Bulletin de la Société belge de Géologie, T. 102 (1-2), 1993, pp. 5-77.
Bulletin van de Belgische Vereniging voor Geologie. Ed. 1994

DINOFLAGELLATES AND DEPOSITIONAL SEQUENCES IN THE LOWER OLIGOCENE (RUPELIAN) BOOM CLAY FORMATION, BELGIUM

by

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ABSTRACT

The Boom Formation in northwestern Belgium consists of approximately 67 meters of alternating silty clay and clayey silt layers, which represent deposition during a major transgressive-regressive cycle (relative sea-level event). The base and the top of the formation are delimited by major sequence boundaries and a minor sequence boundary near the middle of the formation separates the older RU-1 and younger RU-2 sequences. The silty clay - clayey silt alternations in the Boom clay show a high frequency signal, while relative sea-level changes, rate of sediment supply and longer grain size trends are low frequency variables. In all probability eustasy was instrumental in both the low and high frequency trends, but its effect cannot be separated readily from that of subsidence or climate, respectively. Detailed lithostratigraphic studies such as those of Vandenberghe (1978) and Vandenberghe and van Echelpoel (1987) demonstrate the applicability of sequence stratigraphic principles to offshore sections; our results support their sequence stratigraphic interpretation for the Boom Formation.
Palynologically, this study provides an accounting of the dinoflagellate cysts, as well as their distribution and relative abundances in the Boom and underlying Zelzate Formations. In the Boom clay, as exemplified in the Antwerpen area, a marked and rather abrupt influx of dinoflagellate taxa occurred in the transgressive systems tract of the RU-1 sequence and, conversely, a general and gradual reduction of taxa took place in the middle and upper part of the highstand systems tract of the Rupel-2 sequence. Relatively few species appeared or terminated in the intervening section. An impressive number of dinoflagellate bases and tops are positioned in the RU-1 and RU-2 sequences that were deposited in 6 Ma. The majority of bases are found in transgressive deposits whereas the majority of tops occur in highstand deposits.

On the basis of mainly quantitative differences, 12 dinoflagellate associations are recognized; five each from transgressive and highstand systems tracts and two from strata at or near downlap surfaces. Although the correlation value of the associations outside Belgium remains to be determined, it appears that dinoflagellate associations at or near downlap surfaces are characterized by a significant reduction in the number of taxa, or the number of specimens, or both relative to adjacent associations. An analysis of the dinoflagellate taxa by eco-groups (following the approach of Köthe, 1990) indicates that most eco-groups appear to be systems tract tolerant. However, a few may have a moderate preference for certain sequence-related locations.

Comparison of the dinoflagellate distribution in the lower part of the Boom Formation (Belsele-Waas Member) and the Zelzate Formation (Ruisbroek, Watervliet and Bassevelde Members) in Belgium with that in the Priabonian sections in Italy as reported by Brinkhuis and co-workers (1993) shows a seemingly reliable dinoflagellate correlation. The dinoflagellate data raises concern about the placement of the Late Eocene - Early Oligocene boundary in the boundary stratotype at Massignano Section in Italy. This horizon appears to correlate in Belgium to a position well below the base of the Boom Formation.

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Twelve new species and one new genus identified during this study are described and illustrated. The new species are: *Achomosphaera expansa, Caligodinium endoreticulum, Charlesdowniea limitata, Elytrocysta breva, Impagidinium torsium, Impletosphaeridium machaeroides, Membranophoridinum connectum, M. intermedium, Vozzhennikovia cearaichia, V. spinula, Xenicodinium conispinum* and *X. echinoferum. Spiniferites cornutus* (Gerlach 1961) Sarjeant 1970 is transferred to the new genus, *Spiniferella*, as its type species.

KEY WORDS

dinoflagellates, Oligocene, Rupelian, Belgium, sequence stratigraphy, systematic paleontology.

1. SEQUENCE STRATIGRAPHIC INTERPRETATION AND STRATIGRAPHIC POSITION OF THE TYPE RUPELIAN

1.1. Introduction

This paper describes the stratigraphic distribution and relative abundance of dinoflagellate cysts in the Boom clay in Belgium. The Lower Oligocene Boom Formation crops out in northwestern Belgium and is particularly accessible in the area just south of Antwerpen where numerous clay pits provide excellent outcrops in unweathered sections (Figure 1). The Boom Composite Section was studied which included three outcrop sections in the type area of the Boom Formation (Sint Niklaas, Steendorp and Kruibeke sections (Figure 2, left and middle columns) together with the cored interval from a reconnaissance borehole near Antwerpen (Figure 2, right column) which completed the upper part of the composite section not accessible in outcrop. An additional seven samples from the Doel 14E-194 well provided information about the lower boundary of the Boom clay (Figure 3). A total of 113 samples were collected and analyzed for palynomorphs.

The primary objective of this study is to present a statigraphic inventory of the dinoflagellates in the Boom clay although consideration is also given to the relative abundances of individual taxa as well as to a number of groups of dinoflagellates as a function of the stratigraphic section and the sequence stratigraphic interpretation. Dinoflagellates are abundant in most samples and because their cysts are not affected by post-depositional decalcification they represent a promising group for stratigraphic correlation. As a result of decalcification, recovery of planktonic foraminifera and calcareous nannofossils is poor in the Boom Formation.

The Boom clay is one of two prominent clay deposits outcropping in Belgium that led to the definition of formal Cenozoic stages. The lower or Yper clay contains the type for the Lower Eocene Ypresian Stage while the upper clay unit or Boom clay provides the lithostratigraphic basis for the Lower Oligocene Rupelian Stage. The Boom Formation of the Rupel Group is subdivided into the Belsele-Waas, Terhagen and Putte Members (Marechal and Laga, 1988; Figure 2, this paper). In the outcrop area the Boom Formation is underlain by the Ruisbroek Member of the Zelzate Formation.

On closer scrutiny the Boom clay is characterized by alternating clayey silt and silty clay layers which together are approximately one meter thick (Vandenberghe, 1978). The regularity of the clay-silt alternations throughout the Boom clay suggests a long lasting stable sedimentary regime with two principal depositional components. The Boom clay was laid down as a suspension deposit in a relatively shallow inland sea reaching from Poland and Russia in the east to the Atlantic Ocean north of Scotland (Ziegler, 1990). The connection with the Paris Basin and the central Atlantic was effectively sealed by the Artois uplift south of the Anglo-Brabant Massif. A narrow, in places shallow, marine connection existed to the Rhine Graben and beyond to the Tethys.

1.2. Previous work

This study relies on publications by Vandenberghe (1978) on the sedimentology of the Boom clay and on the thesis by van Echelpoel (1991), concerning the quantitative cyclostratigraphy of the Boom Formation. Vandenberghe provided a detailed account of the distribution, correlation and sedimentological characteristics of the Boom clay. In particular, his recognition of the unique characteristics of several of the 18 septarian horizons contributed significantly to a reliable correlation of numerous outcrop sections and boreholes. The sequence stratigraphic interpretation is based on data presented in Vandenberghe (1978) and van Echelpoel (1987), and is complemented by field observations.

1.3. Stratigraphic position

In this paper the Rupelian is considered the lowermost Oligocene Stage. Traditionally, the Eocene-Oligocene

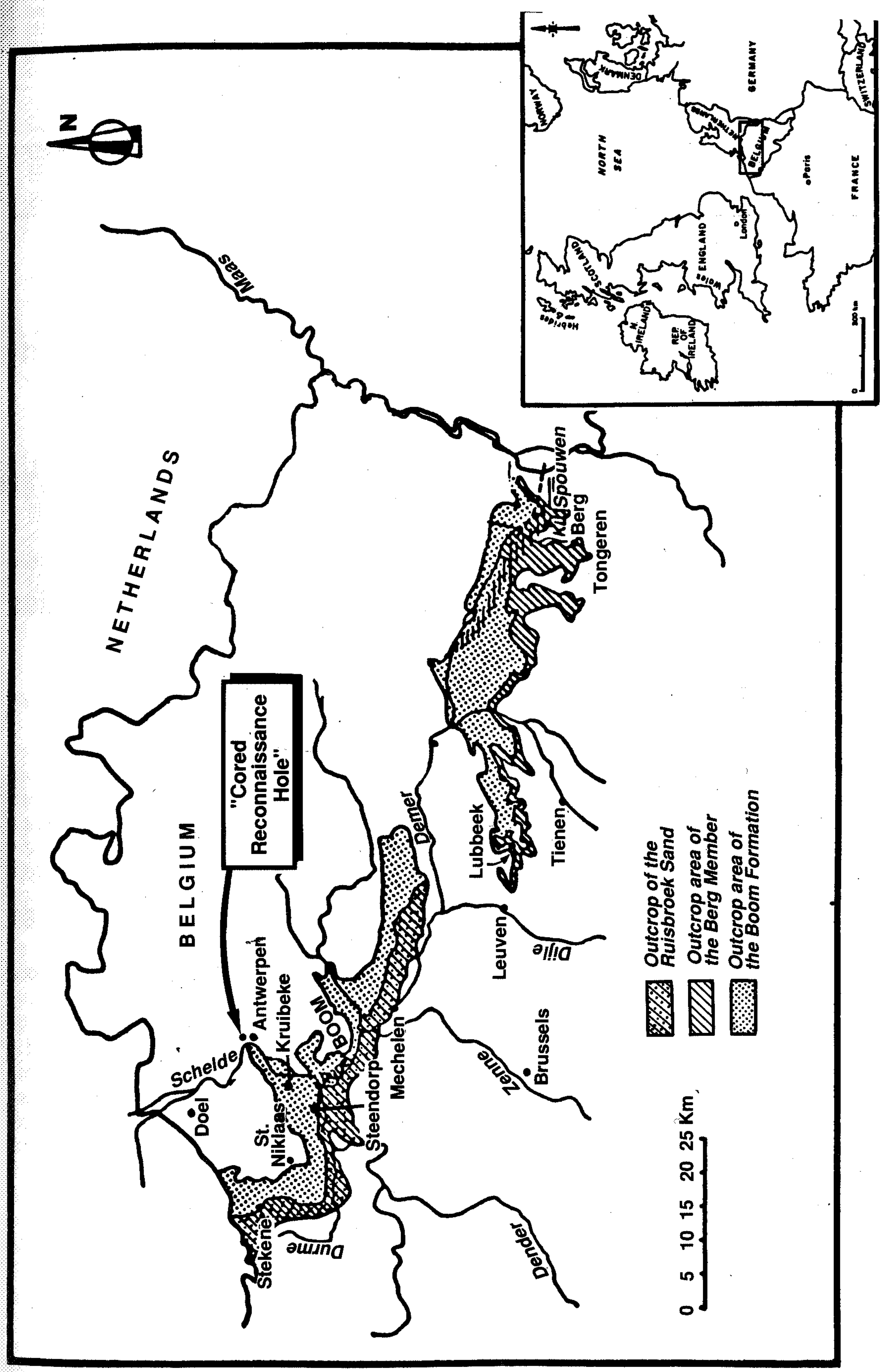


Figure 1. Location and outcrop map, modified from van Echelpoel (1991). Short horizontal marks to the left of each column represent sample positions.

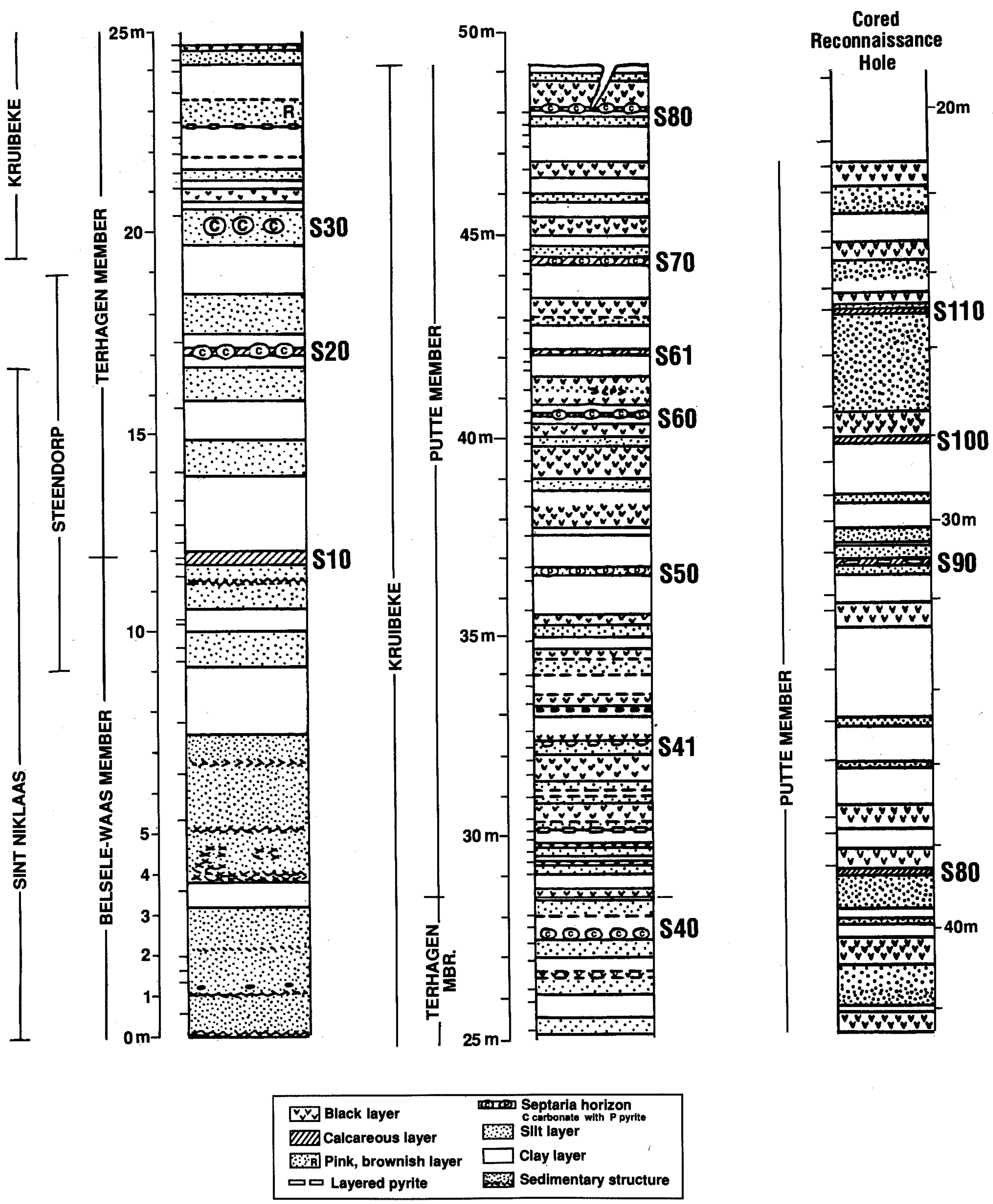


Figure 2. Boom Formation Composite Stratigraphic Section. Left and center columns from Vandenberghe and van Echelpoel (1987), right column from Vandenberghe (pers. comm.).

N. W. BELGIUM					DOEL 14E-194 WELL	
SERIES	STAGE	FORMATION	MEMBER	SYMBOL	SAMPLES	SEQ.
OLIGOCENE	RUPELIAN	BOOM	BELSELE-WAAS	R2c	① 109.75 m	
?	?	ZELZATE	RUISBROEK	S4	② 114.35 m ③ 119.90 m	SB (Haq et al. 36 Ma)
			WATER-VLIET	A4	④ 128.90 m ⑤ 130.90 m	SB
EOCENE	PRIABONIAN		BASSE-VELDE	S3	⑥ 139.90 m ⑦ 159.90 m	SB (Haq et al. 39.5 Ma)

Figure 3. Northwest Belgium lithostratigraphy and the position of samples from the Doel 14E-194 Well.

boundary is placed between the Priabonian and Rupelian Stages but an accurate calibration of the two stratotypes with magnetostatigraphy and low latitude biostratigraphic zonations remains elusive. Hardenbol (1968) reported rare occurrences of *Hantkenina* and *Turborotalia cerroazulensis* from the Blue clay low in the Bressana section, Italy, thus confirming a position not above planktonic foraminifera Zone P 17. Hooyberghs (1983) reported planktonic foraminifera zones P 18 through P 21 while Verbeek (1982) and Steurbaut (1986) each reported calcareous nannofossil zones NP 23 and NP 24 from the Boom clay. Recently, however, a boundary stratotype for the Eocene-Oligocene was accepted by the Commission on Stratigraphy on the recommendation of the International Subcommission on Paleogene Stratigraphy and awaits a final decision by the IUGS. The new boundary stratotype is defined at the Massignano section in Italy at meter level 19 in the Scaglia Cinerea (Premoli Silva *et al.*, 1988). This level coincides with the extinction of the planktonic foraminifera genera *Hantkenina* and *Cribrohantkenina* (P 17-P 18 boundary). The new boundary falls in calcareous nannofossil Zone NP 21, in Magnetic Polarity interval 13R, and has been documented also by strontium, oxygen and carbon isotope analysis. The boundary stratotype is defined in low-latitude, deep water deposits and as such will facilitate stratigraphic correlations especially in low to middle latitude oceanic deposits. However, in the studies leading to the definition of the boundary stratotype no attempt was made to establish the position of the stratotype relative to the Priabonian and Rupelian type sections. Such a correlation is, however, complicated by the neritic nature of the type section of the Priabonian and the boreal location of the type area of the Rupelian. Dinoflagellates represent the most promising fossil group capable of establishing a correlation between the two areas since representatives of this group tend to occur in both neritic and more open marine environments.

Recent studies (Brinkhuis, 1994 ; Brinkhuis & Visscher, in press ; Brinkhuis & Biffi, 1993) present a correlation between the type Priabonian and the Massignano sections using dinoflagellates. Brinkhuis projected the boundary, as defined at the Massignano section, near the top of the nodular limestone bed of the type Priabonian. Thus the boundary occurs near the middle of the type section as defined at the Eocene Colloquium by Hardenbol (1968) and modified recently by Barbin (1986). A comparison of dinoflagellate assemblages described by Brinkhuis (1994) from the Massignano, Priabona, Bressana and the Contessa Highway sections in Italy, with the assemblages discussed here from the Belsele-Waas Member of the Boom Formation and the Ruisbroek, Watervliet and Bassevelde Members of the Zelzate Formation in Belgium, suggests a possible reliable correlation (Figure 4).

Two of the dinoflagellate zones proposed by Brinkhuis (1994) are tentatively identified in the Doel 14E-194 well samples attributed to the Watervliet and Bassevelde Members. The *Areosphaeridium diktyoplokus* Interval Zone (Adi) is recognized in two samples of the Bassevelde Sand while the *Reticulatosphaera actinocoronata* Interval Zone (Rac) is identified in one sample of the Watervliet clay. The appearance of *Wetzeliella gochtii* in the next higher sample at the base of the Ruisbroek sand also agrees with the recovery of this taxon by Brinkhuis (1994) just above the youngest occurrence of *Glaphyrocysta semitecta* in the Bressana section. It thus appears that the top of the Priabonian type section above the Bryozoan Beds correlates well with the base of the Ruisbroek sand in Belgium. The newly accepted Eocene-Oligocene boundary stratotype at Massignano, however, appears to correlate below the Bassevelde member of the Zelzate Formation and may be situated approximately 50 meters below the base of the Boom clay. As a result of these observations, several scenarios are possible: a, Rescind the acceptance of the Massignano Boundary Stratotype--as suggested by Brinkhuis & Visscher (in press); b, Redefine the Priabonian to conform with the new boundary stratotype and extend the base of the Rupelian age down to the top of a redefined Priabonian or; c, Re-introduce the Tongrian Stage between the Priabonian and the Rupelian Stages. A more detailed account of the similarities and differences of the dinoflagellate assemblages in the two areas is given with the Palynological Analysis section of this paper.

1.4. Sequence stratigraphy

The Boom clay, or its German equivalent the "Septarienton", was deposited during a period of high relative sea-level when sediments onlapped Campanian chalk or basement in the Ardennes and Rhenish Massif. During this time of high sea-level much of the hinterland was submerged and as a result no major depocenters are evident in the western part of the North Sea Basin. The entire thickness of the clay was accumulated by settling out of suspension during alternating periods of higher and lower energy depositional environments. A detailed grainsize analysis of the alternating silts and clays (Vandenberghe, 1978), revealed a number of interesting results:

a. Maximum grain size found in the silts is very similar to that found in the clay,
b. Proportion of this similar coarse silt-very fine sand determines whether the sediment appears to be a clay or a silt,
c. Variations in grain size are gradual,
d. Highest proportion of the coarse fraction is in the middle of a silt bed and the highest proportion of fines is in the middle of a clay bed and,
e. Highest concentrations of organic material always occur on top or just below the top of the silt bed.

From these and other observations Vandenberghe concluded that the rhythmicity of the Boom clay is the result of intermittent higher and lower energy environments at the sediment-water interface. The changes from one mode to the next appear gradual and are caused by either climatic changes or eustasy. Van Echelpoel (1991), in a quantative cyclostratigraphic study, tentatively suggested that the clay-silt alternations in the Boom clay are tied to Milankovitch orbital/climatic cycles and that the most likely forcing agents for two principal spectral peaks at 100 cm and 46 cm are eccentricity and obliquity, respectively. Van Echelpoel concluded that both higher order Milankovitch signals are superimposed on a lower order eustasy driven grainsize cyclicity (Figure 5). Van Echelpoel identified a third cycle (lower order) in the thickness changes of individual clay-silt cycles caused by increases in sediment supply as a result of uplift in the Anglo-Brabant Massif. The latter trend, however, does not require uplift, but could simply be the result of an increased sediment supply at the basin margins after the sea-level rise begins to slow down and progradation has filled drowned estuaries.

In summary, the work of Vandenberghe and van Echelpoel (1987) shows: a, The Boom clay represents a major transgressive-regressive cycle (relative sea-level event) in the North Sea Basin. b, Grain size analysis (% of silt >32μm) of the clay and silt beds show a high frequency signal superimposed on a low frequency trend. The low frequency event shows an initial decrease in the > 32μm fraction from the base of the section to the "reddish" bed (R in Figure 5) followed by a slight increase which culminates in the "double band" (DB in Figure 5) at approximately the middle of the Boom clay. A renewed decrease occurs up to septarian level S60, followed by an increase that continues to the top of the section (Vandenberghe and van Echelpoel, 1987). C, The thickness of the clay beds relative to the silt beds also shows a low frequency trend. Clay beds thin initially relative to the silt beds up to the "double band" and then thicken up to the top of the section (van Echelpoel, 1991).

The relative low sediment supply throughout the section offers a unique opportunity to compare high and low

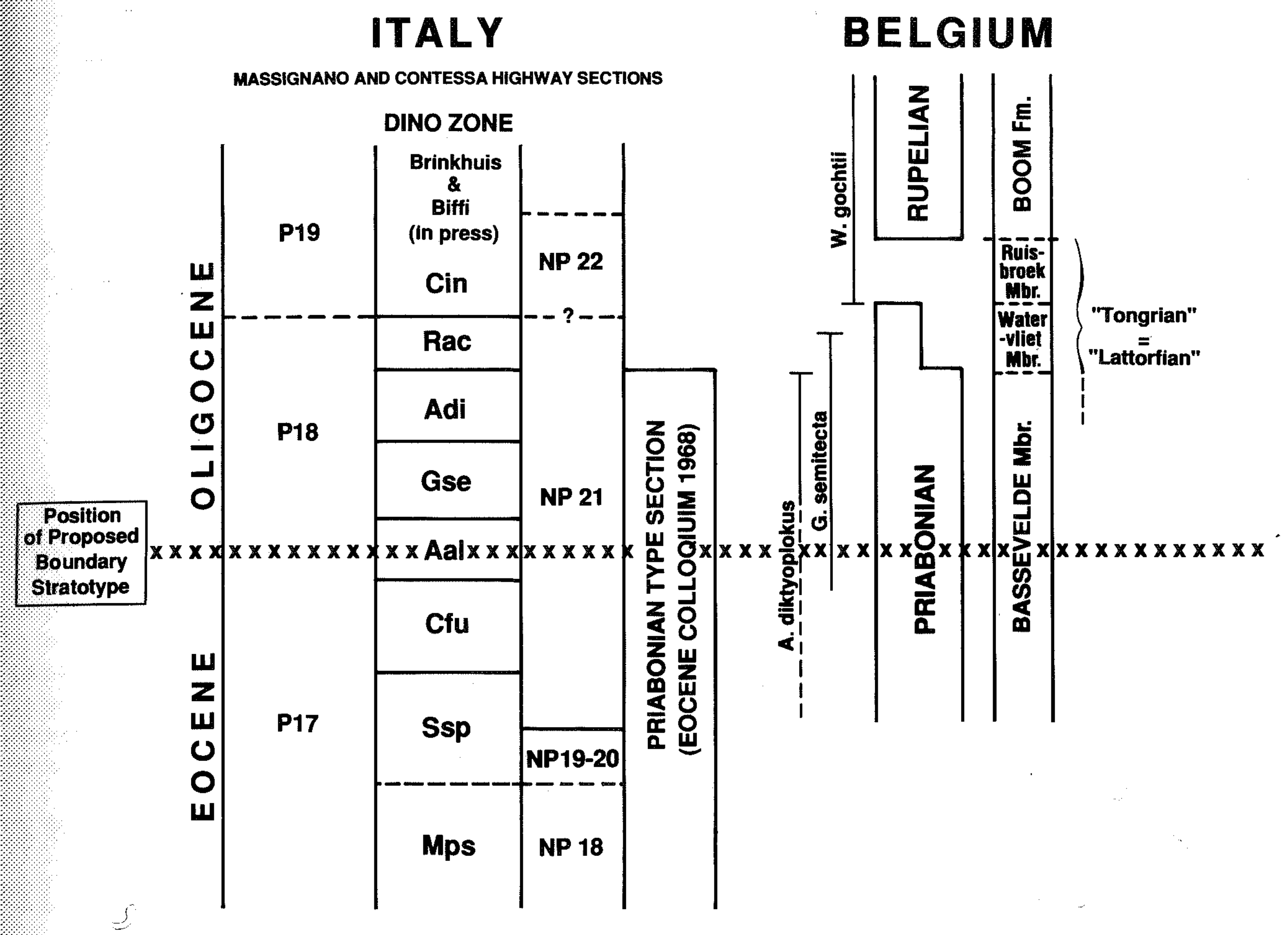


Figure 4. Effect of proposed Eocene-Oligocene boundary stratotype on stratigraphy in Italy and Belgium.

frequency signals in the Boom clay example. Relative sea-level, sediment supply and the longer grain size trends are low frequency variables, while the clay-silt alternations show a high frequency signal. Very likely eustasy figures in both the low and high frequency signals, but cannot be readily separated from subsidence or climate, respectively. To separate eustasy from tectonics requires additional studies, preferably in other basins with different subsidence histories. The studies by Vandenberghe and van Echelpoel (1987) demonstrate that sequence stratigraphic principles can be applied successfully to offshore sections provided observations are made in sufficient detail.

The stratigraphic distribution of the dinoflagellate cysts in the Boom clay is presented here relative to the sequence stratigraphic interpretation proposed by Vandenberghe and van Echelpoel (1987) and van Echelpoel (1991), based primarily on the information summarized above.

The positions of lithological units within a sequence stratigraphic framework are depicted in Text-figure 1. Major sequence boundaries bound the Boom clay at the base and the top, and a minor sequence boundary appears near the middle of the formation, which separates the older RU-1 sequence from the younger RU-2 sequence. At the RU-1 sequence boundary there is evidence of truncation at Lubbeek in the Leuven area in central Belgium. Fluviatile and estuarine incised valley fill deposits of the Kerkom Member of the Borgloon Formation unconformably overlie glauconitic sands of the Upper Eocene Neerrepen Member of the S. H. Hern Formation. The uppermost part of the Kerkom Member at Lubbeek shows tidal influences, while the boundary with the overlying Heide/Berg sand is formed by a distinct transgressive surface. The first dinoflagellates are found directly above the transgressive surface. However, no dinoflagellate data are available from the Heide/Berg sands but preliminary palynological information about the dinoflagellates from the clay immediately overlying the Berg sand suggests a correlation with a horizon between septarian levels S10 and S20 in the Sint Niklaas clay pit. This correlation is in agreement with the identification higher in the section at Lubbeek of septarian level S20 (Vandenberghe, pers. comm.). This tentative correlation suggests an equivalence of the Heide/Berg sands with the

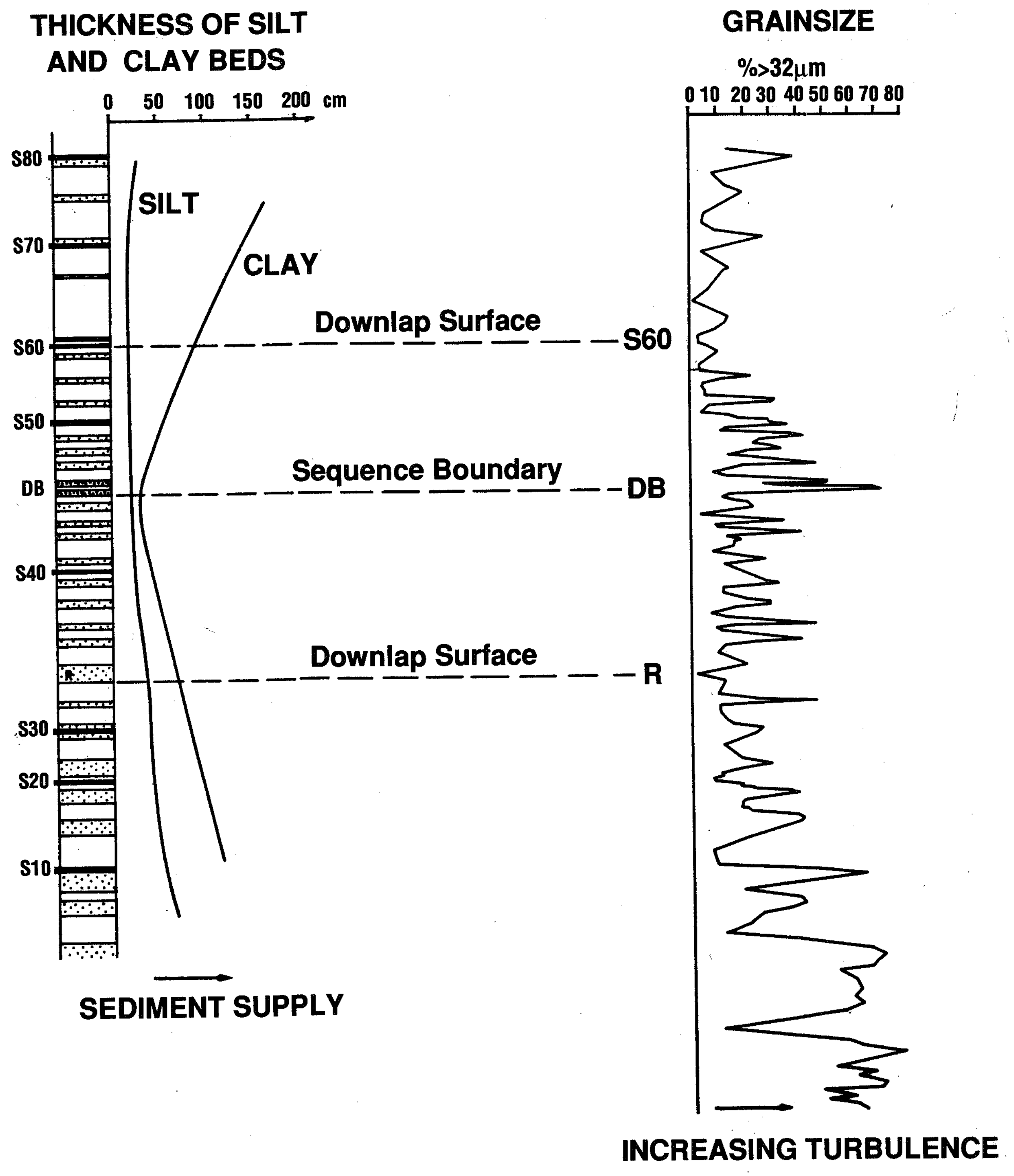
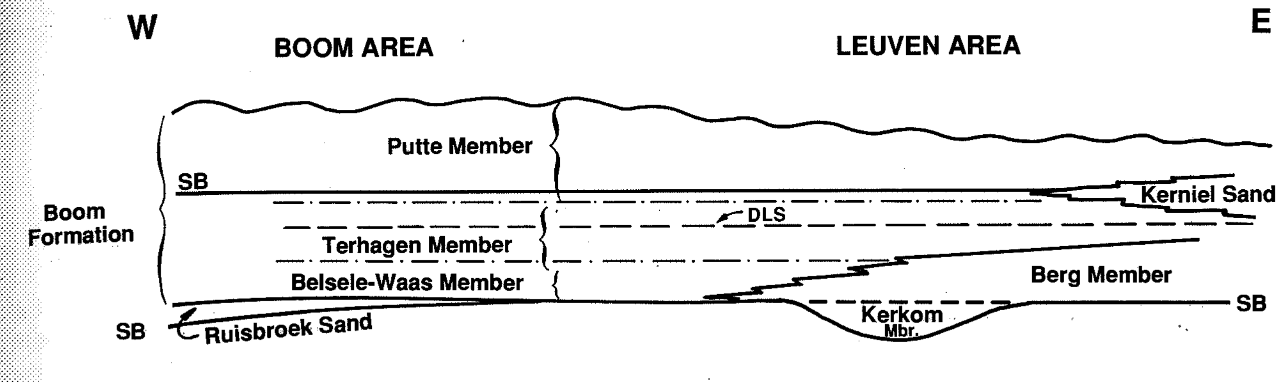


Figure 5. Bed thickness and grain size plots.

Belsele-Waas Member of the Boom clay at Sint Niklaas. The upper part of the Ruisbroek sand, which underlies the Boom clay at Sint Niklaas, may represent the earliest transgressive deposits in western Belgium possibly equivalent to the incised valley fill deposits of the Kerkom Member in central Belgium.

1.5. Sequences and systems tracts

The sequence boundary below the Boom clay within the top of the Ruisbroek sand is either the first or the second sequence boundary in the Oligocene, depending on the final decision on the position of the Eocene-Oligocene boundary. The sequence boundary, RU-1 (RU-1 on Figures), corresponds with the 36 Ma



Text-Figure 1. Sequence framework for lithostratigraphic units in Boom and Leuven areas, Belgium.

sequence of Haq *et al.*, 1988 and its downlap surface at the base of the reddish bed separates the underlying transgressive system tract from the overlying highstand systems tract. The next sequence boundary, RU-2 (Ru-2 on Figures), which equates to the 33 Ma sequence of Haq *et al., ibid.*, is at the base of the "double band" of Vandenberghe (1978); its downlap surface is at septarian level S60 (Figure 5).

2. PALYNOLOGICAL ANALYSES

2.1. Introduction

Procedures. The analysis of Rupelian microplankton is based on the examination the assemblages from 110 samples, 106 surface samples from the Boom Composite Section (Figure 2) and four core samples from the Doel 14E-194 well (Figure 3). To help determine the palynological relationship between the dinoflagellate associations from the Oligocene Boom Clay Formation and underlying Zelzate Formation, four core samples from the latter, also from the Doel 14E-194 well, were studied.

Standard processing techniques were used for the separation of palynomorphs from the rock samples and the resultant residues were sieved; stained slides were prepared from the +33µm and -33µm fractions. Relative abundances were calculated from 250 specimen counts from the +33 µm slides. The relative abundance designates and their definitions are: VR = very rare, 0.4% to <3% (1 - 7 specimens); R = rare, >3% to <6% (8 - 14 specimens); F = frequent, >6% to <12.5% (15 - 31 specimens); C = common, >12.5% to <25.5% (32 - 63 specimens); A = abundant, >25.5% to <50% (64 - 124 specimens) and VA = very abundant, 50% or more (125 or more specimens). Of the 110 Boom clay samples used in this study, only 17 contained insufficient specimens for statistical treatment and the majority of those samples were from the upper eight meters of the Boom Composite Section. Photomicrographs of representative specimens for nearly all microplankton taxa identified in the Boom Formation are shown on the accompanying plates. Only specimens from the composite section shown in Figure 2 were photographed.

2.2. Previous studies

Palynological literature on western European Oligocene dinoflagellates, compared to that on Eocene assemblages, consists of relatively few publications. The early papers (Gocht 1952, 1960, 1969 ; Maier, 1959 ; Gerlach, 1961 ; Brosius, 1963 ; Morgenroth, 1966) dealt mainly with species descriptions. The paper by Gocht (1969) contained some quantitative data on a few Oligocene samples from a Meckelfeld borehole, Germany, and an extensive dinoflagellate assemblage from the Tönisberg borehole was reported by Benedek (1972), also from Germany. Many of the species in the early publications were subsequently re-studied and re-illustrated (Benedek and Sarjeant 1981; Benedek, Gocht and Sarjeant 1982; Sarjeant 1983, 1984). Liengjarern, Costa and Downie (1980) reported on Lower Oligocene dinoflagellates from the Hampshire Basin, England.

Zonations of Oligocene sections proposed by Benedek and Müller (1974, 1976) were later applied to numerous borehole sections in northwest Germany by Benedek (*in* Tobien 1986). The zonations presented by Manum (1976) and by Manum *et al.* (1989) provided information about the dinoflagellate distribution in Oligocene sections from Norwegian Sea DSDP and ODP sites. Costa and Manum (in Vinken 1988) defined a Tertiary dinoflagellate zonation for northwestern Europe which was applied recently, with modification, by Köthe (1990) to boreholes in Germany.

2.3. Dinoflagellates in the Boom composite section

A diverse and well-preserved dinoflagellate assemblage was recovered from the Boom Composite Section in Belgium. The stratigraphic distribution and relative abundances of the taxa are depicted on Figure 6. On the basis of their overall ranges each taxon is assigned to one of the following categories :

1. Taxa whose bases are pre-Rupelian and whose tops are post-Rupelian (39 forms),
2. Taxa whose bases are pre-Rupelian and whose tops are in the Rupelian (13 forms),
3. Taxa whose bases are in the Rupelian and whose tops are post-Rupelian (10 forms, plus *Wetzeliella gochtii*, which is included in the *Wetzeliella symmetrica* 'complex', and
4. Taxa whose bases and tops are in the Rupelian (14 forms).

Forms in Category 1

Achilleodinium biformoides
Achomosphaera alcicornu
Apteodinium australiense
Areosphaeridium pectiniforme
Caligodinium amiculum Nematosphaeropsis spp.
Cordosphaeridium cantharellum
Cordosphaeridium inodes
Cordosphaeridium gracile
Cordosphaeridium minimum
Cribroperidinium tenuitabulatum
Cyclopsiella spp.
Dapsilidinium pseudocolligerum
Deflandrea phosphoritica 'complex'
Dinopterygium spp.
Distatodinium spp.
Heteraulacacysta leptalea
Homotryblium pallidum
Homotryblium plectilum
Hystrichokolpoma cinctum
Hystrichokolpoma rigaudiae
Hystrichokolpoma salacium
Impagidinium dispertitum
Lingulodinium machaerophorum
Membranophoridium aspinatum
Operculodinium centrocarpum
Operculodinium microtriainum
Palaeocystodinium golzowense
Pentadinium laticinctumtaeniagerm
Rhombodinium draco
Spiniferella cornuta
Spiniferites pseudofurcatus
Spiniferites ramosus
Spiniferites spp.
Systematophora placacantha
Tectatodinium grande
Tectatodinium pellitum
Thalassiphora pelagica
Wetzeliella symmetrica 'complex'

The forms in Category 1 comprise the bulk of the Boom Formation dinoflagellate assemblage, both qualitatively and quantitatively. Members of the *Deflandrea phosphoritica* 'complex' dominate the Boom dinoflagellate assemblage, although relatively high abundances were recorded for other taxa in restricted parts of the Boom Composite Section. For example, *Dapsilidinium pseudocolligerum* is sporadically abundant in the Putte Member between 22.59 and 47.00 meters and *Chiropteridium mespilanum* is generally common from the base of the section to 7.90 meters (Belsele-Waas Member) and occasionally common in the Putte Member between 25.88 and 42.41 meters.

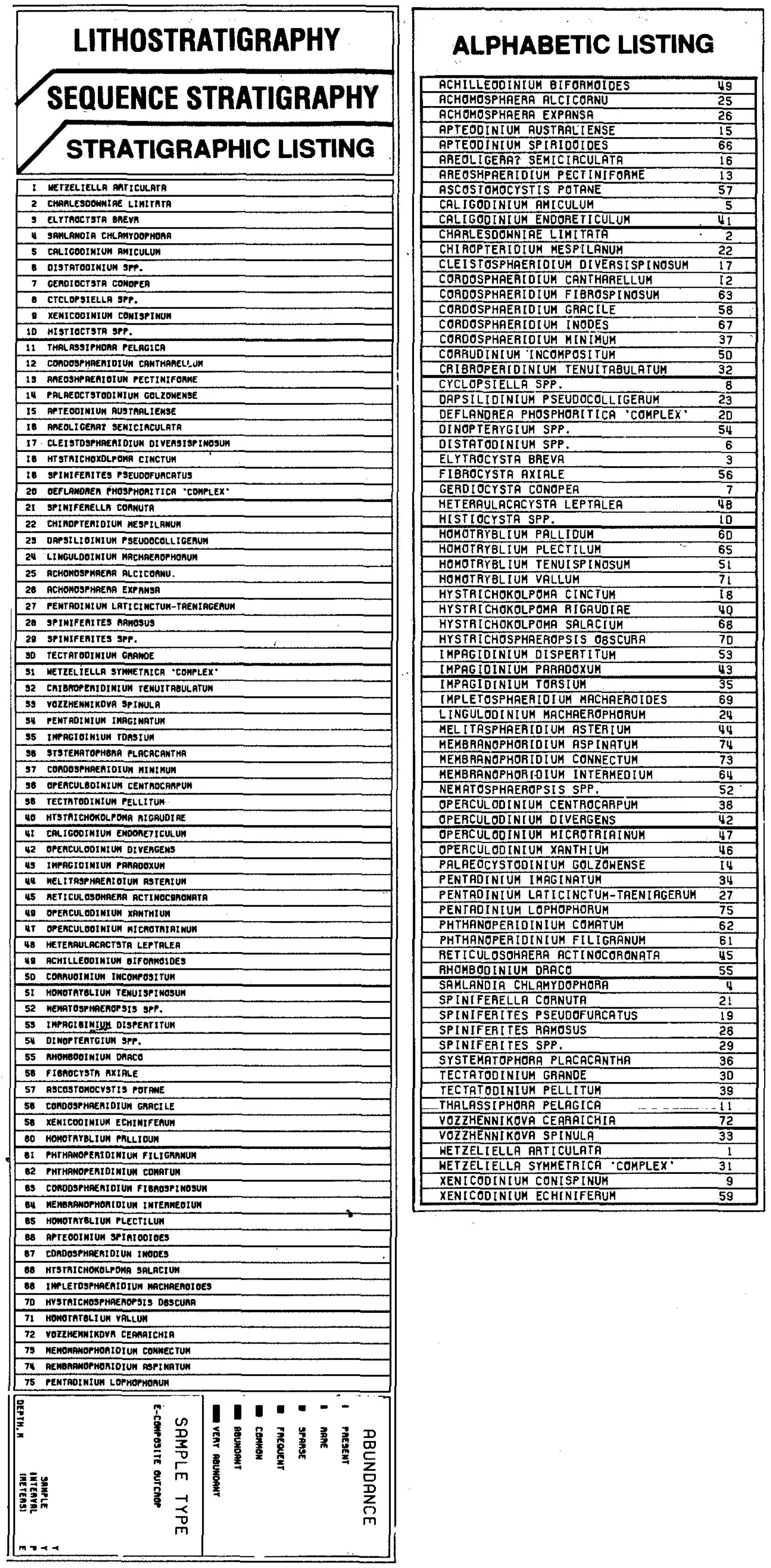
Forms in Category 2

Cleistosphaeridium diversispinum
Cordosphaeridium fibrospinosum
Corrudinium incompositum
Elytrocysta breva
Fibrocysta axialis
Histiocysta spp.
Homotryblium tenuispinosum
Melitasphaeridium asterium
Operculodinium divergens
Phthanoperidinium comatum
Samlandia chlamydophora
Wetzeliella articulata
Xenicodinium conispinum

These taxa, with the exception *Cleistosphaeridium diversispinosum* and *Histiocysta spp.*, occur rarely and sporadically. *Histiocysta spp.* is a dominant taxon in the Belsele-Waas Member from the base of the Boom Composite Section to 11.20 meters and is sparse to common in the Putte Member from 22.59 to 25.88 meters. *Cleistosphaeridium diversispinosum* occurs most abundantly between 23.30 and 43.12 meters (Putte Member).

Forms in Category 3

Apteodinium spiridoides
Areoligera? semicirculata
Chiropteridium mespilanum
Homotryblium vallum
Hystrichosphaeropsis obscura
Impagidinium paradoxum



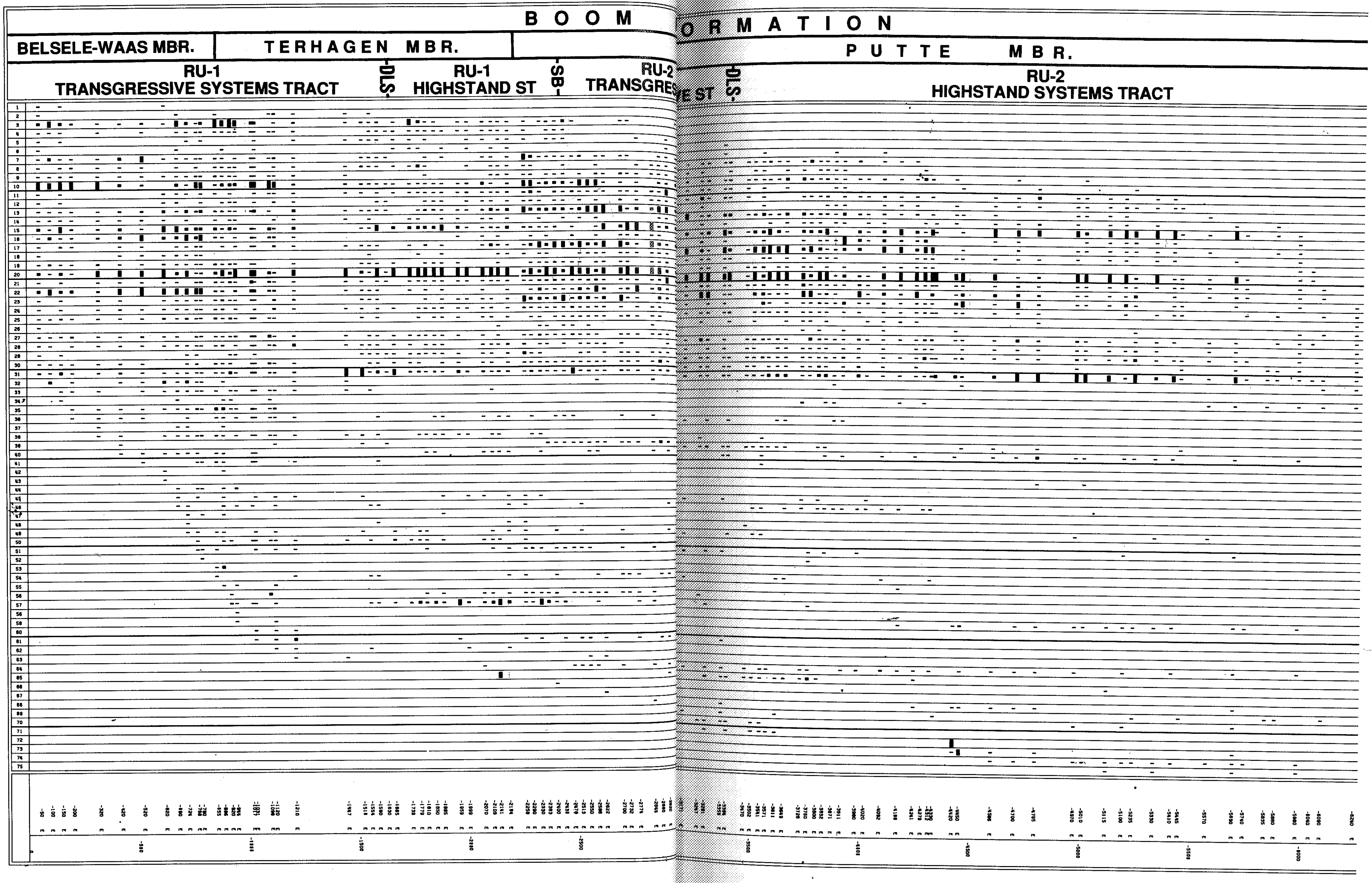


Figure 6. Dinoflagellate occurence and relative abundance chart, Boom Composite Section.

Operculodinium xanthium
Pentadinium lophophorum
Reticulosphaera actinocoronata
*Wetzeliella gochtii***

** Included in the *Wetzeliella symmetrica* 'complex'

Common occurrences of *Areoligera ? semicirculata* were found in samples from the Belsele-Waas Member between 5.20 and 7.90 meters and the Putte Member sample from 39.11 meters is dominated by this species. Although *Areosphaeridium pectiniforme* is present throughout most of the Boom Formation, the species is common to abundant in several Putte Member samples between 22.59 and 31.71 meters. Specimens of *Wetzeliella gochtii* are common in some samples.

Forms in Category 4

Achomosphaera expansa
Ascostomocystis potane
Caligodinium endoreticulum
Charlesdowniea limitata
Gerdiocysta conopea
Impagidinium torsium
Impletosphaeridium machaeroides
Membranophoridium connectum
Membranophoridium intermedium
Pentadinium imaginatum
Phthanoperidinium filigranum
Vozzhennikovia cearaichia
Vozzhennikovia spinula
Xenicodinium echiniferum

Ascostomocystis potane is common in Terhagen Member samples from 19.59 and 21.41 meters, and in the Putte Member at 23.30 meters. The highest abundances of *Elytrocysta breva* are limited to the section between 1.00 and 17.39 meters (Belsele-Waas Member into the Terhagen Member). Most of the species in Category 4 are new.

2.4. Biostratigraphic datums

Of the dinoflagellates in the Boom Composite Section, 37 taxa have their bases, tops, or both in the section. A list of the taxa, the locations of their datum points and the systems tracts in which they occur are presented in Appendix B and the positions of selected tops and bases are depicted on Figure 7. Collectively, these taxa provide a series of reference points of which some may prove useful for placing particular taxa within specific systems tracts in other sections of comparable age.

Within the major transgressive-regressive cycle of the Rupelian, which includes the RU-1 and RU-2 sequences (equivalent to the 36 Ma and 33 Ma sequences of Haq *et al.*, 1988), 22 of 26 bases occur in the transgressive systems tracts and 19 of 30 tops occur in the highstand systems tracts (see Table 1).

This situation is not unique to the Boom Formation. However, what may be peculiar to the formation is that the majority of bases are found in the RU-1 transgressive systems tract and the majority of tops are in the RU-2 highstand systems tract. Thus, there is little change in species contents above and below the RU-2 sequence boundary. We have observed in other Lower Tertiary sections that the upward deepening transgressive systems tracts favor the introduction of species, whereas the extinction of species occurs most frequently in the upward shallowing highstand systems tracts. In most examples, the appearances of taxa are seemingly rather abrupt and are concentrated in the lower part of the transgression. In contrast, the extinctions of taxa during regression are generally gradual but tend to occur mostly during the later part of highstand deposition.

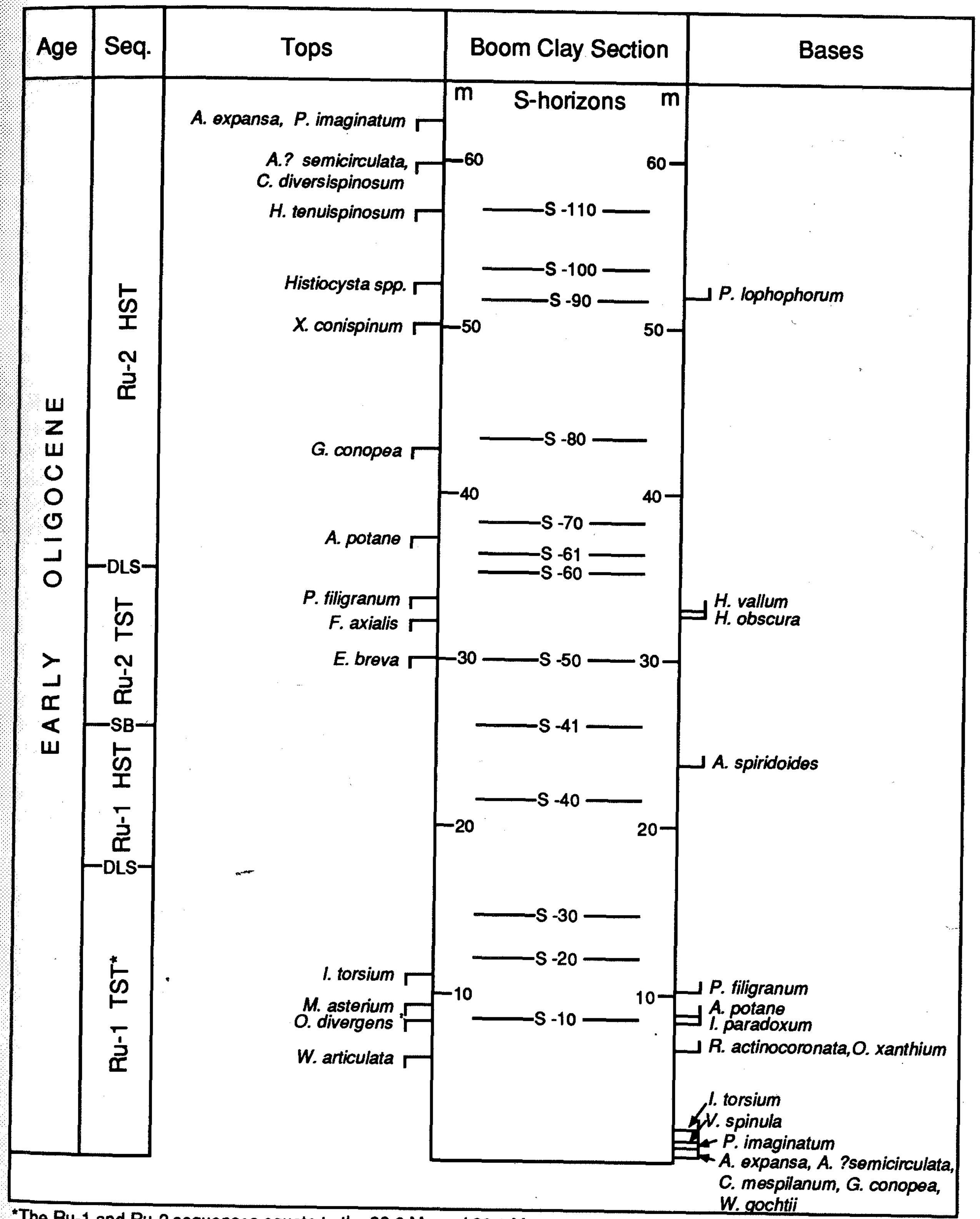
2.5. Succession of dinoflagellate associations

The mainly quantitative characteristics and the succession of dinoflagellate associations, relative to sequence components, are discussed below. Five of the 12 association are from transgressive strata, five from highstand strata, and two from strata at or near downlap surfaces.

Associations from the RU-1 Sequence

Transgressive Systems Tract Associations

There are three associations in this systems tract. The basal association, from 0.50 to 7.90 meters is in the Belsele-Waas Member and begins with a moderately diverse assemblage of 31 taxa which increases to 51 taxa at the top of the interval. The majority of these (40) are pre-existing forms and 11 are first appearing species. Thus, about 80 percent of the taxa are known to occur in Pre-Rupelian sections. Characteristic of the association are the relatively high abundances of *Elytrocysta breva* and *Histiocysta spp.*, either together or separately, along with the common occurrences of *Chiropteridium mespilanum* and *Areoligera ? semicirculata*. Members of the *Deflandrea phosphoritica* 'complex', although frequent to common, do not dominate the association as they do in some younger associations. *Wetzeliella articulata* terminates in this interval.



*The Ru-1 and Ru-2 sequences equate to the 36.0 Ma and 33.0 Ma sequences, respectively, of Haq et al. 1988.

Figure 7. Selected biostratigraphic datum in the Boom Formation. For additinal information consult Appendix B.

	Ru-1 Sequence		Ru-2 Sequence*		Totals
	TST	HST	TST	HST	
Tops	5	2	6	17	30
Bases	18	1	4	3	26

* The Ru-1 and Ru-2 sequences equate to the 36.0 Ma and 33.0 Ma sequences, respectively, of Haq et al. 1988.

Table 1. Distribution of tops and bases relative to system tracts.

In the overlying association from 8.55 to 11.20 meters and mostly from the Terhagen Member, 10 taxa are added of which seven are known from Pre-Rupelian sections. The most frequent occurrences of *Impagidinium* specimens are in this interval. Specimens of *Elytrocysta breva* and *Histiocysta spp.* continue to be abundant, the former in the lower part and the latter in the upper part. Both *Areoligera ? semicirculata* and *Chiropteridium mespilanum* decrease markedly in abundance, whereas members of the *Deflandrea phosphoritica* 'complex' remain common. Three species terminate within these transgressive strata.

The association from 12.10 to 15.90 meters is characterized by the absence of Impagidinium species, a marked decrease in the abundances of *Elytrocysta breva* and *Histiocysta spp.*, and high abundances of either the *Deflandrea phosphoritica* or *Wetzeliella symmetrica* 'complexes', or both. *Cordosphaeridium fibrospinosum* is present and the range of *Charlesdowniae limitata* ends in this interval.

Highstand Systems Tract Associations

The association from the lower part of the RU-1 highstand systems tract (16.30 to 21.84 meters in the Terhagen Member) is dominated consistently by members of the *Deflandrea phosphoritica* 'complex', whose species account for approximately 40 to 70 percent (average, 55 percent) of the specimens in the association. Specimens of *Apteodinium australiense* and *Elytrocysta breva* are sparse to common in the lower part of the interval and common occurrences of Ascostomocystis potane are recorded for the first time in the upper part.

The succeeding association extends from the base of the Putte Member at 22.59 meters to 24.00 meters. Within this interval the relative abundance of the *Deflandrea phosphoritica* 'complex" fluctuates, rather than being fairly constant as in the underlying dinoflagellate association. *Gerdiocysta conopea* and *Histiocysta spp.* are common to abundant in the lower part of the interval, whereas *Cleistosphaeridium diversispinosum* occurs more commonly in the upper part. Specimens of *Histiocysta spp.* are sparse to common and the oldest occurrence of *Apteodinium spiridoides* is in this interval.

Associations from the RU-2 Sequence

Transgressive System Tract Associations

The dinoflagellate association from the Putte Member between 24.38 and 25.88 meters is very similar to that below the RU-2 sequence boundary. The major differences are the very rare occurrences of *Gerdiocysta conopea* and the increase in the abundance of *Chiropteridium mespilanum* in the section above the sequence boundary. The last common occurrence of *Histiocysta spp.* is in this interval and *Dapsilidinium pseudocolligerum* diminishes in abundance. However, *Cleistosphaeridium diversispinosum* remains sparse to common, *Apteodinium australiense* increases in abundance as does *Areosphaeridium pectiniforme*, but to a lesser extent, *Chirpoteridium mespilanus* is sporadically common.

The overall qualitative character of the dinoflagellate association from the RU-2 transgressive section does not differ markedly from the late highstand association of the RU-1 sequence. Six species terminate and four commence in this transgressive interval ; the low number of the latter contrasts sharply with the relatively large number of species (18) which begin in the RU-1 transgressive systems tract.

Highstand Systems Tract Association

The highstand section of the RU-2 sequence extends from 35.02 meters to the top of the Boom Composite Section and lies entirely within the Putte Member. Three dinoflagellate associations are recognized in these strata. The association from 35.02 to 43.30 meters is characterized by relatively high abundances of *Cleistosphaeridium diversispinosum* and the *Deflandrea phosphoritica* 'complex', together with sporadically common ocurrences of *Chiropteridium mespilanum* and *Apteodinium australiense.* The sample at 39.11 meters contains a dinoflagellate suite dominated by specimens of *Areoligera ? semicirculata.* No species originate in this association but four terminate.

This highstand association from 44.20 to 56.90 meters contains dinoflagellate suites which in the lower meter or so of section consist firstly of abundant specimens of *Vozzhennikovia cearaichia* and subsequently of common specimens of *Dapsilidinium pseudocolligerum* and *Membranophoridium connectum.* From 45.96 meters and above, the association, for the most part, contains common to abundant occurrences of *Apteodinium australiense* and members of the *Wetzeliella symmetrica* 'complex'. Specimens of the *Deflandrea phosphoritica* 'complex' are generally common to abundant throughout this interval. Five species appear but seven terminate in the interval.

Samples from the upper highstand section from 57.40 meters and above yielded meagre dinoflagellate suites composed of low numbers of specimens and generally few species. Accordingly, no taxon occurs even sparsely. Eight species terminate in this interval.

Associations at or near Downlap Surfaces

The dinoflagellate associations recovered from or near the downlap surfaces at 16.30 and 34.70 meter levels (top of the transgressive systems tracts) contains a meagre number of specimens and species compared to the dinoflagellates in the underlying and overlying sections. A significant reduction in the number of species, or the number of specimens, or both, appears to be diagnostic of dinoflagellate associations at or adjacent to downlap surfaces. The association from the 16.30 meter level has a marked reduction in both the number of species and of specimens, relative to the adjacent associations; the association from the 34.70 meter level contains slightly fewer species but considerably fewer specimens than found in the immediately preceding sample.

In general, the dinoflagellate associations from the RU-1 transgressive systems tract reflect conditions favorable to the establishment and preservation of a richly diverse and abundant indigenous Rupelian dinoflagellate cyst flora. By the end of the RU-1 transgressive interval, 63 of the 75 microplankton taxa ideniified in the Boom Composite Section are present in an apparently depositionally optimal and stable setting. In addition, of the 26 species whose oldest occurrences are in the Rupelian, 18 appear in the transgressive strata of the RU-1 sequence.

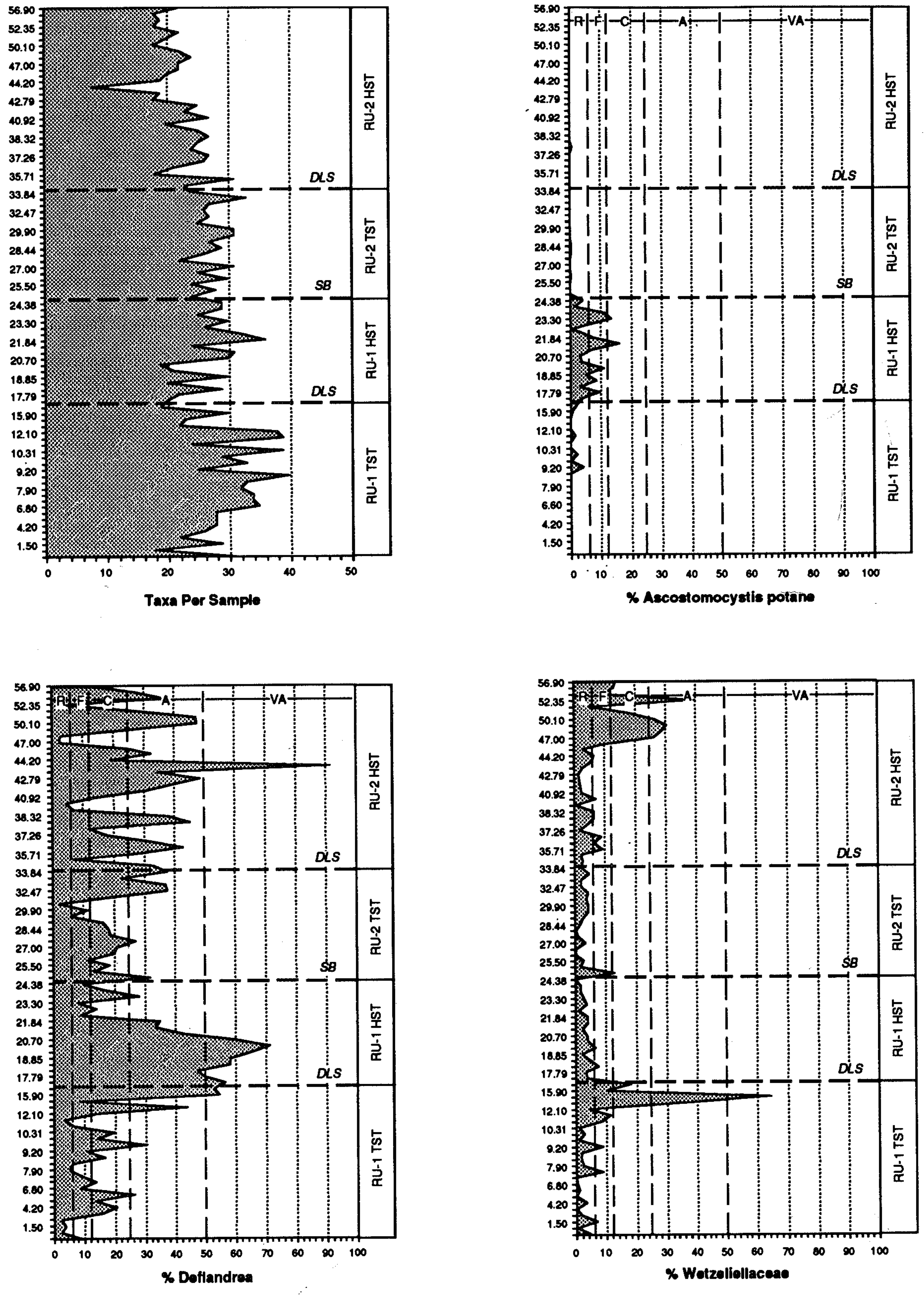
The dinoflagellate associations from the RU-1 highstand systems tract reflect continuing favorable and stable conditions. As such, the highstand associations hardly differ qualitatively from those in the upper part of the underlying transgressive systems tract. However, they do differ quantitatively. Equally favorable depositional, environmental and preservational conditions continued through the transgressive and into the lower highstand strata of the RU-2 sequence. Above these strata is a gradual overall decrease in the number of species in the associations. The uppermost part of the highstand systems tract shows not only a qualitative diminuation of species, but a quantitative reduction in the number of specimens as well. The upward shallowing nature of most of the RU-2 highstand strata is reflected in the dinoflagellate associations by the gradual, upsection decrease in the number of taxa (expressed by the number of species terminations with much fewer accompanying appearances) and the quantitative lessening of specimens in the upper several meters below the top of the section.

2.6. Number of taxa per sample

The number of taxa per sample are shown in Figure 8. In the Rupel 1 transgressive systems tract the average number of taxa per sample is 30. However, the samples from 6.80 to 12.10 meters contain the most diverse assemblages (average, 34 taxa); samples above and below contain an average of 26 forms. Except for the reduction in the number of taxa to 10 in the sample at the RU-1 downlap surface, the average number of taxa per sample remains fairly constant in the overlying highstand section (24), in the RU-2 transgressive section (27) and in the lower five meters of the succeeding highstand strata (24). In the remainder of the RU-2 highstand interval, the average number of taxa per sample drops to 19 in the samples between 41.68 and 54.10 meters and decreases further to an average of 11 taxa per sample in the upper 10 meters of section. These numbers support the conclusion that the establishment of the Boom dinoflagellate assemblage occurred relatively early during the transgressive system tract of the RU-1 sequence. Once established, the assemblage remained relatively constant from the late transgressive deposition of the RU-1 sequence into the early highstand deposition of the RU-2 sequence. Deterioration of the assemblage was at first gradual and then accelerated during late highstand deposition. Plots of data from Boom Composite Section samples above the 56.90 meter level are not shown in Figures 8 through 19 owing to the scarcity of dinoflagellate specimens and taxa in the upper approximately 8 meters of section.

2.7. Paleoecological considerations

The approach of Köthe (1990) to infer paleoecological conditions based on quantitative and qualitative differences in dinoflagellate assemblages was applied to the Boom dinoflagellate assemblage. The 1. short time span (ca. 6 Ma) represented by the Boom Formation in Belgium, 2. paucity or absence of the taxa in some of Köthe's eco-groups, and conversely, 3. dominance in the Boom assemblage of some taxa not included in one of her eco-groups, made it necessary to designate new



Figures 8-11. Upper left : Figure 8, taxa per sample ; Upper right : Figure 9, relative abundances of Ascostomocystis potane Eco-group ; Lower Left : Figure 10, relative abundances of Deflandrea Eco-group ; Lower right : Figure 11, relative abundances of Wetzelelliaceae Eco-group.
R = rare or very rare, F = frequent, C = common, A = abundant, VA = very abundant.

eco-groups and redefine others to accommodate this study. We have, however, tried to maintain the eco-groups of Köthe as much as possible. A comparison of the eco-groups used herein and those of Köthe (1990) are shown in Table 2.

KÖTHE (1990)	**THIS STUDY**
Cribroperidinium	*Apteodinium* + allied types
Spiniferites + *Achomosphaera*	Included in Other
Glaphyrocysta + *Areoligera* + *Systematophora* + *Adnatosphaeridium* + *Riculacysta*	*Chiropteridium* + allied types
Cordosphaeridium	Included in Others
Impletosphaeridium and Related taxa	*Cleistosphaeridium* + allied types
Wetzeliellaceae	*Wetzeliellaceae*
Deflandrea + *Ceratiopsis*	*Deflandrea*
Phthanoperidinium	Included in Others
Areosphaeridium	*Areosphaeridium pectiniforme*
Homotryblium	*Homotryblium* + *Thalassiphora*
Thalassiphora	*Homotryblium* + *Thalassiphora*
Spinidinium densispinatum	Not in Boom Assemblage
All other dinoflagellates	Others
Acritarchs	*Ascostomocystis potane*
No equivalent	*Histiocysta* + *Elytrocysta*
No equivalent	*Impagidinium* + *Corrudinium*

Table 2. Comparison of the eco-group designates

1. *Ascostomocystis potane* Eco-group (Figure 9)
This category contains specimens of the acritarch species *Ascostomocystis potane* only which occurs consistently between 15.54 and 25.88 meters and sporadically down to 9.20 meters and up to 37.60 meters. The species was not reported by Köthe (1990).

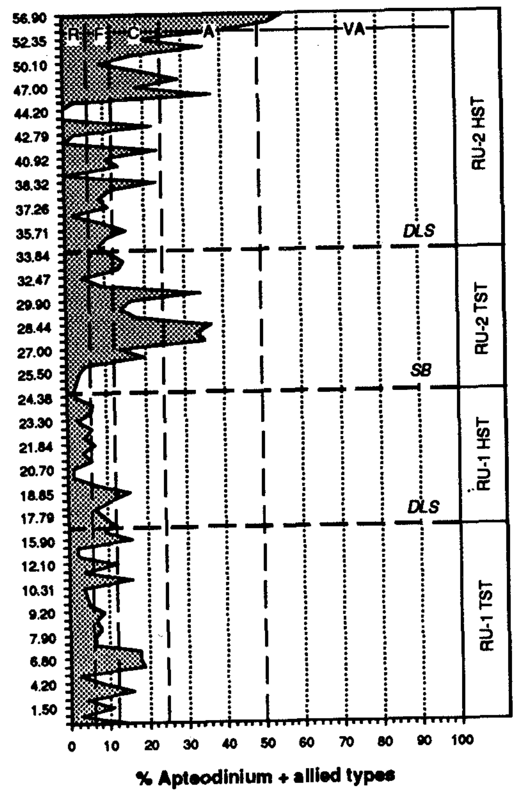
2. *Deflandrea* Eco-group (Figure 10)
This eco-groups consists of the species in the *Deflandrea phosphoritica* 'complex'. *Deflandrea phosphoritica* is the most commonly occurring species, but in some assemblages *D. heterophlycta* may dominate. *Deflandrea spinulosa* is very rare. Members of the complex occur throughout the section.

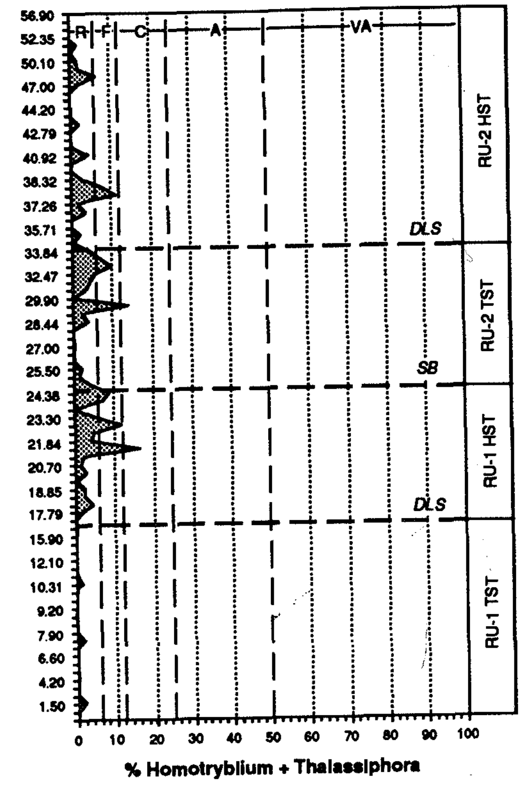
3. Wetzeliellaceae Eco-group (Figure 11).
Included in this eco-group are members of the *Wetzeliella symmetrica* 'complex' together with *Charlesdowniea limitata*, *Rhombodinium draco* and *Wetzeliella articulata*. Members of the group extend throughout the section and are generally less abundant than those in the Deflandrea eco-group.

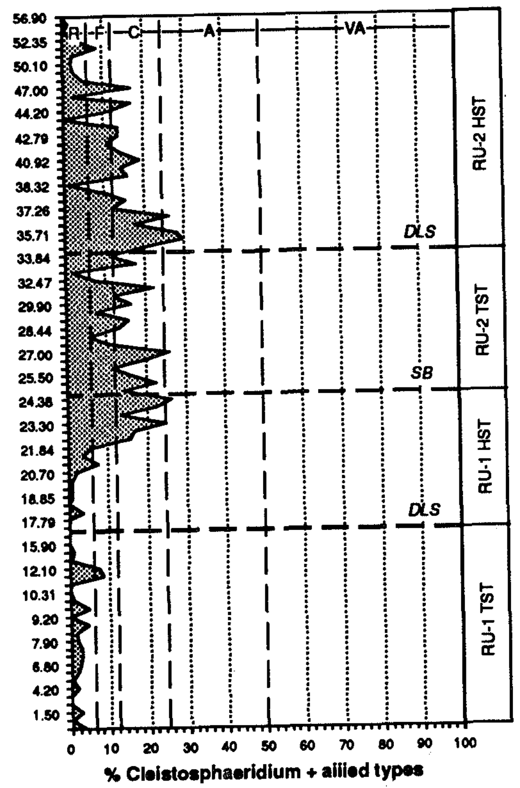
4. *Apteodinium* and allied types Eco-group (Figure 12).
This category includes three species of *Apteodinium*, one of *Cribroperidinium* and two of *Tectatodinium*. *Apteodinium australiense* is the most commonly and consistently occurring species. The group occurs throughout the section and is abundant to very abundant locally.

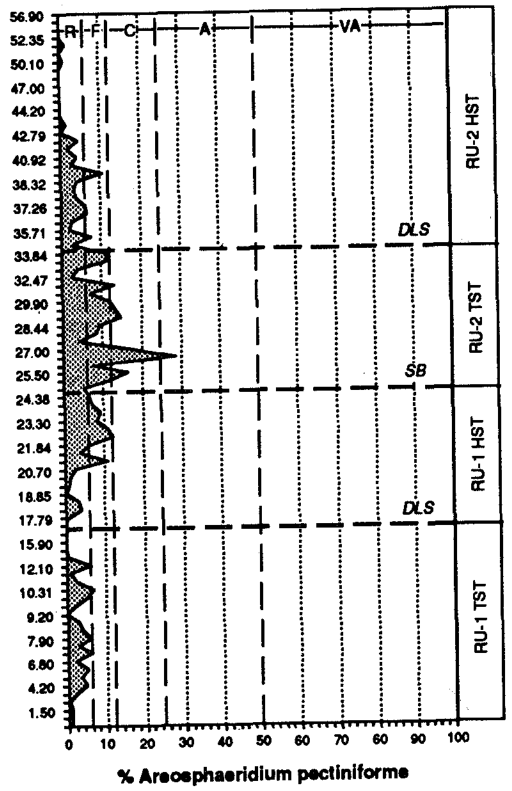
5. *Homotryblium* + *Thalassiphora* Eco-group (figure 13).
This eco-group consists of four species of *Homotryblium* (*H. pallidum, H. plectilum, H. tenuispinosum* and *H. vallum*) plus *Thalassiphora pelagica*. The last is present in the Boom Composite Section from the base to about 55.00 meters. Specimens of *Homotryblium* occur consistently from 21.40 to about 40.00 meters amd sporadically down to 7.66 meters and up to 51.15 meters.

6. *Cleistosphaeridium* + allied types Eco-group (Figure 14).
This eco-group includes *Cleistosphaeridium diversispinosum, Dapsilidinium pseudocolligerum* and *Systematophora placacantha*. Specimens of *C. diversispinosum* are much more abundant than those of the other two species. Representatives of the eco-group occur throughout the section.









Figures 12-15. Upper left : Figure 12, relative abundance of Apteodinium + Allied Types Eco-group ; Upper right : Figure 13, relative abunances of Homotryblium + Thalassiphora Eco-Group ; Lower left : Figure 14, relative abundances of Cleistosphaeridium + Allied Types Eco-group ; Figure 15, relative abundances of Areosphaeridium pectiniforme Eco-group.
R = rare or very rare, F = frequent, C = common, A = abundant, VA = very abundant.

7. *Areosphaeridium pectiniforme* Eco-group (Figure 15).
The nominate species is the only taxon in this category ; the species extends throughout most of the section but is very rare or absent at certain levels.

8. Chiropteridium + allied types Eco-group (Figure 16).
The eco-group includes *Areoligera ? semicirculata*, *Chiropteridium mespilanum*, *Gerdiocysta conopea* and three species of *Membranophoridium*. *Chiropteridium mespilanum* is the most commonly occurring taxon in this category even though relatively high abundances of *A. ? semicirculata* and *G. conopea* occur sporadically. Specimens of the eco-group are present throughout the section.

9. *Histiocysta* + *Elytrocysta* Eco-group (Figure 17).
Specimens of *Elytrocysta breva* and *Histiocysta* spp. comprise this eco-group and either or both forms may be abundant locally. *Elytrocysta breva* occurs consistently from the base of the section to 24.78 meters, and sporadically to 29.90 meters ; *Histiocysta spp.* occurs consistently from the base to 36.49 meters and sporadically to 52.35 meters.

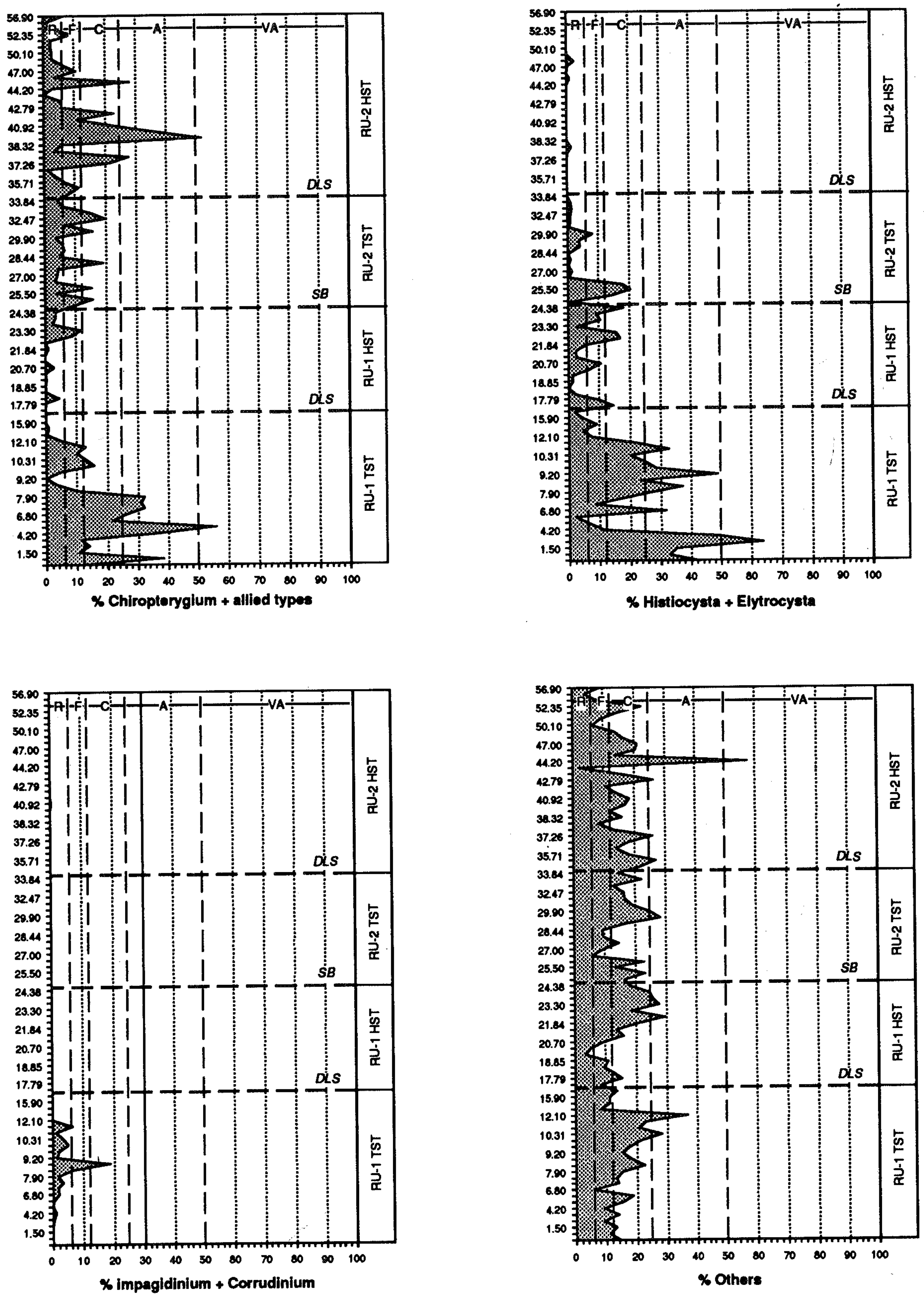
10. *Impagidinium* + *Corrudinium* Eco-group (Figure 18).
Three species of *Impagidinium* and *Corruduniun incompositium* comprise this eco-group. Of the species of *Impagidinium, I. torsium* is the most abundant and occurs mainly in the section below 14.57 meters.

11. Others Eco-group (Figure 19).
This category contains taxa in the Boom assemblege not allocated to one of the previous eco-groups. As such, it includes species that would have otherwise been assigned to the *Cordosphaeridium, Phthanoperidinium* and *Spiniferites + Achomosphaera* eco-groups of Köthe (1990). Although the other eco-group contains 45 taxa, individual genera and species are typically rare or occasionally frequent. Collectively, the components of this eco-group average 15 percent of the specimens in the samples and the most abundantly occurring taxa are assigned to the generically and specifically named eco-groups.

The distribution and relative abundances of the individual eco-groups is shown in Figures 8 to 19 and Figure 20 depicts the stratigraphic positions within the Boom Formation where comparatively high relative abundances are recorded for each of the listed eco-groups, except for the Others Eco-group. Within different parts of the Boom Composite Section, one or more eco-groups are dominant or show a limited stratigraphic preference. For example, the dominant eco-groups in the lower, more silty part (Belsele-Waas Member of the Boom Formation) of the RU-1 transgressive systems tract are *Cleistosphaeridium* (abundant) and *Apteodinium* (common) in the lower part and *Impagidinium* (frequent to common) in the upper part. The *Chiropteridium* and *Histiocysta* eco-groups are abundant throughout most of the interval. Except for the *Apteodinium* eco-group, none of the other eco-groups is dominant in the less silty part of the RU-1 transgressive section, although an abundance peak of the *Wetzeliellaceae* occurs near the top of the interval within the Terhagen Member.

At the base of the upward shallowing RU-1 highstand interval (still within the Terhagen Member) the *Deflandrea* eco-group is very abundant and *Areosphaeridium pectiniforme* is absent at and adjacent to the downlap surface. Specimens of *Ascostomocystis potane* are frequent to common in the upper part of the interval with very abundant *Deflandrea*. *Homotryblium + Thalassiphora* (frequent to common) and *Histiocysta* (common) eco-groups dominate the remainder of the highstand systems tract up to and slightly beyond the RU-2 sequence boundary in the Putte Member. In the transgressive systems tract above the RU-2 sequence boundary, the *Cleistosphaeridium* eco-group is common and remains so through this upward deepening interval. Other dominant eco-groups in the lower to middle part of the RU-2 transgressive systems tract are *Areosphaeridium pectiniforme* (common), *Chiropteridium* (common) and *Apteodinium* (common to abundant). In the upper part, the *Deflandrea* eco-group again becomes abundant. Most of these eco-groups remain dominant in the overlying lower part of the RU-2 highstand systems tract except for the *Areosphaeridium pectiniforme* eco-group. The *Apteodinium* eco-group becomes abundant in the middle part of the RU-2 highstand section; the *Wetzeliellaceae* and *Deflandrea* eco-groups are also abundant in the same interval, and the latter, together with the *Apteodinium* eco-group, become very abundant near the top. *Areosphaeridium pectiniforme* is absent.

Most of the eco-groups appear to be systems tract tolerant, although there are some indications that perhaps a few groups may have a moderate preference for certain sequence-related positions. For example, the *Chiropteridium* eco-group is prevalent in transgressive deposits, but not exclusively so. The *Deflandrea* eco-group very abundant to abundant in sections near the downlap surfaces, but again not exclusively so. The most abundant occurrences of *Areosphaeridium pectiniforme* is in the lower part of the RU-2 transgressive systems tract. However, the species does not show a corresponding abundance increase at a



Figures 16-19. Upper left : Figure 16, relative abundances of Chiropteridium + Allied Types Eco-group ; Upper right, Figure 17, relative abunances of Histiocysta + Elytrocysta Eco-group ; Lower left : Figure 18, relative abundances of Impagidinium + Corrudinium, Eco-gorup ; Lower right : Figure 19, relative abundances of the others category.
R = rare or very rare, F = Frequent, C = Common, A = abundant, VA = very abundant.

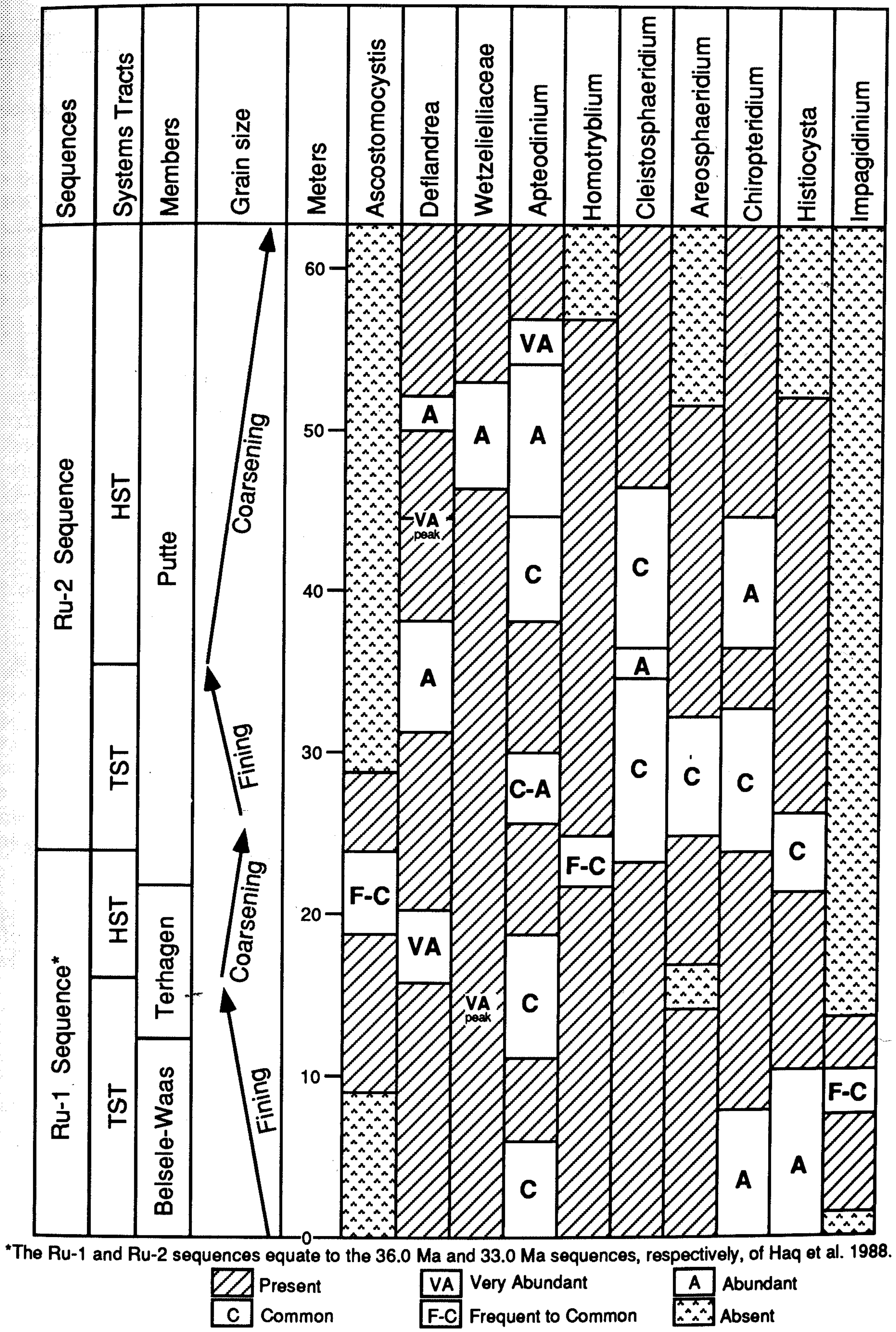


Figure 20. Major abundances of eco-groups relative to sequences.

comparable position in the RU-1 sequence. The *Cleistosphaeridium* eco-group is certainly developed most advantageously from the uppermost part of the RU-1 highstand section to about the middle of the RU-2 highstand section, but seemingly without regard to systems tracts. Thus, the higher concentrations of the most abundantly occurring eco-groups (*Deflandrea*, *Apteodinium* + allied types, *Cleistosphaeridium* + allied types and *Chiropteridium* + allied types) reveal little relation to systems tracts.

2.8. Microplankton association in the Doel 14E-194 well

The interval in the Doel 14E-194 well between drill depths of 109.75 to 159.90 meters contains strata evidently equivalent to the lowermost few meters of the Boom Composite Section, a probably older Lower Oligocene interval and an Upper Eocene section (Figure 3). Figure 21 depicts the occurences and relative abundances of the microplankton from the seven Doel 14E-194 well core samples.

Samples from the Bassevelde Member of the Zelzate Formation at 159.90 and 139.90 meters yielded moderately to highly diverse Upper Eocene dinoflagellate assemblages which contained some species that are not known to occur in Post-Upper Eocene strata. These include *Areosphaeridium diktyoplokus*, *Batiacasphaera compta*, *Lentinia serrata*, *Rhombodinium perforatum* and *Tritonites spinosa* (the last is an acritarch species). The dinoflagellates from the Watervliet Member core at 130.90 meters represent a transitional assemblage which has some typically Eocene species, such as *Glaphyrocysta semitecta* and *Glaphyrocysta ? vicina* along with species associated more with Lower Oligocene than with Upper Eocene assemblages. These include *Fibrocysta axialis, Membranophoridium aspinatum* and *Wetzeliella symmetrica.*

The three samples from the Ruisbroek Member (Zelzate Formation) and the one from the Belsele-Waas Member (Boom Formation) at 128.90, 119.90, 114.35 meters and 109.75 meters, respectively, provided moderately to highly diverse dinoflagellate associations, although considerably fewer specimens were obtained from the deepest core than from the others. Supposedly Oligocene species present in cores include *Areoligera ? semicirculata, Chiropteridium mespilanum, Impagidinium torsium* and *Wetzeliella gochtii*. Specimens of *Histiocysta spp.* and *Elytrocysta breva* dominate the assemblages from 114.35 and 109.75 meters, respectively ; *Achomosphaera alcicornu* and *Chiropteridium mespilanum* are frequent in the assemblage from 119.90 meters. Most of the above information is portrayed graphically in Figure 22.

We equate the section in the Doel 14E-194 well with the high abundances of *Elytrocysta breva* and *Histiocysta spp.* and low abundances of the *Deflandrea phosphorita* 'complex" to the lower part of the Boom Composite Section below the influx of *Areoligera ? semicirculata* and the consistently common occurrence of *Chiropteridium mespilanum*. On the basis of the stratigraphic distribution of the dinoflagellates in the Doel well, together with reported occurrences of key taxa in other European areas, the RU-1 sequence boundary in the Ruisbroek Member of the Zelzate Formation lies certainly in Lower Oligocene (Rupelian) strata. Until a concensus is reached concerning the position of the Eocene-Oligocene boundary, the age of dinoflagellate assemblages from the Zelzate Formation is arguable.

2.9. Dinoflagellate ranges relative to the Rupelian base

Brinkhuis and Biffi (in press) provide a comprehensive discussion of dinoflagellate species in Italian sections regarded as biostratigraphically important with respect to the Eocene-Oligocene boundary. Without exception the key taxa as well as accessory species occur above the hantkeninid extinction level. Comments pertaining to the occurrences of the species discussed by Brinkhuis and Biffi (*ibid.*) in the Boom and Zelzate Formations are given below.

Areologera ? semicirculata : lowest occurrence is in the uppermost sample from the Ruisbroek Member of the Zelzate Formation. The species is present throughout the Boom Formation and is locally abundant.

Areosphaeridium diktypolokus : present only in the Bassevelde Member of the Zelzate Formation.

Diphyes colligerum : occurs only in the lowermost sample from the Bassevelde Member of the Zelzate Formation.

Glaphyrocysta semitecta : present in the Bassevelde and Watervliet Members ; species was not found in the Boom Formation.

Melitasphaeridium pseudocolligerum : found only in the lowest sample from the Bassevelde Member of the Zelzate Formation.

Phthanoperidinium amoenum : not identified in Boom and Zelzate Formations.

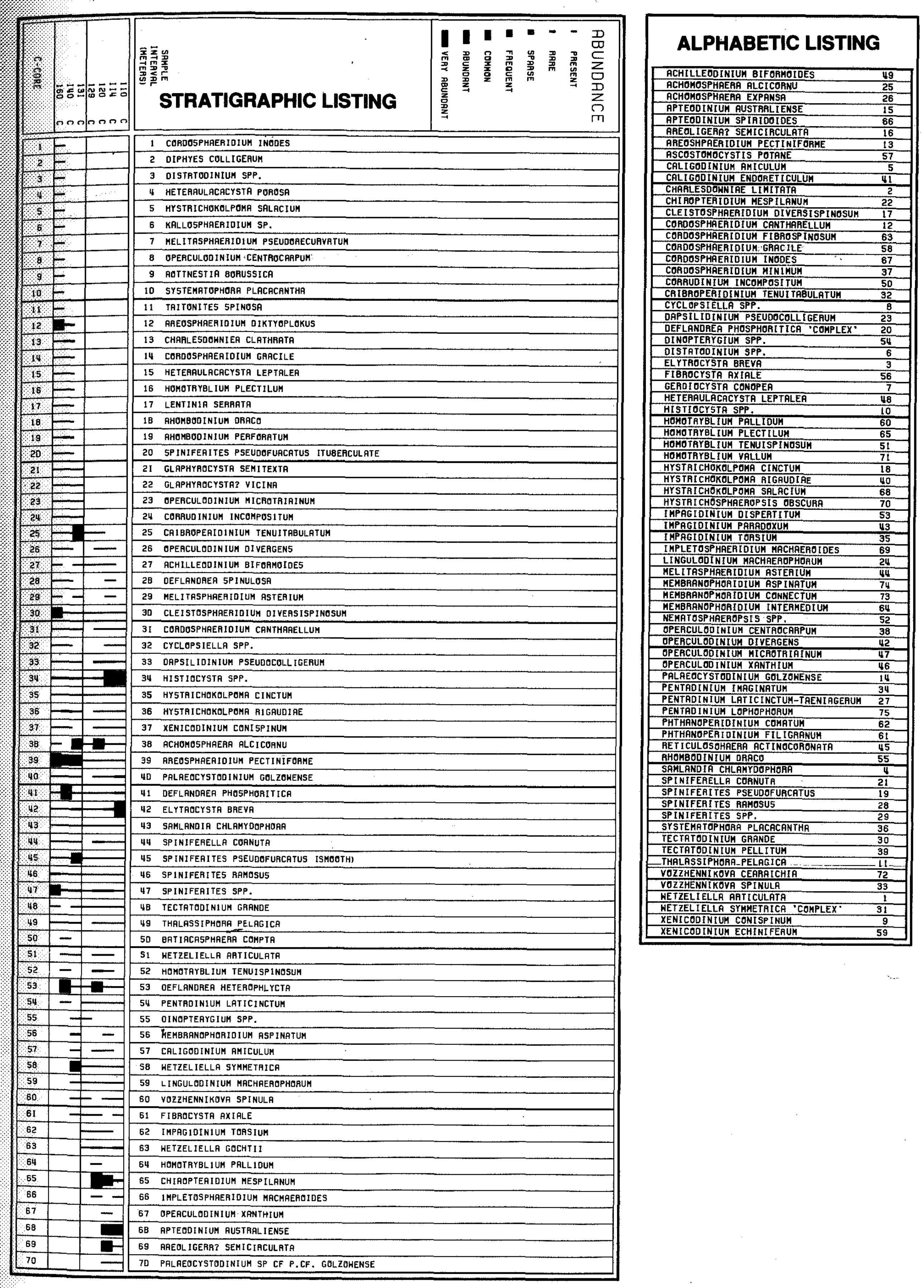


Figure 21. Dinoflagellate occurrence and abundance chart, Doel 14E-194 well.

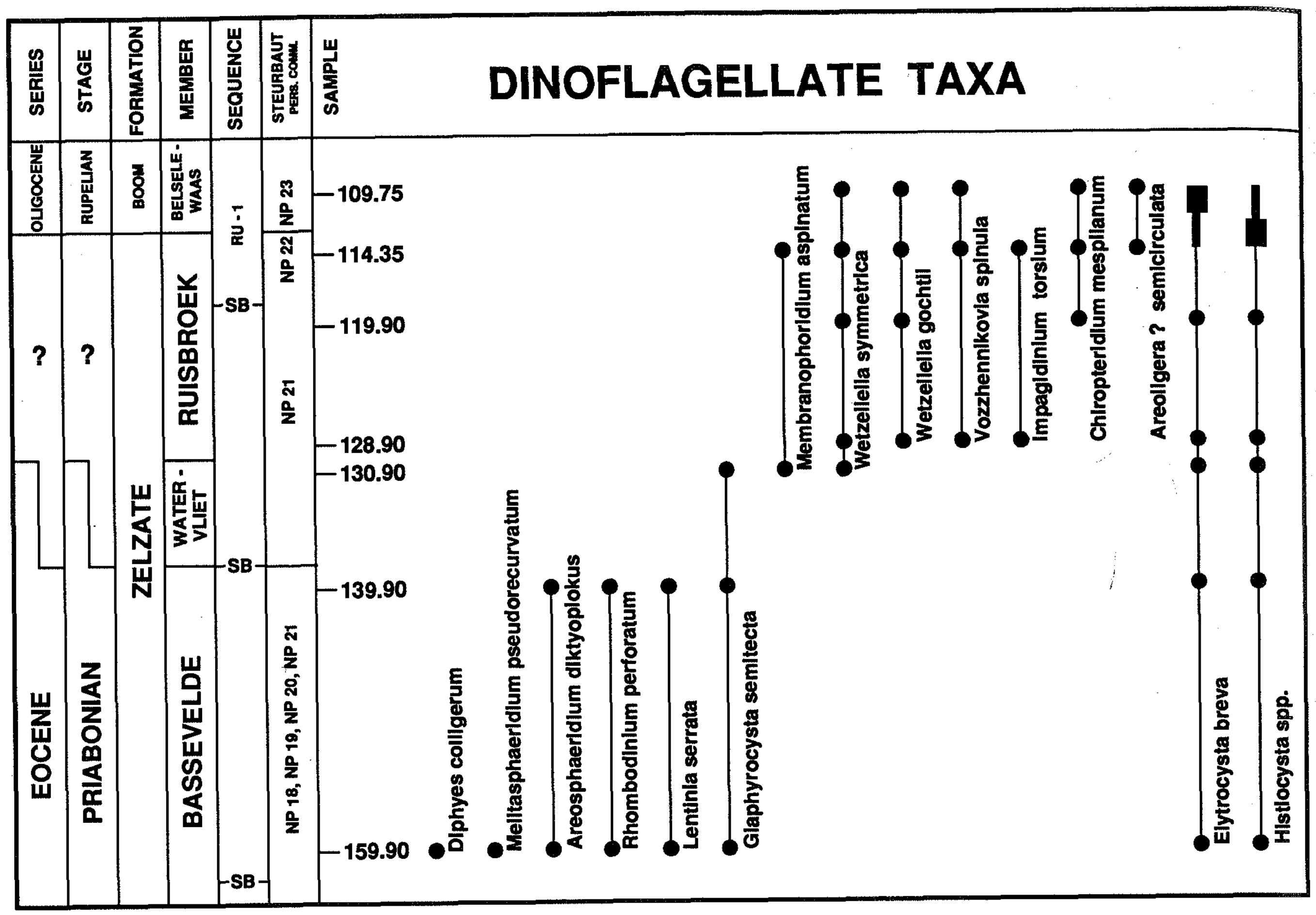


Figure 22. Distribution of selected taxa, Doel 14E-194 well.

Reticulosphaera actinocoronata : present in the Boom Formation from near the top of the Belsele-Waas Member to about midway through the Terhagen Member.

Schematophora speciosa and *Hemiplacophora semilunifera* : neither species was identified in the Boom or Zelzate Formations.

Wetzeliella gochtii : lowest occurrence is near the base of the Ruisbroek Member of the Zelzate Formation and occurs throughout the Boom Formation.

In addition to the species singled out by Brinkhuis and Biffi (*ibid.*), some taxa in the northwest Belgium sections may prove useful for predicting the relative position of the basal Rupelian.

These taxa are:

Ascostomocystis potane and *Phthanoperidinium filigranum* : oldest occurrences are above the Rupelian base in the Terhagen Member of the Boom Formation.

Charlesdowniea spp. : youngest occurrence of the genus is above the base of the Rupelian and near the top of the Terhagen Member of the Boom Formation.

Wetzeliella articulata : youngest occurrence is above the base of the Rupelian in the Belsele-Waas Member of the Boom Formation. Rupelian occurrences could represent reworking. The situation with this species is much that like that of *Areosphaeridium diktyoplokus* in which questions concerning correct identification and reworking are involved.

Pentadinium imaginatum : youngest occurrence at or near the base of the Rupelian in the Belsele-Waas Member of the Boom Formation.

Chiropteridium mespilanum : oldest occurrence in Belgium is below the sequence boundary in the Ruisbroek Member of the Zelzate Formation. Reported older occurrences in other nowthwest European localities requires verification.

Wetzeliella symmetrica : oldest occurrence below the Rupelian base is in the Watervliet Member of the Zelzate Formation and below the oldest occurrence of *Wetzeliella gochtii.*

Glaphyrocysta vicina : occurs only below the Rupelian base ; youngest occurrence in the Watervliet Member of the Zelzate Formation.

Charlesdowniea clathrata, Lentinia serrata and *Rhombodinium perforatum* : each of these species, whose youngest occurrence is in the Bassevelde Member of the Zelzate Formation, terminates below the base of the Rupelian.

2.10. Summary

The important observations and conclusions reported in this study are summarized below. Some of the lithostratigraphic conclusions were derived from the earlier studies of Vandenberghe and van Echelpoel either individually or as co-authors.

1. The Rupelian Boom Formation in northwestern Belgium consists of about 67 meters of alternating silty clay and clayey silt layers which represent a major transgressivie-regressive depositional cycle relative sea-level event. The formation is delimited below and above by major sequence boundaries.
2. The study supports the sequence stratigraphic interpretation presented previously (Vandenberghe, 1978 ; Vandenberghe and van Echelpoel, 1987), including the positions of a minor sequence boundary between the RU-1 and RU-2 sequences and the downlap surfaces.
3. The clayey silt and silty clay layers of the Boom Formation resulted from the settling of particles from suspension during alternating periods of higher and lower depositional energy.
4. The grain size in the clayey silts and silty clays is very similar and the proportion of the coarse silt - very fine sand fractions determines whether the layer appears to be a silt or a clay. Furthermore, variations in grain size are gradational although the highest proportion of the coarser fraction is in the middle of silt beds and the highest proportion of the finer fraction is in the middle of the clay beds.
5. Grain size analysis (% of silt > 32 µm) of the silt and clay beds shows a high frequency signal superimposed on a low frequency trend. Moreover, the thickness of the clay beds relative to the silt beds also shows a low frequency trend. Relative sea-level changes and rate of sediment supply are also low frequency variables.
6. Although eustasy is inevitably involved in low and high frequency trends, its effect cannot be separated readily from that of subsidence or climate, respectively.
7. Well-preserved and diverse dinoflagellate cyst associations occur throughout most of the Boom Formation and the underlying Zelzate Formation. This group of microplankton offers a reliable means for calibrating and correlating sections of comparable age from similar and different environmental and depositional settings.
8. The distribution and relative abundances of the dinoflagellate taxa reveal that a significant number of the species in the Boom assemblage appear rather abruptly in the transgressive systems tract above the RU-1 sequence boundary, and that by the end of the transgressive deposition 84 percent of the Boom clay assemblage taxa are present. Between the upper part of the RU-1 transgressive systems tract and the lower part of the RU-2 highstand systems tract, relatively little qualitative change took place in the dinoflagellate assemblage, although quantitative distinctions are evident. In the section above the early RU-2 highstand strata, gradual reductions in the numbers of taxa and specimens occurs upsection. None-the-less, throughout most of the Boom clay deposition, relatively stable environmental conditions favorable to the vitality and preservation of the dinoflagellates prevailed.
9. Although the Boom clay deposition covers about 6 Ma, appreciable numbers of dinoflagellate bases (26) and tops (30) are positioned within the formation. The majority of bases (22) are situated in transgressive systems tracts whereas the majority of tops (19) are in highstand systems tracts. Dinoflagellate associations from at or near downlap surfaces contain fewer taxa, or fewer specimens, or both than associations from adjacent strata.
10. Quantitative studies of dinoflagellate eco-groups, patterned after the approach of Köthe (1990), demonstrate that most eco-groups in the Boom Clay assemblage are systems tract tolerant. A few eco--groups show slight preferences for particular systems tract positions.
11. Dinoflagellate correlations between Belgium and Italy, the latter based on information from Brinkhuis and co-workers (1993), reveal that the EoceneOligocene boundary as defined in the Massignano boundary stratotype, Italy, occurs not only appreciably below the base of the Boom Formation, i.e., the base of the Rupelian in Belgium, but also well below the top of Priabonian at its type section (Hardenbol 19-68). It also appears that the top of the Priabonian type section correlates with the base of the Watervliet Member of the Zelzate Formation in Belgium. These observations lead to concern about the proposed placement of the recently redefined Eocene-Oligocene boundary. Other options include: reverse the acceptance of the Massignano boundary stratotype as recommended by Brinkhuis and Visscher (in press); redefine the Priabonian to conform to the proposed Eocene-Oligocene boundary and

extend the Rupelian base downward to the top of the redefined Priabonian; or re-introduce the Tongrian Stage in between the Priabonian and Rupelian.

3. DINOFLAGELLATE SYSTEMATICS

3.1 Dinoflagellate taxa

Alphabetical Presentation

Achilleodinium biformoides (Eisenack 1954) Eaton 1976 : pl. 5, figs. 29a-b.
Achomosphaera alcicornu (Eisenack 1954) Davey and Williams *in* Davey *et al.* 1966 : pl. 5, figs. 28a-b.
Achomosphaera expansa sp. nov.: pl. 5, figs. 30a-31c ; pl. 6, figs. 32a-b.
Apteodinium australiense (Deflandre and Cookson 1955) Williams 1978 : pl. 8, figs. 51a-b.
Apteodinium spiridoides Benedek 1972 : pl. 8, figs. 52a-b.
Areoligera ? semicirculata (Morgenroth 1966) Stover and Evitt 1978 : pl. 3, figs. 16-17.
Areosphaeridium pectiniforme (Gerlach 1961) Stover and Evitt 1878 : pl. 1, figs. 1a-2b.
Ascostomocystis potane Drugg and Loeblich 1967 : pl. 12, figs. 76-77.
Caligodinium amiculum Drugg 1970 : pl. 1, fig. 5.
Caligodinium endoreticulum sp. nov. : pl. 1, figs. 3a-b, 4.
Charlesdowniea limitata sp. nov. : pl. 10, figs. 70a-71c.
Chiropteridium mespilanum (Maier 1959) Lentin and Williams 1973 : pl. 9, figs. 62a-b.
Cleistosphaeridium diversispinosum Davey *et al.* 1966 : pl. 1, figs. 6a-b.
Cordosphaeridium cantharellum (Brosius 1963) Gocht 1969 : Pl. 7, fig. 38.
Cordosphaeridium fibrospinisum Davey and William in Davey *et al.* 1966
Cordosphaeridium gracile (Eisenack 1954) Davey and Williams *in* Davey *et al.* 1966
Cordosphaeridium inodes (Klumpp 1953) Eisenack 1954 emended Morgenroth 1968
Cordosphaeridium minimum (Morgenroth 1966) Benedek 1972 : pl. 7, figs. 39a-b.
Corrudinium incompositum (Drugg 1970) Stover and Evitt 1978
Cribroperidinium tenuitabulatum (Gerlach 1961) Helenes 1984 : pl. 8, figs. 53a-b.
Cyclopsiella spp.: pl. 12, figs. 84a-b, 85.
Dapsilidinium pseudocolligerum (Stover 1977) Bujak *et al.* 1980 : pl. 1, figs. 7a-c.
Deflandrea phosphoritica 'complex': pl. 10, figs. 63-65.

The following species and subspecies are included within this category : *Deflandrea heterophylcya* Deflandre and Cookson 1955 (Pl. 10, fig. 63), *Deflandrea phosphoritica phosphoritica* Eisenack 1938 (Pl. 10, fig. 64), *D. phosphoritica australis* Cookson and Eisenack 1961, and *D. spinulosa* Alberti 1959 (Pl. 10, fig. 65).

Dinopterygium spp. : pl. 12, fig. 83.
Distatodinium spp. : pl. 2, figs. 8-9.
Elytrocysta breva sp. nov. : pl. 2, figs. 10a-11b, 12.
Fibrocysta axialis (Eisenack 1965) Stover and Evitt 1978 : pl. 8, fig. 55.
Gerdiocysta conopea Liengjarern *et al.* 1980 : pl. 4, figs. 21a-c.
Heteraulacacysta leptalea Eaton 1976
Histiocysta spp. : pl. 2, figs. 13a-14c.
Homotryblium pallidum Davey and Williams *in* Davey *et al.* 1966 : pl. 13, figs. 87a-b.
Homotryblium plectilum Drugg and Loeblich 1967 : pl. 13, figs. 89a-b.
Homotryblium tenuispinosum Davey and Williams 1966 *in* Davey *et al.* 1966 : pl. 13, figs. 86a-b.
Homotryblium vallum Stover 1977 : pl. 13, figs. 88a-b.
Hystrichokolpoma cinctum Klumpp 1953 : pl. 2, figs. 15a-c.
Hystrichokolpoma rigaudiae Deflandre and Cookson 1955 : pl. 3, figs. 18a-d.
Hystrichokolpoma salaeium Eaton 1976 : pl. 3, figs. 19a-c.
Hystrichosphaeropsis obscura Habib 1972 : pl. 7, figs. 46a-b.
Impagidinium dispertitum (Cookson and Eisenack 1965) Stover and Evitt 1978 : pl. 8, figs. 50a-b.
Impagidinium paradoxum (Wall 1967) Stover and Evitt 1978
Impagidinium torsium sp. nov. : pl. 7, figs. 47a-c, 48; Pl. 8, figs. 49a-c.
Impletosphaeridium machaeroides sp. nov. : pl. 13, figs. 91a-92b.
Lingulodinium machaerophorum (Deflandre and Cookson 1955) Wall 1967 : pl. 13, fig. 90.
Melitasphaeridium asterium Eaton (1976) Bujak *et al.* 1980
Membranophoridium aspinatum Gerlach 1961 ex Gocht 1969 : pl. 5, figs. 26, 27a-b.
Membranophoridium connectum sp. nov. : pl. 4. figs. 22a-23b.
Membranophoridium intermedium sp. nov. : pl. 4, figs. 24a-25b.
Nematosphaeropsis spp.
Operculodinium centrocarpum (Deflandre and Cookson 1955) Wall 1967 : pl. 7, fig. 41
Operculodinium divergens (Eisenack 1954) Stover and Evitt 1978
Operculodinium microtriainum (Klumpp 1953) Islam 1983
Operculodinium xanthium (Benedek 1972) Stover and Evitt 1978 : pl. 7, fig. 40.

Note: The wall and process morphologies of *O. xanthium* favor its retention in *Operculodinium* rather than in *Lingulodinium* as proposed by Benedek and Sarjeant (1981).

Palaeocystodinium golzowense Alberti 1961 : pl. 10, fig. 66.
Pentadinium imaginatum stat. nov. = *Pentadinium laticincum* subsp. *imaginatum* Benedek, 1972, p. 43-44, pl. 2, 11 ; pl. 6, fig. 9 : pl. 9, figs. 57a-b.

This subspecies is herein raised to specific rank. It is differentiated from *Pentadinium laticinctum* and *P. lophophorum* by virtually lacking parasutural folds and additionally from *P. lophophorum* by not having a tuberculate endophragm.

Pentadinium laticinctum-taeniagerum Gerlach 1961 emended Benedek *et al.* 1982 : pl. 9, figs. 56a-b.
Pentadinium lophophorum (Benedek 19721) Benedek *et al.* 1982 : pl. 9, figs. 58-59.
Phthanoperidinium comatum (Morgenroth 1966) Eisenack and Kjellström 1971 : pl. 10, fig. 67.
Phthanoperidinium filigranum (Benedek 1972) Benedek and Sarjeant 1981 : pl. 10, figs. 68-69.
Reticulosphaera actinocoronata (Benedek 1972) Bujak and Matsuoka 1986 : pl. 6, fig. 33.
Rhombodinium draco Gocht 1955
Samlandia chlamydophora Eisenack 1954 : pl. 8, figs. 54a-b.
Spiniferella cornuta (Gerlach 1961) *comb.nov.* : pl. 6, figs. 37a-c.
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 : pl. 6, figs. 34a-c.
Spiniferites ramosus (Ehrenberg 1838) Sarjeant 1970 : pl. 6, figs. 35a-b.
Spiniferites spp. : Pl. 6, fig. 36.
Systematophora placacantha (Deflandre and Cookson 1955) Davey *et al.* 1969 : pl. 3, figs. 20a-c.
Tectatodinium grande Williams *et al.* (in press) : pl. 9, figs. 61a-b.
Tectatodinium pellitum Wall 1967 : pl. 9, figs. 60a-b.
Thalassiphora pelagica (Eisenack 1954) Eisenack and Gocht 1960 emended Benedek and Gocht 1981
Vozzhennikovia cearaichia sp. nov. : pl. 12, figs. 78a-b, 79.
Vozzhennikovia spinula sp. nov. : pl. 12, figs. 80, 81a-82b.
Wetzeliella articulata Eisenack 1938 : pl. 12, fig. 75.
Wetzeliella symmetrica 'complex' : pl. 11, figs. 72a--74b.

This complex consists of *Wetzeliella gochtii* Costa and Downie 1976 (= *Wetzeliella symmentric incisa* Gerlach 1961) : pl. 11, fig. 72, *Wetzeliella symmetrica symmetrica* Weiler 1956 : pl. 11, fig. 74 and a transitional form (Pl. 11, fig. 73) between *W. symmetrica incisa* and *W. symmetrica symmetrica*.

Xenicodinium conispinum sp. nov. : pl. 7, figs. 42a-43b.
Xenicodinium echiniferum sp. nov. : pl. 7, figs. 44a-45c.

3.2. Descriptions of new taxa

GENUS *ACHOMOSPHAERA* Evitt 1963
Achomosphaera expansa sp. nov.

Plate 5, Figures 30a-31c; Plate 6, Figures 32a-b.

Description

Cysts skolochorate with subspherical to ellipsoidal bodies. Endophragm and periphragm smooth and appressed except at the bases of processes; endophragm thicker than periphragm. Processes, which are formed by the periphragm, short relative to body length. Width of processes differs considerably although their length is fairly constant on individual specimens. Processes expanded proximally and most are not joined by parasutural septa. However, closely adjacent processes, particulary those in the paracingular area, may have amalgamated bases or be connected by low septa. Distally, the processes are expanded and branched repeatedly to form relatively simple to complex, irregularly margined, vasiform, fenestrate terminations. Openings in fenestrations variable in size and shape. A few to many processes may be connected distally by narrow trabeculae. The middorsal precingular archeopyle has a monoplacoid, secate operculum. Paratabulation is evidently gonyaulacoid although the general absence of parasutural features makes the number, position and relationship of the paraplates difficult to discern and interpret. Paracingular processes are typically more complex than others and two, relatively wide processes are present in the antapical polar area. Parasulcal processes absent. Size: intermediate; overall length 65 to 85μm, body length 43 to 55μm, body width 34 to 50μm, process length 13.5 to 22μm (most are between 15 and 20μm, wall about 1μm thick.

Comparison

Achomosphaera expansa is similar to *A. andalousiensis* Jan du Chêne 1977 emended Jan du Chêne and Londeix 1988 by having processes with generally more complex fenestrate endings that lack spur-like projections and by having some processes connected by trabeculae. The new species differs from *A. argesensis* Demetrescue 1989 by having more complex distal terminations of the processes and by not having a flat antapical process. *Achomosphaera andalousiensis* and *A. argesensis* occur in post-Paleogene strata.

Types

Holotype : Plate 5, figures 30a-b, Boom Composite Section sample at 23.63 meters. Paratypes: Plate 5, figures 31a-c, and figures 32a-b, Boom Composite Section samples at 37.26 and 21.41 meters, respectively. Type specimens are from the Kruibeke locality.

Occurrence

Achomosphaera extensa extends intermittently throughout the Boom Formation and ocurs most frequently in the Putte Member.

GENUS *CALIGODINIUM* Drugg 1970
Caligodinium endoreticulum sp. nov.

Plate 1, Figures 3a-b, 4

Description

Cysts proximate, ellipsoidal, longer than wide and with slight dorso-ventral flattening. Autophragm rarey folded, about 1.5μm thick, externally smooth; a flocculent cloak may be present. Internally, the autophragm is finely reticulate to punctoreticulate with lumina that are about the same width or wider than the muri. Paratabulation expressed by the apical archeopyle and its triplacoid operculum and by the very short sutures along the principal archeopyle margin. The accessory sutures indicate the presence of six precingular paraplates of which 6'' is narrow and only marginally wider than the parasulcal notch. Other indications of paratabulation absent. Size: intermediate; length of specimens with opercula in place 53 to 61μm, specimens without opercula 41 to 47μm, width 45 to 50μm.

Comment

The opercular configuration of *Caligodinium endoreticulum* is identical to that described for *C. pychnum* Biffi and Manum 1988 and for specimens of *C. amiculum* Drugg 1970 found during this study. On most specimens of *C. endoreticulum* the opercular pieces are adherent and partly disarticulated. Accessory archeopyle sutures are displayed most advantageously on specimens without opercula.

Comparison

Caligodinium endoreticulum differs from *C. amiculum* and *C. pychnum* by having a finely reticulate to punctoreticulate endoreticulation. The internal wall structure of *C. pychnum* appears to be pitted according to Biffi and Manum (1988). *Caligodinium amiculum* and *C. endoreticulum* are essentially smooth externally whereas *C. pychnum* has a retirugulate outer surface.

Types

Holotype : Plate 1, figures 3a-b, Boom Composite Section sample at 7.68 meters, Steendorp locality. Paratype: Plate 1, figure 4, Boom Composite Section sample at 10.17 meters, Sint Niklaas locality.

Occurrence

Caligodinium endoreticulum occurs mainly in the lower part of the Boom Formation in the Belsele-Waas and Terhagen Members. A single specimen was found in the Putte Member at the 35.41 meter level.

GENUS *CHARLESDOWNIEA* Lentin and Vozzhennikova 1989
Charlesdowniea limitata sp. nov.

Plate 10, Figures 70a-71c

Description

Cysts proximate, circumcavate and strongly compressed dorso-ventrally and with subquadragular to pentagular outlines. Apical, two lateral and left antapical horns moderately to well developed; left antapical horn near longitudinal midline. Right antapical horn poorly developed or absent and when present, it is relatively close to the left antapical horn. Endocyst circular or nearly so in outline, periphery close to the pericyst except at the bases of the horns, hence the lateral pericoel is narrow. The endocyst does not protrude into the horns. Periphragm smooth; endophragm smooth or faintly ornamented and may have granulate--like thickenings in the cardinal positions. Processes narrow, generally hollow and are mainly penitabular although scattered intratabular processes present on some paraplates. The fine, aculeate tips of the marginal processes on each paraplate are connected by thin trabeculae thereby forming penitabular process complexes which simulate the shapes of the paraplates. Pandasutural areas essentialy free of processes and intratabular processes are without trabecular connections. Paratabulation is peridiniacean, formula: 4', 3a, 7'', ?5c, 5''', 2''''; epicystal paratabulation styles ortho ventrally and quadra dorsally. A middorsal intercalary archeopyle has a monoplacoid (paraplate 2a), four-sided operculum with narrowly rounded posterior corners; the perioperculum is attached anteriorly and the endoperculum presumably has the same shape as the perioperculum. Size: large; periphragm length and width 102 to 118μm, endophragm length and width 75 to 85μm, process length 3.5 to 5μm.

Comparison

Charlesdowniea limitata differs from *C. aculeata* (Michoux 1988) *comb. nov.* by having a substantially reduced or absent right antapical horn; when both antapical horns are developed the distance between them is considerably less than that on specimens of *C. aculeata*, owing mainly to the positioning of the left antapical horn on *C. limitata*. This horn is much closer to the longitudinal midline of *C. limitata* cysts. Also the right antapical horn is better developed on *C. aculeata*. Michoux (1985) stated that the endocysts of *C. aculeata* may protrude into the horns ; this condition was not observed among specimens of *C. limitata*. On most other species of *Charlesdowniea* the processes either support a more or less continuous ectophragmal covering over each paraplate, as in *C. coleothrypta* (Williams and Downie *in* Davey *et al.* 1966) Lentin and Vozzhennikova 1989, or the penitabular and intratabular processes are joined distally by an ectophragmal reticulum as in *C. tenuivigula* (Williams and Downie *in* Davey *et al.* 1966) Lentin and Vozzhennikova 1989 and *C. variabilis* (Bujak *in* Bujak *et al.* 1980) Lentin and Vozzhennikova 1989.

Types

Holotype : Plate 10, figures 70a-c. Paratype : Plate 10, figures 71a-c. Both specimens are from Boom Composite Section at 11.20 meters, Steendorp locality.

Occurrence.

Most Boom Formation occurrences of *Charlesdowniea limitata* are in the Terhagen Member between 10.71 and 14.47 meters in the Boom Composite Section. A single specimen was recorded from the Belsele-Waas Member at the 0.50 meter level.

GENUS *ELYTROCYSTA* Stover and Evitt 1978
Elytrocysta breva sp. nov.

Plate 2, Figures 10a-11b, 12

Description

Proximate, subspherical, holocavate cysts with an apical archeopyle which is small relative to the diameter of the bodies. Autophragm about 1μm thick and bears numerous, short (up to 2μm long), uniformly distributed, solid projections which are covered distally by a continuous, thin ectophragm. In cross section the projections vary from subcircular to irregularly polygonal and closely adjacent projections may coalesce to form short, discontinuous, usually curved ridges. Archeopyle apical; opercula apparently tetraplacoid and contiguous, although the constituent paraplates are undifferentiated. Opercula mainly secate, but specimens with attached opercula are frequent. Paratabulation expressed by the principal and accessory archeopyle sutures which indicate seven precingular paraplates. The last precingular paraplate is narrow, about as wide as the parasulcal notch; this paraplate may not be separated completely from the operculum. Faint indications of a rather wide, planar paracingulum may be present and the hypocysts lack indications of paratabulation. Size: small to intermediate; cyst diameter 40 to 53μm and most specimens are less than 50μm.

Comment

The thin ectophragm may be incomplete on some specimens and on other than well preserved material, may be lacking entirely. The small size of the cysts, the wide planar paracingulum and the presence of seven precingular paraplates suggest that *Elytrocysts breva* may be allied more closely to Microdinioid genera than to Gonyaulacoid genera with six precingular paraplates.

Comparison

Elytrocysta breva differs from *E. druggii* Stover and Evitt 1978 by having a thicker autophragm supporting the nontabular projections which appear more variable than those on *E. druggii*. Although Drugg (1967) described *E. druggii* (as *Membranosphaera maastrichtia*) as single layered, he noted (p. 30) that .... "One specimen exhibits remnants of an outer filmy layer supported by the processes."

Types

Holotype : Plate 2, figures 10a-b, Boom Composite Section sample at 3.20 meters. Paratypes : Plate 2, figures 11a-b and 12, Boom Composite Section sample at 9.20 meters. All types are from the Sint Niklaas locality.

Occurrence

Specimens of *Elytrocysta breva* occur quite consistently in the Boom Formation from the lowermost sample at the 0.50 meter level (Belsele-Waas Member) to the 29.90 meter level (lower part of the Putte Member). The species is most abundant in samples from and near the S10 horizon. In the Doel 14E-194 well, *Elytrocysta breva* is present in all samples.

GENUS *IMPAGIDINIUM* Stover and Evitt 1978
Impagidinium torsium sp. nov.

Plate 7, Figures 47a-c, 48; Plate 8, Figures 49a-c

Description

Cysts proximate, subspherical ; autophragm about 1µm thick, smooth, faintly scabrate, or with a few scattered granulae. Parasutural septa smooth, tapered distally and of uniform height (2.0 to 4.0µm) ; bases of septa may be finely perforate. The precingular archeopyle, which is offset slightly to the left, has a monoplacoid (paraplate 3''), secate operculum. Paratabulation gonyaulacoid, expressed by parasutural septa ; formula: 3', 6'', 6c, 5''', 1p, 1'''', 2-3s. Hypocystal paratabulation pattern standard sexiform. Parasutural septum 1'/4' absent, although a short medial spur projecting apically from the posterior septum of 1' is present on some specimens. Paracingulum laevorotatory and its anterior ends are offset longitudinally by about two cingular widths; ends also aligned longitudinally or have very little transverse separation. Parasulcus inclined postero-dextrally, relativey wide (5.5 to 9.5µm), and widens posteriorly. Posterior sulcal paraplate delimited anteriorly by horizontal transverse septum; rest of parasulcus may be subdivided by inclined medial septum into anterior and medial sulcal paraplates. Specimens are 40 to 45µm in length and 37 to 42µm in width.

Comparison

Impagidinium torsium resembles *I. dispertitum* (Cookson and Eisenack 1965) Stover and Evitt 1978 but differs from it by being smaller, subspherical rather than ellipsoidal and by having very little transverse separation between the ends of the paracingulum and by having an inclined parasulcus. In addition, scattered granulae may be present on specimens of *I. torsium*.

Types

Holotype : Plate 7, figures 47a-c. Paratypes : Plate 7, figure 48 and Plate 8, figures 49a-c. All type specimens are from the Boom Composite Section sample at the 8.86 meter level, Sint Niklaas locality.

Occurrence

Impagidinium torsium occurs consistently in the Boom Formation s between 2.00 and 11.20 meters in the composite section (Belsele-Waas and Terhagen Members) and is most abundant in samples from and near the S10 horizon. The species was also identified in the three samples from the Ruisbroek Member of the Zelzate Formation in the Doel 14E-194 Well.

GENUS *IMPLETOSPHAERIDIUM* Morgenroth 1966a
Impletosphaeridium machaeroides sp. nov.

Plate 13, Figures 91a-92b

Description

Cysts skolochorate with subspherical, thin-walled central bodies bearing numerous nontabular processes that are nearly uniform in size and shape. Body wall and processes smooth, latter hollow, tapered, and acuminate distally; process length about one-third body diameter. Indications of paratabulation, including an archeopyle, absent. Size: intermediate; overall diameter 55 to 60µm, body diameter 30 to 36µm, process length 12 to 14µm.

Comparison

The processes on *Impletosphaeridium machaeroides* resemble those on specimens of *Lingulodinium machaerophorum* (Deflandre and Cookson 1955) Wall 1967. However, the wall on *L. machaerophorum* is moderately thick and definitely two-layered with a granulate endophragm. In contrast, the wall of *I. machaeroides* is thin and smooth. A simple or compound precingular archeopyle, or an epicystal archeopyle is usually discernible on specimens of *L. machaerophorum*, whereas evidence of archeopyle formation is lacking on *I. machaeroides*.

Types

Holotype : Plate 13, figures 91a-b, Boom Composite Section sample at 52.35 meters (= Cored Reconnaisance Hole sample at a drill depth of 28.46 meters). Paratype : Plate 13, figures 92a-b, Boom Composite Section sample at 36.11 meters, Kruibeke locality.

Occurrence

In the Boom Composite Section specimens of *Impletosphaeridium machaeroides* occur sporadically and rarely in the Putte Member of the Boom Formation between 31.71 and 60.90 meters.

GENUS *MEMBRANOPHORIDIUM* Gerlach 1961 emended Stover and Evitt 1978
Membranophoridium connectum sp. nov.

Plate 4, Figures 22a-23c

Description

Proximate cysts with lenticular bodies having offset parasulcal notches. Endophragm thicker than periphragm, irregularly pitted and without antapical lobation. Periphragm confined to peripheral areas and reinforced and/or supported by short, narrow, relatively widely spaced, radial thickenings within the pericoel. Periphragm continuous dorsally, continuous or interrupted medially along the ventral antapical margin and without conspicuous or consistently-formed protrusions. Archeopyle apical ; operculum presumably tetraplacoid and contiguous although constituent paraplates are undifferentiated, secate. Paratabulation indicated by the principal archeopyle suture and short accessory sutures or notches which delimit the lateral boundaries of six precingular paraplates. Other indications of paratabulation absent. Size : intermediate ; overall width 60 to 69µm, body width 51 to 58µm, pericoel 2 to 6µm wide.

Comparison

Membranophoridium connectum differs from *M. aspinatum* Gerlach 1971 ex Gocht 1969 by having much narrower marginal extensions of the periphragm and supporting structures within the periphragm and by lacking antapical extremities or well-defined lobations. The new species differs from *M. bilobatum* Michoux 1985 by the presence of radial thickenings within the periphragm, an irregularly pitted endophragm and the absence or poor development of antapical projections.

Types

Holotype : Plate 4, figures 22a-c. Paratype : Plate 4, figures 23a-b. Both specimens from the Boom Composite Section sample at 45.96 meters (= Cored Reconnaissance Hole sample at a drill depth of 35.80 meters).

Occurrence

Membranophoridium collectum occurs only in the upper part of the Boom Composite Section in the Putte Member of the Boom Formation between 44.20 and 56.90 meters. The species is particularly common in the sample from the 44.50
meter level.

Membranophoridium intermedium sp. nov.

Plate 4, Figures 24a-25b

Description

Proximate cysts with lenticular bodies having offset parasulcal notches. Endophragm thicker than periphragm, irregularly pitted and with or without small, subcircular unornamented areas ; antapical margin without lobation. Periphragm thin, joined to the endophragm near the lateral margins of the ventral surface, thus leaving most of the ventral surface exposed, but covers the dorsal surface completely. Dorsal periphragm with penitabular arcuate and linear thickenings and ventral periphragm may be prolonged antapically forming usually two, generally bluntly rounded lobations. Archeopyle apical; operculum presumably tetraplacoid and contiguous although its constituent paraplates are undifferentiated, secate. Paratabulation indicated by principal archeopyle suture together with accessory sutures or notches as well as the dorsal periphragmal thickenings. These feature delimit six precingular paraplates of which paraplate 6'' is as wide as or slightly wider than 1' and peaked asymmetrically with the left side shorter than the right side. Dorsally, the middorsal precingular and postcingular paraplates and their laterally adjacent paraplates are delimited partly by penitabular arcuate thickenings that open adcingularly. The antapical paraplate is also delimited by a penitabular, arcuate feature that is open ventrally. Paracingulum expressed by transverse, discontinuous, short, linear thickenings on the dorsal surface. Parasulcus not delimited, but its anterior position is marked by the offset parasulcal notch. Size : intermediate ; overall width 78 to 90µm, body width 68 to 74µm, pericoel 3.5 to 8.5µm wide, antapical lobes up to 14µm long.

Comparison

Membranophoridium intermedium contains features associated not only with other species of *Membranophoridium*, but also with some characteristics of *Areoligera sentosa* Eaton 1976. For example, the ventral aspect of *M. intermedium* closely resembles that of *M. aspinatum* and *M. bilobatum* Michoux 1985, whereas the dorsal aspect, with its penitabular arcuate and linear features, is not dissimilar to the dorsal configuration of A. sentosa. However, according to Eatom (1976) the dorsal penitabular structures on the latter species are...."sail-like, incised distal membranes....[with] pointed crests surmounted by erect or curved acuminate spines.", rather than thickenings. The dorsal surfaces of *M. aspinatum* and *M. bilobatum* are devoid of penitabular features.

Types

Holotype : Plate 4, figures 24a-b, Boom Composite Section sample at 51.90 meters (= Cored Reconnaissance Hole sample at a drill depth of 29.96 meters). Paratype: Plate 4, figures 25a-b, Boom Composite Section sample at 56.90 meters (= Cored Reconnaissance Hole sample at a drill depth of 24.86 meters).

Occurrence

Specimens of *Membranophoridium intermedium* occur fairly consistently in the Putte Member of the Boom Formation in the composite section between 24.78 and 49.70 meters. Above the 49.70 meter level, the species occurs sporadically to the 59.80 meter level. A single specimen was identified in the the sample from the Terhagen Member at the 20.70 meter level.

GENUS *SPINIFERELLA* gen. nov.

Synopsis

Skolochorate cysts with ellipsoidal bodies bearing spiniferate gonal and intergonal processes as well as parasutural septa; paratabulation gonyaulacoid, last precingular paraplate subquadrangular to pentangular, hypocystal paraplate configuration standard sexiform.

Description

Shape. Cysts are skolochorate with ellipsoidal bodies which bear spiniferate, gonal and intergonal processes and parasutural septa formed by the periphragm.
Wall Relationships. Periphragm thin and is appressed to thicker endophragm except where processes and parasutural septa are developed.
Wall Features. Parasutural septa extend between the gonal and intergonal spiniferate processes; a prominent apical process is present on the type species. Endophragm ornamented with features of low relief; periphragm smooth or faintly ornamented.
Excystment Mode. Archeopyle precingular, opening formed by the release of paraplate 3''; operculum monoplacoid and secate.
Paratabulation. Indicated by parasutural septa and processes; gonyaulacoid, formula: 3-4', 6'', 6c, 5''', 1p, 1''''. Last precingular paraplate (6'') relatively large and subquadrangular or pentangular. Hypocystal paratabulation pattern standard sexiform.
Paracingulum. Clearly indicated by transverse parasutural septa and subdivided into six rectangular paraplates by short, longitudinal septa. Paracingulum laevorotatory, anterior ends offset markedly.
Parasulcus. Delimited by parasutural septa; undivided.
Size. Intermediate to large.

Comparison

Spiniferella differs from *Spiniferites* Mantell 1850 emended Sarjeant 1970 by having a relatively large last precingular paraplate that is subquadrangular to pentangular rather than subtriangular. Thus the ventral epicystal paraplate relationships of *Spiniferella* are like those of *Leptodinium* Klement 1960 emended Sarjeant 1982, however, *Leptodinium* does not have processes.

Species (Monotypic)

Type Species. *Spiniferella cornuta* (Gerlach 1961, p. 180-181, pl. 27, figs. 10-12) *comb. nov.* Originally *Hystrichosphaera cornuta* Gerlach 1961.

Spiniferella cornuta comb nov.

Plate 6, Figures 37a-c

Synonymy

1961 - *Hystrichosphaera cornuta* GERLACH, p. 180-181, pl. 27, figs. 10-12.
1970 - *Spiniferites cornutus* (Gerlach 1961) SARJEANT, p. 76.

Emended description

Cysts skolochorate with ellipsoidal bodies (length greater than width) bearing parasutural septa, gonal and intergonal spiniferate processes and a prominent apical horn. Endophragm much thicker than periphragm and uniformly minutely granulate. The thin, smooth to faintly ornamented periphragm appressed to endophragm except where parasutural features, processes and an apical horn are developed. Apical horn long, wider proximally than distally and with two spur-like projections, one at about midlength, the other at about two-thirds the horn length from the base of the horn. Parasutural septa of low to moderate height, straight or concave between processes and merge imperceptibly with process bases. Process stalks beyond septa tapered distally, relatively narrow and with trifurcate or bifurcate tips on gonal and intergonal processes, respectively. The archeopyle is precingular, formed by the release of paraplate 3''; operculum monoplacoid and secate. Paratabulation expressed clearly by the parasutural septa, gonyaulacoid, formula: 3-4', 6'', 6c, 5''', 1p, 1''''. Septum between paraplates 1' and 4' may be reduced or absent. Last precingular paraplate subquadrangular to pentangular and in substantial contact with paraplate 1'. Hypocystal paratabulation pattern arranged in the standard sexiform pattern. Paracingulum laevorotatory, delimited by two, equatorial, parallel, transverse septa divided into six rectangular paraplates by short longitudinal septa. Anterior ends of paracingulum offset by approximately 1½ cingular widths. Size: intermediate to large; overall length 95 to 115µm, body length 50 to 56µm, body width 42 to 47µm, apical horn 31 to 46µm long, process length 12 to 17µm, endophragm 2.5 to 3.5µm wide.

Type

Holotype : specimen illustrated by Gerlach (1961, pl. 27, figs. 10-12) from the Emsbüren-7 borehole, Germany, at 182 meters. The holotype was reported initially from Middle Oligocene strata which are now regarded as probably Lower Oligocene (Rupelian).

Occurrence

Spiniferella cornuta occurs virtually throughout the Boom Formation. Although specimens have been reported (as *Spiniferites cornutus*) from throughout the Paleogene, it is uncertain whether or not they possess features diagnostic of *Spiniferella cornuta*. Presently, the species is known unequivocally from the Lower Oligocene (Rupelian) only.

GENUS *VOZZHENNIKOVIA* Lentin and Williams 1976
Vozzhennikovia cearaichia sp. nov.

Plate 12, Figures 78a-b, 79

Description

Proximate peridiniacean, cornucavate cysts with short apical and left antapical horns. Right antapical horn absent or poorly developed. Endocyst smooth, more or less circular in outline, appressed to periphragm almost everywhere and usually discernible only at the bases of the apical and left antapical horns. Periphragm also thin, outline roundly peridinioid, lateral margins moderately convex, antapical margins straight or nearly so. Surface minutely wrinkled with sparse, seemingly randomly disposed, scattered denticulations. Accumulation bodies commonly present within cysts. Paratabulation indicated by middorsal intercalary archeopyle, when discernible, and a weakly developed paracingulum expressed by faint folds and/or very low ridges. Monoplacoid operculum generally in place, otherwise partly displaced and adherent posteriorly, or rarely released entirely. Other indications of paratabulation absent. Size: intermediate; 50 to 56µm, width 53 to 58µm.

Comparison

Vozzhennikovia cearaichia differs from *V. spinula* by having finer ornamention, a less well defined paracingulum and a more round outline.

Types

Holotype : Plate 12, figure 79. Paratype: Plate 12, figures 78a-b. Both specimens are from the Boom Composite Sample at 44.20 meters (= Cored Reconnaissance Hole sample at a drill depth of 37.56 meters).

Occurrence

This species in abundant in the Putte Member of the Boom Formation at the 44.20 meter level in the composite section.

Vozzhennikovia spinula sp. nov.

Plate 12, Figures 80, 81a-82b

Description

Proximate peridiniacean, cornucavate cysts with short apical and two antapical horns; right antapical horn usually reduced. Endophragm thin, smooth, more or less circular in outline, appressed to periphragm almost everywhere and typically discernible only at the bases of horns. Periphragm also thin, outline peridinioid, lateral margins gently convex, antapical margin straight or nearly so. Periphragmal surface ornamented with numerous, but not densely arranged, spinules and/or coni. Their distribution appears to be nontabular, but some of the ornamentation may be intratabular or possibly penitabular. Accumulation bodies usually present within the cysts. Paratabulation indicated by the middorsal archeopyle, when discernible, and the nearly planar paracingulum. Latter expressed by two, transverse, parallel low ridges with finely denticulate crests. Operculum commonly in place, occasionally released entirely or adherent posteriorly. Other indications of paratabulation absent. Size: intermediate; length 55 to 61μm, width 53 to 58μm.

Comparison

Vozzhennikovia spinula differs from *V. cearaichia* (this paper) by being more coarsely ornamented and by having a better developed paracingulum and a less rounded outline. Other species of *Vozzhennikovia, V. apertura* (Wilson 1967) Lentin and Williams 1976, *V. rotunda* (Wilson 1967) Lentin and Williams 1976 and *V. spinulosa* Wilson 1984, are more densely ornamented than *V. spinula.*

Types

Holotype : Plate 12, figure 80, Boom Composite Section sample at 7.68 meters. Paratypes: Plate 12, figures 81a-b and 82a-b from Boom Composite Section samples at 8.55 and 7.68 meters, respectively. Type specimens are from the Steendorp locality.

Occurrence

Specimens of *Vozzhennikovia spinula* occur quite consistently in the Belsele-Waas and the lower part of the Terhagen Members of the Boom Formation between 1.50 and 15.50 meters in the composite section, above which only a single specimen was recorded at the 21.09 meter level. The species is also known from the Ruisbroek Member of the Zelzate Formation and the Belsele-Waas Member of the Boom Formation in the Doel 14E-194 Well.

Genus *XENICODINIUM* Klement 1960
Xenicodinium conispinum sp. nov.

Plate 7, Figures 42a-43b

Description

Proximate subspherical cysts ; outer surface of relatively thick autophragm puncto-reticulate to finely granulate and also bears coni. Coni more or less evenly distributed, variable in basal diameter, 2 to 2.5μm high and spaced from less than 1μm to about 2μm apart. Archeopyle precingular, operculum monoplacoid and secate. Other indications of paratabulation absent. Size : small ; 40 to 47μm in diameter.

Comparison

The ornamentation of *Xenicodinium conispinum* is similar to that on *Operculodinim placitum* Drugg and Loeblich 1967 but differs in having coni that are higher than the spines on *O. placitum*, and have variable basal diameters.

Types

Holotype : Plate 7, figures 42a-b, Boom Composite Section sample at 39.11 meters, Kruibeke locality. Paratype: Plate 7. figures 43a-b, Boom Composite Section sample at 5.20 meters, Sint Niklaas locality.

Occurrence

In the Boom Formation, *Xenicodinium conispinum* occurs in most of the samples from 0.50 to 50.10 meters (Belsele-Waas to Putte Members) in the composite section. The species is also present in the Bassevelde and Ruisbroek Members of the Zelzate Formation and the Belsele-Waas Member of the Boom Formation in the Doel 14E-194 Well.

Xenicodinium echiniferum sp. nov.

Plate 7, Figures 44a-45c

Description

Proximochorate subcircular cysts ; outer surface of autophragm very faintly ornamented and bears numerous, nontabular, smooth, solid, distally tapered spines with acuminate tips. Spines 8.5 to 12μm long. Archeopyle precingular, operculum monoplacoid and secate. Size : intermediate ; overall diameter 54 to 61μm, body diameter 35 to 39μm.

Comparison

Xenicodinium echiniferum differs from *X. conispinum* by having spines rather than coni. Assignment of this species to *Xenicodinium* is with reservation : it lacks the punctoreticulate ornamentation and the fibroid proximal expansions of the processes characteristic of species of *Operculodinium* Wall 1967. The species also differs from those of *Exochosphaeridium* Davey *et al.* 1966 by having smooth processes and by lacking a distinctive apical structure.

Types

Holotype : Plate 7, figures 44a-c, Boom Composite Section sample at 53.30 meters (= Cored Reconnaissance hole sample at a drill depth of 28.46 meters). Paratype: Plate 7, figures 45a-c, Boom Composite Section sample at 52.35 meters (= Cored Reconnaissance Hole sample at a drill depth of 29.41 meters).

Occurrence

Xenicodinium echiniferum occurs sparingly in the upper part of the Boom Composite Section (Putte Member of the Boom Formation) from 44.20 to 59.80 meters.

ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Noel Vandenberghe of the University of Leuven and Pieter Laga of the Belgian Geological Survey for their continued interest and support of this study. On several occasions they guided and assisted us in the field and shared their considerable expertise on the Tertiary stratigraphy of Belgium. In addition they provided with additional sample material, such as that from the Cored Reconnaissance Hole. We also acknowledge the interest and efforts of our colleagues at Exxon Production Research Company in Houston, Texas, U.S.A.. Specifically to Yow Yuh Chen, Martin B. Farley, Peter McLaughlin and Charles E. Pflum for their participation and contribution to numerous discussions concerning the stratigraphic and paleontologic implications of our data as well as their help in organizing many of the illustrations. Permission for publication was granted by Exxon Production Research Company.

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Field N°		Sample Positions (Figure 2)	(Figure 6)	Formation	Member	Sequence/ Systems Tract
C.R.H. [1]						
		66.85 m	62.40 m	Boom	Putte	RU-2 HST
1.	1.	65.55 m	60.90 m	Boom	Putte	RU-2 HST
2.	2.	64.85 m	60.40 m	Boom	Putte	RU-2 HST
3.	3.	64.25 m	59.80 m	Boom	Putte	RU-2 HST
4.	4.	63.25 m	58.80 m	Boom	Putte	RU-2 HST
5.	6.	62.80 m	58.35 m	Boom	Putte	RU-2 HST
6.	7.	61.95 m	57.40 m	Boom	Putte	RU-2 HST
7.	9.	61.45 m	56.90 m	Boom	Putte	RU-2 HST
8.	10.	60.25 m	55.70 m	Boom	Putte	RU-2 HST
9.	13.	59.00 m	54.45 m	Boom	Putte	RU-2 HST
10.	15.	56.80 m	54.10 m	Boom	Putte	RU-2 HST
11.	16.	57.85 m	53.30 m	Boom	Putte	RU-2 HST
12.	17.	56.80 m	52.35 m	Boom	Putte	RU-2 HST
13.	20.	56.35 m	51.90 m	Boom	Putte	RU-2 HST
14.	21.	55.60 m	51.15 m	Boom	Putte	RU-2 HST
15.	23.	54.55 m	50.10 m	Boom	Putte	RU-2 HST
16.	25.	53.90 m	49.70 m	Boom	Putte	RU-2 HST
17.	26.	52.50 m	47.95 m	Boom	Putte	RU-2 HST
18.	29.	51.55 m	47.00 m	Boom	Putte	RU-2 HST
19.	31.	50.40 m	45.96 m	Boom	Putte	RU-2 HST
20.	32.	48.95 m	44.50 m	Boom	Putte	RU-2 HST
21.	24.	48.65 m	44.20 m	Boom	Putte	RU-2 HST
22.	35.	48.35 m	43.40 m	Boom	Putte	RU-2 HST
23.	37.	48.05 m	43.12 m	Boom	Putte	RU-2 HST
24.	78-1	47.80 m	42.41 m	Boom	Putte	RU-2 HST
25.	77-2	47.60 m	42.41 m	Boom	Putte	RU-2 HST
26.	76-1	47.30 m	41.76 m	Boom	Putte	RU-2 HST
27.	74-1	46.70 m	40.90 m	Boom	Putte	RU-2 HST
28.	72-1	46.20 m	40.20 m	Boom	Putte	RU-2 HST
29.	70-2	45.60 m	39.80 m	Boom	Putte	RU-2 HST
30.	69-2	44.80 m	39.11 m	Boom	Putte	RU-2 HST
31.	67-2	44.50 m	38.71 m	Boom	Putte	RU-2 HST
32.	66-1	44.15 m	38.32 m	Boom	Putte	RU-2 HST
33.	65-1	43.75 m	38.00 m	Boom	Putte	RU-2 HST
34.	64-1	43.00 m	37.60 m	Boom	Putte	RU-2 HST
35.	63-1	42.70 m	37.26 m	Boom	Putte	RU-2 HST
36.	62-1	42.30 m	36.49 m	Boom	Putte	RU-2 HST
37.	60-1	41.95 m	36.11 m	Boom	Putte	RU-2 HST
38.	59-1	41.75 m	35.79 m	Boom	Putte	RU-2 HST
39.	58-1	41.25 m	35.41 m	Boom	Putte	RU-2 HST
40.	57-1	40.75 m	35.02 m	Boom	Putte	RU-2 HST
41.	56-1	40.45 m	34.70 m	Boom	Putte	RU-2 HST
42.	55-1	40.10 m	33.84 m	Boom	Putte	RU-2 HST
43.	53-1	39.90 m	33.59 m	Boom	Putte	RU-2 HST
44.	52-1	39.50 m	32.81 m	Boom	Putte	RU-2 HST
45.	51-1	39.00 m	32.47 m	Boom	Putte	RU-2 HST
46.	49-1	38.35 m	31.71 m	Boom	Putte	RU-2 HST
47.	47-1	37.70 m	31.00 m	Boom	Putte	RU-2 HST
48.	45-1	36.90 m	30.19 m	Boom	Putte	RU-2 HST
49.	44-1	36.50 m	29.90 m	Boom	Putte	RU-2 HST
50.	43-1	35.80 m	29.20 m	Boom	Putte	RU-2 HST
51.	42-1	35.00 m	28.44 m	Boom	Putte	RU-2 HST
52.	40-1	34.20 m	27.74 m	Boom	Putte	RU-2 HST
54.	38-1	33.90 m	27.32 m	Boom	Putte	RU-2 HST
55.	37-1	33.45 m	27.00 m	Boom	Putte	RU-2 HST
56.	36-1	32.80 m	26.22 m	Boom	Putte	RU-2 HST
57.	34-1	32.40 m	25.88 m	Boom	Putte	RU-2 HST
58.	33-1					

Field N°	Sample Positions (Figure 2)	(Figure 6)	Formation	Member	Sequence/ Systems Tract
59. 32-1	32.05 m	25.50 m	Boom	Putte	RU-2 HST
60. 31-1	31.70 m	25.13 m	Boom	Putte	RU-2 HST
61. 30-1	31.15 m	24.78 m	Boom	Putte	RU-2 HST
62. 29-1	30.60 m	24.38 m	Boom	Putte	RU-2 HST
					RU-2 SB (*)
63. 28-1	30.30 m	24.00 m	Boom	Putte	RU-1 HST
64. 27-1	30.05 m	23.63 m	Boom	Putte	RU-1 HST
65. 26-1	29.70 m	23.30 m	Boom	Putte	RU-1 HST
66. 25-1	29.50 m	22.90 m	Boom	Putte	RU-1 HST
67. 24-1	29.20 m	22.59 m	Boom	Putte	RU-1 HST
68. 22-1	28.20 m	21.81 m	Boom	Terhagen	RU-1 HST
69. 21-1	27.90 m	21.41 m	Boom	Terhagen	RU-1 HST
70. 20-1	27.50 m	21.09 m	Boom	Terhagen	RU-1 HST
71. 19-1	27.05 m	20.70 m	Boom	Terhagen	RU-1 HST
72. 17-1	26.30 m	19.99 m	Boom	Terhagen	RU-1 HST
73. 16-1	26.00 m	19.59 m	Boom	Terhagen	RU-1 HST
74. 14-1	25.30 m	18.85 m	Boom	Terhagen	RU-1 HST
75. 13-1	24.70 m	18.50 m	Boom	Terhagen	RU-1 HST
76. 12-1	24.40 m	18.10 m	Boom	Terhagen	RU-1 HST
77. 11-1	24.00 m	17.79 m	Boom	Terhagen	RU-1 HST
78. 10-1	23.50 m	17.39 m	Boom	Terhagen	RU-1 HST
79. 8-1	22.80 m	16.65 m	Boom	Terhagen	RU-1 HST
80. 7-1	22.40 m	16.30 m	Boom	Terhagen	RU-1 DLS
81. 6-1	22.00 m	15.90 m	Boom	Terhagen	RU-1 TST
82. 5-1	21.50 m	15.54 m	Boom	Terhagen	RU-1 TST
83. 4-1	21.15 m	15.59 m	Boom	Terhagen	RU-1 TST
84. 2-1	20.45 m	14.47 m	Boom	Terhagen	RU-1 TST
Steendorp Section					
85. SD-7	17.30 m	12.10 m	Boom	Terhagen	RU-1 TST
86. SD-6	15.20 m	11.20 m	Boom	Terhagen	RU-1 TST
87. SD-5	14.10 m	10.51 m	Boom	Terhagen	RU-1 TST
88. SD-4	12.30 m	9.44 m	Boom	Terhagen	RU-1 TST
89. SD-8	12.00 m	8.86 m	Boom	Terhagen	RU-1 TST
90. SD-3	11.50 m	8.55 m	Boom	Belsele-Waas	RU-1 TST
91. SD-2	10.40 m	7.68 m	Boom	Belsele-Waas	RU-1 TST
92. SD-1	9.75 m	6.80 m	Boom	Belsele-Waas	RU-1 TST
St-Niklaas Section					
93. SN-30	14.00 m	10.98 m	Boom	Terhagen	RU-1 TST
94. SN-29	12.90 m	10.71 m	Boom	Terhagen	RU-1 TST
95. BE- 3	12.30 m	9.20 m	Boom	Terhagen	RU-1 TST
96. SN-25	11.85 m	8.86 m	Boom	Terhagen	RU-1 TST
97. SN-22	10.30 m	7.90 m	Boom	Belsele-Waas	RU-1 TST
98. SN-20	9.40 m	7.24 m	Boom	Belsele-Waas	RU-1 TST
99. SN-17	6.60 m	6.20 m	Boom	Belsele-Waas	RU-1 TST
100. SN-14	5.40 m	5.20 m	Boom	Belsele-Waas	RU-1 TST
101. SN-11	3.70 m	4.20 m	Boom	Belsele-Waas	RU-1 TST
102. SN- 8	2.05 m	3.20 m	Boom	Belsele-Waas	RU-1 TST
103. SN- 4	1.70 m	2.00 m	Boom	Belsele-Waas	RU-1 TST
104. BE- 2	1.40 m	1.50 m	Boom	Belsele-Waas	RU-1 TST
105. SN- 1	0.60 m	1.00 m	Boom	Belsele-Waas	RU-1 TST
106. BE- 1		0.50 m	Boom	Belsele-Waas	RU-1 TST

Field N°	Sample Positions (Figure 20)	Formation	Member
107. 1, 109.75 m	110 m	Boom	Belsele-Waas
108. 2, 114.35 m	114 m	Zelzate	Ruisbroek
109. 3, 119.90 m	120 m	Zelzate	Ruisbroek
110. 4, 128.90 m	129 m	Zelzate	Ruisbroek
111. 5, 130.90 m	131 m	Zelzate	Watervliet
112. 6, 139.90 m	140 m	Zelzate	Bassevelde
113. 7, 159.90 m	160 m	Zelzate	Bassevelde

Appendix A : Sample information.
(1) Cored Reconnaissance Hole
(*) 30.50 m

Note : sample positions in this paper were measured from the base of the Boom Composite Section at the Sint Niklaas locality and are shown on figure 6. Our thickness differ from those published by Vandenberghe and van Echelpoel, 1987 (figure 2). Both sample designations are included below.

APPENDIX B: BIOSTRATIGRAPHIC DATUMS

Taxon	Base	Systems Tract	Taxon	Top	Systems Tract
1. C. diversispinosum	Pre-Rupel		31. A. spiridoides	Post-Rupel	
2. C. fibrospinosum	Pre-Rupel		17. C. mespilanum	Post-Rupel	
3. C. incompositum	Pre-Rupel		26. I. paradoxum	Post-Rupel	
4. F. axialis	Pre-Rupel		34. H. vallum	Post-Rupel	
5. H. tenuispinosum	Pre-Rupel		33. H. obscura	Post-Rupel	
6. M. asterium	Pre-Rupel		25. R. actinocoronata	Post-Rupel	
7. O. divergens	Pre-Rupel		19. W. gochtii	Post-Rupel	
8. P. comatum	Pre-Rupel		18. A. expansa	62.40m	RU-2 HST
9. S. chlamydophora	Pre-Rupel		20. P. imaginatum	62.40m	RU-2 HST
10. W. articulata	Pre-Rupel		32. I. machaeroides	60.90m	RU-2 HST
11. X. conispinum	Pre-Rupel		16. A.? semicirculata	59.80m	RU-2 HST
12. C. limitata	0.50m	RU-1 TST	1. C. diversispinosum	59.80m	RU-2 HST
13. E. breva	0.50m	RU-1 TST	30. M. intermedium	59.80m	RU-2 HST
14. G. conopea	0.50m	RU-1 TST	37. P. lophophorum	59.80m	RU-2 HST
15. Histiocysta spp.	0.50m	RU-1 TST	28. X. ecniniferum	59.80m	RU-2 HST
16. A.? semicirculata	0.50m	RU-1 TST	5. H. tenuispinosum	56.90m	RU-2 HST
17. C. mespilanum	0.50m	RU-1 TST	36. M. connectum	56.90m	RU-2 HST
18. A. expansa	0.50m	RU-1 TST	15. Histiocysta spp.	52.35m	RU-2 HST
19. W. gochtii	0.50m	RU-1 TST	11. X. conispinum	50.10m	RU-2 HST
20. P. imaginatum	1.00m	RU-1 TST	35. V. cearaichia	44.20m	RU-2 HST
21. V. spinula	1.50m	RU-1 TST	2 21. V. spinula		1.50m RU-1 TST
22. I. torsium	2.00m	RU-1 TST	14. G. conopea	42.41m	RU-2 HST
23. C. endoreticulum	5.20m	RU-1 TST	27. A. potane	37.60m	RU-2 HST
24. O. xanthium	6.80m	RU-1 TST	23. C. endoreticulatum	35.41m	RU-2 HST
25. R. actinocoronatum	6.80m	RU-1 TST	29. P. filigranum	RU-2.59m	RU-2 TST
26. I. paradoxum	8.55m	RU-1 TST	4. F. axialis	32.47m	RU-2 TST
27. A. potane	9.20m	RU-1 TST	3. C. incompositum	31.00m*	RU-2 TST
28. X. echiniferum	9.44m	RU-1 TST	9. S. chlamadophora	30.10m*	RU-2 TST
29. P. filigranum	10.31m	RU-1 TST	13. E. breva	30.10m	RU-2 TST
30. M. intermedium	20.70m	RU-1 HST	2. C. fibrospinosum	22.90m	RU-2 TST
31. A. spiridoides	24.00m	RU-1 HST	8. P. comatum	21.84m*	RU-1 HST
32. I. machaeroides	31.71m	RU-2 TST	21. V. spinula	21.09m	RU-1 HST
33. H. obscura	32.47m	RU-2 TST	12. C. limitata	15.54m	RU-1 TST
34. H. vallum	32.81m	RU-2 TST	22. I. torsium	11.20m	RU-1 TST
35. V. cearaichia	44.20m	RU-2 HST	6. M. asterium	9.44m	RU-1 TST
36. M. connectum	44.20m	RU-2 HST	7. O. divergens	8.86m	RU-1 TST
37. P. lophophorm	51.15m	RU-2 HST	10. W. articulata	6.20m	RU-1 TST

* Known to occur stratigraphically higher in Rupelian strata elsewhere

APPENDIX C: LOCATIONS OF ILLUSTRATED SPECIMENS

Species	Sample	Slide/Coordinates	Illustration Plate/Figure		Type
Achilleodinium biformoides	08.86m	3050-G, 1/ 87.5x12.4	5	29a-b	Hypo.
Achomosphaera alcicornu	27.00m	3064AL, 1/100.8x14.8	5	28a-b	Hypo.
Achomosphaera expansa	23.63m	3064AB, L/116.3x07.7	5	30a-b	Holo.
Achomosphaera expansa	37.27m	3064BN, 1/102.8X15.0	5	31a-c	Para.
Achomosphaera expansa	21.41m	3064-W, 1/ 96.3x10.6	6	32a-b	Para.
Apteodinium australiense	20.70m	3064-U, L/ 91.3x13.2	8	51a-b	Hypo.
Apteodinium spiridoides	51.15m	3286-X, 1/102.0x04.2	8	52a-b	Hypo.
Areoligera? semicirculata	39.11m	3064BU, 1/104.2x19.6	3	16	Hypo.
Areoligera? semicirculata	39.11m	3064BU, 1/106.0x17.2	3	17	Hypo.
Areosphaeridium pectiniforme	27.00m	3064AL, 1/ 96.8x01.8	1	1a-b	Hypo.
Areosphaeridium pectiniforme	24.78m	3064AE, 1/109.1x19.5	1	2a-b	Hypo.
Ascostomocystis potane	23.63m	3064AB, 1/ 93.3x14.0	12	76	Hypo.
Ascostomocystis potane	18.85m	3064-P, 1/ 91.0x05.0	12	77	Hypo.
Caligodinium amiculum	00.50m	2735CA, 1/102.0x04.7	1	5	Hypo.
Caligodinium endoreticulum	07.68m	3050-A, 1/ 99.0x03.0	1	3a-b	Holo.
Caligodinium endoreticulum	10.17m	3065AV, 1/111.3x11.3	1	4	Para.
Charlesdownia limitata	11.20m	3050-E, L/ 95.0x14.3	10	70a-c	Holo.
Charlesdownia limitata	11.20m	3050-E, L/ 87.5x04.0	10	71a-c	Para.
Chiropteridium mespilanum	04.20m	3065-Q, 1/ 92.5x09.0	9	62a-b	Hypo.
Cleistosphaeridium diversispinosum	23.30m	3064AA, 1/101.3x06.0	1	6a-b	Hypo.
Cordosphaeridium cantharellum	53.30m	3286-R, 1/104.3x10.6	7	38	Hypo.
Cordosphaeridium minimum	08.86m	3050-G, 1/ 98.0x08.9	7	39a-b	Hypo.
Cribroperidinium tenuitabulatum	06.80m	3050--, 1/ 95.5x01.8	8	53a-b	Hypo.
Cyclopsiella spp.	06.80m	3050--, 1/ 98.6x12.2	12	84a-b	----
Cyclopsiella spp.	00.50m	2735CA, 1/107.0x09.0	12	85	----
Dapsilidinium pseudocolligerum	27.00m	3064AL, 1/104.5x12.5	1	7a-c	Hypo.
Deflandrea heterophlycta	08.55m	3050-B, L/ 98.8x23.0	10	63	Hypo.
Deflandrea phosphoritica	08.55m	3050-B, L/ 92.5x08.0	10	64	Hypo.
Deflandrea spinulosa	04.20m	3065-Q, L/ 88.2x06.8	10	65	Hypo.
Dinopterygium sp.	08.55m	3050-B, 1/ 99.0x09.0	12	83	----
Distatodinium sp.	21.81m	3064-X, 1/101.0x16.9	2	8	----
Distatodinium sp.	18.85m	3064-P, 1/ 91.0x04.3	2	9	----
Elytrocysta breva	03.20m	3065-L, 1/104.8x12.2	2	10a-b	Holo.
Elytrocysta breva	09.20m	2735CC, 1/101.7x07.0	2	11a-b	Para.

Species	Sample	Slide/Coordinates	Illustration Plate/Figure		Type
Elytrocysta breva	09.20m	2735CC, 1/109.4x12.7	2	12	Para.
Fibrocysta axialis	28.44m	3064AQ, 1/ 97.3x12.0	8	55	Hypo.
Gerdiocysta conopea	05.20m	3065-V, 1/ 85.0x17.0	4	21a-c	Hypo.
Histiocysta sp.	08.86m	3065AP, 1/107.5x20.1	2	13a-c	----
Histiocysta sp.	09.20m	2735CC, 1/ 88.5x19.0	2	14a-c	----
Homotryblium pallidum	10.51m	3050-D, L/ 93.6x14.2	13	87a-b	Hypo.
Homotryblium tenuispinosum	21.09m	3064-V, L/ 91.9x08.2	13	86a-b	Hypo.
Homotryblium plectilum	38.00m	3064BQ, 1/113.3x09.5	13	89a-b	Hypo.
Homotryblium vallum	32.81m	3064BB, 1/101.0x20.5	13	88a-b	Hypo.
Hystrichokolpoma cinctum	45.96m	3286AG, 1/109.0x22.1	2	15a-c	Hypo.
Hystrichokolpoma rigaudiae	33.81m	3286AD, 1/102,0x10.5	3	18a-d	Hypo.
Hystrichokolpoma salacium	37.56m	3286AK, 1/ 96.8x22.5	3	19a-c	Hypo.
Hystrichosphaeropsis obscura	35.02m	3064BG, 1/103,1x07,0	7	46a-b	Hypo.
Impagidinium dispertitum	08.86m	3065AP, 1/ 90.0x13.8	8	50a-b	Hypo.
Impagidinium torsium	08.86m	3065AP, 1/ 93.6x12.3	7	47a-c	Holo.
Impagidinium torsium	08.86m	3065AP, 1/ 93.2x19.1	7	48	Para.
Impagidinium torsium	08.86m	3065AP, 1/ 93.2x04.9	8	49a-c	Para.
Impletosphaeridium machaeroides	52.35m	3286-U, 1/103.5x17.8	13	91a-b	Holo.
Impletosphaeridium machaeroides	36.11m	3064BK, 1/105.4x07.4	13	92a-b	Para.
Lingulodinium machaerophorum	03.20m	3065-L, 1/ 92.7x17.0	13	90	Hypo.
Membranophoridium aspinatum	47.95m	3286AD, 1/ 98.8x18.7	5	26	Hypo.
Membranophoridium aspinatum	56.90m	3286-J, 1/ 94.0x05.6	5	27a-b	Hypo.
Membranophoridium connectum	45.96m	3286AG, 1/ 91.0x11.3	4	22a-c	Holo.
Membranophoridium connectum	45.96m	3286AG, 1/108.0x07.4	4	23a-b	Para.
Membranophoridium intermedium	51.90m	3286-V, 1/104.3x22.8	4	24a-b	Holo.
Membranophoridium intermedium	56.90m	3286-J, 1/108.4x20.0	4	25a-b	Para.
Operculodinium centrocarpum (cf.)	18.18m	3064-L, L/ 97.7x04.1	7	41	Hypo.
Operculodinium xanthium	07.24m	3065AE, L/ 94.2x02.5	7	40	Hypo.
Palaeocystodinium golzowense	44.20m	3286AK, 1/ 89.3x03.3	10	66	Hypo.
Pentadinium imaginatum	55.70m	3286-M, 1/107.5x03,5	9	57a-b	Hypo.
Pentadinium laticinctum-taeniagerum	31.00m	3064AV, 1/104.2x16.0	9	56a-b	Hypo.
Pentadinium lophophorum	59.80m	3286-C, 1/ 90.6x07.1	9	58	Hypo.
Pentadinium lophophorum	59.80m	3286-C, 1/ 91.8x08.0	9	59	Hypo.
Phthanoperidinium comatum	22.81m	3064-X, L/ 98.4x08.4	10	67	Hypo.
Phthanoperidinium filigranum	25.50m	3064AG, L/111.0x17.8	10	68	Hypo.

Species	Sample	Slide/Coordinates	Illustration Plate/Figure		Type
Phthanoperidinium filigranum	10.51m	3050-D, 1/ 96.5x09.0	10	69	Hypo.
Reticulosphaera actinocoronata	31.71m	3064AX, 1/103.2x07.0	6	33	Hypo.
Samlandia chlamydophora	21.09m	3064-V, 1/ 84.8x15.0	8	54a-b	Hypo.
Spiniferella cornuta	31.00m	3064AV, 1/ 91.6x05.0	6	37a-b	Hypo.
Spiniferites pseudofurcatus	29.20m	3064AS, 1/100.5x08.0	6	34a-c	Hypo.
Spiniferites ramosu	47.95m	3286AD, 1/106.3x08.5	6	35a-b	Hypo.
Spiniferites sp.	07.68m	3050-A, 1/ 91.2x10.5	6	36	----
Systematphora placacantha	27.00m	3064AL, 1/ 94.0x12.0	3	20a-c	Hypo.
Tectatodinium grande	30.19m	3064AU, 1/ 97.8x13.0	9	61a-b	Hypo.
Tectatodinium pellitum	34.70m	3064BF, 1/ 98.3x03.0	9	60a-b	Hypo.
Vozzhennikovia cearaichia	44.20m	3286AD, 1/ 92.6x10.4	12	78a-b	Para.
Vozzhennikovia cearaichia	44.20m	3286AD, 1/103.2x02.5	12	79	Holo.
Vozzhennikovia spinula	07.68m	3050-A, L/ 99.0x06.3	12	80	Holo.
Vozzhennikovia spinula	07.68m	3050-A, 1/ 89.0x18.8	12	81a-b	Para.
Vozzhennikovia spinula	08.55m	3050-B, L/100.3x22.9	12	82a-b	Para.
Wetzeliella articulata	00.50m	2735CA, 1/ 91.5x12.7	12	75	Hypo.
Wetzeliella gochtii	10.98m	3065AW, L/ 98.0x08.0	11	72a-c	Hypo.
Wetzeliella symmetrica	47.95m	3286AD, 1/ 92.5x18.5	11	73a-c	Hypo.
Wetzeliella symmetrica	30.19m	3064AU, L/ 99.3x23.0	11	74a-b	Hypo.
Xenicodinium conispinum	39.11m	3064BU, 1/ 95.3x18.3	7	42a-b	Holo.
Xenicodinium conispinum	05.20m	3065-V, 2/ 99.0x01.3	7	43a-b	Para.
Xenicodinium echiniferum	53.30m	3286-R, 1/108.0x08.1	7	44a-c	Holo.
Xenicodinium echiniferum	52.35m	3286-U, 1/ 87.6x04.5	7	45a-c	Para.

Holo. = Holotype, Hypo. = Hypotype, Para. = Paratype

Note: Palynological preparations containing the holotypes and paratypes of the new species are housed temporarily at Exxon Production Research Company, P.O. Box 2189, Houston. Texas 77251-2189, U.S.A. Upon completion of additional studies, the preparations will be sent for permanent custody to the Atlantic Geoscience Centre, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2, Attention: Dr. Graham L. Williams.

PLATE 1

Areosphaeridium, Caligodinium, Cleistosphaeridium and *Dapsilidinium*

Figures

1 - 2 *Areosphaeridium pectiniforme*. 1a-b, right lateral views at two focus levels, x 500. 2a-b, left lateral views at two focus levels, x 400.

3 - 4 *Caligodinium endoreticulum sp. nov.* 3a-b, holotype with kalyptra at two focus levels, x 400. 4, paratype, x 500.

5 *Caligodinium amiculum*. x 400.

6 *Cleistosphaeridium diversispinosum*. 6a-b, lateral views at high (6a) and intermediate (6b) focus levels, x 500.

7 *Dapsilidinium pseudocolligerum*. 7a-c, apical views at three successively lower focus levels, x 500.

PLATE 1

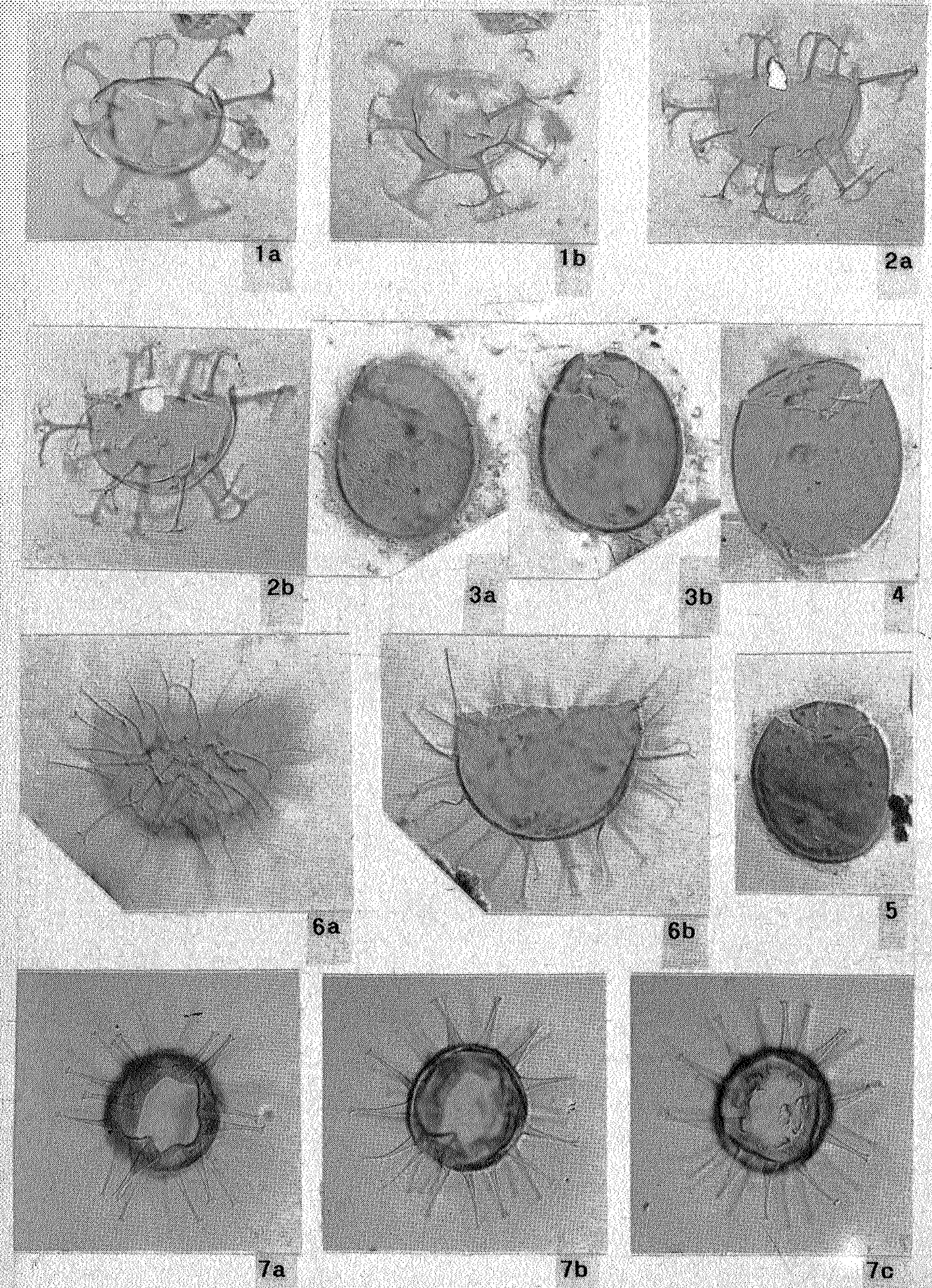

PLATE 2

Distatodinium, Elytrocysta, Histiocysta and *Hystrichokolpoma*

Figures

8 - 9 *Distatodinium spp*. Two specimens at x 400.

10 - 12 *Elytrocysta breva sp. nov.* 10a-b, holotype at high and intermediate focus levels, x 500. 11a-b, paratype at two focus levels, x 500. 12, another paratype at an intermediate focus level showing the operculum, x 500.

13 - 14 *Histiocysta spp*. 13a-c, ventral views of ventral surface (13a), dorsal surface (13c) and at an intermediate focus level (13b), x 500. 14a-c, ventral views of a smaller specimen, focus levels same as above, x 500.

15 *Hystrichokolpoma cinctum*. 15a-c, right lateral views at three successively lower focus levels, x 400.

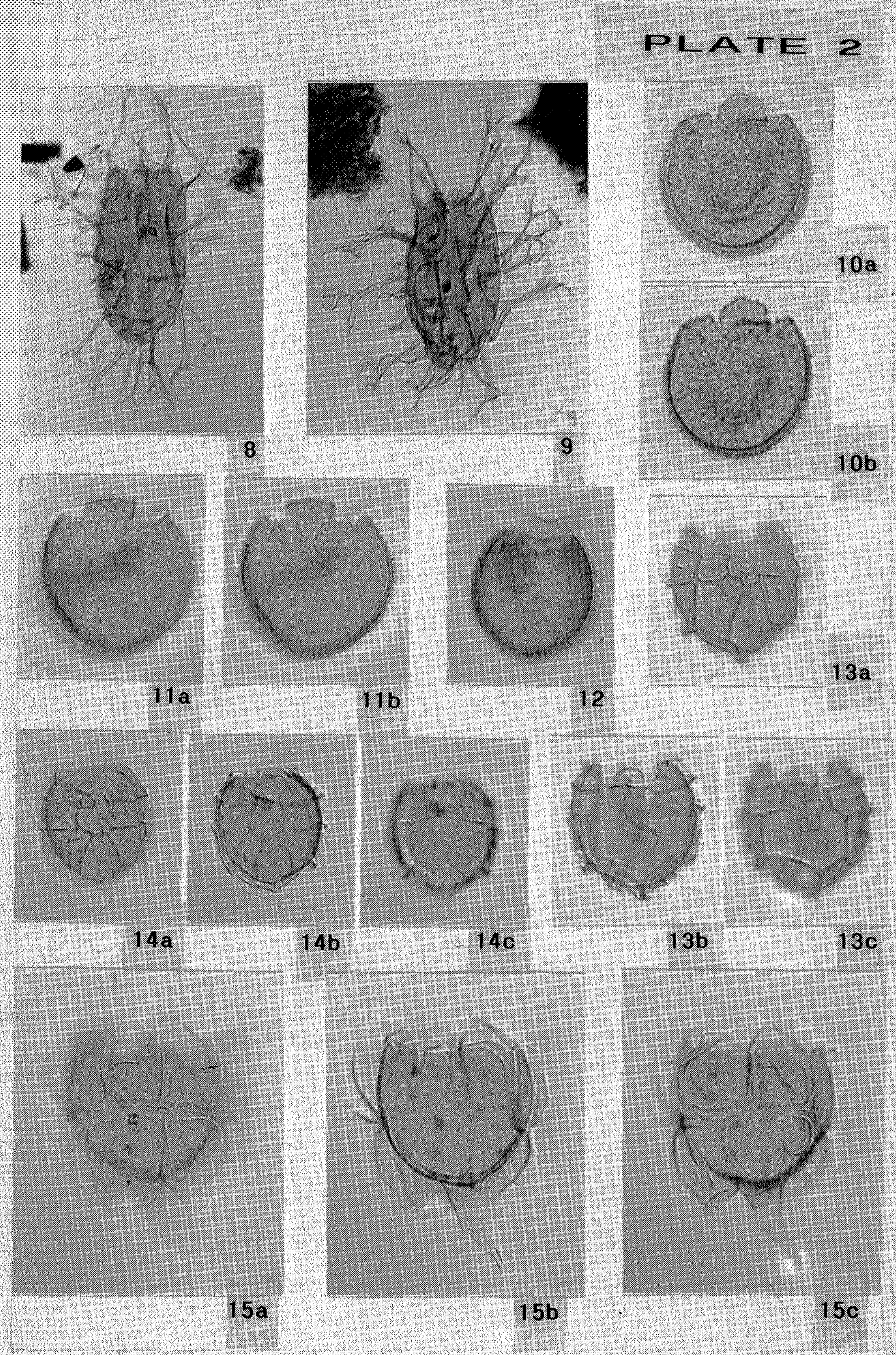

PLATE 3

Areoligera, Hystrichokolpoma and *Systematophora*

Figures

16 - 17 *Areoligera ? semicirculata.* 16. complete specimen, x 310. 17, specimen without operculum, x 400.

18 *Hystrichokolpoma rigaudiae.* 18a-d, dorsal views at successive focus levels from the dorsal to the ventral surfaces, x 400.

19 *Hystrichokolpoma salacium.* 19a-c, successive focus levels from the right lateral to the left lateral surfaces, x400.

20 *Systematophora placacantha.* 20a-c, obligue ventral views of ventral surface (20a), antapical-dorsal surface (20c) showing the penitabular outlines of the antapical and some of the adjacent postcingular paraplates, and an intermediate focus level (20b), x 500.

PLATE 3

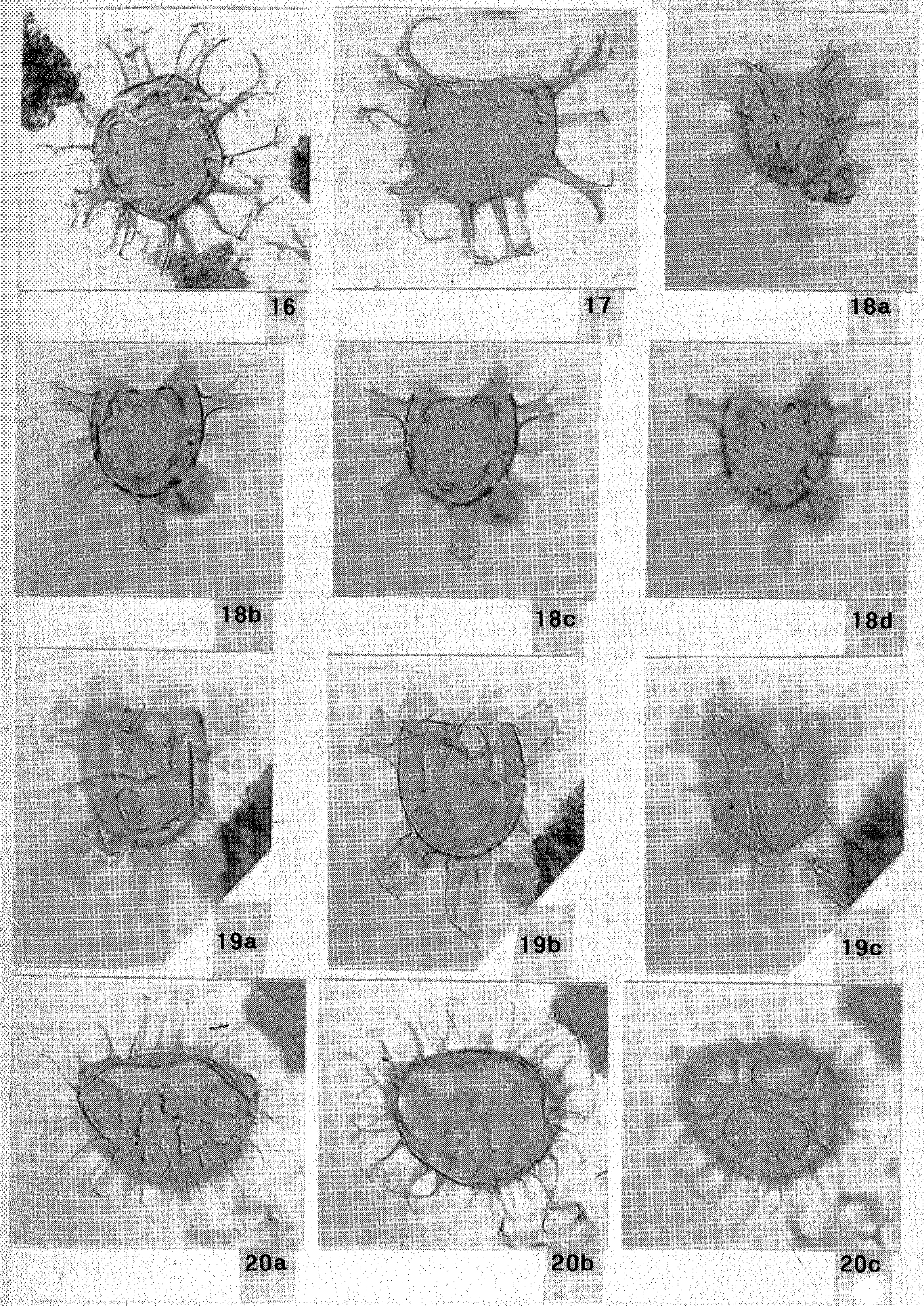

PLATE 4

Gerdiocysta and *Membranophoridium*

Figures

21 *Gerdiocysta conopea.* 21a-c, dorsal views of specimen shown at successively lower focus levels, x 400.

22 - 23 *Membranophoridium connectum sp. nov.* 22a-c, holotype at successively lower focus levels from ventral to dorsal surfaces, x 400. 23a-b, ventral views of paratype showing the ventral and dorsal surfaces, x 400.

24 - 25 *Membranophoridium intermedium sp. nov.* 24a-b, ventral views of holotype showing the ventral and dorsal surfaces, x 400. 25a-b, ventral views of paratype showing ventral and dorsal surfaces, x 400.

PLATE 4

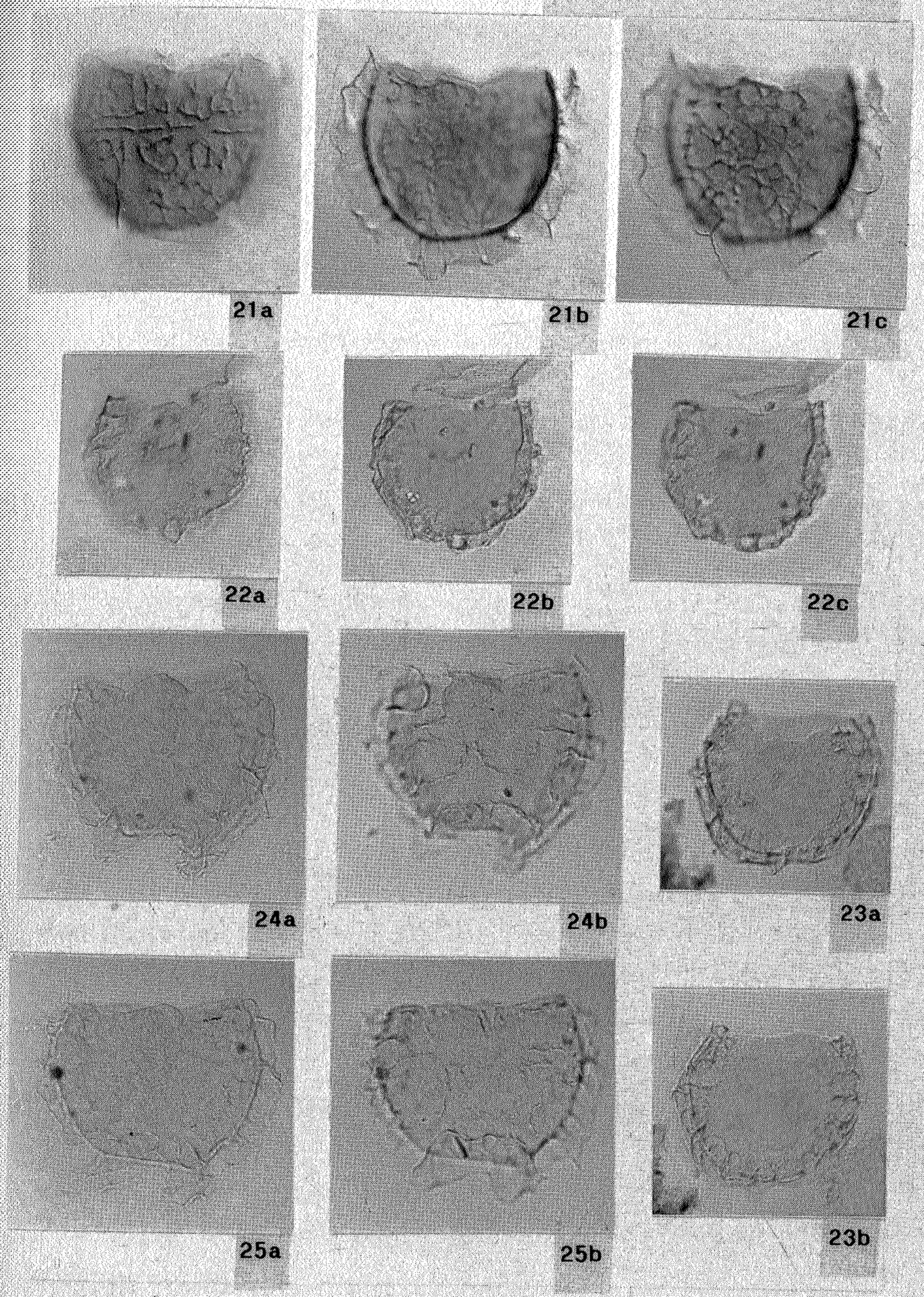

PLATE 5

Achilleodinium, Achomosphaera and *Membranophoridium*

Figures

26 - 27 *Membranophoridium aspinatum*. 26, specimen at mid-focus level, x 310. 27a-b, ventral views of the ventral surface and at mid-focus level, x 310.

28 *Achomosphaera alcicornu*. 28a-b, dorsal views of specimen at two focus levels, x 310.

29 *Achilleodinium biformoides*. 29a-b, oblique ventral views of ventral and dorsal surfaces, x 400.

30 - 31 *Achomosphaera expansa sp. nov.* 30a-b, left lateral views of holotype at two focus levels, x 400. 31a-c, paratype at three focus levels, x 400.

PLATE 5

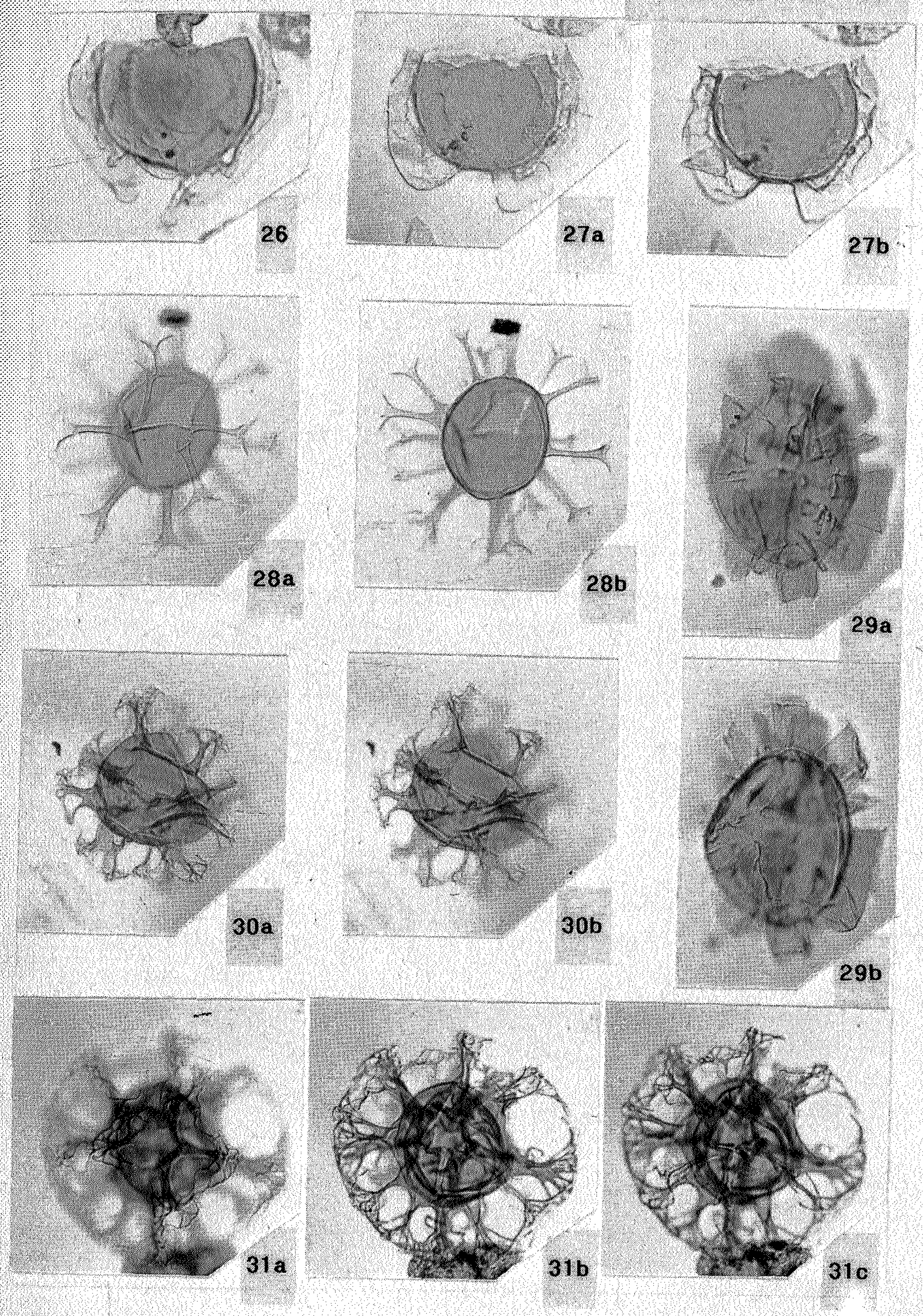

PLATE 6

Achomosphaera, Reticulosphaera, Spiniferella and *Spiniferites*

Figures

32 *Achomosphaera expansa sp. nov*. 32a-b, another paratype at two focus levels, x 400.

33 *Reticulosphaera actinocoronata*. x 400.

34 *Spiniferites pseudofurcatus*. 34a-c, right lateral views of specimen at successively lower focus levels, x310.

35 *Spiniferites ramosus*. 35a-b, dorsal views of dorsal and ventral surfaces, x 400.

36 *Spiniferites sp.* x 400.

37 *Spiniferella cornuta comb. nov*. 37a-c, views perpendicular to last precingular paraplate and shown at three successively lower focus levels from the ventral to the dorsal surfaces, x 400.

PLATE 6

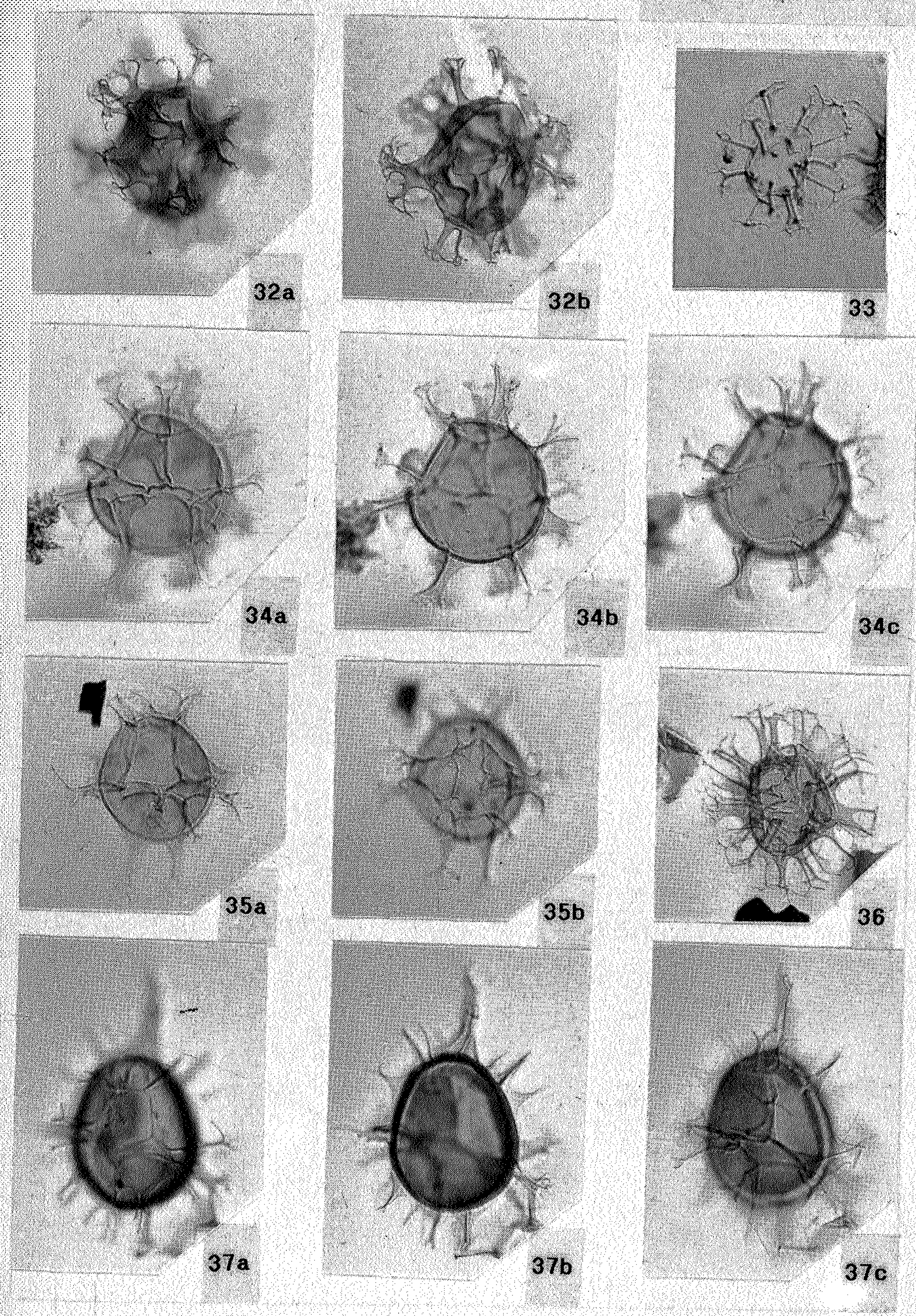

PLATE 7

Cordosphaeridium, Hystrichosphaeropsis, Impagidinium, Operculodinium and *Xenicodinium*

Figures

38 *Cordosphaeridium cantharellum.* x 400.

39 *Cordosphaeridium minimum.* 39a-b, specimen shown at high and intermediate focus levels, x 500.

40 *Operculodinium xanthium.* x 400.

41 *Operculodinium sp. cf. O. centrocarpum.* Specimen with a relatively thick wall, x 400.

42 - 43 *Xenicodinium conispinum sp. nov.* 42a-b, left lateral views of holotype at two focus levels, x 500. 43a-b, right lateral views of paratype at two focus levels, x 500.

44 - 45 *Xenicodinium echiniferum sp. nov.* 44a-c, right lateral views of holotype at successively lower focus levels, x 400. 45a-c, left lateral views of paratype at successively lower focus levels, operculum inside specimen, x 400.

46 *Hystrichosphaeropsis obscura.* 46a-b, high and intermediate focus levels, x 400.

47 - 48 *Impagidinium torsium sp. nov.* 47a-c, dorsal views of holotype at succesively lower focus levels from the dorsal to the ventral surfaces, x 500. 48, oblique apical-ventral view of paratype, x 500.

PLATE 7

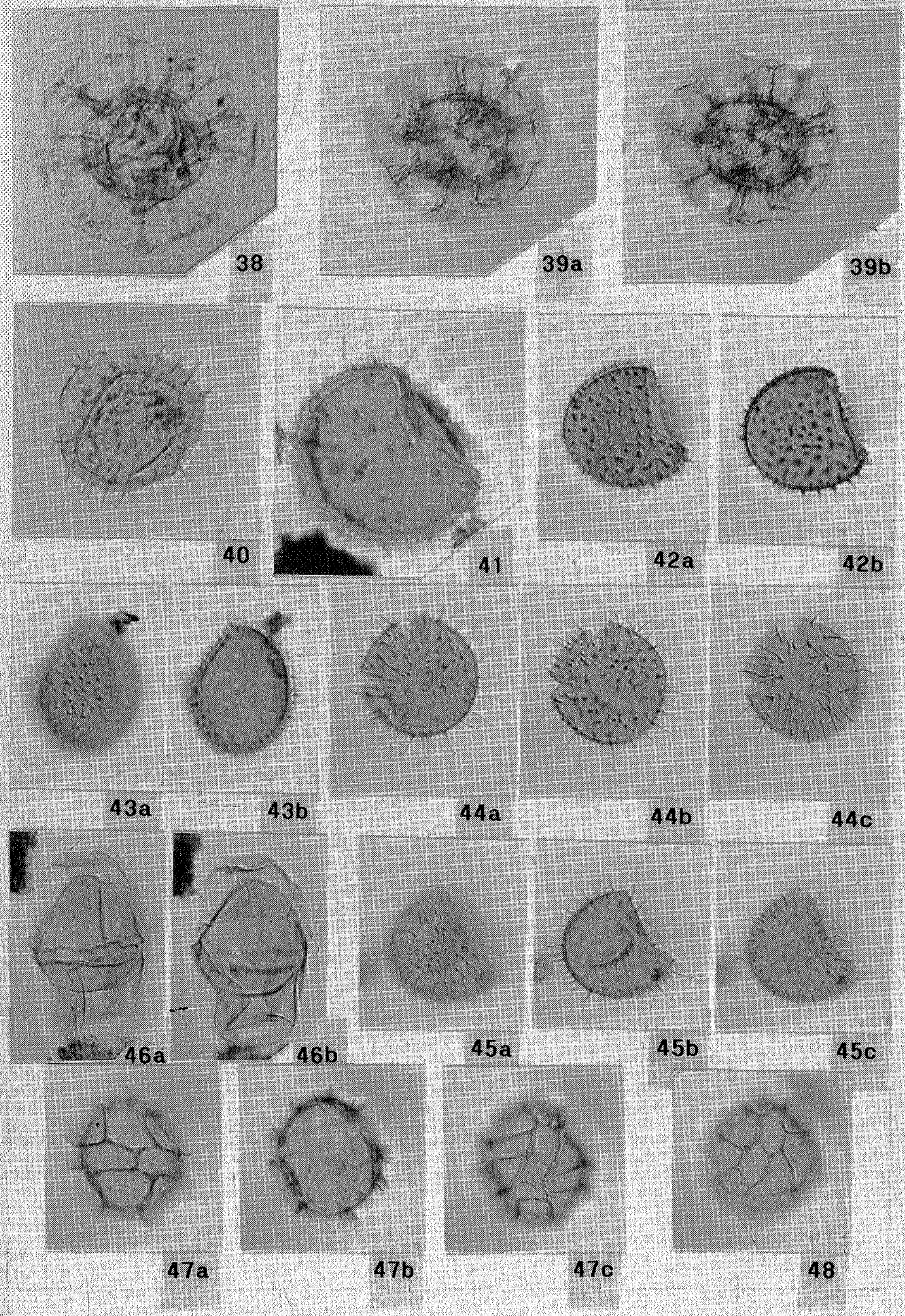

PLATE 8

Apteodinium, Cribroperidinium, Fibrocysta, Impagidinium and *Samlandia*

Figures

49 *Impagidinium torsium sp. nov.* 49a-c, oblique dorsal views of a paratype at three focus levels, x 500.

50 *Impagidinium dispertitum.* 50a-b, dorsal views of dorsal and ventral surfaces, x 500.

51 *Apteodinium australiense.* 51a-b, dorsal views at two focus levels, x 310.

52 *Apteodinium spiridoides.* 52a-b, dorsal views of dorsal and ventral surfaces, x 400.

53 *Cribroperidinium tenuitabulatum.* 53a-b, dorsal views of vental and dorsal surfaces, x 400.

54 *Samlandia chlamydophora.* 54a-b, oblique views of left-dorsal surface at high and intermediate focus levels, x 310.

55 *Fibrocysta axialis.* Oblique left-dorsal view, x 310.

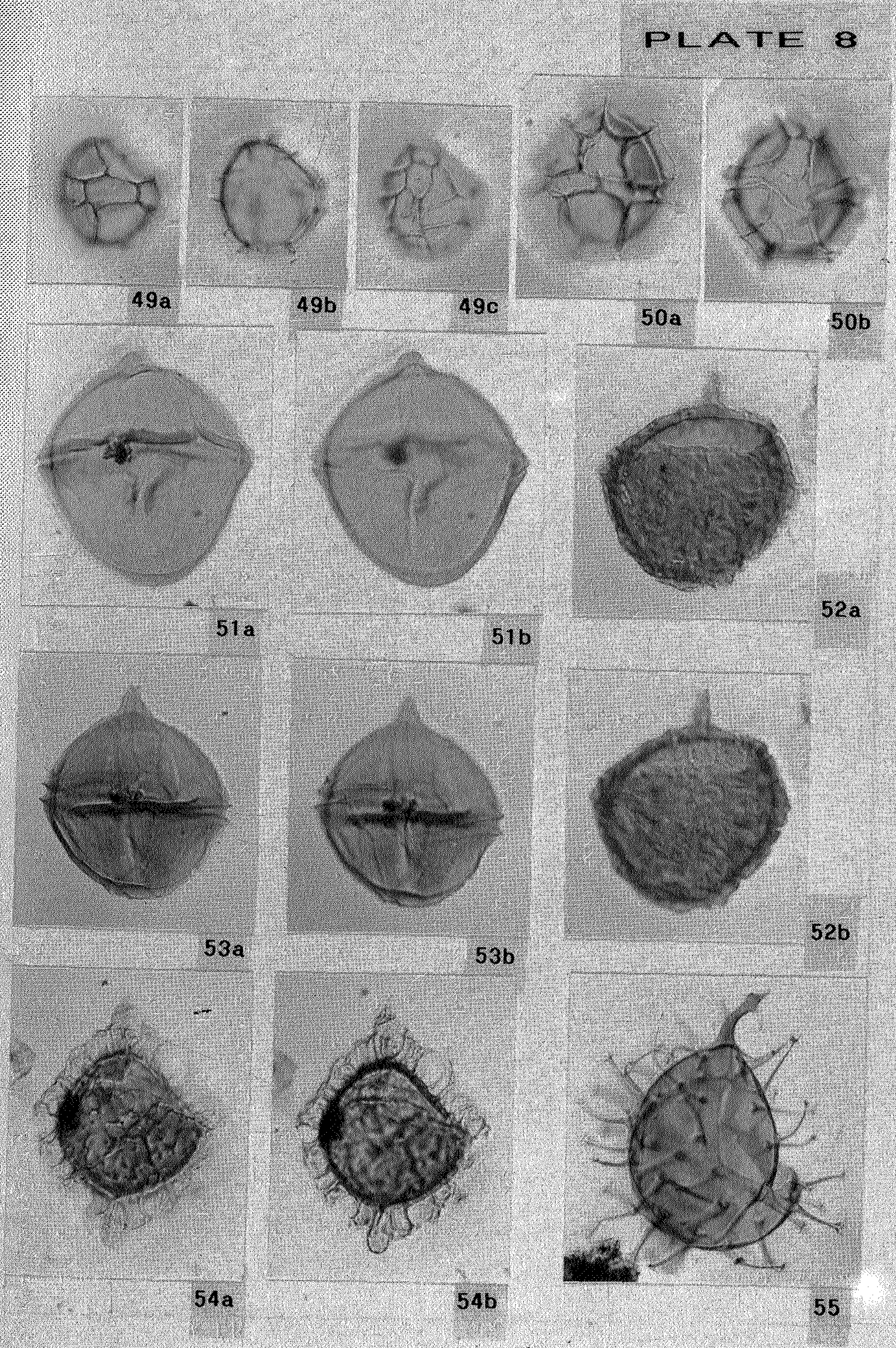

PLATE 9

Chiropteridium, Pentadinium and *Tectatodinium*

Figures

56 *Pentadinium laticinctum-taeniagerum.* 56a-b, dorsal views of dorsal surface and at mid-focus level showing operculum within cyst body, x 400.

57 *Pentadinium imaginatum.* 57a-b, apical-antapical views at two focus levels, x 400.

58 - 59 *Pentadinium lophophorum.* Apical-antapical views of two specimens, x 400.

60 *Tectatodinium pellitum.* 60a-b, left lateral views at two focus levels, x 500.

61 *Tectatodinium grande.* 61a-b, right lateral views at two focus levels, x 500.

62 *Chiropteridium mespilanum.* 62a-b, ventral views of ventral and dorsal surfaces, x 400.

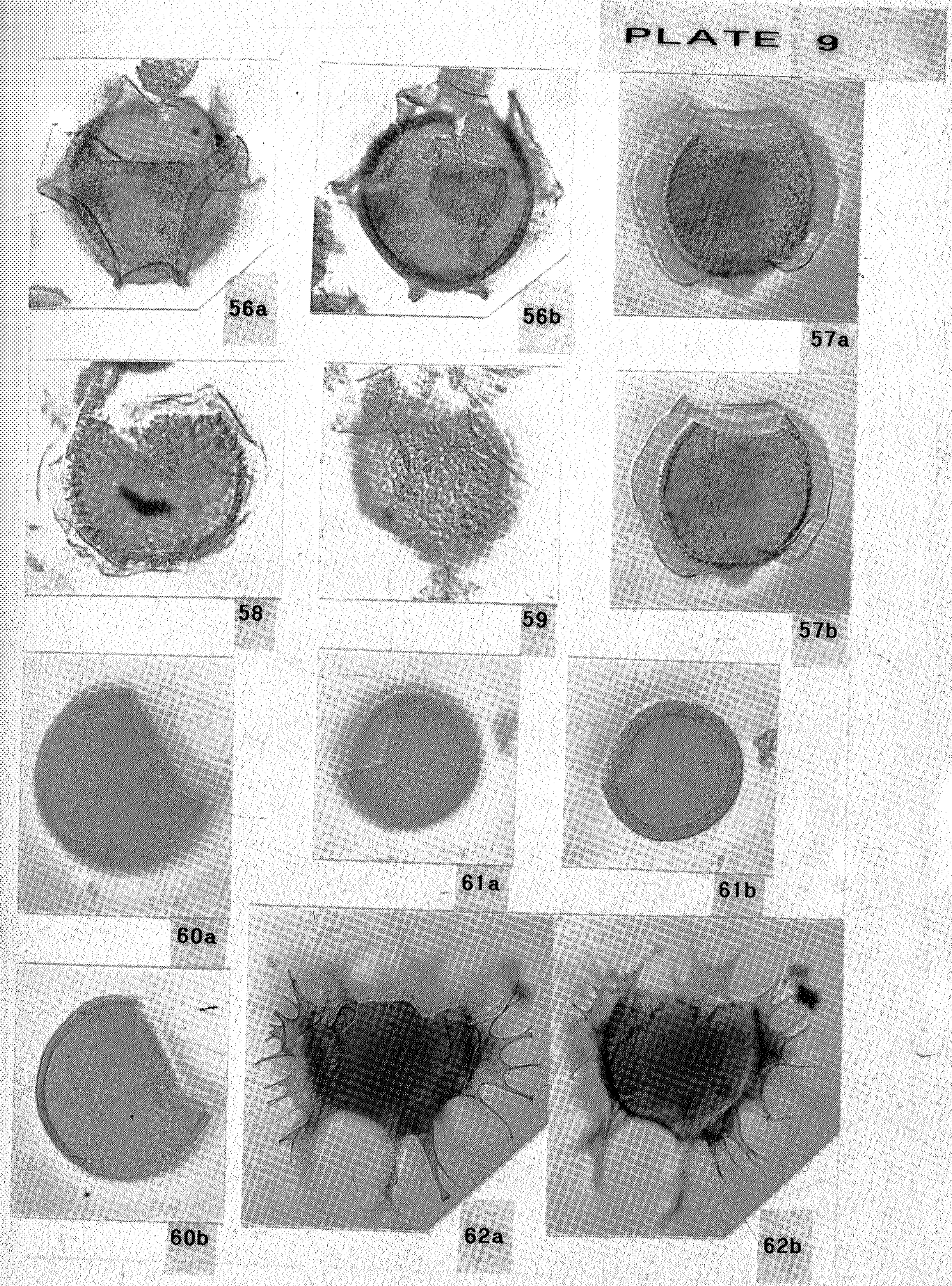

PLATE 10

Charlesdowniea, Deflandrea, Palaeocystodinium and *Phthanoperidinium*

Figures

63 *Deflandrea heterophlycta.* x 310.

64 *Deflandrea phosphoritica.* x 310.

65 *Deflandrea spinulosa.* x 310.

66 *Palaeocystodinium golzowense.* x 250.

67 *Phthanoperidinium comatum.* x 500.

68 - 69 *Phthanoperidinium filigranum.* Two speciemns at x 500.

70 - 71 *Charlesdowniea limitata sp. nov.* 70a-c, dorsal views of holotype at three successively lower focus levels, x 310. 71a-c, dorsal views of paratype at three successively lower focus levels, x 310.

PLATE 10

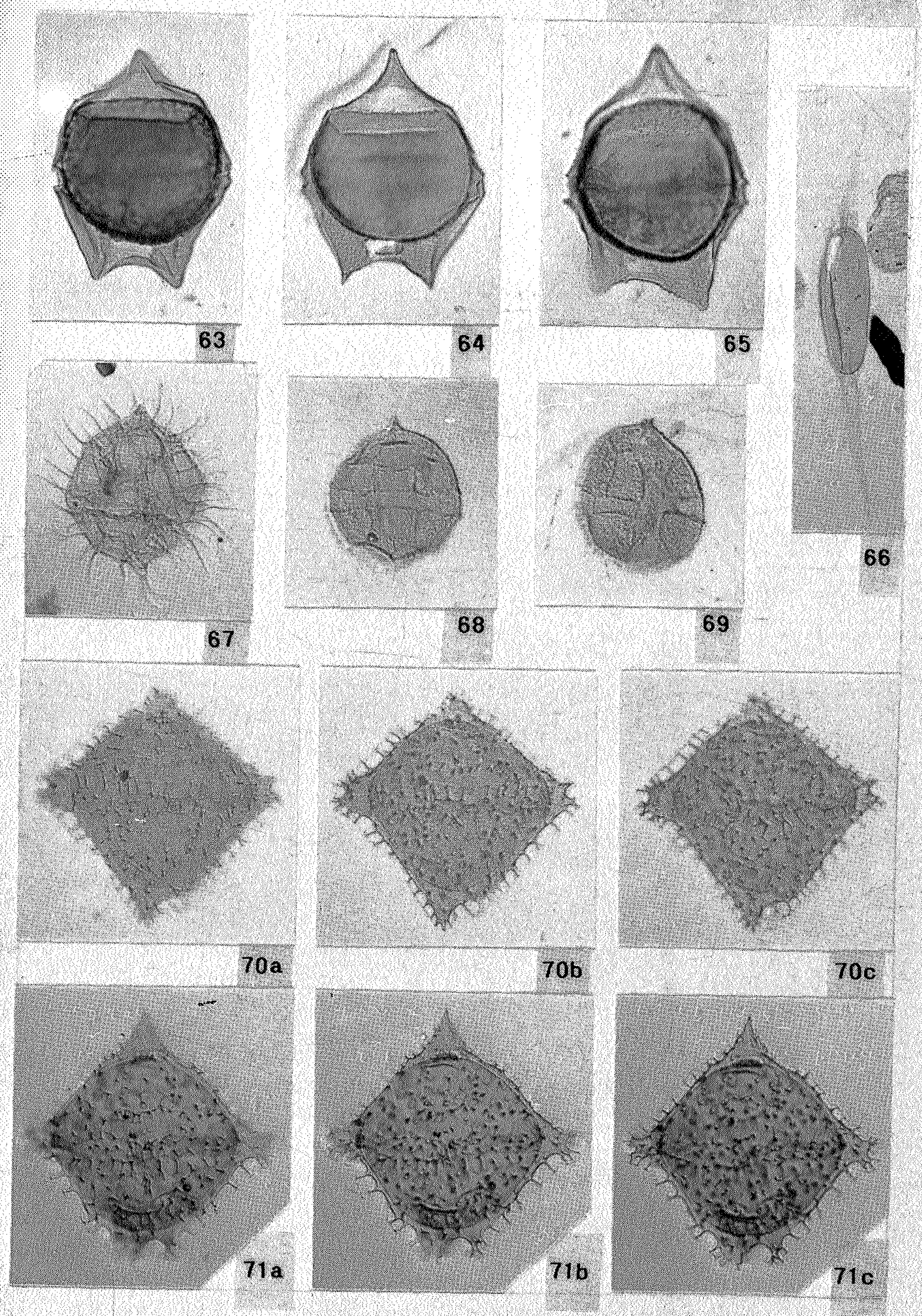

PLATE 11

Wetzeliella

Figures

72 *Wetzeliella gochtii* = *Wetzeliella symmetrica incisa.* 72a-c, ventral views at three successively lower focus levels, x 310.

73 *Wetzeliella symmetrica.* 73a-c, ventral views of transitional form between Wetzeliella symmetrica incisa and *W. symmetrica symmetrica* at three successively lower focus levels, x 310.

74 *Wetzeliella symmetrica symmetrica.* 74a-b, ventral views at two focus levels, x 310.

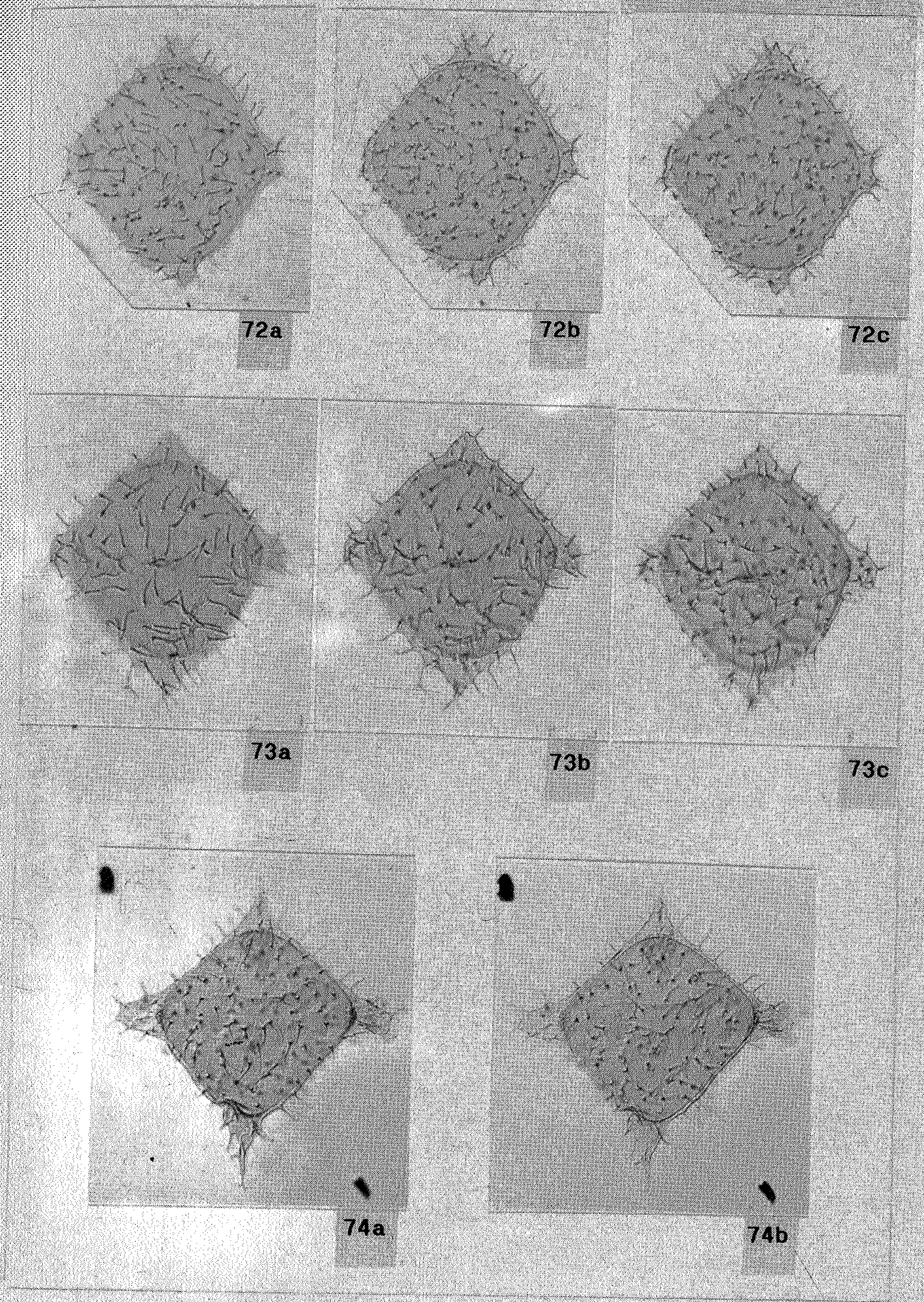

PLATE 12

Ascostomocystis, Cyclopsiella, Dinopterygium, Vozzhennikovia and *Wetzeliella*

Figures

75 *Wetzeliella articula.* Ventral view, x 310.

76 - 77 *Ascostomocystis potane.* Two specimens, x 310.

78 - 79 *Vozzhennikovia cearaichia sp. nov.* 78a-b, dorsal views of paratype at two focus levels, x 400. 79, dorsal view of holotype, x 400.

80 - 82 *Vozzhennikovia spinula sp. nov.* 80, dorsal view of holotype, x 400. 81a-b, dorsal views of paratype at two focus levels, x 400. 82a-b, ventral views of another paratype at two focus levels, x 400.

83 *Dinopterygium sp.* x 500.

84 - 85 *Cyclopsiella spp.* 84a-b, specimen with circular outline at two focus levels, x 400. 85, specimen with elliptical outline, x 400.

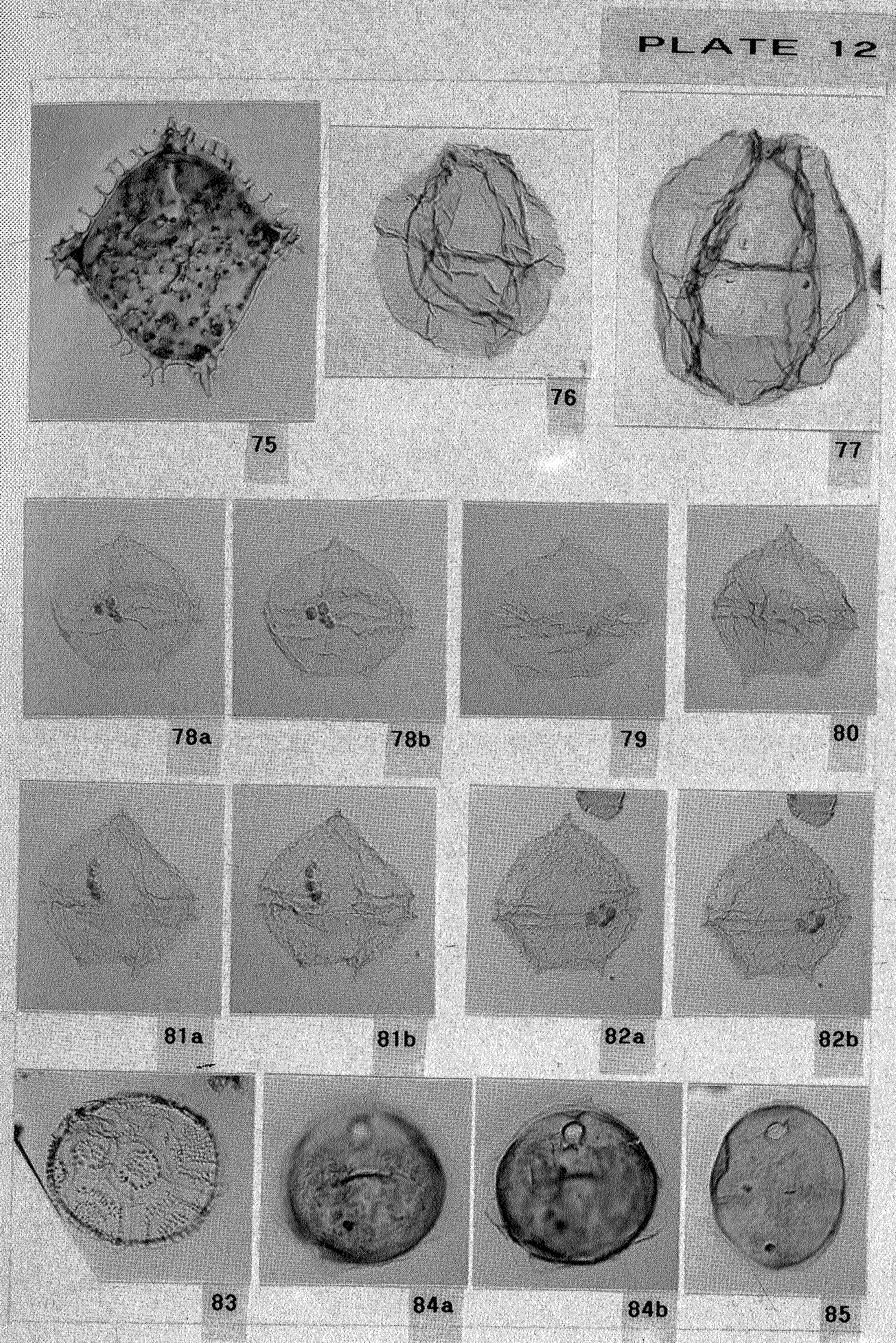

PLATE 13

Homotryblium, Impletosphaeridium and *Lingulodinium*

Figures

86 *Homotryblium tenuispinosum.* 86a-b, specimen at two focus levels, x 400.

87 *Homotyrblium pallidum.* 87a-b, specimen at two focus levels, x 400.

88 *Homotryblium vallum.* 88a-b, specimen at two focus levels, x 400.

89 *Homotryblium plectilum.* 98a-b, specimen at two focus levels, x 400.

90 *Lingulodinium machaerophorum.* x 500.

91 - 92 *Impletosphaeridium machaeroides sp. nov.* 91a-b, holotype at two focus levels, x 500. 92a-b, paratype at two focus levels, x 500.