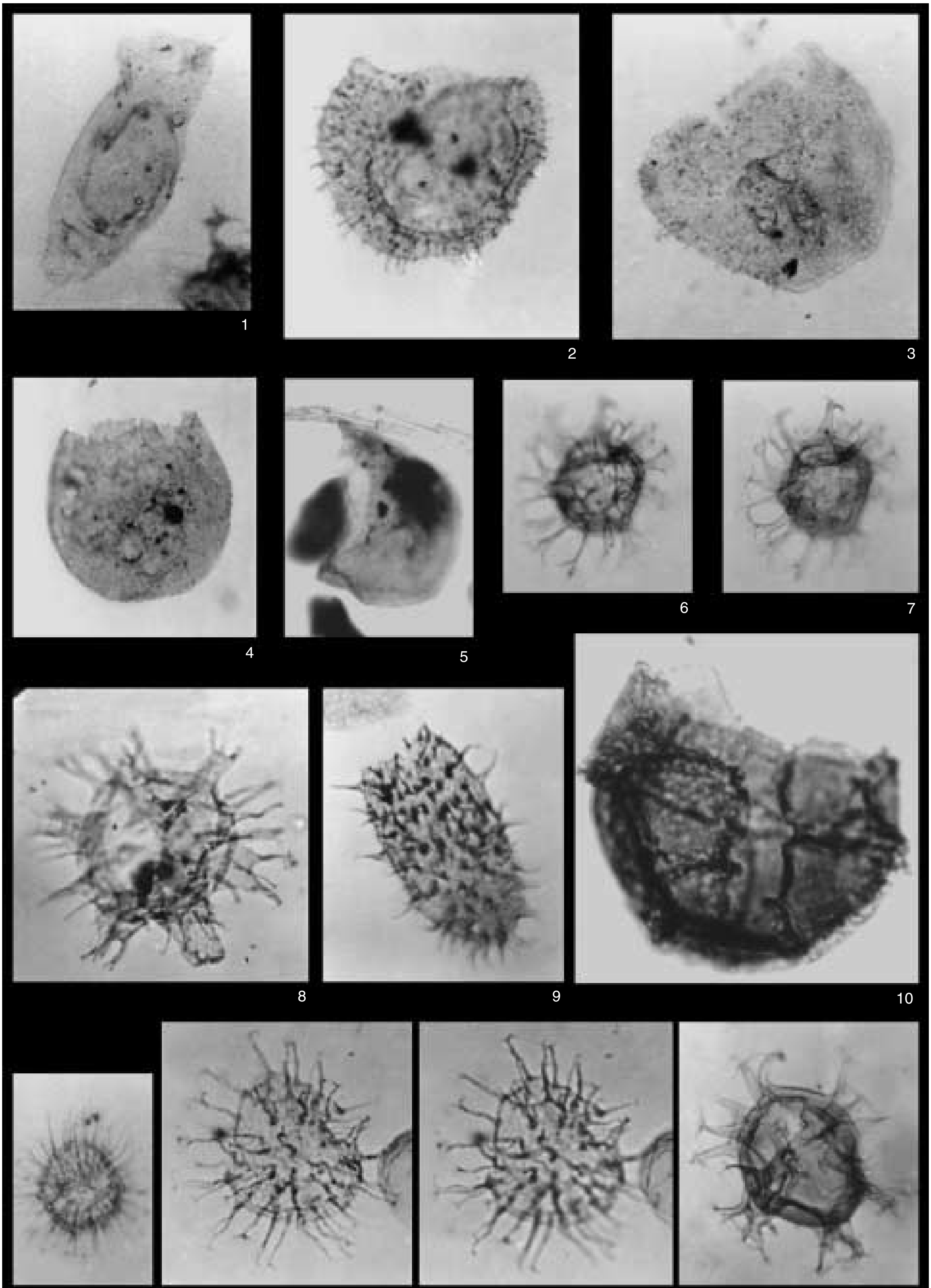

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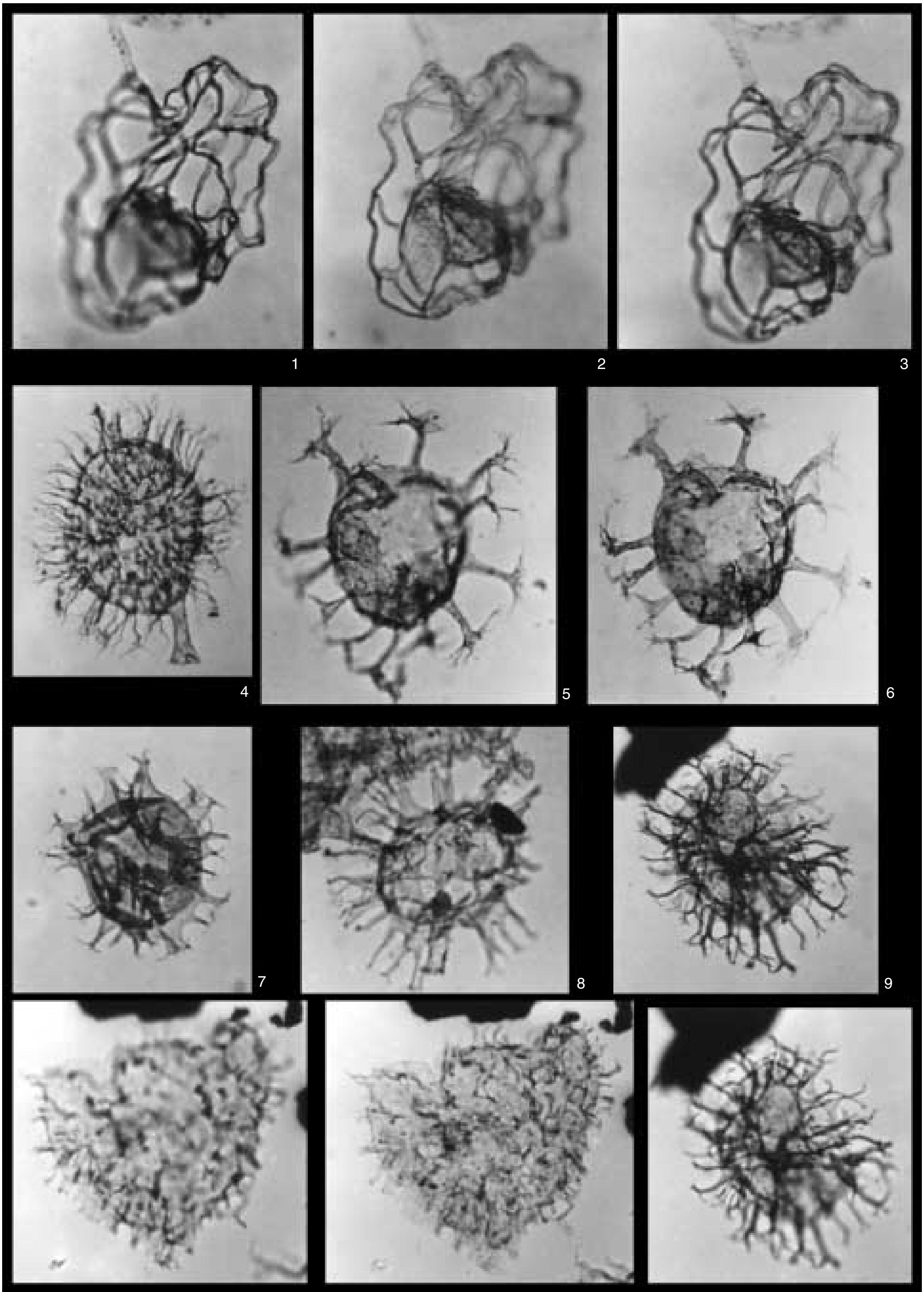

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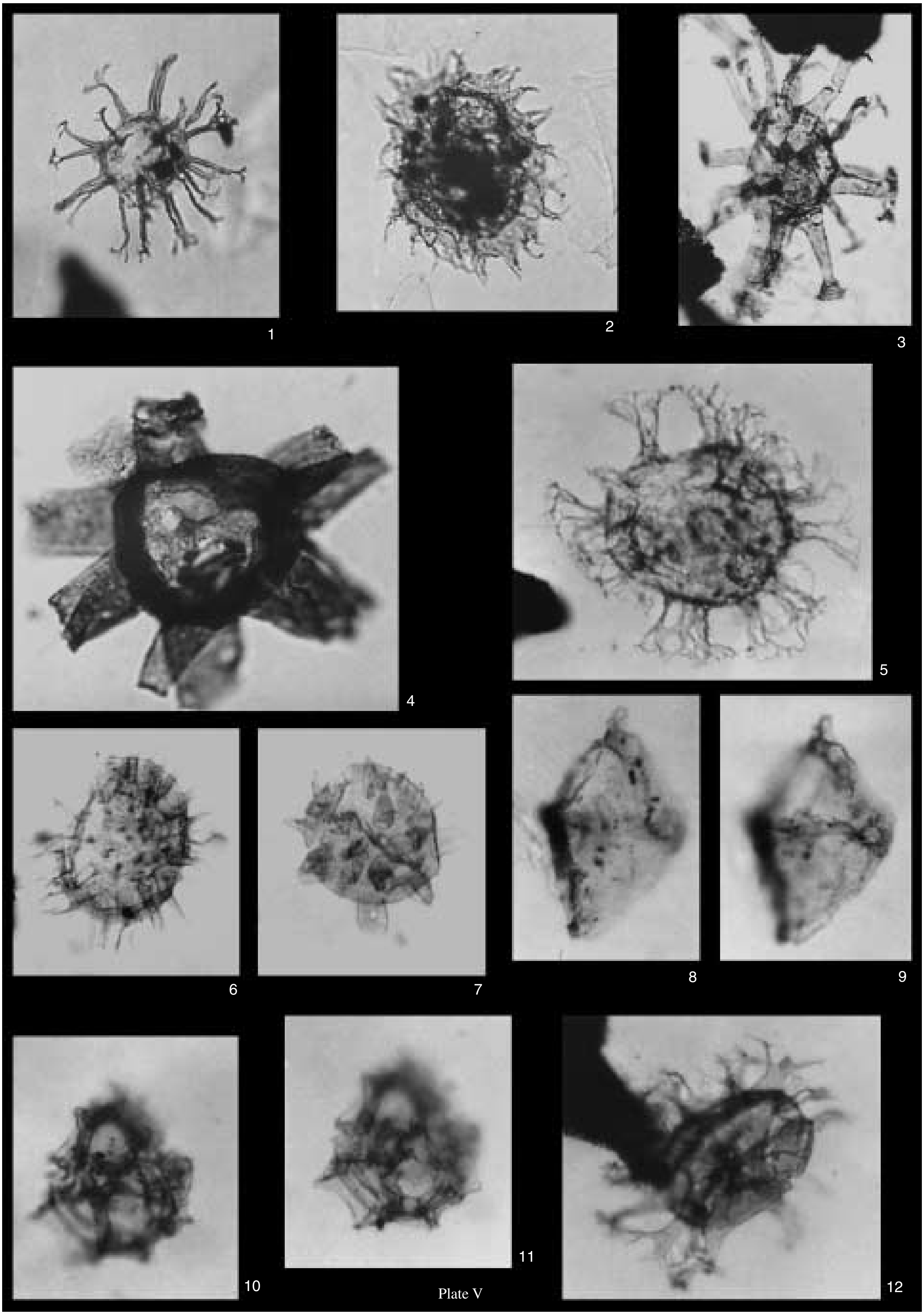

Plate V

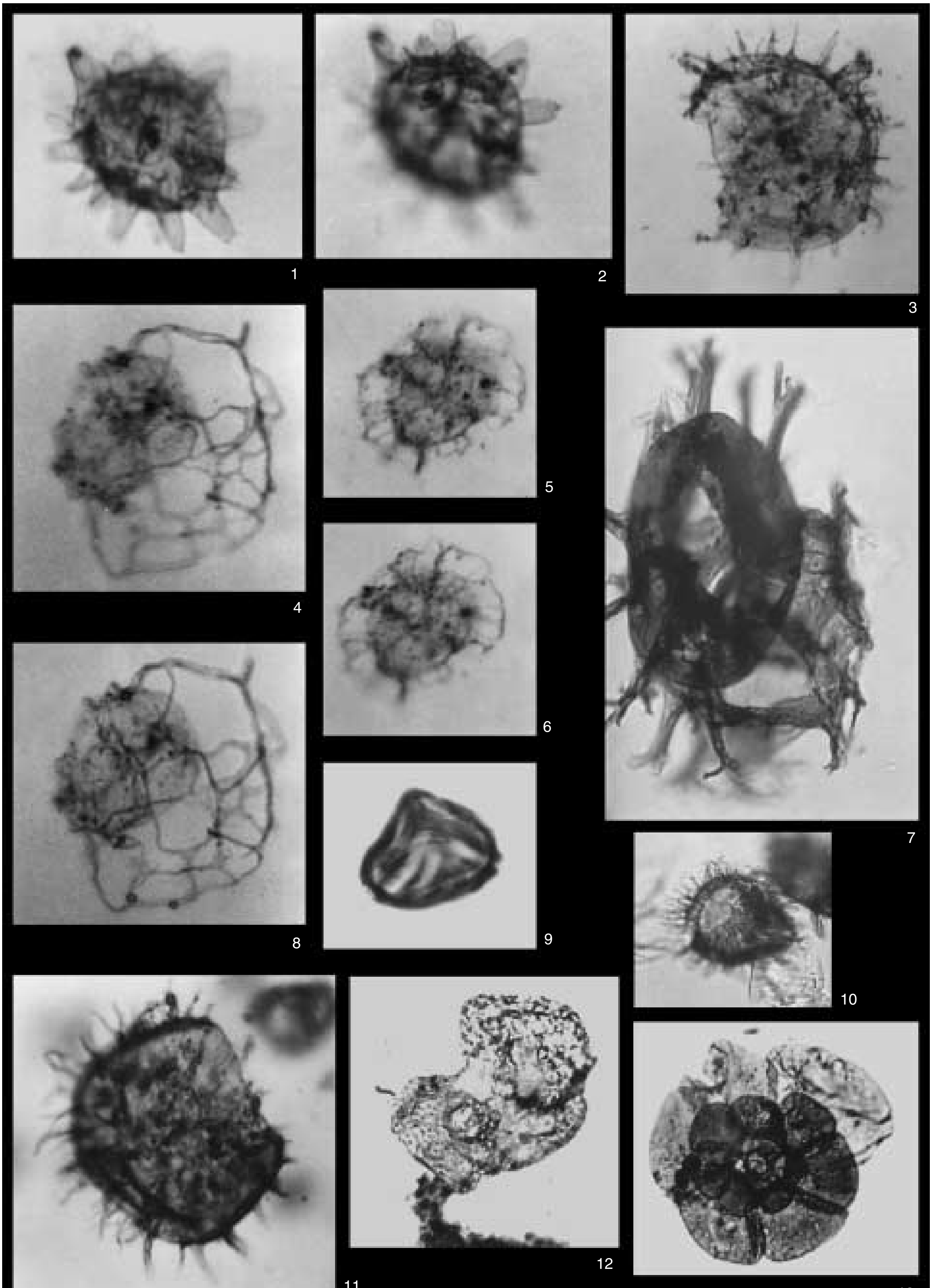

Plate VI