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MIDDLE MIOCENE DINOFLAGELLATE CYSTS FROM THE KORYTNICA CLAYS (GÓRY ŚWIĘTOKRZYSKIE MOUNTAINS, POLAND)

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Abstract: The Miocene Korytnica clays yielded a well preserved and rich dinocyst assemblage consisting of 28 genera and 47 species. The dinocyst assemblage is of early to lower part of middle Badenian (Middle Miocene) age. It belongs to the *Unipontidinium aquaeductum* dinocyst biozone corresponding to calcareous nannoplankton zone NN5-6. Palaeoecological analysis of dinocyst assemblages from Korytnica suggests a warm-water shallow-marine environment with normal salinity during the deposition of the Korytnica clays. Presence of few dinocyst species presumed to be oceanic ones indicates the connection of Korytnica Bay with open sea. Lack of peridinioid dinocysts, considered to be heterotrophic, suggests relatively low nutrient availability and/or a lack of freshwater input into the Korytnica basin. One new dinocyst genus *Svenkodinium* gen. nov. and two species *S. minimum* sp. nov. and *S. versteeghii* sp. nov. are described.

Abstrakt: Analiza palinologiczna iłów korytnickich ujawniła obecność bogatego oraz dobrze zachowanego zespołu dinocyst składającego się z 28 rodzajów i 47 gatunków. Wiek zespołu dinocyst określono na wczesny oraz dolną część środkowego badenu: należy on do dinocystowej zony *Unipontidinium aquaeductum* odpowiadającej nannoplanktonowej zonie NN5-6. Dinocysty z Korytnicy wskazują na ciepłe, płytkomorskie środowisko o normalnym zasoleniu. Obecność kilku przedstawicieli dinocyst uważanych za formy oceaniczne wskazuje na połączenie między płytką zatoką korytnicką a otwartym morzem. Brak dinocyst z grupy peridinioid, uważanych za heterotroficzne, sugeruje niski poziom nutrientów w wodzie i/lub brak dostawy wody slodkiej do zbiornika. Opisano jeden nowy rodzaj dinocyst *Svenkodinium* gen. nov. oraz dwa gatunki *S. minimum* sp. nov. i *S. versteeghii* sp. nov.

Key words: dinoflagellate cysts, biostratigraphy, palaeoecology, Middle Miocene, Carpathian Foredeep Basin

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INTRODUCTION

The paper is a contribution to palaeontological research on the Miocene deposits of the Carpathian Foredeep Basin. The Middle Miocene near-shore deposits in the Korytnica Bay were the subject of many paleontological studies (e. g., Bałuk & Radwański, 1977; Hoffman, 1977). Dinoflagellate cysts have become an important tool in palaeoecological studies in the latest years. Especially useful are the Miocene and younger dinocysts, most of which are still living today. Their habitats are thus well known (e. g., Harland, 1983; Morzadec-Kerfourn, 1988; Edwards & Andrle, 1992).

GEOLOGICAL SETTING

The Miocene Paratethys basin was limited by the Carpathians in the south and by the Góry Świętokrzyskie Mts in the north. The northern margin of the Parathetys extended over southern slopes of the Góry Świętokrzyskie Mts along the valleys developed along Laramian strikes (Kutek & Głazek, 1972). A series of elongated and parallel bays, including the Korytnica Bay, were formed (Radwański, 1969).

The Middle Miocene Korytnica clays occur over a very small area (ca 5 km^2) corresponding to the northernmost part of the Korytnica Bay (Bałuk & Radwański, 1977). The outcrops of the Korytnica clays are restricted to the vicinity of the Korytnica and Karsy villages (Fig. 1). The sedimentary sequence of the Korytnica Basin begins with local brown-coal deposits. They are overlain by yellow-brownish, structureless plastic clays, 40-60 m thick. The clays are covered by sandy marls and *Lithothamnium* limestones up to 10 m thick (Bałuk & Radwański, 1977).

Łuczkowska (1974), on the basis of the appearance of the Miliolidae, stated the Early Tortonian (Badenian) age of the Korytnica clays, considering them as older than the salt clays from Wieliczka. Further foraminiferal studies (Dudziak & Łuczkowska, 1991) allowed to classify the Koryt-

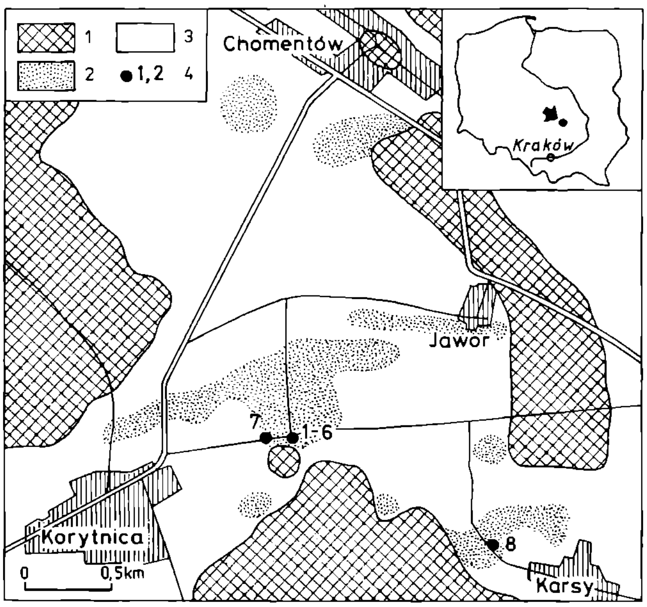

Fig. 1 Location of studied samples (adopted from Bałuk & Radwański, 1977); *1* – land or island areas during the Middle Miocene; *2* – marine areas during the Middle Miocene; *3* – present-day outcrops of the Korytnica clays; *4* – position of taken samples

nica clays within the Candorbulina suturalis Zone, Amphistegina lessonii Subzone of Łuczkowska (1967), attributed to the Moravian Substage.

Calcareous nannoplankton dating of the Korytnica clays (Martini, 1977; Dudziak & Łuczkowska, 1991) gave the NN5-6 and NN5 ages respectively. However, the calcareous nannoplankton assemblages in both cases were poorly preserved and not numerous. Martini (1977) correlated the studied calcareous nannoplankton assemblage with that of the upper part of the Langhian in Italy.

MATERIAL AND METHODS

Eight samples taken from the Korytnica clays in the vicinity of Korytnica have been studied (Fig. 1). The samples 1-6 were taken from an oyster shellbed exposed on the northern slopes of Mt Łysa; sample 7 was taken from the Korytnica clays (north-east slopes of Mt Łysa); sample 8 was taken from a clay outcrop at a hill near the Karsy village. All samples yielded well preserved and diversified palynological assemblages.

Sample preparation followed standard palynological procedure: 38% HCl and 40% HF treatment, heavy liquid ($ZnCl_2$+HCl; s. g. = 2.0 G/cm^3) separation and sieving (15μm nylon sieve). Glycerine jelly was used as a mounting medium for observation in normal light and ELVACITE was used for studies of fluorescence. All palynomorphs were counted from one slide; the second slide was investigated for additional taxa.

PALYNOLOGICAL ASSEMBLAGES

Sample 1 (oyster shellbed, just below the top of Mt Łysa) presumably represents the most shallow and near-shore deposit. Its palynological assemblage is dominated by bisaccate pollen grains which represent approximately 80% of the whole assemblage. Plant tissue remains, second in frequency, do not exceed 15-18%. Marine palynomorphs are represented by algae *Cymatiosphaera* sp. (2%) and the only dinocyst *Batiacasphaera* sp. (2%).

Sample 2 (approximately 2 m below sample 1), and sample 3 contain more numerous palynomorphs. Their palynomorph assemblage is different from that of sample 1: although bisaccate pollen grains still dominate (90%), there is a remarkable decrease in cellular plant debris and increase in marine palynomorphs. Dinocysts represent approx. 5-6%, *Cymatiosphaera* sp. 2%, and other marine algae (e. g., *Tasmanites*) 2-3%. The dinocysts are more diversified: the most numerous are *Spiniferites/Achomosphaera* spp. (mainly *S. ramosus s.l.*) and *Batiacasphaera* spp. A few specimens of *Polysphaeridium zoharyi*, *Lingulodinium machaerophorum*, *Hystrichosphaeropsis minimus*, *Operculodinium israelianum*, *Polysphaeridium*? sp. A and *Dapsilidinium pastielsii* have also been found.

Sample 4 differs from the previous ones by more numerous occurrence of *Cymatiosphaera* sp., among the marine palynomorphs. Dinocyst ratio is similar to that of sample 2. *Spiniferites/Achomosphaera* spp. and *Batiacasphaera* spp. dominate. *Melitasphaeridium choanophorum*, *Hystrichosphaeropsis obscura*, *Reticulatosphaera actinocoronata*, *Hystrichokolpoma rigaudiea*, *Svenkodinium* spp. and *Operculodinium centrocarpum* appear here for the first time. Samples 5 and 6 contain rare palynomorphs of the same type as those in sample 4.

Sample 7 (north-western slopes of Mt Łysa) and sample 8 (vicinity of the Karsy village) are the richest in palynomorphs. They contain all dinocyst species that occur in the Korytnica clays. Sample 8 contains more abundant bisaccate pollen grains than sample 7. This might be a result of land proximity (sample 8) and/or westerly winds (sample 7). The dinocyst assemblage from Karsy (sample 8), contains most numerous specimens of *Batiacasphaera* spp. These forms occur also in other samples studied, but never reach such abundance. The genera *Batiacasphaera* and *Spiniferites/Achomosphaera* dominate in all samples except of sample 1.

BIOSTRATIGRAPHY

No dinocyst zonation for the Miocene deposits of the Carpathian Foredeep Basin is yet available. Age determination of the Korytnica clays, based upon dinocysts, must therefore be made on comparison with dinocyst zonations from other parts of Europe and the North Atlantic (Fig. 2).

The presence of *Unipontidinium aquaeductum* in studied deposits makes it possible to correlate the dinocyst assemblage from the Korytnica clays with Unipontidinium aquaeductum zone of many authors, the base of which is

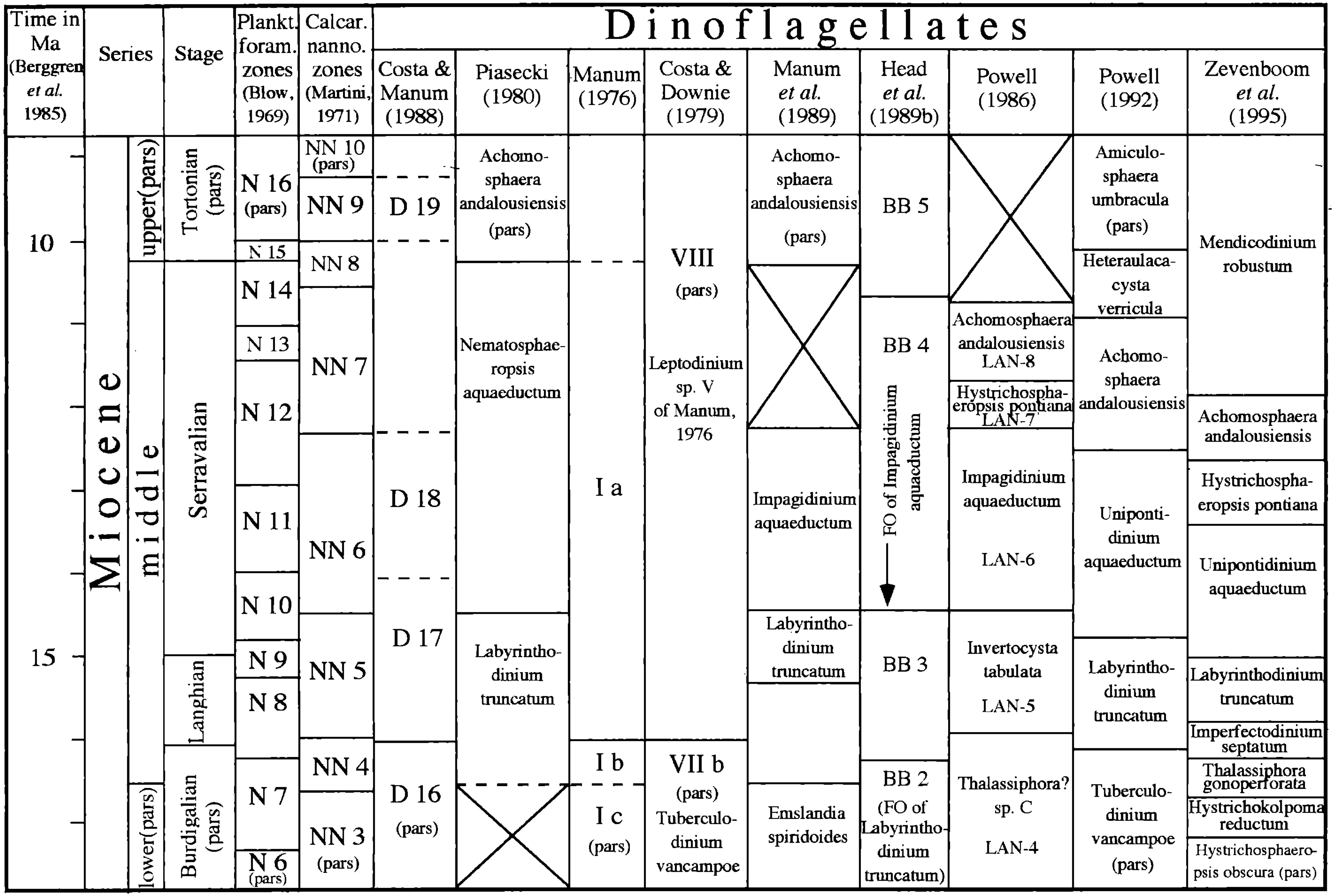

Fig. 2 Dinocyst zonations of Miocene for NW Europe and N Atlantic. Correlation of Miocene division and calcareous nannoplankton and planktonic foraminifera zonation schemes after Berggren *et al.* (1985)

defined by the first occurrence of *U. aquaeductum*, and the top by the first occurrence of *Achomosphaera andalousiensis*, which is not present in the Korytnica clays. This zone is usually dated at the Middle Miocene. The recent authors (e. g., Powell, 1992; Zevenboom *et al.*, 1995) calibrate the Unipontidinium auqaeductum zone against upper part of NN5 and lower part of NN6, which allow to determine the age of the Korytnica clays on early to lower part of middle Badenian. The stratigraphical range for *Unipontidinium aquaeductum* itself, as proposed by Head *et al.* (1989b), is early middle to middle late Miocene (calcareous nannoplankton zones NN5 - NN10 of Martini, 1971).

In the terms of interregional dinocyst zonation of the Miocene (Costa & Manum, 1988), the dinocyst assemblage from the Korytnica clays may be correlated with the D 17 zone, defined by the first appearance of *Hystrichosphaeropsis obscura s. s.* and *Unipontidinium aquaeductum* (as *Nematosphaeropsis aquaeductum*) at the base, and by the last appearance of *Apteodinium spiridoides* at the top. Zone D 17 is calibrated against calcareous nannoplankton zones NN5 - lower part of NN6 of Martini (1971). According to these authors, *Cribroperidinium tenuitabulatum* (as *Millioudodinium tenuitabulatum*) and *Heteraulacacysta campanula* (both present in the Korytnica Clays) appear for the last time at the base of the D 17 Zone.

Manum (1976) in the material from the Norwegian-Greenland Sea reported the first appearance of *Uniponitidinium aquaeductum* (as *Leptodinium* sp. V) from the base of the Subzone 1a (dated at Middle Miocene), which is correlated with zones Labirynthodinium truncatum and Unipontidinium aquaeductum (as *Impagidinium aquaeductum*) of Manum *et al.* (1989).

Piasecki (1980) proposed a Unipontidinium aquaeductum zone (as *Nematosphaeropsis aquaeductum*) in the material from the Danish Hodde Formation, defined in the same way as the U. aquaeductum zone of Manum *et al.* (1989). This zone is dated at the Middle Miocene. *Systematophora placacantha* and *Spiniferites pseudofurcatus*, both present in the Korytnica clays, have their highest occurrence at the top of this zone. In the material from the Norwegian Sea (Manum *et al.*, 1989), they range within the above Achomosphaera andalousiensis zone.

Costa & Downie (1979) recorded *Uniponitidium aquaeductum* (as *Leptodinium* sp. V of Manum, 1976) from the Middle Miocene Biozone VIII, defined by the first appearance of this species. This event was calibrated by Costa & Müller (1978) against the base of the calcareous nannoplankton zone NN5 (i. e. the base of Middle Miocene) of Martini (1971).

Edwards (1984) reported the lowest appearance of *Unipontidinium aquaeductum* from the Middle Miocene sediments of the Rockall Plateau (North Atlantic), and Brown & Downie (1985) did from deposits of the same age of the Bay of Biscay (the first appearance of *U. aquaeductum* is treated by the latter authors as coincident with the Early/Middle Miocene boundary). *Labirynthodinium truncatum*, present in the Korytnica clays, is restricted to the Middle Miocene strata (calcareous nannofosil zone NN7 - NN8 of Martini, 1971) of the Rockall Plateau (Edwards, 1984).

Powell (1986) proposed, in the material from the Piedmont Basin (North Italy), the Unipontidinium aquaeductum (as *Impagidimium aquaeductum*) zone (LAN-6) of the Serravallian (Middle Miocene) age. This zone is defined by the first appearance of several dinocysts (e. g., *Unipontidinium aquaeductum*) at the base, and by the first appearance of *Hystrichosphaeropsis pontiana* (which is not present in the Korytnica clays) at the base of the following LAN-7 zone. It is difficult to correlate the Korytnica dinocyst assemblage with that of these zones (the younger LAN-8 zone is clearly excluded by the appearance of *A. andalousiensis*). The LAN-6 zone is characterized by high abundance of *U. aquaeductum*; it does not occur consistently within the LAN-7 zone. *U. aquaeductum* is very rare in the Korytnica clays presumably due to ecological factors: this species seems to be an oceanic one. Lack of *H. pontiana* (despite the presence of other representatives of this genus) seems to indicate the LAN-6 zone as correlative with the position of the studied deposits. The LAN-6 zone is calibrated against planktonic foraminiferal biozones N 10 (pars) to N 11 of Blow (1969).

Head *et al.* (1989b) established, in the material from the Baffin Bay (North Atlantic), the BB4 Dinocyst Assemblage Zone defined by the first appearance of *Unipontidinium aquaeductum* (as *Impagidinium aquaeductum*)which is restricted to this zone. The top is defined just below the FA of *Leiosphaeridia* sp.

Powell (1992), in the dinocyst zonation for NW Europe, proposed the Unipontidinium aquaeductum Interval Biozone defined by the first appearance of *Unipontidinium aquaeductum* at the base, and by the first appearance of *Achomosphaera andalousiensis* at the top of the zone. *Cribroperidinium tenuitabulatum* and *Heteraulaucacysta campanula* (both present in the Korytnica clays) appear for the last time within this zone.

The Unipontidinium aquaeductum dinocyst zone established by Zevenboom *et al.* (1995) in NW Italy is correlated with an upper part of the calcareous nannoplankton zone NN5 (late Langhian-early Serravallian) and lower part of NN6. It is definited as the interval between the first occurrence of *Unipontidinium aquaeductum* and the first occurrence of *Hystrichosphaeropsis pontiana*, the species not recognized in the studied material.

PALAEOECOLOGY

The dinocyst assemblage from the Korytnica clays is composed of 29 genera and 48 species. It is dominated by *Spiniferites/Achomosphaera* spp. (mainly *S. ramosus*) and *Batiacasphaera* spp. (mainly *B. sphaerica*). *Operculodinium israelianum*, *Polysphaeridium zoharyi*, *Dapsilidinium pastielsii*, *Lingulodinium machaerophorum*, *Cribroperidinium tenuitabulatum*, *Apteodinium* spp., *Reticulatosphaera actinocoronata*, *Systematophora placacantha* and *Hystrichosphaeropsis* spp. appear subordinately. Other species appear as rare or single specimens (see species list). *Cymatiosphaera* sp. (Fig. 15L) dominates among the other marine palynomorphs.

Temperature. This relatively diverse dinocyst assemblage is rather typical for warm environments, contrary to cold-water assemblages, which are characterized usually by much lower diversity (three to four species) (e. g., Harland *et al*., 1980). The species that appear in the Korytnica clays are also presumed to be rather warm-water ones. There are no cold-water taxa in the studied material, such as *Spiniferites frigidus* or *Multispinula minuta* (Harland *et al*., 1980). *Operculodinium centrocarpum*, although presumed to have a wide thermal tolerance (Harland, 1983; Dale, 1983), was found by Wall *et al*., (1977) to become absent tropicwards, whereas *Operculodinium israelianum* is rather typical for warm (McMinn, 1990) and warm-temparate to tropical environments (Dale, 1983). The latter species is much more numerous in the Korytnica clays than *O. centrocarpum*.

Other species present in the Korytnica clays, that are presumed to appear in warm-temperate to tropical environments are, *Tuberculodinium vancampoe* (e. g., Wall *et al*., 1977; Dale, 1983; Harland, 1983), *Polysphaeridium zoharyi* (e. g., Dale, 1983; Harland, 1983) and *Lingulodinium machaerophorum* (e. g., Bakken & Dale, 1986). The latter species includes various morphotypes: the 5P archeopyle (this one is dominating among the *L. machaerophorum* specimens in the Korytnica clays) is typical for low lattitude regions of the Caribbean and the Persian Gulf (Wall *et al*., 1977; Bradford & Wall, 1984).

The dominating species *Spiniferites ramosus* is presumed to have a broad temperature ranges, whereas *Batiacasphaera* spp. together with *Cerebrocysta* (absent in the Korytnica clays) was treated by Head *et al*. (1989a) as a cold-water species. The abundance of *Batiacasphaera* in sample 8 might be an effect of a cooling event during the deposition of the Korytnica clays; however, the other dinocysts from this sample do not confirm this.

Inshore-offshore. *Spiniferites ramosus*, the most common species in the Korytnica clays seems to be a neritic one. Harland (1983) considered this species to be inner to outer neritic form. Its frequent appearance in open marine environments is probably due to current transportation. Wall *et al*. (1977) considered *S. ramosus* to be estuarine species. The majority of other dinocysts from the Korytnica clays are rather typical for neritic environment; *Polysphaeridium zoharyi* (e. g., Wall & Dale, 1969; Dale, 1976; Wall *et al*., 1977; Harland, 1983) and *Tuberculodinium vancampoe* (e. g., Wall *et al*., 1977; Matsuoka, 1981; Harland, 1983; Bradford & Wall, 1984). *Operculodinium israelianum* is presumed to be an estuarian species according to Wall *et al*. (1977), and inner to outer neritic species according to Harland (1983). Bradford & Wall (1984) considered *O. israelianum* to be a near-shore form, while *O. centrocarpum* is thought to be more open marine species (e. g., Reid & Harland, 1977), although its distribution may also be a result of redeposition from the shelf areas basinwards. Morzadec-Kerfourn (1977) considered *O. centrocarpum* to be neritic, although inhabiting deeper regions than other neritic species. Later (Morzadec-Kerfourn, 1983), she found this species to appear together with *O. israelianum* in the outer coastal zone at the depth of 30-50 m.

The presence of *Cymatiosphaera* sp. which represents the cyst stage or phycoma of green algae (Tappan, 1980) seems to confirm the shallow marine character of the Korytnica dinocyst assemblage. It is most numerous in the most near-shore samples taken from the slopes of Mt Łysa. Several authors (e. g. Takahashi, 1971; Wall *et al*., 1973; Al-Ameri, 1986) found this genus in shallow-marine environments, however Head *et al*. (1989a) reported *Cymatiosphaera*? *invaginata* from an oceanic setting of the Labrador Sea.

Another evidence suggesting shallow, near-shore character of the dinocyst assemblage from the Korytnica clays is the almost complete lack of dinocyst taxa considered to represent oceanic realms. Only single specimens of oceanic or outer neritic species such as *Nematosphaeropsis labirynthea*, *Impagidinium aculeatum* (e. g., Morzadec-Kerfourn, 1977; Wall *et al*., 1977; Harland, 1983), *Imperfectodinium septatum* or *Unipontidinium aquaeductum* were found in the Korytnica clays. Their presence confirms the existence of the connection between the shallow Korytnica Bay and the open sea as claimed by Radwański (1969) or Walkiewicz (1975).

Salinity. Many dinocyst species are good indicators of abnormal salinity conditions. For example, euryhaline *Lingulodinium machaerophorum*, if found in almost monospecific assemblages, indicates both low (e. g., Morzadec-Kerfourn, 1976; 1977) and high salinity environments (Williams, 1971). *Polysphaeridium zohari*, if found as a dominating species indicates high salinity conditions (e. g., Morzadec-Kerfourn, 1983). *Tuberculodinium vancampoe* is often associated with higher than normal salinity (e. g., Reid & Harland, 1977), but lower than that tolerated by *P. zoharyi* (Morzadec-Kerfourn, 1979). Neither *L. machaerophorum* nor *P. zoharyi* and *T. vancampoe* appear in the Korytnica clays as dominating species, being rather subordinate ones. Moreover, the length and shape of normally pointed processes of *L. machaerophorum* from the Korytnica clays indicate normal salinity conditions, as opposed to short (Turon, 1984) and club-shaped processes (Wall *et al*., 1973) found in low salinity environment.

All these data suggest normal salinity environment during the deposition of the Korytnica clays.

Nutrients. Peridinioid cysts are often associated with nutrient-rich waters, such as river mouths or upwelling areas (Wall *et al*., 1977). Biffi & Grignani (1983) described from Oligocene deposits of the Niger delta dinocyst assemblages rich in peridinioid taxa. Similar assemblages were reported by Duffield & Stein (1986) from Miocene deltaic environment of the offshore Louisiana. Bujak (1984) showed the correlation between the nutrient-rich environment and the abundance of the peridinioid dinocysts.

The dinocyst assemblage from the Korytnica clays is deprived of peridinioid dinocysts (except for single specimens of *Palaeocystodinium golzowense* and *P. striatogranulosum*). This may indicate low nutrient avaibility and/or a lack of freshwater influx during the deposition of the Korytnica clays. The latter conclusion is supported by the lack of significant amounts of terrigenous palynodebris except for bisaccate pollen grains, which may be air-borne. Similar peridinioid-poor dinocyst assemblage from Mio-

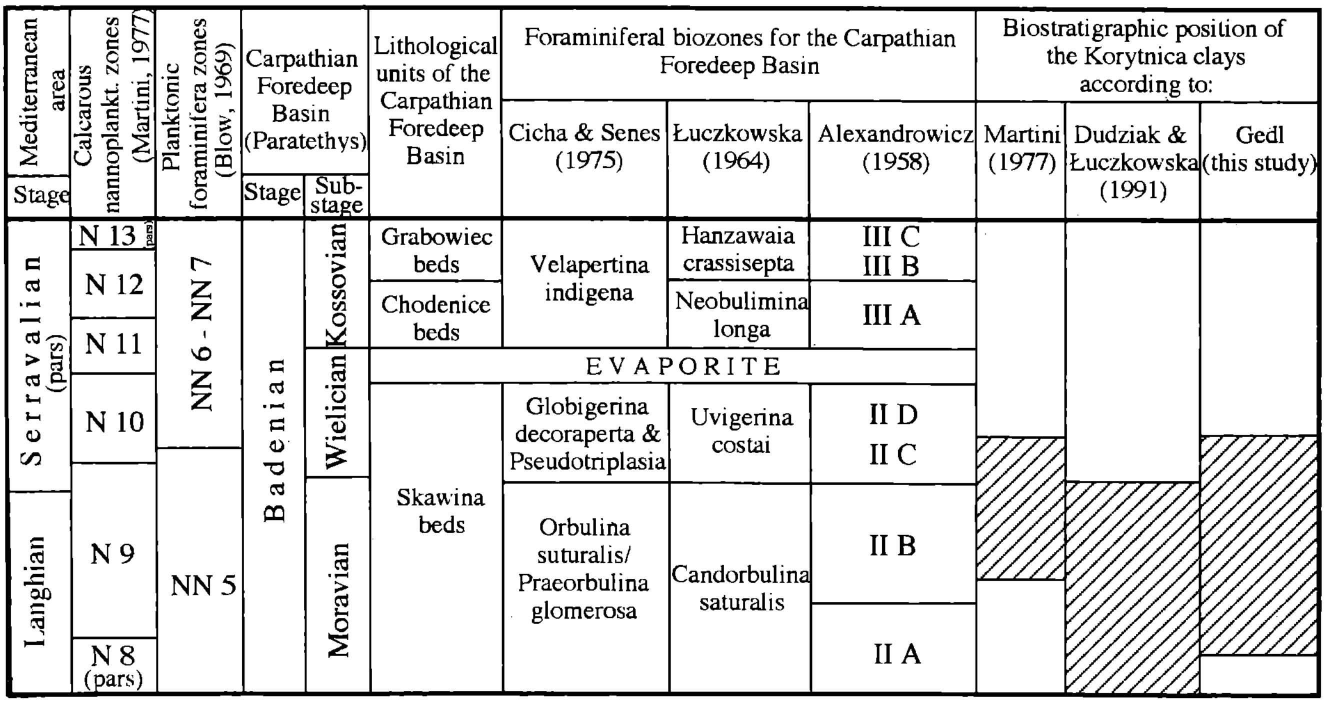

Fig. 3 Foraminiferal division of Middle Miocene deposits of the Carpathian Foredeep Basin and results of micropaleontological research of the Korytnica clays. Correlation of Miocene division in Mediterranean and Paratethys areas after Van der Zwaan *et al.* (1986). Correlation of foraminiferal biozones after Łuczkowska (1978)

cene coastal deposits was described by Piasecki (1980) and Matsuoka (1974).

CONCLUSIONS

1. The dinocysts from the Korytnica clays belong to the Unipontidinium aquaeductum zone of many authors (e.g., Piasecki, 1980; Manum *et al.*, 1989) correlated with calcareous nannoplankton zones NN5-6 (Fig. 2) which agrees well with previous micropaleontological data (Fig. 3).

2. The above results allow to consider the Korytnica clays as isochronous with the Skawina Formation and to treat them as its shallow-marine facies.

3. The dinocyst assemblage from the Korytnica clays seems to be typical for shallow-marine, near-shore environment with normal salinity and rather warm water. The character of the dinocyst assemblage seems to be similar to that of recent sub-tropical or warm-temperate ones.

4. The palynofacies and the lack of peridinioid cysts in the Korytnica clays indicate low nutrient availability and/or a lack of freshwater influx.

5. Despite of the near-shore character of the dinocyst assemblage, the presence of few specimens of oceanic species (*Impagidinium* sp., *U. aquaeductum* or *I. septatum*) indicates connection of the Korytnica Bay with the open-marine basin.

SYSTEMATIC PART

Systematic division after Fensome *et al.* (1993). Taxonomic citations can be found in Lentin & Williams (1993).

Division DINOFLAGELLATA (Bütschli 1885) Fensome *et al.* 1993
Subdivision DINOKARYOTA Fensome *et al.* 1993
Class DINOPHYCEAE Pascher 1914
Subclass PERIDINIPHYCIDAE Fensome *et al.* 1993
Order GONYAULACALES Taylor 1980
Suborder GONYAULACINEAE (Autonym)
Family GONYAULACACEAE Lindemann 1928
Subfamily LEPTODINIOIDEAE Fensome *et al.* 1993

Genus *Systematophora* Klement 1960
Type species *Systematophora areolata* Klement 1960
Systematophora ancyrea Cookson & Eisenack 1965
(Figs 7a, b, i)

Occurrence. Common in samples 7 and 8, rare in the others.
Description. Subspherical cyst with groups of solid processes arising from low and incompletely developed circular ridges. Autophragm between processes finely pitted. Processes relatively long, thin, distally simply branched.

Systematophora placacantha (Deflandre & Cookson 1955) Davey, Downie, Sarjeant & Williams 1969
(Figs 7k, m)

Occurrence. Three damaged specimens were found.
Description. Cyst subspherical with coarsely granulated periphragm. Short and rather slender solid processes arise from circular ridges, which are more complete than in *S. ancyrea*.
Remarks. This species has been assigned to *Systematophora placacantha* because of shorter processes and more completely developed proximal ridges of group processes. These forms are also smaller than specimens of *S. ancyrea*. Bujak & Matsuoka (1986) differentiated these two species by longer and thinner processes and less complete process complexes by *S. ancyrea*, although they observed also intermediate specimens. These two species are often treated conspecifically in the literature (Head *et al*., 1989b).

Subfamily CRIBROPERIDINIOIDEAE Fensome *et al.* 1993

Genus *Apteodinium* Eisenack 1958
Type species *Apteodinium granulatum* Eisenack 1958
Apteodinium conjunctum Eisenack & Cookson 1960
(Figs 4j-l)

Occurrence. Common in samples 7 and 8.
Description. Cyst with subspherical to rhomboidal outline, with well developed apical horn. Cyst wall relatively thick, its outer layer is densely pitted. Paratabulation expressed usually as paracingular ridges and 1P archeopyle; parasulcal tabulation may be recognized in few cases only.

Apteodinium spiridoides (Benedek 1972) Benedek & Sarjeant 1981
(Figs 10K, L)

Occurrence. Present in samples 7 and 8.
Description. Specimens assigned to this genus are characterized by ovoidal outline with more reduced apical horn than that of *A. conjunctum*, and by a thick wall. Outer wall layer is uniformly covered with small circular cavities. SEM analysis reveals very faint parasutural ridges on several specimens, as well as linear distribution of these cavities supporting the parasutural ridges.

Genus *Cribroperidinium* (Neale & Sarjeant 1962) Davey 1969
Type species *Cribroperidinium sepimentum* Neale & Sarjeant 1962
Cribroperidinium tenuitabulatum (Gerlach 1961) Helenes 1984
(Figs 4d-i, 10I, J)

Occurrence. Common in samples 7 and 8; absent in other ones.
Description. Characteristic accessory ridges appear on paraplates. Intratabular areas are finely pitted. Archeopyle precingular (3''). Operculum detached; separate opercular paraplates may be often observed.
Remarks. SEM analysis reveals very faint circular cavities at the surfaces of *C. tenuitabulatum* – the same as typical for *Apteodinium spiridoides*. Several specimens of *A. spiridoides* from Korytnica, as well as from the Norwegian Sea (Head's observation *in* Head & Wrenn, 1992, p. 3), show very faint or incomplete parasutural and accessory ridges. This may indicate close affinity of these two species.

Genus *Hystrichokolpoma* (Klumpp 1953) Williams & Downie 1966
Type species *Hystrichokolpoma cinctum* Klumpp 1953

Hystrichokolpoma rigaudiea Deflandrea & Cookson 1955
(Figs 5a-c, f)

Occurrence. Rare; two complete specimens and three opercular pieces were found.
Description. Large tubular processes are seccate, expanding distally. Antapical process longer than the others, closed distally. Free apical operculum may be sometimes observed.

Hystrichokolpoma truncata Biffi & Manum 1988
(Figs 5i, l)

Occurrence. Only one specimen was found.
Description. Intratabular processes are relatively short and box-like, opened distally with entire, smooth margin. Antapical process longer than the others, distally pointed. Two conical processes present.

Genus *Lingulodinium* Wall 1967 emended Wall & Dale 1973
Type species *Lingulodinium machaerophorum* (Deflandre & Cookson 1955) Wall 1967
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
(Figs 6d, g, i, l, 12A-C)

Occurrence. Appears in almost all samples, common.
Description. The specimens of *L. machaerophorum* from Korytnica belong to two general types: the first one, more common, is characterized by usually (not always) 5P archeopyle and relatively short, numerous processes; the second one by 2P archeopyle and long processes. The shape of processes of both types is similar, typical for the genus: blade-like, distally closed processes arise from broad bases, proximally narrowed and further off broader. Some specimens possess small spines at the ends of processes. The "long process" type of *L. machaerophorum* is usually larger, the central body diameter is 60 μm, the length of processes 20-30 μm. The second type has 6-10 μm long processes and the diameter of its central body is up to 40 μm.

Genus *Operculodinium* Wall 1967
Type species *Operculodinium centrocarpum* (Deflandre & Cookson 1955) Wall 1967
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
(Fig. 6a)

Occurrence. Rare, much less numerous than *O. israelianum*.
Description. Spherical cysts covered with uniform, long, solid, regularly distributed nontabular processes. Processes distally closed, terminating with small expandings or hooks. Periphragm relatively thin, usually smooth or very finely ornamented.

Operculodinium israelianum (Rossignol 1962) Wall 1967
(Figs 6b, c, 13A-F)

Occurrence. Present in the majority of the samples, the most numerous in samples 7 and 8.
Description. *O. israelianum* from Korytnica differs from *O. centrocarpum* by thicker reticulo-fibrous periphragm and fibrous processes, which are usually shorter and conical in shape. Distal terminations are of various shape, the most common are hook-like ones. The length of processes is always the same on a specimen, although it varies much among the specimens from Korytnica. Central body diameter 40-55 μm, length of processes ranging from

3-4 to 10 µm.

Subfamily GONYAULACOIDEAE (Autonym)

Genus *Achomosphaera* Evitt 1963
Type species *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963
Achomosphaera ramulifera (Deflandre 1937) Evitt 1963
(Fig. 15G)

Occurrence. One specimen was found.
Description. Specimen assigned to this species is characterized by spherical central body with periphragm coarsely granulated, with gonal processes only. They are hollow, distally open and trifurcated. The bases of the processes are generally not connected by septa or low ridges, although the processes in the apical part of the cyst seem to be connected by very faint linear structures. Central body diameter 40-45 µm, length of processes 10-20 µm.

Achomosphaera spp.
(Figs 15D-F, H-J)

Occurrence. One of the most common forms.
Description. All representatives of the genus *Achomosphaera* with relatively small dimensions, thin-walled, solid (predominating) or hollow, relatively long processes have been assigned to *Achomosphaera* spp. Central body diameter 30-40 µm, length of processes 15-20 µm.
Remarks. It is often very difficult to differentiate the specimens of *Achomosphaera* spp. from several representatives of *Spiniferites ramosus*. Both have small size and thin wall; their only difference consists in the presence or lack of parasutural ridges.

Genus *Hystrichosphaeropsis* (Deflandre 1935) Sarjeant 1966
Type species *Hystrichosphaeropsis ovum* Deflandre 1935
Hystrichosphaeropsis minimus Zevenboom & Santarelli 1995
(Figs 5m-p, 12I)

Occurrence. Appears in almost all samples; not numerous, although more common than *H. obscura*.
Description. Cavate cyst with pericoel developed in the hypocyst. Endocyst ellipsoidal in shape; endophragm strongly granulated, periphragm smooth. SEM observations revealed, however, that the periphragm in the cingular area is also granular. Paratabulation is expressed by parasutural ridges, well developed in the cingular area and less so on the hypocyst. Length of the pericyst 60 µm, width 42 µm.
Remarks. *Hystrichosphaeropsis minimus* differs from *H. obscura* by reduced apical part of the pericyst, which closely attaches to the endocyst.

Hystrichosphaeropsis obscura Habib 1972
Occurrence. The species appears in majority of the samples as single or rare specimens.
Description. Cyst bicavate; pericoels are developed both in epicyst and hypocyst. Width of pericyst constant. Apical horn well developed.

Genus *Impagidinium* Stover & Evitt 1978
Type species *Impagidinium dispertitum* (Cookson & Eisenack 1965) Stover & Evitt 1978

Impagidinium aculeatum (Wall 1967) Lentin & Williams 1981
Occurrence. One specimen was found.
Description. Cyst small and ellipsoidal. Parasutural septa typically thicker and higher at junction points (N. B. position of the cyst at the edge of the cover glass made it impossible to take picture).

Impagidinium paradoxum (Wall 1967) Stover & Evitt 1978
(Figs 9o, p)

Occurrence. Two specimens were found.
Description. A species of Impagidinium with parasutural septa of equal height.

Impagidinium velorum Bujak 1984
(Figs 8m, n)

Occurrence. Only one specimen was found.
Description. Cyst ellipsoidal, cyst wall very thin. Parasutural septa very high (almost half of the central body diameter), slender and finely folded.

Genus *Imperfectodinium* Zevenboom & Santarelli 1995
Type species *Imperfectodinium bulbosum* Zevenboom & Santarelli 1995
Imperfectodinium septatum Zevenboom & Santarelli 1995
(Figs 9a-d, h, l)

Occurrence. Rare species, appears in samples 7 and 8 only.
Description. Cyst small and ovoidal. Cyst wall relatively thick and smooth. Processes short, solid and cylindrical, proximally connected by incompletely developed low ridges. Archeopyle precingular, operculum free.

Genus *Nematosphaeropsis* (Deflandre & Cookson 1955) Williams & Downie 1966
Type species *Nematosphaeropsis balcombiana* Deflandre & Cookson 1955
Nematosphaeropsis labirynthea (Ostenfeld 1903) Reid 1974
(Figs 7l, n)

Occurrence. One specimen was found.
Description. Bases of processes connected by faint parasutural lines. Processes solid, gonal, distally trifurcate connected by a network of single trabeculae.

Genus *Spiniferites* Mantell 1850 emended Sarjeant 1970
Type species *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1850
Spiniferites belerius Reid 1974
Occurrence. Rare.
Description. Cyst subspherical. Paratabulation expressed as low periphragmal ridges forming at the junctions flexuous, relatively short processes. They are distally furcate.

Spiniferites bentori (Rossignol 1964) Wall & Dale 1970
(Fig. 14H)

Occurrence. Rare.
Description. Processes mainly gonal, relatively short, conical. They seem to be hollow in the basal part, becoming solid distally. Terminating branches solid and thin, usually bifid.

Spiniferites membranaceous (Rossignol 1964) Sarjeant 1970
(Figs 7d-f, 14J)

Occurrence. Rare.
Description. Cyst ovoidal. Periphragm smooth or micrograntulate. Paratabulation expressed as low ridges between the processes, which are hollow and closed distally. They are usually of two types, gonal with trifurcate distal terminations, and intergonal with bifurcate extremities. Processes delimiting the antapical plate are connected by high membranous ridge.

Spiniferites mirabilis (Rossignol 1964) Sarjeant 1970
(Figs 14K, L)

Occurrence. Rare.
Description. *S. mirabilis* differs from *S. membranaceous* by having predominating gonal processes which are solid rather than hollow, as it is the case with the latter. Antapical plate 1'''' is surrounded by high membranous ridge forming tubular antapical process.

Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
(Fig. 7o)

Occurrence. Rare.
Description. Cyst subspherical, large in comparison with other *Spiniferites* species. Cyst wall thick. Gonal processes long, hollow, tubiform, distally slightly expanded and trifurcate. Paratabulation expressed by periphragmal ridges of various height.

Spiniferites ramosus (Ehrenberg 1838) Mantell 1850
(Figs 7c, g, j, 14A-G, I)

Occurrence. One of the most common taxa, dominating in some samples.
Description. Cyst spherical to ovoidal, and of variable dimensions. Paratabulation clearly expressed by low membranous ridges getting higher at the bases of processes. Processes hollow, rigid or flexuous, of different height. Gonal processes predominate, intergonal processes are present on some specimens only. Gonal processes typically trifurcate, intergonal ones distally bifurcate; terminations of both types often show further branching. Periphragm smooth to finely granulated.
Remarks. *S. ramosus* from Korytnica shows a great variability; however, in this paper, it is treated as one species without further specifications.

Spiniferites sp. B of Piasecki 1980
(Figs 15A-C)

Occurrence. Common.
Description. Cyst with very thin wall, which is rather smooth and covered by numerous fine folds. Processes of different length (mainly short), tubiform and very wide. Their distal margins are smooth, denticulate or trifurcate, typically for the genus. Some processes are connected by high membranes. Archeopyle precingular.
Remarks. Piasecki (1980) stated a similarity between the processes of *Spiniferites pseudofurcatus* and the described species. *S. pseudofurcatus*, however, has rather thicker periphragm; its processes are still thinner and longer. The distal terminations of *S. pseudofurcatus* are always trifurcate, whereas the processes of *Spiniferites* sp. B of Piasecki (1980) are of various shapes.

Genus *Tectatodinium* Wall 1967
Type species *Tectatodinium pellitum* Wall 1967
Tectatodinium psilatum Wall & Dale 1973
(Figs 9m, n)

Occurrence. Rare.
Description. Ellipsoidal cyst with clearly visible thickening in the equatorial area. Cyst wall relatively thick, covered by very small granulae. Archeopyle precingular 1P.

Genus *Unipontidinium* Wrenn 1988
Type species *Unipontidinium aquaeductum* (Piasecki 1980) Wrenn 1988
Unipontidinium aquaeductum (Piasecki 1980) Wrenn 1988
(Figs 5d, e, g, h, j, k, 12D-G)

Occurrence. Rare, four specimens only were found.
Description. Cyst spherical. Short processes distally branched and connected, reflecting the paratabulation. Aqueduct-like branchings finely perforated. Cyst wall smooth or very finely granulated. Precingular archeopyle rarely observable. Central body diameter 35-40 μm; length of processes 5-8 μm, their thickness does not exceed 3 μm.

Subfamily UNCERTAIN

Genus *Habibacysta* Head, Norris & Mudie 1989
Type species *Habibacysta tectata* Head, Norris & Mudie 1989
Habibacysta tectata Head, Norris & Mudie 1989
(Figs 10A, B)

Occurrence. Rare.
Description. Spherical cyst with very thick wall. Endophragm smooth and thin (< 0.5 μm), periphragm composed of a very dense moose-like structure (its thickness reaches 3 μm). Archeopyle precingular (1P), operculum free. Cyst diameter 40μm.

Genus *Melitasphaeridium* Harland & Hill 1979
Type species *Melitasphaeridium choanophorum* (Deflandre & Cookson 1955) Harland & Hill 1979
Melitasphaeridium choanophorum (Deflandre & Cookson 1955) Harland & Hill 1979
(Figs 8c, f, 13K, L)

Occurrence. Appears in almost all samples, although it is not numerous.
Description. Cyst spherical, small. Cyst wall relatively thin, smooth. Processes tubiform, thin and hollow, distally expanded and terminated with seccate margin. Length of seccae varies even in one specimen, although relatively short ones predominate. Archeopyle precingular. A number of processes suggests their intratabular character.
Remarks. Some of the specimens assigned as *M. choanophorum* have processes terminating with relatively small platform and long seccae, typical for *M. asterium* (Fig. 13L). Some other specimens of *M. choanophorum* with broad distal platform and numerous, short spines, possess also processes with terminations typical for *M. asterium* (Fig. 13K). Thus, it seems questionable to distinguish between these two species.

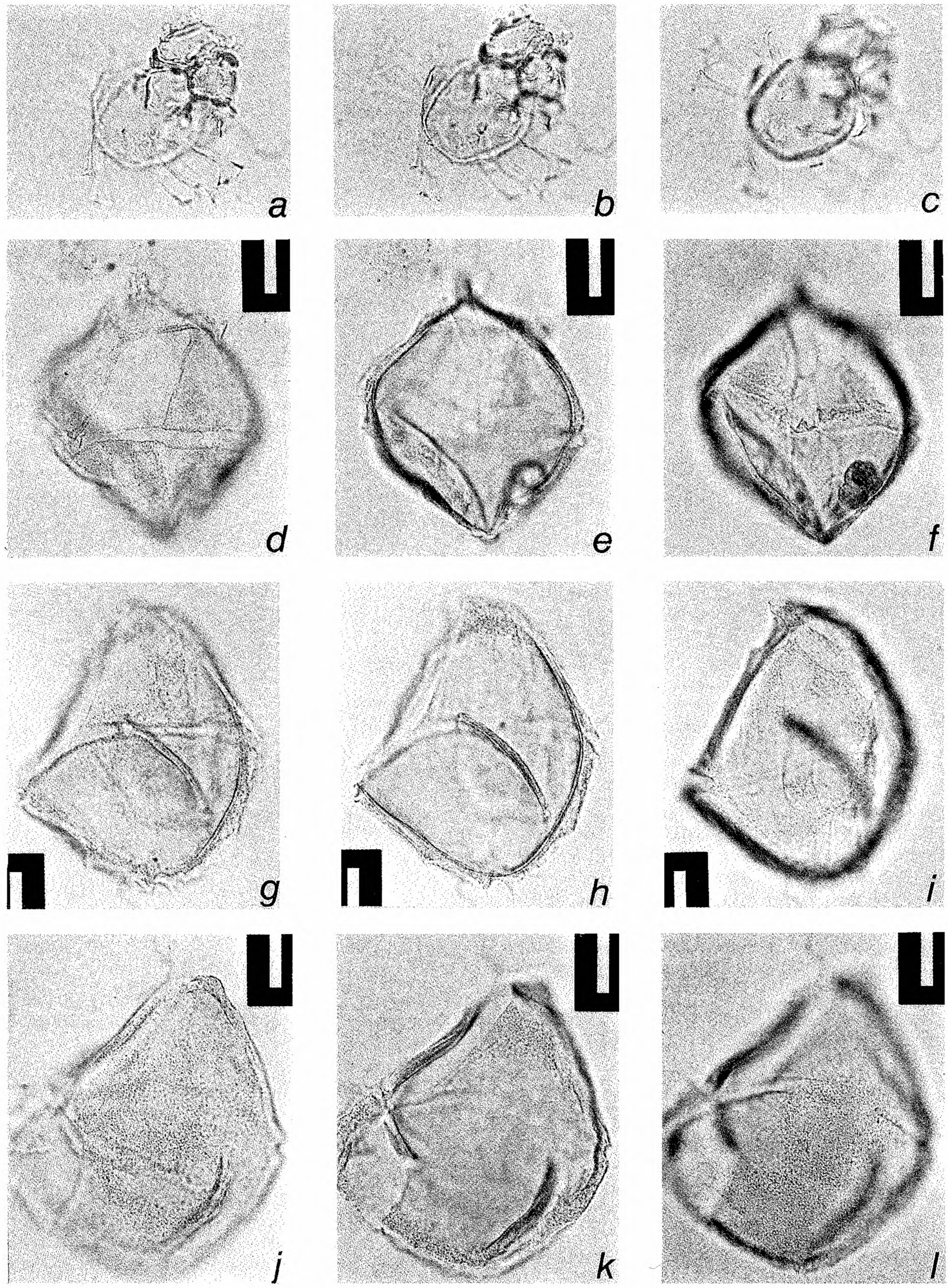

Fig. 4 All figures x 560. **(a-c)** *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams 1966, sample 7 [G 37]; **(d-i)** *Cribroperidinium tenuitabulatum* (Gerlach 1961) Helenes 1984, **d-f**: sample 8 [H 34.1], **g-i**: sample 8 [J 33.2]; **(j-l)** *Apteodinium conjunctum* Eisenack & Cookson 1960, sample 8 [P 35.3]

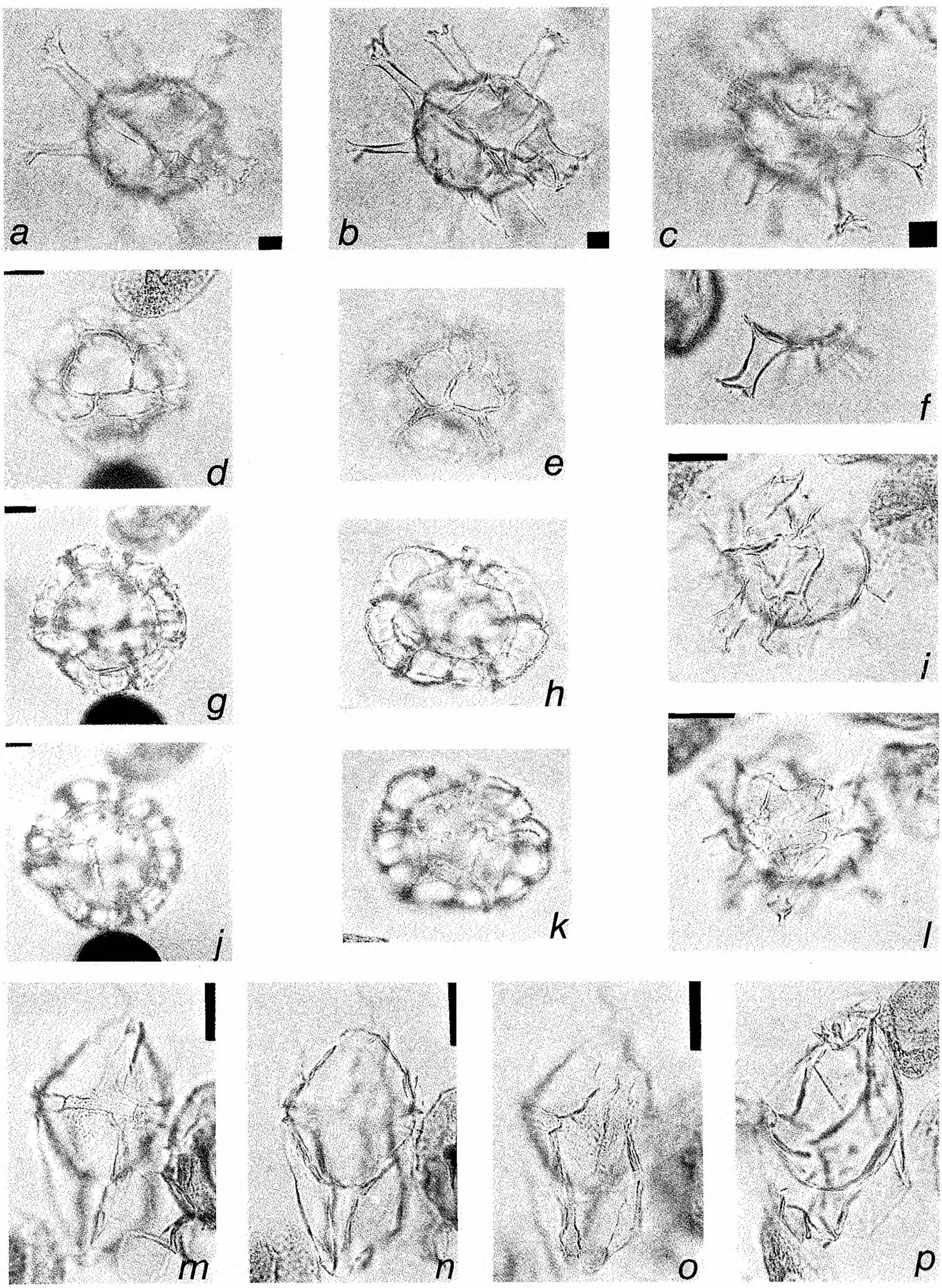

Fig. 5 All figures x 560. **(a-c, f)** *Hystrichokolpoma rigaudiea* Deflandrea & Cookson 1955, **a-c**: sample 8 [R 39.4], **f**: sample 8 [V 42]; **(d, e, g, h, j, k)** *Unipontidinium aquaeductum* (Piasecki 1980) Wrenn 1988, **d, g, j**: sample 8 [O 45], **e, h, k**: sample 8 [R 43.3]; **(i, l)** *Hystrichokolpoma truncata* Biffi & Manum 1988, sample 7 [Q 34.3]; **(m-p)** *Hystrichosphaeropsis minimus* Zevenboom & Santarelli 1995, **m-o**: sample 7 [T 31], **p**: sample 7 [L 48.3]

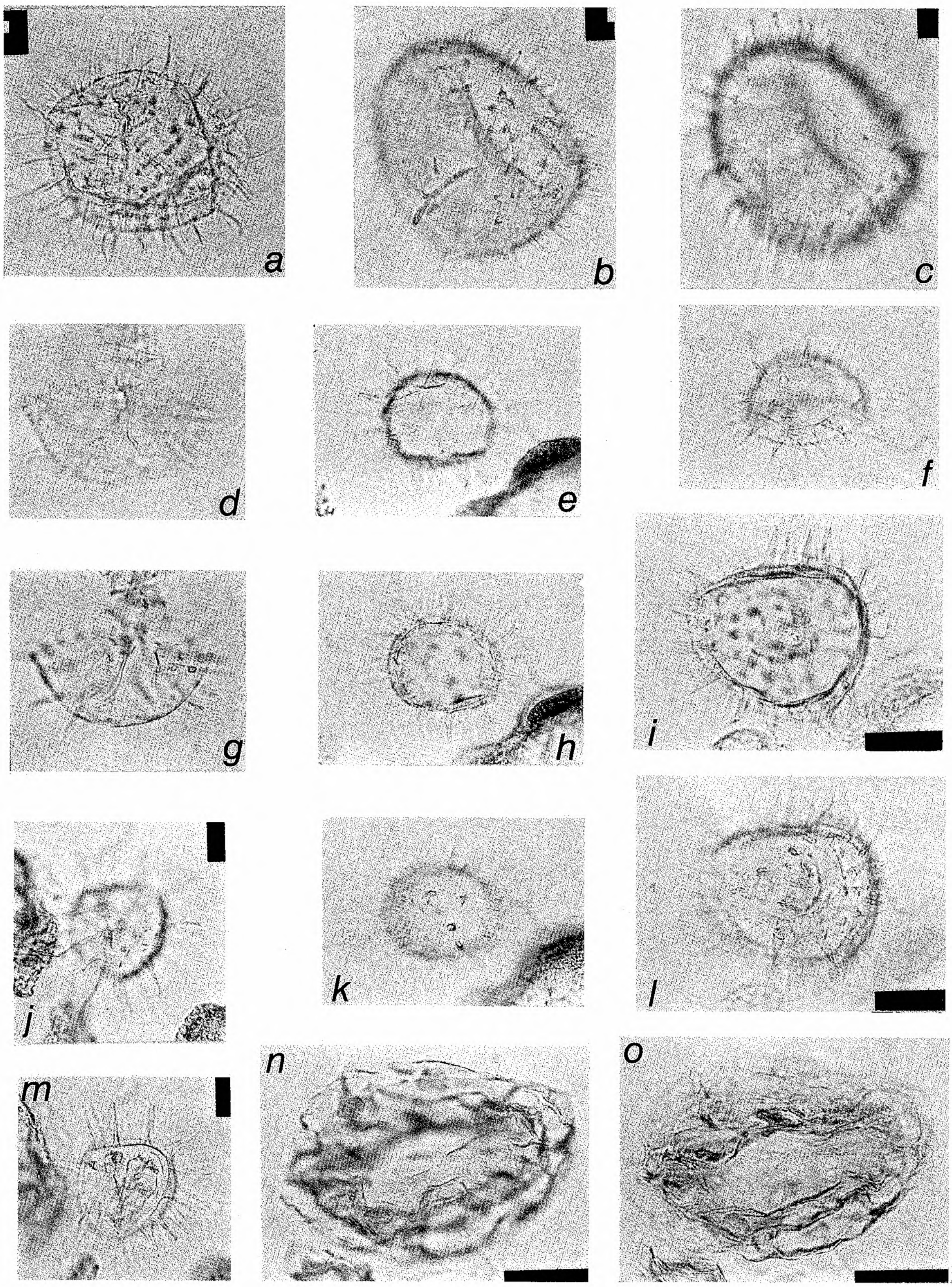

Fig. 6 All figures x 560. **(a)** *Operculodinium centrocarpum* (Deflandre & Cookson 1955) Wall 1967, sample 7 [D 38.4]; **(b, c)** *Operculodinium israelianum* (Rossignol 1962) Wall 1967; sample 8 [E 36]; **(d, g, i, l)** *Lingulodinium machaerophorum* (Deflandre & Cookson 1955) Wall 1967, **d, g**: sample 7 [E 32.2], **i, l**: sample 7 [M 31]; **(e, h, k)** *Polysphaeridium*? sp. A, sample 8 [C 45]; **(f, j, m)** *Dapsilidinium pastielsii* (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980, **f**: sample 8 [H 48.1], **j, m**: sample 8 [Q 40]; **(n, o)** *Tuberculodinium vancampoe* (Rossignol 1962) Wall 1967, sample 8 [R 33.2]

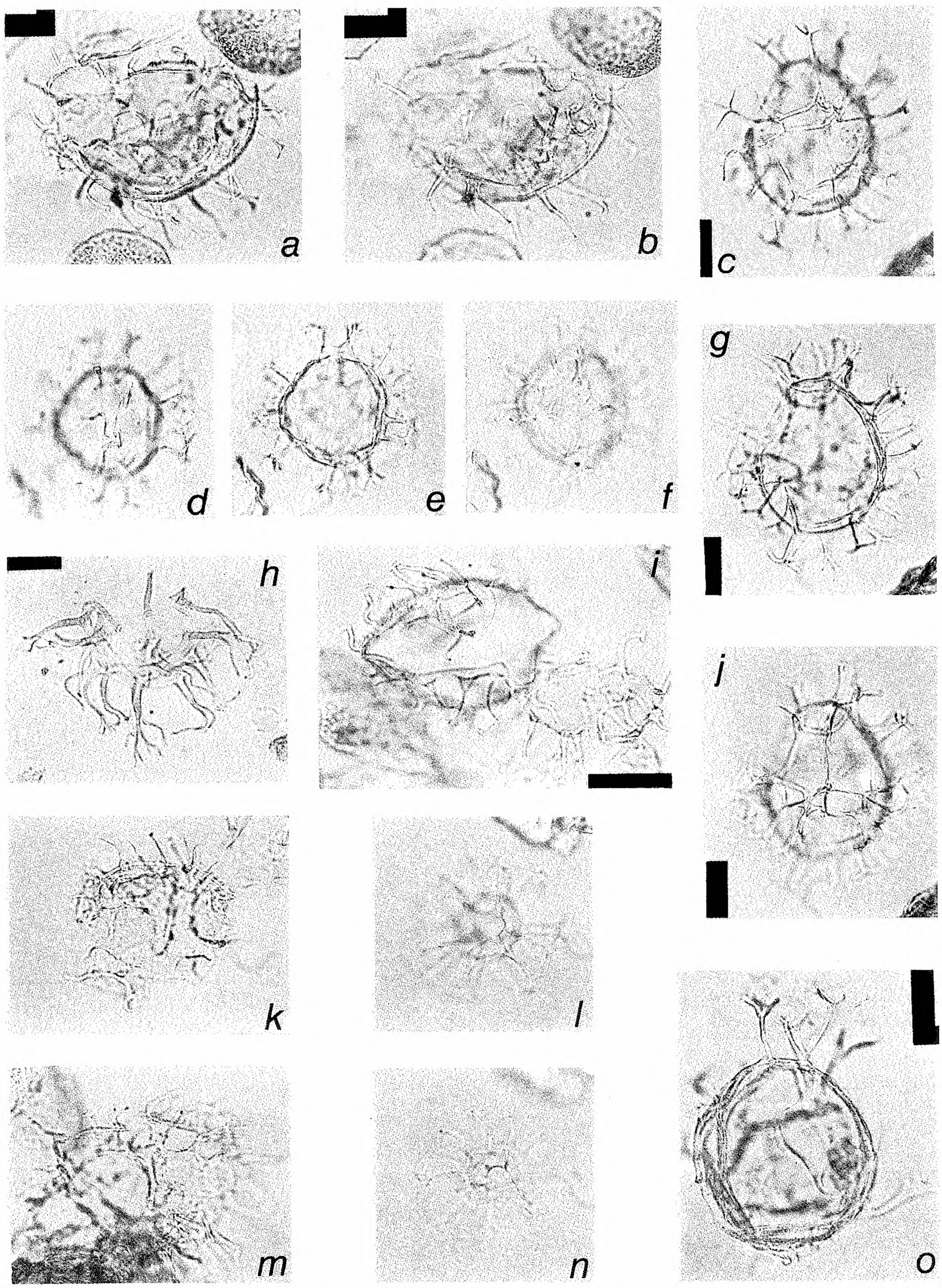

Fig. 7 All figures x 560. **(a, b, i)** *Systematophora ancyrea* Cookson & Eisenack 1965, **a, b**: sample 7 [N 38.3], **i**: sample 7 [R 47]; **(c, g, j)** *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1850, sample 7 [K 37.4]; **(d-f)** *Spiniferites membranaceous* (Rossignol 1964) Sarjeant 1970, sample 8 [R 37.3]; **(h)** *Surculosphaeridium* sp., sample 8 [L 37]; **(k, m)** *Systematophora placacantha* (Deflandre & Cookson 1955) Davey, Downie, Sarjeant & Williams 1969, sample 8 [S 46.2]; **(l, n)** *Nematosphaeropsis labirynthea* (Ostenfeld 1903) Reid 1974, sample 8 [K 41]; **(o)** *Spiniferites pseudofurcatus* (Klumpp 1953) Sarjeant 1970, sample 7 [L 47.3]

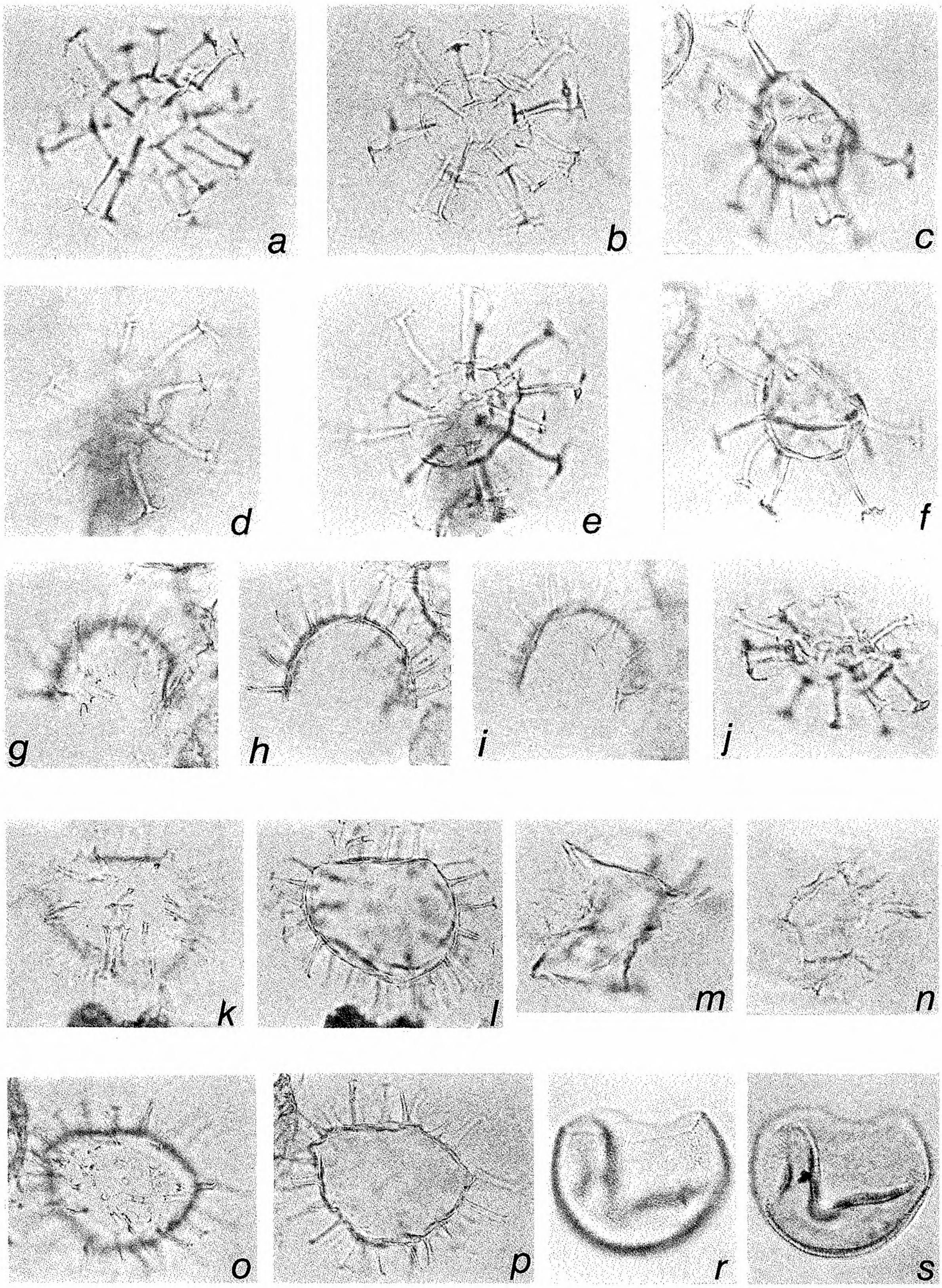

Fig. 8 Figures **(g-i, k, l, o, p)** x 560, figures **(a-f, j, m, n, r, s)** x 680. **(a, b, d, e, j)** *Reticulatosphaera actinocoronata* (Benedek 1972) Bujak & Matsuoka 1986, **a, b**: sample 7 [W 46], **d, e**: sample 8 [C 45], **j**: sample 8 [M 39.2]; **(c, f)** *Melitasphaeridium choanophorum* (Deflandre & Cookson 1955) Harland & Hill 1979, sample 7 [N 38.3]; **(g-i, k, l, o, p)** *Polysphaeridium zoharyi* (Rossignol 1962) Bujak, Downie, Eaton & Williams 1980, **g-i**: sample 8 [J 36], **k, l**: sample 8 [T 48.2], **o, p**: sample 8 [T 43]; **(m, n)** *Impagidinium velorum* Bujak 1984, sample 8 [D 38.1]; **(r, s)** *Batiacasphaera micropapillata* Stover 1977, sample 8 [G 42.1]

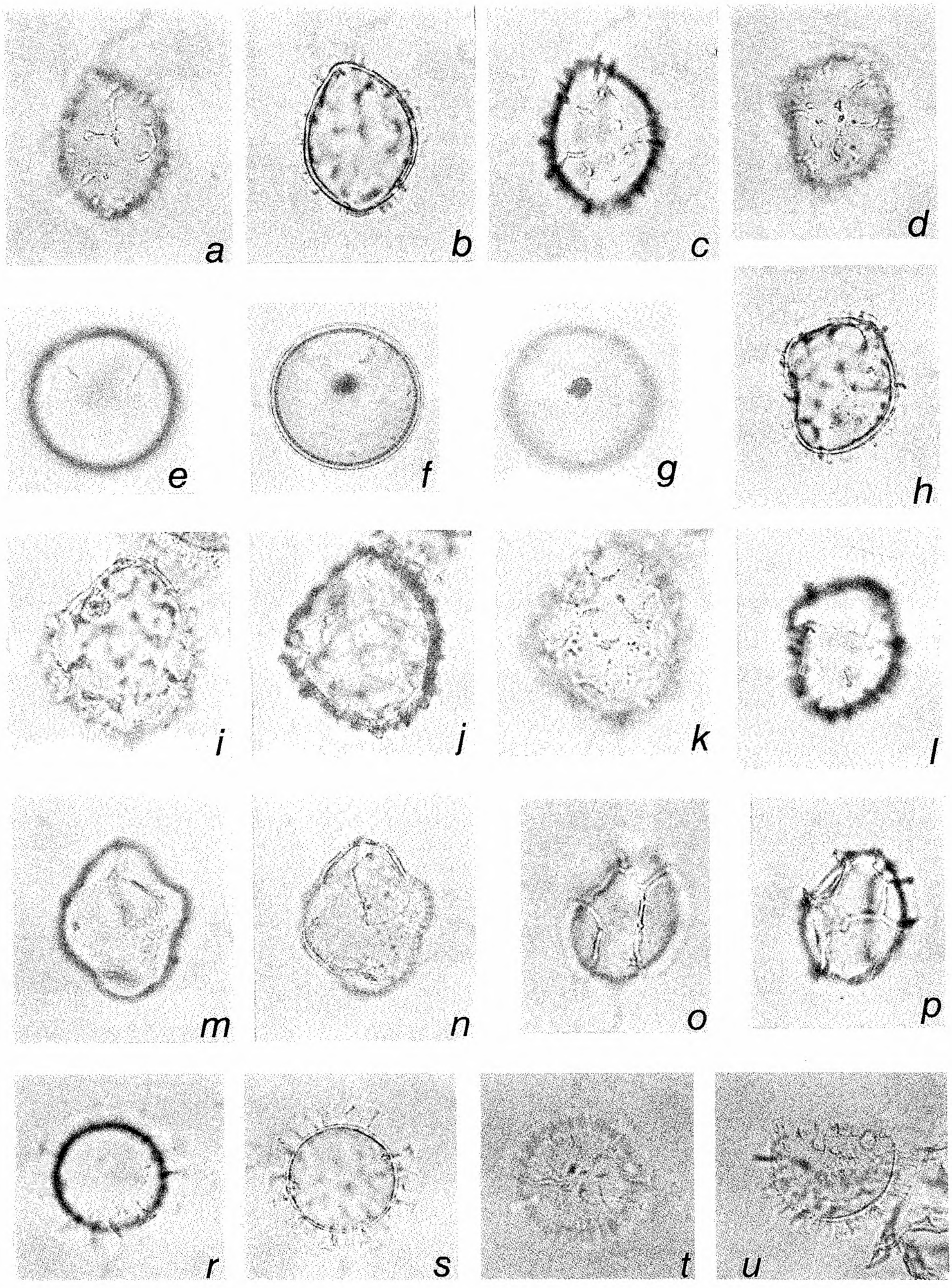

Fig. 9 All figures x 680. **(a-d, h, l)** *Imperfectodinium septatum* Zevenboom & Santarelli 1995, **a-c**: sample 8 [P 35.3], **d, h, l**: sample 8 [M 42]; **(e-g)** *Batiacasphaera sphaerica* Stover 1977, sample 8 [F 31.4]; **(i-k)** *Pyxidinopsis tuberculata* Versteegh & Zevenboom 1995, sample 8 [Q 49.4]; **(m, n)** *Tectatodinium psilatum* Wall & Dale 1973, sample 8 [P 46]; **(o, p)** *Impagidinium paradoxum* (Wall 1967) Stover & Evitt 1978, sample 8 [G 30.3]; **(r-u)** *Labyrinthodinium truncatum* Piasecki 1980, **r-t**: sample 8 [B 49.4], **u**: sample 7 [E 32.2]

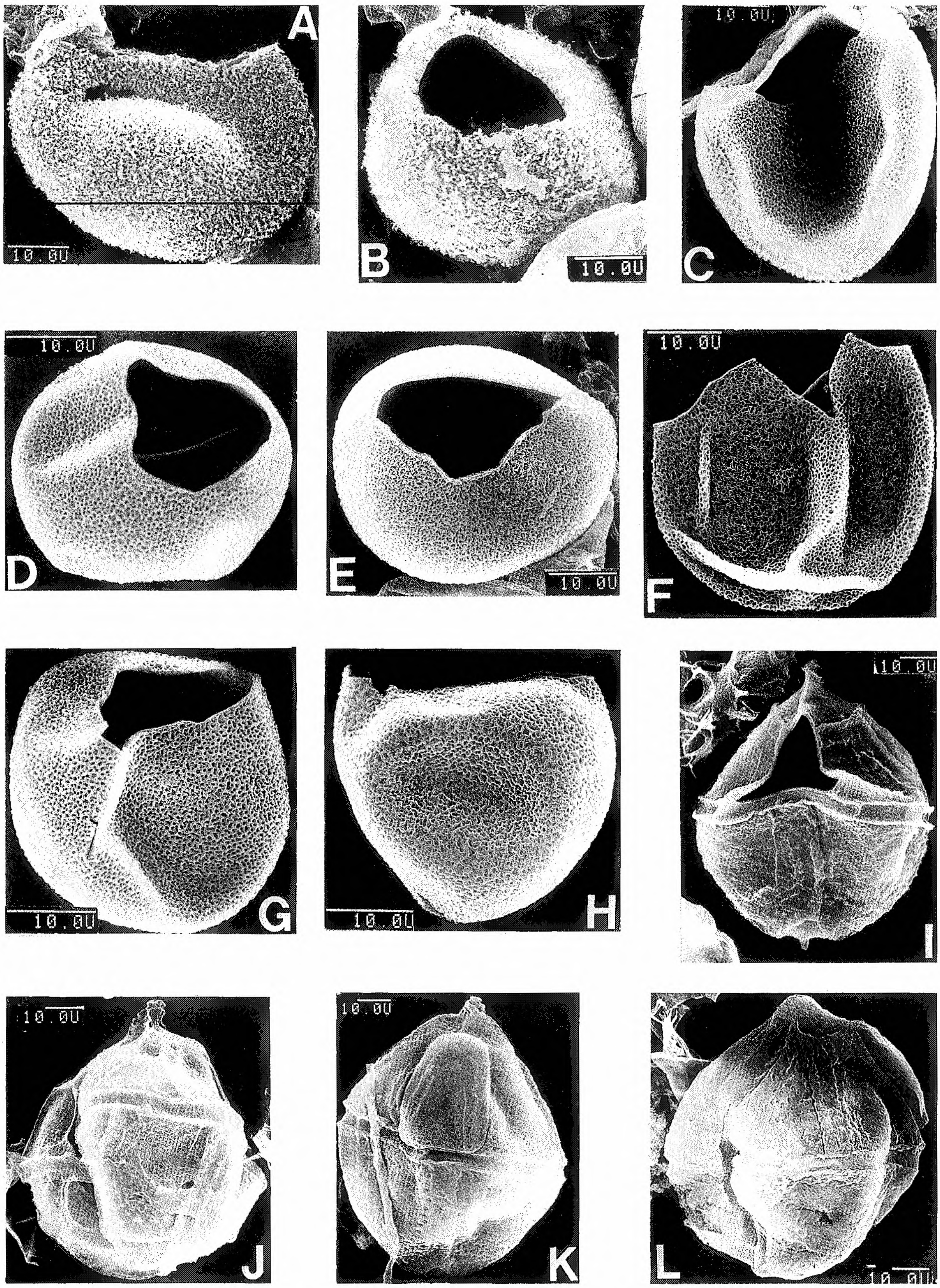

Fig. 10 Scale bar 10 µm. **(A, B)** *Habibacysta tectata* Head, Norris & Mudie 1989; **(C-E, G, H)** *Batiacasphaera sphaerica* Stover 1977; **(F)** *Batiacasphaera micropapillata* Stover 1977; **(I, J)** *Cribroperidinium tenuitabulatum* (Gerlach 1961) Helenes 1984; **(K, L)** *Apteodinium spiridoides* (Benedek 1972) Benedek & Sarjeant 1981

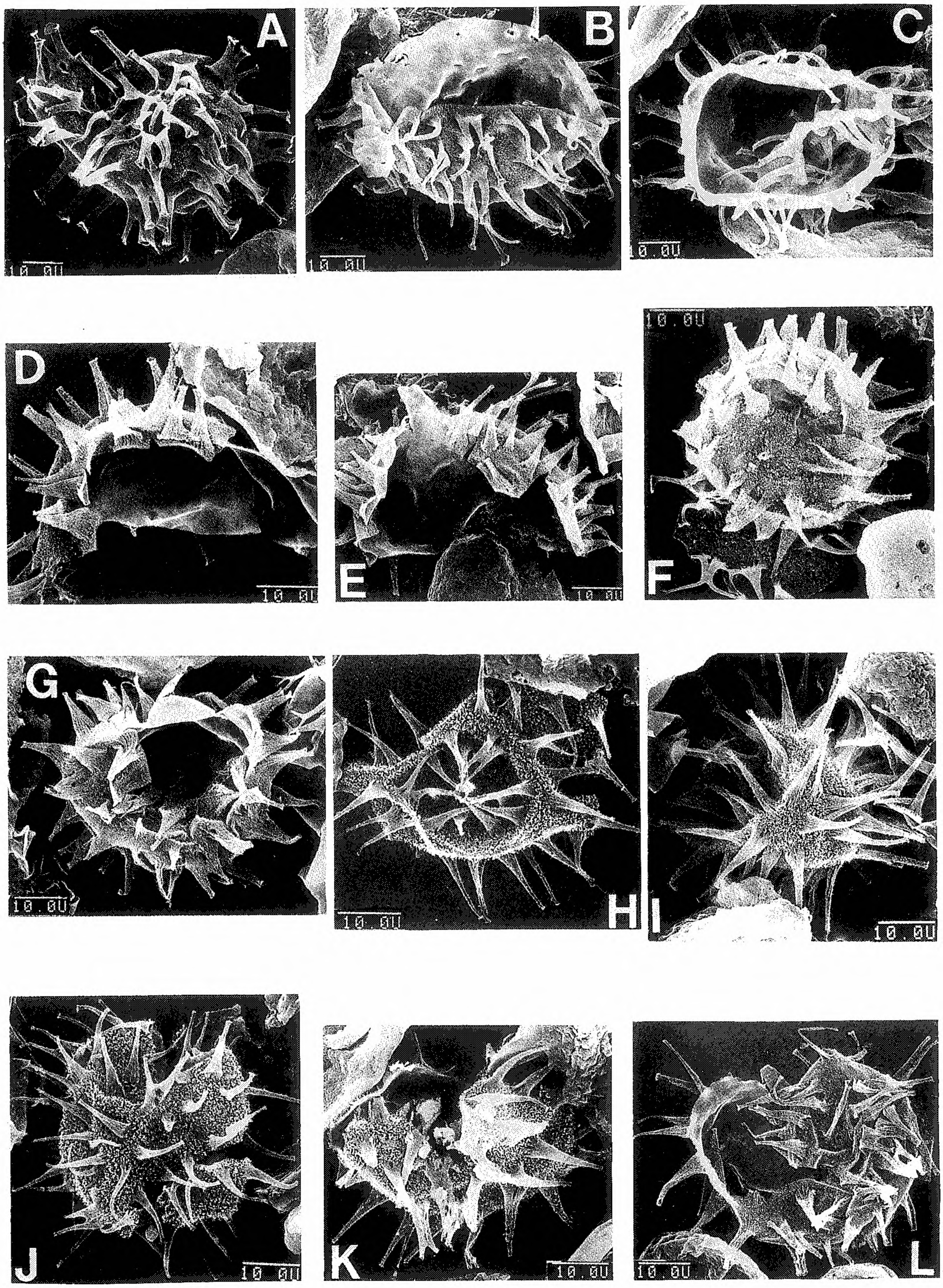

Fig. 11 Scale bar 10 μm. **(A-C)** *Polysphaeridium zoharyi* (Rossignol 1962) Bujak, Downie, Eaton & Williams 1980; **(D-G)** *Polysphaeridium*? sp. A; **(H-L)** *Dapsilidinium pastielsii* (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980

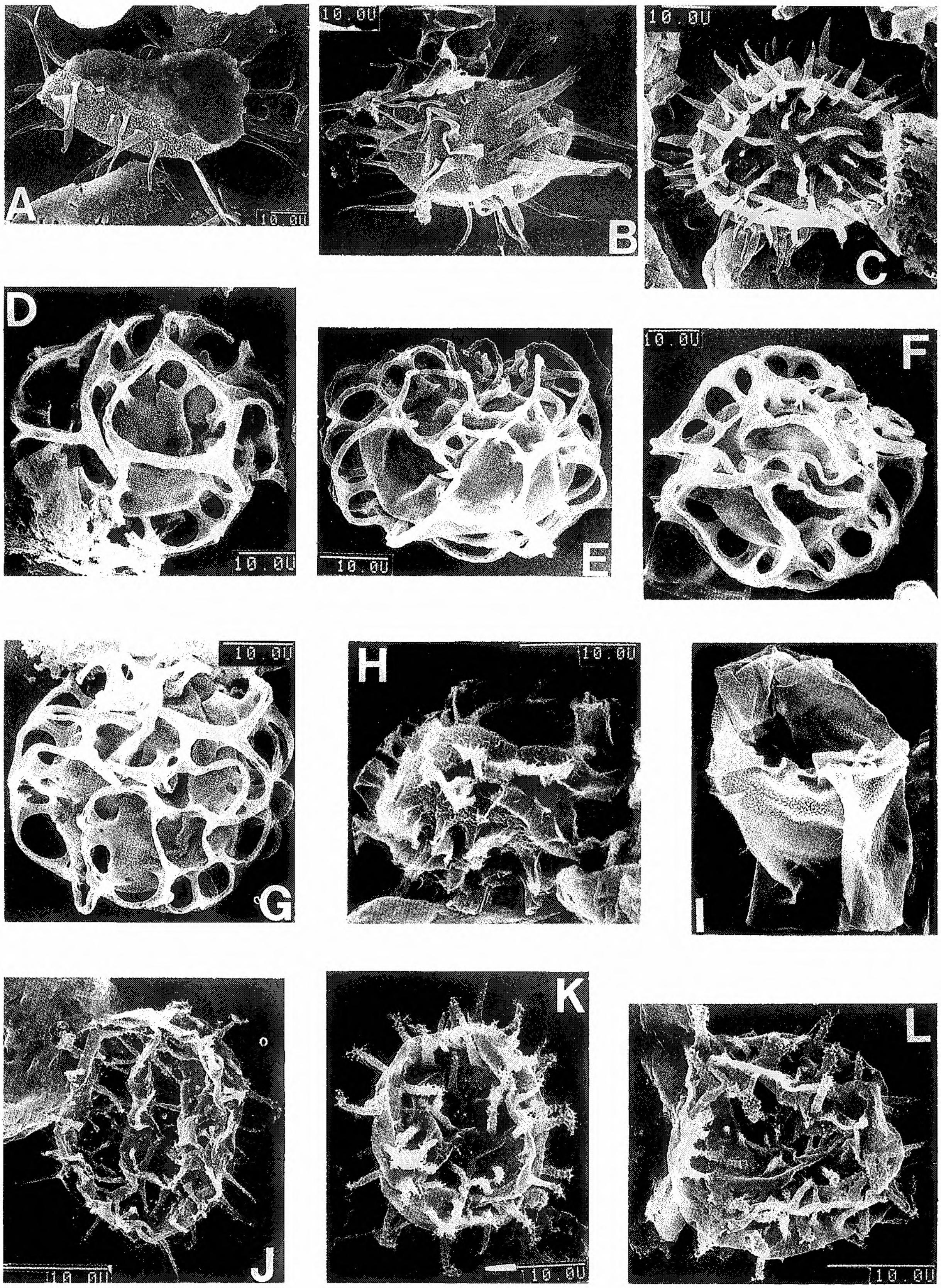

Fig. 12 Scale bar 10 μm. **(A-C)** *Lingulodinium machaerophorum* (Deflandre & Cookson 1955) Wall 1967; **(D-G)** *Unipontidinium aquaeductum* (Piasecki 1980) Wrenn 1988; **(H)** *Labyrinthodinium truncatum* Piasecki 1980; **(I)** *Hystrichosphaeropsis minimus* Zevenboom & Santarelli 1995; **(J)** *Svenkodinium minimum* Gedl gen. et sp. nov.; **(K, L)** *Svenkodinium versteeghii* gen. et sp. nov.

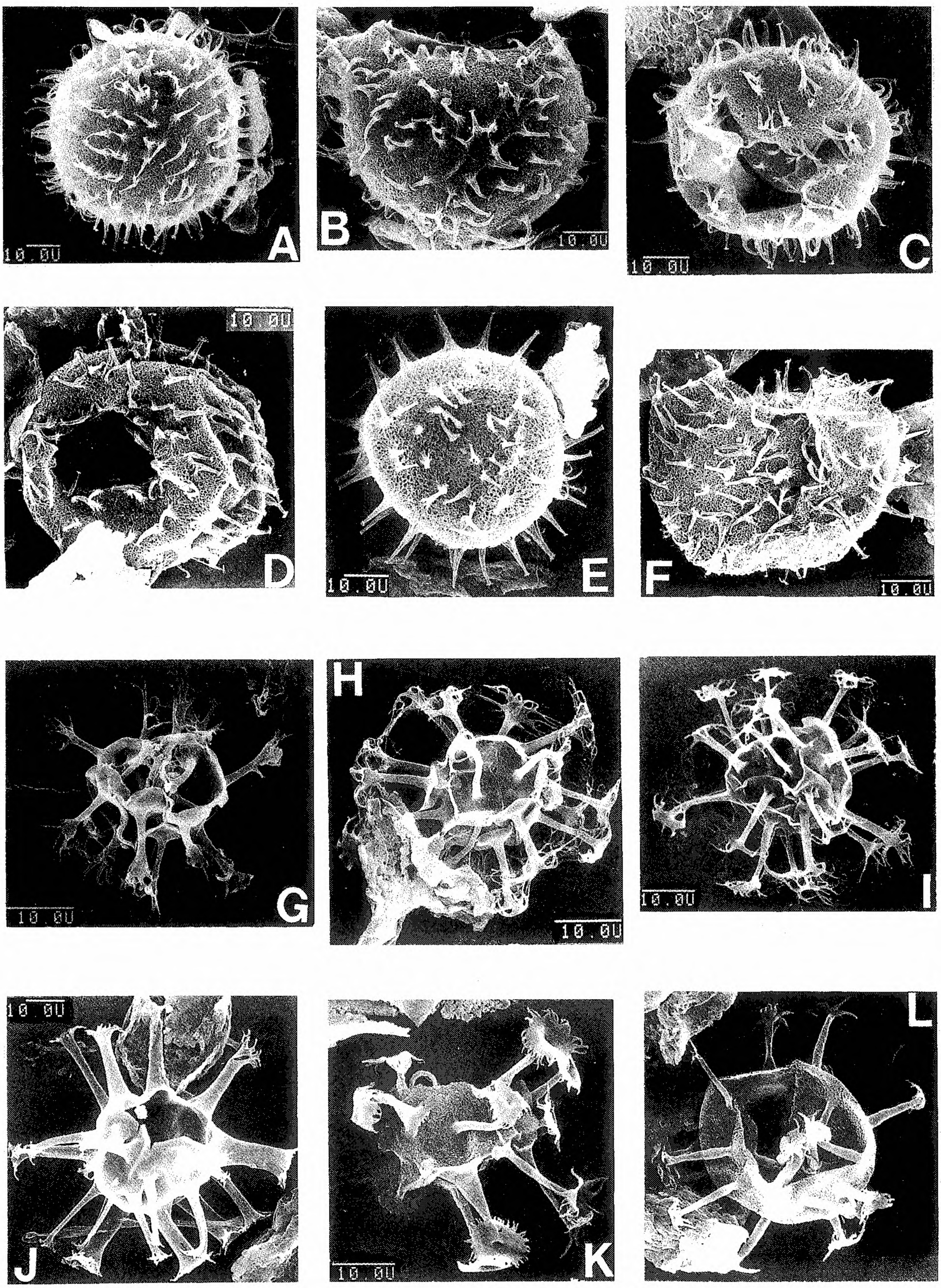

Fig. 13 Scale bar 10 μm. **(A-F)** *Operculodinium israelianum* (Rossignol 1962) Wall 1967; **(G-I)** *Reticulatosphaera actinocoronata* (Benedek 1972) Bujak & Matsuoka 1986; **(J)** *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams 1966; **(K, L)** *Melitasphaeridium choanophorum* (Deflandre & Cookson 1955) Harland & Hill 1979

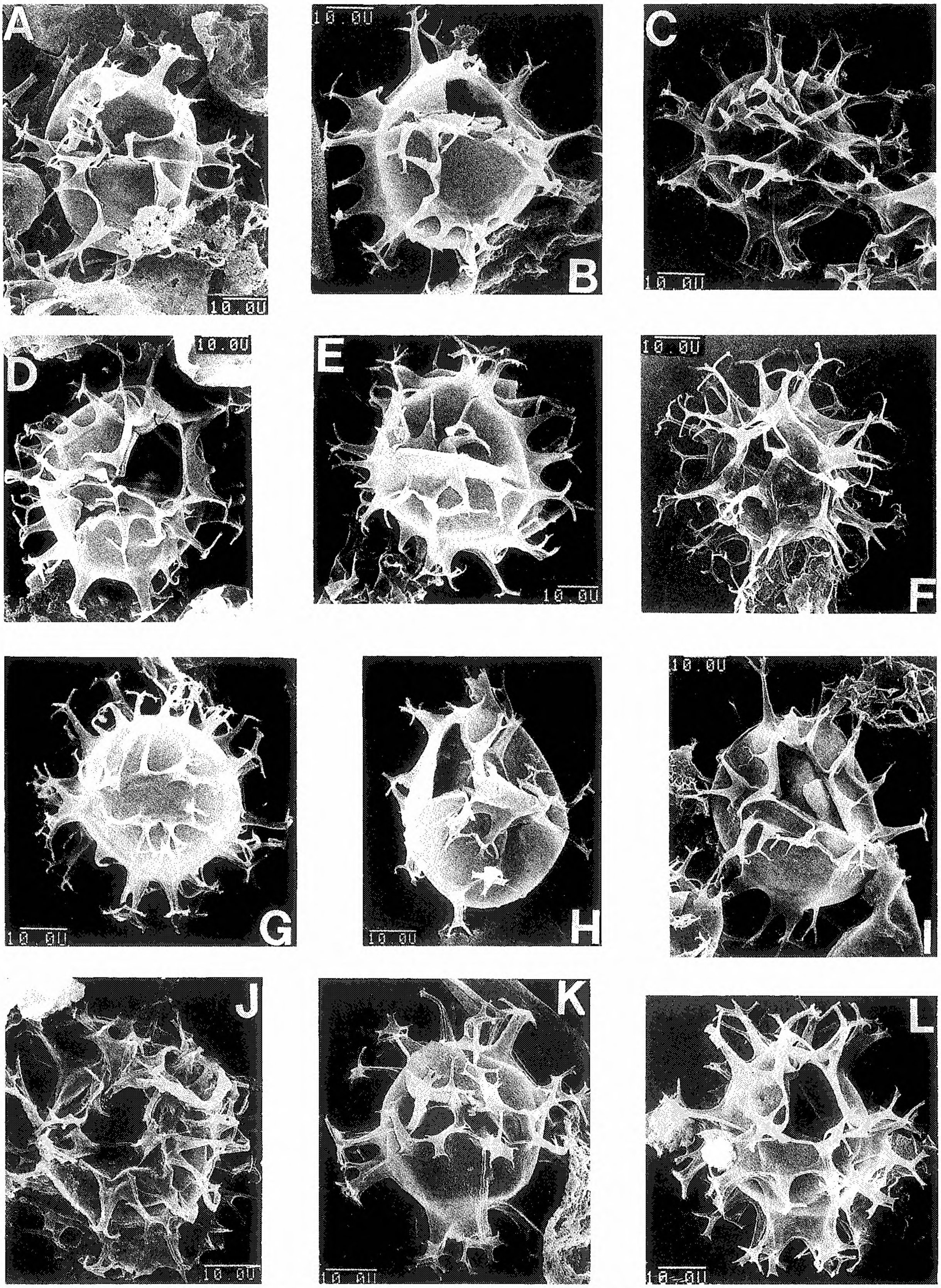

Fig. 14 Scale bar 10 μm. **(A-G, I)** *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1850; **(H)** *Spiniferites bentori* (Rossignol 1964) Wall & Dale 1970; **(J)** *Spiniferites membranaceous* (Rossignol 1964) Sarjeant 1970; **(K, L)** *Spiniferites mirabilis* (Rossignol 1964) Sarjeant 1970

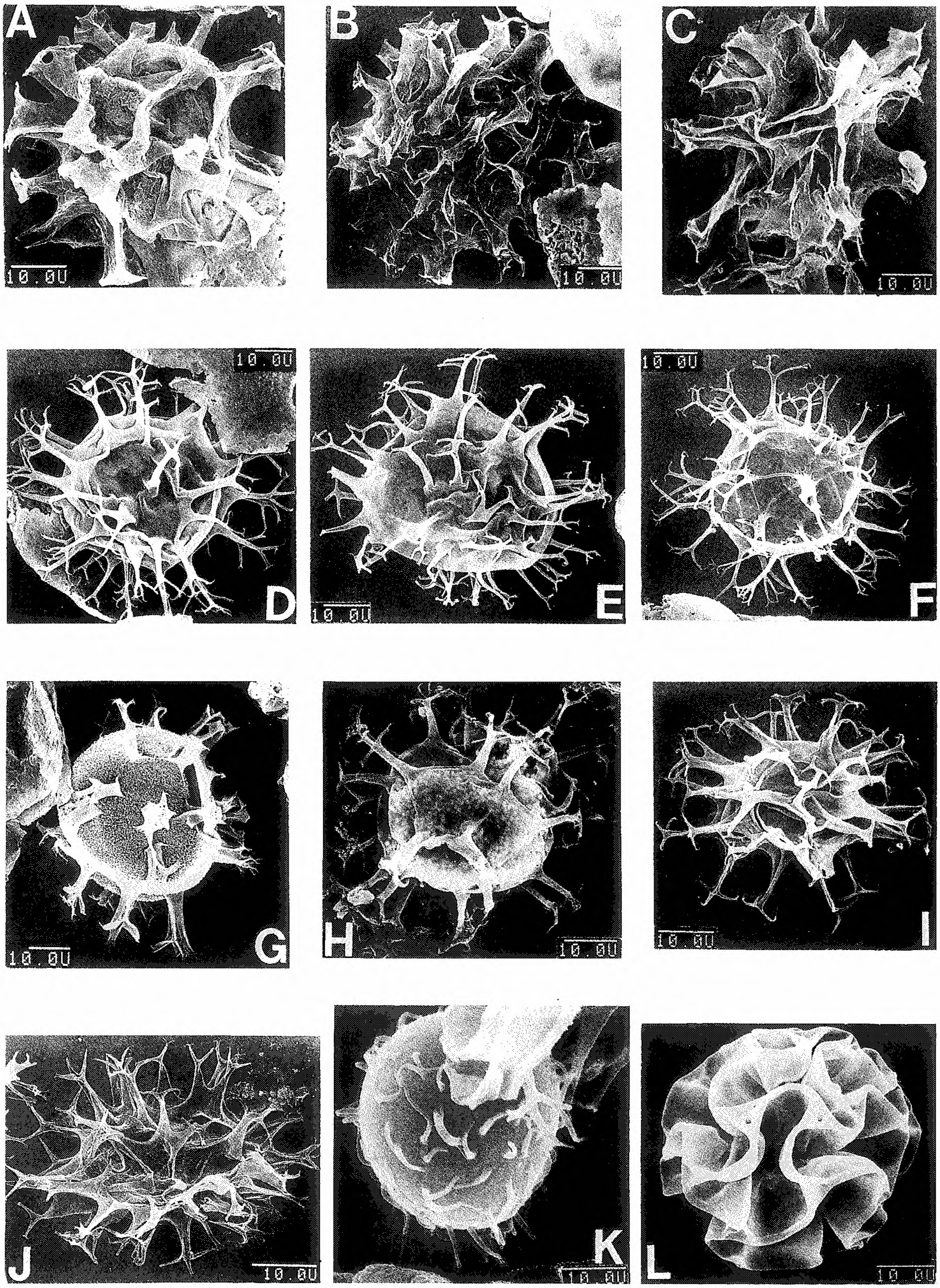

Fig. 15 **(A-C)** *Spiniferites* sp. B of Piasecki (1980); **(D-F, H-J)** *Achomosphaera* spp.; **(G)** *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963; **(K)** Acritarch; **(L)** *Cymatiosphaera* sp.

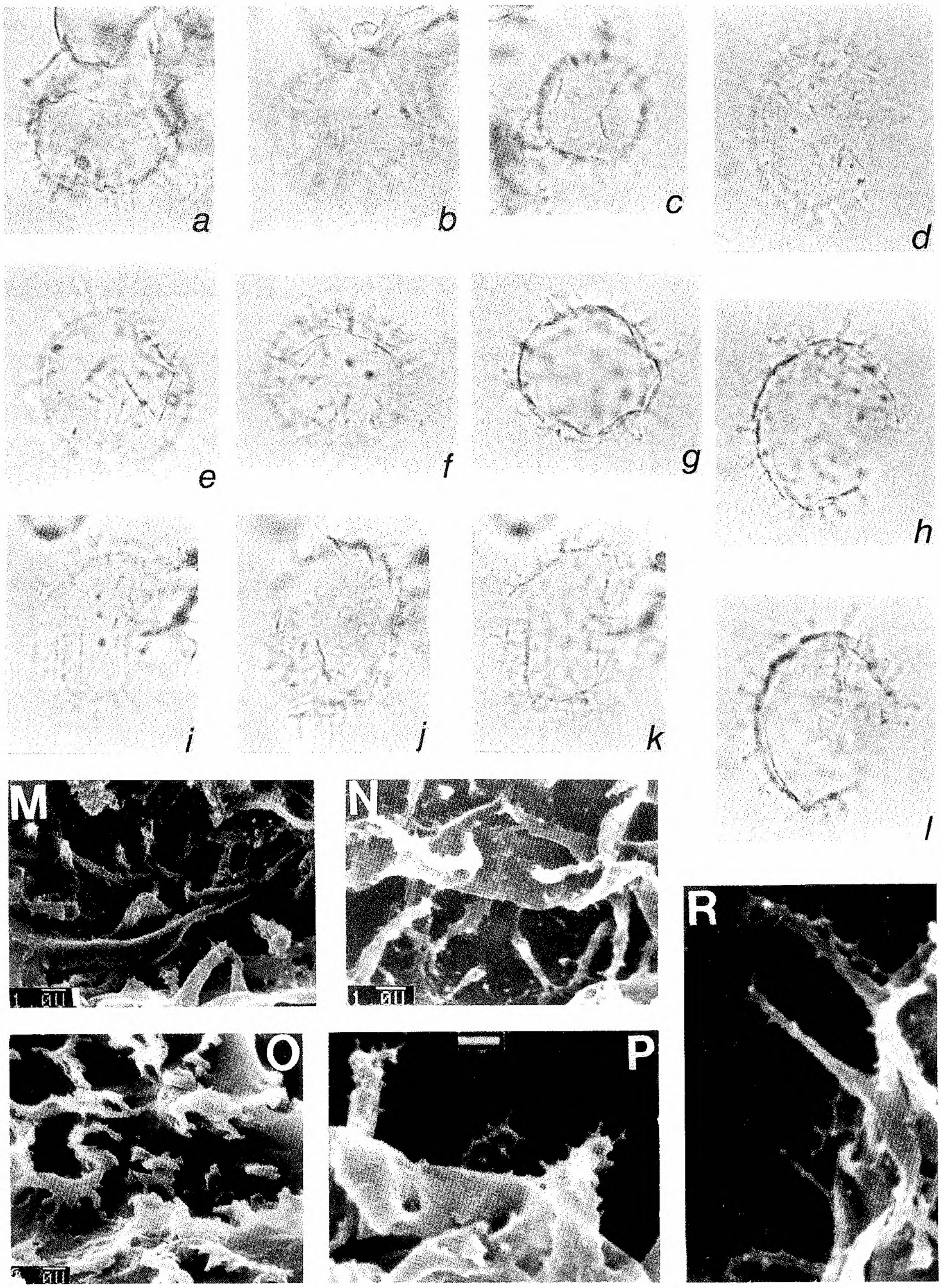

Fig. 16 Figures **(a-l)** x 1500. **(a, b, i-k, N, R)** *Svenkodinium minimum* gen. et sp. nov., **a, b**: paratype, sample 8 [S 44.1], **i-k**: holotype, sample 8 [U 33.1], **N**: surface relief (scale bar 1 µm), **R**: processes (scale bar 0.5 µm); **(c-h, l, M, P)** *Svenkodinium versteeghii* gen. et sp. nov., **c**: sample 8 [P 47], **d, h, l**: holotype, sample 8 [Q 43.1], **e**: sample 8 [H 45.4], **f, g**: sample 8 [O 36], **M**: surface relief (scale bar 1 µm), **P**: processes (scale bar 0.5 µm); **(O)** *Svenkodinium* sp. A., surface relief (scale bar 1 µm)

Genus *Pyxidinopsis* Habib 1975
Type species *Pyxidinopsis challengerensis* Habib 1975
Pyxidinopsis tuberculata Versteegh & Zevenboom 1995
(Figs 9i, k)

Occurrence. Only one specimen was found.
Description. Subcircular cyst has a thick wall covered by solid, short and blunt processes, proximally connected by low septa. Archeopyle precingular.

Genus *Surculosphaeridium* Davey, Downie, Sarjeant & Williams 1966
Type species *Surculosphaeridium cribrotubiferum* (Sarjeant 1960) Davey, Downie, Sarjeant & Williams 1969
Surculosphaeridium sp.
(Fig. 7h)

Occurrence. Two damaged specimens were found.
Description. Processes solid, distally branched, typical of the genus. Periphragm smooth without parasutural features. Archeopyle apical.
Remarks. Several specimens of *Surculosphaeridium*, a Cretaceous genus, have been reported from the Miocene or younger strata; see e. g., Duffield & Stein (1986), Wrenn & Kokinos (1986), Head *et al.* (1989a). Examination of the Korytnica specimens in fluoroscent light reveals red-dull colour typical for older, reworked dinocysts. All other *in situ* dinocysts show very intensive, yellow-orange fluorescent light.

Suborder GONIODOMINEAE Fensome *et al.* 1993
Family GONIODOMACEAE Lindemann 1928
Subfamily GONIODOMOIDEAE (Autonym)
Genus *Heteraulacacysta* Drugg & Loeblich 1967
Type species *Heteraulacacysta campanula* Drugg & Loeblich 1967
Heteraulacacysta campanula Drugg & Loeblich 1967

Occurrence. Rare, two specimens in apical-antapical view were found.
Description. Areas between low parasutural ridges finely pitted. Paracingular crest relatively narrow in relation to cyst diameter.

Subfamily HELGOLANDINIOIDEAE Fensome *et al.* 1993

Genus *Tuberculodinium* Wall 1967
Type species *Tuberculodinium vancampoe* (Rossignol 1962) Wall 1967
Tuberculodinium vancampoe (Rossignol 1962) Wall 1967
(Figs 6n, o)

Occurrence. Two specimens were found.
Description. Cysts subspherical, relatively large. Processes short, barrel-shaped.

Subfamily PYRODINIOIDEAE Fensome *et al.* 1993

Genus *Hystrichosphaeridium* (Deflandre 1937) emended Davey & Williams 1966
Type species *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams 1966
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams 1966
(Figs 4a-c, 13J)

Occurrence. Two specimens were found.
Description. The SEM observation reveals smooth periphragm lacking in parasutural features. Endophragm microreticulate. Intratabular processes cylindrical, opened distally, with aculeate tips. Parasulcal processes apparently more slender than the others.

Genus *Polysphaeridium* (Davey & Williams 1966) emended Bujak, Downie, Eaton & Williams 1980
Type species *Polysphaeridium subtile* (Davey et Williams 1966) emended Bujak, Downie, Eaton & Williams 1980
Polysphaeridium zoharyi (Rossignol 1962) Bujak, Downie, Eaton & Williams 1980
(Figs 8g-i, k, l, o, p, 11A-C)

Occurrence. Numerous; present in almost all samples.
Description. Two archeopyle types were recognized among the specimens from Korytnica: an epicystal one (Figs 8k, j, o, p) and an tA+5P one, with one precingular paraplate attached to hypocyst (Figs 8g-i).
Some processes (two or three) often arise from a common base or are joined together in the medial part (Figs 8l, 11A). The Korytnica specimens show a variety of process dimensions, from long and thin to relatively short and broad. A gradual passage between these two morphotypes was observed.
Remarks. Specimens with long and relatively thin processes typical for *P. subtile* are here assigned to *P. zoharyi*; these two species are treated as conspecific.

Polysphaeridium? sp. A
(Figs 6e, h, k, 11D-G)

Occurrence. Moderately common.
Description. Cyst subspherical. Endophragm smooth, periphragm covered with densely distributed granulae. Nontabular processes hollow, relatively short, with broad bases and narrowed tips, which are slightly expanded. Bases of processes have root-like linear structures, often combined with linear perforation. Archeopyle epicystal, tA+5P.
Remarks. This species is tentatively assigned to the genus *Polysphaeridium*. It differs from all the other *Polysphaeridium* species by having a double layered cyst wall whereas, according to the original diagnosis, it should posses only an autophragm. This feature suggests the affinity of *Polysphaeridium* sp. A to *Dapsilidinium*, which has an apical archeopyle rather than epicystal one. This species is distinguished from *P. zoharyi* by coarsely granular periphragm; processes of *P. zoharyi* are relatively smooth. Also the shape of these processes is different: they are more conical than tubiform in *P. zoharyi*, being characterized by linear perforations at the bases. In both species, the processes tend to arise from common bases.

Suborder UNCERTAIN
Family UNCERTAIN

Genus *Batiacasphaera* (Drugg 1970) emended Morgan 1975 emended Dorhofer & Davies 1980
Type species *Batiacasphaera compta* Drugg 1970
Batiacasphaera micropapillata Stover 1977
(Figs 8r, s, 10F)

Occurrence. Common, appears in almost all samples.
Description. Cyst spherical or subspherical due to foldings of the cyst wall. Autophragm relatively thin with papillate micro-ornamentation at the surface. Archeopyle apical; operculum free, relatively large.

Batiacasphaera sphaerica Stover 1977
(Figs 9e-g, 10C-E, G, H)

Occurrence. One of the dominating species among the dinocysts from the Korytnica clays.
Description. *B. sphaerica* from Korytnica differs from *B. micropapillata* by a slightly thicker cyst wall, smaller dimensions, and by its spherical shape. Its reticulate surface shows the same distribution pattern of muri and lacuna. Average diameter is 25 µm.
Remarks. The difference between *B. sphaerica* and *B. micropapillata* in the material from Korytnica is very small, the former showing a sphaerical shape. In this case, a further separation of these species may not be necessary.

Genus *Dapsilidinium* Bujak, Downie, Eaton & Williams 1980
Type species *Dapsilidinium pastielsii* (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980
Dapsilidinium pastielsii (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980
(Figs 6f, j, m, 11H-L)

Occurrence. Common species.
Description. Cyst subspherical, often deformed. Cyst wall coarsely granular. Numerous nontabular processes hollow, distally open and narrowed. Length of processes varies, although the long ones (half of the central body diameter) predominate. Surface of processes rather smooth, although some of them are covered by scattered spines or granulae. Archeopyle apical.

Genus *Labyrinthodinium* Piasecki 1980
Type species *Labyrinthodinium truncatum* Piasecki 1980
Labyrinthodinium truncatum Piasecki 1980
(Figs 9r-u, 12H)

Occurrence. Appears in almost all samples, but is not numerous.
Description. Small spherical cyst. Processes hollow, distally expanded, connected by trabeculae. The specimens from Korytnica are characterized by relatively short and thin processes. Archeopyle apical.

Genus *Reticulatosphaera* Matsuoka 1983 emended Bujak & Matsuoka 1986
Type species *Reticulatosphaera stellata* Matsuoka 1983
Reticulatosphaera actinocoronata (Benedek 1972) Bujak & Matsuoka 1986
(Figs 8a, b, d, e, j, 13G-I)

Occurrence. A common species.
Description. Spherical cyst with numerous intratabular, solid and smooth processes. Processes distally branched, often (but not always) interconnected by a trabecular network. Periphragm smooth. Archeopyle rarely visible. Central body diameter 15-25 µm; length of uniform processes 9-12 µm.

UNKNOWN AFFINITY

Svenkodinium gen. nov.
(Figs 12J-L, 16a-R)

Type species. *Svenkodinium minimum* sp. nov.
Etymology. In memory of Svenek, the author's best friend.
Diagnosis. Very small, spherical or subspherical skolochorate cyst (central body diameter rarely exceeds 25 µm) with thin cyst wall. Presumably autophragm only, separation of endo- and periphragm difficult because of small dimensions. External surface of the cyst covered by small spines, processes and other forms of low relief appearing at the same specimens. Processes rather solid, rigid, distally capitating, covered by very small spines or granulae. Maximum length of processes does not exceed 4-5 µm. Archeopyle apical formed by the loss of all apical plates; identified in few cases only.
Discussion. This genus differs from all dinocyst genera by its small size and characteristic shape of spines and processes wich are covered by small spines.

Svenkodinium minimum sp. nov.
(Figs 12J, 16 a, b, i-k, N, R)

Holotype. Sample 8, England Finder coordinate [U 33.1].
Paratype. Sample 8, England Finder coordinate [S 44.1].
Type Locality. Karsy village, Holy Cross Mts, Poland.
Type Stratum. Korytnica clays.
Etymology. *Minimum* (lat.) - small, with reference to the small dimensions.
Diagnosis. A species of *Svenkodinium* with narrow and long processes (Figs 16N, R).
Comparisons. It differs from *S. versteeghii* by longer and slender processes.

Svenkodinium versteeghii sp. nov.
(Figs 12K, L, 16c-h, l, M, P)

?1995 Acritarch sp. B, Versteegh & Zevenboom, p. 107, pl. VI, fig. 3, 6
Holotype. Sample 8, England Finder coordinate [Q 43.1].
Paratype. Sample 8, England Finder coordinate [O 36].
Type Locality. Karsy village, Holy Cross Mts, Poland.
Type Stratum. Korytnica clays.
Etymology. After Dr G. J. M. Versteegh who has first figured this species.
Diagnosis. A species of *Svenkodinium* with short and bluntely pointed processes (Fig. 16P).
Comparisons. This species is smaller and usually has more spherical shape than *S. minimum*.
Discussion. *Svenkodinium versteeghii* represents presumably a form described by Versteegh & Zevenboom (1995) as Acritarch sp. B.

Svenkodinium sp. A
(Fig. 16O)

Remarks. SEM observations revealed the presence of a form resembling the representatives of the genus *Svenkodinium*. It is characterized by a spherical shape and cover of irregular forms of low relief (up to 2-3 µm), resembling in shape the processes of *S. minimum*. Diameter of the central body 20 µm.

The lack of light microscope observation makes the description of a new species impossible.

Order PERIDINIALES Haeckel 1894
Suborder PERIDINIINEAE (Autonym)
Family PERIDINIACEAE Ehrenberg 1831
Subfamily DEFLANDREOIDEAE Bujak & Davies 1983
Genus *Palaeocystodinium* Alberti 1961
Type species *Palaeocystodinium golzowense* Alberti 1961
Palaeocystodinium golzowense Alberti 1961

Occurrence. One specimen was found.
Description. Cyst cornucavate, typically elongated. Periphragm smooth, thin, finely folded. Endocyst ellipsoidal, smooth. Archeopyle not visible.

Paleocystodinium striatogranulosum Zevenboom & Santarelli 1985

Occurrence. One damaged specimen consisting of central body and one polar horn was found.
Description. Subspherical central body has smooth periphragm, the periphragmal horn is covered in its distal part by tooth-like striae.

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APPENDIX
List of dinoflagellate cysts found in the Korytnica clays

Achomosphaera ramulifera (Deflandre 1937) Evitt 1963 (Fig. 15G)
Achomosphaera spp. (Figs 15D-F, H-J)
Apteodinium conjunctum Eisenack & Cookson 1960 (Figs 4j-l)
Apteodinium spiridoides (Benedek 1972) Benedek & Sarjeant 1981 (Figs 10K, L)
Batiacasphaera micropapillata Stover 1977 (Figs 8r, s, 10F)
Batiacasphaera sphaerica Stover 1977 (Figs 9e-g, 10C-E, G, H)
Cribroperidinium tenuitabulatum (Gerlach 1961) Helenes 1984 (Figs 4d-i, 10I, J)
Dapsilidinium pastielsii (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980 (Figs 6f, j, m, 11H-L)
Dubridinium cavatum Reid 1977
Habibacysta tectata Head, Norris & Mudie 1989 (Figs 10A, B)
Heteraulacacysta campanula Drugg & Loeblich 1967
Hystrichokolpoma rigaudiea Deflandrea & Cookson 1955 (Figs 5a-c, f)
Hystrichokolpoma truncata Biffi & Manum 1988 (Figs 5i, l)
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams 1966 (Figs 4a-c, 13J)
Hystrichosphaeropsis minimus Zevenboom & Santarelli 1995 (Figs 5m-p, 12I)
Hystrichosphaeropsis obscura Habib 1972
Impagidinium aculeatum (Wall 1967) Lentin & Williams 1981
Impagidinium paradoxum (Wall 1967) Stover & Evitt 1978 (Figs 9o, p)
Impagidinium velorum Bujak 1984 (Figs 8m, n)
Imperfectodinium septatum Zevenboom & Santarelli 1995 (Figs 9a-d, h, l)
Labyrinthodinium truncatum Piasecki 1980 (Figs 9r-u, 12H)
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967 (Figs 6d, g, i, l, 12A-C)
Melitasphaeridium choanophorum (Deflandre & Cookson 1955) Harland & Hill 1979 (Figs 8c, f, 13K, L)
Nematosphaeropsis labiryinthea (Ostenfeld 1903) Reid 1974 (Figs 7l, n)
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967 (Fig. 6a)
Operculodinium israelianum (Rossignol 1962) Wall 1967 (Figs 6b, c, 13A-F)
Palaeocystodinium golzowense Alberti 1961
Palaeocystodinium striatogranulosum Zevenboom & Santarelli 1995
Polysphaeridium zoharyi (Rossignol 1962) Bujak, Downie, Eaton & Williams 1980 (Figs 6e, h, k, 11D-G)
Polysphaeridium? sp. A (Figs 6e, h, k, 11D-G)
Pyxidinopsis tuberculata Versteegh & Zevenboom 1995 (Figs 9i, k)
Reticulatosphaera actinocoronata (Benedek 1972) Bujak & Matsuoka 1986 (Figs 8a, b, d, e, j, 13G-I)
Spiniferites belerius Reid 1974
Spiniferites bentori (Rossignol 1964) Wall & Dale 1970 (Fig. 14H)
Spiniferites membranaceous (Rossignol 1964) Sarjeant 1970 (Figs 7d-f, 14J)
Spiniferites mirabilis (Rossignol 1964) Sarjeant 1970 (Figs 14K, L)
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 (Fig. 7o)
Spiniferites ramosus (Ehrenberg 1838) Mantell 1850 (Figs 7c, g, j, 14A-G, I)
Spiniferites sp. B of Piasecki (1980) (Figs 15A-C)
Surculosphaeridium sp. (Fig. 7h)
Svenkodinium minimum gen. et sp. nov. (Figs 12J, 16a, b, i-k, N, R)
Svenkodinium versteeghii gen. et sp. nov. (Figs 12K, L, 16c-h, l, M, P)
Svenkodinium sp. A (Fig. 16O)
Systematophora ancyrea Cookson & Eisenack 1965 (Figs 7a, b, i)
Systematophora placacantha (Deflandre & Cookson 1955) Davey, Downie, Sarjeant & Williams 1969 (Figs 7k, m)
Tectatodinium psilatum Wall & Dale 1973 (Figs 9m, n)
Tuberculodinium vancampoe (Rossignol 1962) Wall 1967 (Figs 6n, o)
Unipontidinium aquaeductum (Piasecki 1980) Wrenn 1988 (Figs 5d, e, g, h, j, k, 12D-G)

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Streszczenie

Środkowomioceńskie cysty Dinoflagellata z iłów korytnickich (Góry Świętokrzyskie, Polska)

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Badania palinologiczne objęły osiem próbek pobranych z powierzchniowych odsłonięć iłów korytnickich w rejonie wsi Korytnica i Karsy (Fig. 1). Próbki 1-6 pobrano z północnych stoków Łysej Góry z muszlowców ostrygowych oraz brązowych iłów, próbkę 7 pobrano z odsłonięcia iłów korytnickich na północno-wschodnim zboczu, natomiast próbkę 8 z iłów korytnickich odsłaniających się w pobliżu Karsów. Próbki poddano standardowym metodom maceracji palinologicznej.

Próbki 1-6 charakteryzują się niewielkim udziałem palinomorfów morskich (zwłaszcza dinocyst) i są zdominowane przez palinomorfy lądowe, zwłaszcza ziarna pyłków. Odmiennie wygląda palinofacja próbek 7 i 8 gdzie dinocysty występują w dużych ilościach i są zróżnicowane. Dominuje morfotyp dinocysty *Spiniferites/Achomosphaera* i *Batiacasphaera* spp., oraz podrzędnie występują *Operculodinium israelianum*, *Polysphaeridium zoharyi*, *Dapsilidinium pastielsii*, *Lingulodinium machaerophorum*, *Cribroperidinium tenuitabulatum*, *Apteodinium* spp., *Reticulatosphaera actinocoronata*, *Polysphaeridium*? sp. A oraz *Svenkodinium* spp.

Wiek iłów korytnickich w oparciu o dinocysty jest możliwy do ustalenia wyłącznie w porównaniu z zonacjami dinocystowymi z NW Europy czy N Atlantyku (Fig. 2) – dotychczas nie ustalono dinocystowej biostratygrafii miocenu zapadliska przedkarpackiego. Obecność *Unipontidinium aquaeductum* w iłach korytnickich pozwala na zaliczenie badanych utworów do zony Unipontidinium aquaeductum opisanej przez wielu autorów (m.in. Manum, 1976; Piasecki, 1980; Powell, 1986b). Zona ta jest przeważnie definiowana jako interwał od pierwszego pojawienia się *U. aquaeductum* do pierwszego pojawienia się *Achomosphaera andalousiensis*, obecności której, pomimo dużego udziału rodzaju *Achomosphaera* w badanym zespole, nie stwierdzono. *Unipontidinium aquaeductum* w zespole korytnickim jest dinocystą rzadką, ale wynika to raczej z jej preferencji środowiskowych niż z różnic wiekowych. Zona Unipontidinium aquaeductum jest najczęściej korelowana z nannoplanktonową zoną NN5-NN6. Według niektórych autorów obejmuje ona również górną część zony NN4 (Fig. 2). Różnice te wynikają z niejednolitych korelacji bio- i chronostratygraficznych. Wyniki tych badań zgodne są z dotychczasowymi opracowaniami mikropaleontologicznymi (Fig. 3), które podobnie datowały iły korytnickie (np. Martini, 1977; Dudziak & Łuczkowska, 1991).

Próba rekonstrukcji warunków depozycji iłów korytnickich na podstawie analizy zespołu dinocyst generalnie potwierdza wyniki poprzednich badań (m. in. Radwański, 1969; Bałuk, 1975; Bałuk & Radwański, 1977). Sam zespół dinocyst (dominacja *Spiniferites/Achomosphaera* i *Batiacasphaera* spp. oraz brak form peridinioid) nie był nigdy opisany w literaturze. Stosunkowo zróżnicowany zespół dinocyst (48 gatunków) jest raczej typowy dla wód ciepłych w przeciwieństwie do zubożałych zespołów zimnowodnych (np. Harland *et al.*, 1980). Brak również form typowo zimnolubnych, natomiast obecne są gatunki ciepłolubne, takie jak *Operculodinium israelianum* czy *Tuberculodinium vancampoe* (np. Dale, 1983).

Większość z dinocyst stwierdzonych w iłach korytnickich jest raczej formami płytkowodnymi, przybrzeżnymi: *Spiniferites* spp., *Polysphaeridium zoharyi*, *Tuberculodinium vancampoe* czy *Operculodinium israelianum* (np. Wall *et al.*, 1977). Również obecność algi *Cymatiosphaera* sp., uważanej za formę nerytyczną (np. Al-Ameri, 1986) potwierdza tezę płytkowodnych, przybrzeżnych warunków depozycji iłów korytnickich. Kolejnym potwierdzeniem jest nieomal całkowity brak dinocyst uważanych za typowe dla otwartego morza (np. rodzaj *Impagidinium*). Niemniej obecność pojedynczych przedstawicieli tego oraz podobnych rodzajów sugeruje iż zatoka korytnicka nie była całkowicie izolowana, i że miała kontakt z otwartym zbiornikiem.

Zasolenie wód zatoki korytnickiej na podstawie dinocyst wydaje się być normalne: brak dominacji gatunów uważanych za typowe dla środowisk brakicznych czy o podwyższonym zasoleniu, takich jak *Lingulodinium machaerophorum* czy *Polysphaeridium zoharyi* (np. Morzadec-Kerfourn, 1976; 1983). Również cechy morfologiczne niektórych dinocyst nie wskazują na jakiekolwiek zmiany zasolenia (np. Turon, 1984).

Cechą charakterystyczną badanego zepołu dinocyst jest brak form peridinioid (reprezentowanych przez dwa pojedyncze okazy), uważanych za powiązane z żyznymi wodami estuariów (np. Wall *et al.*, 1977). Sugerowało by to niski poziom nutrientów w wodzie spowodowany być może brakiem dostawy wody rzecznej do zbiornika. Jest to prawdopodobne tym bardziej, iż palinomorfy lądowe reprezentowane są przede wszystkim przez dwuworkowe ziarna pyłku posiadające duże możliwości lotne czy pławne, brak natomiast dużych ilości innych palinomorfów oraz tkanek roślin lądowych dostarczanych przez rzeki.