Annales Societatis Geologorum Poloniae (1997), vol. 67: 203–215.

PALYNOLOGICAL STUDY OF AN OLISTOLITH FROM THE SO-CALLED SUCHA FORMATION, ZAWOJA IG-1 BOREHOLE (FLYSCH CARPATHIANS, POLAND): AGE AND PALAEOENVIRONMENT

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Gedl, P., 1997. Palynological study of an olistolith from the so-called Sucha Formation, Zawoja IG-1 borehole (Flysch Carpathians, Poland): age and palaeoenvironment. *Ann. Soc. Geol. Polon.*, 67: 203–215.

Abstract: Palynological research of an olistolith from the so-called Sucha Formation from the Zawoja IG-1 borehole indicates that it represents a continuous section of Lower Cretaceous (Barremian–Albian) deposits rather than a complex of several olistoliths of different age. The black shale complex of this olistolith is comparable with the Spas shales or the Veřovice shales and lower part of the Lgota beds. Based on the quantative analysis of the dinocyst assemblages Barremian–Albian sea level fluctuations in the Carpathian flysch basin are reconstructed.

Abstrakt: Badania palinologiczne utworów olistolitu z tzw. formacji suskiej w wierceniu Zawoja IG-1 wykazały, że reprezentuje on ciągły profil dolnokredowych osadów, a nie zespołów mniejszych olistolitów różnego wieku. Wiek olistolitu określono w oparciu o dinocysty na barrem–najwyższy alb. Najprawdopodobniej odpowiada on łupkom spaskim lub łupkom wierzowskim i dolnej części warstw lgockich. Analiza zespołów dinocyst pozwoliła na odtworzenie wahań poziomu morza jakie zachodziły w barremie–albie w basenie Karpat fliszowych.

Key words: dinocysts, Early Cretaceous, biostratigraphy, palaeoenvironment, Flysch Carpathians, Poland.

Manuscript received 17 September 1996, accepted 3 March 1997

INTRODUCTION

The Sucha Formation was defined by Ślączka (1977) in the Sucha IG-1 borehole (at a depth of 2901–3168 m) below the Carpathians overthrust. It represents a lower part of the Miocene: Ottnangian?–Karpatian (Strzępka, 1981) or Eggenburgian–Ottnangian (Garecka *et al.*, 1996). The formation was described as continental (brackish) variegated deposits in the lowermost and uppermost parts, separated by a 165-m thick complex of olistoliths. The olistolith complex was composed of several black and red olistoliths of the flysch shales (from several milimetres to several metres thick) embedded in a tawny-red loamy-sandy matrix (Ślączka, 1977). The lowermost part of the formation in the Sucha IG-1 borehole (3142–3168 m) has been attributed by Moryc (1989) to the Lower Triassic platform deposits.

An Early Cretaceous microfauna was found in olistolith complex of the Zawoja IG-1 borehole (Moryc, 1989). The purpose of the present paper is to determine the age and environmental conditions of the Lower Cretaceous deposits of the so-called Sucha Formation from this borehole by the use of quantitative palynological analysis.

MATERIAL

The Zawoja IG-1 borehole was located in the western part of the Flysch Carpathians, near Sucha Beskidzka (Fig. 1). According to Moryc (1989), it subsequently penetrated the overthrust Carpathian units (3825 m thick), then presumably Miocene deposits (1000 m thick) and terminated at a depth of 4825 m within red deposits considered to represent the Triassic platform deposits. Moryc recognized the Sucha Formation from a depth of 4407 m to 4666 m. Because this section is developed differently from the stratotype, it is here referred to as the "so-called Sucha Formation". In the Zawoja IG-1 borehole it is developed as a uniform complex of dark-coloured (predominantly black), non-calcareous claystones and mudstones with infrequent intercalations of thin-bedded, slightly lighter-coloured sandstones. In contrast, the Sucha Formation from the Sucha IG-1 borehole is composed of several separate olistolith units. In the Zawoja IG-1 borehole there is no trace of variegated continental deposits in the upper and lower part of this unit such as known from the Sucha IG-1 borehole (Ślączka, 1977).

The samples for palynological analysis have been taken from each cored interval of the so-called Sucha Formation in the Zawoja IG-1 borehole from the following depths:

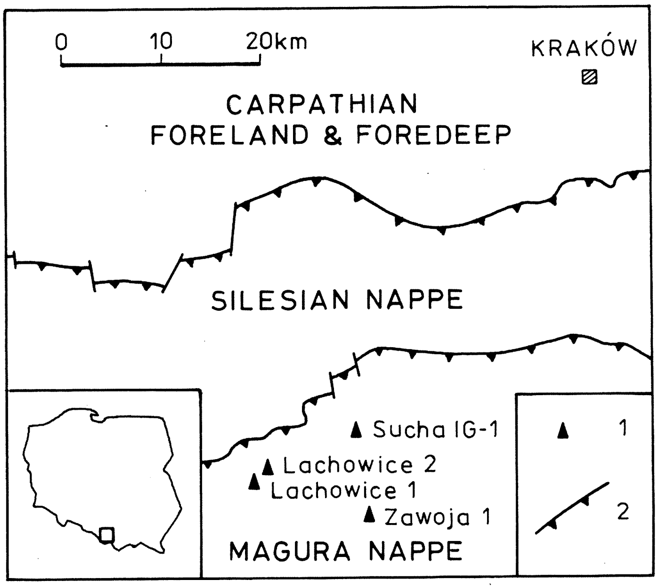

Fig. 1. Location of the Zawoja IG-1 and the neighbouring boreholes (simplified from Garecka *et al.*, 1996): *1* – borehole, *2* – overthrustings

4630–4637 m (Z-17a, 17b), 4580–4589 m (Z-16a, 16b, 16c), 4494–4502 m (Z-15a, 15b) and 4237–4240 m (Z-14a, 14b).

METHODS

The samples were processed following the standard palynological procedure: 20–30 G of cleaned and crushed rock was treated with 40% hydrofluoric acid (HF) to remove silicates (samples gave no reaction with 38% chloric acid (HCl)); organic matter was separated with heavy liquid ($ZnCl_2$ + HCl; s. g. = 2.0 G/cm^3), sieved on a 15 µm nylon sieve and transferred into glycerine water for storage. Glycerine-gelatine jelly was used as a mounting medium; two slides were made from each sample. They are stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences in Kraków.

The studied organic matter can be divided into four main groups following Tyson (1995):

a) opaque and semi-opaque phytoclasts (this group represents oxidized organic remains of unknown, presumably terrestrial origin),

b) terrestrial plant tissue (cellular structure is preserved),

c) sporomorphs (pollen and spores),

d) marine palynomorphs (within this group several subgroups can be distinguished, among which the most important in the studied material are dinocysts).

Recently, several authors have considered the value of dinocysts as palaeoenvironmental change indicators during the Cretaceous (e. g., Hunt, 1987; Lister & Batten, 1988; Leereveld, 1995). Here, the environmentally important dinocyst groups are defined after Leereveld (1995).

Oceanic group. This group comprises dinocysts which presumably lived under open-marine conditions. Dominance of this group usually indicates deep oceanic settings. This group is represented in the Zawoja IG-1 borehole by *Pterodinium* (*P. cingulatum* and *P. premnos*).

Neritic group. This group comprises taxa of unspecified neritic conditions. It is represented by *Oligosphaeridium* (i. e., *O. complex*, *O. asterigerum*, *O. diluculum* and *O. perforatum*), *Spiniferites*, and morphologically similar *Achomosphaera*.

Outer neritic group. This group characterizes the outer neritic environment. It comprises *Chlamydophorella nyei* and morphologically comparable *Gardodinium trabeculosum*.

Inner neritic group. It comprises the representatives of *Cribroperidinium* and *Apteodinium*, genera considered to be near-shore species (e. g., Hunt, 1987; Lister & Batten, 1988). In this study, morphologically similar *Trichodinium castanea* is included within this group.

Littoral group. This group comprises near-shore dinocyst species living under normal marine conditions. These are the representatives of acavate Ceratiaceae such as *Canningia*, *Circulodinium* and *Pseudoceratium*.

Low-salinity group. This group comprises the cavate Ceratiaceae represented in the studied material by *Odontochitina* and *Muderongia*. These genera often occur as dominant taxa in brackish deposits (e. g., Batten, 1982). In addition, included in this group are *Palaeoperidinium cretacea* and *Subtilisphaera* spp. (Fig. 2).

BIOSTRATIGRAPHY OF THE BLACK SHALE OLISTOLITH

The lowermost sample Z-17b is of Barremian, possibly Late Barremian age (Fig. 3). This is based on co-occurrence of *Odontochitina operculata* and *Kleithriasphaeridium corrugatum* (e. g., Heilmann-Clausen, 1987).

The samples Z-17a, Z-16c, Z-16b, Z-16a and Z-15b are characterized by the dominance of a few long-ranging, shallow-marine dinocyst taxa: *Cribroperidinium* spp., *Oligosphaeridium complex* and *Kiokansium unituberculatum*. The only diagnostic dinocyst species found in sample Z-16a is *Hystrichosphaerina schindewolfii,* which indicates the age not younger then the earliest Albian (Costa & Davey, 1992) or latest Aptian (Leereveld, 1995).

The samples Z-15a, Z-14b and Z-14a are of Albian age based on the presence of *Litosphaeridium arundum* in the sample Z-15a (e. g., Heilmann-Clausen, 1987). The presence of *Apteodinium maculatum* subsp. *grande* and *Xiphophoridium alatum* suggests a middle or more probably Late Albian age in the higher samples (e. g., Williams & Bujak, 1985). Based on the first occurrence of *Litosphaeridium siphoniphorum* and *Isabelidinium gallium* sample Z-14a may correspond to the Late Albian (e. g., Heilmann-Clausen, 1987).

The Aptian/Albian boundary is difficult to localize precisely in the studied interval because of the lack of the cored material. It lies somewhere between the Upper Aptian sample Z-16a and the higher sample Z-15a, which is of Middle or Late Albian age (sample Z-15b presumably also represents the Albian).

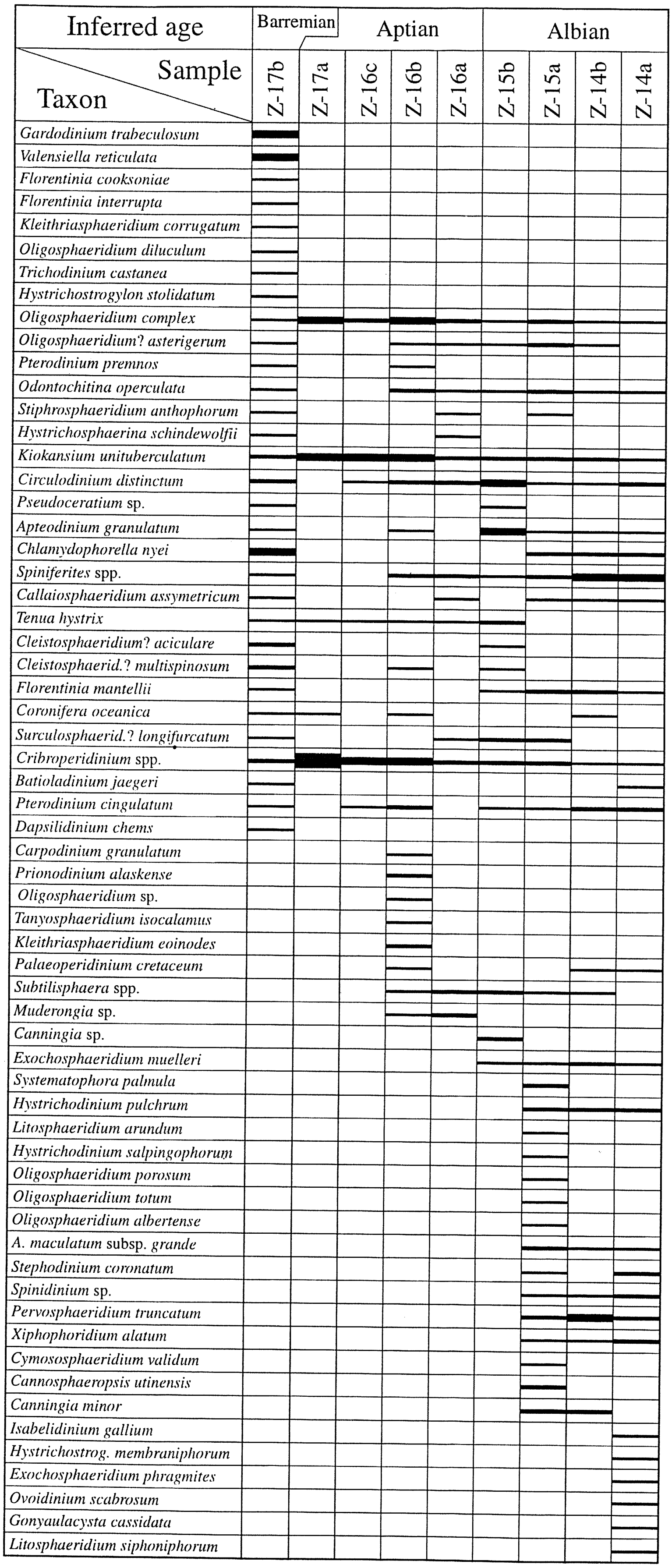

Fig. 2. Distribution of dinocysts in the Lower Cretaceous olistolith of the so-called Sucha Formation from the Zawoja IG-1 borehole

PALAEOENVIRONMENT OF THE BLACK SHALE OLISTOLITH

Results

The palynofacies of sample Z-17b is dominated by terrestrial organic matter, mainly plant tissue remains, opaque particles, sporomorphs. Marine palynomorphs (dinocyst and microforaminifera linings) are not frequent. The Barremian dinocyst assemblage of the lowermost sample is characterized by a high diversity of dinocysts typical for normal marine conditions, and by the presence of numerous representatives of the "outer neritic group", *Chlamydophorella nyei* and *Gardodinium trabeculosum* (Fig. 2).

The palynofacies of samples Z-17a and Z-16c is composed of opaque particles and poorly diversified dinocyst assemblage dominated by *Cribroperidinium*, *Oligosphaeridium* and *Kiokansium*.

The palynofacies of sample Z-16b is characterized by a dominance of opaque particles and by more diversified dinocyst assemblage than that in sample Z-16c. The dinocyst assemblage becomes again more diversified, its "neritic group" becomes more numerous (especially *Spiniferites* spp.), and the "inner neritic" group (*Cribroperidinium* spp.) ceases to dominate. *Pterodinium cingulatum* and *P. premnos* are more numerous than in the lower samples, although they still represent less than 1% of the whole assemblage. Spores are numerous although they are subordinate to dinocysts. This ratio is opposite in the next higher sample (Z-16a) where dinocysts are rare, and terrestrial palynomorphs, especially spores, dominate. The dinocyst assemblage of this sample is again characteristic for near-shore environment. This assemblage is even more littoral in character than that from the samples Z-16c and Z-17a. It is characterized by relatively common dinocysts of the "low-salinity group", *Subtilisphaera* sp. and *Muderongia* sp.

The palynofacies of samples Z-15b, and especially Z-15a, is similar to that of sample Z-17b; it is composed of opaque particles, plant remains and a diversified marine palynomorph assemblage (mainly dinocysts). The most numerous palynomorphs in sample Z-15b are the representatives of the "littoral group" (*Circulodinium distinctum* and *Canningia* sp.), and of "inner neritic group", such as *Apteodinium granulatum* and *Cribroperidinium* spp. Cavate Ceratiaceae (as *Odontochitina costata*) are less numerous, *Muderongia* sp. is absent. Only *Subtilisphaera* sp. appears remarkably. Few specimens of *Pterodinium cingulatum* are also present. The dinocyst assemblage in sample Z-15a resembles that of sample Z-17b: both are characterized by relatively diversified dinocyst association and the presence of *Chlamydophorella nyei*, representative of the "outer neritic

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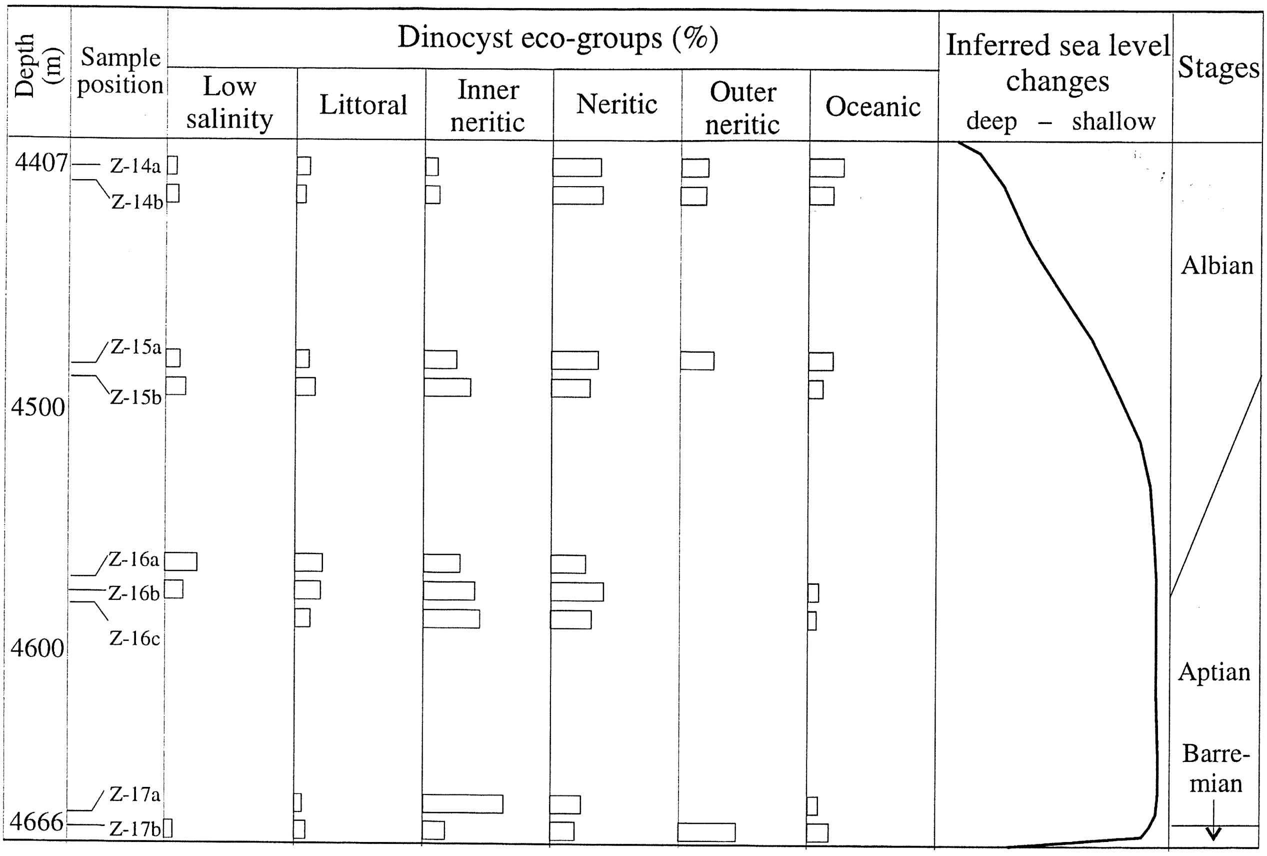

Fig. 4. Distribution of dinocyst eco-groups and reconstruction of the depositional palaeoenvironment of the Lower Cretaceous black shale olistolith of the so-called Sucha Formation from the Zawoja IG-1 borehole

comparable dinocyst assemblage to that described by Jamiński (1995) from the Albian Lgota beds of Lanckorona. Książkiewicz (1975; p. 344) estimated the depth of the deposition of Veřovice shales as "outer neritic zone and more probably the upper bathyal depths". This statement could be applicable to shales and palynomorph assemblage of sample Z-17b (outer neritic setting). The stratigraphically higher deposits show more shallow-marine character of their palynomorph assemblages. Książkiewicz (1975) mentioned a very shallow-marine depositional environment in the lower part of the Lgota beds. This could correspond with shallow-marine environment of samples Z-16. According to Książkiewicz (1975; p. 344), the upper part of the Lgota beds was deposited at "depths not greater than the upper bathyal zone". Only the dinocyst assemblages from samples Z-14a and Z-14b may correspond to the above described conditions.

CONCLUSIONS

The so-called Sucha Formation in the Zawoja IG-1 borehole is developed differently than at its stratotype the Sucha IG-1 borehole. It is a 260-m thick single olistolith of black shales with infrequent sandstones instead of a complex of several smaller olistoliths. Miocene is not evidenced in the investigated interval. The black shale olistolith in the Zawoja IG-1 borehole contains dinocyst assemblages of Barremian to Late Albian age (Fig. 3). The olistolith corresponds in age with the Spas shales or the upper part of the Veřovice shales and possibly also a lower part of the Lgota beds from the Flysch Carpathians. The dinocyst assemblages indicate distinct shallowings close to the Barremian/Aptian and Aptian/Albian boundaries in the Carpathian basins. The Barremian and Albian deposits appear to have been deposited in a relatively deep setting (Fig. 4).

Acknowledgements

The author would like to thank Dr H. Leereveld and Drs R. Verreussel (Laboratory of Palaeobotany and Palynology, Utrecht, The Netherlands) for their aid during preparation of this paper. The author is deeply indebted to Dr E. Jawor (Polish Petroleum Company, Kraków) for making samples available for this study. Prof. Dr N. Oszczypko (Institute of Geological Sciences, Jagiellonian University, Kraków) is greatfully acknowledged for very helpful discussion. Special thanks are due to Prof. Dr K. Birkenmajer (Institute of Geological Sciences, Polish Academy of Sciences, Kraków) for his editorial help and discussion while preparing this paper for publication. Dr. M. Nowogrodzka-Zagórska (Collegium Medicum, Jagiellonian University, Kraków) helped the author during the SEM observations. Elżbieta Gedl is acknowledged for preparing the photographs for this publication. In 1996, the author's work was also assisted by an award from the Foundation for Polish Science.

APPENDIX

List of dinocyst taxa from the so-called Sucha Formation in the Zawoja IG-1 borehole is provided below. The dinocyst range-chart is shown at the Fig. 2. All taxonomic citations can be found in Lentin & Williams (1993). A selection of the taxa is shown in Figures 5–10 with sample code and England Finder coordinates indicated.

Apteodinium granulatum Eisenack, 1958a emend. Lucas-Clark, 1987
Apteodinium maculatum subsp. *grande* (Cookson & Hughes, 1964) Below, 1981a
Batioladinium jaegeri (Alberti, 1961) Brideaux, 1975
Callaiosphaeridium asymmetricum (Deflandre & Courteville, 1939) Davey & Williams, 1966
Canningia minor Cookson & Hughes, 1964
Canningia sp.
Cannosphaeropsis utinensis O. Wetzel, 1932 emend. Marheinecke, 1992
Carpodinium granulatum Cookson & Eisenack, 1962b emend. Leffingwell & Morgan, 1977
Chlamydophorella nyei Cookson & Eisenack, 1958
Circulodinium distinctum (Deflandre & Cookson, 1955) Jansonius, 1986
Circulodinium sp.
Cleistosphaeridium? *aciculare* Davey, 1969a
Cleistosphaeridium? *multispinosum* (Singh, 1964) Brideaux, 1971
Coronifera oceanica Cookson & Eisenack, 1958 emend. May, 1980
Cribroperidinium spp.
Cymososphaeridium validum Davey, 1982
Dapsilidinium chems (Below, 1982c) Lentin & Williams, 1985
Exochosphaeridium muelleri Yun, 1981
Exochosphaeridium phragmites Davey, Downie, Sarjeant & Williams, 1966
Florentinia cooksoniae (C. Singh, 1971) Duxbury, 1980
Florentinia interrupta Duxbury, 1980
Florentinia mantellii (Davey & Williams, 1966b) Davey & Verdier, 1973
Gardodinium trabeculosum (Gocht, 1959) Alberti, 1961
Gonyaulacysta cassidata (Eisenack & Cookson, 1960) Sarjeant, 1966b
Hystrichodinium pulchrum Deflandre, 1935
Hystrichosphaeridium salpingophorum (Deflandre, 1935) Deflandre, 1937b
Hystrichosphaerina schindewolfii Alberti, 1961
Hystrichostrogylon membraniforum Agelopoulos, 1964
Hystrichostrogylon stolidatum (Duxbury, 1980) Stover & Williams, 1987
Isabelidinium gallium (Davey & Verdier, 1973) Stover & Evitt, 1978
Kiokansium unituberculatum (Tasch, 1964) Stover & Evitt, 1978
Kleithriasphaeridium corrugatum Davey, 1974
Kleithriasphaeridium eoinodes (Eisenack, 1958a) Davey, 1974 emend. Sarjeant, 1985a
Litosphaeridium arundum (Eisenack & Cookson, 1960) Davey, 1979b
Litosphaeridium siphoniphorum (Cookson & Eisenack, 1958) Davey & Williams, 1966b emend. Lucas-Clark, 1984
Muderongia sp.
Odontochitina operculata (O. Wetzel, 1933a) Deflandre & Cook-

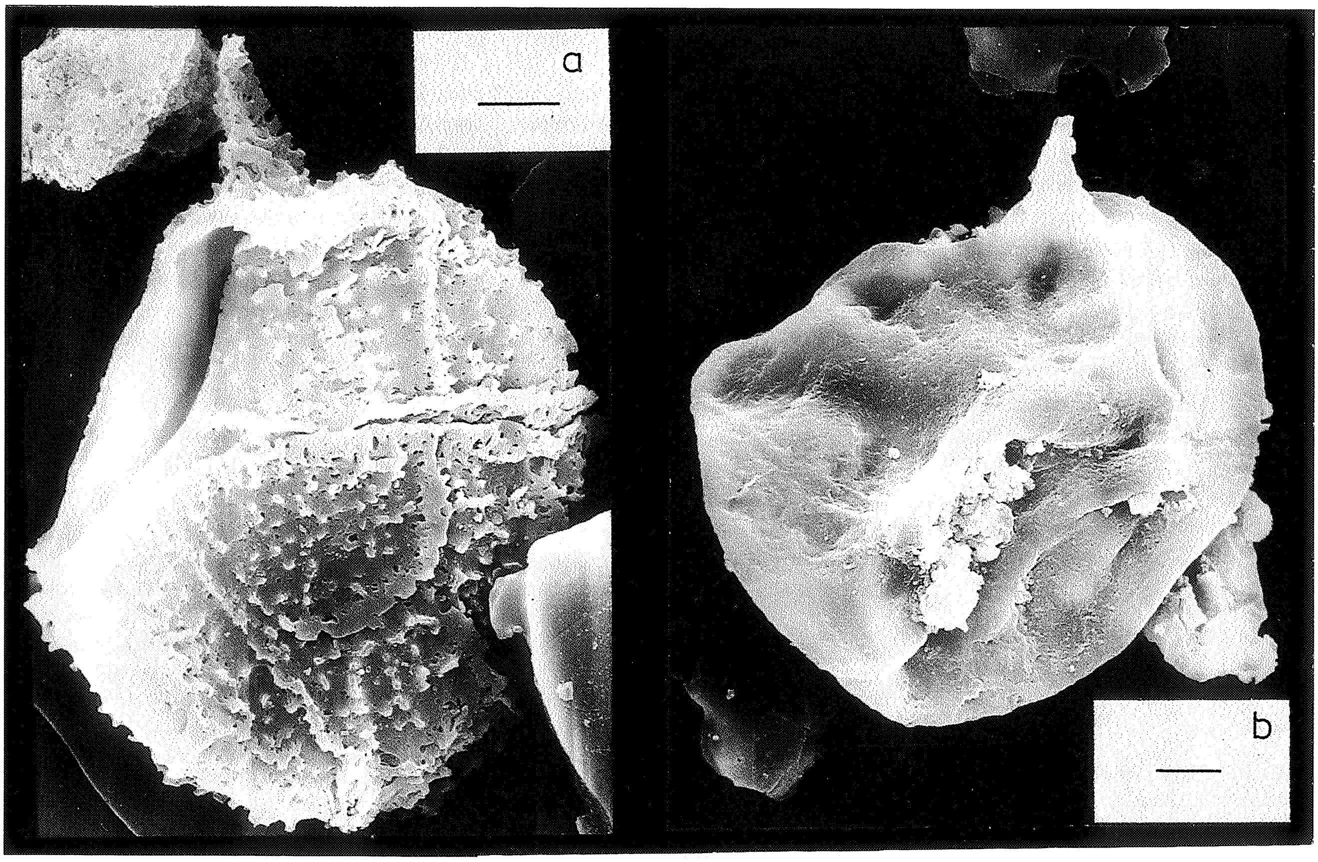

Fig. 5. Dinocysts from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a.** *Cribroperidinium* sp. (sample Z-16b); **b.** *Apteodinium maculatum* subsp. *grande* (sample Z-14a). Scale bars indicate 10 μm

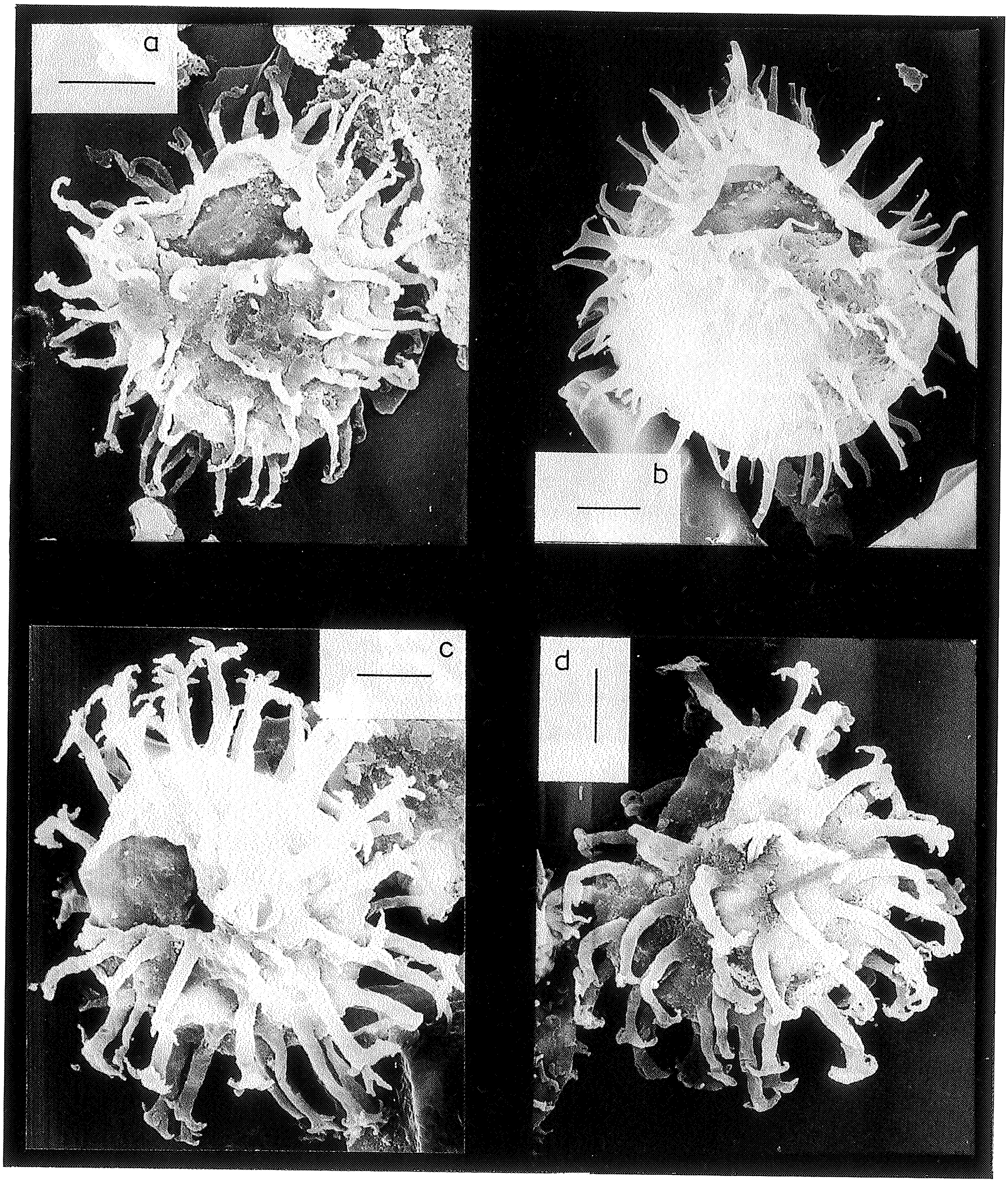

Fig. 6. Dinocysts from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a, c, d.** *Kiokansium unituberculatum* (sample Z-16b); **b.** *Exochosphaeridium muelleri* (sample Z-15a). Scale bars indicate 10 μm

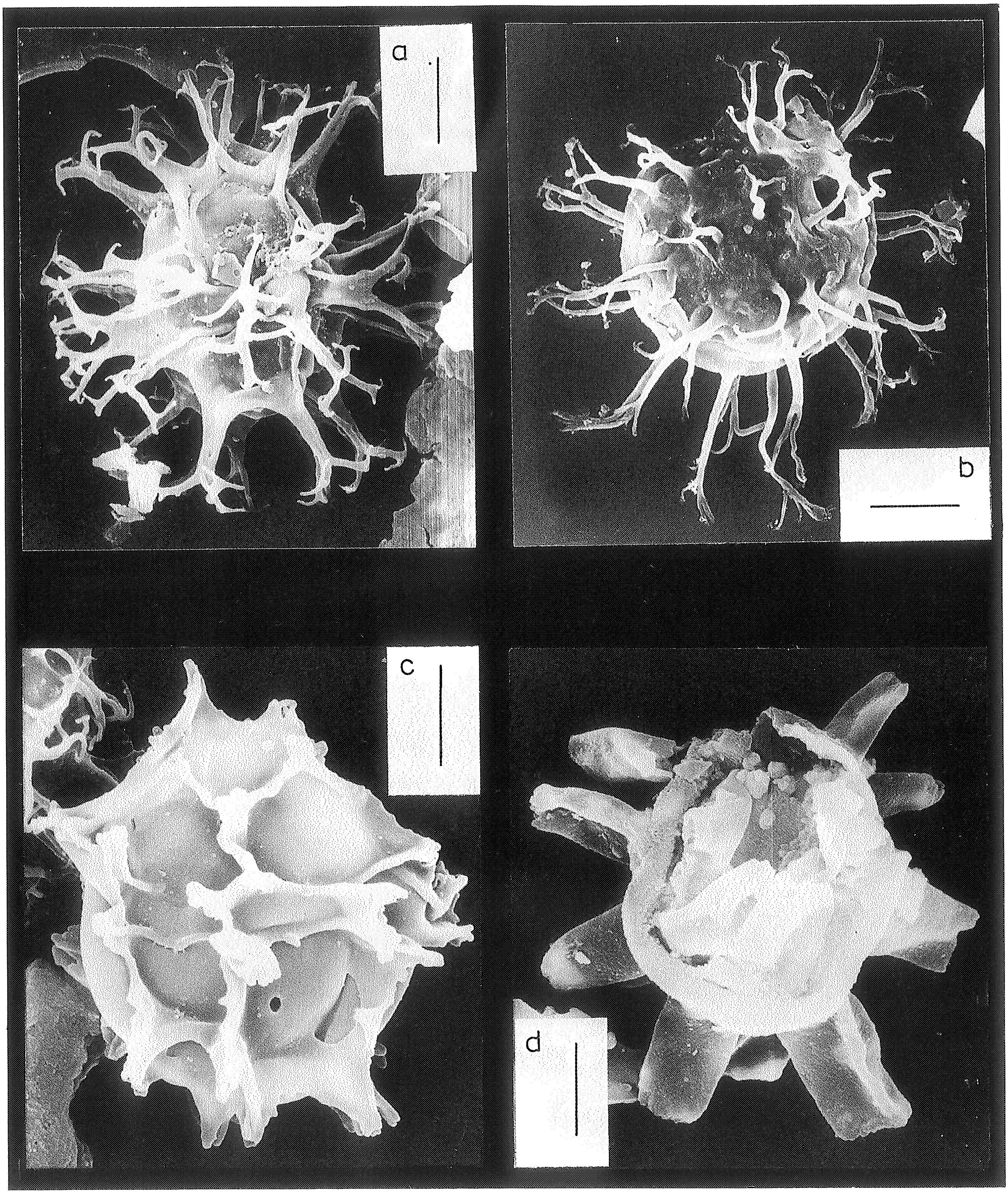

Fig. 7. Dinocysts from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a.** *Spiniferites* sp. (sample Z-15a); **b.** ?*Surculosphaeridium longifurcatum* (sample Z-15a); **c.** *Pterodinium cingulatum* (sample Z-14a); **d.** *Litosphaeridium siphoniphorum* (sample Z-14a). Scale bars indicate 10 μm

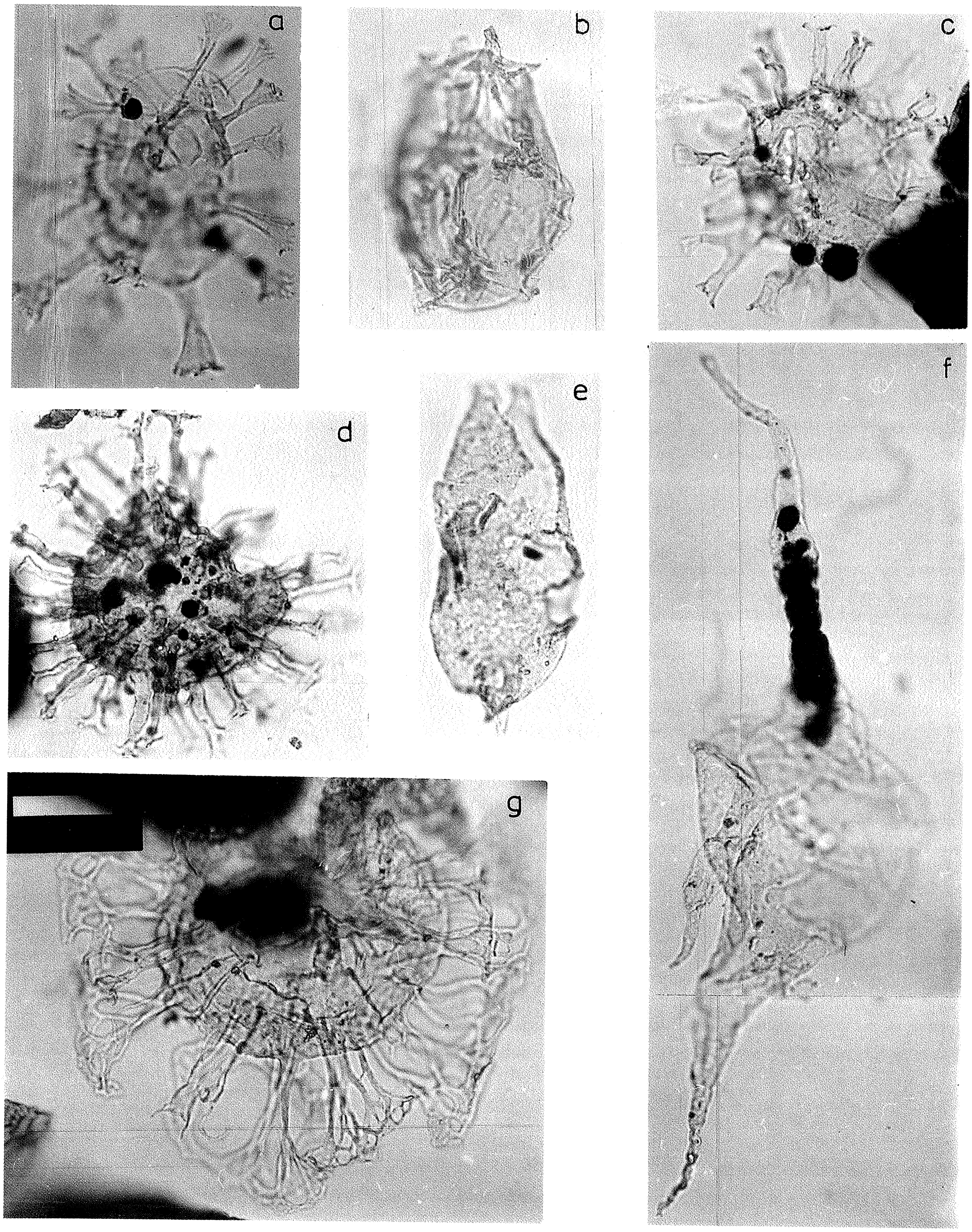

Fig. 8. Dinocysts from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a.** *Kleithriasphaeridium corrugatum* (sample Z-17b, [Q51.4]); **b.** *Carpodinium granulatum* (sample Z-16b, [N39.2]); **c.** *Florentinia mantellii* (sample Z-17b, [E45.2/4]); **d.** *Kiokansium unituberculatum* (sample Z-16b, [K41.2]); **e.** *Batioladinium jaegeri* (sample Z-17b, [C40.3]); **f.** *Odontochitina operculata* (sample Z-17b, [L44]); **g.** *Hystrichosphaerina schindewolfii* (sample Z-17b, [S41.3]). Scale bar on figure 8g indicates 20 μm and refers to all other figures

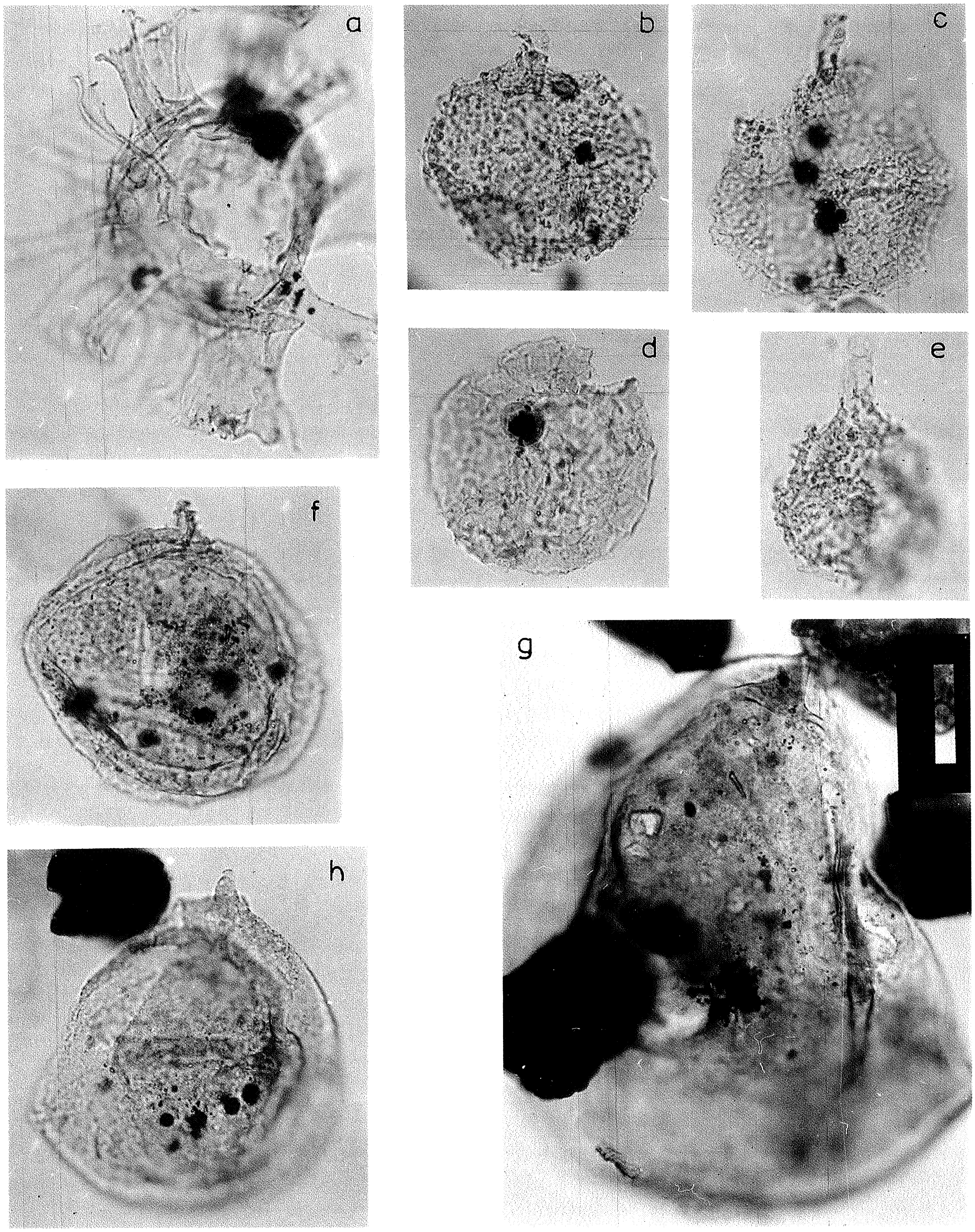

Fig. 9. Dinocysts from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a.** *Florentinia cooksoniae* (sample Z-17b, [E47.1/2]); **b.** *Chlamydophorella nyei* (sample Z-17b, [F39.4]); **c, e.** *Gardodinium trabeculosum* (sample Z-17b: c – [G43], e – [H39]); **d.** *Valensiella reticulata* (sample Z-17b, [D43.4]); **f.** *Trichodinium castanea* (sample Z-17b, [F37.2]); **g.** *Apteodinium maculatum* subsp. *grande* (sample Z-15a, [L50.2]); **h.** *Apteodinium granulatum* (sample Z-17b, [E48]). Scale bar on figure 9g indicates 20 μm and refers to all other figures

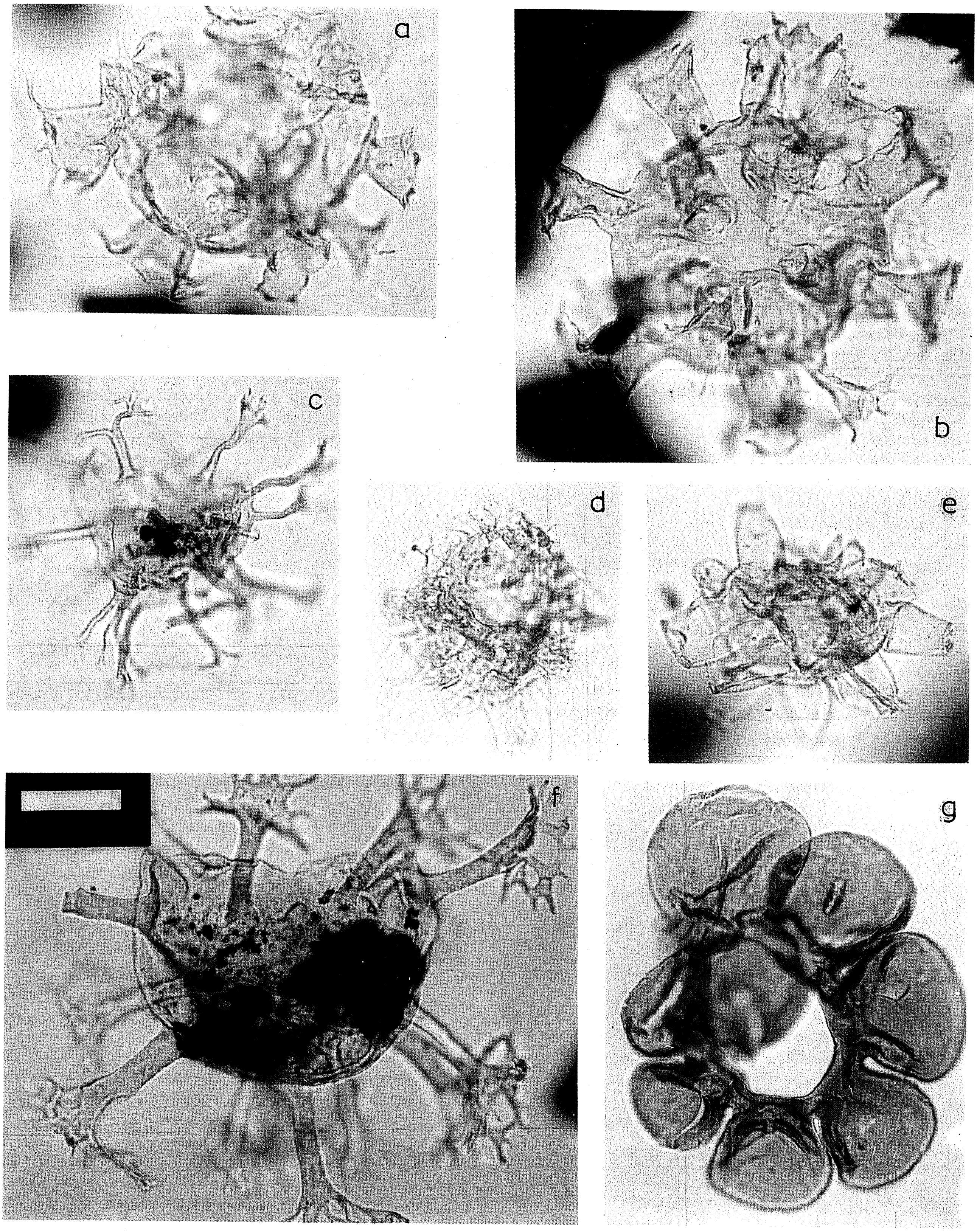

Fig. 10. Palynomorphs from the so-called Sucha Formation from the Zawoja IG-1 borehole: **a.** *Oligosphaeridium porosum* (sample Z-15a, [P42.1]); **b.** *Oligosphaeridium albertense* (sample Z-15a, [N39]); **c.** *Surculosphaeridium*? *longifurcatum* (sample Z-15a, [M45]); **d.** *Coronifera oceanica* (sample Z-17b, [H47.2]); **e.** *Litosphaeridium siphoniphorum* (sample Z-14a, [C48.2]); **f.** *Oligosphaeridium diluculum* (sample Z-17b, [N37.4]); **g.** microforaminifera lining (sample Z-17b, [M47.3]). Scale bar on figure 10f indicates 20 μm and refers to all other figures

son, 1955
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 porosum Lentin & Williams, 1981
Oligosphaeridium totum Brideaux, 1971
Oligosphaeridium sp.
Ovoidinium scabrosum (Cookson & Hughes, 1964) Davey, 1970
Palaeoperidinium cretaceum Pocock, 1962 emend. Harding, 1990a
Pervosphaeridium truncatum (Davey, 1969a) Below, 1982c emend. Masure, 1988b
Prionodinium alaskense Leffingwell & Morgan, 1977
Pseudoceratium sp.
Pterodinium cingulatum (O. Wetzel, 1933b) Below, 1981a
Pterodinium premnos Duxbury, 1980
Spinidinium sp.
Spiniferites spp.
Stephodinium coronatum Deflandre, 1936a
Stiphrosphaeridium anthophorum (Cookson & Eisenack, 1958) Lentin & Williams, 1985
Subtilisphaera spp.
Surculosphaeridium? longifurcatum (Firtion, 1952) Davey, Downie, Sarjeant & Williams, 1966
Systematophora palmula Davey, 1982b
Tanyosphaeridium isocalamus (Deflandre & Cookson, 1955) Davey & Williams, 1969
Trichodinium castanea (Deflandre, 1935) Clarke & Verdier, 1967
Valensiella reticulata (Davey, 1969a) Courtinat, 1989
Xiphophoridium alatum (Cookson & Eisenack, 1962b) Sarjeant, 1966b

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Streszczenie

STUDIUM PALINOLOGICZNE OLISTOLITU Z TZW. FORMACJI SUSKIEJ Z OTWORU ZAWOJA IG-1 (KARPATY FLISZOWE, POLSKA): WIEK I PALEOŚRODOWISKO

Przemysław Gedl

Celem niniejszego artykułu było ustalenie wieku oraz warunków powstania olistolitu czarnych łupków tzw. formacji suskiej w wierceniu Zawoja IG-1 (Fig. 1). Formacja ta stanowi część osadów wieku mioceńskiego: ?ottnang–karpat według Ślączki (1977) i Strzępki (1981) oraz eggenburg–ottnang według Gareckiej *et al.* (1996), znajdujących się pod nasunięciem karpackim. Formacja suska została opisana po raz pierwszy przez Ślączkę (1977) w wierceniu Sucha IG-1 (2901–3168 m). Obejmuje ona kontynentalno-brakiczne osady wykształcone w stropowej i spągowej części jako pstre osady klastyczne oraz rozdzielający je 165 metrowy kompleks olistostromowy. Kompleks ten składa się z kilkumilimetrowych do kilkumetrowych czarnych i czerwonych olistolitów łupków fliszowych tkwiących w brunatnoczerwonym ilastopiaszczystym spoiwie (Ślączka, 1977). Dolna część tzw. formacji suskiej w wierceniu Sucha IG-1 (3142–3168 m) została jednak zaliczona przez Moryca (1989) do platformowych osadów triasu dolnego. Badania mikrofaunistyczne olistolitów jednostki suskiej dały rozbieżne wyniki: wiek paleogeński w wierceniu Sucha IG-1 (Ślączka, 1977) oraz dolnokredowy w otworze Zawoja IG-1 (Moryc, 1989).

Strop utworów podścielających nasunięcie karpackie w otworze Zawoja IG-1 (Fig. 1) został nawiercony na głębokości 3825 m, natomiast spąg – na głębokości 4852 m, poniżej którego znajdują się już pstre utwory, najprawdopodobniej triasu dolnego (Moryc, 1989). Utwory uznawane za tzw. formację suską w wierceniu Zawoja IG-1 kontaktują od góry z formacją stryszawską wykształconą jako ogniwo z Bielska w stropowej partii (3825– 4220 m) i jako ogniwo ze Stachorówki w dolnej partii (4220–4407 m); natomiast od dołu kontaktują z formacją z Zawoji (4666–4825 m) (Moryc, 1989; Marecka, 1991).

W wierceniu Zawoja IG-1 tzw. formacja suska wykształcona jest zupełnie odmiennie od stratotypowego profilu w wierceniu Sucha IG-1. Jest to jednolity kompleks ciemnych (przeważnie czarnych) silnie zlustrowanych, bezwapnistych iłowców i mułowców z rzadkimi przewarstwieniami cienkoławicowych, nieco jaśniejszych piaskowców. Analiza dostępnych odcinków rdzeniowanych wiercenia sugeruje, że jest to jeden olistolit, w przeciwieństwie do tzw. formacji suskiej z otworu Sucha IG-1 gdzie jej odcinek olistolitowy składa się z wielu oddzielnych bloków.

Wiek tzw. formacji suskiej w wierceniu Zawoja IG-1 określony został na podstawie obecności dinocyst (Fig. 2) na późny barrem–późny alb (Fig. 3). Ostatnie pojawienie się gatunku *Kleithriasphaeridium corrugatum* w najniższej próbce Z-17b świadczy o jej barremskim wieku. Próbki od Z-17a do Z-16a są zdominowane przez zubożałe zespoły płytkowodnych dinocyst i dokładne określenie ich wieku jest niemożliwe. Jedyną formą przewodnią jest *Hystrichosphaerina schindewolfii*, która po raz ostatni pojawia się w najwyższym apcie (Leereveld, 1995) lub najniższym albie (Costa & Davey, 1992). Dinocysty występujące w wyższych próbkach od Z-15a do Z-14a są już wieku albskiego. *Litosphaeridium arundum* stwierdzone w próbce Z-15a datuje ją na alb, natomiast obecność *Litosphaeridium siphoniphorum* oraz *Isabelidinium gallium* w próbce Z-14a sugeruje jej górnoalbski wiek.

Analiza zespołów dinocyst pozwoliła na stwierdzenie różnic w głębokości basenu w czasie depozycji badanych łupków (Fig. 4). Autor wykorzystał w tej analizie podział kredowych dinocyst ze względu na ich preferencje środowiskowe (Leereveld, 1995). Próbki Z-17b charakteryzuje obecność dinocyst typowych raczej dla środowiska szelfu zewnętrznego (*Chlamydophorella nyei, Gardodinium trabeculosum*) i przedstawicieli gatunku *Pterodinium*, typowego dla wód oceanicznych. Najprawdopodobniej w zupełnie odmiennych warunkach powstały utwory reprezentowane przez próbki od Z-17a do Z-15b. Zespół dinocyst z tych próbek jest wyraźnie zdominowany przez formy płytkowodne (m.in. rodzaj *Cribroperidinium, Apteodinium* i *Circulodinium*), co wskazuje na znaczne spłycenie środowiska depozycji w stosunku do osadów z próbki Z-17b. Próbka Z-16a, w której licznie występują dinocysty znane z przybrzeżnych wysłodzonych zbiorników (*Odontochitina* i *Muderongia*) reprezentuje osady deponowane w warunkach litoralnych.

Odmienny charakter mają zespoły dinocyst z próbek Z-15a, a zwłaszcza Z-14b i Z-14a. Są one bardziej zróżnicowane (cecha charakterystyczna dla środowiska pełnomorskiego). W próbce Z-17b występuje *Chlamydophorella nyei*, dinocysta szelfu zewnętrznego. Próbki Z-14b i Z-14a są zdominowane przez rodzaj *Spiniferites*; stosunkowo licznie wystepuje *Pterodinium cingulatum*, forma oceaniczna. Świadczy to o pogłębieniu się zbiornika w albie.

Olistolit z wiercenia Zawoja IG-1 odpowiada pod względem wieku łupkom spaskim lub łupkom wierzowskim i młodszej części warstw Igockich.