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LOWER CRETACEOUS PALYNOMORPHS FROM THE SKOLE NAPPE (OUTER CARPATHIANS, POLAND)

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Abstract: Lower Cretaceous deposits of the Spas Shale from the Skole Nappe in Poland have been palynologically studied in several localities. Special emphasis has been put on the dinocyst assemblages. The Spas Shale consists of black shales which are intercalated with green shales in the uppermost part. All the samples yielded rich and well preserved dinocyst and other palynomorph assemblages. The age of the studied deposits, based on dinocysts, spans from middle-late Barremian to latest Albian (Vraconian). Palynofacies of the middle-upper Barremian samples are characteristic for the neritic paleoenvironment. That contradicts previous data based on foraminiferal and lithological researches and may suggest transport of shallow marine organic matter into the deeper part of the basin. The Albian palynofacies is characteristic for an open marine paleoenvironment influenced by land-derived material. The studied dinocysts are almost entirely warm-water taxa. The presence of a few cold-water species in the Barremian samples suggests a connection between the Tethyan and Boreal provinces.

Key words: Early Cretaceous, Polish Flysch Carpathians, Skole Nappe, Spas Shale, paleoenvironment, biostratigraphy, palynofacies, Dinoflagellate cysts.

Introduction

The aim of the present paper is to specify the age and paleoenvironment of the Spas Shale (Skole Nappe, Flysch Carpathians, Poland; Fig. 1) on the basis of palynofacies analysis with special emphasis put on dinocyst assemblages. The Lower Cretaceous deposits of the Skole Nappe in its Polish part have never been palynologically studied — some dinocyst taxa have been reported from the Ukrainian part (Vialov et al. 1989). The age of these deposits has been determined as Barremian–Albian on the basis of foraminifers (Olszewska 1984). Ammonites, found rarely in the Spas Shale, confirm this age (Szymakowska 1981). The stratigraphic position of the Spas Shale makes them an equivalent of the Veřovice Shale (in the lower part) and the Lgota Beds (in the upper part) of the Silesian Nappe (Polish Flysch Carpathians) (Książkiewicz 1956). This paper is part of a comprehensive palynological study of the Carpathian Lower Cretaceous deposits.

Material and methods

The Spas Shale is part of the black deposits which are common in the Lower Cretaceous of the Flysch Carpathians and are fully developed in the Ukrainian part (Vialov et al. 1988). They contain soft, black shales in the lower part, becoming hard, black or greenish-black in colour in the upper part. The Spas Shale passes upwards into the Upper Cretaceous (Cenomanian) „green radiolarian shales“ (e.g. Gucik 1963; Kotlarczyk 1979, 1988).

Eleven samples were collected from several noncontinuous outcrops in the eastern part of the Skole Nappe in the vicinity of Rybotycze village (Fig. 2; Fig. 3). The following sections were studied:

— Skrzypowy section, located in a right tributary of the Wiar River, SE of Rybotycze (Fig. 4); samples 1, 2 and 4 were taken from the soft black shales, samples 5 and 6 represent hard silicified black shales intercalated with thin-bedded black sandstones whereas samples 11, 11A and 12 represent green and black-greenish shales;

— Grabnik section, located in the Grabnik Forest, NW of Rybotycze (Fig. 4), one sample was taken from hard black shales;

— Sopotnik section, the outcrops are located on the banks of the Sopotnik Stream, near Sopotnik village, SE of Rybotycze (Fig. 5); samples were taken from very soft black shales.

The samples were processed following the standard palynological procedure: 20–25 G of cleaned and crushed material was dissolved in 40% HCl and 38% HF, the residue was sieved on a 15 μm sieve and centrifuged in heavy liquid ($ZnCl_2$ + HCl; s.g. = 2.0 G/cm^3). Glycerine-gelatine jelly was used as a mounting medium.

Palynofacies analysis was based on several fitoclast and palynomorph groups distinguished by Batten (1996):

— structural organic matter (SOM; black woody particles, brown woody particles and cuticules);

— amorphic organic matter (AOM);

— palynomorphs: including land-derived palynomorphs (i.e. sporomorphs, fungi and freshwater algae (e.g. *Botryococcus*, *Pediastrium*, *Pterospermopsis*) and marine palynomorphs (dinocysts, acritarchs, scolecodonts, foraminiferal linnings).

Six paleoenvironmentally significant dinocyst groups were recognized following Leereveld (1995). These are: low-salinity, littoral, inner neritic, neritic, outer neritic and ocean-

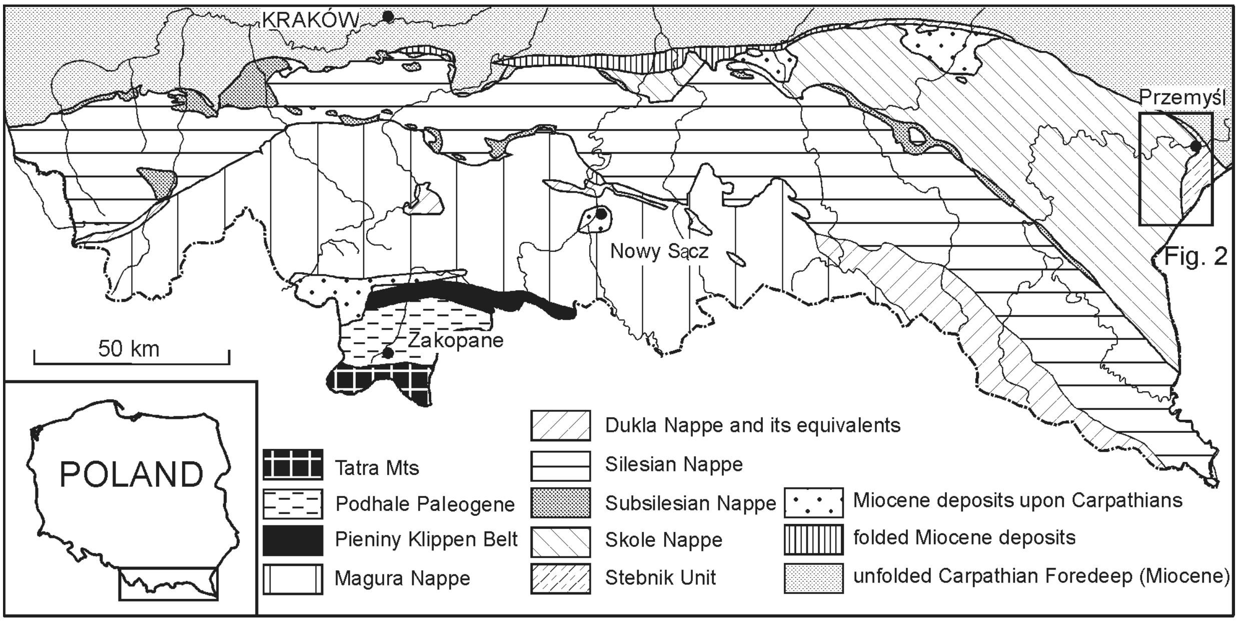
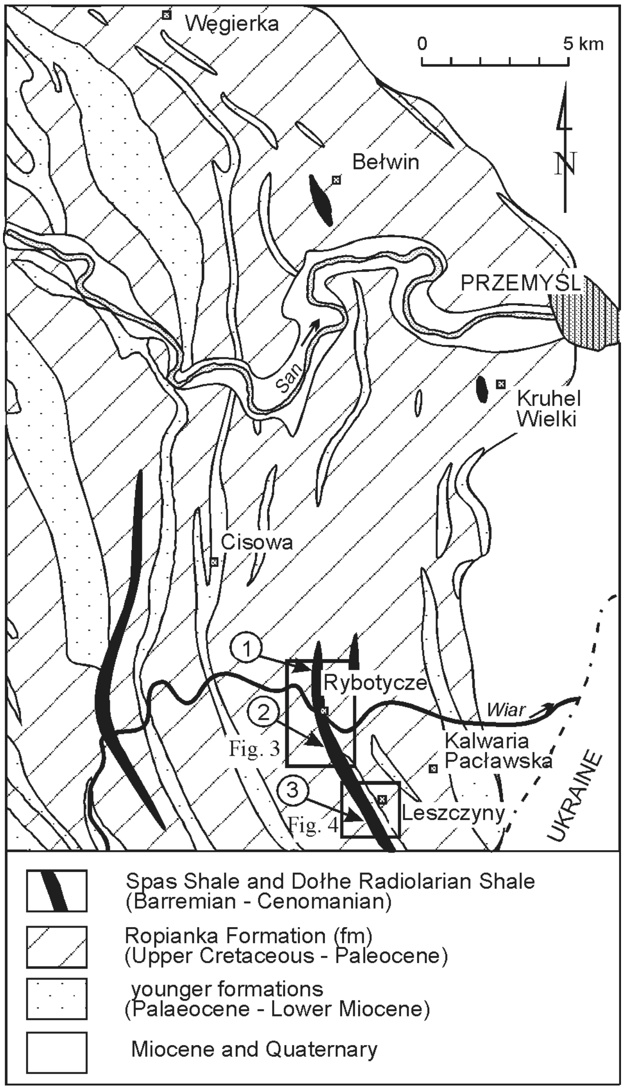


Fig. 1. Tectonic units of Polish Carpathians (after Książkiewicz 1972) with indication of the area of study.



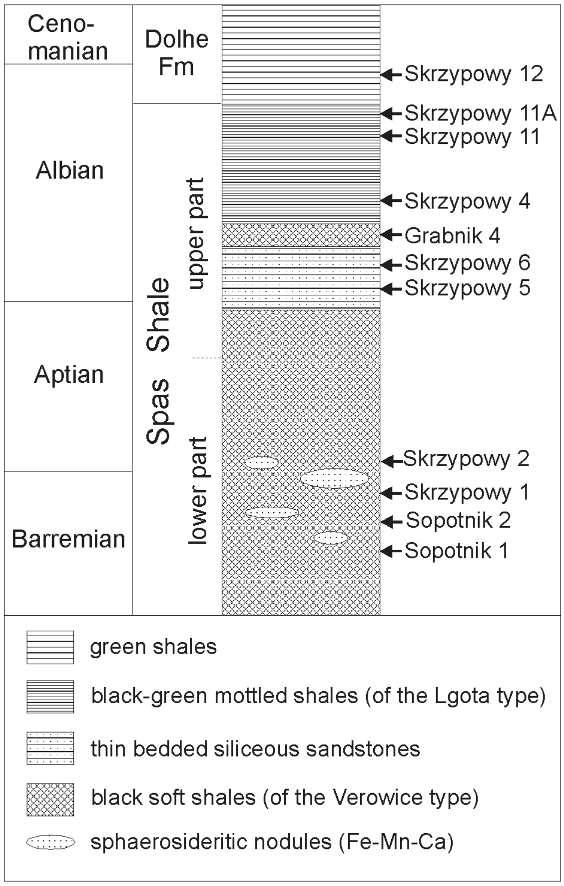


Fig. 3. Distribution of the samples in the lithostratigraphic scheme of the Spas Shale (after Kotlarczyk 1988; modified).

Fig. 2. Geological map of the study area (after Kotlarczyk 1979) with the position of the investigated Lower Cretaceous sections: 1 — Grabnik; 2 — Skrzypowy; 3 — Sopotnik.

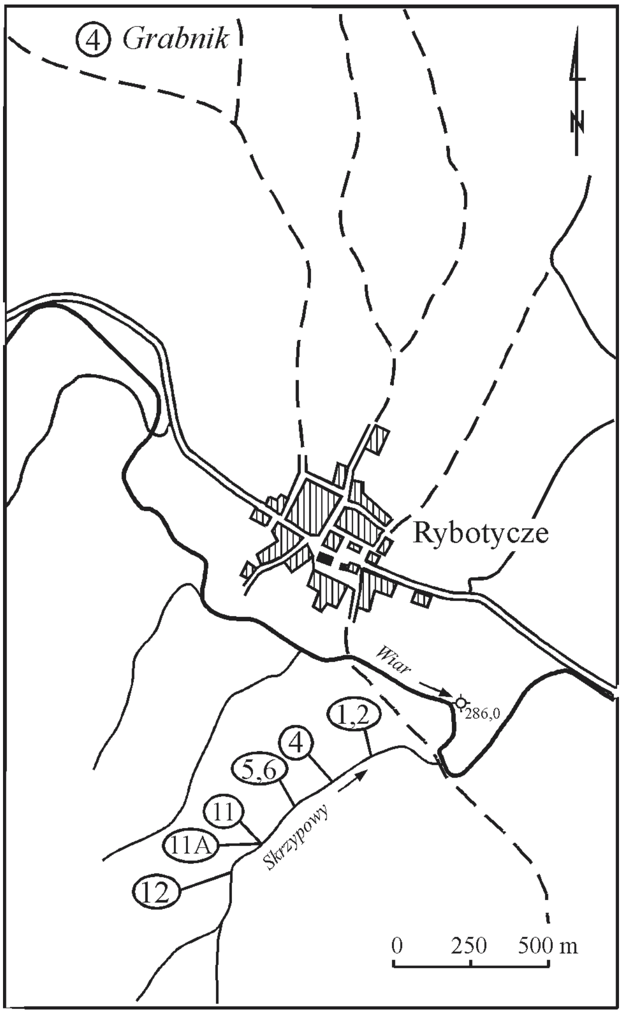


Fig. 4. Location of samples from the Skrzypowy and Grabnik section.

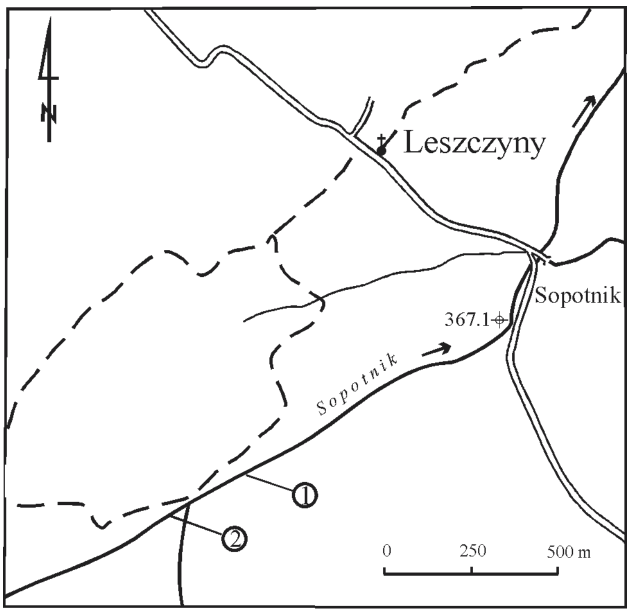


Fig. 5. Location of samples from the Sopotnik section.

ic groups. Warm-water and cold-water taxa were recognized according to Leereveld (1995).

Results

All investigated samples yielded rich, well preserved and diversified fitoclast and palynomorph assemblages. The changes of their ratios and changes of dinocyst paleoenvironmental groups are presented in Fig. 6. A very rich dinocyst assemblage was stated: 250 taxa were recognized (for the species list see *Appendix*).

Interpretation

Biostratigraphy

The age of the investigated deposits is middle-late Barremian to latest Albian (Vraconian) on the basis of dinocysts. No typical Aptian dinocyst assemblage was found in the Spas Shale: dinocysts from the investigated deposits represent Barremian and Albian. Characteristic dinocyst events from the studied material are presented in Fig. 7.

The middle-late Barremian was recognized in the material from the Sopotnik section only (soft black shales). This is based on the presence of several dinocyst taxa. The first occurrence of *Fromea quadrugata* (Pl. II: Fig. 5), *Paleoperidinium cretaceum*, *Prolixosphaeridium parvispinum* (Pl. IV: Figs. 4–5) and *Pseudoceratium securigerum* (Pl. III: Figs. 7, 9) was described by many authors from the middle Barremian (e.g. Duxbury 1977, 1980; Antonescu & Avram 1980; Reneville & Raynaud 1981; Heilmann-Clausen 1987; Leereveld 1995). The middle-late Barremian age of the Spas Shale from the Sopotnik section is also suggested by the presence of *Muderongia neocomica* (Pl. I: Figs. 6–7), which appears for the last time in the Late Barremian in the Tethyan realm (Leereveld 1995) or in the earliest Aptian in the Boreal province (Duxbury 1983; Heilmann-Clausen 1987), and *Fromea quadrugata* known from the middle-upper Barremian deposits only (Duxbury 1983; Heilmann-Clausen 1987).

The uppermost Barremian–lowermost Aptian was discovered in the lower part of the Skrzypowy section represented by soft black shales (samples 1 and 2). This is indicated by the occurrence of both *Cepadinium ventriosum* (Pl. II: Figs. 1–3) and *Membranosphaera* sp. A (Davey 1979) (Pl. III: Fig. 5), which are taxa with a known lowermost range in the earliest Aptian (Duxbury 1983; Davey 1979), and *Muderongia neocomica* and *Fromea quadrugata*, which are known to have their last occurrence in the uppermost Barremian (e.g. Duxbury 1983).

The Early Albian was recognized in the hard black shales from the middle part of the Skrzypowy section (samples 5 and 6). This was concluded on the basis of the appearance of the following taxa: *Ellipsodinium rugulosum* (Pl. III: Figs. 3, 6), *Paleotetradinium silicorum* (Pl. IV: Fig. 1), *Florentinia stellata* and *Tehamadinium coummium* (Pl. IV: Fig. 8), which are known to have their first occurrences in

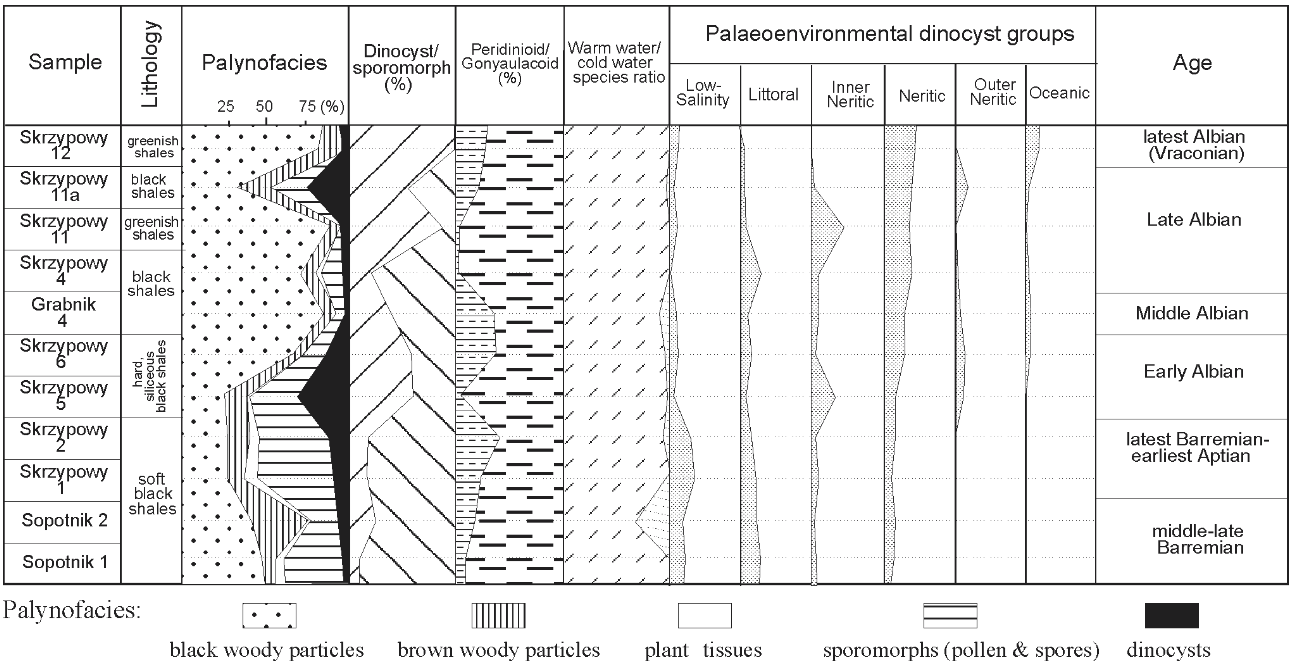


Fig. 6. Palynofacies and dinocyst paleoenvironmental groups in the studied Spas Shale.

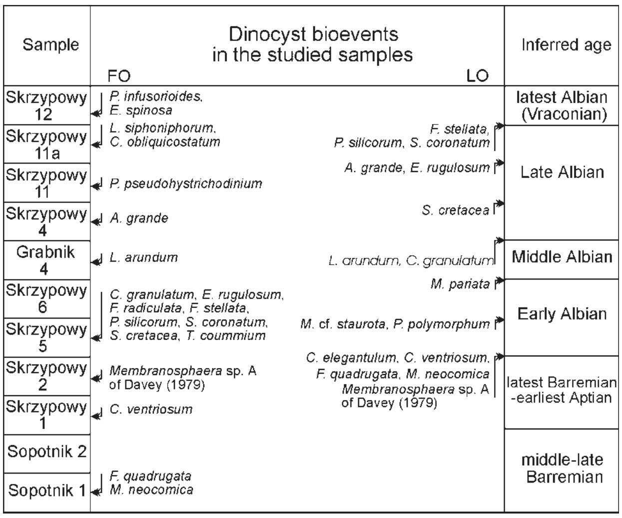


Fig. 7. Dinocyst events in the studied Spas Shale.

the Early Albian (Davey & Verdier 1971, 1973; Jan Du Chêne et al. 1986; Prössl 1990) and *Pseudoceratium polymorphum* (Pl. III: Figs. 4, 8), *Muderongia* cf. *staurota* and *Muderongia pariata*, which, according to Davey (1979), Heilmann-Clausen (1987) and Prössl (1990) occurs for the last time in the Early Albian. Other dinocyst taxa present in samples 5 and 6, like *Cauca parva, Carpodinium granulatum, Systematophora cretacea*, *Stephodinium coronatum* (Pl. IV: Fig. 6) and *Florentinia radiculata*, are often reported from the Lower Albian sediments (Davey 1979; Heilmann-Clausen 1987; Prössl 1990).

For the hard, silicified black shales from the Grabnik section, a Middle Albian age was concluded on the basis of the presence of *Lithosphaeridium arundum* (Pl. VI: Fig. 5), of which the known stratigraphic range is limited to the uppermost Early Albian–lowermost Late Albian (e.g. Prössl 1990).

The Late Albian was recognized in several samples from the Skrzypowy section. The most important dinocyst event allowing the recognition of Upper Albian deposits is the appearance of *Apteodinium grande* (Pl. VIII: Fig. 8). This taxon is known from the Upper Albian deposits exclusively (e.g. Heilmann-Clausen 1987; Prössl 1990). *Apteodinium grande* was found in samples 4 (black soft shales) and 11 (green soft shales intercalated with black ones). Additionally, *Pervosphaeridium pseudohystrichodinium* (Pl. V: Fig. 2), another Late Albian taxon, was found in sample 11. Sample 11A (soft black-greenish intercalation of the green shales) contained the following Late Albian dinocysts: *Pervosphaeridium pseudohystrichodinium*, *Carpodinium obliquicostatum* (Pl. VII: Figs. 2–3) and *Litosphaeridium siphoniphorum* (Pl. VI: Figs. 1, 7) (Davey & Verdier 1973; Heilmann-Clausen 1987; Prössl 1990).

The latest Albian (Vraconian) was identified in the Skrzypowy section in sample 12 which represents the green shales. This age was concluded on the basis of the presence of *Palaeohystrichophora infusorioides* (Pl. VI: Figs. 2–3). Its first occurrence was described from Vraconian deposits by Davey & Verdier (1973). Moreover, the following characteristic taxa are present in this sample: *Epelidosphaeridia spinosa* (Pl. VI: Figs. 8–10), *Achomosphaera sagena*, *Cleistosphaeridium armatum*, *Exochosphaeridium muelleri*, *Odontochitina costata*, *Pterodinium cingulatum* subsp. *reticulatum* and *Florentinia cooksoniae*. Some of dinocysts present in this sample are also known from Cenomanian deposits. However, the lack of typical Cenomanian taxa and the presence of few taxa for which the known last occurrence is Vraconian (e.g. *Florentinia cooksoniae*) demonstrates the Vraconian age for the sample 12.

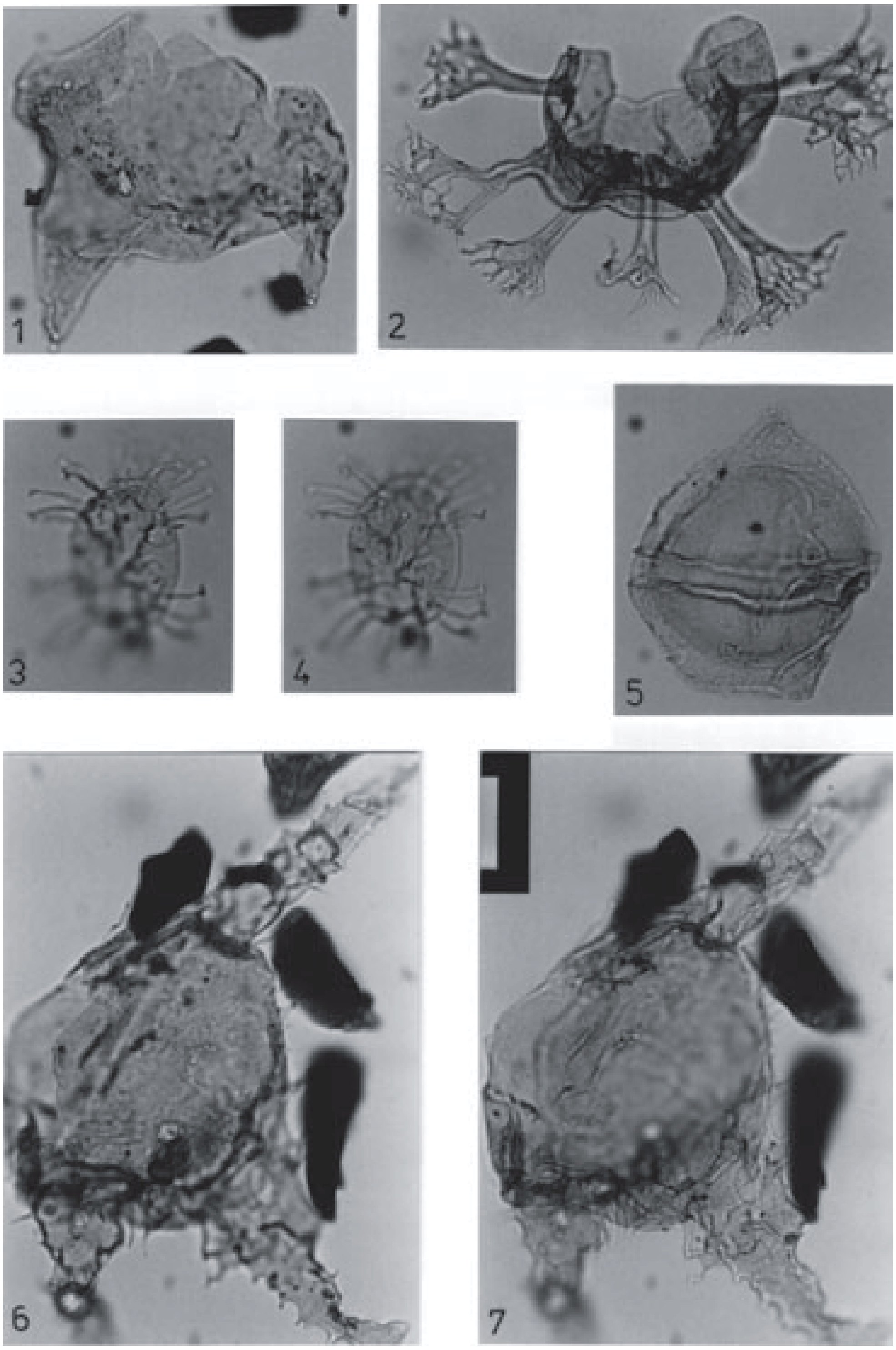


Plate I: Fig. 1 — *Pseudoceratium expolitum* (Skrzypowy 2; W31/2). **Fig. 2** — *Oligosphaeridium pulcherrimum* (Skrzypowy 1; O46/3). **Figs. 3–4** — *Bourkidinium* sp. 1 of Leereveld (1995) (Sopotnik 2; S39). **Fig. 5** — *Subtilisphaera perlucida* (Skrzypowy 2; P44/1). **Figs. 6–7** — *Muderongia neocomica* (Sopotnik 1; E46) (scale bar in Fig. 7 indicates 20 µm for all figures of Plates I–VIII, and 100 µm for all figures of Plates IX–X).

Paleoenvironment

The palynofacies of the oldest samples (middle-late Barremian) consists mainly of land-derived material such as sporomorphs, black and brown fitoclasts and plant tissues (Pl. IX: Figs. 1–2). Dinocysts are relatively rare (up to 5 % of the palynofacies). Most of the paleoecologicaly significant dinocysts present in these samples (*Circulodinium, Pseudoceratium* (e.g. Pl. I: Fig. 1; Pl. II: Figs. 9–10)*, Odontochitina* (Pl. II: Fig. 6)*, Subtilisphaera* (Pl. I: Fig. 5)*, Mud-*

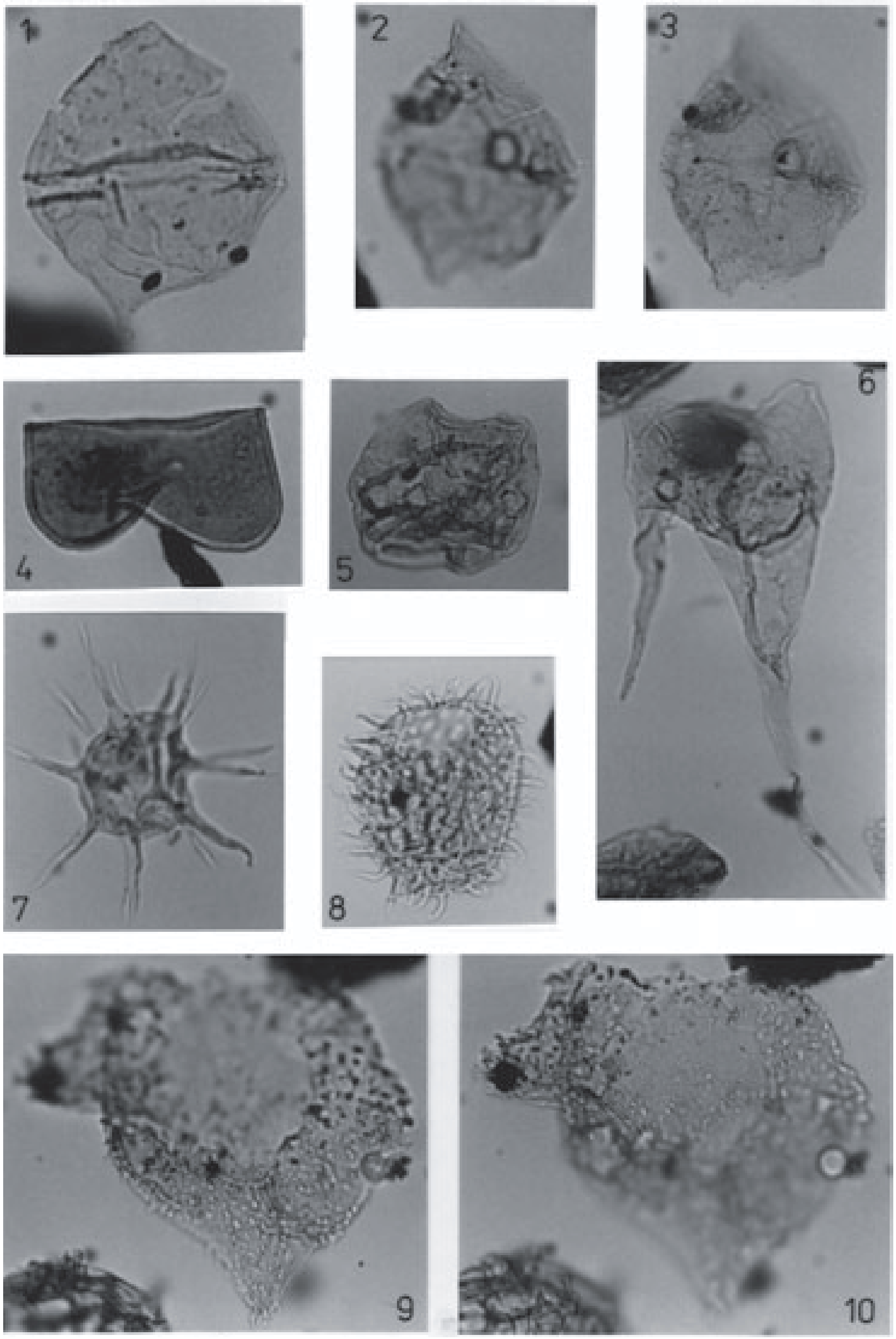


Plate II: Fig. 1 — *Cepadinium ventriosum* (Skrzypowy 1; P45/2). **Figs. 2–3** — *Cepadinium ventriosum* (Skrzypowy 2; V42/1). **Fig. 4** — *Schizocystia laevigata* (Skrzypowy 1; F31/2). **Fig. 5** — *Fromea quadrugata* (Skrzypowy 2; Q41/1). **Fig. 6** — *Odontochitina operculata* (Skrzypowy 2; D43). **Fig. 7** — Acritarch (Skrzypowy 2; F42/2). **Fig. 8** — *Protoellipsodinium spinosum* (Grabnik 4; V44). **Figs. 9–10** — *Pseudoceratium retusum* (Sopotnik 2; O44). For scale see explanation for Plate I.

erongia (Pl. I: Figs. 6–7)) belong to the brackish and littoral group (up to 40 %). Neritic dinocysts are also present but oceanic taxa are absent. This type of palynofacies is believed to be characteristic of relatively shallow marine environment influenced by land-derived material. However, the lithology of the Spas Shale and the data based on Foraminifera (Olszewska 1984) suggest a paleoenvironment deeper than neritic but above the CCD level (upper bathial zone) during the sedimentation of the Barremian deposits. Therefore, the presence of shallow marine palynofacies can be interpreted as a

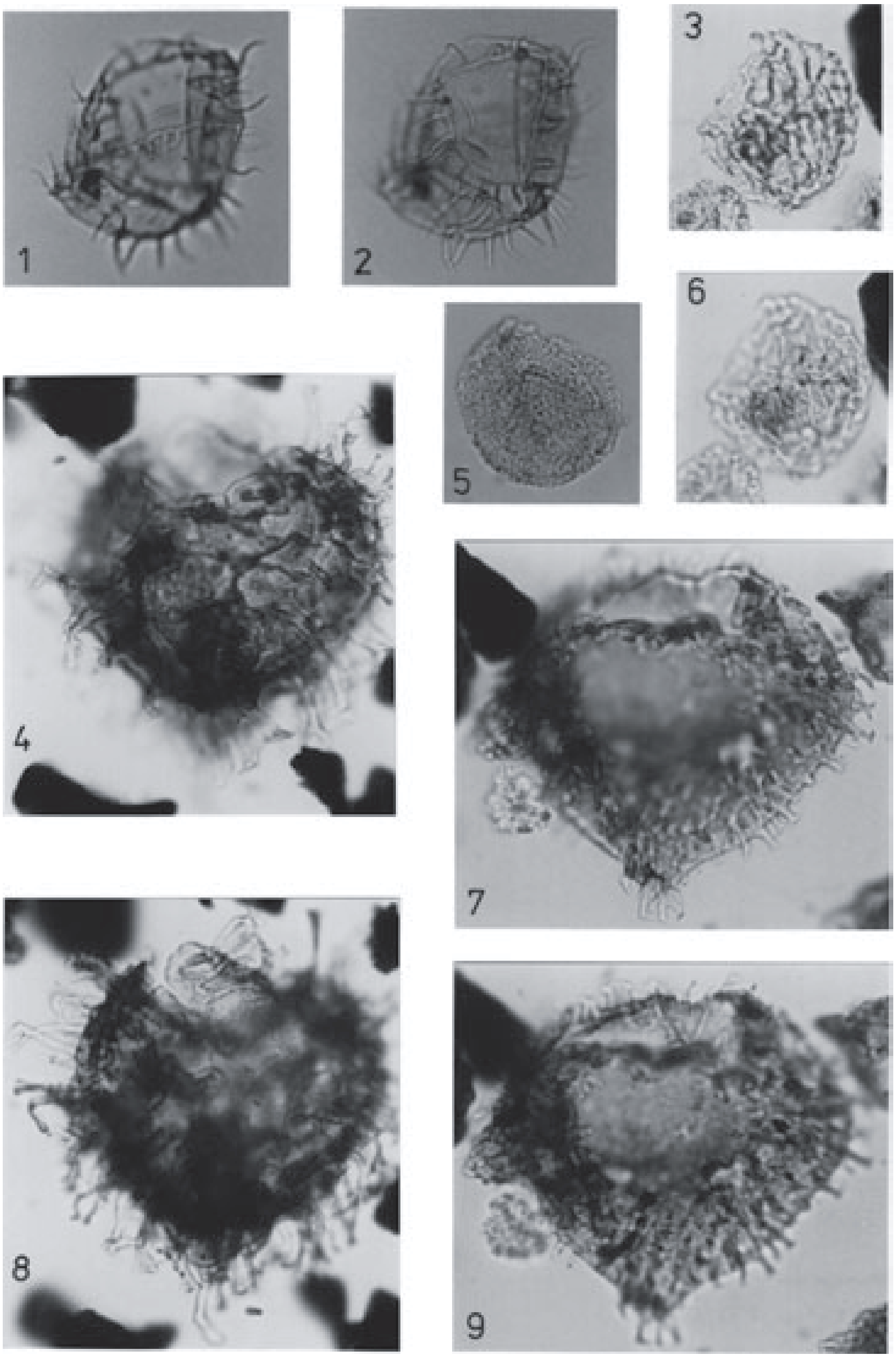


Plate III: Figs. 1–2 — *Ctenidodinium elegantulum* (Sopotnik 2; T38/2). **Figs. 3, 6** — *Ellipsodinium rugulosum* (Skrzypowy 6; C41/3). **Figs. 4, 8** — *Pseudoceratium polymorphum* (Skrzypowy 4; N36/3). **Fig. 5** — *Membranosphaera* sp. A of Davey (1979) (Skrzypowy 5; L29/4). **Figs. 7, 9** — *Pseudoceratium securigerum* (Sopotnik 1; R33/3). For scale see explanation for Plate I.

result of redeposition of shelf material into the deeper part of the basin (upper slope?). A similar depositional setting can be concluded for the uppermost Barremian-lowermost Aptian deposits (domination of brackish and littoral dinocysts) (Pl. IX: Fig. 3). The presence of few oceanic dinocysts (much less then 1 % of the whole dinocyst assemblage) is remarkable.

The palynofacies of the Albian samples contain less land-derived material (Pl. X: Figs. 1–3). Neritic, outer neritic and oceanic dinocyst ratio increase gradually reaching a maximum in

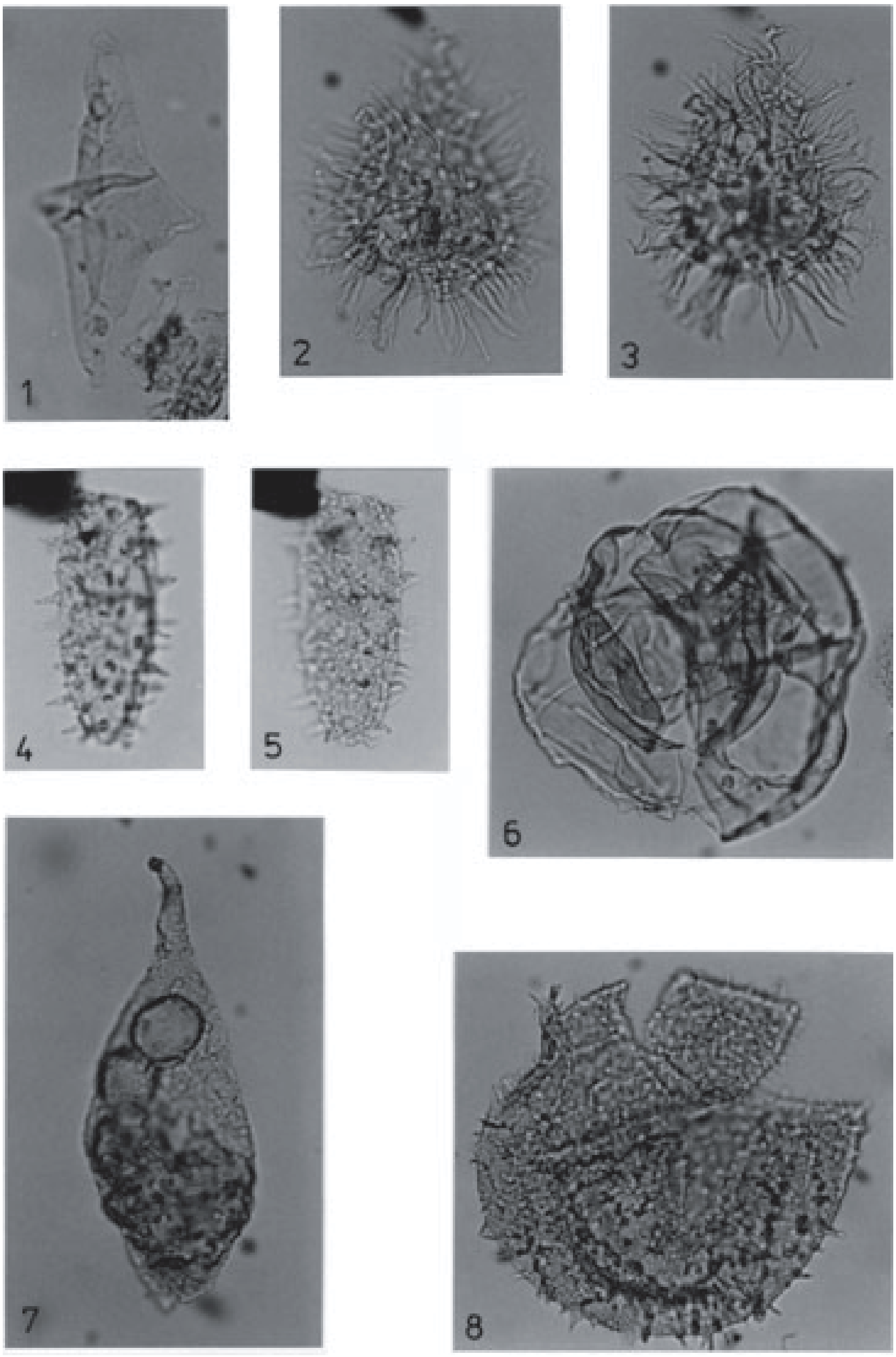


Plate IV: Fig. 1 — *Palaeotetradinium silicorum* (Skrzypowy 11A; L35/2). **Figs. 2–3** — *Coronifera oceanica* (Skrzypowy 11A; Y50/1). **Figs. 4–5** — *Prolixosphaeridium parvispinum* (Grabnik 4; M44/4). **Fig. 6** — *Stephodinium coronatum* (Skrzypowy 11A; W50). **Fig. 7** — *Batioladinium jaegeri* (Skrzypowy 6; X45/1). **Fig. 8** — *Tehamadinium coummium* (Skrzypowy 5; G37/1). For scale see explanation for Plate I.

the Vraconian. Similarly, the ratio of marine to land-derived palynomorphs grew during the Albian, indicating the increase of pelagic sedimentation. Agluttinated Foraminifera assemblages of the Aptian-Albian deposits suggest bathial-abyssal paleoenvironment (Olszewska 1984). Oceanic dinocysts present in the Albian part of the Spas Shale confirm these data.

Among the Spas Shale dinocysts with known thermal preferences, the overwhelming majority represents the warm-water taxa (*Pterodinium* (Pl. VIII: Figs. 3, 6), *Subtilisphaera*

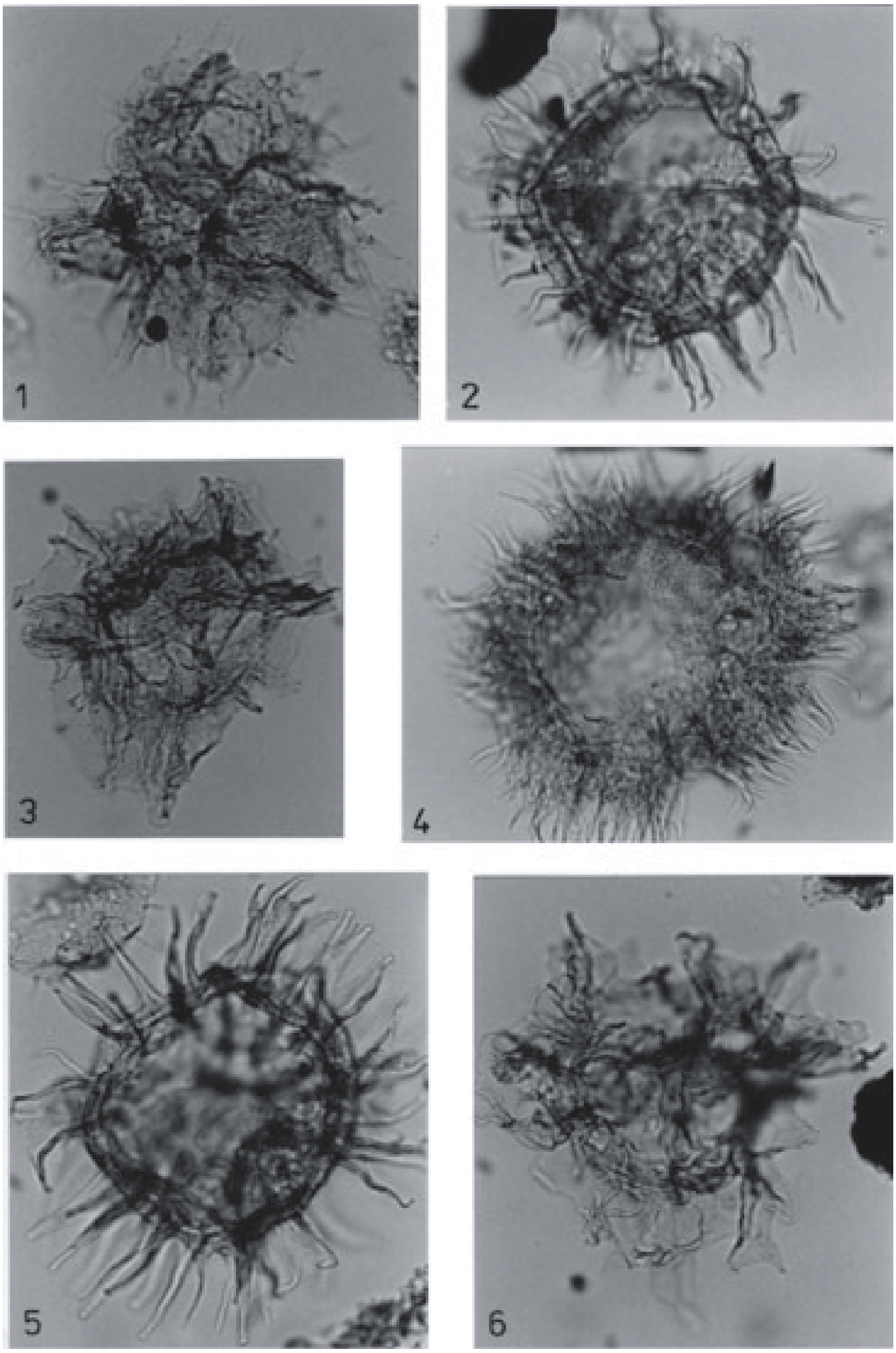


Plate V: Fig. 1 — *Xiphophoridium alatum* (Skrzypowy 11A; U42/1). **Fig. 2** — *Pervosphaeridium pseudohystrichodinium* (Skrzypowy 11A; M50/1). **Fig. 3** — *Dinopterygium cladoides* (Skrzypowy 11A; W45/2). **Fig. 4** — *Exochosphaeridium arnace* (Skrzypowy 11A; E50/4). **Fig. 5** — *Pervosphaeridium pseudohystrichodinium* (Skrzypowy 11A; S34/2). **Fig. 6** — *Dinopterygium cladoides* (Skrzypowy 11A; U45/4). For scale see explanation for Plate I.

(Pl. I: Fig. 5), *Dapsilidinium, Cometodinium, Tehamadinium* (Pl. IV: Fig. 8)). Only one Barremian sample contains a remarkably increased number of cold-water species. This might indicate the existence of a connection between the Tethys and Boreal provinces during this period.

Conclusions

1. The investigated Spas Shale contain very rich and diversified dinocysts which appear to be a good biostratigraphic tool for the Early Cretaceous.

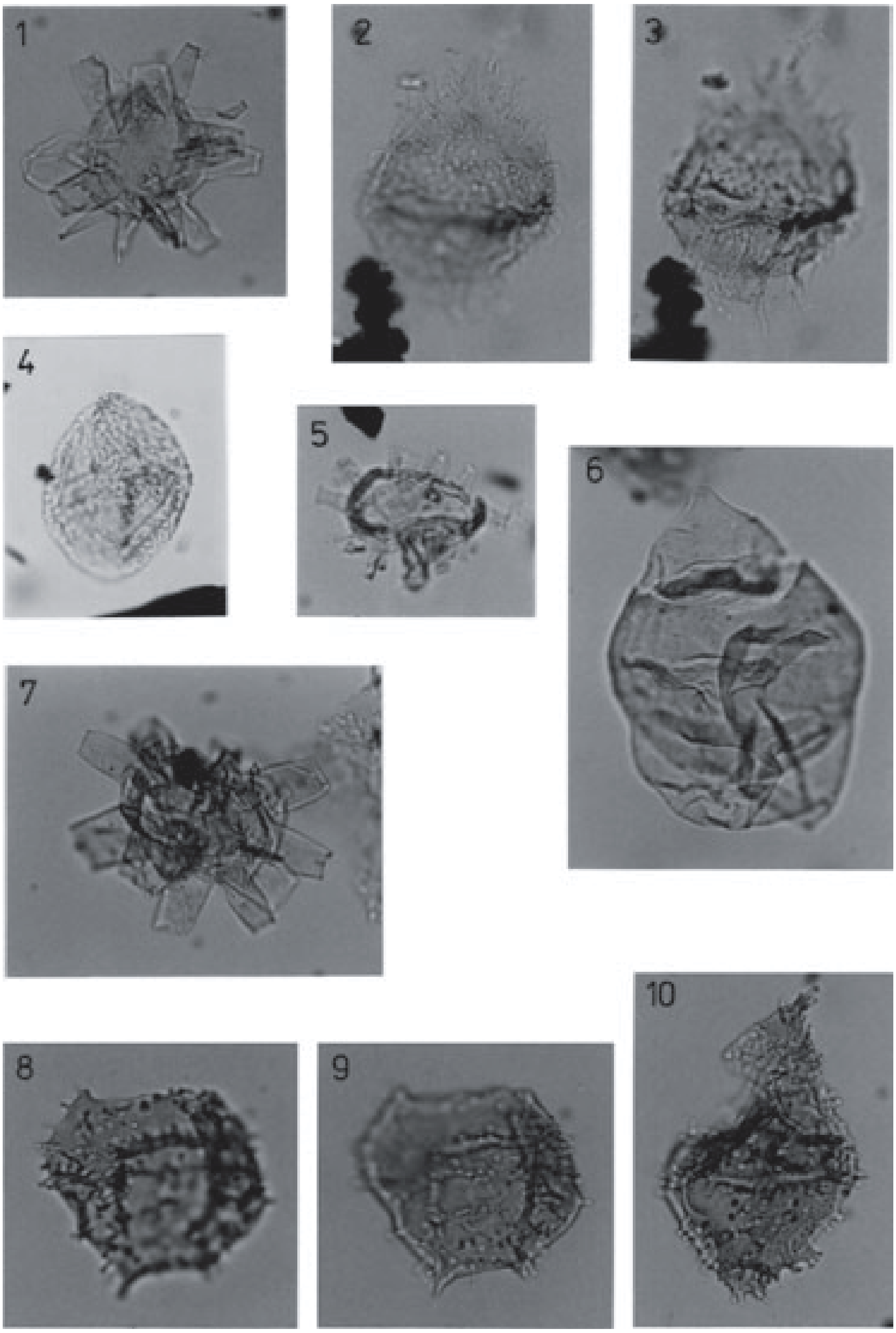


Plate VI: Fig.1 — *Litosphaeridium siphoniphorum* (Skrzypowy 11A; E32/1). **Figs. 2–3** — *Palaeohystrichophora infusorioides* (Skrzypowy 12; Q33/4). **Fig. 4** — *Ellipsodinium reticulatum* (Grabnik 4; F43/4). **Fig. 5** — *Litosphaeridium arundum* (Grabnik 4; Q40/2). **Fig. 6** — *Ovoidinium scabrosum* (Skrzypowy 11A; N38/4). **Fig. 7** — *Litosphaeridium siphoniphorum* (Skrzypowy 11A; W38/2). **Figs. 8–9** — *Epelidosphaeridia spinosa* (Skrzypowy 12; M49/4). **Fig. 10** — *Epelidosphaeridia spinosa* (Skrzypowy 12; K52/1). For scale see explanation for Plate I.

2. More than 250 dinocyst taxa were recognized from the studied Spas Shale.

3. The age of the studied deposits, on the basis of the dinocysts, spans from the middle-late Barremian to the latest Albian. No typical Aptian dinocyst assemblages were found.

4. The palynofacies of the middle-upper Barremian samples are typical of the neritic paleoenvironment. This contradicts previous data based on foraminiferal and lithological research (Olszewska 1984; Kotlarczyk 1988) and may suggest transport of shallow marine organic matter into the deeper part of the basin.

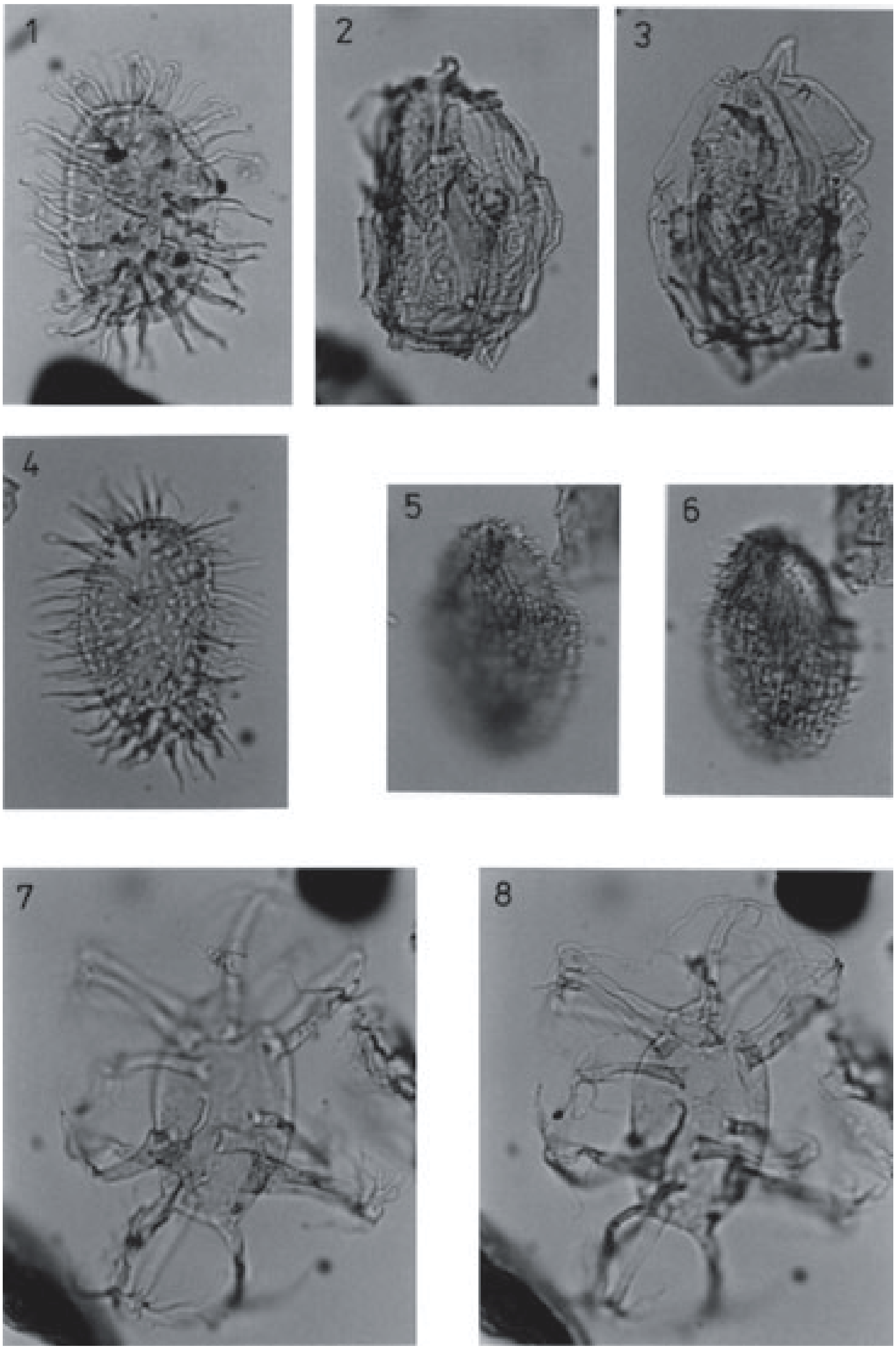


Plate VII: Fig. 1 — *Protoellipsodinium clavulum* (Skrzypowy 6; U41). **Fig. 2** — *Carpodinium obliquicostatum* (Skrzypowy 11A; O51/1). **Fig. 3** — *Carpodinium obliquicostatum* (Skrzypowy 11A; T50/1). **Fig. 4** — *Protoellipsodinium longispinosum* (Skrzypowy 11A; W47/1). **Figs. 5–6** — *Protoellipsodinium spinocristatum* (Grabnik 4; U49). **Figs. 7–8** — *Oligosphaeridium prolixospinosum* (Skrzypowy 11A; K44/4). For scale see explanation for Plate I.

5. The Albian palynofacies are characteristic of an open marine palaeoenvironment influenced by land-derived material.

6. Cold-water dinocysts from one midle-late Barremian sample indicate the influence of the Boreal province.

Acknowledgements: The present study was carried under scientific guidance of Dr. Han Leereveld and Dr. Roel Verruseul (Laboratory of Palaeobotany and Palynology, Utrecht, The Netherlands) to whom the author is gratefully indebted. The author's stay in the LPP was

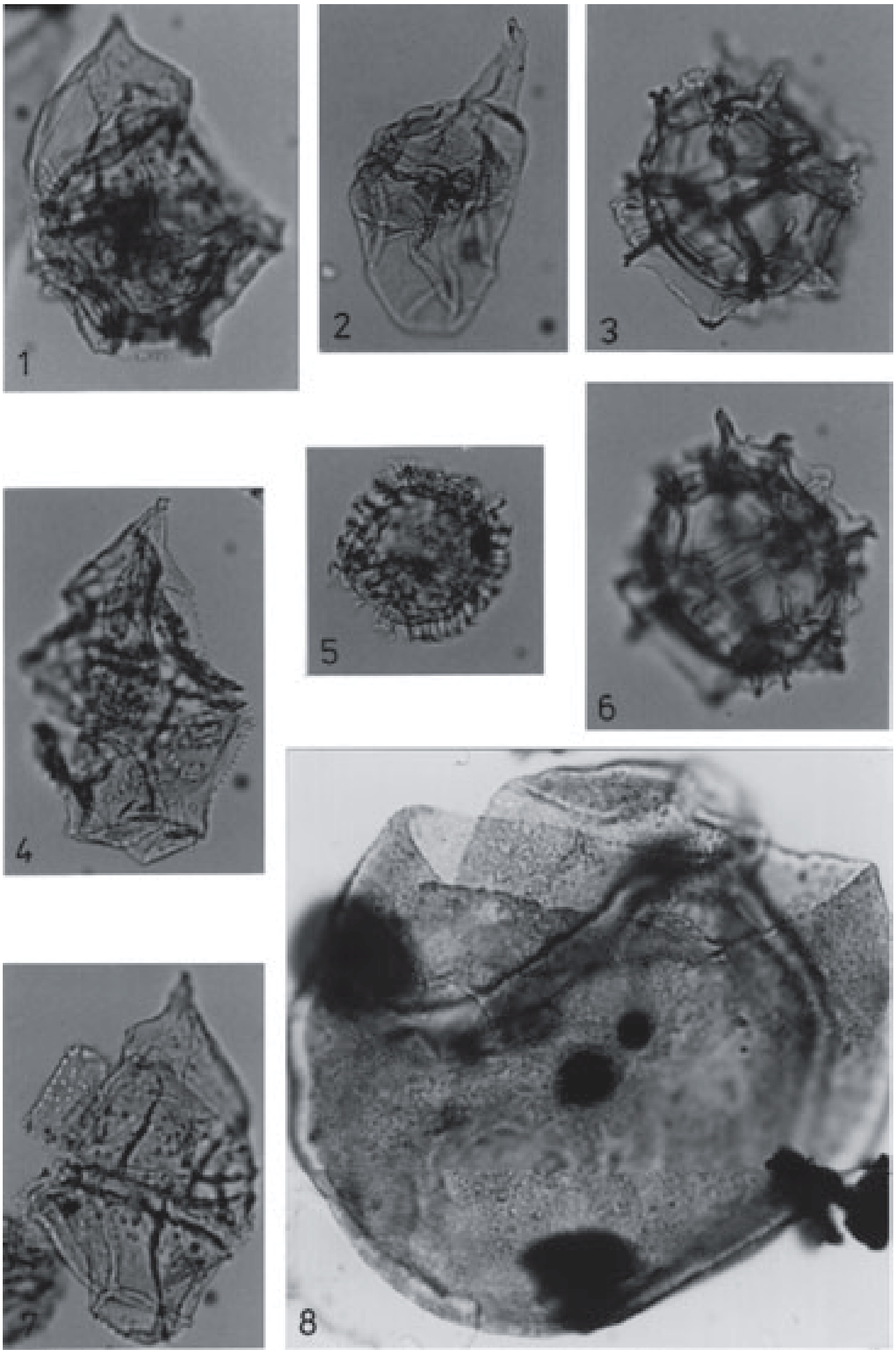


Plate VIII: Fig. 1 — *Gonyaulacysta cassidata* (Skrzypowy 11A; T35/4). **Fig. 2** — *Dingodinium coerviculum* (Skrzypowy 2; K37/2). **Figs. 3, 6** — *Pterodinium cingulatum* (Skrzypowy 11A; E39/1). **Fig. 4** — *Gonyaulacysta extensa* (Skrzypowy 11A; R42/3). **Fig. 5** — *Chlamydophorella nyei* (Skrzypowy 11A; L50). **Fig. 7** — *Gonyaulacysta extensa* (Skrzypowy 11A; J50/3). **Fig. 8** — *Apteodinium grande* (Skrzypowy 11; D43/3). For scale see explanation for Plate I.

possible due to the TEMPUS IMG. Dr. Adam Gasiński (Institute of Geological Sciences, Jagiellonian University, Kraków, Poland) was supervisor of the author's M.Sc. thesis, which is presented in this paper. Prof. Janusz Kotlarczyk (University of Mining and Metallurgy, Kraków, Poland) is gratefully acknowledged for introducing the author to the geology of the study area. The author is also deeply indebted to Mr. Przemysław Gedl, (Institute of Geological Sciences, Polish Academy of Sciences, Kraków, Poland) for the whole aid received

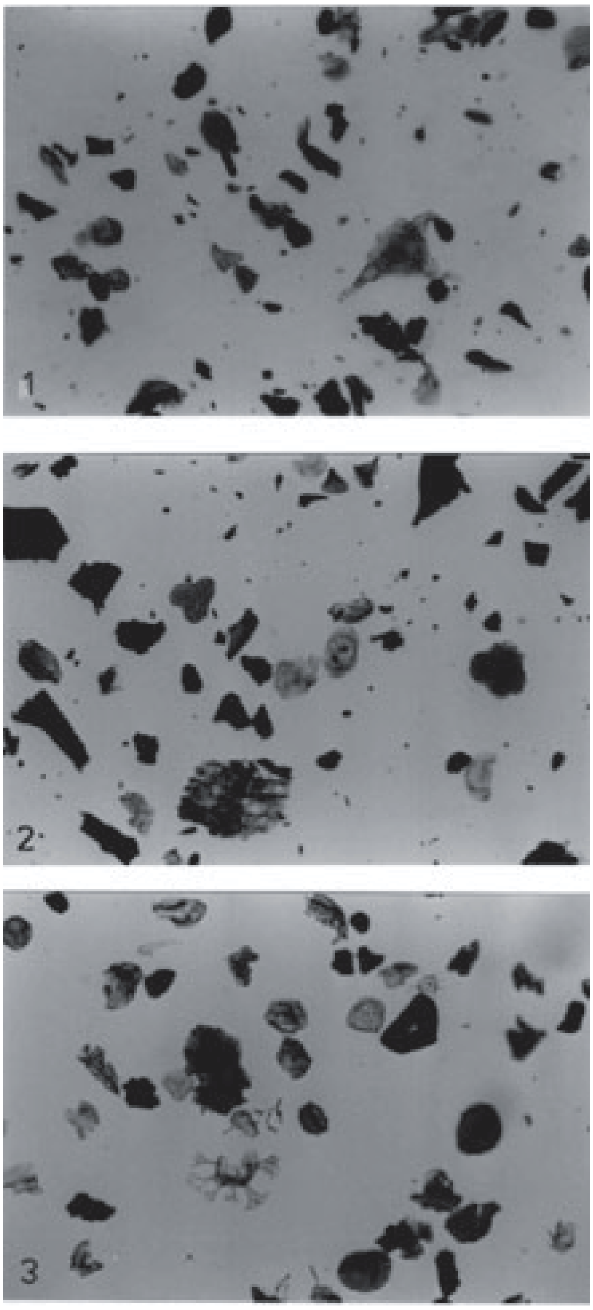


Plate IX: Shallow-marine palynofacies: **Fig. 1** — Sopotnik 1. **Fig. 2** — Sopotnik 2. **Fig. 3** — Skrzypowy 1. For scale see explanation for Plate I.

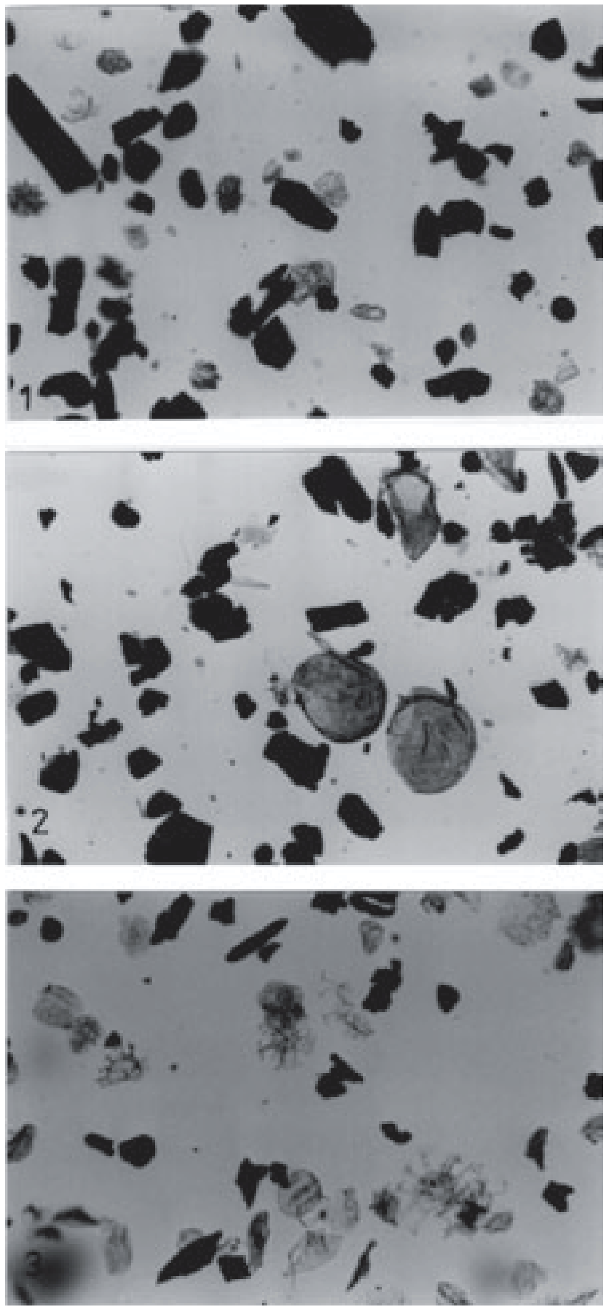


Plate X: Open-marine palynofacies with some reworked palynomorphs. **Fig. 1** — Grabnik 4. **Fig. 2** — Skrzypowy 11. **Fig. 3** — Skrzypowy 11A. For scale see explanation for Plate I.

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Appendix

An alphabetic index of dinocyst taxa found in the Spas Shale is provided below. Taxonomic citations can be found in Lentin & Williams (1993).

Achomosphaera neptuni (Eisenack 1958a) Davey & Williams 1966a
Achomosphaera ramulifera (Deflandre 1937b) Evitt 1963
Achomosphaera reticulata Clarke & Verdier 1967
Achomosphaera sagena Davey & Williams 1966a
Achomosphaera verdieri Below 1982c

Achomosphaera cf. *ramulifera* (Davey 1979)
Achomosphaera spp.
Adnatosphaeridium tutulosum Cookson & Eisenack 1960a
Apteodinium grande Cookson & Hughes 1964; (Pl. VIII: Fig. 8)
Apteodinium granulatum Eisenack 1958a
Apteodinium maculatum Eisenack & Cookson 1960
Apteodinium spp.
Atopodinium haromense Thomas & Cox 1988
Batiacasphaera spp.
Batioladinium jaegerii (Alberti 1961) Brideaux 1975; (Pl. IV: Fig. 7)
Batioladinium micropodum (Eisenack & Cookson 1960) Brideaux 1975
Bourkidinium granulatum Morgan 1975
Bourkidinium sp. 1 (Leereveld 1995); (Pl. I: Figs. 3–4)
Callaiosphaeridium asymetricum (Deflandre & Courteville 1939) Davey & Williams 1966b
Canningia colliveri Cookson & Eisenack 1960b
Canningia minor Cookson & Hughes 1964
Canningia palliata Brideaux 1977
Canningia reticulata Cookson & Eisenack 1960b
Canningia ringnesiorum Manum & Cookson 1964
Canningia spp.
Carpodinium granulatum Cookson & Eisenack 1962b
Carpodinium obliquicostatum Cookson & Hughes 1964; (Pl. VII: Figs. 2–3)
Cauca parva (Alberti 1961) Davey & Verdier 1971
Cepadinium ventriosum (Alberti 1959b) Lentin & Williams 1989; (Pl. II: Figs. 1–3)
Cerbia tabulata (Davey & Verdier 1974) Below 1981a
Cerbia cf. *tabulata* of Leereveld 1995
Chlamydophorella ambigua (Deflandre 1937b) Stover & Helby 1987d
Chlamydophorella discreta Clarke & Verdier 1967
Chlamydophorella nyei Cookson & Eisenack 1958; (Pl. VIII: Fig. 5)
Chlamydophorella spp.
Chytroeisphaeridia chytroeides (Sarjeant 1962a) Downie & Sarjeant 1965
Chytroeisphaeridia spp.
Circulodinium attadalicum (Cookson & Eisenack 1962b) Helby 1987
Circulodinium distinctum (Deflandre & Cookson 1955) Jansonius 1986
Circulodinium spp.
Cleistosphaeridium armatum (Deflandre 1937b) Davey 1969a
Cleistosphaeridium multispinosum (Singh 1964) Brideaux 1971
Cleistosphaeridium sp. A of Brideaux 1971
Cleistosphaeridium sp. BE of Brideaux 1971
Cleistosphaeridium spp.
Cometodinium comatum Srivastava 1984
Cometodinium habibii Monteil 1991a
Cometodinium obscurum Deflandre & Courteville 1939
Cometodinium whitei (Deflandre & Courteville 1939) Stover & Evitt 1978
Cometodinium spp.
Coronifera albertii Millioud 1969
Coronifera oceanica Cookson & Eisenack 1958; (Pl. IV: Figs. 2–3)
Coronifera spp.
Cribroperidinium auctificum (Brideaux 1971) Stover & Evitt 1978
Cribroperidinium diaphane (Cookson & Eisenack 1958) Stover & Evitt 1978
Cribroperidinium edwardsii (Cookson & Eisenack 1958) Davey 1969a
Cribroperidinium intricatum Davey 1969a
Cribroperidinium muderongese (Cookson & Eisenack 1958) Davey 1969a
Cribroperidinium orthoceras (Eisenack 1958) Davey 1969a
Cribroperidinium spinoreticulatum (McIntyre & Brideaux 1980) Arhus 1992
Cribroperidinium tensiftense Below 1981a
Cribroperidinium spp.
Ctenidodinium elegantulum Millioud 1969; (Pl. III: Figs. 1–2)
Cyclonephelium chabaca Below 1981a
Cyclonephelium compactum Deflandre & Cookson 1955
Cyclonephelium crassimarginatum Cookson & Eisenack 1974
Cyclonephelium paucimarginatum Cookson & Eisenack 1962b
Cyclonephelium vannophorum Davey 1969a
Cymososphaeridium validum Davey 1982b
Dapsilidinium deflandrei (Valensi 1947) Lentin & Williams 1981
Dapsilidinium laminaspinosum (Davey & Williams 1966b) Lentin & Williams 1981
Dapsilidinium multispinosum (Davey 1974) Bujak et al. 1980
Dapsilidinium warreni (Habib 1976) Lentin & Williams 1981
Dapsilidinium spp.
Diconodinium glabrum Eisenack & Cookson 1960
Dingodinium coerviculum Cookson & Eisenack 1958; (Pl. VIII: Fig. 2)
Dinopterygium cladoides Deflandre 1935; (Pl. V: Figs. 3, 6)
Dinopterygium spp.
Discorsia nanna (Davey 1974) Duxbury 1977
Dissiliodinium globulus Drugg 1978
Dissiliodinium spp.
Ellipsodinium reticulatum Duxbury 1980; (Pl. VI: Fig. 4)
Ellipsodinium rugulosum Clarke & Verdier 1967; (Pl. III: Figs. 3, 6)
Endoscrinium bessebae Below 1981a
Endoscrinium campanula (Gocht 1959) Vozzhennikova 1967
Endoscrinium glabrum (Duxbury 1977) Below 1981a
Epelidosphaeridia spinosa (Cookson & Hughes 1964) Davey 1969a; (Pl. VI: Figs. 8–10)
Exochosphaeridium arnace Davey & Verdier 1973; (Pl. V: Fig. 4)
Exochosphaeridium muelleri Yun 1981
Exochosphaeridium phragmites Davey et al. 1966
Exochosphaeridium spp.
Eyrea nebulosa Below 1984
Florentinia cooksoniae (Singh 1971) Duxbury 1980
Florentinia deanei (Davey & Williams 1966b) Davey & Verdier 1973
Florentinia laciniata Davey & Verdier 1973
Florentinia mantelli (Davey & Williams 1966b) Davey & Verdier 1973
Florentinia radiculata (Davey & Williams 1966b) Davey & Verdier 1973
Florentinia stellata (Maier 1959) Below 1982a
Florentinia spp.
Fromea amphora Cookson & Eisenack 1958
Fromea quadrugata Duxbury 1980; (Pl. II: Fig. 5)
Gardodinium trabeculosum (Gocht 1959) Alberti 1961
Gonyaulacysta cassidata (Eisenack & Cookson 1960) Sarjeant 1966b; (Pl. VIII: Fig. 1)
Gonyaulacysta cretacea (Neale & Sarjeant 1962) Sarjeant 1969
Gonyaulacysta diutina Duxbury 1977
Gonyaulacysta extensa Clarke & Verdier 1967; (Pl. VIII: Figs. 4, 7)
Gonyaulacysta helicoidea (Eisenack & Cookson 1960) Sarjeant 1966b
Gonyaulacysta spp.
Hapsocysta dictyota Davey 1979b
Heterosphaeridium heteracanthum (Deflandre & Cookson 1955) Eisenack & Kjellstroem 1971a
Hystrichodinium pulchrum Deflandre 1935
Hystrichodinium ramoides Alberti 1961
Hystrichodinium voightii (Alberti 1961) Davey 1974
Hystrichodinium spp.
Hystrichosphaeridium recurvatum (White 1842) Lejeune-Carpentier 1940
Hystrichosphaeridium spp.
Hystrichosphaerina schindewolfii Alberti 1961
Hystrichostrogylon membraniphorum Agelopoulos 1964
Hystrichostrogylon spp.
Kiokansium corollum Below 1984
Kiokansium unituberculatum (Tasch 1964) Stover & Evitt 1978
Kiokansium spp.

Kleithriasphaeridium eoinodes (Eisenack 1958a) Davey 1974
Kleithriasphaeridium fasciatum (Davey & Williams 1966b) Davey 1974
Leberidocysta chlamydata (Cookson & Eisenack 1962b) Stover & Evitt 1978
Lithodinia stoveri (Millioud 1969) Gocht 1976
Lithodinia sp. A Leereveld 1995
Litosphaeridium arundum (Eisenack & Cookson 1960) Davey 1970b; (Pl. VI: Fig. 5)
Litosphaeridium siphoniphorum (Cookson & Eisenack 1958) Davey & Williams 1966b; (Pl. VI: Figs. 1, 7)
Litosphaeridium spp.
Maghrebinia spp.
Membranosphaera sp. A Davey 1979b; (Pl. III: Fig. 5)
Mendicodinium caperatum Brideaux 1977
Mendicodinium groenlandicum (Pocock & Sarjeant 1972) Davey 1979c
Mendicodinium spp.
Microdinium echinatum Clarke & Verdier 1967
Microdinium ornatum Cookson & Eisenack 1960a
Muderongia neocomica (Gocht 1957) Lentin & Williams 1993; (Pl. I: Figs. 6–7)
Muderongia pariata Duxbury 1983
Muderongia tabulata (Raynaud 1978) Monteil 1991b
Muderongia cf. *staurota* (Davey 1979)
Muderongia spp.
Nannoceratiopsis spp.
Occisucysta balios Gitmez (1970)
Occisucysta spp.
Odontochityna costata Alberti 1961
Odontochityna operculata (O. Wetzel 1930a) Deflandre & Cookson 1955; (Pl. II: Fig. 6)
Odontochityna singhii Morgan 1980
Odontochitina spp.
Oligosphaeridium albertense (Pocock 1962) Davey & Williams 1969
Oligosphaeridium asterigerum (Gocht 1959) Davey & Williams 1969
Oligosphaeridium complex (White 1842) Davey & Williams 1966b
Oligosphaeridium diluculum Davey 1982b
Oligosphaeridium djenn Below 1982c
Oligosphaeridium irregulare (Pocock 1962) Davey & Williams 1969
Oligosphaeridium perforatum (Gocht 1959) Davey & Williams 1969
Oligosphaeridium poculum Jain 1977b
Oligosphaeridium prolixispinosum Davey & Williams 1966b; (Pl. VII: Figs. 7–8)
Oligosphaeridium pulcherrimum (Deflandre & Cookson 1955); Davey & Williams 1966b; (Pl. I: Fig. 2)
Oligosphaeridium totum subsp. *totum* Brideaux 1971
Oligosphaeridium verrucosum Davey 1979b
Oligosphaeridium spp.
Operculodinium spp.
Ovoidinium diversum (Davey 1979)
Ovoidinium incomptum Duxbury 1983
Ovoidinium scabrosum (Cookson & Hughes 1964) Davey 1970; (Pl. VI: Fig. 6)
Ovoidinium spp.
Palaeohystrichophora infusorioides Deflandre 1935; (Pl. VI: Figs. 2–3)
Palaeoperidinium cretacaeum Pocock 1962
Palaeotetradinium silicorum Deflandre 1936b; (Pl. IV: Fig. 1)
Pareodinia ceratophora Deflandre 1947c
Pareodinia sp. 1 of Davey 1982
Pareodinia spp.
Pervosphaeridium pseudohystrichodinium (Deflandre 1937b) Yun 1981; (Pl. V: Figs. 2, 5)
Pervosphaeridium truncatum (Davey 1969a) Below 1982c
Pervosphaeridium truncigerum (Deflandre 1937b) Yun 1981
Pervosphaeridium spp.
Prolixosphaeridium parvispinum (Deflandre 1937b) Davey et al.1969; (Pl. IV: Figs. 4–5)
Prolixosphaeridium sp. A of Monteil 1993
Protoellipsodinium clavulum Davey & Verdier 1974; (Pl. VII: Fig. 1)
Protoellipsodinium longispinosum Prössl 1990; (Pl. VII: Fig. 4)
Protoellipsodinium spinocristatum Davey & Verdier 1971; (Pl. VII: Figs. 5–6)
Protoellipsodinium spinosum Davey & Verdier 1971; (Pl. II: Fig. 8)
Pseudoceratium anaphrissum (Sarjeant 1966c) Bint 1986
Pseudoceratium eisenackii (Davey 1969a) Bint 1986
Pseudoceratium expolitum Brideaux 1971; (Pl. I: Fig. 1)
Pseudoceratium polymorphum (Eisenack 1958a) Bint 1986; (Pl. III: Figs. 4, 8)
Pseudoceratium retusum Brideaux 1977; (Pl. II: Figs. 9–10)
Pseudoceratium securigerum (Davey & Verdier 1974) Bint 1986; (Pl. III: Figs. 7, 9)
Pseudoceratium spp.
Pterodinium bab Below 1981a
Pterodinium cingulatum (O. Wetzel 1933b) Below 1981a; (Pl. VIII: Figs. 3, 6)
Pterodinium cingulatum subsp. *granulatum* (Clarke & Verdier 1967) Lentin & Williams 1981
Pterodinium cingulatum subsp. *perforatum* (Clarke & Verdier 1967) Davey & Williams 1971
Pterodinium cingulatum subsp. *reticulatum* (Davey & Williams 1966a) Lentin & Williams 1981
Pterodinium cornutum Cookson & Eisenack 1962b
Pterodinium premnos Duxbury 1980
Pterodinium spp.
Raetiaedinium truncigerum (Deflandre 1937b) Kirsch 1991
Rhombodella paucispina (Alberti 1961) Duxbury 1980
Rhombodella vesca Duxbury 1980
Rhombodella sp. A
Rhynchodiniopsis fimbriata (Duxbury 1980) Sarjeant 1982b
Rhynchodiniopsis spp.
Schizocystia laevigata Cookson & Eisenack 1962a; (Pl. II: Fig. 4)
Schizocystia rara Playford & Dettmann 1965
Schizocystia rugosa Cookson & Eisenack 1962a
Sentusidinium spp.
Spinidinium boydii Morgan 1975
Spinidinium echinoidea (Cookson & Eisenack 1960a) Lentin & Williams 1976
Spiniferites ancoriferus Cookson & Eisenack 1974
Spiniferites cornutus (Gerlach 1961) Sarjeant 1970
Spiniferites crassipelis (Deflandre & Cookson 1965) Sarjeant 1970
Spiniferites lenzii Below 1982c
Spiniferites ramosus (Ehrenberg 1838) Mantell 1854
Spiniferites scabrosus (Clarke & Verdier 1967) Lentin & Williams 1975
Spiniferites spp.
Stephodinium coronatum Deflandre 1936a; (Pl. IV: Fig. 6)
Stephodinium spinulosum Duxbury 1983
Stiphrosphaeridium anthophorum (Cookson & Eisenack 1958) Lentin & Williams 1985
Stiphrosphaeridium dictiophorum (Cookson & Eisenack 1958) Lentin & Williams 1976
Subtilisphaera cheit Below 1981a
Subtilisphaera deformans (Davey & Verdier 1973) Stover & Evitt 1978
Subtilisphaera perlucida (Alberti 1959b) Jain & Millepied 1973; (Pl. I: Fig. 5)
Subtilisphaera pirnaensis (Alberti 1959b) Jain & Millepied 1973
Subtilisphaera terrula (Davey 1974) Lentin & Williams 1976
Subtilisphaera zawia Below 1981a
Subtilisphaera spp.
Surculosphaeridium longifurcatum (Firtion 1952) Davey et al. 1966
Surculosphaeridium trunculum Davey 1979b
Surculosphaeridium spp.

Systematophora complicata Neale & Sarjeant 1962
Systematophora cretacea Davey 1979b
Systematophora siliba Davey 1979b
Systematophora spp.
Taleisphaera hydra Duxbury 1979a
Tanyosphaeridium boletum Davey 1974
Tanyosphaeridium regulare Davey & Williams 1966b
Tanyosphaeridium variecalamum Davey & Williams 1966b
Tanyosphaeridium spp.
Tehamadinium coummium (Below 1981a) Jan du Chêne et al. 1986a; (PL. IV: Fig. 8)
Tehamadinium sousensis (Below 1981a) Jan du Chêne et al. 1986a
Tenua? sp. B of Brideaux 1977
Thallasiphora pelagica (Eisenack 1954b) Eisenack & Gocht 1960
Trichodinium castanea (Deflandre 1935) Clarke & Verdier 1967
Trichodinium speetonensis Davey 1974
Valensiella reticulata (Davey 1969a) Courtinat 1989
Wallodinium krutzschii (Alberti 1961) Habib 1972
Wallodinium luna (Cookson & Eisenack 1960a) Lentin & Williams 1973
Xiphophoridium alatum (Cookson & Eisenack 1962b) Sarjeant 1966b; (Pl. V: Fig. 1).

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