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Late Eocene – early Oligocene organic-walled dinoflagellate cysts from Folusz, Magura Nappe, Polish Carpathians*

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ABSTRACT. This paper provides documentation of organic-walled dinoflagellate cysts recorded from the Eocene-Oligocene transition interval exposed at Folusz, northern part of the Magura Nappe, Carpathians, Poland. Dinoflagellate cysts (147 taxa have been recognized) are reported for the first time from this area, 31 dinoflagellate cyst species left in open nomenclature are described. Their distribution suggests late Eocene age of the basal part of the Szymbark shale and early Oligocene age of the uppermost part of this unit and of the Magura Formation. Some dinoflagellate cyst species from the studied section have stratigraphic ranges different from those of higher latitudes. Palaeoenvironmental preferences of selected species are suggested. Frequent recycled dinoflagellate cysts are noted, including Jurassic, Cretaceous and early Palaeogene taxa.

KEY WORDS: dinocysts, Eocene-Oligocene transition, palaeoenvironment, recycling, Magura Nappe, Carpathians

INTRODUCTION

Organic-walled dinoflagellate cysts (hereafter dinocysts) from the Eocene-Oligocene transition interval in the Outer Polish Carpathians were studied from several sections from the external tectonic units (i.e., the Skole Nappe, the Silesian Nappe and the Dukla Nappe) and from a single section in the southernmost part of the Magura Nappe (Gedl 2001, 2004). These intervals consist of the so-called sub-Menilite Globigerina marl unit followed by organic-rich Menilite beds (or their equivalents). Dinocyst assemblages from these deposits show a significant turnover that likely reflects palaeoenvironmental changes during late Eocene through early Oligocene times in this part of the Carpathian basin (Gedl 1999). The Eocene-Oligocene transition exposed at Folusz is devoid of the sub-Menilite Globigerina marl unit and the organic-rich sediments (Leszczyński & Malata 2002). The character of the sediments from Folusz suggests different palaeoenvironmental conditions during that time in the northern part of the Magura basin than in other parts of the Carpathian basins. Their reconstruction was studied recently by Leszczyński and Malata (2002) and Gedl and Leszczyński (2005). Dinocysts found during the latter study are illustrated in this paper. Comments on their palaeoenvironmental preferences and descriptions of species left in open nomenclature are given.

GEOLOGICAL SETTING

The Folusz section is one of the best-exposed Eocene-Oligocene transition sections in the northernmost part of the Magura Nappe (the Siary zone sensu Koszarski et al. 1974). It is located at the northern foothills of the Magura Wątkowska Range in the Beskid Niski Mts (Fig. 1). Its lower part is developed

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as the Szymbark shale unit (sensu Kopciowski 1996) resting upon the Łabowa Shale Formation. Thick-bedded Magura Formation in the remaining part of the section overlies the latter. This unit is subdivided into the so-called Zembrzyce beds and the Wątkowa sandstone unit in the topmost part of section (for detail section lithology – see Leszczyński & Malata 2002).

The Eocene-Oligocene transition in the northern part of the Magura Nappe is developed differently than in external Carpathian tectonic units. It consists mainly of turbiditic deposits: these are predominantly thick-bedded sandstones with subordinate shale intercalations (Leszczyński & Malata 2002). There are no deposits similar to the sub-Menilite Globigerina marl unit or organic-rich Menilite beds that are typical for the Eocene-Oligocene transition in external Carpathian tectonic units (cf. Leszczyński 1997). However, at some localities in the eastern part of the Siary zone, including the Folusz area, the Eocene-Oligocene transition is characterized by more fine-grained turbidite development (e.g. Sikora 1970). Biostratigraphical data (Blaicher & Sikora 1963, Oszczypko-Clowes 2001, Malata in Leszczyński & Malata 2002, Oszczypko-Clowes in Leszczyński & Malata 2002, Gedl in Gedl & Leszczyński 2005) indicate, although not consistently, that the Eocene-Oligocene boundary occurs in an upper part of the Szymbark shale (see Gedl & Leszczyński 2005). This interpretation is supported by the results of a radiometric dating of the tuffite layer (van Couvering et al. 1981), presumably the one found by Leszczyński (Leszczyński & Malata 2002) in the topmost part of the Szymbark shale (Fig. 2).

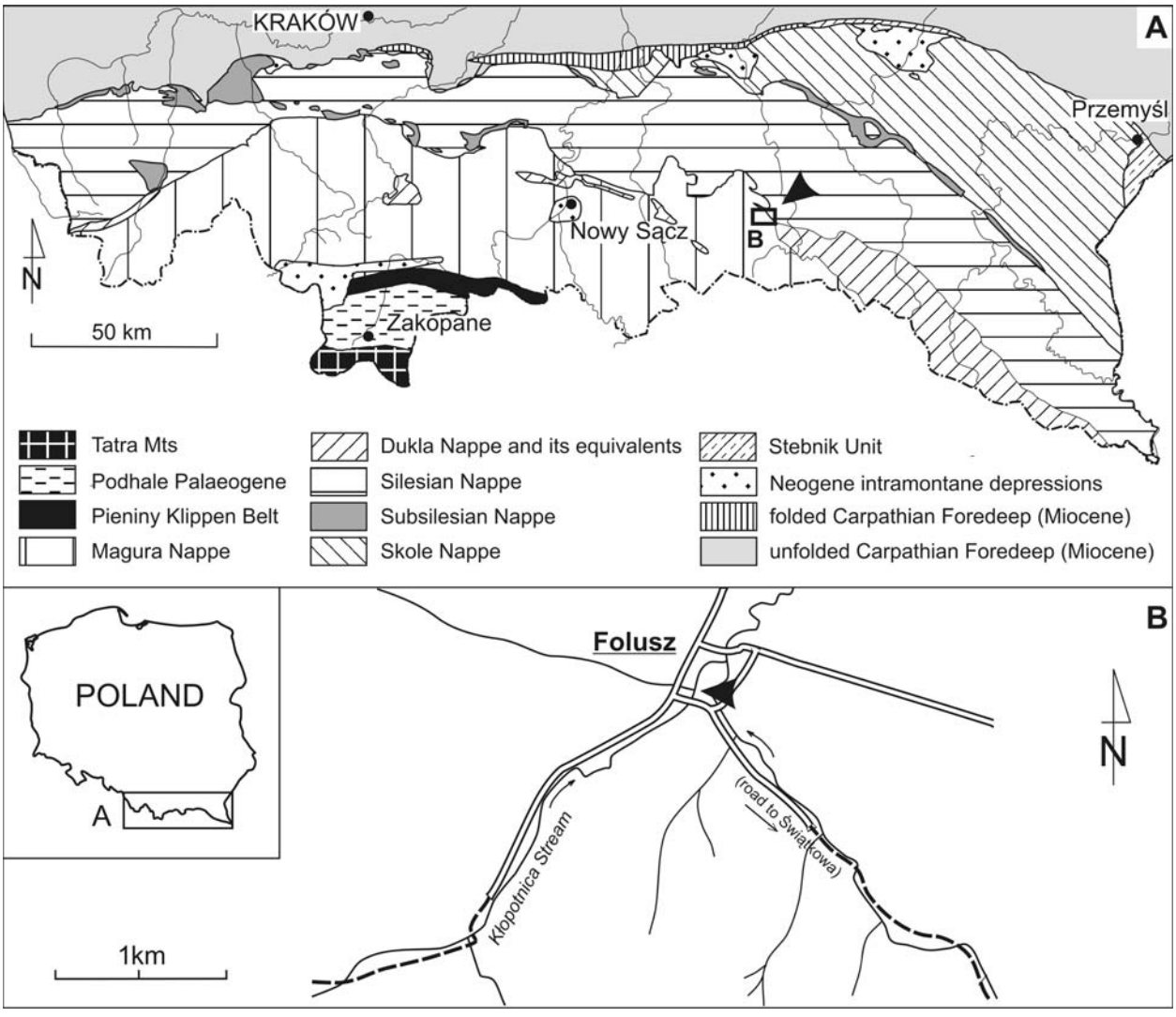


Fig. 1. Location of study area: **A** – at background of tectonic map of Polish Carpathians (after Książkiewicz 1977); **B** – arrowed at topographic scetch-map (adopted from Gedl & Leszczyński 2005)

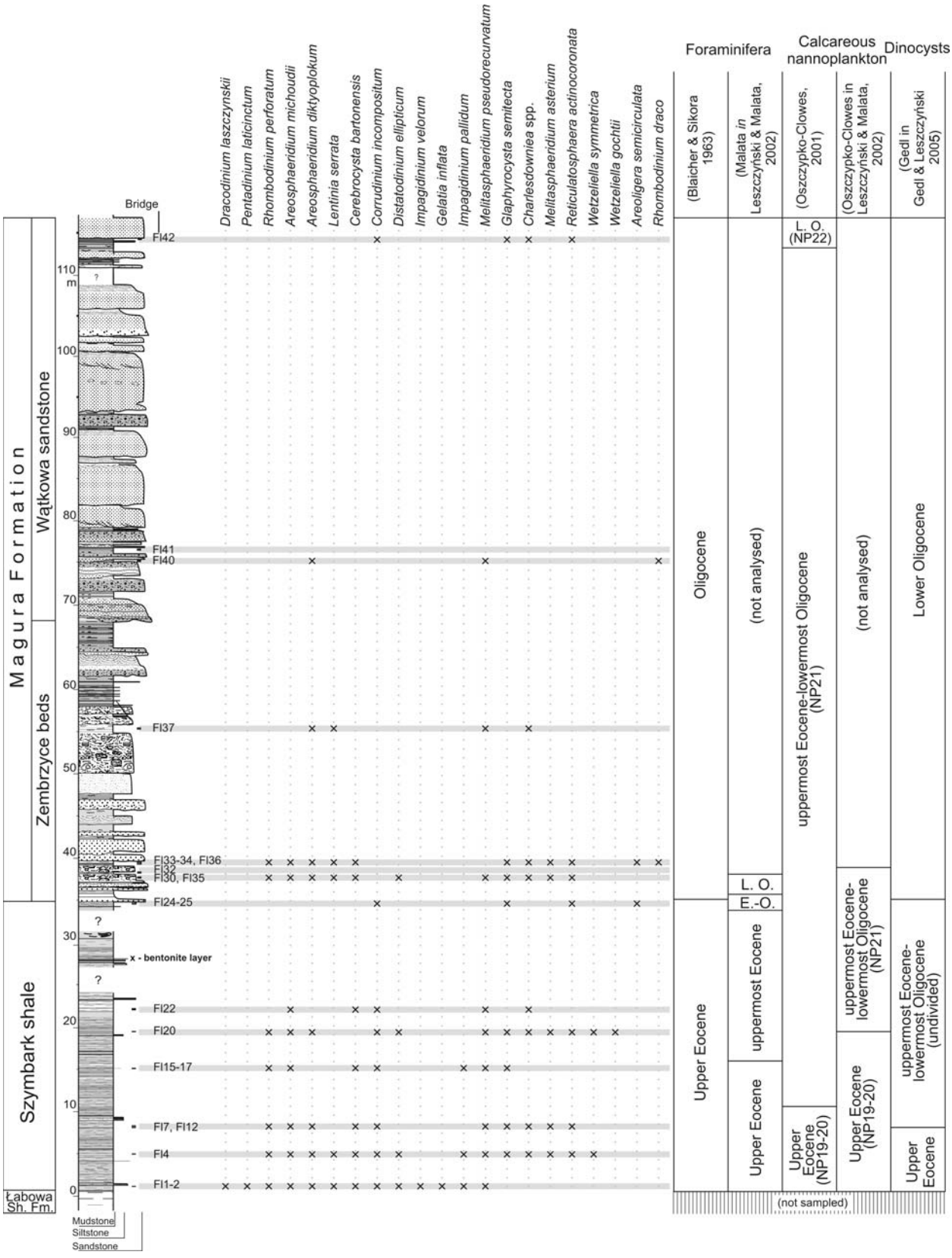


Fig. 2. Lithostratigraphy, lithology (after Leszczyński in Leszczyński & Malata 2002), occurrence of selected dinocyst species and results of previous biostratigraphical studies of Folusz section. Abbreviations: **Łabowa Sh. Fm.** – Łabowa Shale Formation; **L. O.** – Lower Oligocene; **E.-O.** – Eocene-Oligocene; **Fl** – sample

MATERIAL AND METHODS

Twenty-two samples have been investigated for dinocysts (Fig. 2). They were processed following standard palynological procedure including 38% hydrochloric acid (HCl) treatment, 40% hydrofluoric acid (HF) treatment, heavy liquid ($ZnCl_2$+HCl; density 2.0 g/cm^3) separation, and 15 µm nylon-mesh sieving. The quantity of rock processed approximates 30 g for each sample. Two slides were made from each sample using glycerine jelly as a mounting medium. All dinocysts were counted from one of two slides. The second slide was scanned for additional dinocyst taxa. The rock samples, palynological residues and slides are stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

DINOCYST ASSEMBLAGES

147 dinocyst taxa have been recognized in the Folusz section (Fig. 3, Pls 1–18). A part of them is represented by recycled specimens (see chapter "Recycled dinocysts"). The most frequent dinocyst assemblage, composed of more than 100 species, has been found in the Szymbark shale (samples Fl01-Fl22). The following dinocyst taxa have been found exclusively in the Szymbark shale: *Amphorosphaeridium*? *multispinosum*, *Cribroperidinium tenuitabulatum*, *Enneadocysta arcuata*, *E. fenestrata*, *Fibrocysta vectensis*, *Gelatia inflata*, *Heterosphaeridium* sp. A, *Homotryblium caliculum*, *Hystrichokolpoma salacia*, *Impagidinium gibrense*, *I. pallidum*, *I. velorum*, *Lejeunecysta hyalina*, *L. fallax*, *L. tenella*, *Leptodinium membraniphorum*, *Lingulodinium pycnospinosum*, *Pentadinium laticinctum*, *Spiniferites membranaceus*, *Operculodinium* aff. *centrocarpum*, *O. deconinckii*, *O.*? *hirsutum*, *Phelodinium* sp., *Polysphaeridium subtile*, *Selenopemphix coronata*, *S.* aff. *selenoides*, *Thalassiphora* sp. A., *Wetzeliella gochtii*, *W. symmetrica*, and *Wilsonidium intermedium*. Many other dinocysts that occur in the Szymbark shale, have been found also in the mud flows from the basal part of the Zembrzyce beds, where they are presumably partialy recycled: *Areoligera semicirculata*, *Cerebrocysta bartonensis*, *Charlesdowniea clathrata*, *C. coleothrypta*, *Cordosphaeridium funiculatum*, *Dapsilidinium pseudocolligerum*, *Dinopterygium* sp. A, *Fibrocysta* aff. *vectensis*, *Homotryblium vallum*, *Hystrichokolpoma cinctum*, *Impagidinium aculeatum*, *I. brevisulcatum*, *Lentinia serrata*, *Melitasphaeridium asterium*, *Membranilarnacia*? sp. A, *Membranophoridium aspinatum*, *Operculodinium tiara*, *Palaeocystodinium golzowense*, *Phthanoperidinium comatum*, *Pyxidinopsis* spp., *Rhombodinium perforatum*, *Selenopemphix armata*, *Spiniferites pseudofurcatus* and *Systematophora placacantha*.

Dinocysts from the Magura Formation are less frequent. Following dinocyst species have been found exclusively in this lithostratigraphic unit: *Achomosphaera alcicornu*, *A. sagena*, *Adnatosphaeridium* sp., *Cordosphaeridium minimum*, *Dapsilidinium multispinosum*, *D. pastielsii*, *Dinopterygium* sp. B, *Diphyes* aff. *colligerum*, *Enneadocysta multicornuta*, *Glaphyrocysta intricata* (recycled?), *Heteraulacacysta* sp., *Lejeunecysta lata*, *Paucisphaeridium inversibuccinum* (recycled?), *Pentadinium*? *circumsutum*, *Phthanoperidinium amiculum*, *P.* aff. *amiculum*, *Polysphaeridium zoharyi*, *Rhombodinium draco*, *R.* sp. A, *Selenopemphix* sp. A and *Turbiosphaera symmetrica*.

Palynofacies of the Folusz samples is composed almost entirely of terrestrial elements. Dinocysts are strongly dispersed by land plant tissue remains and sporomorphs – they rarely exceed 1–2% of palynofacies. Dinocysts are the most frequent in samples Fl4 and Fl7 (the Szymbark shale), where they reach 8%. No dinocysts or only single indeterminable specimens have been found in samples Fl34 and Fl41 (the Zembrzyce beds and the Wątkowa sandstone respectively). Dinocyst distribution shows clear relation to the sediment type: they are relatively frequent in the turbidites or mudflows (presumably in part recycled) whereas they are relatively rare in the background (hemipelagic) deposits (see Gedl & Leszczyński 2005).

Dinocyst assemblage from the Folusz section is characterized by frequent occurrence of chorate Gonyaulacales. These are *Spiniferites ramosus*, representatives of the genera *Homotryblium* (*H. tenuispinosum* and *H. plectilum*) and *Areosphaeridium* (mainly *A. michoudii*). Majority of other chorate Gonyaulacales found in the Szymbark shale occurs as single specimens per sample of they occur as relatively frequent in single samples only (e.g. *Operculodinium* spp., *Systematophora placacantha*, *Areoligera undulata*, *Enneadocysta* aff. *pectiniformis*). Noteworthy is the presence of the *Impagidinium* in this part of the investigated section. Mainly *Deflandrea* spp. and infre-

quent *Charlesdowniea* spp. and the Congruentidiaceae represent Peridiniales.

There is no considerable qualitative change of the dinocyst assemblages throughout the investigated section, especially across the Eocene-Oligocene transitional interval located in the upper part of the Szymbark shale. There is only a general decline in dinocyst frequency observed. This contrasts with the pronounced change that characterizes the dinocysts from the Eocene-Oligocene transition interval from the Polish Outer Carpathians where the sub-Menilite Globigerina marl and the Menilite beds are developed (however, it is possible that frequent recycling of dinocysts may mask true changes – see Gedl & Leszczyński 2005). Very rich and diversified dinocyst assemblages from the sub-Menilite Globigerina marl unit disappear in its topmost part or very impoverished assemblages from the Menilite beds dominated by Peridiniales replace them. This change was interpreted as the result of several factors, among which increase of nutrient availability in the surface waters caused by fresh water influx (e.g. Gedl 1999). The dinocyst succession throughout the Folusz section indicates different palaeoenvironmental conditions that prevailed during the latest Eocene and early Oligocene in the northern part of the Magura basin (Gedl & Leszczyński 2005).

Besides dinocysts, infrequent acritarchs and microforaminifera occur occasionally. Acritarchs represented by one morphotype of *Veryhachium* affinity (Pl. 18, figs 11, 12) have been found mainly in the lower part of the Szymbark Shale (samples Fl1-Fl7; they are the most frequent in the sample Fl4). Trochospiral and planispiral morphotypes of microforaminifera (Pl. 18, figs 15–26) are very rare in studied section except for the sample Fl4 where they are relatively frequent. A palynomorph of uncertain to the author origin occurs as very frequent in samples Fl12-17 (Pl. 18, figs 13, 14). This palynomorph resembles a palynomorph illustrated by Brinkhuis (1992, Pl. 1, fig 1) and refered by him to genus et species indet. of Biffi and Manum (1988).

REMARKS ON BIOSTRATIGRAPHY

The age-assessment of the Folusz section based on dinocysts has been presented by Gedl and Leszczyński (2005). Upper Eocene strata have been recognized in the lower part of the Szymbark shale below sample Fl7 (Fig. 2). This interval is characterized by the co-occurrence of dinocyst species *Areosphaeridium diktyoplokum*, *A. michoudii*, and *Rhombodinium perforatum* in this interval. The last appearance of *Areosphaeridium diktyoplokum* is commonly believed to have taken place at the Eocene-Oligocene boundary (e.g. Biffi & Manum 1988, Stover et al. 1996), although Brinkhuis (1994) demonstrated its early Oligocene last appearance (for discussion see also Berggren et al. 1995 and Brinkhuis & Visscher 1995). Also *Areosphaeridium michoudii* and *Rhombodinium perforatum* have their stratigraphic ranges limited to late Eocene (Powell 1992, Bujak & Mudge 1994).

The Eocene-Oligocene boundary has not been precisely established in the investigated section. This is due to increased recycling that has been noted (see chapter "Recycled dinocysts"). The interval between samples Fl12 and Fl24 has been assigned as undivided uppermost Eocene-lowermost Oligocene (Fig. 2). The Lower Oligocene strata have been recognized above sample Fl24, i.e. above the lowest occurrence of *Areoligera*? *semicirculata*, a species known from Oligocene deposits (e.g. Morgenroth 1966, Powell 1992, Stover & Hardenbol 1993, Brinkhuis 1994, Stover et al. 1996).

Wetzeliella gochtii and *Reticulatosphaera actinocoronata* that are widely considered to be Oligocene species have been reported from Upper Eocene part of the Folusz section. The lowest occurrences of *Wetzeliella gochtii* (e.g. Costa & Downie 1976, 1979, Gruas-Cavagnetto & Barbin 1988) and *Reticulatosphaera actinocoronata* (e.g. Manum et al. 1989) have been usually reported from the Lower Oligocene strata of higher latitudes. Occurrence of these species in Upper Eocene strata of the Polish Carpathians (see also Gedl 2004) seems to confirm observations of some authors who earlier suggested their late Eocene first appearances in lower latitudes (Châteauneuf 1980, Bujak in van Couvering et al. 1981, El-Beialy 1988, Brinkhuis 1994, Coccioni et al. 2000). Also *Homotryblium vallum*, which according to Stover et al. (1996) has its lowest occurrence close to the Rupelian-Chattian boundary, have been found in the Upper Eocene strata of the Polish Carpathians (Gedl 2004, this paper).

REMARKS ON PALAEOENVIRONMENTAL PREFERENCES OF SELECTED DINOCYSTS

Deposits exposed in investigated section at Folusz are mainly turbidites consisting of sediments reworked from shallower areas into deeper, central parts of the basin. However, especially in the lower part (the Szymbark shale) hemipelagic sediments occur frequently. Distribution of several dinocyst species in sediments in question shows apparent relation to the sediment type. Two groups of dinocyst species have been distinguished. These that occur mainly in turbidites or mudflows are believed to have inhabited more inshore palaeoenvironments in relation to the dinocysts that predominate in hemipelagic sediments.

Wetzelielloideae. Representatives of this subfamily are rare in investigated deposits. However, they have been found almost exclusively in turbiditic or mud-flow deposits (*Charlesdowniea* spp., *Rhombodinium* sp. A, *R. draco*, *Wetzeliella symmetrica*, and *W. gochtii*). This suggests their near-shore preferences, which agrees with previous interpretations (e.g. Downie et al. 1971, Goodman 1979, Islam 1984, Köthe 1990). The exception is *Rhombodinium perforatum*, which frequent occurrence in hemipelagites implies more offshore preferences.

Lentinia serrata. This species has been found mainly in the basal part of the Szymbark shale where it frequently occurs in hemipelagites. Therefore, offshore preferences of this species could be suggested. Occurrence of *Lentinia serrata* in Lower Oligocene turbidites of the Zembrzyce beds may be a result of recycling: Stover et al. (1996) show that stratigraphic range of *Lentinia serrata* in mid- and high-latitudes is limited to Eocene. However, Williams et al. (2004) show Rupelian range of this species in equatorial areas.

***Deflandrea* spp**. Representatives of this genus are found in both turbidites and hemipelagites, however, they occur more frequently in the latter. The genus *Deflandrea* is usually associated with near-shore, estuarine environments (e.g. Islam 1984, Köthe 1990), although Brinkhuis et al. (1992) points at relation of this genus to nutrient availability rather than to distance from shoreline. The results of this study seem to confirm the latter interpretation.

Congruentidioideae. Congruentidioideae from the Folusz section has been found in both turbidites (e.g. *Lejeunecysta fallax*, *L. hyaline* and *L. lata*) and hemipelagites (*Lejeunecysta tenella*, *Phelodinium* sp., and *Selenopemphix coronata*). In investigated material, their majority has been found in late Eocene Szymbark shale. The Lower Oligocene strata of the Magura Formation contain much less frequent Congruentidioideae, which at least in part may be recycled because they occur in mud flows (*Lejeunecysta lata*, *Selenopemphix armata*, *Selenopemphix.* sp. A). Representatives of Congruentidioideae are often found in eutrophic environments (e.g. Biffi & Grignani 1983).

Polysphaeridium. Very rare specimens of *Polysphaeridium zoharyi* and *P. subtile* have been found mainly in turbidites and mud flows. Distribution of *Polysphaeridium zoharyi* in recent sediments is associated with near-shore environments (e.g. Wall & Dale 1969, Dale 1976, Wall et al. 1977). Occurrence of this species in investigated sediments indicates on similar preferences of these species also during early Oligocene.

Homotryblium. Representatives of this genus occur in both turbidites and hemipelagites. The genus *Homotryblium* is widely accepted as the marginal marine dinocyst (e.g. Brinkhuis 1994, Zevenboom et al. 1994), tolerant to hypersalinar conditions (e.g. Sluijs et al. 2005). However, *Homotryblium tenuispinosum* and *H. aculeatum*, i.e. the species of *Homotryblium* characterized by long processes in relation to the central body diameter, have been found mainly in the turbidites and mud-flows. Meanwhile, *Homotryblium* species with shorter processes, *H. plectilum* and especially *H. vallum*, occur relatively frequent in the hemipelagites. This may suggest relative offshore preferences of the two latter species in relation to *Homotryblium tenuispinosum* and *H. aculeatum*, which presumably have inhabited near-shore settings. This palaeoenvironmental interpretation is contradictory to the one of Dybkjær (2004) who regarded *Homotryblium vallum* and *H. plectilum* as more inshore in relation to *H. tenuispinosum*.

Homotryblium tenuispinosum (and morphologically similar species *H. pallidum* and *H. aculeatum*) and *H. plectilum* are the most abundant species of *Homotryblium* that occur

in the Upper Eocene and Oligocene strata of Polish Carpathians (Gedl 2000, 2004). Monospecific assemblages of this species were found in uppermost part of the sub-Menilite Globigerina marl (Gedl 2001).

Membranophoridium aspinatum. This species have been found in the Szymbark shale mainly in hemipelagites, whereas its occurrence in the Zembrzyce beds is limited to mud flow deposits. The hitherto record of this species in Polish Carpathians suggests that *M. aspinatum* has favoured near-shore environments – it occurs in monospecific assemblages in proximal flysch deposits of the Szaflary beds (Podhale Flysch; Gedl 2000) and it is almost absent in the Upper Eocene offshore facies (Gedl 2004). In the light of this interpretation, the occurrence of *M. aspinatum* in hemipelagites from investigated Folusz deposits is enigmatic.

Impagidinium. Representatives of the genus *Impagidinium* (except of *Impagidinium.* sp. D) occur in investigated deposits mainly in the hemipelagites. It confirms offshore preferences of this genus suggested by other authors (e.g. Brinkhuis et al. 1992, Brinkhuis 1994, Zevenboom et al. 1994, Dale 1996, Rochon et al. 1999).

Gelatia inflata. This species has been found in hemipelagic deposits of the Folusz section. This suggests its offshore preferences. *Gelatia inflata*, a typical high-latitude species (e.g. Bujak 1984), has been found in hemipelagites from the lowermost part of the Szymbark shale (samples Fl1 and Fl2). Another two high-latitude dinocyst species, ***Impagidinium pallidum*** and ***I. velorum***, have been found in hemipelagites from the basal part of the Szymbark shale. Their occurrence in low-latitude Carpathian basins might be a result of climatic changes.

Enneadocysta pectiniformis. *E. pectiniformis* has been found mainly in the turbidites. This suggests its near-shore preferences. Similar, neritic setting of this species was concluded by Brinkhuis (1994). Different, offshore preferences of morphological similar ***Enneadocysta*** aff. ***pectiniformis***, can be suggested on the basis of its abundance in hemipelagites. Brinkhuis et al. (2003) suggested relatively oligotrophic and offshore preferences for the genus *Enneadocysta*.

Tectatodinium aff. ***pellitum***. Occurrence of *Tectatodinium* aff. *pellitum* almost exclusively in hemipelagic sediments implies offshore palaeoenvironmental preferences of this species. *Tectatodinium pellitum* is treated as a cosmopolitan species that occurs from estuarine to oceanic settings (e.g. Harland 1983, Wrenn & Kokinos 1986, Edwards & Andrle 1992). Head (1994) suggested warm-water preferences of *T. pellitum*. This feature, if applied to *Tectatodinium* aff. *pellitum*, would suggest a warming period that followed a cooling event during sedimentation of the lower part of the Szymbark shale recorded by the occurrence of high-latitude dinocyst species.

Cerebrocysta bartonensis. Almost exclusive occurrence of *Cerebrocysta bartonensis* in hemipelagic deposits suggests offshore preferences of this species. However, this species may be recycled in the Folusz section. Its stratigraphic range is believed to be limited to Bartonian in the northern hemisphere (Bujak et al. 1980).

Corrudinium? sp. **A**. This species occurs in both types in sediments, being more frequent in hemipelagites, which possibly reflects its more offshore preferences.

Corrudinium incompositum. This species occurs in studied material mainly in the hemipelagites being rather absent in turbidites. This implies offshore preferences of this species. Brinkhuis and Biffi (1993) included *Corrudinium incompositum* to high-latitude dinocysts. However, there is no clear correlation observed in the studied material between the distribution of this species and other oceanic high-latitude dinocysts (i.e. *Gelatia inflata*, *Impagidinium velorum* and *I. pallidum*), which occur in the basal part of the Szymbark shale only.

Areosphaeridium michoudii. *A. michoudii* occurs in both turbidites and hemipelagites being the most frequent in the former. Occurrence of *Areosphaeridium michoudii* in the studied material suggests near-shore preferences of this species. Its frequency correlates with abundance of *Homotryblium* specimens, a genus believed to have inhabited near-shore waters (Brinkhuis 1994).

Areoligera and ***Glaphyrocysta***. Representatives of these genera have been found in the Folusz section mainly in the turbidites. This

is interpreted as reflection of their near shore preferences.

Several authors (e.g. Downie et al. 1971, Brinkhuis & Zachariasse 1988, Brinkhuis et al. 1992) have drawn similar conclusions, regarding *Glaphyrocysta* and *Areoligera* as inhabitors of marginal marine environmnets.

Other dinocyst species, which distributions show clear relation to sediment types, include: *Amphorosphaeridium*? *multispinosum*, *Fibrocysta vectensis*, *F.* aff. *vectensis*, *Samlandia chlamydophora*, *Operculodinium tiara*, *Rottnestia borussica*, *Systematophora placacantha* and *Thalassiphora pelagica*. These species, which have been found mainly in turbiditic deposits, presumably have inhabited near shore environments.

RECYCLED DINOCYSTS

Pre-Eocene dinocyst species, mainly Middle Jurassic and Cretaceous have been found throughout the Folusz section. *Nannoceratopsis* spp. and *Ctenidodinium ornatum/combazii* represent the Middle Jurassic dinocysts. The Cretaceous dinocysts are: *Chatangiella ditissima*, *Cyclonephelium compactum*, *Florentinia* sp., *Pseudoceratium pelliferum*, *Surculosphaeridium*? *longifurcatum*, and *Trigonopyxidia ginella*.

Several dinocyst species, which have been recorded from the Folusz section, are known to have their latest appearances in higher latitudes in early-middle Eocene. Following species are presumably recycled: *Adnatosphaeridium multispinosum* (latest appearance in Priabonian; Powell 1992, Stover et al. 1996), *Adnatosphaeridium vittatum* (Lutetian highest occurrence in the North Sea; Bujak & Mudge 1994), *Apectodinium quinquelatum* (the genus *Apectodinium*, except of *Apectodinium homomorphum*, is believed to have its highest occurrence in Lower Eocene; e.g. Harland 1979), *Eatonicysta ursulae* (Lutetian latest appearance; Stover et al. 1996), *Diphyes pseudoficusoides* (Lutetian latest appearance; Bujak & Mudge 1994), *Areoligera sentosa* (the highest occurrence in the North Sea in lower Bartonian; Bujak & Mudge 1994), *Glaphyrocysta intricata* (the range of this species is limited to upper part of Lutetian-Bartonian; Powell 1992), *Heteraulacacysta porosa* (last appearance in the Middle Eocene; e.g. Stover et al. 1996), *Hystrichosphaeridium* sp. (the highest occurrence of the genus *Hystrichosphaeridium* is reported from the Lower Eocene; e.g. Stover et al. 1996), *Paucisphaeridium inversibuccinum*.

Flysch sedimentation is usually associated with increased recycling. It is very likely that at least a part of dinocysts that have been found in investigated section, especially in the Magura Formation, is recycled. However, lack of precise biostratigraphy of the Folusz section and frequent diachronous dinocyst events during late Eocene and early Oligocene makes distinguishing of the recycled specimens difficult. For example, Powell (1992) and Bujak (1994) report the highest occurrence of *Rottnestia borussica* from the top of Bartonian in the North Sea. This species was found in Mediterranean also in Lower Oligocene (Brinkhuis & Biffi 1993).

Among those species that occur in both the Szymbark shale and the Magura Formation, following could be treated as recycled in the latter lithostratigraphic unit: *Areosphaeridium michoudii* (the highest occurrence at the top of NP18 Zone of the North Sea; Bujak & Mudge 1994, and NP19-20 Zone in the Flysch Carpathians; Gedl 2004), *Lentinia serrata* (stratigraphic range of *Lentinia serrata* is limited to Eocene; Stover et al. 1996), *Rhombodinium perforatum* (stratigraphic top range of *Rhombodinium perforatum* is believed to be limited to Priabonian; e.g. Powell 1992).

Possibly also recycling may have caused occurrence of *Areosphaeridium diktyoplokum* in the Magura Formation. Continuous occurrence of this species is noted from the lower part of the Szymbark shale only (samples Fl1-Fl7). It occurs in this unit also in sample Fl20 taken from sediment that bears turbiditic features (Gedl & Leszczyński 2005). Its higher occurences within the Magura Formation are evidenced from samples Fl30 and Fl35 (mudflow deposits), and samples Fl36, Fl37, Fl40 representing turbidites.

SYSTEMATIC PART

In this chapter short descriptions of dinocyst species that are not included in Williams et al. (1998) are given. The dinocyst taxa are arranged per family and subfamily following the dinocyst classification proposed by

Fensome et al. (1993). Their distribution, as well of other dinocysts, in studied material is shown in Figure 3 and they are illustrated in Plates 1–18. Their alphabetic list is provided in the Appendix.

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 *Enneadocysta* Stover & Williams 1995

Type species: *Enneadocysta pectiniformis* (Gerlach 1961) Stover & Williams 1995

Enneadocysta aff. ***pectiniformis*** (Gerlach 1961) Stover & Williams 1995

Pl. 2, figs 6, 9–14

Material. This taxon occurs in the Szymbark shale only (Fig. 3:56). It is most abundant in the hemipelagites.

Description. Subspherical skolochorate cyst with intratabular processes and process complexes. Paracingulum free of processes. Solid intratabular processes single, slender, relatively long, occasionally two stems arise from common base. Processes distally licrate with very long branches, sporadically jointed at the ends forming a circulum. Branches with smooth inner margins and often denticulate outer margins. Intratabular process complexes on hypocystal paraplates distally connected by trabecula. Archeopyle apical, operculum free.

Genus *Oligosphaeridium* Davey & Williams 1966

Type species. *Oligosphaeridium complex* (White 1842) Davey & Williams 1966

***Oligosphaeridium*?** sp.

Pl. 4, figs 16, 17

Material. Two poorly preserved specimens questionably assigned to genus *Oligosphaeridium* were found in the basal part of the Szymbark shale (sample Fl4, Fig. 3:65).

Description. Subspherical chorate cyst with buccinate processes and smooth periphragm. Process margins aculeate. Archeopyle type uncertain due to cyst wrinkling, presumably apical.

Remarks. This taxon was tentatively included into the genus *Oligosphaeridium* on the basis of number and shape of the processes – archeopyle type was not stated unquestionably. Specimen of *Oligosphaeridium*? sp. resembles *Oligosphaeridium buciniferum* in shape of processes, and presumably is recycled.

Subfamily **Cribroperidinioideae** Fensome et al. (1993)

Genus *Diphyes* Cookson 1965

Type species. *Diphyes colligerum* (Deflandre & Cookson 1955) Cookson 1965

Diphyes aff. ***colligerum*** (Deflandre & Cookson 1955) Cookson 1965

Pl. 5, fig. 11

Material. One specimen was found in the basal part of the Wątkowa sandstone (sample Fl40, Fig. 3:147).

Remarks. This species differs from *Diphyes colligerum* by the shape of the large antapical process. The process is tubular and distally expanded with secate margin. Jan du Chêne (1987) described a similar antapical process by the species cf. *Diphyes* sp. 1.

Genus *Operculodinium* Wall 1967

Type species. *Operculodinium centrocarpum* (Deflandre & Cookson 1955) Wall 1967

Operculodinium aff. ***centrocarpum*** (Deflandre & Cookson 1955) Wall 1967

Pl. 3, fig. 23

Material. A single specimen was found in the basal part of the Szymbark shale (sample Fl4, Fig. 3:74).

Description. A species of *Operculodinium* characterised by its small size. Height of an ellipsoidal central body does not exceed 40 µm,

its width slightly exceeds 30 μm. Processes solid, tapering towards the ends, terminated with very tiny branching.

Genus *Thalassiphora* Eisenack & Gocht 1960

Type species. *Thalassiphora pelagica* (Eisenack 1954) Eisenack & Gocht 1960

Thalassiphora aff. ***pelagica*** (Eisenack 1954) Eisenack & Gocht 1960

Pl. 4, fig. 5

Material. A single specimen was found in the Zembrzyce beds (sample Fl36, Fig. 3:136).

Description. A species of *Thalassiphora* with densely reticulate periphragm.

Thalassiphora **sp. A**

Pl. 4, fig. 4

Material. Two specimens were found in the Szymbark shale (Fig. 3:98).

Description. A species of *Thalassiphora* characterised by the presence of infrequent acuminate, relatively short processes on periphragm.

Subfamily **GONYAULACOIDEAE** (Autonym)

Genus *Corrudinium* Stover & Evitt 1978

Type species. *Corrudinium incompositum* (Drugg 1970) Stover & Evitt 1978

Corrudinium**? sp. A**

Pl. 4, figs 6–9, 11, 12

Material. *Corrudinium*? sp. A has its lowest occurrence in the higher part of the Szymbark shale (sample Fl22, Fig. 3:107). It occurs higher up the section in the Zembrzyce beds and the Wątkowa sandstone.

Description. Large subspherical proximate cyst with thick cyst wall. Periphragm smooth, appressed with endophragm, except for where it forms blade-like, relatively short processes. Processes of variable width, from spine-like to septa-shaped, arranged linear, giving the appearance of paratabulation. Intratabular areas smooth or covered with loosely spaced tubercules. Archeopyle precingular, formed by loss of single paraplate, presumably 3". Operculum free.

Remarks. This species is provisionally included in the genus *Corrudinium*. Its general shape, development of incomplete septa and precingular 1P archeopyle resembles the species *Cerebrocysta poulsenii*, from which it differs by much larger dimension, presence of tubercules and less distinct pattern of septa, suggesting an incomplete paratabulation.

Genus *Impagidinium* Stover & Evitt 1978

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

Impagidinium **sp. A**

Pl. 8, figs 1–6

Material. This species has a continuous range in hemipelagites of the Szymbark shale up to sample Fl15(Fig. 3:18). Its higher single occurrences are noted from the Lower Oligocene part of the section.

Description. Small spherical to ellipsoidal species of *Impagidinium* with smooth cyst wall and relatively high parasutural septa of equal height. Distal margins of septa smooth, thickenings in junction points evident.

Remarks. Similar species of *Impagidinium* described as *Impagidinium* sp. cf. *I.* sp. B of Head and Norris (1989) was found in Oligocene of the Podhale region (Gedl 2000).

Impagidinium **sp. B**

Pl. 8, figs 7–12, 14

Material. *Impagidinium* sp. B was found mainly in the hemipelagites of the Szymbark shale (up to sample Fl22, Fig. 3:19). One specimen was found in the mud-flows from the basal part of the Lower Oligocene Zembrzyce beds.

Description. Ellipsoidal proximochorate cyst with smooth cyst wall. Parasutural ridges high in relation to central body diameter (app. 1/3 to 1/2 of the diameter). The ridges are characterized by various height (highest in junction points, slightly concave between) and serrate to denticulate distal margins.

Impagidinium sp. C

Pl. 8, fig. 13

Material. A single specimen was found in hemipelagite from the lower part of the Szymbark shale (sample Fl12, Fig. 3:96).

Description. A species of *Impagidinium* characterized by pear-shaped central body, epicyst much longer than hypocyst, and strongly concave septa among the precingular and postcingular paraplates.

Impagidinium sp. D

Pl. 7, fig. 15

Material. One specimen of this species was found in the Zembrzyce beds (sample Fl36, Fig. 3:135).

Description. A species of *Impagidinium* characterized by shagreenate to very densely scabrate cyst wall. Parasutural septa low.

Genus *Rottnestia* Cookson & Eisenack 1961

Type species. *Rottnestia borussica* (Eisenack 1954) Cookson & Eisenack 1961

Rottnestia aff. *borussica* (Eisenack 1954) Cookson & Eisenack 1961

Pl. 6, figs 9, 10, 15

Material. Three specimens were found in studied section (Fig. 3:94).

Remarks. This species differs from *Rottnestia borussica* by the lack of apical horn; it may be also very poorly developed. The cyst is thus hypocavate but it has all the other features of *Rottnestia*, i.e. the parasutural septa and trifurcate gonal processes.

Genus *Tectatodinium* Wall 1967

Type species. *Tectatodinium pellitum* Wall 1967

Tectatodinium aff. *pellitum* Wall 1967

Pl. 10, figs 5–9

Material. This species was found in the Szymbark shale and the Zembrzyce beds. It occurs within both units in hemipelagites except of the turbiditic sample Fl37, (Fig. 3:37).

Description. Spherical cyst with very thin and smooth pedium (inner layer; see: Head 1994, p. 295, text-fig. 3) covered by distally open irregular luxuria (outer layer). Luxuria composed of slender, solid hair-like fibres, closely spaced giving the felt-like impression. Archeopyle precingular, single paraplate involved.

Remarks. This species differs from *Tectatodinium pellitum* in having thinner luxuria composed of more rigid and more isolated fibres easily distinguishable under light microscopy. *Tectatodinium pellitum* has more homogenous luxuria.

Remarks on palaeoenvirionment. Occurrence of *Tectatodinium* aff. *pellitum* almost exclusively in hemipelagic sediments implies oceanic palaeoenvironmental preferences of this species.

Subfamily Uncertain

Genus *Fibrocysta* Stover & Evitt 1978

Type species. *Fibrocysta bipolaris* (Cookson & Eisenack 1965) Stover & Evitt 1978

Fibrocysta aff. *vectensis* (Eaton 1976) Stover & Evitt 1978

Pl. 3, fig. 10

Material. This species occurs in one turbiditic sample from the Szymbark shale and in two samples from the basal part of the Zembrzyce beds (Fl35 and Fl36; Fig. 3:84).

Remarks. These specimens have no prominent apical process but all the other features are typical for this species.

Genus *Pyxidinopsis* Habib 1976

Type species. *Pyxidinopsis challengerensis* Habib 1976

Pyxidinopsis sp. A

Pl. 10, fig. 10

Material. A single specimen was found in the upper part of the Szymbark shale (sample Fl22, Fig. 3:104).

Descritpion. Subspherical cyst with cyst wall covered by tiny granules, which often tend to fuse. Cyst wall has reticulate-vermiculate appearence in planar view; the granules appear to be positive elements at the cross-section. Archeopyle precingular.

Pyxidinopsis? sp. B

Pl. 10, fig. 11

Material. A single specimen was found in the uppermost part of the Szymbark shale (sample Fl24, Fig. 3:109).

Description. Spherical cyst with thick cyst wall composed of densely spaced, interconnected proximally solid cones. Cones height equal to their base width. Archeopyle precingular.

Pyxidinopsis sp. C

Pl. 10, fig. 13

Material. A single specimen was found in the mud flows of the basal part of the Zembrzyce beds (sample Fl30, Fig. 3:114).

Description. Relatively large spherical cyst with densely rugulate cyst wall. Archeopyle precingular.

Pyxidinopsis sp. D

Pl. 10, fig. 15

Material. A single specimen was found in hemipelagite from the basal part of the Zembrzyce beds (sample Fl33, Fig. 3:126).

Description. Spherical cyst with thick wall composed of solid tiny, irregular, closely spaced cones often fused with each other forming low ribs. The latter form of positive ornament gives rugulate appearence in planar view. Archeopyle precingular.

Pyxidinopsis sp. E

Pl. 10, fig. 14

Material. A single specimen was found in the basal part of the Zembrzyce beds (sample Fl36, Fig. 3:128).

Description. Spherical cyst with relatively thick, densely reticulate cyst wall. Muri of equal height, together with small dimensions of lumina giving the smooth appearence of the cyst wall. Lumina very small, circular in outline, densely spaced, not interconnecting with each other. Archeopyle precingular.

Family **Areoligeraceae** Evitt 1963

Genus *Adnatosphaeridium* Williams & Downie 1966

Type species. *Adnatosphaeridium vittatum* Williams & Downie 1966

Adnatosphaeridium sp. A

Pl. 11, fig. 16

Material. A single specimen of this species was found in turbiditic deposit from the middle part of the Zembrzyce beds (sample Fl37, Fig. 3:140).

Description. Elongate ellipsoidal skolochorate cyst with intratabular processes connected distally by ribbonlike trabeculae. Archeopyle apical, operculum free.

Remarks. General shape of the central body and processes resemble the genus *Distatodinium*. The latter genus, however, never possesses processes connected distally to such a degree.

Genus *Glaphyrocysta* Stover & Evitt 1978

Type species. *Glaphyrocysta retiintexta* (Cookson 1965) Stover & Evitt 1978

Glaphyrocysta sp. A

Pl. 11, fig. 5

Material. A single specimen of this species was found in the turbiditic sample Fl4 from the lower part of the Szymbark shale (Fig. 3: 724).

Description. A species of *Glaphyrocysta* with solid arcuate processes connected distally by non-perforate trabeculae. Central body lenticular, processes arranged in peripheral areas.

Remarks. Similar species of *Glaphyrocysta* with non-perforate trabeculae was found in Upper Oligocene of the Podhale region (Gedl 2000).

Glaphyrocysta sp. B

Pl. 11, fig. 3

Material. A single specimen of this species was found in the basal part of the Zembrzyce beds (sample Fl36, Fig. 3:131).

Description. A species of *Glaphyrocysta* with short processes of equal height, united distally by trabeculae. Trabeculae show only minor perforations in its proximal parts.

Suborder **GONIODOMINEAE** Fensome et al. 1993
Family **GONIODOMACEAE** Lindemann 1928
Subfamily **GONIODOMOIDEAE** (Autonym)

Genus *Heteraulacacysta* Drugg & Loeblich Jr 1967

Type species. *Heteraulacacysta campanula* Drugg & Loeblich Jr 1967

Heteraulacacysta sp. A

Pl. 13, figs 12, 13, 18

Material. The occurrence of this species is limited to the basal part of the Zembrzyce beds (samples Fl33, Fl35 and Fl36; Fig. 3:118).

Description. A small species of *Heteraulacacysta* with very poorly developed parasutural septa. Rugulate ornamentation of the autophragm developed.

Subfamily **PYRODINIOIDEAE** Fensome et al. (1993)

Genus *Dinopterygium* Deflandre 1935

Type species. *Dinopterygium cladoides* Deflandre 1935

Dinopterygium sp. A

Pl. 13, figs 10, 11

Material. *Dinopterygium* sp. A occurs in lower part of the Szymbark shale (samples Fl4 and Fl7) and in the middle part of the Zembrzyce beds in sample Fl37; (Fig. 3:82).

Description. A species of *Dinopterigium* characterized by the presence of very low, often elongated irregular verruca in the intratabular areas. Verruca occasionally arranged in rows along the parasutural septa and generally grouped in intratabular clusters. Parasutural septa very low.

Remarks. This species, similarly as the *Dinopterygium* sp. B, is included in the genus *Dinopterygium* since the positive structures show intratabular arrangement. *Heteraulacacysta*, a very similar genus occurring in Folusz section, has the positive ornamentation structures, if present, distributed uniformly.

Dinopterygium sp. B

Pl. 13, fig. 14

Material. A single specimen was found in the middle part of the Zembrzyce beds (sample Fl37, Fig. 3:139).

Description. A species of *Dinopterigium* with gemmate intratabular areas. Gemma form clusters in central parts of intratabular areas; their shape reflect the shape of paraplates.

Remarks. See remarks by *Dinopterygium* sp. A.

Genus *Homotryblium* Davey & Williams 1966

Type species. *Homotryblium tenuispinosum* Davey & Williams 1966

Homotryblium? sp. A

Pl. 13, figs 1–9

Material. It occurs in the topmost part of the Szymbark shale, the Zembrzyce beds and the lower part of the Wątkowa sandstone (Fig. 3:112).

Description. Subspherical chorate cyst with intratabular hollow, striate, distally open processes and tubercules at the central body. Cingular processes posses the same features as the others being only smaller. Archeopyle variable, apical or epicystal. Operculum free.

Remarks. Specimens of *Homotryblium*? sp. A are represented by two morphotypes differing by archeopyle type: apical and precingular. All the other features, i.e. sculpture of the cyst wall, shape and striation of the processes are the same. Therefore, they are believed to represent the same species. This taxon is tentatively assigned to the genus *Homotry-*

blium, although it presumably represents an undescribed taxon characterized by variable archeopyle.

Remarks. Similar specimens were found in the Upper Eocene of central and northern Italy by Brinkhuis (1992) and Brinkhuis and Biffi (1993). These authors referred them to *Homotryblium* sp. (specimens with epicystal archeopyle) and *Hystrichokolpoma* sp. (specimens with apical archeopyle). *Homotryblium*? sp. A occurs in the Folusz section in its Oligocene part only.

Suborder **UNCERTAIN**
Family **UNCERTAIN**

Genus *Heterosphaeridium* Cookson & Eisenack 1968

Type species. *Heterosphaeridium conjunctum* Cookson & Eisenack 1968

***Heterosphaeridium* sp. A**

Pl. 11, fig. 11

Material. This species was found only in turbidite from basal part of the Szymbark shale (sample Fl4, Fig. 3:70).

Description. Lenticular chorate cyst with apical archeopyle and uniformly distributed processes. Slender processes are thickest at the base, getting narrow towards the top, terminated with bifurcation and, less common, trifurcation or acuminate. Processes in sulcal zone short, acuminate or simply branched. Archeopyle apical, archeopyle suture zigzag, parasulcal notch offset, operculum free.

Genus *Membranilarnacia* Eisenack 1963

Type species. *Membranilarnacia leptoderma* (Cookson & Eisenack 1958) Eisenack 1963.

***Membranilarnacia*? sp. A**

Pl. 1, figs 10–13

Material. This species occurs in the Folusz section in the lower part of the Szymbark shale (samples Fl4 and Fl7) and in the lower part of the Zembrzyce beds in sample Fl32; (Fig. 3:61).

Description. Small chorate cyst with apical archeopyle and processes connected by periphragm. Processes solid and occasionally presumably hollow distally terminated with platform-like structure giving the support for the periphragm. Processes relatively long, from ½ to 1 of the central body diameter. Periphragm not always complete, presumably due to poor state of preservation.

Remarks. This species was tentatively included into the genus *Membranilarnacia* on the basis of apical archeopyle and the presence of the periphragm supported by processes. However, the poor state of preservation and small dimensions of the cysts make often impossible to recognise the diagnostic features (e.g. the type of archeopyle and not always completely developed periphragm).

Order **PERIDINIALES** Haeckel 1894
Suborder **PERIDINIINEAE** (Autonym)
Family **PERIDINIACEAE** Ehrenberg 1831
Subfamily **PALAEOPERIDINIOIDEAE** (Vozzhennikova 1961) Bujak & Davies 1983

Genus *Phthanoperidinium* Drugg & Loeblich Jr. 1967

Type species. *Phthanoperidinium amoenum* Drugg & Loeblich Jr. 1967

Phthanoperidinium* aff. *amiculum Liengjarern, Costa & Downie 1980

Pl. 17, fig. 30

Material. *Phthanoperidinium* aff. *amiculum* was found in the mud flow and overlying deposits from the basal part of the Zembrzyce beds (samples Fl35 and Fl36 respecticely; Fig. 3:121).

Remarks. This species is characterised by very indistinct sutural ridges. No intratabular ornamentation was observed.

Subfamily **DEFLANDREOIDEAE** Bujak & Davies 1983

Genus *Deflandrea* Eisenack 1938

Type species. *Deflandrea phosphoritica* Eisenack 1938

Deflandrea spp.

Pl. 15, figs 1–15

Material. *Deflandrea* spp. occur throughout the whole section. However, representatives of this genus never occur frequently (Fig. 3:9).

Remarks. Representatives of this genus were determined at the genus level. These are mainly bicavate to circumcavate, occasionally cornucavate species of *Deflandrea*. One symmetrically placed apical horn and two antapical horns (of which one is usually slightly reduced) are generally sharply pointed (species at Plate 15, fig. 12 has blunt horn terminations). Endocyst is commonly smooth, rarely finely granular (Pl. 15, figs 1, 2). No isolated forms of relief like thick tubercules (known by *Deflandrea heterophlycta*) were observed on endocyst. Pericyst rather thin, smooth (Pl. 15, fig. 8) or finely granulate (Pl. 15, figs 1, 2, 11, 15). Paratabulation expressed mainly by paracingulum (equatorial depression band) and parasulcus. Less frequently small spines are grouped in intratabular areas separated by smooth pandasutural bands. Intercalary archeopyle is always wide.

Occurrence in Polish Carpathians. Genus *Deflandrea* is widely distributed in Eocene-Oligocene deposits of Polish Carpathians. It occurs as a very frequent genus among the dinocysts from the Upper Eocene and Oligocene. Numerous representatives of this genus were found in the Upper Eocene-Lower Oligocene of Leluchów (Gedl 2004). *Deflandrea* spp. are among the most frequent dinocysts in the Oligocene Podhale Flysch where they occasionally occur in almost monospecific assemblages (Gedl 2000). Dominance of this genus is also often observed in the Lower Oligocene strata of Outer Carpathians (Gedl 2001).

Subfamily **WETZELIELLOIDEAE** (Vozzhennikova 1961) Bujak & Davies 1983

Genus *Rhombodinium* Gocht 1955

Type species. *Rhombodinium draco* Gocht 1955

Rhombodinium **sp. A**

Pl. 16, fig. 7

Material. A single specimen was found in deposits overlying the mud flows from the basal part of the Zembrzyce beds (sample Fl36, Fig. 3:133).

Description. A species of *Rhombodinium* characterized by densely folded periphragm. Apical and lateral horns well developed, one antapical horn reduced.

Remarks. Similar species of *Rhombodinium* with folded periphragm was described from Oligocene Podhale Flysch (Gedl 2000).

Family **CONGRUENTIDIACEAE** Schiller 1935
Subfamily **CONGRUENTIDIOIDEAE** (Autonym)

Genus *Selenopemphix* Benedek 1972

Type species. *Selenopemphix nephroides* Benedek 1972

Selenopemphix aff. ***selenoides*** Benedek 1972

Pl. 17, figs 24–27

Material. This species occurs in the lower part of the Szymbark shale (samples Fl2 and Fl4; Fig. 3:42).

Remarks. This species resembles *Selenopemphix selenoides* in general shape, especially in its crescentic appearance in polar view. It differs by the lack of denticulate crests on paracingular margins.

Selenopemphix **sp. A**

Pl. 17, fig. 17

Material. A single specimen was found in the deposits overlying the mud flows from the basal part of the Zembrzyce beds (sample Fl33, Fig. 3:124).

Description. Almost circular (in polar view) species of *Selenopemphix* with deeply incised sulcal area and serrate distal ends of paracingular margins.

SUMMARY

1. 147 dinocyst taxa have been recognized in the Szymbark shale unit and the Magura Formation (late Eocene – early Oligocene) exposed at Folusz.

2. The majority of dinocysts found at Folusz represents the order Gonyaulacales. Infrequent representatives of the order Peridiniales belong to subfamilies Palaeoperidinioideae, Deflandreoideae, Wetzelielloideae and Congruentidioideae. Moreover, except for the genus *Deflandrea*, the Peridiniales are represented by single or very rare specimens.

3. Several dinocyst species have been left in open nomenclature

4. The co-occurrence of *Areosphaeridium diktyoplokum*, *A. michoudii*, and *Rhombodinium perforatum* in the lower part of the Szymbark shale suggest a late Eocene age. The Eocene-Oligocene boundary has not been precisely established in the investigated section. The uppermost part of the Szymbark shale above the lowest occurrence of *Areoligera*? *semicirculata*, and overlying Magura Formation are of early Oligocene age.

5. *Wetzeliella gochtii*, *Reticulatosphaera actinocoronata*, and *Homotryblium vallum*, dinocyst species known from Oligocene strata of higher latitudes, have been found in the Upper Eocene deposits exposed at Folusz. This indicates diachronism of their first appearances.

6. On the basis of distribution in turbiditic and hemipelagites, onshore-offshore preferences of several dinocyst taxa are suggested. These treated as near shore species include: *Areoligera* spp., *Areosphaeridium michoudii*, *Enneadocysta pectiniformis*, *Glaphyrocysta* spp., *Homotryblium aculeatum*, *H. tenuispinosum*, *Polysphaeridium* spp., and the representatives of the Wetzelielloideae. Following dinocysts found in hemipelagites are treated as offshore: *Cerebrocysta bartonensis*, *Corrudinium incompositum*, *Enneadocysta* aff. *pectiniformis*, *Gelatia inflata*, *Impagidinium* spp., *Lentinia serrata*, and *Rhombodinium perforatum*.

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APPENDIX

An alphabetical listing of dinocyst taxa found in the Folusz section is provided below. Numbers in parentheses refer to Figure 3; they are followed by reference to appropriate photomicrographs in Plates 1 to 18. Several poorly preserved specimens that were not determined below generic level are indicated with "sp.". "Spp." stands for a genus represented by several not determined species. Asterisks indicate the pre-Eocene taxa.

Achomosphaera alcicornu (Eisenack 1954) Davey & Williams 1966 (Fig. 3:123)

Achomosphaera ramulifera (Deflandre 1937) Evitt 1963 (Fig. 3:50; Pl. 6, figs 1–3)

Achomosphaera sagena Davey & Williams 1966 (Fig. 3:142)

Adnatosphaeridium multispinosum Williams & Downie 1966 (Fig. 3:120; Pl. 11, fig. 15)

Adnatosphaeridium vittatum Williams & Downie 1966 (Fig. 3:76; Pl. 11, figs 10, 14)

Adnatosphaeridium sp. A (p. 38, Fig. 3:140; Pl. 11, fig. 16)

Amphorosphaeridium? *multispinosum* (Davey & Williams 1966) Sarjeant 1981 (Fig. 3:81; Pl. 3, figs 17, 18, 22)

Apectodinium quinquelatum (Williams & Downie 1966) Costa & Downie 1979* (Fig. 3:144; Pl. 18, fig. 10)

Areoligera semicirculata (Morgenroth 1966) Stover & Evitt 1978 (Fig. 3:111; Pl. 11, fig. 12)

Areoligera sentosa Eaton 1976 (Fig. 3:67; Pl. 12, figs 2, 4, 6)

Areoligera undulata Eaton 1976 (Fig. 3:53; Pl. 12, figs 1, 3, 5, 7)

Areoligera sp. (Fig. 3:99; Pl. 11, fig. 13)

Areosphaeridium diktyoplokum (Klumpp 1953) Eaton 1971 (Fig. 3:7; Pl. 1, figs 1, 6)

Areosphaeridium michoudii Bujak 1994 (Fig. 3:6; Pl. 1, figs 3–5, 7–9)

Cerebrocysta bartonensis Bujak 1980 (Fig. 3:11; Pl. 10, figs 1–4)

Charlesdowniea clathrata (Eisenack 1938) Lentin & Vozzhennikova 1989 (Fig. 3:64; Pl. 16, figs 1, 4)

Charlesdowniea coleothrypta (Williams & Downie 1966) Lentin & Vozzhennikova 1989 (Fig. 3:55; Pl. 16, figs 2, 3)

Charlesdowniea sp. (Fig. 3:90)

Chatangiella ditissima (McIntyre 1975) Lentin & Williams 1976* (Fig. 3:95; Plate 18, fig. 6)

Cordosphaeridium funiculatum Morgenroth 1966 (Fig. 3:26; Pl. 3, figs 11, 12)

Cordosphaeridium inodes (Klumpp 1953) Eisenack 1963 (Fig. 3:110; Pl. 3, fig. 6)

Cordosphaeridium minimum (Morgenroth 1966) Benedek 1972 (Fig. 3:122; Pl. 3, figs 13, 14)

Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978 (Fig. 3:12; Pl. 7, figs 1–5)

Corrudinium? sp. A (p. 36, Fig. 3:107; Pl. 4, figs 6–9, 11, 12)

Cribroperidinium tenuitabulatum (Gerlach 1961) Helenes 1984 (Fig. 3:79; Pl. 4, fig. 15)

*Ctenidodinium ornatum/combazii** (p. 34, Fig. 3:75; Pl. 18, fig. 1)

Cyclonephelium compactum Deflandre & Cookson 1955* (Fig. 3:105; Pl. 1, fig. 14)

Dapsilidinium multispinosum (Davey 1974) Bujak, Downie, Eaton & Williams 1980 (Fig. 3:125; Pl. 5, fig. 6)

Dapsilidinium pastielsii (Davey & Williams 1966) Bujak, Downie, Eaton & Williams 1980 (Fig. 3: 146; Pl. 5, fig. 5)

Dapsilidinium pseudocolligerum (Stover 1977) Bujak, Downie, Eaton & Williams 1980 (Fig. 3:59; Pl. 5, figs 1–4)

Deflandrea spp. (p. 41, Fig. 3:9; Pl. 15, figs 1–15)

Dinopterygium sp. A (p. 39, Fig. 3:82; Pl. 13, figs 10, 11)

Dinopterygium sp. B (p. 39, Fig. 3:139; Pl. 13, fig. 14)

Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965 (Fig. 3:93; Pl. 5, figs 7–10)

Diphyes aff. *colligerum* (Deflandre & Cookson 1955) Cookson 1965 (p. 35, Fig. 3:147; Pl. 5, fig. 11)

Diphyes pseudoficusoides Bujak 1994 (Fig. 3:100; Pl. 5, fig. 12)

Distatodinium ellipticum (Cookson 1965) Eaton 1976 (Fig. 3:39; Pl. 5, figs 20–22)

Dracodinium laszczynskii Gedl 1995 (Fig. 3:17; Pl. 16, fig. 13)

Eatonicysta ursulae (Morgenroth 1966) Stover & Evitt 1978 (Fig. 3:115; Pl. 1, fig. 15)

Enneadocysta arcuata (Eaton 1971) Stover & Williams 1995 (Fig. 3:86; Pl. 2, figs 4, 7)

Enneadocysta fenestrata (Bujak 1976) Stover & Williams 1995 (Fig. 3:60; Pl. 2, fig. 8)

Enneadocysta multicornuta (Eaton 1971) Stover & Williams 1995 (Fig. 3:145; Pl. 2, fig. 5)

Enneadocysta pectiniformis (Gerlach 1961) Stover & Williams 1995 (Fig. 3:54; Pl. 2, figs 1–3)

Enneadocysta aff. *pectiniformis* (Gerlach 1961) Stover & Williams 1995 (p. 35, Fig. 3:56; Pl. 2, figs 6, 9–14)

Fibrocysta vectensis (Eaton 1976) Stover & Evitt 1978 (Fig. 3:89)

Fibrocysta aff. *vectensis* (Eaton 1976) Stover & Evitt 1978 (p. 37, Fig. 3:84; Pl. 3, fig. 10)

Florentinia sp.* (Fig. 3:134; Pl. 18, fig. 9)

Gelatia inflata Bujak 1984 (Fig. 3:20; Pl. 10, fig. 16)

Glaphyrocysta intricata (Eaton 1971) Stover & Evitt 1978 (Fig. 3:117; Pl. 11, figs 8, 17)

Glaphyrocysta semitecta (Bujak 1980) Lentin & Williams 1981 (Fig. 3:57; Pl. 11, figs 1, 2, 4, 6, 7)

Glaphyrocysta sp. A (p. 38, Fig. 3:72; Pl. 11, fig. 5)

Glaphyrocysta sp. B (p. 39, Fig. 3:131; Pl. 11, fig. 3)

Glaphyrocysta sp. (Fig. 3:137; Pl. 11, fig. 9)

Heteraulacacysta? *leptalea* Eaton 1976 (Fig. 3:68; Pl. 13, figs 19–23)

Heteraulacacysta porosa Bujak 1980 (Fig. 3:80; Pl. 13, figs 15–17)
Heteraulacacysta sp. A (p. 39, Fig. 3:118; Pl. 13, figs 12, 13, 18)
Heterosphaeridium sp. A (p. 40, Fig. 3:70; Pl. 11, fig. 11)
Homotryblium aculeatum Williams 1978 (Fig. 3:38; Pl. 14, figs 1–3)
Homotryblium caliculum Bujak 1980 (Fig. 3:66; Pl. 14, fig. 6)
Homotryblium plectilum Drugg & Loeblich 1967 (Fig. 3:48; Pl. 14, figs 4, 5)
Homotryblium tenuispinosum Davey & Williams 1966 (Fig. 3:4; Pl. 14, figs 7–9)
Homotryblium vallum Stover 1977 (Fig. 3:34; Pl. 14, figs 10–14)
Homotryblium? sp. A (p. 39, Fig. 3:112; Pl. 13, figs 1–9)
Hystrichokolpoma cinctum Klumpp 1953 (Fig. 3:88)
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955 (Fig. 3:45; Pl. 5, figs 13, 15, 16)
Hystrichokolpoma salacia Eaton 1976 (Fig. 3:63; Pl. 5, fig. 14)
Hystrichosphaeridium sp. (Fig. 3:130; Pl. 1, fig. 16)
Impagidinium aculeatum (Wall 1967) Lentin & Williams 1981 (Fig. 3:16; Pl. 7, figs 6–9)
Impagidinium brevisulcatum Michoux 1985 (Fig. 3:33; Pl. 9, figs 7–12)
Impagidinium dispertitum (Cookson & Eisenack 1965) Stover & Evitt 1978 (Fig. 3:15; Pl. 7, figs 10, 12, 13, 16)
Impagidinium gibrense Michoux 1985 (Fig. 3:92; Pl. 7, fig. 14)
Impagidinium pallidum Bujak 1984 (Fig. 3:43; Pl. 8, figs 15–17)
Impagidinium velorum Bujak 1984 (Fig. 3:25; Pl. 7, figs 17, 18)
Impagidinium sp. A (p. 36, Fig. 3:18; Pl. 8, figs 1–6)
Impagidinium sp. B (p. 36, Fig. 3:19; Pl. 8, figs 7–12, 14)
Impagidinium sp. C (p. 37, Fig. 3:96; Pl. 8, fig. 13)
Impagidinium sp. D (p. 37, Fig. 3:135; Pl. 7, fig. 15)
Lejeunecysta fallax (Morgenroth 1966) Artzner & Dörhöfer 1978 (Fig. 3:58; Pl. 17, fig. 4)
Lejeunecysta hyalina (Gerlach 1961) Artzner & Dörhöfer 1978 (Fig. 3:85; Pl. 17, 5)
Lejeunecysta lata Biffi & Grignani 1983 (Fig. 3:132; Pl. 17, fig. 7)
Lejeunecysta tenella (Morgenroth 1966) Wilson & Clowes 1980 (Fig. 3:28; Pl. 17, fig. 8)
Lejeunecysta sp. (Fig. 3:49; Pl. 17, figs 9, 10)
Lentinia serrata Bujak 1980 (Fig. 3:5; Pl. 17, figs 1–3)
Leptodinium membranigerum Gerlach 1961 (Fig. 3:36; Pl. 7, fig. 11)
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967 (Fig. 3:31; Pl. 14, figs 17–19)
Lingulodinium pycnospinosum (Benedek 1972) Stover & Evitt 1978 (Fig. 3:97; Pl. 14, figs 20, 21)
Melitasphaeridium asterium (Eaton 1976) Bujak, Downie, Eaton & Williams 1980 (Fig. 3:71; Pl. 10, figs 17–19)
Melitasphaeridium pseudorecurvatum (Morgenroth 1966) Bujak, Downie, Eaton & Williams 1980 (Fig. 3:44; Pl. 10, figs 20–23)
Membranilarnacia? sp. A (p. 40, Fig. 3:61; Pl. 1, figs 10–13)
Membranophoridium aspinatum Gerlach 1961 (Fig. 3: 32; Pl. 12, figs 8–13)
Nannoceratopsis dictyambonis Riding 1984* (Fig. 3: 141; Pl. 18, fig. 2)
Nannoceratopsis gracilis Alberti 1961* (Fig. 3:40; Pl. 18, figs 3, 4)
Nematosphaeropsis labyrinthus (Ostenfeld 1903) Reid 1974 (Fig. 3:41; Pl. 6, figs 16–18)
Oligosphaeridium? sp. (p. 35, Fig. 3:65; Pl. 4, figs 16, 17)
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967 (Fig. 3:13; Pl. 3, figs 1–9)
Operculodinium aff. *centrocarpum* (Deflandre & Cookson 1955) Wall 1967 (p. 35, Fig. 3:74; Pl. 3, fig. 23)
Operculodinium deconinckii Lentin & Williams 1989 (Fig. 3:91; Pl. 3, fig. 24)
Operculodinium? *hirsutum* (Ehrenberg 1838) Lentin & Williams 1973 (Fig. 3:106; Pl. 3, fig. 19)
Operculodinium microtriainum (Klumpp 1953) Islam 1983 (Fig. 3:30; Pl. 3, figs 20, 21)
Operculodinium tiara (Klumpp 1953) Stover & Evitt 1978 (Fig. 3:62)
Palaeocystodinium golzowense Alberti 1961 (Fig. 3:47; Pl. 17, fig. 31)
Paucisphaeridium inversibuccinum (Davey & Williams 1966) Bujak 1980 (Fig. 3:113; Pl. 5, figs 17–19)
Pentadinium? *circumsutum* (Morgenroth 1966) Stover & Evitt 1978 (Fig. 3:138; Pl. 9, fig. 3)
Pentadinium laticinctum Gerlach 1961 (Fig. 3:14; Pl. 9, figs 4, 6)
Pentadinium laticinctum granulatum Gocht 1969 (Fig. 3:22; Pl. 9, fig. 5)
Phelodinium sp. (Fig. 3:27; Pl. 17, figs 28, 29)
Phthanoperidinium amiculum Liengjarern, Costa & Downie 1980 (Fig. 3:127; Pl. 17, fig. 6)
Phthanoperidinium aff. *amiculum* Liengjarern, Costa & Downie 1980 (p. 40, Fig. 3:121; Pl. 17, fig. 30)
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellström 1971 (Fig. 3:2; Pl. 17, fig. 12)
Polysphaeridium subtile Davey & Williams 1966 (Fig. 3:21; Pl. 14, figs 15, 16)
Polysphaeridium zoharyi (Rossignol 1962) Bujak, Downie, Eaton & Williams 1980 (Fig. 3:116)
Pseudoceratium pelliferum Gocht 1957* (Fig. 3:108; Pl. 18, fig. 5)
Pyxidinopsis psilata (Wall & Dale 1973) Head 1994 (Fig. 3:119; Pl. 10, fig. 12)
Pyxidinopsis sp. A (p. 37, Fig. 3:104; Pl. 10, fig. 10)
Pyxidinopsis? sp. B (p. 38, Fig. 3:109; Pl. 10, fig. 11)
Pyxidinopsis sp. C (p. 38, Fig. 3:114; Pl. 10, fig. 13)
Pyxidinopsis sp. D (p. 38, Fig. 3:126; Pl. 10, fig. 15)
Pyxidinopsis sp. E (p. 38, Fig. 3:128; Pl. 10, fig. 14)
Reticulatosphaera actinocoronata (Benedek 1972) Bujak & Matsuoka 1986 (Fig. 3:73; Pl. 10, figs 24–29)
Rhombodinium draco Gocht 1955 (Fig. 3:129; Pl. 16, figs 5, 6)

Rhombodinium freienwaldense (Gocht 1955) Costa & Downie 1979 (Fig. 3:24; Pl. 16, fig. 8)

Rhombodinium perforatum (Jan du Chêne & Châteauneuf 1975) Lentin & Williams 1977 (Fig. 3:3; Pl. 16, figs 9, 11, 12, 16)

Rhombodinium sp. A (p. 41, Fig. 3:133; Pl. 16, fig. 7)

Rottnestia borussica (Eisenack 1954) Cookson & Eisenack 1961 (Fig. 3:78; Pl. 6, figs 11, 14)

Rottnestia aff. *borussica* (Eisenack 1954) Cookson & Eisenack 1961 (p. 37, Fig. 3:94; Pl. 6, figs 9, 10, 15)

Samlandia chlamydophora Eisenack 1954 (Fig. 3:103; Pl. 4, figs 13, 14, 18)

Selenopemphix armata Bujak 1980 (Fig. 3:83; Pl. 17, figs 13–16)

Selenopemphix coronata Bujak 1980 (Fig. 3:10; Pl. 17, figs 22, 23)

Selenopemphix nephroides Benedek 1972 (Fig. 3:8; Pl. 17, fig. 11)

Selenopemphix aff. *selenoides* Benedek 1972 (p. 41, Fig. 3:42; Pl. 17, figs 24–27)

Selenopemphix sp. A (p. 41, Fig. 3:124; Pl. 17, fig. 17)

Spiniferites bentorii (Rossignol 1964) Wall & Dale 1970 (Fig. 3:46; Pl. 6, fig. 13)

Spiniferites membranaceous (Rossignol 1964) Sarjeant 1970 (Fig. 3:29; Pl. 6, fig. 8)

Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 (Fig. 3:23; Pl. 9, figs 1, 2)

Spiniferites ramosus (Ehrenberg 1838) Loeblich & Loeblich 1966 s.l. (Fig. 3:1; Pl. 6, figs 4–7, 12)

Surculosphaeridium? *longifurcatum* (Firtion 1952) Davey, Downie, Sarjeant & Williams 1966* (Fig. 3: 87; Pl. 18, fig. 7)

Systematophora placacantha (Deflandre & Cookson 1955) Davey, Downie, Sarjeant & Williams 1966 (Fig. 3:51; Pl. 1, figs 2, 17)

Tectatodinium aff. *pellitum* Wall 1967 (p. 37, Fig. 3: 37; Pl. 10, figs 5–9)

Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960 (Fig. 3:69; Pl. 4, figs 1–3)

Thalassiphora aff. *pelagica* (Eisenack 1954) Eisenack & Gocht 1960 (p. 36, Fig. 3:136; Pl. 4, fig. 5)

Thalassiphora sp. A (p. 36, Fig. 3:98; Pl. 4, fig. 4)

Tityrosphaeridium cantharellus (Brosius 1963) Sarjeant 1981 (Fig. 3:52; Pl. 3, fig. 15)

Trigonopyxidia ginella (Cookson & Eisenack 1960) Downie & Sarjeant 1965* (Fig. 3:35; Pl. 18, fig. 8)

Turbiosphaera symmetrica Bujak 1980 (Fig. 3:143; Pl. 4, fig. 10)

Wetzeliella gochtii Costa & Downie 1976 (Fig. 3:102; Pl. 16, fig. 14)

Wetzeliella symmetrica Weiler 1956 (Fig. 3:77; Pl. 16, fig. 15)

Wilsonidium intermedium (Cookson & Eisenack 1961) Costa & Downie 1979 (Fig. 3:101; Pl. 16, fig. 10)

PLATES

Scale bar at first photomicrograph of every plate indicates 25 μm and refers to all other photomicrographs. Slide code and England Finder references are given.

Plate 1

1, 6. *Areosphaeridium diktyoplokum*: 1 – Fl2b (Q40.4); 6 – operculum, Fl4b (Y32.2)

2, 17. *Systematophora placacantha*: 2 – Fl4a (L36.2); 17 – Fl20a (D32)

3–5, 7–9. *Areosphaeridium michoudii*: 3 – Fl2b (P36.3–4); 4 – Fl4b (N47.1–2); 5 – Fl2a (S45); 7 – operculum, Fl1 (F43.1); 8 – operculum, Fl1 (M41.2–4); 9 – operculum, Fl4b (W39.1)

10–13. *Membranilarnacia*? sp. A: 10 – Fl4b (P38.3); 11 – Fl32b (O48.1); 12 – Fl7 (N54.4); 13 – Fl4a (X39.1)

14. *Cyclonephelium compactum*, Fl22a (F41)

15. *Eatonicysta ursulae*, Fl30a (P43.2)

16. *Hystrichosphaeridium* sp., Fl36a (N38.4)

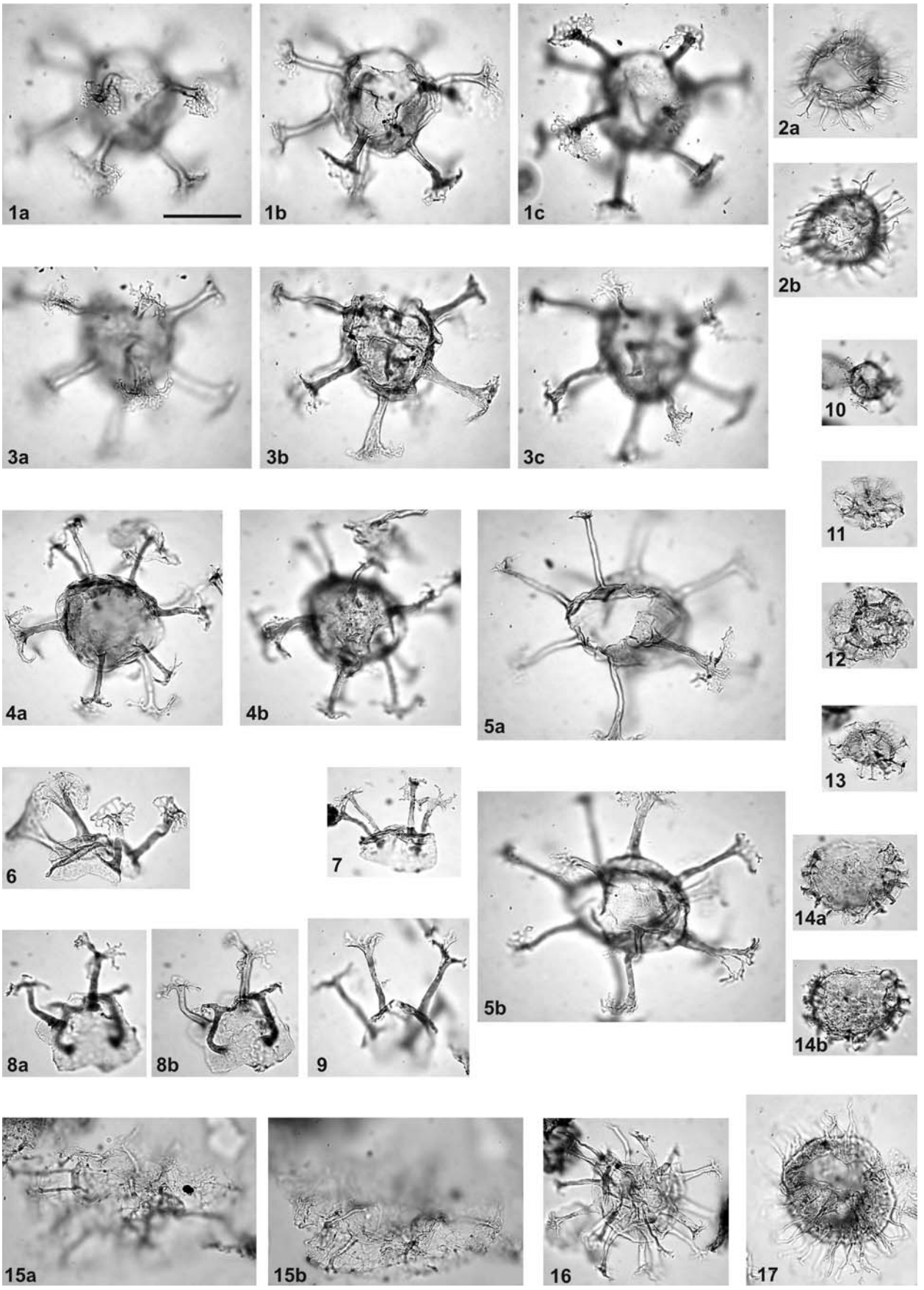

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Plate 2

1–3. *Enneadocysta pectiniformis*: 1 – Fl4a (P31.3); 2 – Fl4b (E31); 3 – Fl42a (J44)

4, 7. *Enneadocysta arcuata*: 4 – Fl4b (Q32.3); 7 – Fl12a (U43)

5. *Enneadocysta multicornuta*, Fl40a (R45.1–3)

6, 9–14. *Enneadocysta* aff. *pectiniformis*: 6 – Fl15b (O34.3–4); 9 – Fl15b (Y27.1–2); 10 – Fl15b (N45); 11 – Fl15b (M49.3); 12 – Fl15a (V39.3–4); 13 – Fl4a (P47.2); 14 – Fl15a (P49.1–2)

8. *Enneadocysta fenestrata*, Fl4a (G49.1)

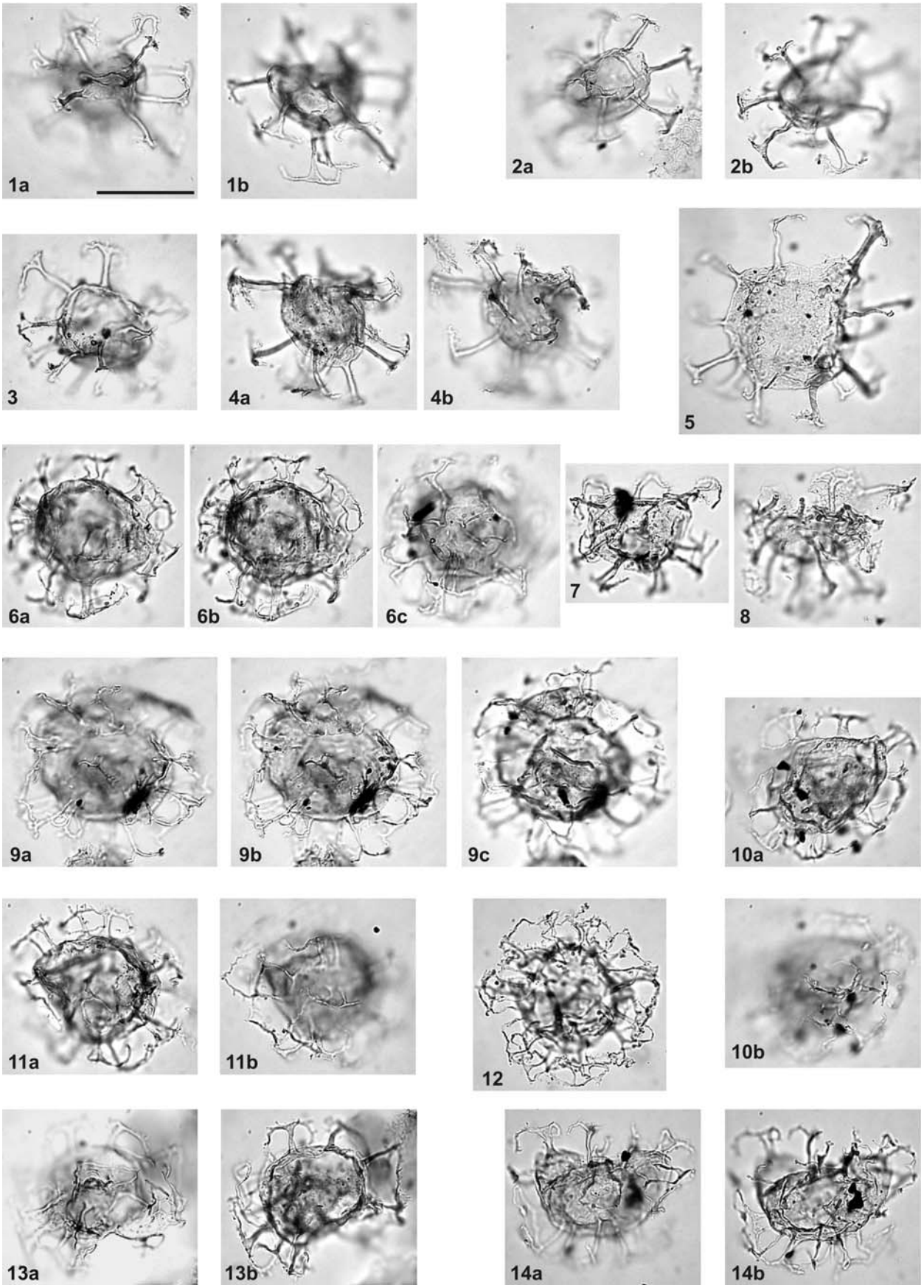

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Plate 3

1–9. *Operculodinium centrocarpum*: 1 – Fl37b (E44.1–3); 2 – Fl2b (K30.2); 3 – Fl2b (F32.2); 4 – Fl2a (Q50.3); 5 – Fl2a (O39.1–3); 6 – Fl12a (L29); 7 – Fl24b (V40.1); 8 – Fl12a (L29.4); 9 – Fl20a (H36.1–3)

10. *Fibrocysta* aff. *vectensis*, Fl35a (W37.2)

11, 12. *Cordosphaeridium funiculatum*: 11 – operculum, Fl36a (L45); 12 – Fl4b (F40.4)

13, 14. *Cordosphaeridium minimum*: 13 – Fl42a (L47.1); 14 – Fl35b (N33)

15. *Tityrosphaeridium cantharellus*, Fl4b (G40)

16. *Cordosphaeridium inodes*, Fl24a (O41.3–4)

17, 18, 22. *Amphorosphaeridium multifurcatum*: 17 – Fl4a (X30.1); 18 – Fl4a (V36); 22 – Fl4b (X30.1)

19. *Operculodinium*? *hirsutum*, Fl22b (L36)

20, 21. *Operculodinium microtriainum*: 20 – Fl24a (J31.2); 21 – Fl4b (K47.4)

23. *Operculodinium* aff. *centrocarpum*, Fl4a (N37.3)

24. *Operculodinium deconinckii*, Fl7 (F46.1)

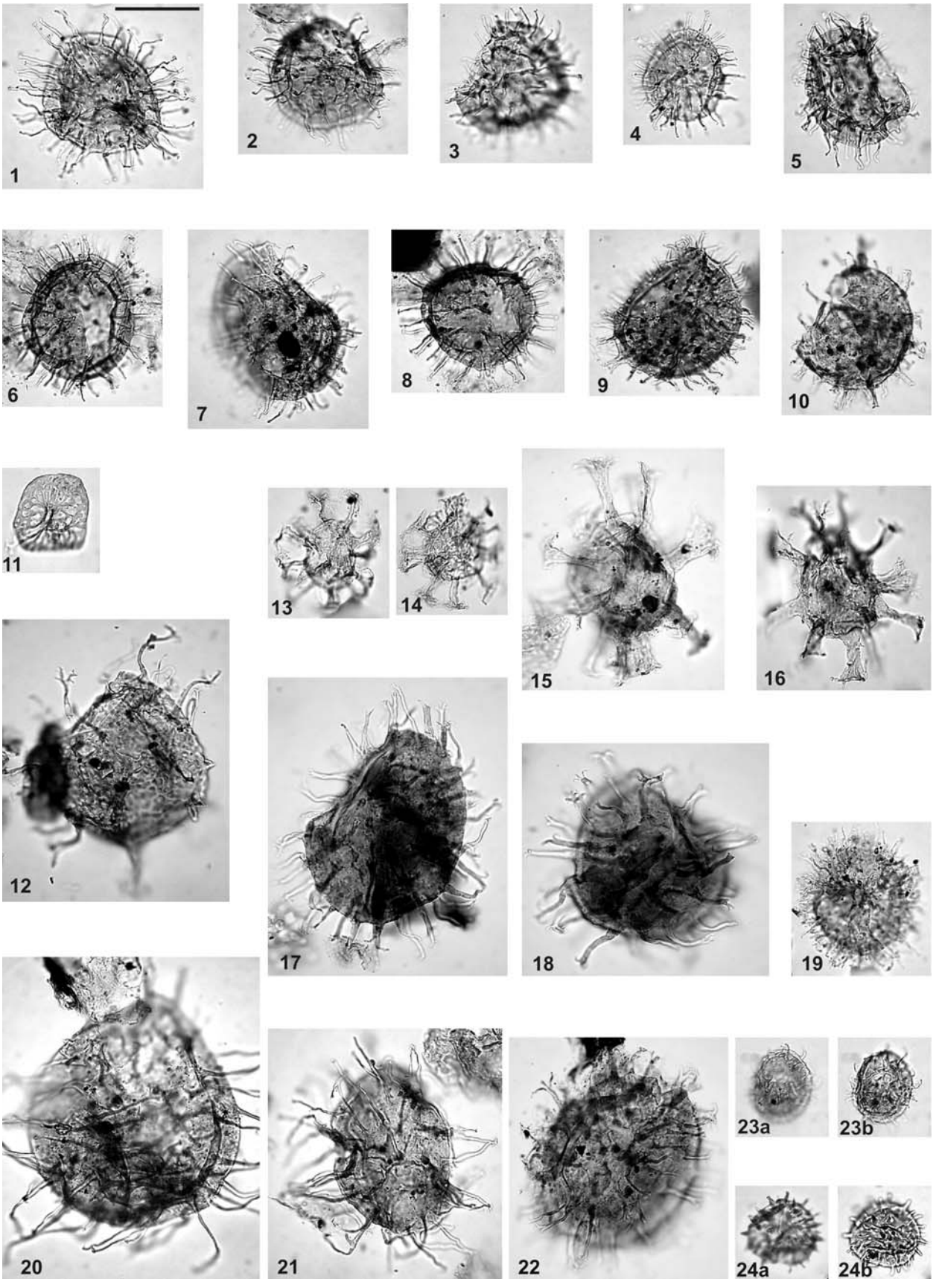

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Plate 4

1–3. *Thalassiphora pelagica*: 1 – Fl36b (W37.1–3); 2 – Fl4b (S39); 3 – Fl36b (Q44.1)

4. *Thalassiphora* sp. A, Fl15b (M46.1–3)

5. *Thalassiphora* aff. *pelagica*, Fl36b (X40.2)

6–9, 11, 12. *Corrudinium*? sp. A: 6 – Fl22b (R49); 7 – Fl24b (K43.1); 8 – Fl22b (P42.2); 9 – Fl33b (F37.1); 11 – Fl24a (M31.3); 12 – Fl37a (J45)

10. *Turbiosphaera symmetrica*, Fl37a (Q44.3–4)

13, 14, 18. *Samlandia chlamydophora*: 13 – Fl40b (F32.2); 14 – Fl36a (P49.1); 18 – Fl20b (M29.1–2)

15. *Cribroperidinium tenuitabulatum*, Fl4a (U37.2)

16, 17. *Oligosphaeridium*? sp.: 16 – Fl4a (J34.1–2); 17 – Fl4a (U31–2)

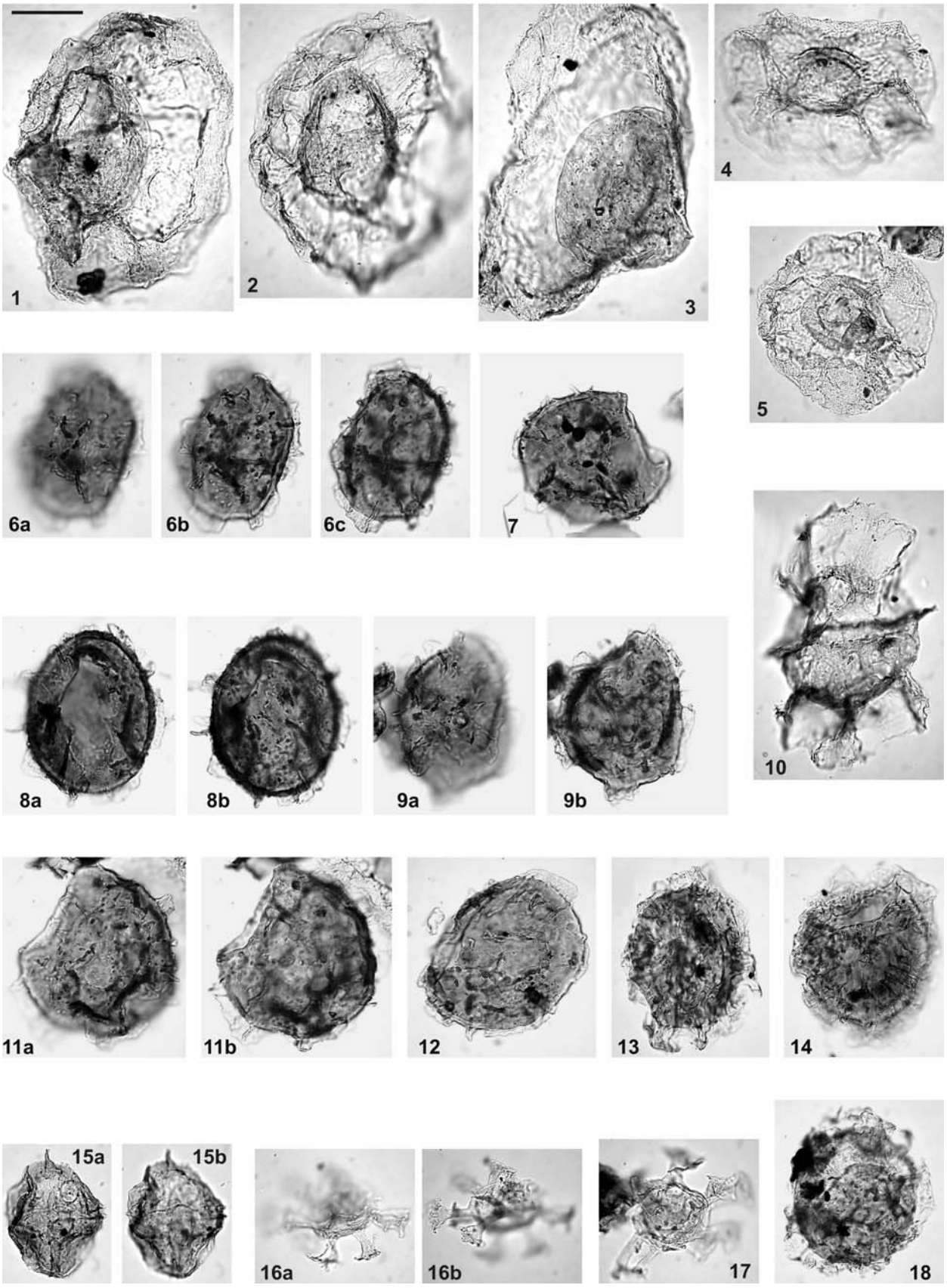

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Plate 5

1–4. *Dapsilidinium pseudocolligerum*: 1 – Fl4b (X39.4); 2 – Fl12b (L38.4); 3 – Fl33b (P29); 4 – Fl4b (O38.1)

5. *Dapsilidinium pastielsii*, Fl40a (U37.2)

6. *Dapsilidinium multispinosum*, Fl33b (R39.3)

7–10. *Diphyes colligerum*: 7 – Fl12b (N39.2); 8 – Fl35a (D39); 9 – Fl42a (U37.3); 10 – Fl7 (P50.1)

11. *Diphyes* aff. *colligerum*, Fl40b (D29)

12. *Diphyes pseudoficusoides*, Fl20a (E41.2)

13, 15, 16. *Hystrichokolpoma rigaudiae*: 13 – Fl24a (H48.1-3); 15 – Fl12a (G30.2); 16 – Fl2b (T29.1)

14. *Hystrichokolpoma salacia*, Fl4a (O48)

17–19. *Paucisphaeridium inversibuccinum*: 17 – Fl30a (J34.1); 18 – Fl32b (F43.4); 19 – Fl35a (Y36)

20–22. *Distatodinium ellipticum*: 20 – Fl4b (G34); 21 – Fl20b (J38.2); 22 – Fl2b (F35)

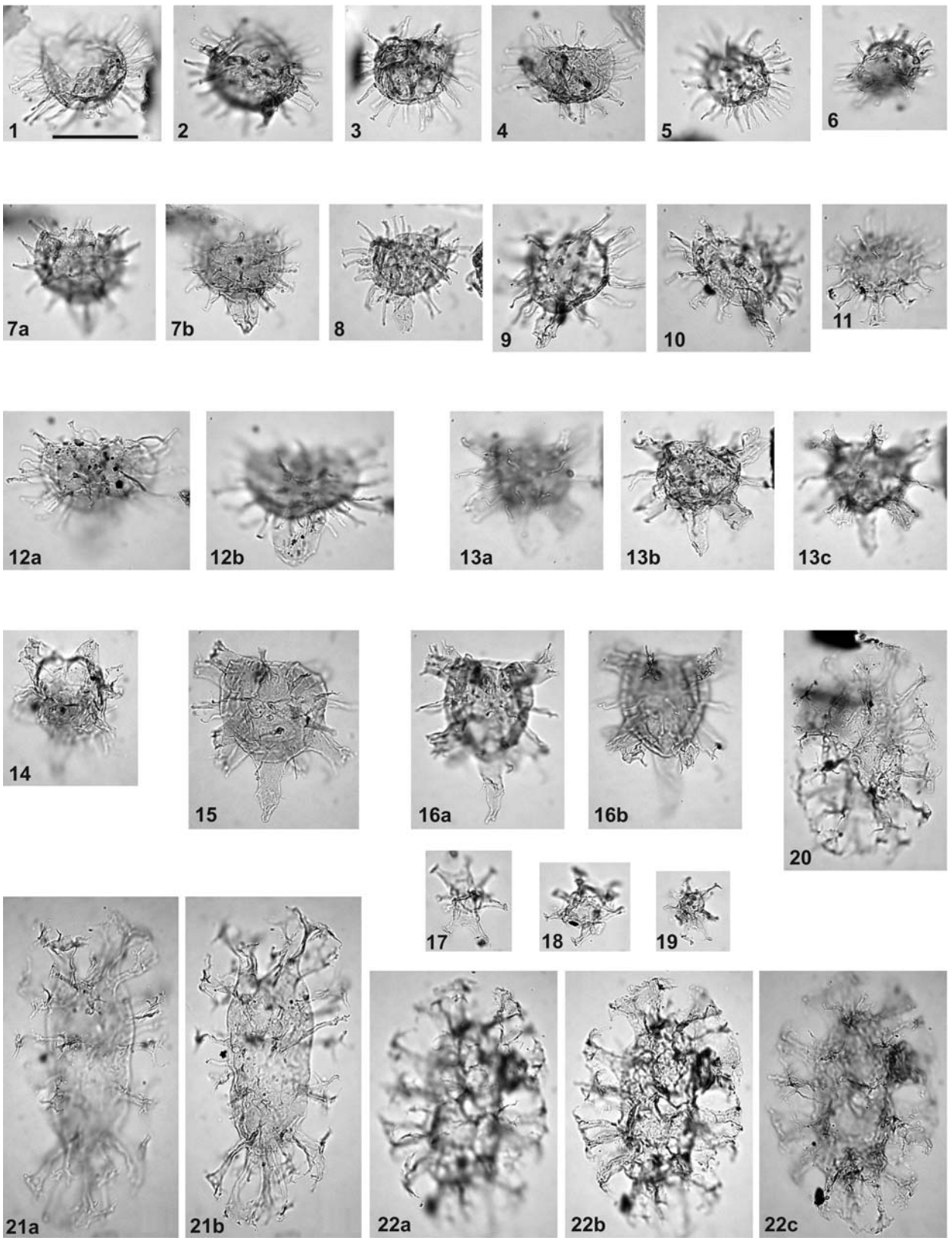

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Plate 6

1–3. *Achomosphaera ramulifera*: 1 – Fl4b (Y48.3–4); 2 – Fl12a (T32.1); 3 – Fl36a (H49)

4–7, 12. *Spiniferites ramosus* s.l.: 4 – Fl33b (W46.2); 5 – Fl2b (W35.3); 6 – Fl2a (O37.2); 7 – Fl4a (E46.3); 12 – Fl20b (J38.2)

8. *Spiniferites membranaceus*, Fl2a (O32)

9, 10, 15. *Rottnestia* aff. *borussica*: 9 – Fl40b (U31.2); 10 – Fl35a (U43.3); 15 – Fl7 (W35.3–4)

11, 14. *Rottnestia borussica*: 11 – Fl33b (R35); 14 – Fl4a (T32.2)

13. *Spiniferites bentorii*, Fl2b (U35.3)

16–18. *Nematosphaeropsis labyrinthus*: 16 – Fl42b (E43.1–3); 17 – Fl12a (Q41); 18 – Fl2b (J36.2–4)

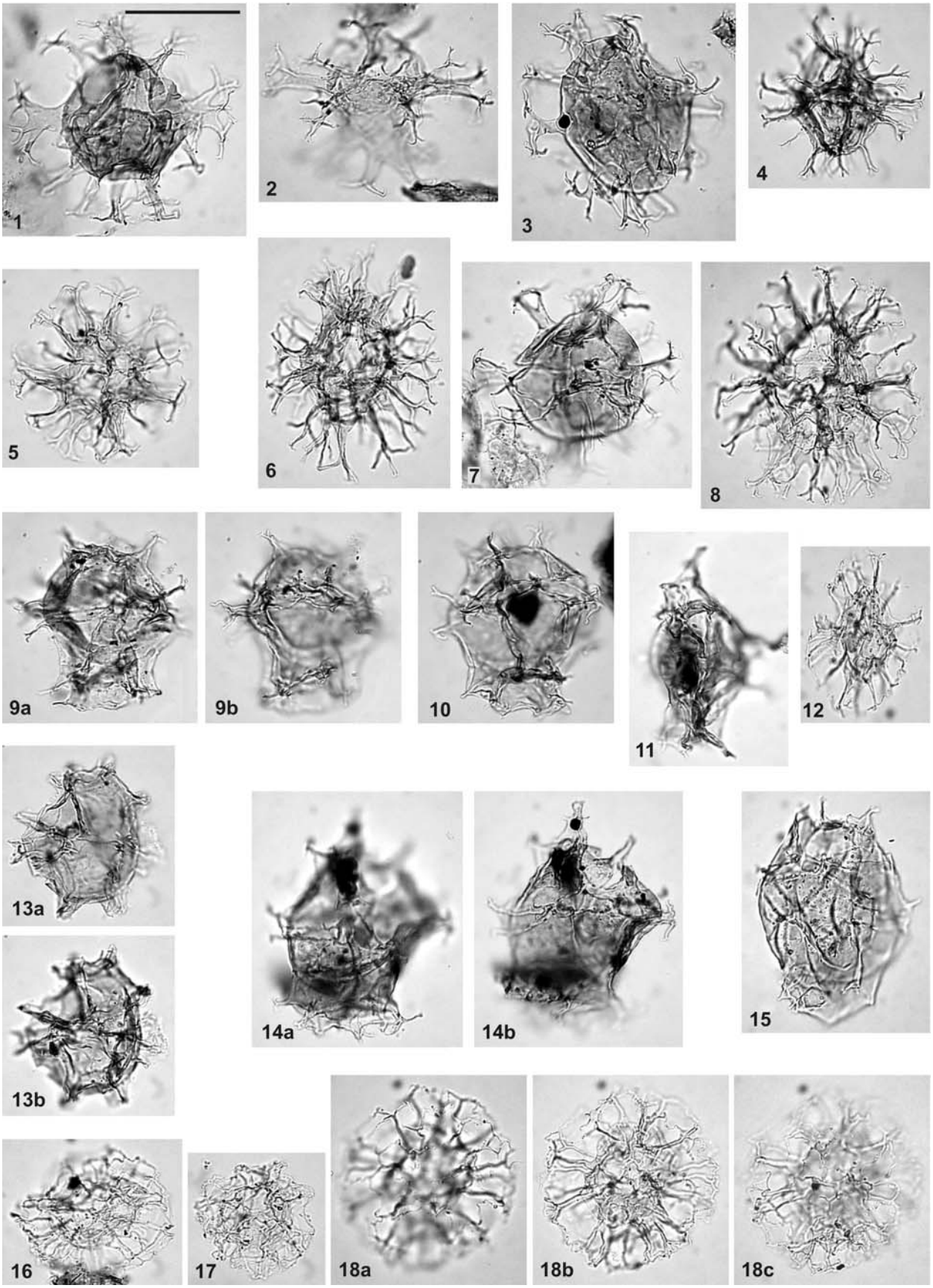

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Plate 7

1–5. *Corrudinium incompositum*: 1 – Fl1 (M41.4); 2 – Fl7 (C36.4); 3 – Fl12a (H34.1); 4 – Fl12a (R39); 5 – Fl15a (U43)

6–9. *Impagidinium aculeatum*: 6 – Fl1 (K42); 7 – Fl2b (W37.2); 8 – Fl2a (L51.4); 9 – Fl30a (X43.1–2)

10, 12, 13, 16. *Impagidinium dispertitum*: 10 – Fl12a (R48); 12 – Fl12b (L38.4); 13 – Fl30b (K47); 16 – Fl24b (K39.3)

11. *Leptodinium membranigerum*, Fl2a (S45.2)

14. *Impagidinium gibrense*, Fl7 (N35.1)

15. *Impagidinium* sp. D, Fl36b (U31.3–4)

17, 18. *Impagidinium velorum*: 17 – Fl1 (O35.1); 18 – Fl2a (Q32.2)

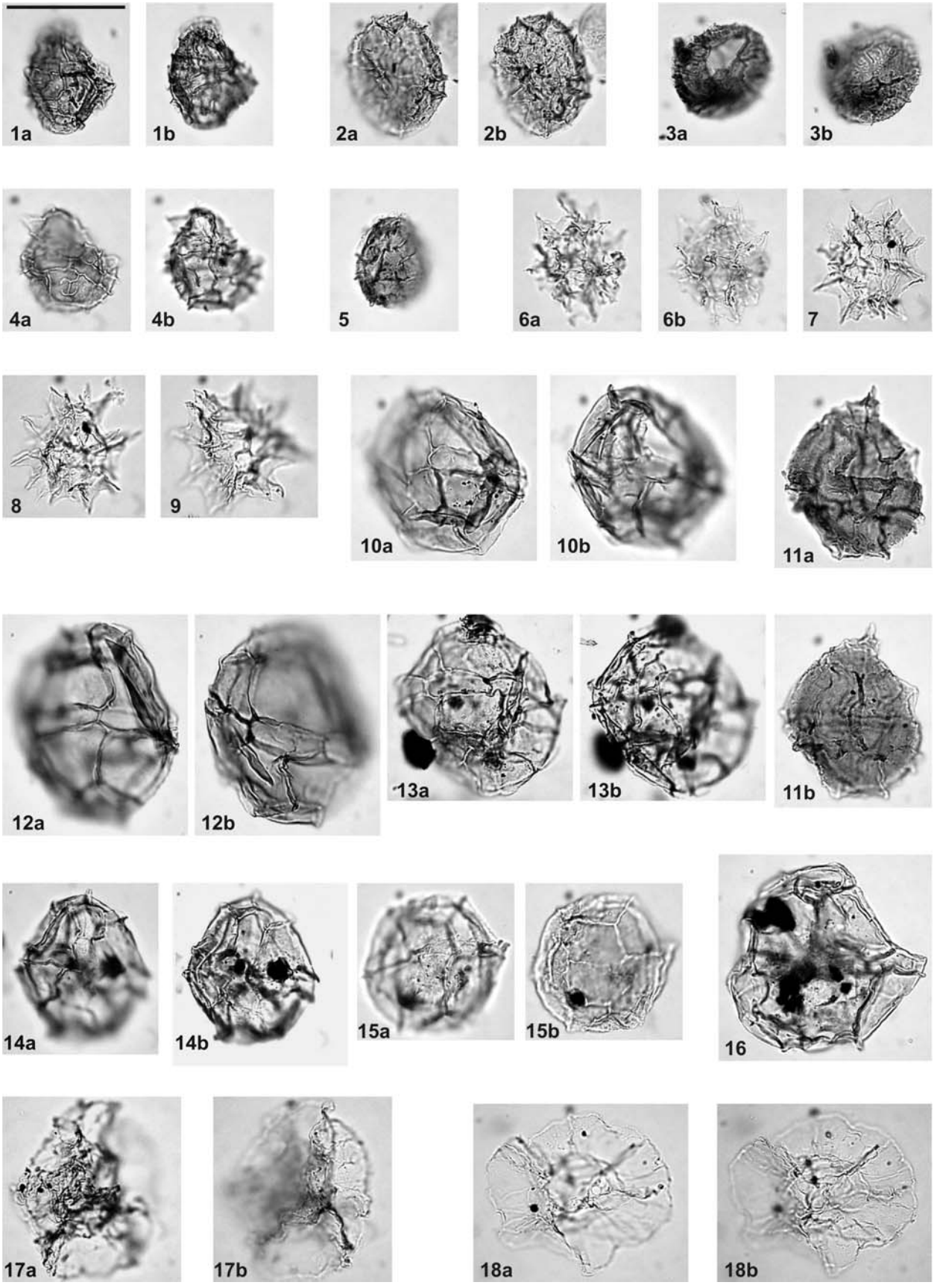

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Plate 8

1–6. *Impagidinium* sp. A: 1 – Fl1 (O49); 2 – Fl2a (G47.2); 3 – Fl2a (R34.2); 4 – Fl2b (G42.3); 5 – Fl12b (V43.1); 6 – Fl12b (H46.4)

7–11, 14. *Impagidinium* sp. B: 7 – Fl1 (T47.3); 8 – Fl20b (Q48.1); 9 – Fl2b (W33); 10 – Fl2a (D46.1–3); 11 – Fl2b (M44.3–4); 12 – Fl12a (H35.3); 14 – Fl22a (D35.3)

13. *Impagidinium* sp. C, Fl12a (N32)

15–17. *Impagidinium pallidum*: 15 – Fl2b (P29); 16 – Fl15b (G41.3); 17 – Fl4a (X39.1)

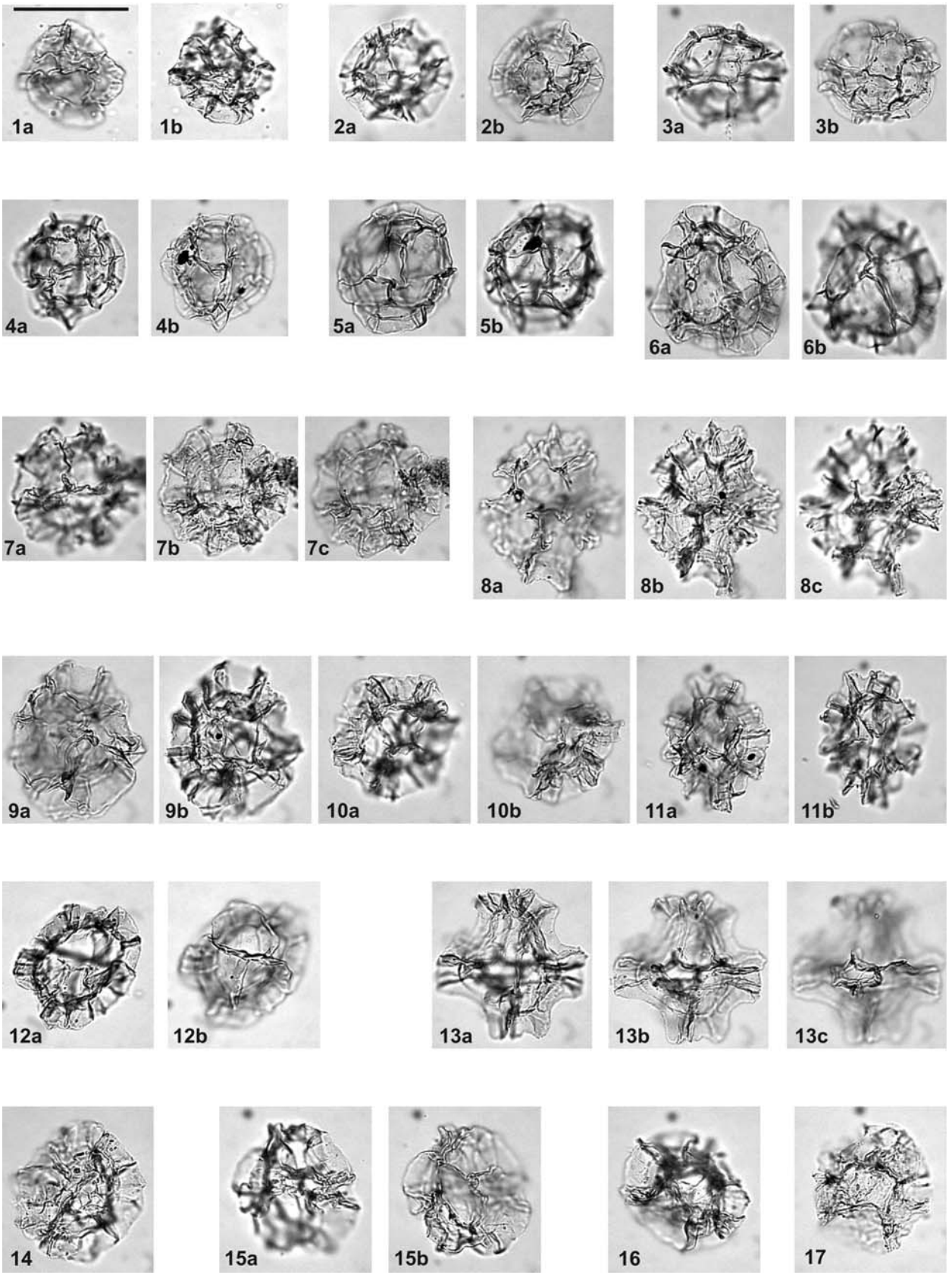

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Plate 9

1, 2. *Spiniferites pseudofurcatus*: 1 – Fl2b (J39.1–3); 2 – Fl1 (L46.1)

3. *Pentadinium*? *circumsutum*, Fl37a (K53.1)

4, 6. *Pentadinium laticinctum*: 4 – Fl2a (T44.3); 6 – Fl1 (F40.4)

5. *Pentadinium laticinctum granulatum*, Fl1 (K34)

7–12. *Impagidinium brevisulcatum*: 7 – Fl4a (F49.4); 8 – Fl22b (P42); 9 – Fl2a (K37.3–4); 10 – Fl33a (M46.2); 11 – Fl12b (L50.4); 12 – Fl7 (G47.4)

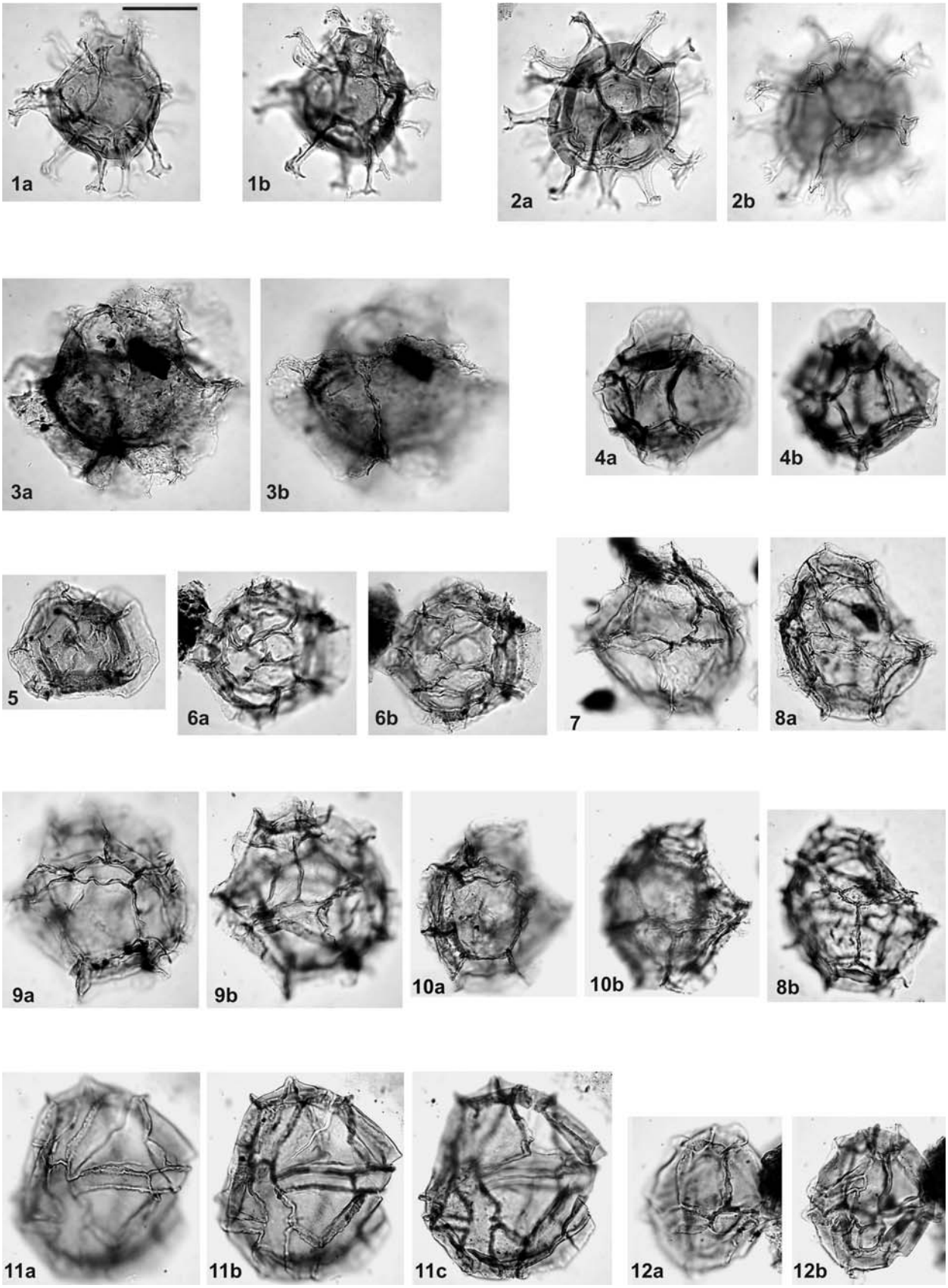

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Plate 10

1–4. *Cerebrocysta bartonensis*: 1 – Fl15b (N42.3); 2 – Fl2b (X43.1–2); 3 – Fl33a (F43.1–3); 4 – Fl35a (E35.4)

5–9. *Tectatodinium* aff. *pellitum*: 5 – Fl22b (M30.3); 6 – Fl12a (N38.3); 7 – Fl7 (M36.2); 8 – Fl2a (T40.1); 9 – Fl12a (G34)

10. *Pyxidinopsis* sp. A, Fl22a (E42.3–4)

11. *Pyxidinopsis*? sp. B, Fl24a (K42.4)

12. *Pyxidinopsis psilata*, Fl35a (D37)

13. *Pyxidinopsis* sp. C, Fl30a (N31.1)

14. *Pyxidinopsis* sp. E, Fl36a (M45)

15. *Pyxidinopsis* sp. D, Fl33b (R43)

16. *Gelatia inflata*, Fl1 (H37.2)

17–19. *Melitasphaeridium asterium*: 17 – Fl20b (N36.1–2); 18 – Fl30a (K40); 19 – Fl7 (H45.2)

20–23. *Melitasphaeridium pseudorecurvatum*: 20 – Fl4b (W39.1); 21 – Fl2b (S45.3); 22 – Fl22b (Q39.2); 23 – Fl30b (M35.2–4)

24–29. *Reticulatosphaera actinocoronata*: 24 – Fl35b (M46.4); 25 – Fl36b (L29); 26 – Fl20a (D40.2); 27 – Fl4a (N37); 28 – Fl12a (D47.2–4); 29 – Fl33b (Q37.3)

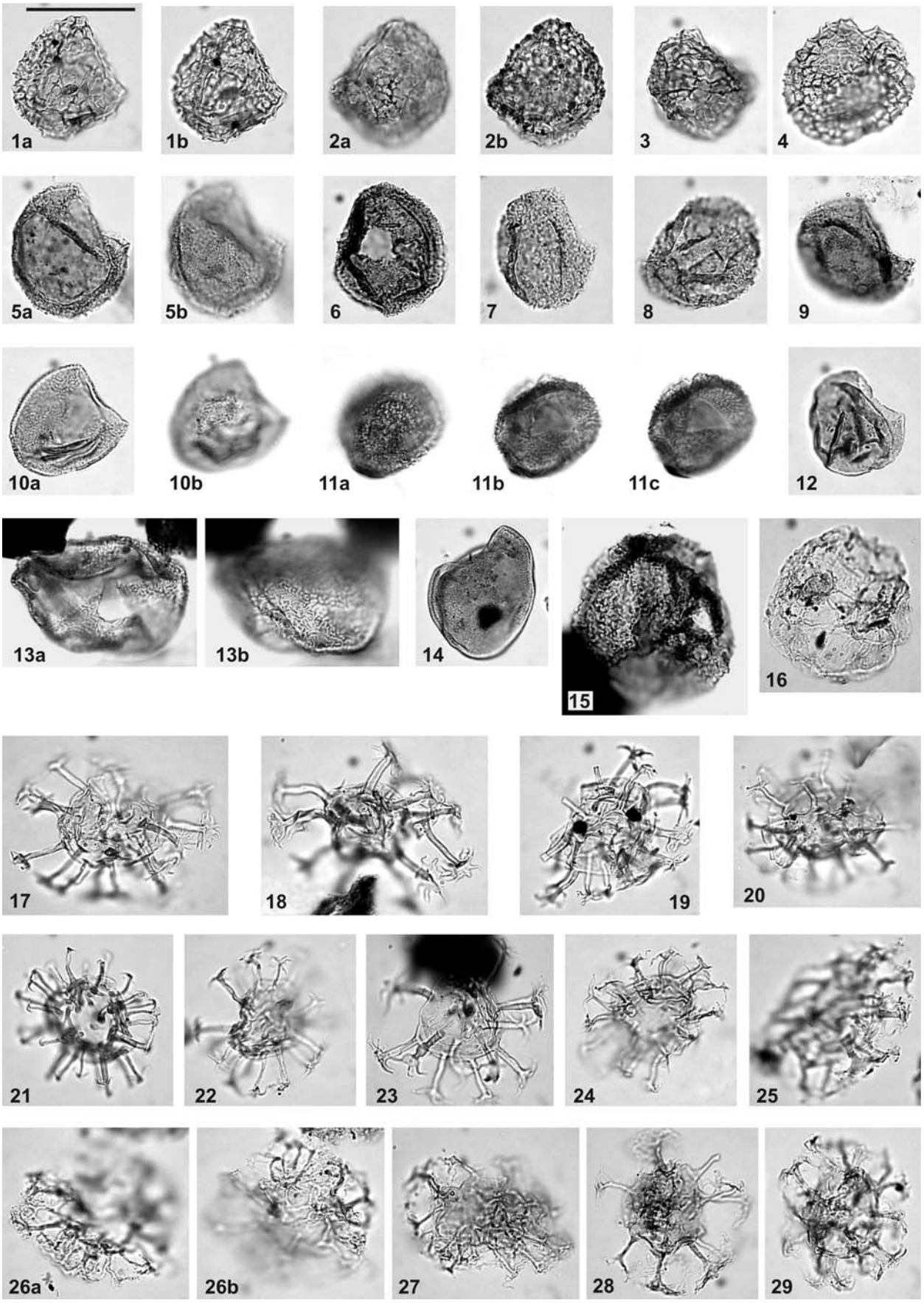

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Plate 11

1, 2, 4, 6, 7. *Glaphyrocysta semitecta*: 1 – Fl4b (S39.4); 2 – Fl20a (F38.4); 4 – Fl4b (K49.3); 6 – operculum, Fl16b (G37.4); 7 – Fl4a (U36.2)

3. *Glaphyrocysta* sp. B, Fl36a (P51.1)

5. *Glaphyrocysta* sp. A, Fl4a (N48.1)

8, 17. *Glaphyrocysta intricata*: 8 – Fl37b (X46.3); 17 – Fl30b (D37)

9. *Glaphyrocysta* sp., Fl37b (H46.2)

10, 14. *Adnatosphaeridium vittatum*: 10 – Fl4a (P44); 14 – Fl35a (H48.1–2)

11. *Heterosphaeridium* sp. A, Fl4a (Q33.2)

12. *Areoligera semicirculata*, Fl33b (E35.2)

13. *Areoligera* sp., Fl16b (K.47.2)

15. *Adnatosphaeridium multispinosum*, Fl35a (M49)

16. *Adnatosphaeridium* sp. A, Fl37a (L39)

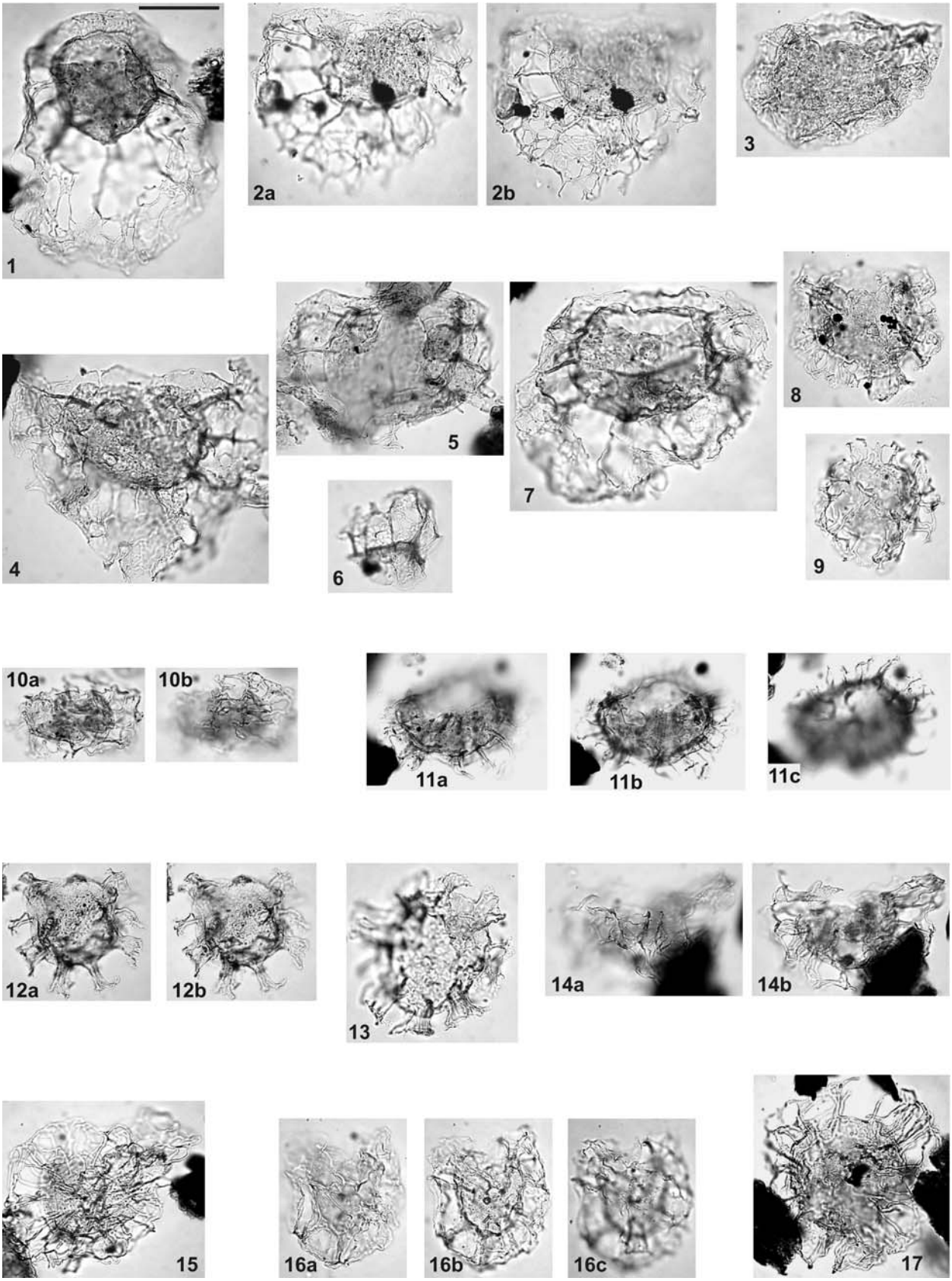

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Plate 12

1, 3, 5, 7. *Areoligera undulata*: 1 – Fl4a (N30.2); 3 – Fl4a (N38.1); 5 – Fl4a (M44.1); 7 – Fl4b (W39.1)

2, 4, 6. *Areoligera sentosa*: 2 – Fl20a (L42.2); 4 – Fl4a (K33.2); 6 – Fl4b (X47.4)

8–13. *Membranophoridium aspinatum*: 8 – Fl2b (U30.4); 9 – Fl2a (M34.2–4); 10 – Fl2a (T39.2); 11 – Fl4a (M41.1); 12 – Fl4b (W31.1–3); 13 – Fl2a (T39)

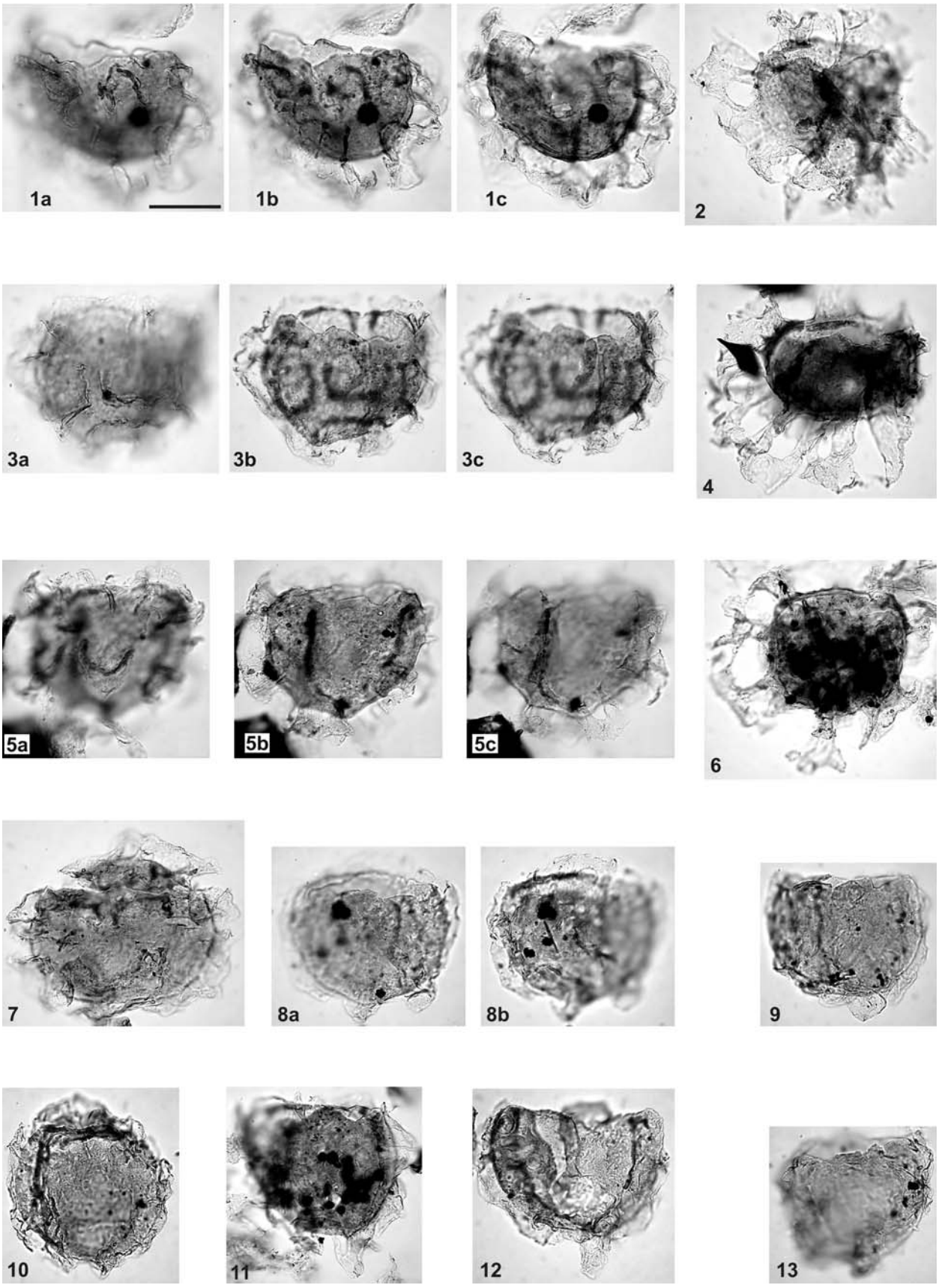

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Plate 13

1–9. *Homotryblium* sp. A: 1 – Fl37b (M44.2); 2 – Fl40a (E41.3); 3 – Fl37b (P40.3); 4 – Fl24b (N45); 5 – Fl37b (M47.1); 6 – Fl37a (J47.4); 7 – Fl37a (J39.2–4); 8 – Fl40a (J40.2); 9 – Fl37b (W51)

10, 11. *Dinopterygium* sp. A: 10 – Fl37b (R40.3); 11 – Fl4b (K38)

12, 13, 18. *Heteraulacacysta* sp. A: 12 – Fl36a (P51.1); 13 – Fl33b (F44); 18 – Fl33b (T37.2–4)

14. *Dinopterygium* sp. B, Fl37a (V48.3)

15–17. *Heteraulacacysta porosa*: 15 – Fl4a (V43.1-3); 16 – Fl4b (K49.4); 17 – Fl4b (L45.2)

19–23. *Heteraulacacysta*? *leptalea*: 19 – Fl22a (U39.1–2); 20 – Fl12b (G33); 21 – Fl12a (B38.3–4); 22 – Fl33a (W45.4); 23 – Fl12a (E37.1–3)

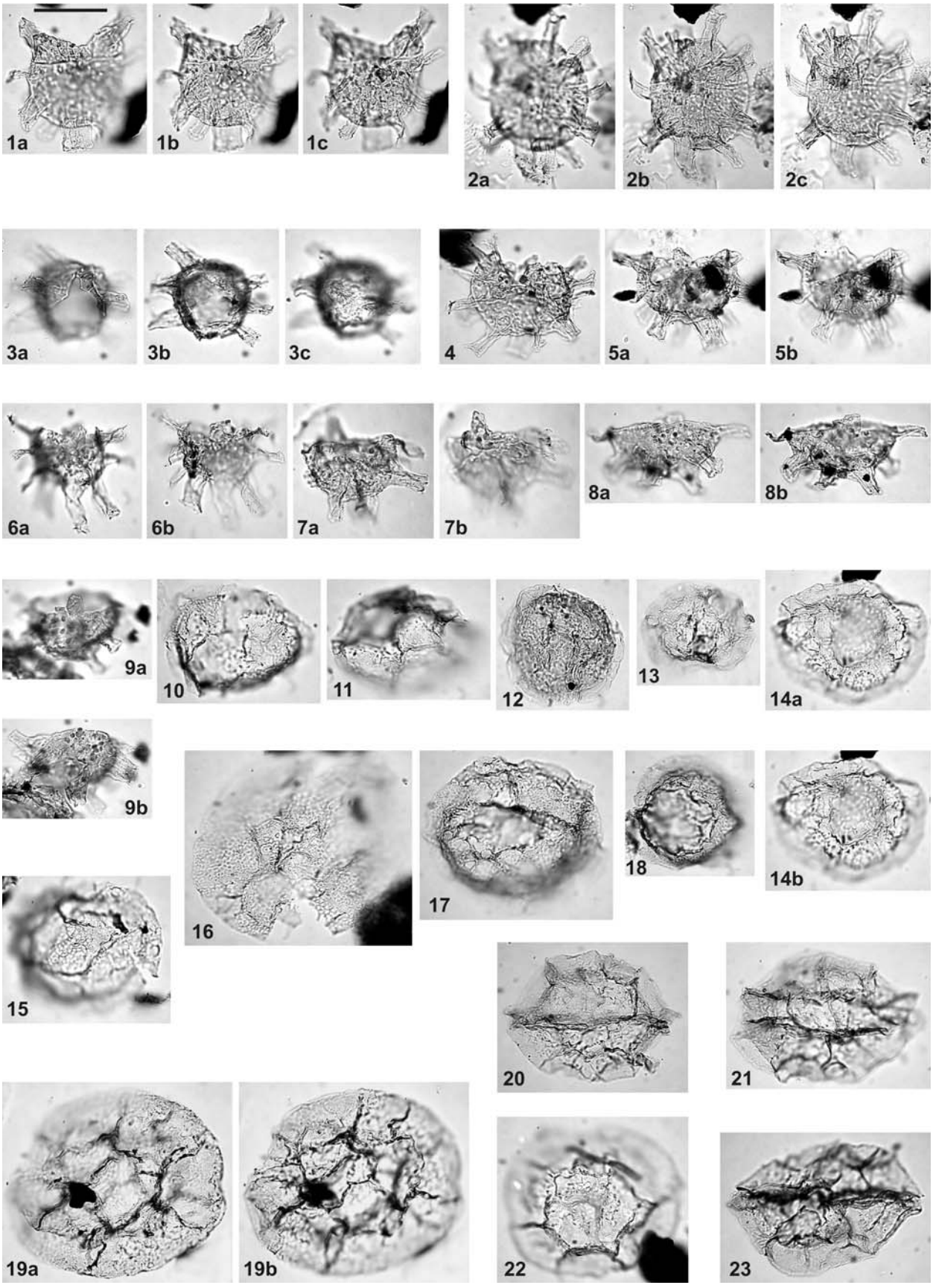

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Plate 14

1–3. *Homotryblium aculeatum*: 1 – Fl35a (J46.4); 2 – Fl2b (G49.1); 3 – Fl12b (X42)

4, 5. *Homotryblium plectilum*: 4 – Fl35a (H34.1); 5 – Fl12a (M45.3)

6. *Homtryblium caliculum* Fl4a (J29)

7–9. *Homotryblium tenuispinosum*: 7 – Fl30b (S36.2); 8 – Fl2a (D45); 9 – small specimen with short processes, Fl42a (S50.3)

10–14. *Homotryblium vallum*: 10 – Fl12b (F45.1); 11 – Fl12b (H41.4); 12 – specimen with very short processes, Fl2a (O48); 13 – Fl12b (O49.4); 14 – Fl12a (M44.1)

15, 16. *Polysphaeridium subtile*: 15 – Fl4b (D50.1); 16 – Fl1 (J48)

17–19. *Lingulodinium machaerophorum*: 17 – Fl2a (D41.3); 18 – Fl2a (M35.2); 19 – Fl4a (M49.2)

20, 21. *Lingulodinium pycnospinosum*: 20 – Fl15a (D52.2); 21 – Fl22a (N30.2)

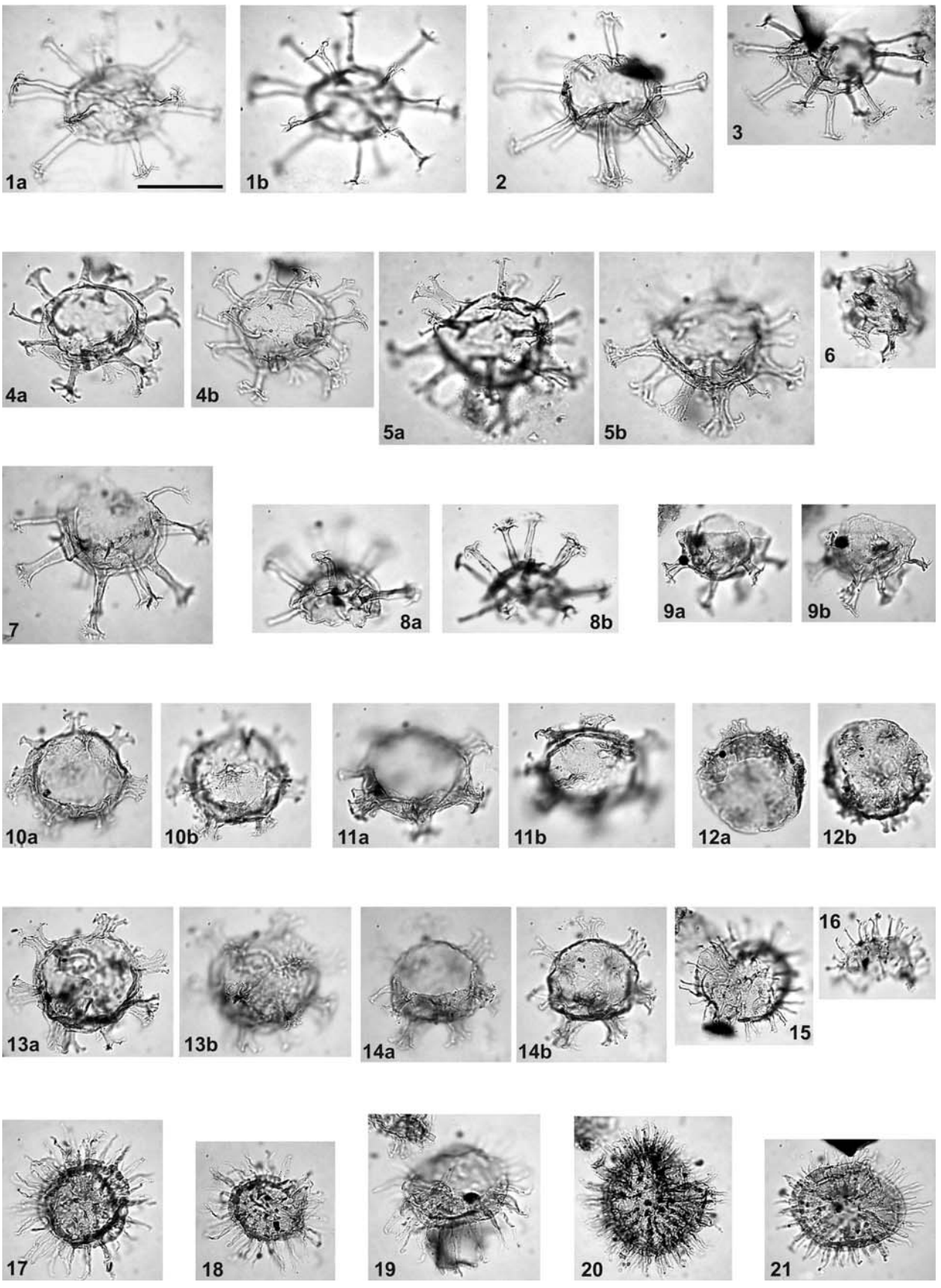

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Plate 15

1–15. *Deflandrea* spp.: 1 – Fl35a (C34.4); 2 – Fl1 (P47.3); 3 – Fl1 (E38); 4 – Fl12b (J45.1); 5 – Fl15a (F48.3); 6 – Fl15a (U41); 7 – Fl15a (W41.3); 8 – Fl15b (F36); 9 – Fl16b (L37.1); 10 – Fl4a (F49.2); 11 – Fl33a (Q38.4); 12 – Fl17b (F42); 13 – Fl22a (S35.1–2); 14 – Fl33a (W44); 15 – Fl36a (T47.1–2)

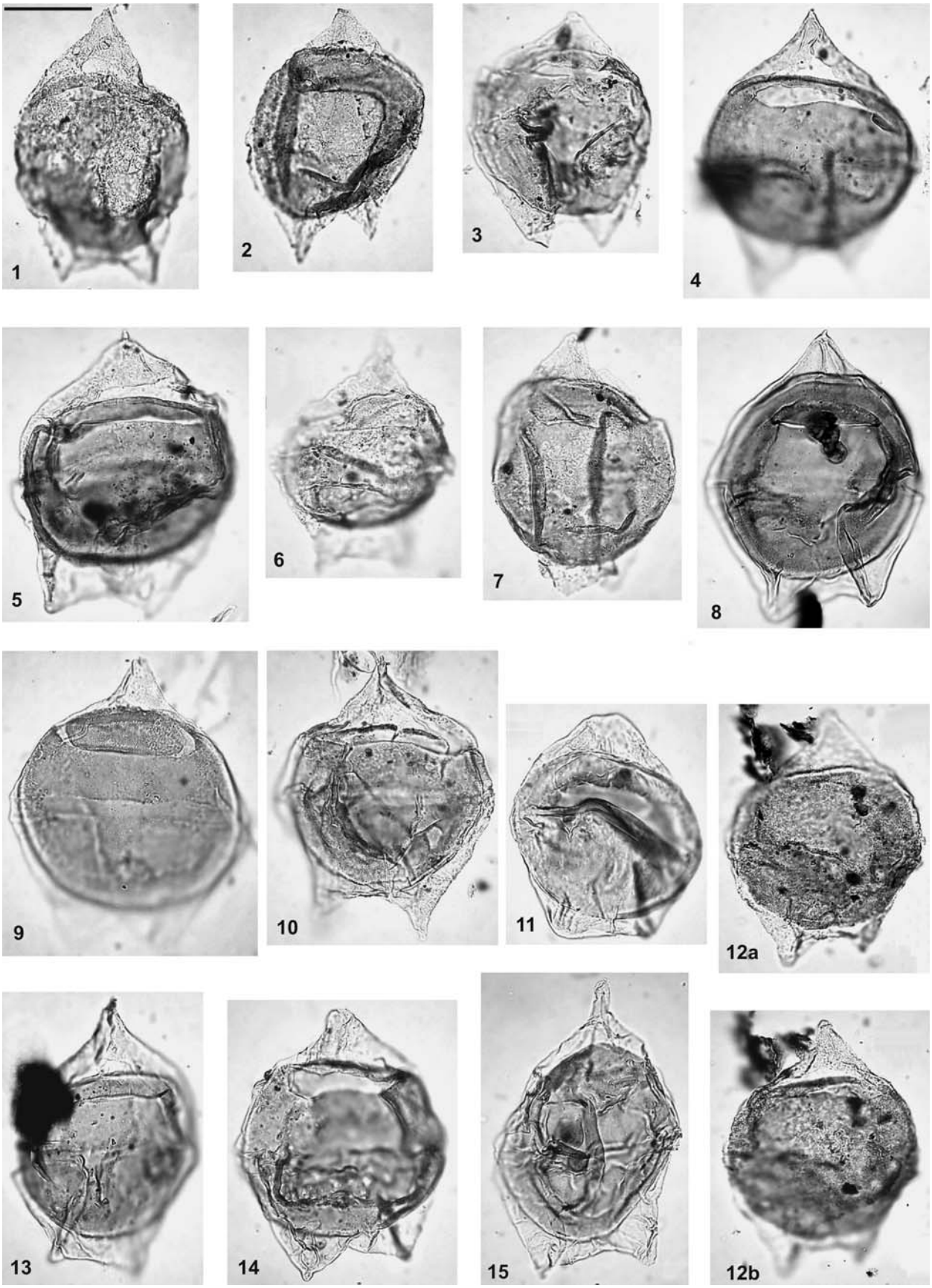

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Plate 16

1, 4. *Charlesdowniea clathrata*: 1 – Fl4a (T34.1–2); 2 – Fl12b (E53.4)
2, 3. *Charlesdowniea coleothrypta*: 2 – Fl36a (S44); 3 – Fl4b (H46.3)
5, 6. *Rhombodinium draco*: 5 – Fl36a (T44.1); 6 – Fl40a (Q31.1)
7. *Rhombodinium* sp. A, Fl36b (F35.1)
8. *Rhombodinium freienwaldensis*, Fl1 (M40.1)
9, 11, 12, 16. *Rhombodinium perforatum*: 9 – Fl1 (E47.2); 11 – Fl1 (K42); 12 – Fl2b (W35.2–4); 16 – Fl1 (H40.4)
10. *Wilsonidium intermedium*, Fl20a (W48.3–4)
13. *Dracodinium laszczynskii*, Fl1 (G44.1–3)
14. *Wetzeliella gochtii*, Fl20b (C42)
15. *Wetzeliella symmetrica*, Fl20a (K42.3)

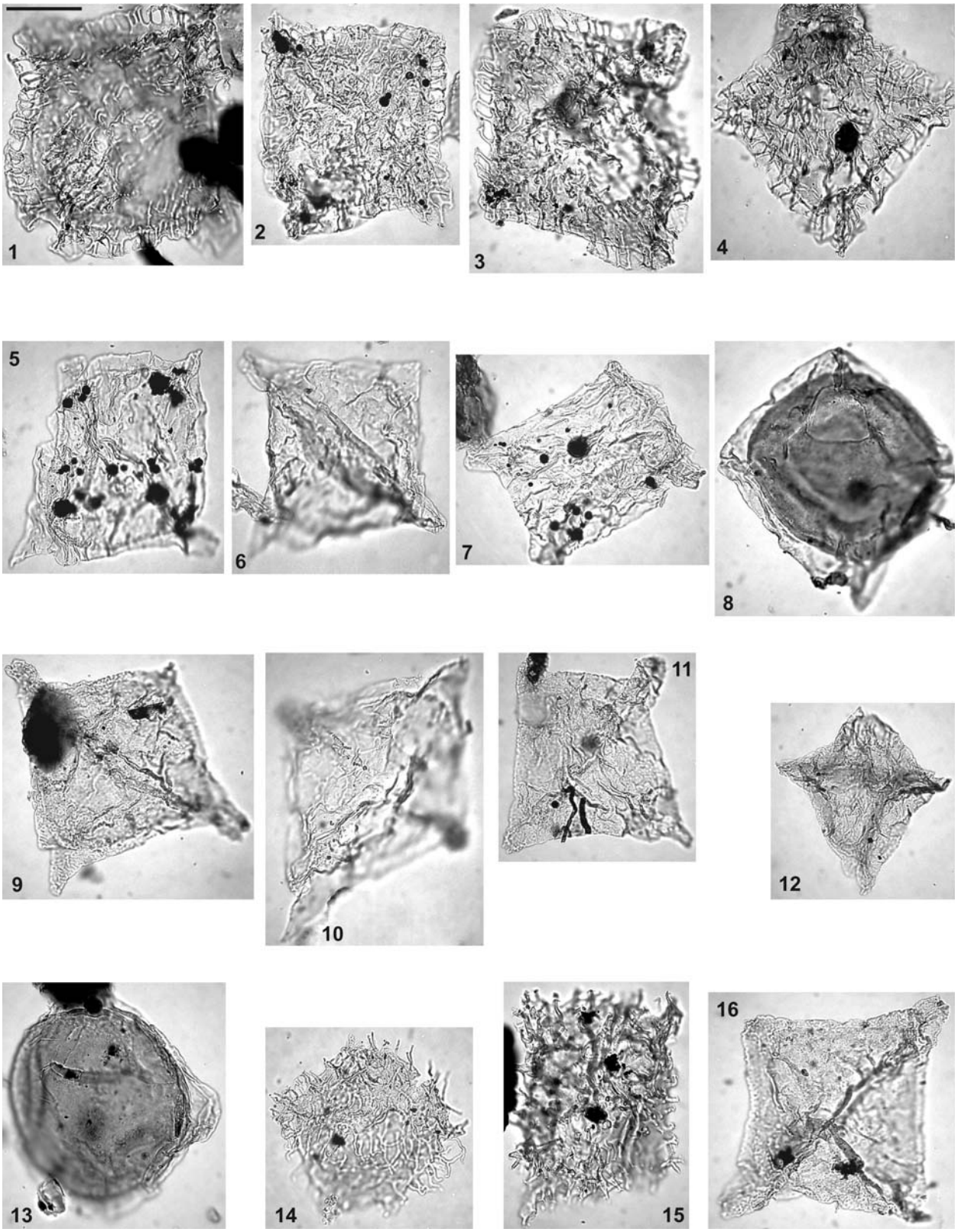

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Plate 17

1–3. *Lentinia serrata*: 1 – Fl1 (F35.1–3); 2 – Fl1 (Q42); 3 – Fl35a (N34.1–3)
4. *Lejeunecysta fallax*, Fl4a (E38.4)
5. *Lejeunecysta hyalina*, Fl4b (Q32.1)
6. *Phthanoperidinium amiculum*, Fl36a (G54.1–3)
7. *Lejeunecysta lata*, Fl36b (L46.4)
8. *Lejeunecysta tenella*, Fl1 (U43)
9, 10. *Lejeunecysta* sp.: 9 – Fl7 (T37.1); 10 – Fl42a (Q48)
11. *Selenopemphix nephroides*, Fl1 (R47.2)
12. *Phthanoperidinium comatum*, Fl4b (J36.1–2)
13–16. *Selenopemphix armata*: 13 – Fl7 (R39.4); 14 – Fl36a (F45.4); 15 – Fl4b (E32.4); 16 – Fl4b (Y48.1–3)
17. *Selenopemphix* sp. A, Fl33a (T48.1–3)
18–21. *Selenopemphix nephroides*: 18 – Fl4a (M49.2); 19 – Fl4a (Q35.1); 20 – Fl4a (X47.2); 21 – Fl7 (K39.1)
22, 23. *Selenopemphix coronata*: 22 – Fl1 (E35.2–4); 23 – Fl1 (S35.3)
24–27. *Selenopemphix* aff. *selenoides*: 24 – Fl2b (N46.1–3); 25 – Fl4a (C32.4); 26 – Fl36a (H56.2); 27 – Fl36a (K43.1–3)
28, 29. *Phelodinium* sp.: 28 – Fl1 (U44.1–2); 29 – Fl7 (K41.3)
30. *Phthanoperidinium* aff. *amiculum*, Fl35a (H31.2)
31. *Palaeocystodinium golzowense*, Fl36b (U41.3)

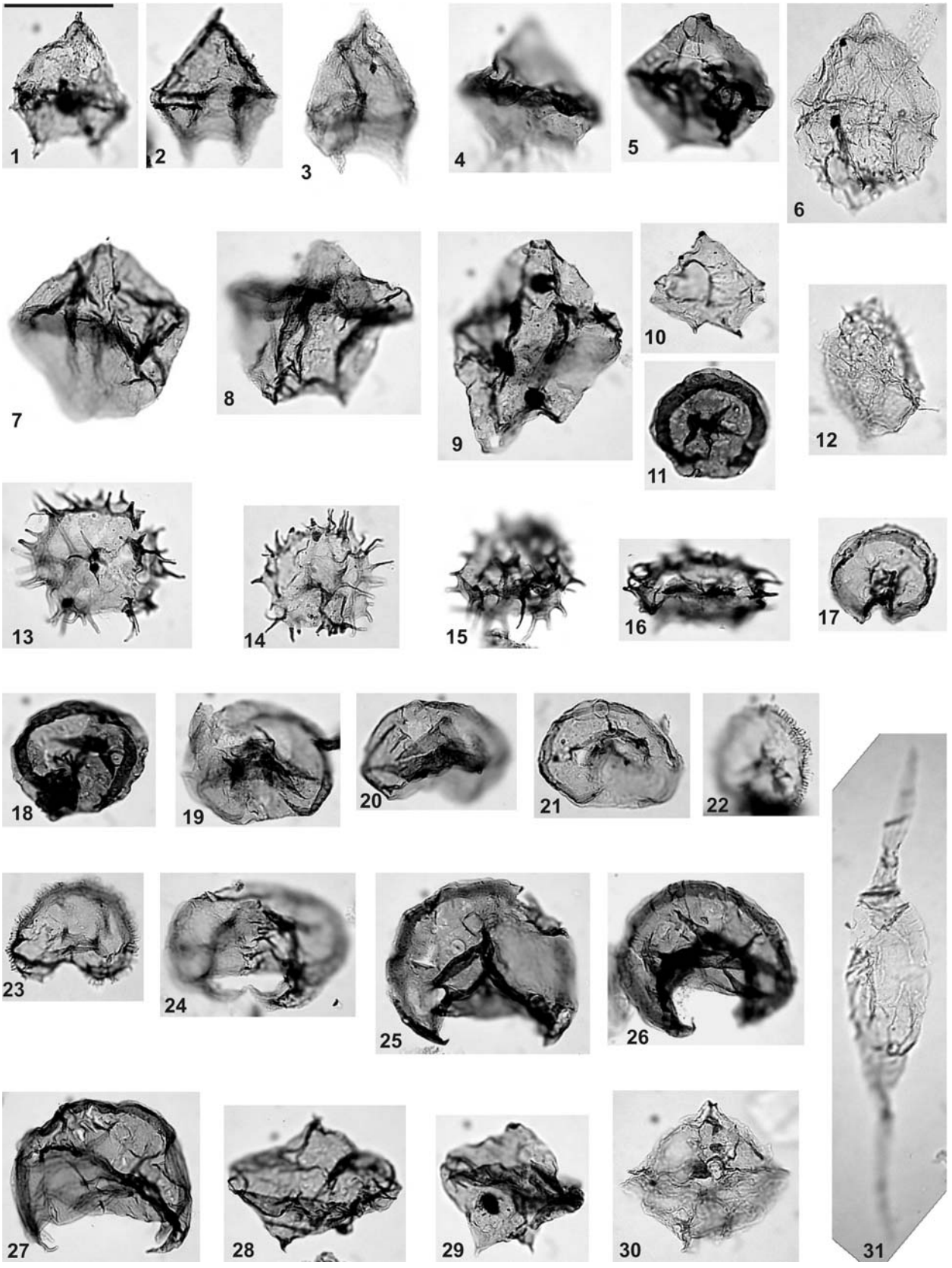

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Plate 18

Aquatic palynomorphs and pre-Eocene dinocysts from Folusz section

1. *Ctenidodinium ornatum/combazii*, Fl4a (M36.4)
2. *Nannoceratopsis dictyambonis*, Fl37a (M47.1)
3, 4. *Nannoceratopsis gracilis*: 3 – Fl32b (H42.4); 4 – Fl2b (F35.2)
5. *Pseudoceratium pelliferum*, Fl24a (J51.1)
6. *Chatangiella ditissima*, Fl12a (E30.1)
7. *Surculosphaeridium*? *longifurcatum*, Fl4b (W46.1–3)
8. *Trigonopyxidia ginella*, Fl2a (P35)
9. *Florentinia* sp., Fl36b (R37.3–4)
10. *Apectodinium quinquelatum*, Fl37a (R43.2–4)
11, 12. *Veryhachium*-type acritarch, Fl4a
13, 14. Incertae sedis palynomorphs (Prasinophyte algae genus *Schizosporis*?), Fl12b
15–26. Microforaminifera, Fl4b

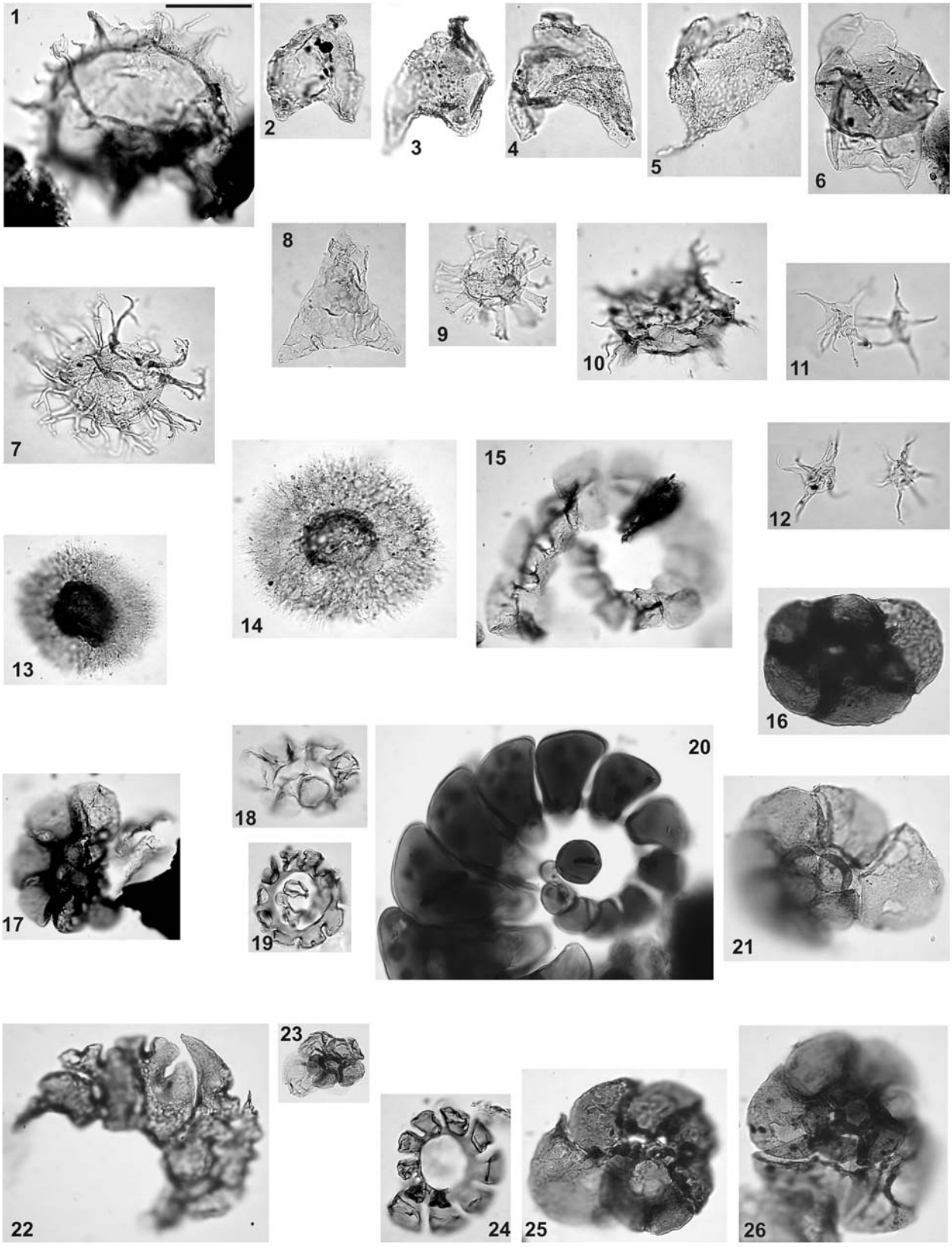

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Fig. 3. Dinocyst distribution in Folusz section. Taxon numbers refer to species list in Appendix. Inferred age is based on dinocysts (Gedl & Leszczyński 2005). Line widths reflect number of specimens counted. Abbreviation: W. s. – Wątkowa sandstone