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OF SELECTED MESOZOIC-CENOZOIC
DINOFLAGELLATE TAXA IN THE
NORTHERN HEMISPHERE**

Graham L. Williams,
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MORPHOLOGY AND STRATIGRAPHIC RANGES OF SELECTED MESOZOIC-CENOZOIC DINOFLAGELLATE TAXA IN THE NORTHERN HEMISPHERE

Abstract

Morphological and stratigraphic information for 239 fossil dinoflagellate taxa known to occur in northern hemisphere palynomorph assemblages constitute the major part of this paper. To facilitate identification the dinoflagellate entities, the species, genera, or 'complexes' are arranged in 17 groups, of which 16 are based on morphological characteristics. The remaining group contains forms that could not be assigned appropriately to one of the morphological groups. Arrangement of the individual taxa into the morphological groups enables the major characteristics of the various groups to be compared easily and the critical features of dinoflagellates within a single group to be identified readily. The total ranges of the dinoflagellate cysts, expressed in both relative and absolute ages, are compiled in three range charts. Range information is also presented in a series of summarizing appendices. Illustrative material includes line drawings for each of the 239 taxa. These drawings are organized into two sets; one set is arranged morphologically, whereas the other set is arranged stratigraphically.

Four new morphological terms are introduced and defined: standard sexiform, inclined sexiform, contiguous operculum, and disarticulated (or non-contiguous) operculum. We now consider *Meiourogon-yaulax* Sarjeant to be a junior taxonomic synonym of *Lithodinia* Eisenack 1935 emended Gocht 1975b. Accordingly, we return or attribute the species previously assigned to *Meiourogon-yaulax* to *Lithodinia*. We also reassign *Liesbergia scarburghensis* (Sarjeant 1964) Berger 1986 to *Trichodinium* Eisenack and Cookson 1960 as a new combination and describe a new species, *Tectatodinium grande*.

Résumé

En majeure partie, cet article contient l'information morphologique et stratigraphique relative à 239 taxons de Dinoflagellés fossiles dont l'existence est connue dans les assemblages de palynomorphes qui caractérisent l'hémisphère Nord. Pour faciliter leur identification, on a réparti les différents types, espèces, genres ou «complexes» de Dinoflagellés en 17 groupes, dont 16 sont basés sur des caractéristiques morphologiques. Le groupe restant contient des formes qui n'ont pu être convenablement attribuées à aucun des groupes morphologiques. La disposition des taxons individuels en ces groupes morphologiques permet de facilement comparer les principales caractéristiques des divers groupes et d'identifier clairement les détails essentiels des Dinoflagellés appartenant à un groupe donné. Les intervalles totaux des dinokystes, exprimés à la fois par des âges relatifs et par des âges absolus, ont été compilés dans trois tableaux des intervalles stratigraphiques. Cette information apparaît également sous forme résumée dans une série d'annexes. Les illustrations comprennent des dessins de chacun des 239 taxons. Ces dessins se répartissent en deux groupes; l'un organisé morphologiquement, l'autre stratigraphiquement.

Quatre nouveaux termes morphologiques ont été introduits et définis: sexiforme standard, sexiforme incliné, opercule contigu, et opercule désarticulé (ou non contigu). On considère actuellement *Meiourogon-yaulax* Sarjeant comme un synonyme taxonomique mineur de *Lithodinia* Eisenack 1935 modifié par Gocht 1975b. En conséquence, l'espèce auparavant attribuée à *Meiourogon-yaulax* est restituée à *Lithodinia*. On restitue également une nouvelle combinaison, *Liesbergia scarburghensis* (Sarjeant 1964) Berger 1986, à *Trichodinium* Eisenack et Cookson 1960 et on décrit une nouvelle espèce nommée *Tectatodinium grande*.

SUMMARY

The objectives of this paper are to document the northern hemisphere stratigraphic ranges of 239 fossil dinoflagellate taxa in the Mesozoic-Cenozoic and to provide the necessary morphological information needed to permit their easy identification. The first attempt at such a compilation was for the short course, "A Survey of Dinoflagellate Biostratigraphy". This course – presented in 1984 by Robin J. Helby, Evan J. Kidson, Lewis E. Stover and Graham L. Williams – highlighted the morphological characteristics and the stratigraphic ranges of about 300 taxa from both hemispheres. The selection of the taxa was based on their ease of recognition and identification, stratigraphic relevance, and concise knowledge of occurrences.

Subsequent to the course, the southern hemisphere stratigraphic ranges for the Mesozoic dinoflagellates were published by Helby (1987), Helby et al. (1987), Helby and Stover (1987a, 1987b) and Stover and Helby (1987a). Consequently, we have excluded southern hemisphere data in this paper. This allowed for a reduction in the number of taxa from about 300 to 239, even though we include several taxa as yet undescribed in 1984.

The 239 taxa are predominantly individual species, but 24 are undifferentiated genera (e.g. *Lejeunecysta* spp.) and 10 are 'complexes'. For undifferentiated genera no attempt has been made to recognize and name individual species, thus their stratigraphic ranges are those for the genus. A complex typically includes two or more species, but never all the species, of one genus. An example is the *Apectodinium homomorphum* complex, which includes *Apectodinium geometricum*, *A. homomorphum* and *A. sumissum*. Separation of these species is often difficult and unrewarding in view of their closely similar stratigraphic ranges.

To facilitate recognition, the individual taxa are placed into one of 16 morphological groups and a miscellaneous group; detailed discussions of these groups form the main part of the text. These morphological groups do not constitute a classification nor do they represent an attempt to unite possibly phylogenetically related forms.

Within each group are given the morphological and identifying characteristics of each taxon. There is also at least one accompanying illustration in the form of a line drawing showing those features which are diagnostic for easy recognition. The morphological groups and their salient distinguishing characteristics are:

- I. The *Batiacasphaera-Tectatodinium* Group contains relatively simple, subspherical to ellipsoidal, proximate to proximochoate cysts that rarely show paratabulation. Taxa with apical archeopyles are assigned to the *Batiacasphaera* Subgroup, which includes 9 species and 2 genera. Taxa with precingular archeopyles are assigned to the *Tectatodinium* Subgroup, which includes 15 species.

SOMMAIRE

Dans le présent article, les auteurs se proposent de décrire les intervalles stratigraphiques, dans l'hémisphère Nord, de 239 taxons de Dinoflagellés fossiles d'âge mésozoïque et cénozoïque et de fournir l'information morphologique nécessaire pour faciliter leur interprétation. Un premier essai de compilation a servi au cours intensif intitulé «A Survey of Dinoflagellate Biostratigraphy» (un examen de la biostratigraphie des Dinoflagellés). Ce cours, présenté en 1984 par Robin J. Helby, Evan J. Kidson, Lewis E. Stover et Graham L. Williams, a mis en relief les caractéristiques morphologiques et les intervalles stratigraphiques d'environ 300 taxons provenant des deux hémisphères. On a choisi les taxons en fonction de leur facilité d'identification, de leur pertinence stratigraphique et du degré de connaissance concise de leur manifestation.

Suite au cours, Helby (1987), Helby et coll. (1987), Helby et Stover (1987a, 1987b), et Stover et Helby (1987a) ont publié les intervalles stratigraphiques des Dinoflagellés d'âge mésozoïque appartenant à l'hémisphère Sud. En conséquence, on a exclu de cet article les données relatives à l'hémisphère Sud. Il a ainsi été possible de réduire le nombre de taxons d'environ 300 à 239, bien que plusieurs taxons non encore décrits en 1984 ont toutefois été inclus.

Les 239 taxons représentent surtout des espèces individuelles, mais 24 sont des genres non différenciés (p. ex. *Lejeunecysta* spp.) et 10 sont des «complexes». En ce qui concerne les genres non différenciés, on n'a pas cherché à identifier et à nommer les espèces individuelles, et par conséquent leurs intervalles stratigraphiques sont ceux des genres. Un complexe se compose typiquement d'au moins deux espèces, mais jamais de toutes les espèces d'un même genre. Il peut s'agir, par exemple, du complexe constitué par *Apectodinium homomorphum*, qui comprend *Apectodinium geometricum*, *A. homomorphum* et *A. sumissum*. Distinguer ces espèces les unes des autres est souvent un travail ingrat et difficile, étant donné qu'elles se situent dans des intervalles stratigraphiques très rapprochés.

Pour faciliter leur identification, on place les taxons individuels dans l'un de 16 groupes morphologiques et dans un groupe varié; le corps du texte contient l'étude détaillée de ces groupes. Les groupes morphologiques ne constituent ni une classification, ni un effort pour unir des formes peut-être phylogénétiquement apparentées.

Pour chaque groupe, sont présentées les caractéristiques morphologiques et celles permettant d'identifier chacun des taxons. On y joint au moins une illustration sous forme de dessin au trait mettant en évidence les détails caractéristiques qui facilitent l'identification. Les groupes morphologiques et leurs traits saillants sont les suivants:

- I. Le groupe de *Batiacasphaera-Tectatodinium* contient des dinokystes relativement simples, subsphériques à ellipsoïdaux, proximates à proximochoates, qui montrent rarement des signes de paratabulation. Les taxons comportant des archeopyles apicaux sont placés dans le sous-groupe de *Batiacasphaera*, qui comprend neuf espèces et deux genres. Les taxons comportant des archeopyles précingulaires sont placés dans le sous-groupe de *Tectatodinium*, qui comprend 15 espèces.

- II. The *Impagidinium-Gonyaulacysta* Group consists of proximate to proximochorate, subspherical to ellipsoidal cysts with precingular archeopyles; these cysts usually show some evidence of paratabulation which, when sufficiently discernible, is gonyaulacacean with a sexiform hypocystal pattern. Acavate taxa are assigned to the *Impagidinium* Subgroup, which includes 9 species and one complex. Cavate taxa are assigned to the *Gonyaulacysta* Subgroup, which includes 9 species, one complex, *Scriniodinium luridum* sensu Deflandre (1938b) and *Scriniodinium luridum* sensu Gocht (1970b).
 - III. The *Cordosphaeridium-Hystrichosphaeridium* Group comprises predominantly skolochorate, acavate cysts with intratabular, nontabular, parasutural or penitabular processes: the paratabulation, when sufficiently discernible, is gonyaulacacean. Taxa with precingular archeopyles are assigned to the *Cordosphaeridium* Subgroup, which includes 27 species and 2 genera. Taxa with apical archeopyles are assigned to the *Hystrichosphaeridium* Subgroup, which includes 24 species and one complex.
 - IV. The *Heteraulacacysta* Group consists of proximate to skolochorate cysts, which may have parasutural, intratabular or nontabular ornamentation: the archeopyles are epicystal or hemicystal and the paratabulation, when sufficiently discernible, approximates the tabulation on the modern genus *Goniodoma* Stein 1883 (*al. Triadinium* Dodge 1981), which has a quinqueform pattern on its hyposome. Seven species are assigned to this group.
 - V. The *Muderongia* Group contains proximate to proximochorate, acavate or cavate cysts, which have ceratioid outlines, apical archeopyles and offset parasulcal notches: horns may be apical, cingular/postcingular, and antapical. The group includes 8 species and 2 genera.
 - VI. The *Glaphyrocysta* Group consists of proximate, proximochorate or skolochorate, lenticular cysts with apical archeopyles and offset parasulcal notches. Ten species and one complex are assigned to this group.
 - VII. The *Deflandrea* Group includes proximate to proximochorate, commonly cavate, spheroidal to peridinioid cysts with archeopyles that invariably involve at least one middorsal intercalary paraplate and may involve all of the apical and anterior intercalary paraplates: the paratabulation, when sufficiently discernible, is peridiniacean, with the hexa-style dorsal epicystal pattern. Eleven species, 8 genera and 1 complex are assigned to this group.
 - VIII. The *Wetzeliiella* Group contains proximate to proximochorate, commonly cavate, subcircular to peridinioid cysts with monoplacoid middorsal intercalary archeopyles:
- II. Le groupe d'*Impagidinium-Gonyaulacysta* se compose de dinokystes proximates à proximochorates, subsphériques à ellipsoïdaux, avec archéopyles précingulaires; ils montrent des signes de paratabulation qui, lorsqu'ils sont suffisamment décelables, sont de type gonyaulacacéen avec motif hypokystique sexiforme. Les taxons acavates sont placés dans le sous-groupe d'*Impagidinium*, qui comprend neuf espèces et un complexe. Les taxons de type cavate sont attribués au sous-groupe de *Gonyaulacysta*, qui comprend neuf espèces, un complexe, *Scriniodinium luridum* sensu Deflandre (1938b) et *Scriniodinium luridum* sensu Gocht (1970b).
 - III. Le groupe de *Cordosphaeridium-Hystrichosphaeridium* comprend des dinokystes principalement skolochorates, acavates, comportant des processus intratabulaires, non tabulaires, parasuturaux ou pénitabulaires; la paratabulation, lorsqu'elle est suffisamment décelable, est de type gonyaulacacéen. Les taxons comportant des archéopyles précingulaires sont placés dans le sous-groupe de *Cordosphaeridium*, qui comprend 27 espèces et deux genres. Les taxons comportant des archéopyles apicaux sont placés dans le sous-groupe d'*Hystrichosphaeridium*, qui comprend 24 espèces et un complexe.
 - IV. Le groupe de *Heteraulacacysta* se compose de dinokystes proximates à skolochorates, qui peuvent avoir une ornementation parasuturale, intratabulaire ou non tabulaire; les archéopyles sont épikystiques ou hémikystiques et la paratabulation, lorsqu'elle est suffisamment décelable, s'apparente à celle du genre moderne *Goniodoma* Stein 1883 (*al. Triadinium* Dodge 1981), qui présente un motif de forme pentagonale sur son hyposome. Sept espèces sont placées dans ce groupe.
 - V. Le groupe de *Muderongia* contient des dinokystes proximates à proximochorates, acavates ou cavates, avec contours cératioïdes, archéopyles apicaux et entailles parasulcaires décalées les unes par rapport aux autres; les cornes peuvent être apicales, cingulaires ou postcingulaires, et antiapicales. Le groupe comprend huit espèces et deux genres.
 - VI. Le groupe de *Glaphyrocysta* comprend des dinokystes proximates, proximochorates ou skolochorates, lenticulaires, avec archéopyles apicaux et entailles parasulcaires décalées les unes par rapport aux autres. Dix espèces et un complexe sont placées dans ce groupe.
 - VII. Le groupe de *Deflandrea* comprend des dinokystes proximates à proximochorates, souvent cavates, sphéroïdes à péricinoïdes, avec archéopyles qui comportent invariablement au moins une paraplaque intercalaire médio-dorsale et peuvent inclure toutes les paraplaques intercalaires apicales et antérieures: la paratabulation, lorsqu'elle est suffisamment décelable, est de type périciniacéen, avec motif épikystique dorsal de style hexagonal. Onze espèces, huit genres et un complexe sont placés dans ce groupe.
 - VIII. Le groupe de *Wetzeliiella* contient des dinokystes proximates à proximochorates, souvent cavates, subcirculaires à péricinoïdes avec archéopyles médiadorsaux intercalaires

the paratabulation, when sufficiently discernible, is peridiniacean with the quadra-style dorsal epicystal pattern. Three species and 5 complexes are assigned to this group.

- IX. The *Rhaetogonyaulax* Group comprises proximate to proximochorate, subspherical, elongate or trapezoidal cysts with apical, intercalary or combined archeopyles: the paratabulation, when discernible, is neither standard gonyaulacacean nor standard peridiniacean and includes camerate precingular and bicamerate anterior intercalary paraplates. Five species and 3 genera are assigned to this group.
 - X. The *Ctenidodinium* Group includes proximate to proximochorate cysts with nontabular, intratabular or parasutural ornamentation and epicystal, combined apical and precingular or combined apical, intercalary and precingular archeopyles: the paratabulation, when sufficiently discernible, is gonyaulacacean with a sexiform hypocystal pattern. Ten species and one genus are assigned to this group.
 - XI. The *Lithodinia* Group contains proximate to proximochorate, acavate or circumcavate cysts with apical archeopyles: the paratabulation, when sufficiently determinable from the parasutural or penitabular ornamentation, is gonyaulacacean and most commonly with a sexiform hypocystal pattern. Thirteen species and one genus are assigned to this group.
 - XII. The *Microdinium* Group consists of proximate to skolochorate, paratabulate cysts, with partiform hypocystal patterns. Four species and two genera are assigned to this group.
 - XIII. The *Palaeoperidinium* Group includes proximate, cavate, subcircular to peridinioid cysts with combined archeopyles which always include precingular paraplates. When sufficiently discernible, the paratabulation is peridiniacean with the hexa-style dorsal epicystal pattern. Four species are assigned to this group.
 - XIV. The *Batioladinium* Group contains elongate, ellipsoidal cysts, which may have apical or antapical horns: the archeopyle is presumed to be apical and has a strongly inclined ventral suture. Three species are assigned to this group.
 - XV. The *Pareodinia* Group consists of elongate, ellipsoidal cysts with an apical protrusion: the archeopyle is intercalary and formed from the loss of one or more bicamerate anterior intercalary paraplates. Two species and one genus are assigned to this group.
 - XVI. The *Nannoceratopsis* Group represents species in a single genus, *Nannoceratopsis*. These species are compressed laterally and possess minute epicysts and large, elongate hypocysts: the archeopyle is a small, cingular opening. Four species are assigned to this group.
- de type monoplacoïde: la paratabulation, lorsqu'elle est suffisamment décelable, est de type péridiniacéen avec motif épikystique dorsal de style tétragonal. Trois espèces et cinq complexes sont placés dans ce groupe.
- IX. Le groupe de *Rhaetogonyaulax* comprend des dinokystes proximates à proximochorates, subsphériques, allongés ou trapézoïdaux, avec archéopyles apicaux, intercalaires ou combinés: la paratabulation, lorsqu'elle est décelable, n'est pas du type gonyaulacacéen ni du type péridiniacéen normaux, et comprend des paraplaques précingulaires à loge et des paraplaques intercalaires antérieures à double loge. Cinq espèces et trois genres sont placés dans ce groupe.
 - X. Le groupe de *Ctenidodinium* comprend des dinokystes proximates à proximochorates avec ornementation non tabulaire, intratabulaire ou parasuturale et des archéopyles épikystiques de type combiné, apical et précingulaire, ou des archéopyles de type combiné, apical, intercalaire et précingulaire: la paratabulation, lorsqu'elle est suffisamment décelable, est de type gonyaulacacéen avec motif hypokystique sexiforme. Dix espèces et un genre sont placés dans ce groupe.
 - XI. Le Groupe de *Lithodinia* contient des dinokystes proximates à proximochorates, acavates ou circumcavates, avec archéopyles apicaux: la paratabulation, lorsqu'elle se laisse suffisamment déterminer d'après l'ornementation parasuturale ou pénitabulaire, est de type gonyaulacacéen et présente le plus souvent un motif hypokystique sexiforme. Treize espèces et un genre sont placés dans ce groupe.
 - XII. Le Groupe de *Microdinium* se compose de dinokystes proximates à skolochorates, paratabulaires, avec motifs hypokystiques partiformes. Quatre espèces et deux genres sont placés dans ce groupe.
 - XIII. Le Groupe de *Paleoperidinium* comprend des dinokystes proximates, cavates, subcirculaires à péridinioïdes, avec archéopyles combinés incluant toujours des paraplaques précingulaires. Lorsqu'elle est suffisamment décelable, la paratabulation est de type péridiniacéen avec motif épikystique dorsal de style hexagonal. Quatre espèces sont placées dans ce groupe.
 - XIV. Le Groupe de *Batioladinium* contient des dinokystes ellipsoïdaux allongés, qui peuvent avoir des cornes apicales ou antapicales: l'archéopyle est sans doute apical et présente une suture ventrale fortement inclinée. Trois espèces sont placées dans ce groupe.
 - XV. Le Groupe de *Pareodinia* se compose de dinokystes ellipsoïdaux allongés avec protrusion apicale: l'archéopyle est intercalaire et formé par la perte d'une ou de plusieurs paraplaques intercalaires antérieures à double loge. Deux espèces et un genre sont placés dans ce groupe.
 - XVI. Le Groupe de *Nannoceratopsis* représente les espèces d'un seul genre, *Nannoceratopsis*. Ces espèces sont latéralement comprimées et possèdent des épikystes minuscules et de grands hypokystes allongés: l'archéopyle est une petite ouverture cingulaire. Quatre espèces sont placées dans ce groupe.

XVII. The Miscellaneous Group. Morphologically, the taxa included here cannot be assigned readily to any of the other 16 groups. These taxa are placed in one of three stratigraphic categories: Tertiary (12 species, one genus); Cretaceous (6 species, one genus); Triassic-Jurassic (7 species, one genus).

Stratigraphic ranges of the dinoflagellate cysts, expressed in both relative and absolute ages (to the nearest 1 Ma), are given in three range charts. For each chart, the species are listed alphabetically and numbered, and presented sequentially, according to their tops or youngest occurrences. A species' numbered position on a range chart is obtainable by consulting the accompanying alphabetic listing. A set of stratigraphic plates provides line drawings of the taxa ordered almost invariably according to their positions on the range charts.

Base references for the range charts were those presented in Williams and Bujak (1985) and those compiled for the 1984 Short Course, "A Survey of Dinoflagellate Biostratigraphy". Additional stratigraphic information was obtained from the 40 publications listed in the Introduction. We also provide a brief assessment of the relative quality of northern hemisphere biostratigraphic information by stages from the Pleistocene to the Norian.

The appendices present listings of the taxa contained in each morphological group (Appendix A), pertinent stratigraphic information (Appendices B-H) and a detailing of the absolute ages for the Mesozoic-Cenozoic stages (Appendix I).

It has been considered necessary to introduce four new morphological terms to satisfactorily characterize the morphology of certain taxa. These terms are: standard sexiform, inclined sexiform, contiguous operculum, and disarticulated (or non-contiguous) operculum.

Taxonomic concerns have also necessitated some changes. We now follow Gocht (1975b) and Fenton (1981) in regarding *Meiourogoniaulax* Sarjeant in Davey et al., 1966 as a taxonomic junior synonym of *Lithodinia* Eisenack 1935 emended Gocht 1975b. Within *Lithodinia* we include 32 species. These consist of: 5 species originally assigned to *Lithodinia*; 19 species originally assigned to *Meiourogoniaulax* but subsequently transferred to *Lithodinia* by other authors, and 8 species assigned to *Meiourogoniaulax* which we consider to be assignable to *Lithodinia* and that are, accordingly, transferred to that genus. The species *Lithodinia areolata* is returned to *Epilopsphaera*. Of the three remaining species of *Meiourogoniaulax*, we assign *Meiourogoniaulax cantrellii* to *Lanterna*, *Meiourogoniaulax dicrypta* to *Escharisphaeridia*, and *Meiourogoniaulax sagena* to *Ellipsoidictyum*. *Meiourogoniaulax decapitata* is treated as a taxonomic junior synonym of *Meiourogoniaulax* (now *Lithodinia*) *valensii*. We also reassign *Liesbergia scarburghensis* (Sarjeant 1964) Berger 1986 to *Trichodinium* as a new combination and describe the new species *Tectatodinium grande*.

XVII. Le Groupe varié. Morphologiquement, les taxons inclus ici ne peuvent être facilement attribués à aucun des 16 autres groupes. Ces taxons sont placés dans l'une de trois catégories stratigraphiques: Tertiaire (12 espèces, un genre); Crétacé (six espèces, un genre); Jurassique et Trias (sept espèces, un genre).

Les intervalles stratigraphiques des dinokystes, exprimés à la fois par des âges relatifs et des âges absolus (avec une précision de 1 Ma) sont présentés dans trois tableaux stratigraphiques. Dans chacun de ces tableaux, les espèces sont citées selon un ordre alphabétique et numérotées, et présentées de façon séquentielle, suivant leur occurrence la plus récente ou sommitale. On peut déterminer la position numérotée d'une espèce dans un tableau stratigraphique en consultant la liste alphabétique qui accompagne ce tableau. Un ensemble de planches stratigraphiques illustre à l'aide de dessins au trait les des taxons rangés presque invariablement selon leur position dans les tableaux stratigraphiques.

Les références de base qui ont servi à l'établissement des tableaux stratigraphiques sont les références indiquées dans Williams et Bujak (1985) et les références compilées à l'intention du cours intensif de 1984 intitulé «A Survey of Dinoflagellate Biostratigraphy». On a obtenu de l'information stratigraphique supplémentaire dans les 40 publications citées dans l'introduction. On procède également à une évaluation succincte de la qualité relative de l'information biostratigraphique relative à l'hémisphère Nord, qui porte sur tous les étages allant du Pléistocène au Norien.

Dans les annexes, figurent des listes des taxons contenus dans chaque groupe morphologique (annexe A), ainsi que l'information stratigraphique afférente (annexes B-H) et un compte rendu détaillé de l'âge absolu des étages allant du Mésozoïque au Cénozoïque (annexe I).

On a considéré comme nécessaire d'introduire quatre nouveaux termes morphologiques pour caractériser de façon satisfaisante la morphologie de certains taxons. Il s'agit des termes suivant: sexiforme normal, sexiforme incliné, opercule contigu, et opercule désarticulé (ou non contigu).

Des problèmes d'ordre taxonomique ont aussi imposé certains changements. Comme Gocht (1975b) et Fenton (1981), on considère maintenant *Meiourogoniaulax* Sarjeant dans Davey et al. 1966 comme un synonyme taxonomique mineur de *Lithodinia* Eisenack 1935 modifié par Gocht 1975b. On place dans *Lithodinia* 32 espèces. Il s'agit de cinq espèces initialement attribuées à *Lithodinia*; 19 espèces initialement attribuées à *Meiourogoniaulax* mais ensuite rapportées à *Lithodinia* par certains auteurs, et huit espèces attribuées à *Meiourogoniaulax* que l'on considère attribuables à *Lithodinia* et qui sont, en conséquence, placées dans ce genre. L'espèce *Lithodinia areolata* est replacée dans *Epilopsphaera*. Parmi les trois espèces restantes de *Meiourogoniaulax*, on attribue *Meiourogoniaulax cantrellii* à *Lanterna*, *Meiourogoniaulax dicrypta* à *Escharisphaeridia*, et *Meiourogoniaulax sagena* à *Ellipsoidictyum*. *Meiourogoniaulax decapitata* est considérée un synonyme taxonomique mineur de *Meiourogoniaulax* (maintenant *Lithodinia*) *valensii*. Enfin, on replace aussi *Liesbergia scarburghensis* (Sarjeant 1964) Berger 1986 dans *Trichodinium* en tant que nouvelle combinaison et l'on donne à la nouvelle espèce le nom de *Tectatodinium grande*.

INTRODUCTION

Our understanding of the diverse morphology of fossil dinoflagellates has advanced considerably during the last three decades. This is due in part to the comprehensive studies of such authors as Evitt (1961c, 1967, 1985), Stover and Evitt (1978), Bujak and Davies (1983), and Jan du Chêne et al. (1986a) and in part to the continually improving methods for recovering and examining palynomorphs, as well as to an enhanced appreciation for the complexity and variability of many dinoflagellate cysts.

Advances in the comprehension of dinoflagellate cyst morphology are accompanied by a concomitant growth in the utilization of fossil dinoflagellates in biostratigraphic and allied studies. Triassic to Pleistocene dinoflagellate zonation proposed through the mid-1980s are depicted and summarized in the extensive review by Williams and Bujak (1985), which also contains illustrations of many biostratigraphically important species. Recently, a trend is developing to correlate dinoflagellate zonation to the standard Late Cretaceous and Tertiary planktonic foraminiferal zones, to the Jurassic to Tertiary calcareous nannofossil zones, and to Jurassic and Cretaceous ammonite zones. Attempts are also being made to relate such zonation to an absolute time scale and to depositional sequences (Haq et al., 1987).

However, the objectives of this paper are not to present another zonation, but rather to synthesize and introduce the most recent information on the ranges of 239 dinoflagellate taxa. To a large extent, this effort is an update of a major part of the 16th Palynology Short Course presented at Baton Rouge, Louisiana, in 1984. The course, entitled "A Survey of *Dinoflagellate Biostratigraphy*", was developed and presented by Robin J. Helby, Evan J. Kidson, Lewis E. Stover and Graham L. Williams, with the encouragement and support of George F. Hart.

In the course, morphological and stratigraphic data were presented for about 300 dinoflagellate taxa from both the northern and southern hemispheres, and the ranges given for a majority of the forms were composites of data from both hemispheres. Dinoflagellate taxa selected for inclusion in the course were considered to be morphologically distinctive and readily identifiable. In addition, their stratigraphic ranges were reasonably well established and their taxonomies fairly stable. Subsequent to the course, documentation of the southern hemisphere stratigraphic data appeared in print (Helby et al., 1987) and all key taxa as well as some accessory forms were illustrated (Helby 1987, Helby et al., 1987, Helby and Stover 1987a, Stover and Helby 1987a).

Criteria for the selection of the 239 taxa discussed in this paper are essentially the same as those used for the above course. For this publication, however, the ranges of forms that occur in both hemispheres were adjusted to reflect only their northern hemisphere occurrences. Moreover, some new taxa, which were undescribed when the selections for the course material were made, have been included. And lastly, the ranges of many forms were revised on the basis of post-1984 information.

The dinoflagellate taxa discussed herein consist mostly of individual species, but some are undifferentiated genera and still others are 'complexes'. The concept of individual species requires no explanation. Undifferentiated genera, of which *Dinogymnium* spp. is one of the 24 recognized herein (see list below), comprise taxa for which no attempt was made to distinguish separate species. Use of undifferentiated genera frequently indicates that either their species are difficult to separate consistently, or that their ranges are uncertain, or both. Although the identifications or ranges of certain species may be suspect, frequently the total range of the genus can be defined quite precisely. A list of undifferentiated genera follows.

<i>Andalusiella</i> spp.	<i>Phthanoperidinium</i> spp.
<i>Dinogymnium</i> spp.	<i>Protoellipsodinium</i> spp.
<i>Druggidium</i> spp.	<i>Selenopemphix</i> spp.
<i>Hystrichodinium</i> spp.	<i>Senegalinium</i> spp.
<i>Isabelidium</i> spp.	<i>Stephanelytron</i> spp.
<i>Lanterna</i> spp.	<i>Sumatradinium</i> spp.
<i>Lanternosphaeridium</i> spp.	<i>Susadinium</i> spp.
<i>Lejeunecysta</i> spp.	<i>Sverdrupiella</i> spp.
<i>Microdinium</i> spp.	<i>Trithyrodinium</i> spp.
<i>Noricysta</i> spp.	<i>Valensiella</i> spp.
<i>Pareodinia</i> spp.	<i>Wanaea</i> spp.
<i>Parvocysta</i> spp.	<i>Xenascus</i> spp.

A 'complex' commonly involves two or more species, but not all of the species in a particular genus. An example is the *Areosphaeridium arcuatum* 'complex' which contains *A. arcuatum*, *A. pectiniforme* and *A. multicornutum*, but not *A. diktyoplokos*. In some complexes, such as the *Deflandrea phosphoritica* 'complex', the species concept is expanded by the inclusion of morphotypes (See Plate 3 (Fig. 9-11) for the three drawings depicting the complex); *Deflandrea heterophlycta* and its morphotypes are also included in the *D. phosphoritica* 'complex'. The section entitled "Morphological complexes" discusses the complexes and lists their contents.

Format

The main part of the text deals almost exclusively with the morphological groups to which the fossil dinoflagellates are assigned, be they species, genera or 'complexes'. As explained later, the morphological groups are for convenience of discussion only, and they constitute neither a classification nor an attempt to organize possibly phylogenetically related forms under a single heading. Some groups, however, may inadvertently have phylogenetic significance. To determine rapidly the morphological group to which a taxon has been assigned, consult Appendix A.

The section "Morphologic groups and illustrations" is preceded by an alphabetical listing of the taxa, including their complete citations. Stratigraphic information is presented in Appendices B through H and in three range charts (in pocket). When reference is made to stratigraphic ranges, we use the terms "top" and "base". We have adopted this terminology, rather than "first" and "last" because of the ambiguity of those terms. For example, many published zonations by

non-industry palynologists use the first (oldest) and last (youngest) occurrences of forms to define biostratigraphic zones. In contrast, nearly all zonations developed and used within industry apply only to first (youngest occurrences) or first downhole appearances to define unit tops, and rarely, if ever, employ bases (oldest occurrences) or last downhole appearances as part of a zonation because of contamination problems. Thus the meaning of "first" and "last" depends on one's approach to zonation, but more importantly, on the type of section and material being studied (surface vs. subsurface; core vs. cuttings). In our usage, top is equivalent to the youngest occurrence, which was termed the Last Appearance Datum (LAD) by Berggren and Van Couvering (1978) and base is equivalent to the oldest occurrence, which was termed the First Appearance Datum (FAD) by Berggren and Van Couvering (1978).

Appendices B, C and D report the tops and bases of each taxon in millions of years before the present (Ma). The age of a taxon's top determines its position on the range charts. Those with the youngest tops appear on the left, and taxa with successively older tops appear to the right of the previously younger taxon. Appendices E, F and G show the tops and bases that occur at specific time horizons beginning with the Recent and progressing through successive geological ages to within the Late Triassic Norian (218 Ma), usually in 1 Ma increments. We have adopted the Geologic Time Scale presented by Haq et al. (1987, see Appendix I) against which dinoflagellate ranges are plotted and relative ages are assigned. With respect to system boundaries, we place the Jurassic-Cretaceous boundary between the Portlandian and Ryazanian, i.e. within the Berriasian. Placement of other system boundaries follows conventional usage. We also recognize the Rhaetian Stage.

Line drawings, the vast majority of which were prepared especially for this publication, are included for all forms in the Alphabetic Listing of Dinoflagellate Taxa. The drawings, although based for the most part on illustrations of holotypes, may be somewhat schematic. This was done to emphasize those morphological features which best characterize a particular form. For those illustrations in which paratabulation is presented, we use the Kofoidian system of plate designation. The drawings are included in each of two sets. In the first set (Fig. 1-27) the illustrations are arranged morphologically, and are included with the descriptions of the morphological groups. The illustrations in the second set (Plates 1-14) are arranged stratigraphically and accompany the range charts.

The stratigraphic range of each taxon was determined from several sources which included both unpublished and published data. Unpublished data were supplied principally by the authors, and in some cases our information was augmented and usually substantiated by that from colleagues in academia, industry and various geological surveys. However, an appreciable amount of range data were derived from literature sources, which required considerable close scrutiny and evaluation. As a general rule, range data were not accepted unless they were accompanied by a clear, confirming illustration of the cited taxon. Literature in which only general or indefinite ages were given (e.g. Early Tertiary,

Senonian, Aptian-Albian, Middle Jurassic) was also excluded from further consideration. Conversely, heavy reliance was placed on dinoflagellate occurrence information that was dated by independent means (e.g. ammonites, calcareous nannofossils). Naturally, not everyone will agree with our selection of source material nor with the ranges presented herein, which are based to some extent on subjective considerations. We anticipate that many ranges will be modified, but hopefully not extensively, as more precise age interpretations become known. Each range chart has two headers: in the upper header the taxa are arranged alphabetically; in the lower header they are arranged according to stratigraphic position and numbered consecutively. The number assigned to each species is also given in the upper header.

Our base references for ranges were the range charts in Williams and Bujak (1985), in which a considerable amount of biostratigraphic data available prior to 1984 was synthesized, and the range charts constructed exclusively for the 1984 Short Course. Additional publications that proved especially useful in determining or confirming some of the stratigraphic ranges presented herein are cited below along with the stratigraphic intervals that they cover:

Berger (1986), Callovian-Oxfordian
Brinkhuis and Leereveld (1988), Maastrichtian-Danian
Corradini and Biffi (1988), Early Pliocene
Costa and Manum (1988), Paleocene-Miocene
Damassa (1988), Maastrichtian-Danian
Davey (1982), Portlandian-Valanginian
Davies (1985), Pliensbachian-Aalenian
Duxbury (1980), Barremian
Duxbury (1983), Aptian-Early Albian
Edwards (1984), Miocene
Harland (1979a), Thanetian-Ypresian
Harland (1982a), Quaternary
Harland and Hill (1979), Middle Miocene
Heilmann-Clausen (1985), Danian-Ypresian
Helenes (1984), Kimmeridgian-Maastrichtian
Herngreen et al. (1986), Maastrichtian
Hultberg (1985), Maastrichtian-Danian
Hultberg (1986), Maastrichtian-Danian
Islam (1983c), Ypresian
Jan du Chêne and Londeix (1988), Serravallian-Holocene
Liengjareem et al. (1980), Priabonian-Rupelian
Marheincke (1986), Maastrichtian
Marshall and Batten (1988), Cenomanian-Turonian
Matsuoka (1983), Early Miocene-Pleistocene
Michoux (1985), Ypresian-Lutetian
Powell (1986a), Chattian-Aquitania
Powell (1986b), Chattian-Serravallian
Powell (1986c), Tortonian-Messinian
Powell (1988), Aquitanian-Serravallian
Riding (1984), Aalenian
Riding (1987), Sinemurian-Kimmeridgian
Riding and Sarjeant (1985), Hettangian-Portlandian
Riding and Thomas (1988), Oxfordian-Portlandian
Riding et al. (1985), Bathonian
Riley and Fenton (1982), Callovian-Oxfordian
Singh (1983), Cenomanian

Srivastava (1984), Barremian
 Thomas and Cox (1988), Oxfordian-Kimmeridgian
 Thomsen and Heilmann-Clausen (1985), Danian-Thantian
 Tocher and Jarvis (1987), Turonian
 Woollam and Riding (1983), Rhaetian-Ryazanian

Compilations such as this normally expose both the strengths and weaknesses of the consulted source material. Our analysis revealed that detailed stratigraphic information concerning dinoflagellate ranges in the northern hemisphere varied from excellent to poor. In almost all instances, moderately well to intensely or extensively covered stratigraphic intervals result in good or excellent data. These, in turn, commonly reflect either specific interests (e.g. boundary problems, economic incentives), or the relative convenience of suitably fossiliferous sections. In some cases relatively poor and fair ratings result from a paucity or lack of information due often to the absence of appropriate sections or the prevalence of unfavorable lithologies, whereas other low ratings reflect inadequate age control or questionably identified material, or both. Given below is a brief assessment of the relative quality of northern hemisphere biostratigraphic information by series or stage from the Pleistocene to the Upper Triassic Norian.

Pleistocene, Fair; somewhat sparse and limited geographically
 Pliocene, Poor; very rare sources
 Miocene, Messinian; Poor, due largely to unfavorable lithologies
 Miocene, Tortonian; Fair, data rather limited geographically
 Miocene, Serravallian; Fair, somewhat better than for the Tortonian, but still limited geographically
 Miocene, Langhian; Very poor, possibly due to stage's short time span
 Miocene, Burdigalian; Fair, data limited geographically
 Miocene, Aquitanian; Fair to good, better and more widespread data than for the Burdigalian
 Oligocene, Chattian; Poor, may be due to unfavorable lithologies
 Oligocene, Rupelian; Fair to good, better control needed outside type area
 Eocene, Priabonian; Good
 Eocene, Bartonian; Excellent
 Eocene, Lutetian; Good to excellent
 Eocene, Ypresian; Excellent
 Paleocene, Thanetian; Poor to good, more data needed from the younger part
 Paleocene, Danian; Poor to good, more data needed from the younger part; very oldest part commonly not represented by strata
 Cretaceous, Maastrichtian; Good to excellent, generally well known because of efforts to define the Mesozoic-Cenozoic boundary; older part less well known than younger part
 Cretaceous, Campanian; Fair, definitive studies needed
 Cretaceous, Santonian; Fair, definitive studies needed
 Cretaceous, Coniacian; Fair, definitive studies needed
 Cretaceous, Turonian; Fair to good, relatively recent studies improved data base

Cretaceous, Cenomanian; Good, refinement needed at boundaries
 Cretaceous, Albian; Fair to excellent, best data is from the younger part, middle and older parts need improvement
 Cretaceous, Aptian; Fair, detailed data limited geographically
 Cretaceous, Barremian; Good
 Cretaceous, Hauterivian; Fair, detailed data limited geographically
 Cretaceous, Valanginian; Fair, detailed data limited geographically
 Cretaceous, Ryazanian; Fair to good, improved geographic coverage needed
 Jurassic, Portlandian; Poor to fair, limited data possibly due to unfavorable lithologies
 Jurassic, Kimmeridgian; Excellent
 Jurassic, Oxfordian; Excellent
 Jurassic, Callovian; Good to excellent
 Jurassic, Bathonian; Fair to good
 Jurassic, Bajocian; Poor to fair, younger part somewhat better known than older part
 Jurassic, Aalenian; Poor to fair, older part better known
 Jurassic, Toarcian; Poor to fair, limited studies
 Jurassic, Pliensbachian; Poor, due mainly to unfavorable lithologies, especially in the middle and older parts
 Jurassic, Sinemurian; Very poor, unfavorable lithologies
 Jurassic, Hettangian; Very poor, unfavorable lithologies
 Triassic, Rhaetian; Poor to fair, limited sources
 Triassic, Norian; Poor, more limited sources

New terms

Under the heading of gonyaulacoid patterns, Evitt (1985, p. 90) distinguished four hypocystal groups. One of these, which he termed sexiform, consists of an antapical paraplate (1''') surrounded by six other paraplates (ps, lp, and 3'''-6''' or 2'''-5'''). Typically, 1''' is relatively large, more or less symmetrical longitudinally, and has three long sides (two lateral and one dorsal) where 1''' contacts 3'''-5''' or 2'''-4''' and three short sides where 1''' touches ps, lp and the last postcingular paraplate. In this paper we refer to this pattern as **Standard Sexiform** (Fig. 1). The standard sexiform hypocystal pattern is exemplified by such genera as *Ctenodinium* Deflandre 1938b emended Benson 1985, *Impagidinium* Stover & Evitt 1978 and *Spiniferites* Mantell 1850 emended Sarjeant 1970.

In contrast to those genera with the standard sexiform pattern, others may have a relatively small, asymmetrical antapical paraplate, which is inclined with respect to the longitudinal axis. The right lateral side is longer than either the left lateral or dorsal sides and the contact between 1''' and the last postcingular paraplate is appreciably closer to the paracingulum than the 1'''/lp contact. We name this hypocystal pattern **Inclined Sexiform** (Fig. 2). The inclined sexiform pattern is present on such genera as *Cribroperidinium* Neale & Sarjeant 1962 emended Helenes 1984 and *Occisucysta* Gímez 1970 emended Jan du Chêne et al., 1986b.

In describing opercula, we use the terms Monoplacoid, Diplacoid, Triplacoid, Tetraplacoid and Polyplacoid for opercula consisting of one, two, three, four and more than

four paraplates, respectively. Monoplacoid and polyplacoid were terms used by Evitt (1985, p.124) as was biplacoid. From his figure 6.2 (*ibid.*) however, we conclude that Evitt regarded biplacoid as subordinate to polyplacoid. It is important to record not only the number of paraplates and the series to which they belong, but also whether the constituent paraplates remain together or become separated in multiparaplate opercula. When paraplates fail to disassociate, as is the case of many genera with apical opercula, the term **Contiguous Opercula** is applied; when the paraplates separate, the terms **Non-contiguous** or **Disarticulated Opercula** are used. Thus, the operculum of *Luxadinium* Brideaux & McIntyre 1975, which is a single opercular piece composed of six paraplates, is polyplacoid and contiguous. The operculum of *Trithyrodinium* Drugg 1967, which usually consists of three separated paraplates, is triplacoid and non-contiguous. In *Homotryblum*, Davey and Williams in Davey et al. 1966, the operculum is polyplacoid (10 paraplates), in part contiguous (3 paraplates remain together as an opercular piece), and in part disarticulated (7 individually separated paraplates).

The term "haplotabular" (Downie and Sarjeant in Davey et al., 1966, p.14) was proposed for apical archeopyles presumably formed by the release of a single paraplate. Monoplacoid applies more generally to single-paraplate opercula, regardless of archeopyle type. Downie and Sarjeant (*ibid.*) also introduced the term "tetratabular" for an apical archeopyle with four paraplates. We recommend suppression of tetratabular and replacement by the more encompassing term, tetraplacoid.

Acknowledgments

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The authors are indebted to all who attended the Sixteenth Palynology Short Course, "A Survey of Dinoflagellate Biostratigraphy", held at Baton Rouge, Louisiana in 1984. The discussions and interactions with those in the course were invaluable in helping us to better circumscribe the key taxa and to delimit their stratigraphic ranges. In 1989, L.E. Stover conducted an informal, revised version of the 1984 course at Exxon Production Research Company, Houston, Texas, for which new plates were prepared. These plates consisted almost exclusively of modified line drawings of those used in 1984, together with numerous new ones. The participants (Y.Y. Chen, M.B. Farley, A. Jameossanie and M. Rueda) pointed out some inaccuracies as well as inconsistencies among the drawings. Their astute observations contributed in no small measure to the accuracy and fidelity of the drawings contained herein.

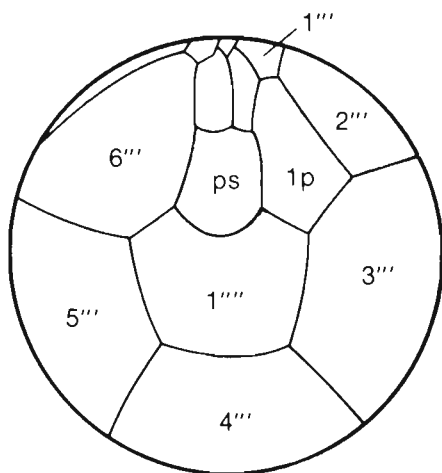


Figure 1. Standard sexiform antapical pattern. After Evitt (1985, Fig. 5.9C)

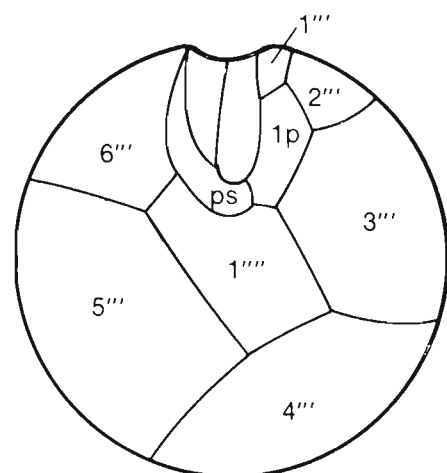


Figure 2. Inclined sexiform antapical pattern. After Evitt (1985, Fig. 10.9J)

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Special acknowledgment

It is with pleasure that we, the authors of this publication, acknowledge the contributions to palynology of Dr. George F. Hart. In this regard, we do not refer so much to his scientific activities within the aegis of Louisiana State University (LSU), with which he has been associated for more than 25 years, nor to his more than 50 scientific publications. Rather, we refer to his successful efforts, dating back to 1968, towards fostering palynology and making available to his students and colleagues, the latest developments in palynology and allied paleontological disciplines.

It was largely through George's efforts that the First Annual Meeting of the American Association of Stratigraphic Palynologists (AASP) was held at Baton Rouge, Louisiana in 1968. In the next few years, as a member of the AASP Publications Committee, George was instrumental in arranging for the LSU journal, *Geoscience and Man*, to be the vehicle for the publication of the AASP's annual proceedings. Thus, during the formative and very tenuous years of AASP, George's devotion and endeavors contributed significantly to its eventual success.

However, his greatest enterprise, and perhaps that for which he will be remembered most by the palynological community, is the LSU Palynology Short Course Series. These courses, presented between 1968 and 1985, offered palynologists the opportunity to become familiar with the most recent developments in various aspects of palynology. In all, 16 such courses were offered (14 on palynomorphs and one each on calcareous nannofossils and diatoms). It is to George's credit that he recognized early the need for such courses, undertook their organization and provided the media for their presentation. The practical nature of the courses and the immediate application of the material presented were factors which contributed to the success of the series.

ALPHABETIC LISTING OF DINOFLAGELLATE TAXA

** = Name and/or citation differs from that in Lentin and Williams, 1989

A

- Achilleodinium biformoides* (Eisenack 1954) Eaton 1976.
Achomosphaera alaicornu (Eisenack 1954) Davey & Williams *in* Davey et al., 1966.
Achomosphaera andalousiensis Jan du Chêne 1977 emended Jan du Chêne & Londeix 1988.
Achomosphaera? neptuni (Eisenack 1958) Davey & Williams *in* Davey et al., 1966.
Adnatosphaeridium multispinosum Williams & Downie *in* Davey et al., 1966.
Aldorfia aldorfensis (Gocht 1970b) Stover & Evitt 1978.
Aldorfia deflandrei (Clarke & Verdier 1967) Stover & Evitt 1978.**
Alisocysta circumtabulata (Drugg 1967) Stover & Evitt 1978.
Alisocysta margarita (Harland 1979a) Harland 1979a.
Alisocysta reticulata Damassa 1979.
Amiculosphaera umbracula Harland 1979b.
Andalusiella Riegel 1974 emended Riegel & Sarjeant 1982; treated herein as *Andalusiella* spp.
Angustidinium acribes (Davey & Verdier 1971) Goodman & Evitt 1981 emended.
Apectodinium augustum (Harland 1979c) Lentin & Williams 1981.
Apectodinium homomorphum (Deflandre & Cookson 1955) Lentin & Williams 1977b; treated herein as a complex.
Aprobolocysta eilema Duxbury 1977.
Apteodinium australiense (Deflandre & Cookson 1955) Williams 1978.
Apteodinium granulatum Eisenack 1958 emended Lucas-Clark 1987.
Apteodinium spiridoides Benedek 1972.
Apteodinium syzygium (Dörhöfer & Davies 1980) Stover & Williams 1987.
Areoligera? semicirculata (Morgenroth 1966b) Stover & Evitt 1978. [provisional generic assignment introduced herein.]
Areoligera senonensis Lejeune-Carpentier 1938.
Areosphaeridium arcuatum Eaton 1971; treated herein as a complex.
Areosphaeridium diktyoplopus (Klumpp 1953) Eaton 1971.

B

- Batiacasphaera compta* Drugg 1970.
Batiacasphaera micropapillata Stover 1977.
Batiacasphaera sphaerica Stover 1977.
Batioladinium longicornutum (Alberti 1961) Brideaux 1975.
Batioladinium micropodum (Eisenack & Cookson 1960) Brideaux 1975.

Bejuia polygonalis (Beju 1983) Stover & Williams 1987.
Biconidinium longissimum Islam 1983.
Biorbifera johnewingii Habib 1972
Bitectatodinium tepikiense Wilson 1973.

C

Caligodinium amiculum Drugg 1970.
Callaiosphaeridium asymmetricum (Deflandre & Courteville 1939) Davey & Williams *in* Davey et al., 1966.
Cannosphaeropsis utinensis O. Wetzel 1933b emended Sarjeant 1985.
Carpatella cornuta Grigorovich 1969 emended Damassa 1988.**
Carpathodinium predae (Beju 1971) Drugg 1978.
Cassiculosphaeridia magna Davey 1974.
Cauca parva (Alberti 1961) Davey & Verdier 1971.
Cerbia tabulata (Davey & Verdier 1974) Below 1981.
Cerodinium diebelii (Alberti 1959) Lentin & Williams 1987.
Cerodinium speciosum (Alberti 1959) Lentin & Williams 1987.
Chatangiella ditissima (McIntyre 1975) Lentin & Williams 1976.
Chatangiella verrucosa (Manum 1963) Lentin & Williams 1976.
Chichaouadinium vestitum (Brideaux 1971) Bujak & Davies 1983.
Chiropteridium mespilum (Maier 1959) Lentin & Williams 1973; treated herein as a complex.
Chlamydophorella ambigua (Deflandre 1937) Stover & Helby 1987b.**
Circulodinium distinctum (Deflandre & Cookson 1955) Jansonius 1986.
Cladopyxidium saeptum (Morgenroth 1968) Stover & Evitt 1978.
Compositosphaeridium polonicum (Gorka 1965) Erkmen & Sarjeant 1980.
Conneximura fimbriata (Morgenroth 1968) May 1980.
Cordosphaeridium cantharellum (Brosius 1963) Gocht 1969.
Cordosphaeridium fibrospinosum Davey & Williams *in* Davey et al., 1966.
Cordosphaeridium funiculatum Morgenroth 1966a.
Cordosphaeridium gracile (Eisenack 1954) Davey & Williams *in* Davey et al., 1966.
Coronifera oceanica Cookson & Eisenack 1958 emended May 1980.
Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978.
Cribroperidinium edwardsii (Cookson & Eisenack 1958) Davey 1969a; treated herein as a complex.
Cribroperidinium tenuitabulatum (Gerlach 1961) Helenes 1984.
Ctenidodinium continuum Gocht 1970b.
Ctenidodinium elegantulum Millioud 1969 emended Below 1981.
Ctenidodinium ornatum (Eisenack 1935) Deflandre 1938b.

D

Danea californica (Drugg 1967) Stover & Evitt 1978.
Dapcodinium priscum Evitt 1961a emended Below 1987a.
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al., 1980.
Deflandrea oebisfeldensis Alberti 1959.
Deflandrea phosphoritica Eisenack 1938; treated herein as a complex.
Dichadogonyaulax culmula (Norris 1965) Loeblich & Loeblich 1968.
Dichadogonyaulax? panneae (Norris 1965) emended Sarjeant *in* Davey et al., 1969.
Dinogymnium Evitt et al., 1967; treated herein as *Dinogymnium* spp.
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965 emended Goodman & Witmer 1985.
Discorsia nanna (Davey 1974) Duxbury 1977 emended Khowaja-Ateequzzaman et al., 1985.
Distatodinium paradoxum (Brosius 1963) Eaton 1976.
Dracodinium condylos (Williams & Downie *in* Davey et al., 1966) Costa & Downie 1979.
Druggidium Habib 1973 emended Harding 1986; treated herein as *Druggidium* spp.

E

Eatonicysta ursulae (Morgenroth 1966a) Stover & Evitt 1978.
Egmontodinium expiratum Davey 1982.
Egmontodinium polyplacophorum Gitmez & Sarjeant 1972.
Egmontodinium torynum (Cookson & Eisenack 1960b) Davey, 1979b.
Ellipsoidictyum cinctum Klement 1960.
Eocladopyxis peniculata Morgenroth 1966a.
Epelidosphaeridia spinosa (Cookson & Hughes 1964) Davey 1969a.
Evittosphaerula paratabulata Manum 1979.
Eyachia prisca Gocht 1979.

F

Fibrocysta axialis (Eisenack 1965) Stover & Evitt 1978.
Filisphaera filifera Bujak 1984.
Florentinia cooksoniae (Singh 1971) Duxbury 1980.
Florentinia mantellii (Davey & Williams *in* Davey et al., 1966) Davey & Verdier 1973.

G

Gardodinium trabeculosum (Gocht 1959) Alberti 1961.
Geiselodinium inaffectum Drugg 1978.**
Glaphyrocysta exuberans (Deflandre & Cookson 1955) Stover & Evitt 1978 emended Sarjeant 1986.

Glaphyrocysta ordinata (Williams & Downie *in* Davey et al., 1966) Stover & Evitt 1978.
Glossodinium dimorphum Ioannides et al., 1977.
Gochteodinia mutabilis (Riley *in* Fisher & Riley 1980) Davey 1982.
Gochteodinia villosa (Vozzhennikova 1967) Norris 1978.
Gonyaulacysta cassidata (Eisenack & Cookson 1960) Sarjeant *in* Davey et al., 1966; treated herein as a complex.
Gonyaulacysta eisenackii (Deflandre 1938b) Dodekova 1967 emended Sarjeant 1982.
Gonyaulacysta jurassica (Deflandre 1938b) Norris & Sarjeant 1965 emended Sarjeant 1982.

H

Hebecysta brevicornuta Bujak & Fisher 1976.
Heteraulacacysta porosa Bujak *in* Bujak et al., 1980.
Heterosphaeridium difficile (Manum & Cookson 1964) Ioannides 1986.
Homotryblium plectilum Drugg & Loeblich 1967.
Homotryblium tenuispinosum Davey & Williams *in* Davey et al., 1966.
Homotryblium vallum Stover 1977.
Hystrichodinium Deflandre 1935 emended Clarke & Verdier 1967; treated herein as *Hystrichodinium* spp.
Hystrichokolpoma bulbosum (Ehrenberg 1838) Morgenroth 1968 emended.
Hystrichokolpoma cinctum s.l. Klumpp 1953.
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955.
Hystrichosphaeridium salpingophorum Deflandre 1935 emended Davey & Williams *in* Davey et al., 1966.
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams *in* Davey et al., 1966.
Hystrichosphaerina schindewolfii Alberti 1961.
Hystrichosphaeropsis obscura Habib 1972.
Hystrichosphaeropsis ovum Deflandre 1935.

I

Impagidinium aquaeductum (Piasecki 1980) Lentin & Williams 1985.
Impagidinium dispertitum (Cookson & Eisenack 1965a) Stover & Evitt 1978.
Impagidinium patulum (Wall 1967) Stover & Evitt 1978.
Invertocysta tabulata Edwards 1984.
Isabelidinium Lentin & Williams 1977a; treated herein as *Isabelidinium* spp.

J-K

Kiokansium williamsii Singh 1983.
Kisselovia coleothrypta (Williams & Downie *in* Davey et al., 1966) Lentin & Williams 1976; treated herein as a complex.
Kleithriasphaeridium loffrense Davey & Verdier 1976.

L

Labyrinthodinium truncatum Piasecki 1980.
Laciniadinium arcticum (Manum & Cookson 1864) Lentin & Williams 1980.**
Lanterna Dodekova 1969 emended Courtinat 1989; treated herein as *Lanterna* spp.**
Laternosphaeridium Morgenroth 1966a emended Stover & Evitt 1978; treated herein as *Laternosphaeridium* spp.
Leberidocysta chlamydata (Cookson & Eisenack 1962) Stover & Evitt 1978.
Lejeunecysta Artzner & Dörhöfer 1978 emended Bujak *in* Bujak et al., 1980; treated herein as *Lejeunecysta* spp.
Lentinia serrata Bujak *in* Bujak et al., 1980.
Liasidium variabile Drugg 1978.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967.
Lithodinia deflandrei (Sarjeant 1968) Gocht 1975.**
Lithodinia jurassica Eisenack 1935 emended Gocht 1975.
Lithodinia stoveri (Millioud 1969) new combination, this publication.**
Litosphaeridium arundum (Eisenack & Cookson 1960) Davey 1979a emended Lucas-Clark 1984.
Litosphaeridium siphoniphorum (Cookson & Eisenack 1958) Davey & Williams *in* Davey et al., 1966 emended Lucas-Clark 1984.
Luehndea spinosa Morgenroth 1970.
Luxadinium propatulum Brideaux & McIntyre 1975.

M

Mancodinium semitabulatum Morgenroth 1970 emended Below 1987b.
Manumiella? cretacea (Cookson 1956) Bujak & Davies 1983.
Melitasphaeridium choanophorum (Deflandre & Cookson 1955) Harland & Hill 1979.
Melitasphaeridium pseudorecurvatum (Morgenroth 1966a) Bujak et al., 1980.
Membranophoridium aspinatum Gerlach 1961 *ex* Gocht 1969.
Microdinium Cookson & Eisenack 1960a emended Stover & Evitt 1978; treated herein as *Microdinium* spp.
Moesiodinium raileanui Antonescu 1974.
Muderongia simplex Alberti 1961.
Muderongia tetracantha (Gocht 1957) Alberti 1961.
Muratodinium fimbriatum (Cookson & Eisenack 1967) Drugg 1970.

N

Nannoceratopsis gracilis Alberti 1961 emended Evitt 1962.
Nannoceratopsis pellucida Deflandre 1938a emended Evitt 1961b.
Nannoceratopsis senex van Helden 1977.
Nannoceratopsis tricerias Drugg 1978.
Nelchinopsis kostromiensis (Vozzhennikova 1967) Wiggins 1972.

Nematosphaeropsis lemniscata Bujak 1984 emended Wrenn 1988.

Noricysta Bujak & Fisher 1976 emended Dörhöfer & Davies 1980; treated herein as *Noricysta* spp.

O

Occisucysta balios Gitmez 1970 emended Jan du Chêne 1986.

Odontochitina costata Alberti 1961 emended Clarke & Verdier 1967.

Odontochitina operculata (O. Wetzel 1933a) Deflandre & Cookson 1955.

Odontochitina porifera Cookson 1956.

Oligosphaeridium complex (White 1842) Davey & Williams in Davey et al., 1966.

Oligosphaeridium patulum Riding & Thomas 1988.

Operculodinium divergens (Eisenack 1954) Stover & Evitt 1978.

Ovoidinium cinctum (Cookson & Eisenack 1958) Davey 1970.

Ovoidinium verrucosum (Cookson & Hughes 1964) Davey 1970.

P

Palaeocystodinium golzowense Alberti 1961.

Palaeohystrichophora infusorioides Deflandre 1935.

Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967.

Palynodinium grallator Gocht 1970a.

Pareodinia Deflandre 1947 emended Stover & Evitt 1978; treated herein as *Pareodinia* spp.

Parvocysta Bjaerke 1980; treated herein as *Parvocysta* spp.

Pentadinium laticinctum Gerlach 1961 emended Benedek et al., 1982.

Pervosphaeridium? truncigerum (Deflandre 1937) Yun 1981.

Phallocysta eumekes Dörhöfer & Davies 1980 emended Below 1987a.

Phoberocysta neocomica (Gocht 1957) Millioud 1969 emended Helby 1987.

Phthanoperidinium Drugg & Loeblich 1967 emended Edwards & Bebout 1981; treated herein as *Phthanoperidinium* spp.

Polysphaeridium congregatum (Stover 1977) Bujak et al., 1980.

Polysphaeridium zoharyi (Rossignol 1962) Bujak et al., 1980.

Prolixosphaeridium parvispinum (Deflandre 1937) Davey et al., 1969.

Protoellipsodinium Davey & Verdier 1971; treated herein as *Protoellipsodinium* spp.

Psaligonyaulax deflandrei Sarjeant in Davey et al., 1966. emended Sarjeant 1982.

Pseudoceratium pelliferum Gocht 1957.**

Pseudoceratium polymorphum (Eisenack 1958) Bint 1986.

Q-R

Reticulatosphaera actinocoronata (Benedek 1972) Bujak & Matsuoka 1986.

Reutlingia gochtii Drugg 1978 emended Below 1987a.

Rhaetogonyaulax rhaetica (Sarjeant 1963) Loeblich & Loeblich 1968 emended Below 1987a.

Rhombodinium draco Gocht 1955.

Rhombodinium porosum Bujak 1979; treated herein as a complex.

Rhynchodiniopsis cladophora (Deflandre 1938b) Below 1981.

Rhynchodiniopsis? regalis (Gocht 1970b) Jan du Chêne et al., 1985.

Rigaudella aemula (Deflandre 1938b) Below 1982.

S

Samlandia chlamydophora Eisenack 1954.

Scrinocassis dictyotus (Cookson & Eisenack 1969) Beju 1971.**

Scrinocassis weberi Gocht 1964.

Scriniodinium? campanula (Gocht 1959) Stover & Evitt 1978.**

Scriniodinium crystallinum (Deflandre 1938b) Klement 1960.

Scriniodinium luridum (Deflandre 1938b) Klement 1960 sensu Deflandre 1938b.**

Scriniodinium luridum (Deflandre 1938b) Klement 1960 sensu Gocht 1970b.**

Selenopemphix Benedek 1972 emended Bujak in Bujak et al., 1980; treated herein as *Selenopemphix* spp.

Senegalinium Jain & Millepied 1973 emended Stover & Evitt 1978; treated herein as *Senegalinium* spp.

Senoniasphaera inornata (Drugg 1970) Stover & Evitt 1978.

Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976.

Sirmiodiniopsis orbis Drugg 1978.

Sirmiodinium grossii Alberti 1961 emended Warren 1973.

Spiniferites ellipsoideus Matsuoka 1983.

Spiniferites elongatus Reid 1974.

Spiniferites mirabilis (Rossignol 1964) Sarjeant 1970.

Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 emended Sarjeant 1981.

Spiniferites septatus (Cookson & Eisenack 1967) McLean 1971.

Spiniferites splendidus Harland 1979b

Spongodinium delitiense (Ehrenberg 1838) Deflandre 1936b emended Lucas-Clarke 1987.

Stephanelytron Sarjeant 1961 emended Stover et al., 1977; treated herein as *Stephanelytron* spp.

Stiphodinium coronatum Deflandre 1936a.

Stiphrosphaeridium anthophorum (Cookson & Eisenack 1958) Davey 1982.

Suessia swabiana Morbey 1975 emended Below 1987a.

Sumatradinium Lentin & Williams 1976; treated herein as *Sumatradinium* spp.

Surculosphaeridium? longifurcatum (Firtion 1952) Davey et al., 1966.

Susadinium Dörhöfer & Davies 1980; treated herein as *Susadinium* spp.
Sverdrupiella Bujak & Fisher 1976; treated as *Sverdrupiella* spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al., 1966 emended May 1980.

T

Tanyosphaeridium variecalamus Davey & Williams in Davey et al., 1966.
Tectatodinium grande new species, this publication.
Thalassiphora patula (Williams & Downie in Davey et al., 1966) Stover & Evitt 1978.
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960 emended Benedek & Gocht 1981.
Triblastula utinensis O. Wetzel 1933b emended Sarjeant 1985b.
Trichodinium castanea (Deflandre 1935) Clarke & Verdier 1967.
Trichodinium scarburghense (Sarjeant 1964) new combination, this publication.**
Trinovantedinium capitatum Reid 1977.
Trithyrodinium Drugg 1967 emended Lentini & Williams 1976; treated herein as *Trithyrodinium* spp.
Tuberculodinium vancampoe (Rossignol 1962) Wall 1967.
Tubotuberella apatela (Cookson & Eisenack 1960b) Ioannides et al., 1977 emended Sarjeant 1982.

U-V

Valensiella Eisenack 1963 emended Courtinat 1989; treated herein as *Valensiella* spp.
Valvaeodinium lineatum (Wille & Gocht 1979) Below 1987b.
Valvaeodinium punctatum (Wille & Gocht 1979) Below 1987b.
Vesperopsis Bint 1986; treated herein as *Vesperopsis* spp.

W

Wanaea Cookson & Eisenack 1958 emended Fensome 1981; treated herein as *Wanaea* spp.
Wetzeliella articulata Eisenack 1938; treated herein as a complex.
W. symmetrica Weiler 1956; treated herein as a complex.

X-Y-Z

Xenascus Cookson & Eisenack 1969 emended Stover & Helby 1987a; treated herein as *Xenascus* spp.
Xiphophoridium alatum (Cookson & Eisenack 1962) Sarjeant in Davey et al., 1966.

MORPHOLOGICAL GROUPS AND ILLUSTRATIONS

Introduction

The 239 taxa for which we offer stratigraphic data are distributed among 16 morphological groups (Groups I to XVI) and one miscellaneous group (Group XVII). For each of the morphological groups a summary of its diagnostic features is given under the heading Group Characteristics; also provided are lists of the included taxa together with guides to the identification of the forms and occasional comments. Groups I, II and III are divided into subgroups. Group XVII contains a heterogeneous assortment of forms which lack morphological continuity. For ease of presentation, this group is subdivided according to the ages of its constituent species into Triassic-Jurassic, Cretaceous and Cenozoic subgroups.

Arrangement of the taxa into morphological groups facilitates comparison of the major characteristics of the different groups and also enables the commonalities, similarities and minor differences among taxa in the same group to be readily identified. The groups were organized without a concerted regard to possible phylogenetic relationships. Should one or more groups reflect or demonstrate phylogenetic relationships, they do so inadvertently. In a broad sense, Groups I to IV, VI, and X to XII contain forms that most palynologists would regard as gonyaulacacean; similarly, Groups VII, VIII and XIII consist of forms commonly interpreted as peridiniacean, whereas Group XVI includes species that Fensome et al. (1990) place in the order Nannoceratopsiales.

Group I: BATIACASPHAERA / TECTATODINIUM and allied forms

Group characteristics

Cysts are proximate to proximochorate, body generally subspherical, less commonly ellipsoidal, acavate or holocavate, with or without an apical horn and a single antapical horn. External surface of acavate forms is smooth, reticulate, or ornamented with features of low relief; holocavate forms have hollow and/or solid projections that may be nontabular or arranged mostly in rows. Body may be enclosed by a kalyptra; hypocyst may have one or more coronas. Archeopyle is apical or precingular. Paratabulation indicated usually by the archeopyle alone, by the archeopyle and paracingulum, rarely by parasutural or penitabular features.

Subdivision

Group I is divided into two subgroups. One, the *BATIACASPHAERA* subgroup (Fig. 3), comprises forms with apical archeopyles whose opercula are typically tetraplacoid and contiguous, rarely otherwise. Species in the *BATIACASPHAERA* subgroup are:

Batiacasphaera compta Drugg 1970

Batiacasphaera micropapillata Stover 1977
Batiacasphaera sphaerica Stover 1977
Caligodinium amiculum Drugg 1970 -- We concur with Lentin and Williams (1989, p. 44) that the holotypes need to be studied before *Caligodinium aceras* (Manum & Cookson 1964) Lentin & Williams 1973 can be declared the senior nomenclatural synonym of *C. amiculum*.
Cassiculosphaeridia magna Davey 1974
Chlamydophorella ambigua (Deflandre 1937) Stover & Helby 1987b -- We regard this species as a dinoflagellate cyst rather than an acritarch (see Lentin and Williams 1989, p. 59).
Ellipsoidictyum cinctum Klement 1960
Gardodinium trabeculosum (Gocht 1959) Alberti 1961
Labyrinthodinium truncatum Piasecki 1980
Stephanellytron spp.
Valensiella spp.

The other subgroup, the *TECTATODINIUM* subgroup (Fig. 4), consists of forms with precingular archeopyles. Their opercula are generally middorsal and monoplacoid, although species with diplacoid or possibly triplacoid opercula are included. Species in the *TECTATODINIUM* subgroup are:

Aldorfia alдорфensis (Gocht 1970b) Stover & Evitt 1978
Aldorfia deflandrei (Clarke & Verdier 1967) Stover and Evitt 1978
Apteodinium australiense (Deflandre & Cookson 1955) Williams 1978
Apteodinium granulatum Eisenack 1958 emended Lucas-Clark 1987
Apteodinium spiridoides Benedek 1972
Apteodinium syzygium (Dörhöfer & Davies 1980) Stover & Williams 1987
Bitectatodinium tepikiense Wilson 1973
Carpateella cornuta Grigorovich 1969 emended Damassa 1988 -- We agree with Damassa that specimens referred to *C. cornuta* by Fechner & Mohr (1986) are misidentified. Illustrations in Damassa (1988) indicate that this species has a large, standard sexiform antapical paraplate rather than a small, oblique sexiform paraplate. Therefore, *C. cornuta* should not be considered as a member of the *Cribrerodinium* complex.
Filisphaera filifera Bujak 1984
Samlandia chlamydophora Eisenack 1954
Scriniocassis dictyotus (Cookson & Eisenack 1960b) Beju 1971
Scriniocassis weberi Gocht 1964
Tectatodinium grande new species, herein
Trichodinium castanea (Deflandre 1935) Clarke & Verdier 1967
Trichodinium scarburghense (Sarjeant 1964) new combination, herein

Comments and/or guides to identification

In the *BATIACASPHAERA* subgroup (Fig. 3), differentiation of the three *Batiacasphaera* species is based mainly on differences in surface ornamentation: *B. compta* has a reticulation in which the muri are composed of numerous,

closely-spaced rods or "blebs" of small size and nonuniform shape. In contrast, the surface of *B. micropapillata* is finely papillate, finely granulate, or punctoreticulate with the ornamentation on individual specimens usually, but not necessarily, of a single type. *Batiacasphaera sphaerica*, whose ornamentation is similar to that of *B. micropapillata*, is granulate, or microreticulate, or a combination thereof. However, specimens of the latter species are commonly folded, whereas those of the former species characteristically lack folds.

Cassiculosphaeridia magna, *Ellipsoidictyum cinctum*, *Labyrinthodinium truncatum* and *Valensiella* spp. are reticulate. They differ mainly in the sizes of the lumina and the heights of the muri, relative to the body diameters: in *L. truncata* the lumina are large and the muri are narrow and high. As such, the muri are essentially intersecting septa; in *C. magna*, the lumina are small and the muri are low; in *E. cincta*, the lumina are, in general, of intermediate size, but some may be larger or smaller than the others, and the muri are narrow and of moderate height. A paracingulum is evident on many specimens and other traces of paratabulation may be discernible. *Valensiella* spp., which tends to be ellipsoidal, has moderately-sized lumina and septa which form a perfect to imperfect reticulum. The reticulum is covered by a thin ectophragm that is complete, or nearly so.

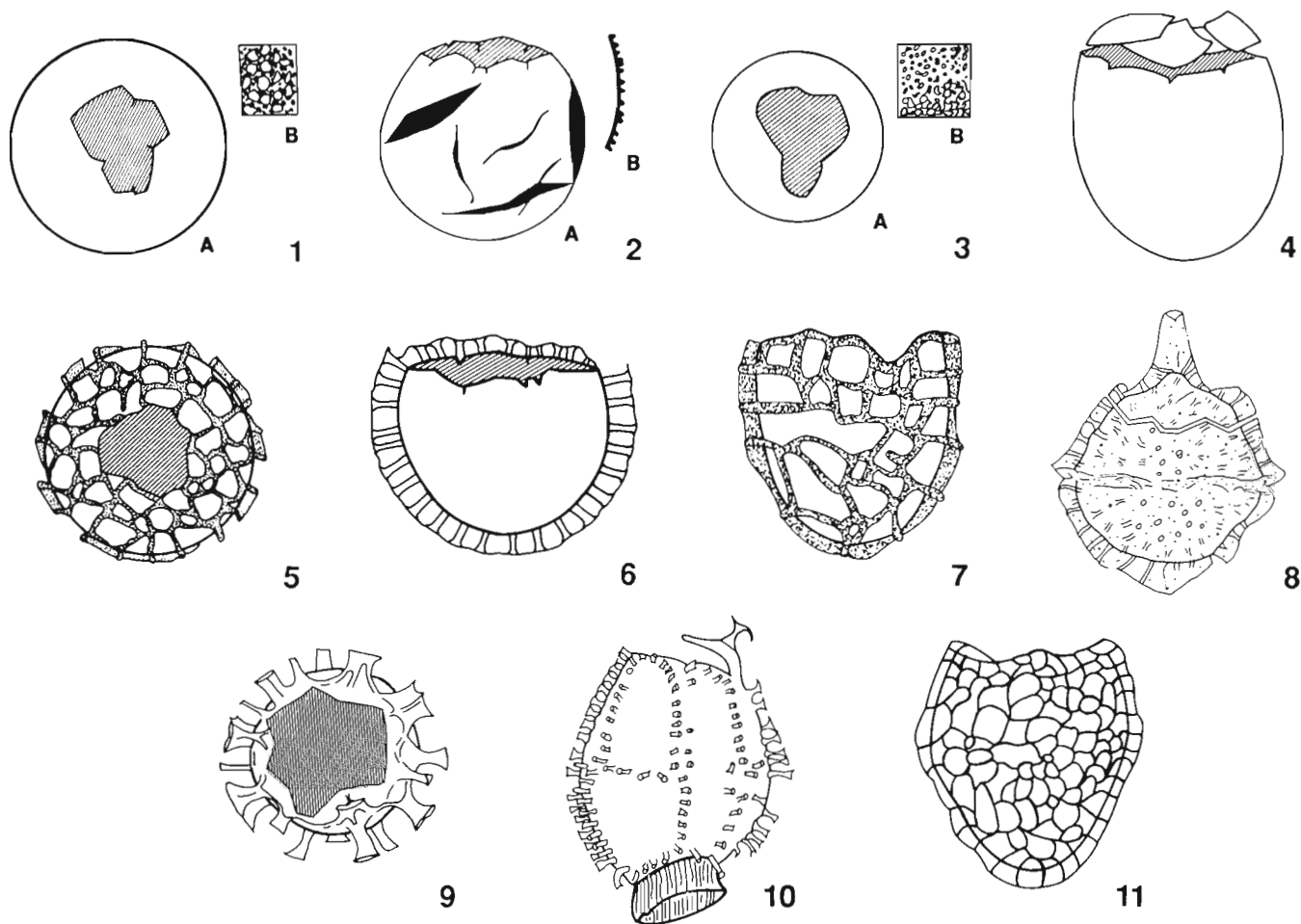
Other forms in the *BATIACASPHAERA* subgroup that possess thin ectophragms are: *Chlamydophorella ambigua*, *Gardodinium trabeculosum* and *Stephanellytron* spp.; *C. ambigua* differs from *G. trabeculosum* in being smaller, in lacking a prominent apical horn (some specimens of *C. ambigua* have short apical horns or bulges), and in possessing stouter, more randomly distributed processes. Nontabular forms of *Stephanellytron* spp. resemble *C. ambigua*, but differ in having one or more corona and shorter projections; other forms of *Stephanellytron* spp., which also possess coronas, have mostly linearly-arranged (parasutural and/or penitabular) tubular projections. The last species in this subgroup, *Caligodinium amiculum*, is included with reservation. Its simple ellipsoidal body and apical archeopyle argue for its inclusion, however, the operculum is polyplacoid and noncontiguous rather than tetraplacoid and contiguous, as are the opercula of all other species in the subgroup. In addition, the body of *C. amiculum* may be enclosed by a kalyptra.

The simplest forms in the *TECTATODINIUM* subgroup (Fig. 4) consist of spherical bodies with precingular archeopyles. These include *Tectatodinium grande* and *Bitectatodinium tepikiense*. Each has very thick, cancellous walls and precingular archeopyles. In the former species, the operculum is monoplacoid and middorsal, in the latter it is diplacoid, consisting of the middorsal paraplate and the adjacent left paraplate.

Differentiation of the four *Apteodinium* species in the *TECTATODINIUM* subgroup is by differences in wall thickness, in size and in shape. The wall typically has a smooth, homogeneous inner surface, and a fibrous outer part that tends to be densely packed proximally and generally becomes more loosely packed distally. *Apteodinium*

Figures 3 to 27

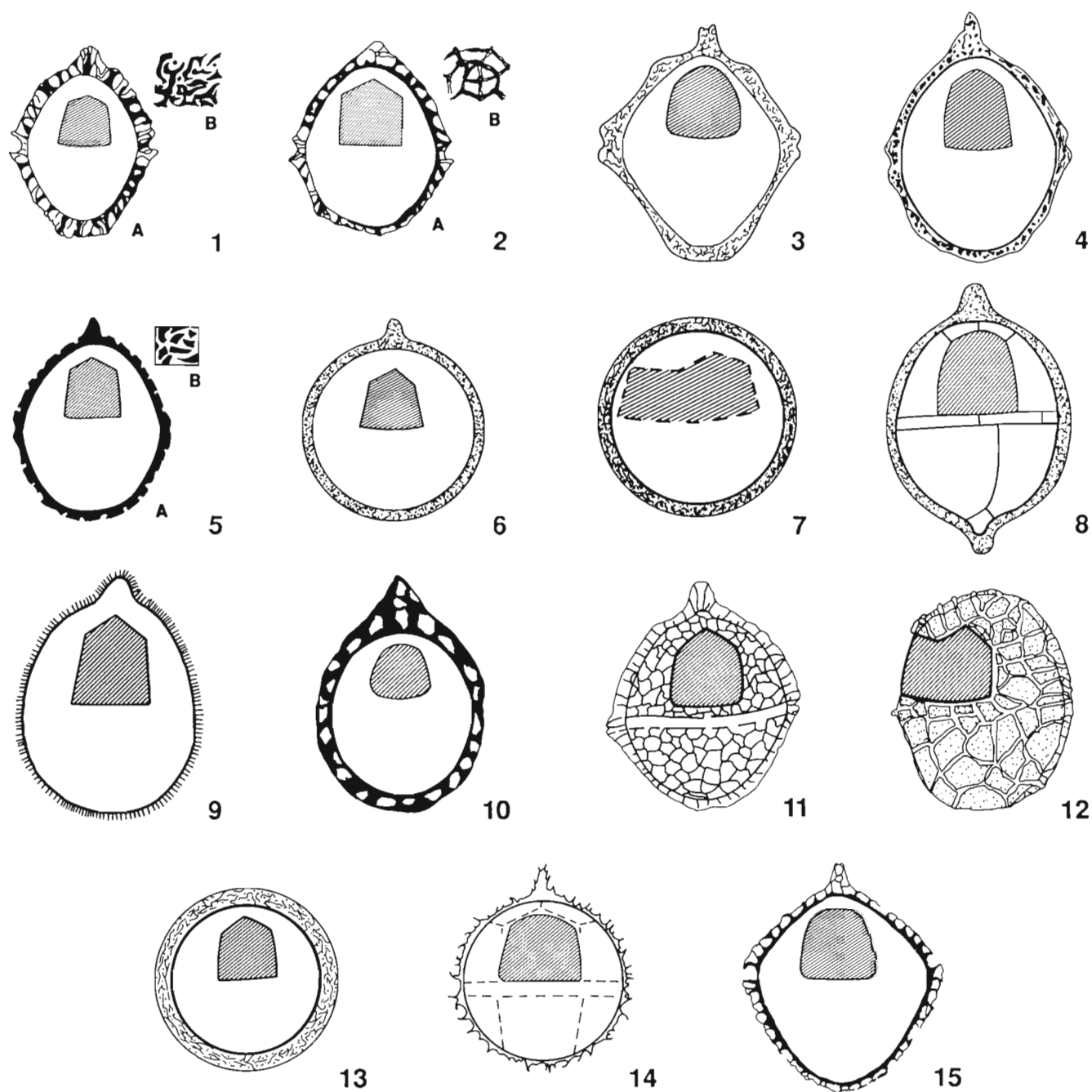
Alphanumeric designation in brackets denotes the position of that taxon on one of the three range charts. T = Tertiary-Holocene range chart (no. 3), C = Cretaceous range chart (no. 2), J = Triassic-Jurassic range chart (no. 1).



In this and subsequent Figures, the cross-hatching denotes the archeopyle.

- | | |
|--|--|
| 1A,B <i>Batiacasphaera compta</i> (T-65), apical surface (1A) | 6. <i>Chlamydophorella ambigua</i> (C-53), ventral surface |
| 2A,B <i>Batiacasphaera micropapillata</i> (T-28), ventral surface (2A) | 7. <i>Ellipsoidictyum cinctum</i> (J.-23), ventral surface |
| 3A,B <i>Batiacasphaera sphaerica</i> (T-27), apical surface (3A) | 8. <i>Gardodinium trabeculosum</i> (C-77), ventral surface |
| 4. <i>Caligodinium amiculum</i> (T-44), lateral surface | 9. <i>Labyrinthodinium truncatum</i> (T-23), apical surface |
| 5. <i>Cassiculosphaeridia magna</i> (C-92), apical surface | 10. <i>Stephanelytron</i> sp. (J.-25), right lateral surface |
| | 11. <i>Valensiella</i> sp. (J.-26), lateral surface |

Figure 3. Group I, Subgroup IA, *BATIACASPHAERA* Subgroup.



All views of dorsal surfaces unless otherwise stated

- 1A,B *Aldorfia aldorfensis* (J.-43)
- 2A,B *Aldorfia deflandrei* (C-38)
3. *Apteodinium australiense* (T-31)
4. *Apteodinium granulatum* (C-68)
- 5A,B *Apteodinium spiridoides* (T-34)
6. *Apteodinium syzygium* (J.-47)
7. *Bitectatodinium tepikiense* (T-3)
8. *Carpatella cornuta* (T-100)

9. *Filisphaera filifera* (T-12)
10. *Samlandia chlamydophora* (T-57)
11. *Scrinocassis dictyotus* (J.-19)
12. *Scrinocassis weberi* (J.-51), oblique right dorsal surface
13. *Tectatodinium grande* (T-48)
14. *Trichodinium castanea* (C-43)
15. *Trichodinium scarburghense* (J.-34)

Figure 4. Group I, Subgroup IB, *TECTATODINIUM* Subgroup.

syzygium has a subspherical body and is smaller than the other species of *Apteodinium*, whose bodies are longer than wide. In *A. australiense* the wall is often variable in thickness with the thicker parts produced at the cardinal positions. The wall of *A. granulatum* is more or less uniform in thickness, and the overall size of the species is typically less than that of *A. australiense* and larger than *A. syzygium*. The wall of *A. spiridoides* is scoured by sinuous, anastomosing channels which between them leave variously-shaped islands of thicker wall material. *Carpatella cornuta* is similar to *Apteodinium granulatum*, but differs in having a single, medial, antapical protrusion or horn and may show some paratabulation.

Specimens of *Trichodinium* are similar to those of *Apteodinium* in shape and in possessing short apical horns or tufts; they differ in lacking the fibrous walls, having instead relatively thin walls with a sparse to dense covering of short spines and coni which may coalesce to form short, discontinuous, often sinuous chains (*T. castanea*), or have a uniform covering of short, narrow spines, of which some may be joined distally by trabeculae (*T. scarburghense*). *Filisphaera filifera* has a dense covering of radiating fibres and either a monoplacoid or diplacoid operculum.

Specimens of *Samlandia* and *Scriniocassis* are basically reticulate and have a more or less continuous ectophragm overlying the reticulum. In *Samlandia chlamydotheca*, the reticulation is imperfect and the cyst outline in dorsal ventral view may have bulges in the cardinal positions. Clear reflections of paratabulation may be seen under the SEM. The reticulation on *Scriniocassis dictyotus* tends to be nearly perfect, the specimens are seen typically in dorsal-ventral view, and they have a monoplacoid operculum; in contrast, specimens of *Scriniocassis weberi* have a perfect to imperfect reticulation, show no preferred orientation, and the operculum is di- or possibly triplacoid, with the archeopyle generally extending the full width of the body. Some specimens of *S. weberi* may have monoplacoid opercula.

Group II: IMPAGIDINIUM / GONYAULACYSTA and allied forms

Group characteristics

Cysts are proximate to proximochorate, generally subspherical to ellipsoidal, but may be elongate, are acavate to variously cavate, and may possess an apical horn. External surfaces may be smooth or ornamented with nontabular and/or parasutural features of low to moderate relief; intratabular features, when present, are also of low to moderate relief. Archeopyles are precingular; opercula are monoplacoid and middorsal or diplacoid with a middorsal plus the adjacent left paraplate. Paratabulations may be partly to completely expressed, and when sufficiently delineated are gonyaulacacean. Hypocystal configurations are either standard or oblique sexiform.

Subdivision

Group II is divided into two subgroups with acavate forms included in the *IMPAGIDINIUM* Subgroup (Fig. 5) and cavate forms included in the *GONYAULACYSTA* Subgroup (Fig. 6). Species in the *IMPAGIDINIUM* Subgroup are:

- Corrudinium incompositum* (Drugg 1970) Stover & Evitt 1978
- Cribrerodinium edwardsii* 'complex'
- Cribrerodinium tenuitabulatum* (Gerlach 1961) Helenes 1984
- Impagidinium aquaeductum* (Piasecki 1980) Lentin & Williams 1985
- Impagidinium dispersitum* (Cookson & Eisenack 1965a) Stover & Evitt 1978
- Impagidinium patulum* (Wall 1967) Stover & Evitt 1978
- Occisucysta balios* Gitmez 1970 emended Jan du Chêne et al., 1986
- Rhynchodiniopsis cladophora* (Deflandre 1938b) Below 1981
- Rhynchodiniopsis? regalis* (Gocht 1970b) Jan du Chêne et al., 1986
- Spongodinium delitiense* (Ehrenberg 1838) Deflandre 1936b emended Lucas-Clark 1987

Species in the *GONYAULACYSTA* Subgroup are:

- Gonyaulacysta cassidata* 'complex'
- Gonyaulacysta eisenackii* (Deflandre 1938b) Dodekova 1967 emended Sarjeant 1982
- Gonyaulacysta jurassica* (Deflandre 1938b) Norris & Sarjeant 1965 emended Sarjeant 1982
- Hystrichosphaeropsis obscura* Habib 1972
- Hystrichosphaeropsis ovum* Deflandre 1935
- Psaliogonyaulax deflandrei* Sarjeant in Davey et al., 1966 emended Sarjeant 1982
- Scriniodinium? campanulum* (Gocht 1959) Stover & Evitt 1978
- Scriniodinium crystallinum* (Deflandre 1938b) Klement 1960
- Scriniodinium luridum* (Deflandre 1938b) Klement 1960 sensu Deflandre 1938b
- Scriniodinium luridum* (Deflandre 1938b) Klement 1960 sensu Gocht 1970b
- Triblastula utinensis* O. Wetzel 1933b emended Sarjeant 1985b
- Tubotuberella apatela* (Cookson & Eisenack 1960b) Ioannides et al., 1977 emended Sarjeant 1982

Comments and/or guides to identification

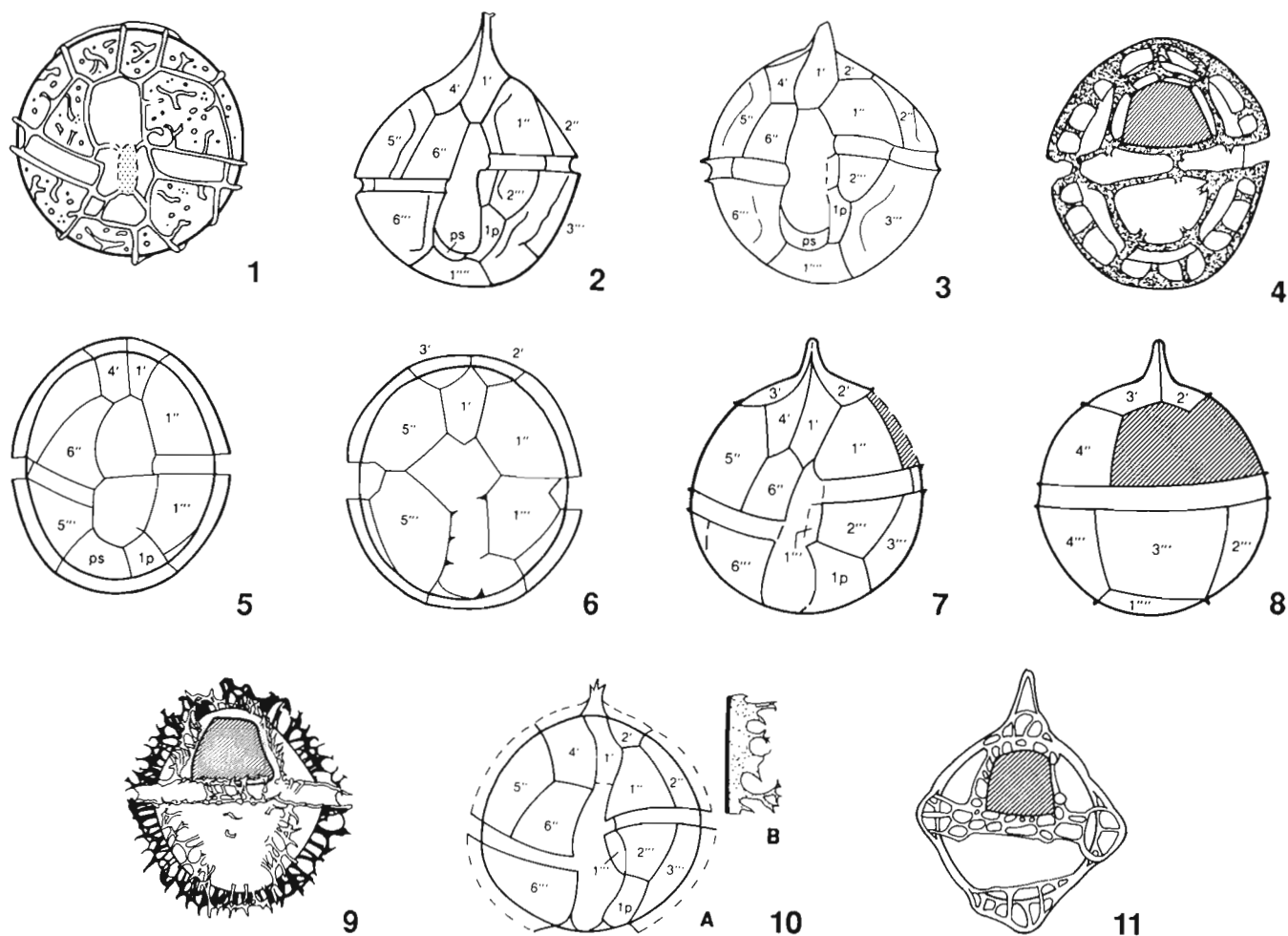
Within the *IMPAGIDINIUM* Subgroup (Fig. 5), species of *Impagidinium* and *Corrudinium* are characterized by having triangular-shaped last precingular paraplates (6'' just barely contacts or fails to contact 1') and standard sexiform hypocystal patterns. *Impagidinium dispersitum*, the type species of the genus, has a more or less complete paratabulation denoted by low parasutural ridges. The parasulcal area contains three, relatively large paraplates (as, ms, ps). On *I. aquaeductum*, the parasutural features are

moderately high, colonnade-like structures that are joined distally. The distances between adjacent columns varies considerably. The paratabulation on *I. patulum* is reflected by ridges or low septa and is reduced significantly on the ventral surface. In general, the parasutural ridges or septa are undeveloped at the following positions:

1. between the first and last apicals,
2. between the last precingular and the parasulcus,
3. posterior to the anterior paracingular septa on the large postcingular paraplates on each side of the parasulcus (posterior paracingular septa missing), and
4. at the anterior boundary of the posterior sulcal paraplate.

Corrudinium corrugatum is distinguished by its small size plus the presence of intratabular markings consisting of isolated, discontinuous ridges and granules. Spurs off the parasutural and intratabular ridges may be present.

Specimens of *Rhynchodiniopsis*, like those of *Impagidinium* and *Corrudinium*, have standard sexiform hypocystal patterns, but unlike the last two genera, have quadrangular or pentagonal last precingular paraplates. Moreover, the parasutural features on *Rhynchodiniopsis* consist of rows of spines or processes that may arise from basal ridges. In *R. cladophora*, the spines and/or processes are free distally, whereas in *R. regalis* the spines are joined distally and additional, shorter projections may arise from the distal connections.



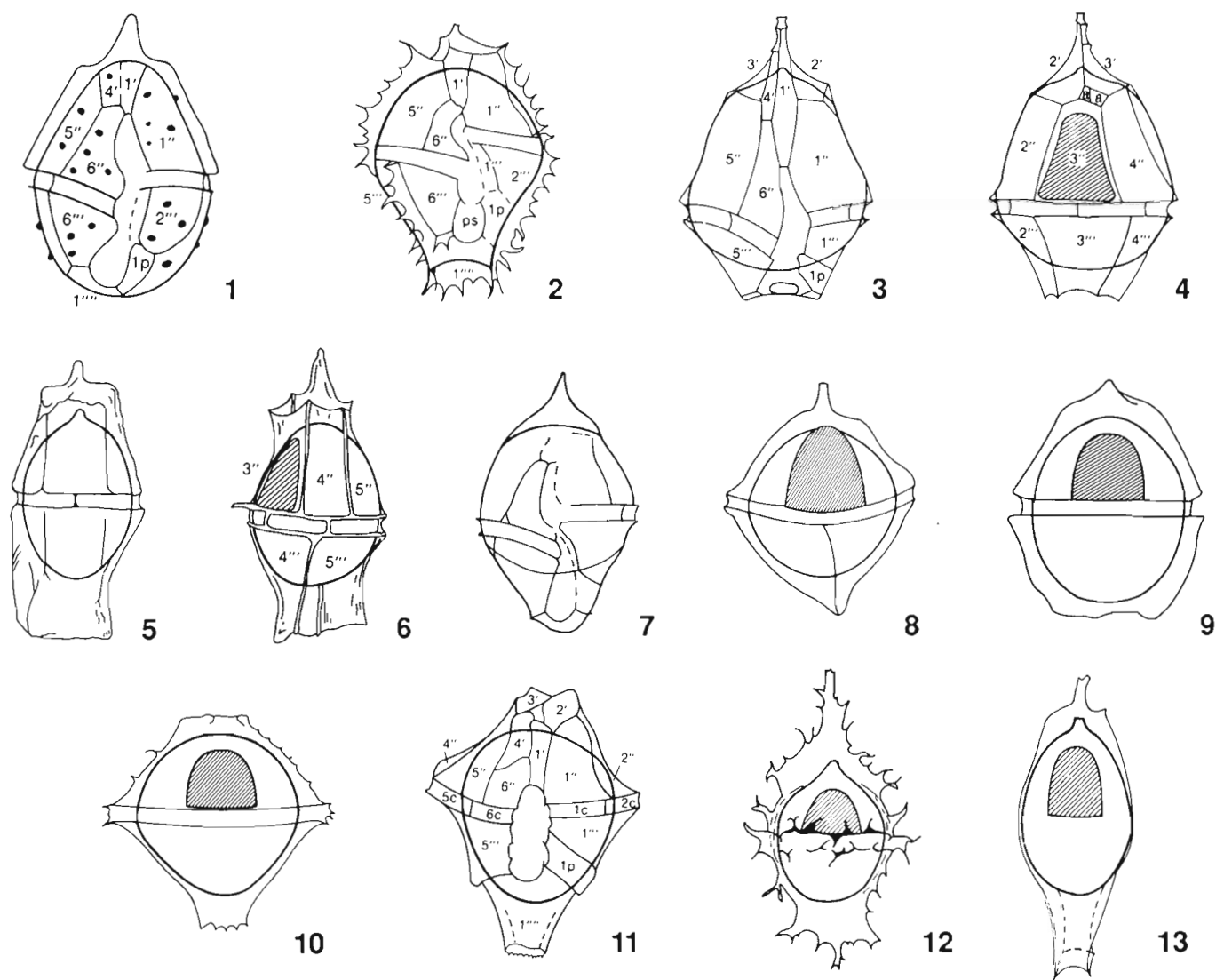
1. *Corrudinium incompositum* (T-52), ventral surface
2. *Cribroperidinium edwardsii* (C-60), ventral surface
3. *Cribroperidinium tenuitabulatum* (T-35), ventral surface
4. *Impagidinium aquaeductum* (T-24), dorsal surface
5. *Impagidinium disperitum* (T-46), ventral surface

6. *Impagidinium patulum* (T-2), ventral surface
- 7-8 *Rhynchodiniopsis cladophora* (J.-22), ventral and dorsal surfaces, respectively
9. *Rhynchodiniopsis? regalis* (J.-44), dorsal surface
- 10A,B *Occisucysta balios* (J.-18), dorsal surface (10A)
11. *Spongodinium delitiense* (T-108), dorsal surface

Figure 5. Group II, Subgroup IIA, *IMPAGIDINIUM* Subgroup.

The remaining forms in the *IMPAGIDINIUM* Subgroup (i.e. *Cribroperidinium edwardsii* 'complex', *C. tenuitabulatum*, *Occisucysta balios*, and *Spongodinium delitiense*, differ in having oblique sexiform hypocystal patterns with strongly asymmetrical posterior sulcal paraplates. The antapical paraplate is very small, relative to the adjacent postcingular paraplates, is appreciably longer than wide, and lies oblique to the longitudinal medial plane of the specimens. Forms within the *Cribroperidinium edwardsii* 'complex' (for contents, consult the section captioned "Morphological Complexes"), invariably have

growth ridges on a majority of the paraplates, together with usually prominent, continuous or interrupted parasutural ridges and well-developed apical horns. In contrast, specimens of *C. tenuitabulatum* have less prominent apical horns and parasutural ridges, are smaller, and may be in part faintly reticulate. *Occisucysta balios*, which has the same paratabulation pattern as species in the *Cribroperidinium edwardsii* 'complex', lacks growth ridges, has less conspicuous parasutural ridges and has a diplacoid rather than a monoplacoid operculum. The paratabulation on *Spongodinium delitiense*, aside from the archeopyle and



1. *Gonyaulacysta cassidata* (C-69), ventral surface
2. *Gonyaulacysta eisenackii* (J.-29), ventral surface
- 3,4 *Gonyaulacysta jurassica* (J.-24), ventral and dorsal surfaces, respectively
5. *Hystriosphæropsis obscura* (T-19), lateral view
6. *Hystriosphæropsis ovum* (C-40), right lateral view
7. *Psaligonyaulax deflandrei* (C-49), ventral surface
8. *Scriniodinium? campanula* (C-57), dorsal surface
9. *Scriniodinium crystallinum* (J.-28), dorsal surface
10. *Scriniodinium luridum sensu* Deflandre (1938b) (J.-21), dorsal surface
11. *Scriniodinium luridum sensu* Gocht (1970b) (J.-42), ventral surface
12. *Triblastula utinensis* (C-26), dorsal surface
13. *Tubotuberella apatela* (C-100), dorsal surface

Figure 6. Group II, Subgroup IIB, *GYNAULACYSTA* Subgroup.

paracingulum, is typically not indicated, and when expressed, it is difficult to discern. Characteristic of the species is the occurrence of bubble-like inclusions within the cyst wall, or between the cyst walls (depending on how the wall is interpreted). The inclusions vary considerably in size, number and distribution both within and among specimens.

All species in the *GONYAULACYSTA* Subgroup (Fig. 6) have middorsal precingular archeopyles and monoplacoid free opercula. Well tabulated species reveal that the opercula are released 3'' paraplates. *Gonyaulacysta jurassica* specimens are longitudinally elongate with an apical horn (usually prominent) and have epicysts that are significantly larger than the hypocysts. The gonyaulacacean paratabulation reflected by parasutural features, is unusual in that the precingular paraplates are elongate with an exceptionally narrow 6'' paraplate. Anteriorly, usually two minute intercalary paraplates are present and posteriorly, an opisthople occurs within paraplate 1'''. On *Gonyaulacysta eisenackii*, the paracingulum divides the cysts equatorially into approximately equal parts, thus the epicysts and hypocysts are similar in size. In further contrast to *Gonyaulacysta jurassica*, *G. eisenackii* lacks or has a much reduced apical horn, has neither anterior intercalary paraplates nor opisthopyles, and generally has more deeply incised septa. Members of the *Gonyaulacysta cassidata* 'complex' typically lack hypopericoels and an epipericoel may be present or reduced to a small vacuity beneath the apical horn (cornucavate). Scattered tubercles may be present and the paratabulation is commonly clearly expressed by parasutural features. The hypocystal pattern is standard sexiform and the last precingular (6'') is subtriangular. Except for *Gonyaulacysta jurassica*, nearly all of the remaining species now in *Gonyaulacysta* should probably be allocated to other genera.

As demonstrated by the drawings, there is little difference in basic morphology between specimens of *Gonyaulacysta eisenackii* and those of *Scriniodinium luridum sensu* Gocht 1970b. However, the latter lacks spine-crested septa, has a more extended posterior protrusion and perhaps most importantly, has a quadrate rather than a subtriangular last precingular paraplate (6''). On *Scriniodinium luridum sensu* Deflandre, the parasutural features are absent or only vaguely indicated; consequently the paratabulation is poorly expressed. In addition, *S. luridum sensu* Deflandre is less elongate (more quadrate in outline) than *S. luridum sensu* Gocht 1970b and has a shorter antapical protrusion. *Scriniodinium crystallinum* has a broadly elliptical outline and a short apical protrusion. *Scriniodinium? campanula* has an apical horn as well as a narrowly rounded antapical protrusion. The provisional assignment of this species reflects the presence of a middorsal hypocystal fold or ridge that extends from the paracingulum to the antapex. Other species of *Scriniodinium* do not have this feature.

Relatively narrow, longitudinally elongate species in the *GONYAULACYSTA* Subgroup are *Hystrichosphaeropsis obscura*, *H. ovum*, *Triblastula utinensis* and *Tubotuberella apatela*. The last has no parasutural features but does have a long, narrow posterior protrusion and an elongate ellipsoidal endocyst with a short apical projection. A short apical

endocystal projection is also present on specimens of *Hystrichosphaeropsis obscura* which has some parasutural features indicating the precingular paraplates, the postcingular paraplates and the paracingulum. On both species of *Hystrichosphaeropsis* the periphragm does not become significantly narrower posteriorly, as it does on *Tubotuberella apatela*. *Hystrichosphaeropsis ovum* has a longer apical horn than *H. obscura* and the paratabulation of the former is better expressed owing to the more obvious parasutural features. The pericyst of *Triblastula utinensis* is ornamented with seemingly randomly distributed spines; only along the equatorial area do the spines reflect some paratabulation (the paracingulum). As with the species of *Hystrichosphaeropsis*, the anterior end has a horn and the posterior end is broadly truncate in *Triblastula utinensis*. The last species in the *GONYAULACYSTA* Subgroup, *Psalligonyaulax deflandrei*, is epicavate only and has low parasutural ridges from which a partial gonyaulacacean paratabulation can be determined. The outline of the last precingular paraplates (6'') is subtriangular.

Group III: CORDOSPHAERIDIUM / HYSTRICHOSPHAERIDIUM and allied forms

Group characteristics

Cysts are dominantly skolochorate, rarely proximochorate, and typically acavate with subspherical to elongate ellipsoidal bodies, which almost always bear prominent processes. The processes are usually of one distribution type: intratabular, non-tabular, parasutural, or penitabular, and may or may not be similar in size and shape. In addition, the processes, although generally separated from each other, may be connected proximally by ridges or septa and/or joined distally by trabeculae. The majority of forms have apical archeopyles with contiguous tetraplacoid opercula, or precingular archeopyles with mainly monoplacoid, middorsal opercula; a few have combined apical and precingular archeopyles with polyplacoid opercula. The paratabulation is expressed incompletely (by archeopyle alone or together with the paracingulum) to completely so (almost exclusively by processes and archeopyle margins). When indicated sufficiently, the paratabulation is gonyaulacacean; paracingular processes may be present or absent.

Subdivision

Species in Group III are assigned to either of two subgroups on the basis of archeopyle type. The *CORDOSPHAERIDIUM* Subgroup (Fig. 7, 8) contains forms with precingular archeopyles having mainly monoplacoid opercula. The *HYSTRICHOSPHAERIDIUM* Subgroup (Fig. 9, 10) consists of forms with apical archeopyles and mostly tetraplacoid opercula. Species included in the *CORDOSPHAERIDIUM* Subgroup are:

Achilleodinium biformoides (Eisenack 1954) Eaton 1976
Achomosphaera alcornu (Eisenack 1954) Davey & Williams in Davey et al., 1966
Achomosphaera andalousiensis Jan du Chêne 1977 emended Jan du Chêne & Londeix 1988

Achomosphaera? neptuni (Eisenack 1958) Davey & Williams *in* Davey et al., 1966
Cordosphaeridium cantharellum (Brosius 1963) Gocht 1969
Cordosphaeridium fibrospinosum Davey & Williams *in* Davey et al., 1966
Cordosphaeridium funiculatum Morgenroth 1966a
Cordosphaeridium gracile (Eisenack 1954) Davey & Williams *in* Davey et al., 1966
Coronifera oceanica Cookson & Eisenack 1958 emended May 1980
Fibrocysta axialis (Eisenack 1965) Stover & Evitt 1978
Florentinia cooksoniae (Singh 1971) Duxbury 1980
Florentinia mantellii (Davey & Williams *in* Davey et al., 1966) Davey & Verdier 1973. This species may have a combined archeopyle, Type tA + P.
Hystrichodinium spp.
Kiokansium williamsii Singh 1983
Kleithrasphaeridium loffrense Davey & Verdier 1976
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967. The archeopyle of this species varies from precingular Types 2P to 5P, to combined apical and precingular, Type tA + 5P, or to Type tA + tP, when all epicystal paraplates are removed.
Melitasphaeridium choanophorum (Deflandre & Cookson 1955) Harland & Hill 1979
Melitasphaeridium pseudorecurvatum (Morgenroth 1966a) Bujak et al., 1980
Nematosphaeropsis lemniscata Bujak 1984 emended Wrenn 1988
Operculodinium divergens (Eisenack 1954) Stover & Evitt 1978
Pervosphaeridium? truncigerum (Deflandre 1937) Yun 1981
Protoellipsodinium spp.
Reticulosphaera actinocoronata (Benedek 1972) Bujak & Matsuoka 1986
Spiniferites ellipsoideus Matsuoka 1983
Spiniferites elongatus Reid 1974
Spiniferites mirabilis (Rossignol 1964) Sarjeant 1970
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970 emended Sarjeant 1981
Spiniferites septatus (Cookson & Eisenack 1967) McLean 1971
Spiniferites splendidus Harland 1979b

Species in the *HYSTRICHOSPHAERIDIUM* Subgroup include:

Adnatosphaeridium multispinosum Williams & Downie *in* Davey et al., 1966
Areosphaeridium arcuatum 'complex'
Areosphaeridium diktyoplokus (Klumpp 1953) Eaton 1971
Compositosphaeridium polonicum (Gorka 1965) Erkmen & Sarjeant 1980
Dapsilodinium pseudocolligerum (Stover 1977) Bujak et al., 1980
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965 emended Goodman & Witmer 1985. The archeopyle of this species may be apical only, Type [4A], the most common type, or precingular, Type P, or combined apical and precingular, Types [4A] + P, or [4A] + 2P.

Discorsia nanna (Davey 1974) Duxbury 1977 emended Khowaja-Ateequzzaman et al., 1985
Distatodinium paradoxum (Brosius 1963) Eaton 1976
Heterosphaeridium difficile (Manum & Cookson 1964) Ioannides 1986
Hystrichokolpoma bulbosum (Ehrenberg 1838) Morgenroth 1968 emended
Hystrichokolpoma cinctum s.l. Klumpp 1953
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Hystrichosphaeridium salpingophorum Deflandre 1935 emended Davey & Williams *in* Davey et al., 1966
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937 emended Davey & Williams *in* Davey et al., 1966
Hystrichosphaerina schindewolfii Alberti 1961
Litosphaeridium arundum (Eisenack & Cookson 1960) Davey 1979a emended Lucas-Clark 1984
Litosphaeridium siphoniphorum (Cookson & Eisenack 1958) Davey & Williams *in* Davey et al., 1966 emended Lucas-Clark 1984
Oligosphaeridium complex (White 1842) Davey & Williams *in* Davey et al., 1966
Oligosphaeridium patulum Riding & Thomas 1988
Prolixosphaeridium parvispinum (Deflandre 1937) Davey et al., 1969
Rigaudella aemula (Deflandre 1938b) Below 1982
Stiphrosphaeridium anthophorum (Cookson & Eisenack 1958) Davey 1982
Surculosphaeridium? longifurcatum (Firtion 1952) Davey et al., 1966
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al., 1966 emended May 1980
Tanyosphaeridium variecalamus Davey & Williams *in* Davey et al., 1966

Comments and/or guides to identification

Within the *CORDOSPHAERIDIUM* subgroup (Fig. 7, 8), the four species of *Cordosphaeridium* listed above have subspherical or broadly ellipsoidal bodies bearing fibrous intratabular processes, typically with one process per paraplate. Species distinctions are made on the shapes of the processes or conspicuous ornamentation on the body. Processes on *Cordosphaeridium gracile* are relatively long and narrow with slightly expanded tips; processes on *C. cantharellum* are also relatively narrow, but vary considerably in length from specimen to specimen. The process tips are flared and recurved proximally to give the processes an umbrella-like appearance. On *C. fibrospinosum*, the large processes are penitabular, wide and relatively short, so that their lengths more or less equal their widths; they are not expanded distally. *Cordosphaeridium funiculatum* has intratabular processes similar in shape to those on *C. gracile*, and a somewhat coarsely reticulate body in which the muri are more obvious than the lumen. *Operculodinium divergens* has a similarly ornamented body, but it differs from *C. funiculatum* in having more numerous nontabular processes rather than intratabular processes. The body of *Pervosphaeridium? truncigerum*, which is striatopunctate, is similar in appearance to that of *O. divergens* and *C. funiculatum* but is much more finely

ornamented. On *P. truncigerum*, the nontabular, faintly fibrous processes are about the same in length, and differ in width. However, the narrow processes rarely dominate, according to Yun (1981, p. 27). The species has a 2P (2'' + 3'') archeopyle (*ibid.* pl. 9, fig. 9a-b). The body of *Fibrocysta axialis* is ellipsoidal and bears numerous fibrous, nontabular processes with distinctive apical and antapical projections or processes. The apical process may be branched and quite long.

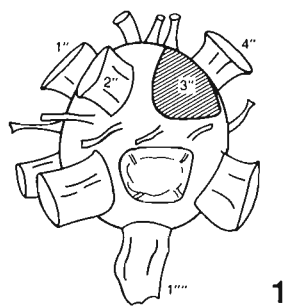
Specimens of *Kleithrasphaeridium loffrense* are like those of *Cordosphaeridium gracile*, but *K. loffrense* has smooth rather than fibrous processes. *Florentinia*, according to Davey and Verdier (1973, p. 315) "... is characterized by the presence of extremely variable processes, one or more per reflected plate area. Two or more types of processes occur in each species and there is some variation in the number, particularly in species possessing finer processes." On *F. mantellii*, the paracingular processes are commonly narrow and closed distally, whereas the precingular and postcingular processes are wide and open distally. *Florentinia cooksoniae* has tubular processes that are clearly open distally and nearly uniform in length, but differ considerably in width. The species might be placed more appropriately in *Kleithrasphaeridium* because its processes are of a single type. The body of *Achilleodinium biformoides* is usually broadly ellipsoidal and the thin-walled, smooth to faintly ornamented penitabular processes are short and wide; the paracingular processes are, in contrast, narrow and the antapical process may be longer than the others. Processes on *Melitasphaeridium choanophorum* have narrow, smooth, tubular stems with abruptly expanded cup-like structures with aculeate or secate rims. On *M. pseudorecurvatum*, the processes are similar to those on *M. choanophorum* but lack the cup-like distal expansions and instead have aculeate fringes at the ends of the processes. The archeopyle on some specimens of *M. pseudorecurvatum* has a trapezoidal outline.

Both *Kiokansium williamsii* and *Protoellipsodinium* spp. have narrowly ellipsoidal bodies bearing numerous nontabular processes. Those on *K. williamsii* are narrow and long with expanded, aculeate tips, whereas those on *Protoellipsodinium* spp., which are also narrow but tapered, have acuminate tips. In addition, *K. williamsii* has a Type 2P archeopyle and *Protoellipsodinium* spp. has a Type P archeopyle. The body of *Coronifera oceanica* is more broadly rounded than that of *Protoellipsodinium* spp., and bears numerous, solid, acuminate processes and a single large, apparently open antapical process.

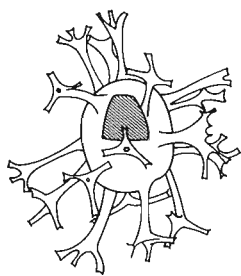
Species discussed thus far have, for the most part, intratabular or nontabular processes and species separation relies heavily on recognizing differences in the shapes and construction of the processes, and to a lesser extent, on the ornamentation of the bodies. The next group of species from the genera *Achomosphaera*, *Nematosphaeropsis* and *Spiniferites* characteristically bear gonial processes, and some have intergonal ones as well. All have, or are presumed to have, Type P archeopyles with monoplacoid opercula. *Achomosphaera andalusiensis* has only gonial processes whose terminations are branched and coarsely fenestrate. *Achomosphaera alcornu* also has only gonial processes, but their tips are broad, solid and flat with generally truncated or

irregular ends. The same types of processes and process tips occur on specimens of *Spiniferites pseudofurcatus*, which differs from *A. alcornu* in having parasutural ridges and/or septa connecting the bases of processes. Matsuoaka (1983, p. 133) stated that *S. ellipsoideus* "... is characterized by the elongate cyst body with somewhat membranous parasutural septa in the hypocyst. This species resembles *Spiniferites elongatus* in having the elongate cyst body, but differs from the latter in possessing a shorter and wider cyst body." Although we presently acknowledge both *S. ellipsoideus* and *S. elongatus*, we strongly suspect that they are conspecific; apparently the only distinction is a very minor difference in body shape, however, verification requires examination of the holotypes. Specimens of *S. mirabilis* have relatively long gonial and intergonal processes that are generally single. Exceptions are processes in the antapical area that are joined by membranous septa throughout most of their length and those closely-spaced processes mostly in the paracingular area that arise from a mutual base. *Spiniferites splendidus* is very similar to *S. mirabilis* in having both gonial and intergonal processes and antapical, membranous structures. It differs from *S. mirabilis* in being larger and in having more numerous, wide processes with common bases (flamboyant processes of Harland, 1979b). *Spiniferites septatus* has a vacuolate body. Its gonial processes, except for their tips, are also partly or completely vacuolate. Moreover, the parasutural markings are commonly faint and obscured by the moderately thick body wall. Processes on *Nematosphaeropsis lemniscata* are narrow and relatively long with initially trifurcate and secondarily bifurcate tips that are connected to adjacent processes by trabeculae. Intergonal processes are present on this species, the archeopyle is rarely discernible, and the presence of parasutural features on the body has not been demonstrated.

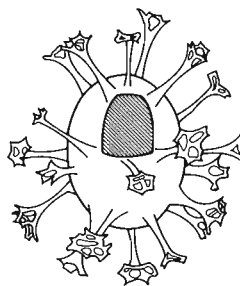
The remaining four species in the *CORDOSPHERIDIUM* Subgroup more or less stand alone insofar as their morphology is concerned. *Achomosphaera? neptuni* has a fibroreticulate body and smooth to fibrous processes. The processes tend to be somewhat flattened and have simply branched tips. These may be quite long, relative to the length of the processes, and have simple acuminate or blunt ends. The provisional assignment expresses uncertainties about the archeopyle. The processes on *Hystrichodinium* spp. are usually long, gradually tapered, and acuminate or simply branched distally. They are parasutural, and may be numerous or sparse; tubercles may be present in the intratabular areas. *Lingulodinium machaerophorum* has variable archeopyles and, therefore, it could just as well have been placed in another group. However, it is in this group because the dominant archeopyle type is precingular, rather than combined apical and precingular. Its subspherical body has numerous, hollow, blade-like, nontabular processes with variously disposed granules at or near the ends of the processes. The archeopyle varies from Types P to 5P, to [tA + P] + 5P. The last species in this subgroup, *Reticulatosphaera actinocoronata*, possesses solid, cylindrical processes with multi-branched tips. As in *Spiniferites*, the first branch is usually trifurcate and subsequent branching may be simple or complex. Often the final branches are very thin and they do not connect with the terminal branches from adjacent



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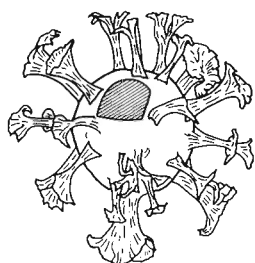
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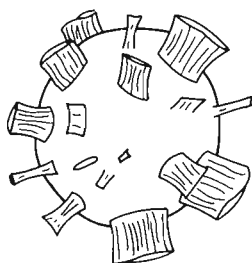
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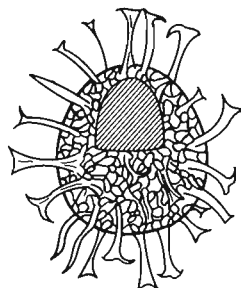
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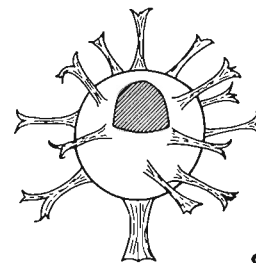
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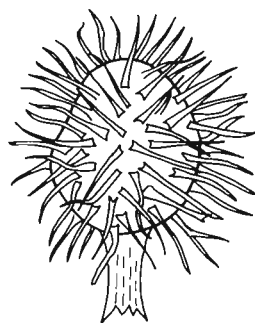
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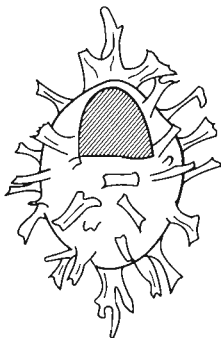
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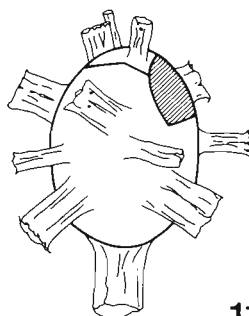
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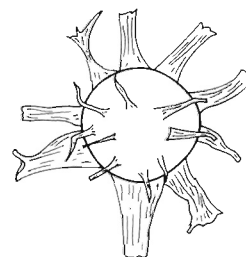
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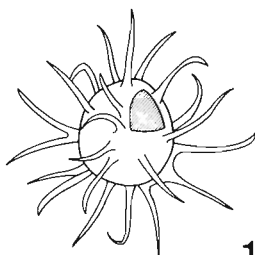
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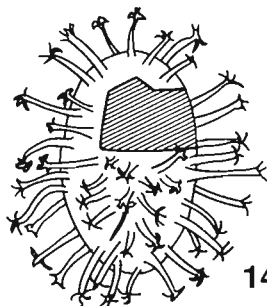
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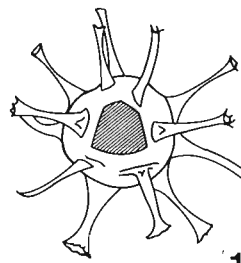
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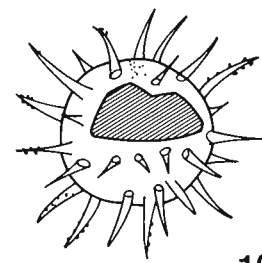
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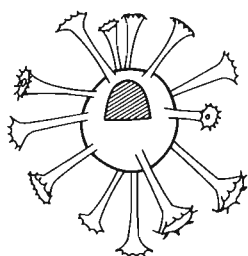
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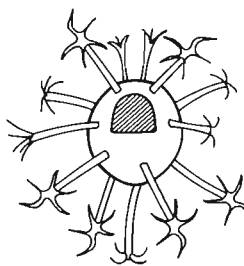
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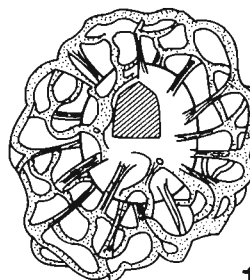
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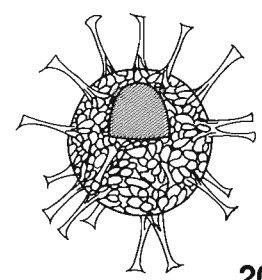
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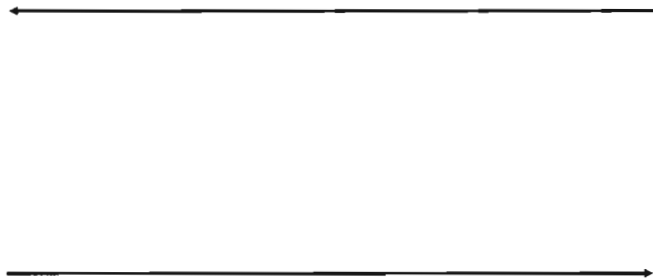
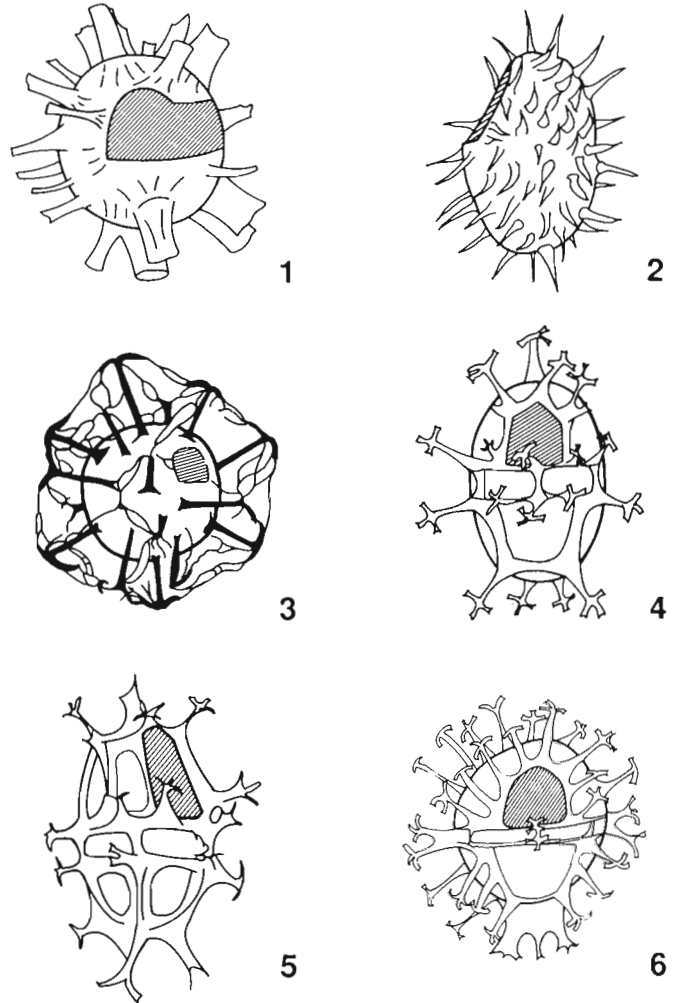


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Left

Figure 7. Group III, Subgroup IIIA, *CORDOSPHAERIDIUM* Subgroup.

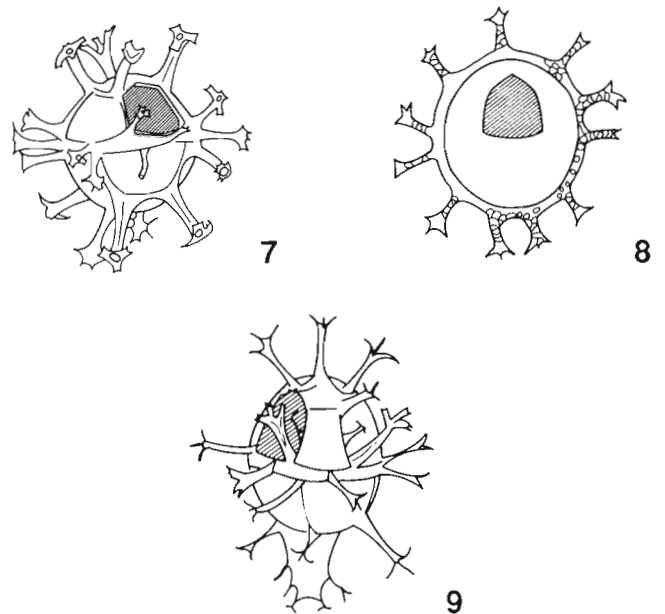
1. *Achilleodinium biformoides* (T-58), oblique left lateral surface
2. *Achomosphaera alcornu* (T-33), dorsal surface
3. *Achomosphaera andalousiensis* (T-17), dorsal surface
4. *Achomosphaera? neptuni* (C-84), oblique right lateral surface
5. *Cordosphaeridium cantharellum* (T-41), dorsal surface
6. *Cordosphaeridium fibrospinosum* (T-61), ventral surface
7. *Cordosphaeridium funiculatum* (T-67), dorsal surface
8. *Cordosphaeridium gracile* (T-54), dorsal surface
9. *Coronifera oceanica* (C-36), right lateral surface
10. *Fibrocysta axialis* (T-60), dorsal surface
11. *Florentinia cooksoniae* (C-61), left lateral surface
12. *Florentinia mantellii* (C-56), ventral surface
13. *Hystriodinium* sp. (C-37), oblique left lateral surface
14. *Kiokansium williamsii* (C-64), dorsal surface
15. *Kleithriasphaeridium loffrense* (C-46), dorsal surface
16. *Lingulodinium machaerophorum* (T-10), dorsal surface
17. *Melitasphaeridium choanophorum* (T-11), dorsal surface
18. *Melitasphaeridium pseudorecurvatum* (T-72), dorsal surface
19. *Nematosphaeropsis lemniscata* (T-13), dorsal surface
20. *Operculodinium divergens* (T-62), dorsal surface

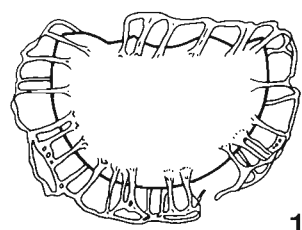


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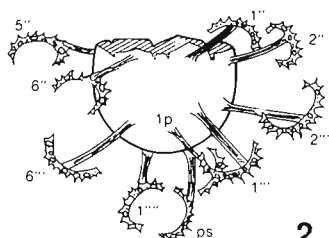
Figure 8. Group III, Subgroup IIIA, *CORDOSPHAERIDIUM* Subgroup. (cont.)

1. *Pervosphaeridium? truncigerum* (C-48), dorsal surface
2. *Protoellipsodinium* sp. (C-76), right lateral surface
3. *Reticulosphaera actinocoronata* (T-14), left oblique dorsal surface
4. *Spiniferites ellipsoideus* (T-21), dorsal surface
5. *Spiniferites elongatus* (T-1), left oblique dorsal surface
6. *Spiniferites mirabilis* (T-5), dorsal surface
7. *Spiniferites pseudofurcatus* (T-30), left oblique dorsal surface
8. *Spiniferites septatus* (T-89), dorsal surface
9. *Spiniferites splendidus* (T-20), right oblique dorsal surface

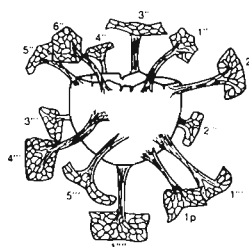




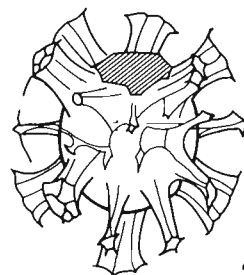
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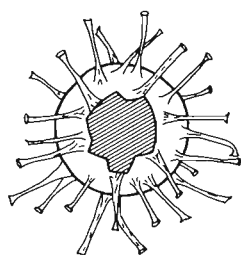
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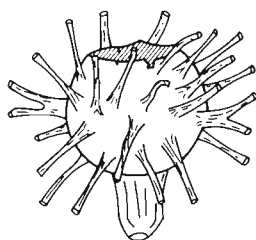
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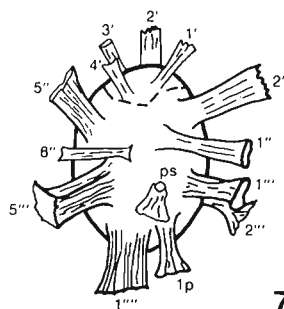
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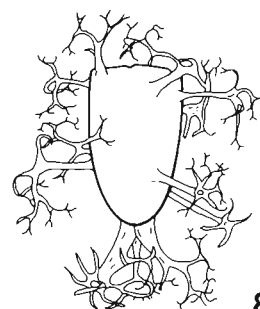
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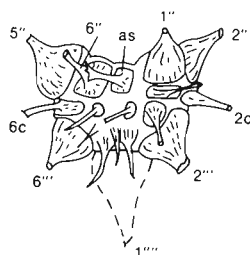
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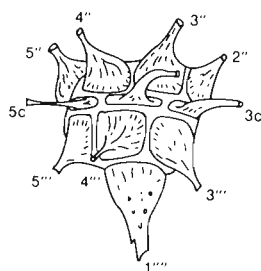
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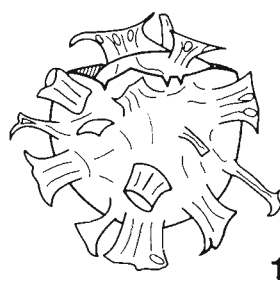
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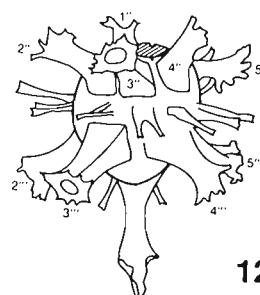
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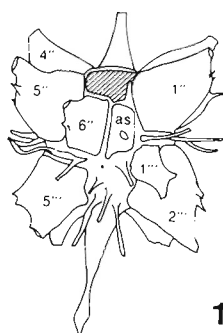
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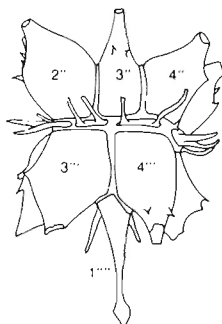
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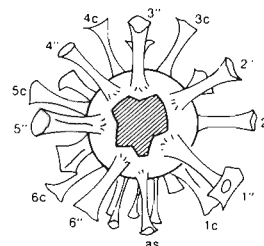
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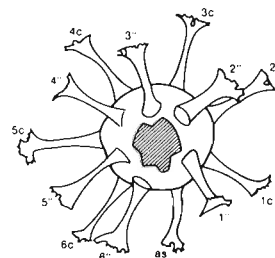
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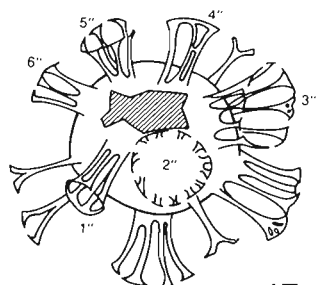
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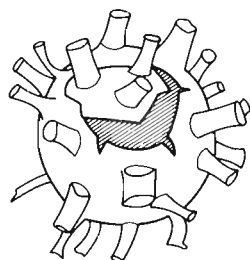
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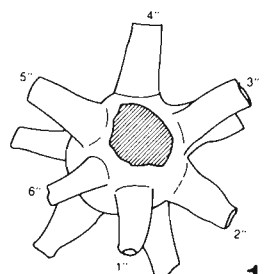
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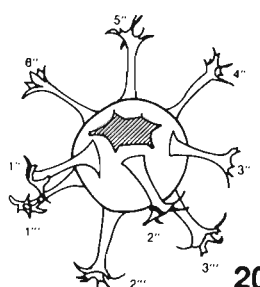
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processes. The archeopyle, although reported as precingular, has not been adequately documented for this species, mainly because the body is almost always complexly folded.

Species with apical, Type [4A] archeopyles whose tetraplacoid opercula are contiguous and usually free are included in the *HYSTRICHOSPHAERIDIUM* Subgroup (Fig. 9, 10). For the most part genera and species are recognized by differences in the shape and structure of the processes and on their distribution, including the presence or absence of paracingular processes. There are within the subgroup 11 species whose intratabular and/or penitabular processes or process complexes depict essentially complete paratabulations. These are typified by *Hystrichosphaeridium tubiferum* which has hollow, tubiform intratabular processes with smooth or faintly ornamented walls and gently flared, open tips rimmed with secæ or aculeae. Favorably preserved specimens show circular markings where the processes arise from the body. Process length is more or less constant on individual specimens, the width varies according to the size and position of the reflected paraplate—the wider the process, the larger the paraplate. Specimens of *H. salpingophorum* differ from those of *H. tubiferum* in having generally wider and slightly fibrous processes with subquadrate distal openings. The fibrous, hollow, distally-expanded and somewhat angular processes on *Compositosphaeridium polonicum* customarily have 3 or 4 ribs (up to 6) along their length; proximally, the ribs extend onto the body where they form a polygonal network. The process tips may have aculeae or secæ. As with *Hystrichosphaeridium tubiferum* and *H. salpingophorum*, the processes on *Compositosphaeridium polonicum* vary in width according to their position. On *Litosphaeridium arundum* the processes are

generally tubular with straight sides, although distally some processes may narrow slightly. The number of processes varies from 35 to 45; there are two processes on each of the cingular paraplates and most postcingular paraplates bear two or more processes. In contrast, most epicystal paraplates and the antapical paraplate have single processes. Opercula are adnate. *Surculosphaeridium? longifurcatum* has mostly solid and narrow processes with slightly tapered stems and deeply incised, branched tips. The paracingular processes are usually bifurcate and other processes are more complexly branched.

Process complexes rather than single processes occupy the large paraplates on *Heterosphaeridium difficile*, *Hystrichosphaerina schindewolfii* and *Systematophora placacantha*. The last species has penitabular, subcircular to elliptical ridges from which arise several slender processes with narrowly expanded tips. These are not connected distally. Most process complexes on *Hystrichosphaerina schindewolfii* are vasiform to nearly cylindrical with fenestrate/perforate sides; the individual process complexes are connected distally by ring trabeculae. Paracingular complexes are rectilinear and the tips may not be joined. Individual groups of processes on *Heterosphaeridium difficile* are commonly difficult to distinguish and differentiate clearly from adjacent complexes. The better defined ones have a prominent narrow or wide process surrounded by one or more very narrow processes and may be interconnected distally by discontinuous trabeculae and proximally by low ridges. With an increase in the number of processes, their average width decreases and the density of the proximal connections increases to the extent that the body becomes reticulate; individual process complexes eventually become unrecognizable.

Specimens of *Hystrichokolpoma* differ from those of *Hystrichosphaeridium* by having mostly large, distally open penitabular processes outside the paracingulum and parasulcus and much narrower, distally open or closed processes within the paracingulum and parasulcus. Thus, by virtue of their type as well as their size and construction, two distinct kinds of processes occur on *Hystrichokolpoma*, whereas only one kind of process is present on *Hystrichosphaeridium*, although the processes may differ in width. The large processes on *Hystrichokolpoma bulbosum*, which have very wide bases, decrease in width rather abruptly at about midheight to form short, narrow distal endings. Narrower processes are closed distally, pointed, but still have expanded bases. On *H. cinctum* s.l. the large processes are inflated over most of their length so that only the distal one fourth or so is constricted. These processes may have or lack fistules, spinules or tubules projecting from their sides. Each cingular paraplate has either two or three narrow processes. The large processes on *H. rigaudiae* are more or less tubular with expanded bases and tips; the latter have denticulate to aculeate fringes. Paracingular and parasulcal processes are very narrow and may vary in length among individuals. Some specimens are devoid of paracingular processes.

Within the *HYSTRICHOSPHAERIDIUM* Subgroup are six species which lack paracingular processes and typically bear 17 intratabular or penitabular processes that are clearly

Figure 9. Group III, Subgroup IIIB, *HYSTRICHOSPHAERIDIUM* Subgroup.

1. *Adnatosphaeridium multispinosum* (T-75), ventral surface
2. *Areosphaeridium arcuatum* (T-53), ventral surface
3. *Areosphaeridium diktyoplokus* (T-66), ventral surface
4. *Compositosphaeridium polonicum* (J-33), ventral surface
5. *Dapsilidinium pseudocolligerum* (T-25), apical surface
6. *Diphyes colligerum* (T-69), ventral surface
7. *Discorsia nanna* (C-79), ventral surface
8. *Distatodinium paradoxum* (T-37), lateral surface
- 9,10 *Hystrichokolpoma bulbosum* (T-105), ventral and dorsal surfaces, respectively
11. *Heterosphaeridium difficile* (C-52), ventral surface
12. *Hystrichokolpoma rigaudiae* (T-15), dorsal surface
- 13,14 *Hystrichokolpoma cinctum* (T-43), ventral and dorsal surfaces, respectively
15. *Hystrichosphaeridium salpingophorum* (T-87), apical surface
16. *Hystrichosphaeridium tubiferum* (T-83), apical surface
17. *Hystrichosphaerina schindewolfii* (C-78), oblique apical surface
18. *Litosphaeridium arundum* (C-70), oblique apical surface
19. *Litosphaeridium siphoniphorum* (C-59), apical surface
20. *Oligosphaeridium complex* (T-81), apical surface

separated from each other. Processes on *Oligosphaeridium complex* are tubular and relatively narrow with expanded ends. Commonly circular markings occur at the bases of the processes where they arise from the body and distally the tips are simply flared or branched and rimmed by a few aculeae. In contrast, processes on *O. patulum* are vasiform and multifurcate distally with numerous digitations. *Stiphrosphaeridium anthophorum* also has vasiform processes, but their expanded ends are fenestrate and perforate, and their distal margins are circumscribed by smooth ring trabeculae. *Discorsia nanna* has basically tubular processes that are striate; some processes may be quadrangular in cross-section. Specimens are small, less than 50.0 μ m. The processes on *Litosphaeridium siphoniphorum* are mainly penitabular; in shape they vary from ampullate to truncated-conical to subcylindrical. The body is faintly ornamented to punctoreticulate and the ornamentation extends onto the processes. *Areosphaeridium diktyoplokus* has solid, narrow, intratabular processes whose distal terminations are perforate and infundibular or planar and simulate. Insofar as we can ascertain, the hypocystal pattern on the last six species is standard sexiform. In contrast, specimens attributed to the *Areosphaeridium arcuatum* 'complex' are interpreted as having a partiform hypocystal pattern. The intratabular processes have narrow, solid stems and mainly arcuate (occasionally branched) distal terminations. On the precingular and postcingular processes,

the open sides of the arcuate endings are nearer the paracingulum. Specimens in this complex may possess or lack paracingular processes.

The process distribution on the next five species is nontabular or undetermined and these forms have either subspherical or elongate ellipsoidal bodies. Specimens of *Dapsilidinium pseudocolligerum* have subspherical bodies bearing numerous, hollow, distally open nontabular processes that are moderately tapered. Their distal ends are slightly expanded. The statements for *D. pseudocolligerum* are equally valid for *Diphyes colligerum*, but the latter has a single, large antapical process which the former lacks. Very rare specimens of *D. colligerum* have combined archeopyles. *Distatodinium paradoxum*, *Prolixosphaeridium parvispinum* and *Tanyosphaeridium variecalamus* have elongate ellipsoidal bodies and isolated processes. Those on *Distatodinium paradoxum* have narrow stems and multibranched, complex distal terminations; *Prolixosphaeridium parvispinum* has relatively short, simple acuminate processes, whereas *Tanyosphaeridium variecalamus* has narrow, tubular to slightly tapered and distally open processes.

The final two species in the *HYSTRICHOSPHAERIDIUM* Subgroup, *Adnatosphaeridium multispinosum* and *Rigaudella aemula*, differ from others by having processes that are linked distally by trabeculae. In *R. aemula*, the relatively few intratabular processes are vasiform with

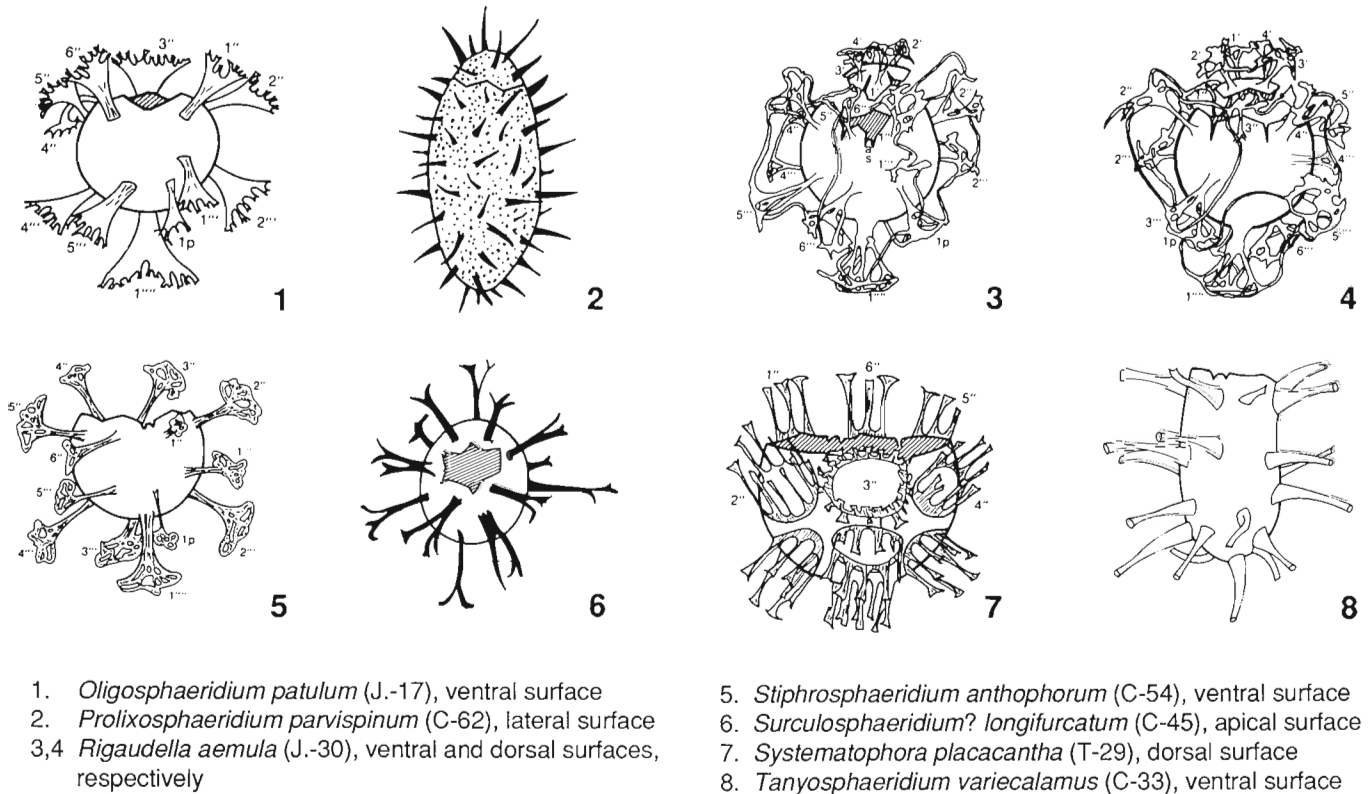


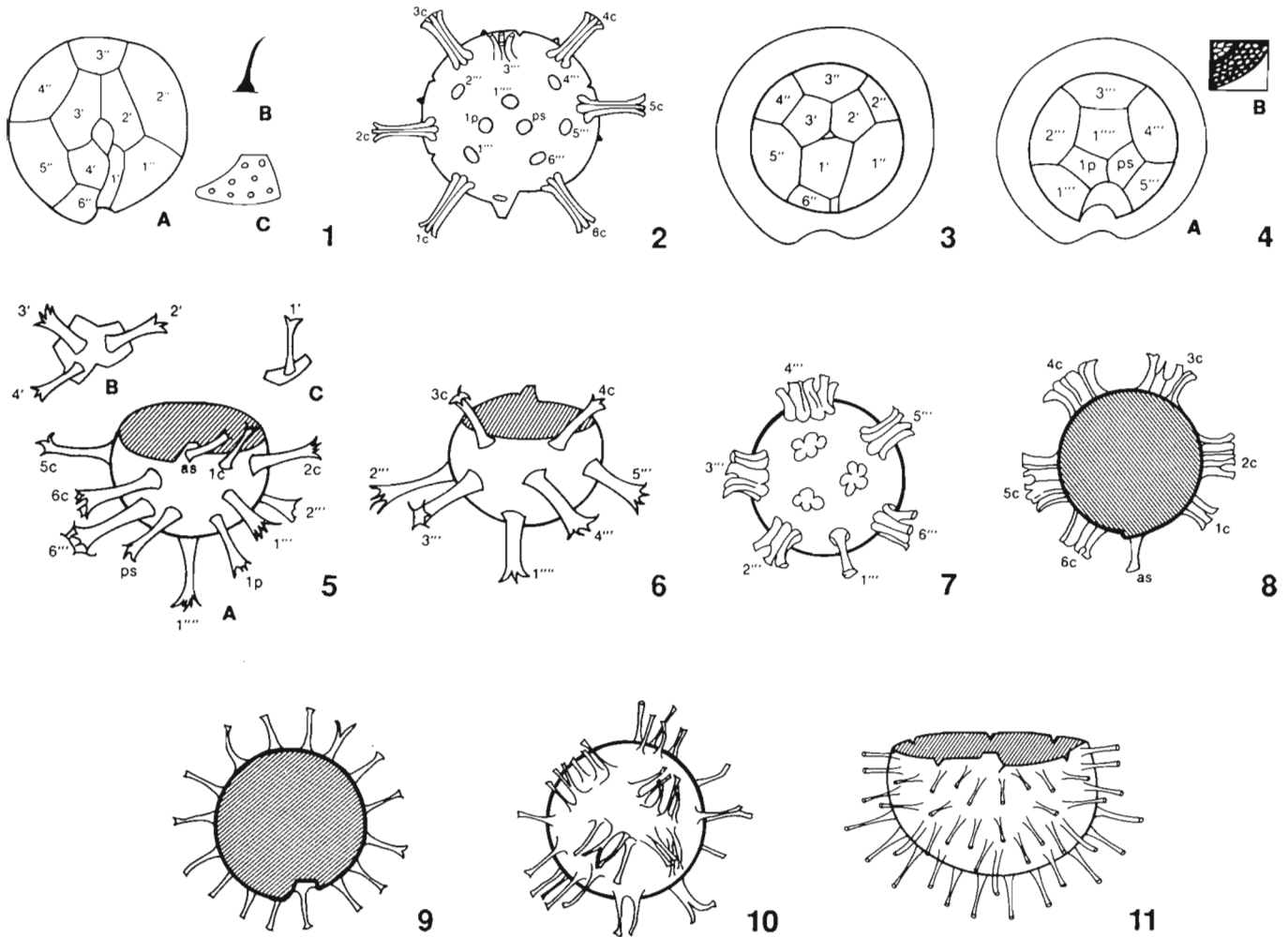
Figure 10. Group III, Subgroup IIIB, *HYSTRICHOSPHAERIDIUM* Subgroup. (cont.)

fenestrate distal parts that are joined to adjacent processes by simple, solid trabeculae. The species does not have paracingular processes. Specimens of *A. multispinosum* have numerous individual processes and/or process complexes, of which some are paracingular, as well as intricate networks of interconnecting trabeculae.

Group IV: *HETERAULACYSTA* and allied forms

Group characteristics

Cysts in Group IV (Fig. 11) are proximate to skolochorate, acavate with a subspherical body which bears one or more of the following features: parasutural ridges or crenulations with or without intervening perforations, intratabular processes, intratabular clusters of low projections, nontabular processes



1A-C *Eocladopyxis peniculata* (T-77), epicycst configuration (1A)

2. *Homotryblium plectilum* (T-40), epicycst configuration

3,4A-B *Heteraulacysta porosa* (T-74), epicycst and hypocyst configuration (3 & 4)

5A-C,6 *Homotryblium tenuispinosum* (T-68), ventral and dorsal surfaces (5A & 6)

7,8 *Homotryblium vallum* (T-39), epicycst and cingular configurations, respectively

9,10 *Polysphaeridium congregatum* (T-50), cingular and hypocyst configurations, respectively

11. *Polysphaeridium zoharyi* (T-9), ventral surface of hypocyst

Figure 11. Group IV, *HETERAULACYSTA* Group.

or spines. The archeopyles are epicystal or hemicystal (combined apical and precingular) and the opercula, although polyplacoid, consist of either a single piece with ten contiguous paraplates (exclusive of preapicals), or eight opercular pieces comprising six disarticulated precingular paraplates, a single apical paraplate (1') and a contiguous apical piece (2'-4'). The paratabulation pattern approximates the tabulation on the modern genus *Goniodoma* Stein 1883 (*al. Triadinium* Dodge 1981); the hypocystal pattern is quinqueform. In *Homotryblum* and especially in *Polysphaeridium*, the paratabulation is more evident on the epicysts than on the hypocysts.

Species

Eocladopyxis peniculata Morgenroth 1966a
Heteraulacacysta porosa Bujak in Bujak et al., 1980
Homotryblum plectilum Drugg & Loeblich 1967
Homotryblum tenuispinosum Davey & Williams in Davey et al., 1966
Homotryblum vallum Stover 1977
Polysphaeridium congregatum (Stover 1977) Bujak et al., 1980
Polysphaeridium zoharyi (Rossignol 1962) Bujak et al., 1980

Comments and/or guides to identification

Heteraulacacysta porosa differs from all of the other species in this group by having a hemicystal operculum and perforations (pores) on the cingular flanges and in all intervening areas between parasutural features. The paratabulation is expressed by the parasutural features. All other species in Group IV have opercula consisting of eight opercular pieces and parasulcal tabs are always present. Specimens of *Homotryblum* have intratabular processes, one per paraplate, and species are based primarily on differences in the construction, shape and proportions of the processes. *Homotryblum tenuispinosum* has a smooth to finely granular body and tubular processes that are expanded both proximally and distally, but more so distally. Also, the distal ends have serrate or aculeate margins. The processes may be virtually indistinguishable from those on *Hystrichosphaeridium tubiferum* and in fact, specimens of *Homotryblum tenuispinosum* have been misidentified as *Hystrichosphaeridium tubiferum*. Most processes on *Homotryblum plectilum*, at least the wider ones, consist of generally four or more tubules whose bases form a rosette pattern and whose distal ends commonly splay outwards, or expand slightly, or both. The body wall is thin and smooth or faintly ornamented. From time to time various authors have considered *H. plectilum* as the junior synonym of the Australian species *Homotryblum floripes* (Deflandre & Cookson 1955) Stover 1975. The southern hemisphere form, in contrast to the typically northern hemisphere *H. plectilum*, has a distinctly granular body in which the periphragm is about twice as thick as the endophragm. To the best of our knowledge, *H. floripes* is a strictly southern hemisphere species. *Homotryblum vallum* is similar to *H. plectilum*, but differs from the latter species in having wide, taeniate paracingular processes rather than simple, narrow ones. In

general, specimens of *H. vallum* have shorter processes than those on *H. plectilum*, however, transitional forms between the two species are known.

The processes on species of *Polysphaeridium* are generally nontabular and those on the epicysts tend to be somewhat clustered, although the clarity of the individual intratabular clusters varies considerably. For example, on specimens of *Polysphaeridium zoharyi* the processes tend to be evenly distributed with little indication of intratabular clustering. In addition, the processes rarely merge proximally with adjacent ones. On specimens of *P. congregatum*, however, intratabular clustering is fairly evident and within the clusters, the process bases frequently merge. In general, processes on *P. zoharyi* are short, tubular and with expanded tips, whereas those of *P. congregatum* are longer, tapered and less flared distally. The hypocysts of specimens of *Homotryblum* and *Polysphaeridium*, unlike their epicysts, do not separate into several pieces but remain intact. *Eocladopyxis peniculata* has acuminate nontabular processes that are evenly distributed over the entire body. The epicysts normally disaggregate into eight piece opercula and the hypocysts may likewise disarticulate along some or all parasutures into a variable number of pieces. In this respect, specimens of *Eocladopyxis peniculata* differ from those of *Homotryblum* and *Polysphaeridium*, as well as in possessing acuminate processes.

Group V: MUDERONGIA and allied forms

Group characteristics

Cysts in Group V (Fig. 12) are proximate to proximochorate, acavate or cavate, dorsoventrally flattened and with an offset parasulcal notch. Outlines of autophragm or periphragm are basically ceratioid; apical and antapical horns are nearly always present and one or two cingular/postcingular horns may be reduced to very well developed. Cornucavation is clearly evident on some forms, others may be circumcavate or acavate. Archeopyles are apical, margins are angular (zigzag) with the first precingular paraplate characteristically planate anteriorly; opercula are tetraplacoid, contiguous and typically free. The paratabulation is generally expressed incompletely by the archeopyle margin (first precingular paraplate is planate) together with faint to conspicuous, inconsistently-occurring parasutural features. Other ornamentation features are absent or of low to moderate relief and generally not confined parasuturally.

Species

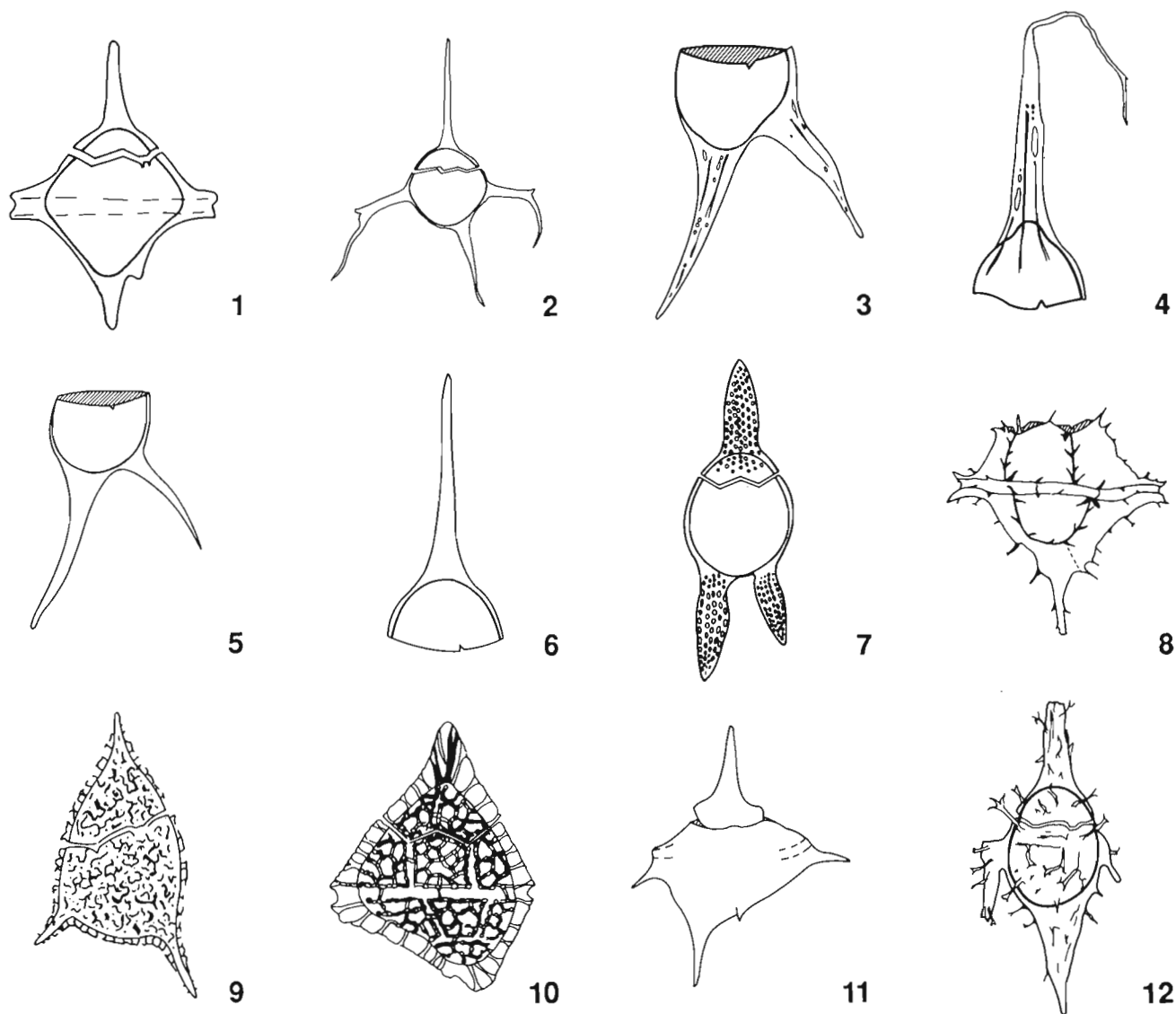
Muderongia simplex Alberti 1961
Muderongia tetracantha (Gocht 1956) Alberti 1961
Odontochitina costata Alberti 1961 emended Clarke & Verdier 1967
Odontochitina operculata (Wetzel 1933) Deflandre & Cookson 1955
Odontochitina porifera Cookson 1956
Phoberocysta neocomica (Gocht 1957) Millioud 1969 emended Helby 1987
Pseudoceratium pelliferum Gocht 1957

Pseudoceratium polymorphum (Eisenack 1958) Bint 1986
Vesperopsis spp.
Xenascus spp.

Comments and/or guides to identification

Separation of species of *Muderongia* is based on the number of horns (4 vs. 5), the shape, size and amount of posterior deflection of the cingular/postcingular horns and to a much lesser extent, the proportions of the horn lengths and body size.

Muderongia simplex has five horns of which the right antapical horn is reduced considerably. The cingular/postcingular horns are relatively short, wide, with terminal medial notches, and are not deflected posteriorly. In contrast, *Muderongia tetracantha* has four horns (only one antapical horn) and its cingular/postcingular horns are relatively long, narrow and inclined posteriorly, especially those parts of the horns that extend beyond the medial notches. The basic morphology of *Phoberocysta neocomica* is like that of *Muderongia simplex* except that the former has much shorter cingular/postcingular horns and scattered



1. *Muderongia simplex* (C-94), dorsal surface
2. *Muderongia tetracantha* (C-83), ventral surface
- 3,4 *Odontochitina costata* (C-39), ventral surface and operculum
- 5,6 *Odontochitina operculata* (C-35), ventral surface and operculum

7. *Odontochitina porifera* (C-51), dorsal surface
8. *Phoberocysta neocomica* (C-88), dorsal surface
9. *Pseudoceratium pelliferum* (C-85), dorsal surface
10. *Pseudoceratium pelliferum* (C-73), dorsal surface
11. *Vesperopsis* sp. (C-66), ventral surface
12. *Xenascus* sp. (C-32), ventral surface

Figure 12. Group V, MUDERONGIA Group.

processes. Specimens of *Odontochitina* have three horns – one apical and two antapical horns, or one postcingular and one antapical horn. Species are based on the shape and construction of the horns and also on their length relative to the size of the body. The horns of *Odontochitina operculata* are long and gently tapered, smooth or faintly ornamented, and may contain a few perforations; *O. costata*, which is similar in size and shape to *O. operculata*, has longitudinal ribs or markings together with commonly occurring circular to elliptical openings along the horns. The horns on *O. porifera*, compared to the other two species, are short with numerous perforations that are generally aligned in imperfect longitudinal rows. The apical horn is wider and may be slightly longer than the antapical horns.

Specimens of *Pseudoceratium* normally have asymmetrically triangular outlines accentuated by single apical, antapical and right cingular/postcingular horns. A less well-developed left cingular/postcingular horn may be present. *Pseudoceratium pelliferum* has uniformly distributed, short projections whose distal ends may be joined here and there to form an incomplete ectophragm. As the name implies, specimens of *Pseudoceratium polymorphum* vary in shape, ranging from nearly circular with a short apical horn to asymmetrically triangular with obvious horns; its projections are more widely spaced than those of *P. pelliferum* and may form a reticulum. On *Xenascus* spp. the apical and left antapical horns are usually prominent with relatively wide bases; the cingular/postcingular horn has a short horizontal component and a longer posterior part. The base of this compound process may be very broad and may merge with that of the antapical horn. Processes, mostly gonial, are sparse to frequent, and these help define the paratabulation. The final taxon in this group, *Vesperopsis* spp., has a single wall layer that is very thin and commonly folded. Species supposedly have adnate opercula, but they are more often than not separated from the rest of the cyst. Paratabulation is very rarely discernible, except occasionally under the SEM.

Group VI: GLAPHYROCYSTA and allied forms

Group characteristics

Cysts in Group VI (Fig. 13) are proximate, proximochorate or skolochorate and have lenticular bodies possessing offset parasulcal notches. Cavation, when present, is circumcavate or gymnocavate. The surface of proximate and proximochorate cysts may be ornamented with relatively short nontabular and or penitabular processes or projections. In contrast, skolochorate cysts bear relatively long processes, process complexes, or gonial processes. The long processes may be connected distally by trabeculae and the ornamentation may be reduced or absent on the middorsal and midventral surface, regardless of the type of ornamentation. Archeopyles are apical with contiguous, tetraplacoid opercula whose transverse dimensions are greater than their dorsal-ventral dimensions. First precingular paraplates are camerate. The presumed gonyaulaccean paratabulation is rarely completely delineated.

Species

- Areoligera? semicirculata* (Morgenroth 1966b) Stover & Evitt 1978
Areoligera senonensis Lejeune-Carpentier 1938
Cerbia tabulata (Davey & Verdier 1974) Below 1981
Chiropteridium mespilanum 'complex'
Circulodinium distinctum (Deflandre & Cookson 1955) Jansonius 1986
Glaphyrocysta exuberans (Deflandre & Cookson 1955) Stover & Evitt 1978 emended Sarjeant 1986
Glaphyrocysta ordinata (Williams & Downie in Davey et al., 1966) Stover & Evitt 1978
Membranophoridium aspinatum Gerlach 1961 ex Gocht 1969
Palynodinium grillator Gocht 1970a
Senoniasphaera inornata (Drugg 1970) Stover & Evitt 1978
Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976

Comments and/or guide to identification

Specimens of *Circulodinium distinctum* are proximochorate and have numerous, nontabular processes. Most processes are separated from each other, although some adjacent processes may be joined distally. The posterior margin of the body can be slightly lobate. The processes on *Cerbia tabulata* are similar to those on *Circulodinium distinctum*, but they are aligned in penitabular rows which essentially delineate the paratabulation. In addition the processes in the intratabular areas on *Cerbia tabulata* are sparser and shorter than the penitabular ones. Specimens of *Senoniasphaera* are proximate, have smooth or faintly ornamented endocysts and thinner pericysts that are separated peripherally (circumcavate). In *Senoniasphaera jurassica* the width of the separation is fairly constant, whereas in *S. inornata* the pericoel increases in width antapically, and the posterior margin can be lobate. We regard *Meiourugonyaulax staffinensis* Gitmez 1970 as a junior taxonomic synonym of *Senoniasphaera jurassica*.

Specimens of *Membranophoridium aspinatum* have a smooth or faintly striate sometimes perforate periphragm, which (1) is closely appressed to the endophragm over most of the ventral and dorsal surfaces, (2) extends narrowly to moderately beyond the lateral limits of the endocyst, and (3) is antapically bilobate. Longitudinal, slightly arcuate markings near the margins of the body mark the locations where the periphragm separates from the endophragm. When the periphragm is moderately to deeply incised to the extent that spines and/or processes of various widths are developed, the specimens are assigned to the *Chiropteridium mespilanum* 'complex'.

Specimens of *Areoligera senonensis* are generally skolochorate and possess process complexes with low bases from which arise a few to several narrow, simple processes with usually blunt tips. The process complexes are arcuate (open towards the paracingulum) and neither the complexes nor the separate processes are connected distally. The species *A. semicirculata* is provisionally assigned to *Areoligera* because its processes generally have wide, unincised stems

and the individual processes are more clearly discernible than on most species of *Areoligera*. However, some processes (mainly those on the hypocyst) are arcuate in cross-section. The basic morphology of *Areoligera* is seen also in the skolochorate form *Glaphyrocysta ordinata*, but on it the process complexes are connected distally, the individual complexes tend to be less well defined, and the bases are

significantly higher than those of *Areoligera senonensis*. The integrity of the individual process complexes is even less evident on specimens of *Glaphyrocysta exuberans*. This species has numerous narrow processes (apparently several per complex, but this is difficult to demonstrate conclusively) that are connected distally by a perforate to fenestrate, incomplete ectophragm. The last species in Group VI is

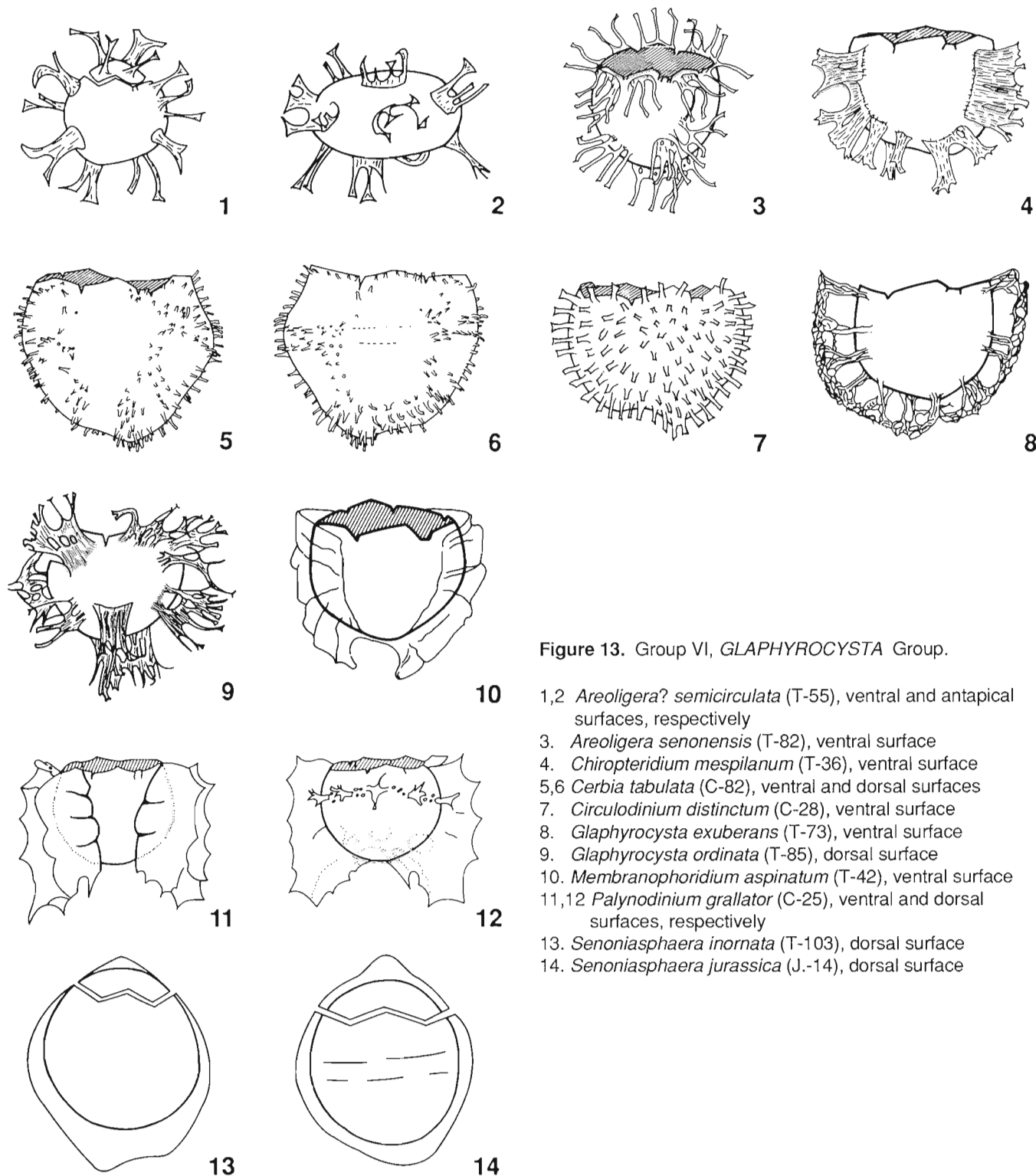
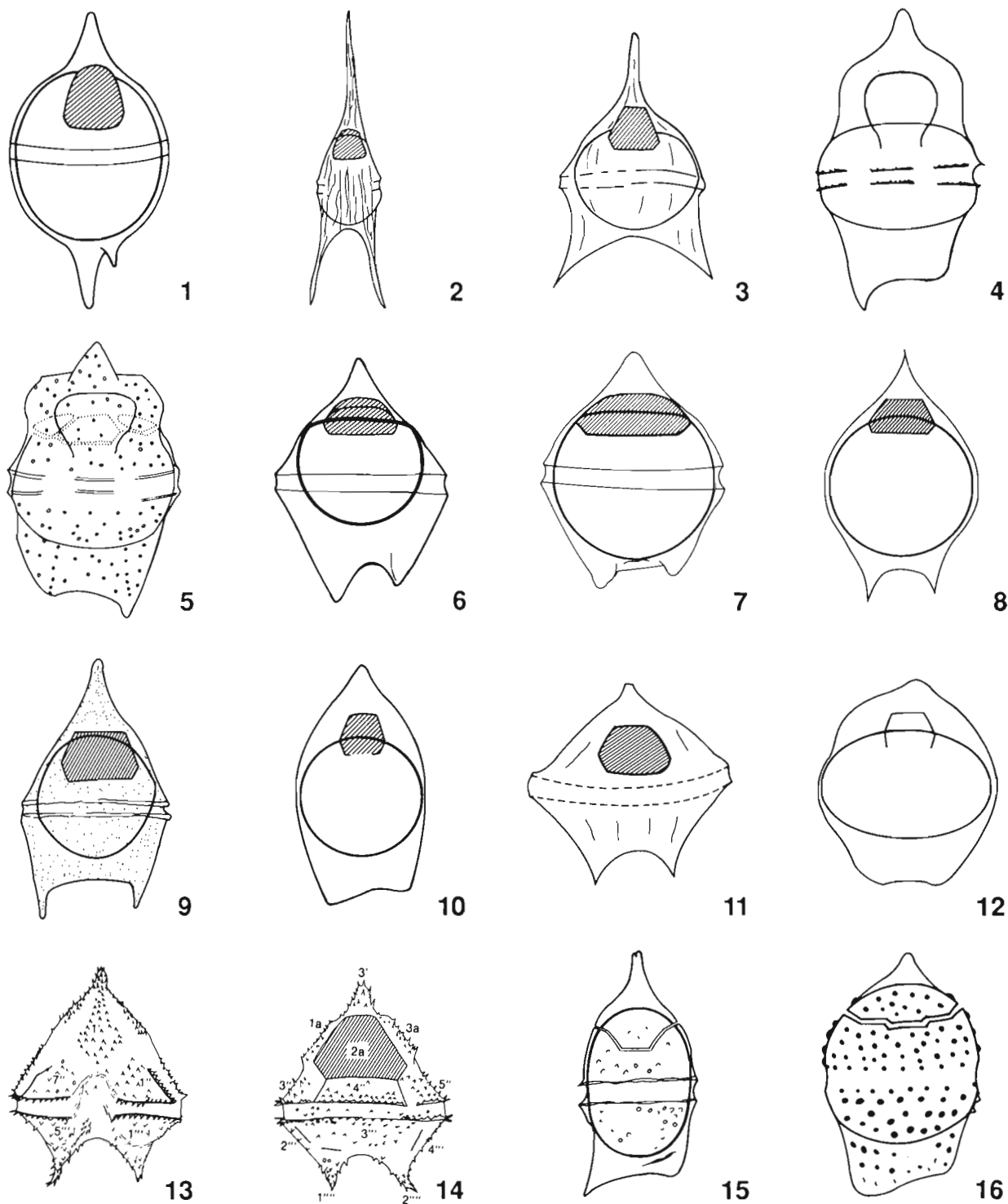


Figure 13. Group VI, GLAPHYROCYSTA Group.

- 1,2 *Areoligera? semicirculata* (T-55), ventral and antapical surfaces, respectively
3. *Areoligera senonensis* (T-82), ventral surface
4. *Chiropteridium mespilum* (T-36), ventral surface
- 5,6 *Cerbia tabulata* (C-82), ventral and dorsal surfaces
7. *Circulodinium distinctum* (C-28), ventral surface
8. *Glaphyrocysta exuberans* (T-73), ventral surface
9. *Glaphyrocysta ordinata* (T-85), dorsal surface
10. *Membranophoridium aspinatum* (T-42), ventral surface
- 11,12 *Palynodinium grallator* (C-25), ventral and dorsal surfaces, respectively
13. *Senoniasphaera inornata* (T-103), dorsal surface
14. *Senoniasphaera jurassica* (J.-14), dorsal surface



All views of dorsal surfaces unless otherwise stated

1. *Andalusiella* sp. (T-101)

2. *Cerodinium diebelii* (T-106)

3. *Cerodinium speciosum* (T-86)

4. *Chatangiella ditissima* (C-44)

5. *Chatangiella verrucosa* (C-42)

6.-8. *Deflandrea phosphoritica* (T-45)

9. *Deflandrea oebisfeldensis* (T-91)

10. *Isabelidium* sp. (C-31)

11. *Lejeunecysta* sp. (T-8)

12. *Manumiella? cretacea* (T-107)

13,14. *Lentinia serrata* (T-70), ventral surface (13)

15. *Ovoidinium cinctum* (C-67)

16. *Ovoidinium verrucosum* (C-65)

Figure 14. Group VII, *DEFLANDREA* Group.

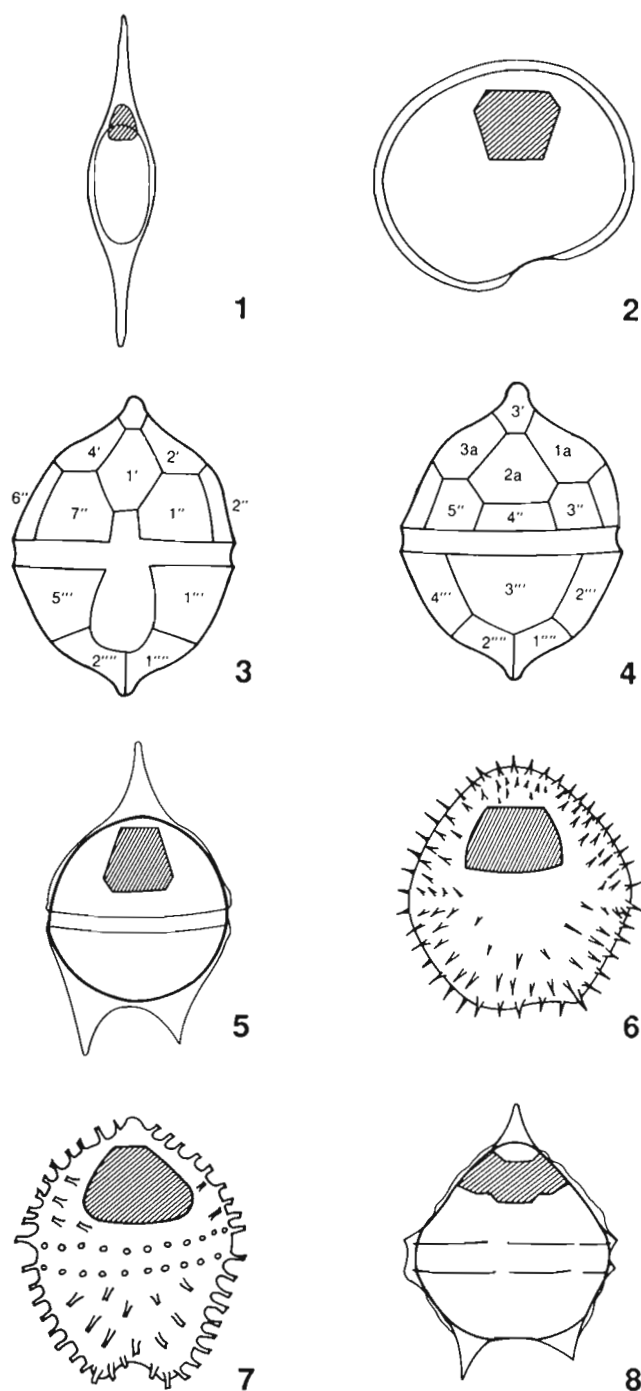


Figure 15. Group VII, *DEFLANDREA* Group. (cont.)

All views of dorsal surfaces unless otherwise stated

1. *Palaeocystodinium golzowense* (T-26)
2. *Selenopemphix* sp. (T-7), apical surface
- 3,4 *Phthanoperidinium* sp. (T-51), ventral surface (3)
5. *Senegalinium* sp. (T-59)
6. *Sumatradinium* sp. (T-22)
7. *Trinovantedinium capitatum* (T-4)
8. *Trithyrodinium* sp. (T-99)

Palynodinium grallator. This proximochorate to skolo-chorate species has a lenticular body with conspicuous and numerous gonal processes. Somewhat less evident are two inflated features that are confined to the right and left ventral surfaces and which resemble the sacci on bisaccate gymnosperm pollen, hence, the term gymnocavate, when specimens are observed in apical-antapical views.

Group VII: *DEFLANDREA* and allied forms

Group characteristics

Cysts in Group VII (Fig. 14, 15) are generally proximate, rarely proximochorate, and usually dorso-ventrally compressed. Outlines differ considerably – shapes are fusiform, subcircular, elliptical to peridinioid, and typically with some apical and antapical horn development. Cavation, when present, is mainly bicavate or circumcavate, rarely otherwise. The archeopyles are mostly intercalary with middorsal, monoplacoid or triplacoid opercula. They are free or adnate posteriorly, and the relative sizes and shapes of the monoplacoid opercula differ more between genera than within them. When periarcheopyles and endoarcheopyles are discernible, their opercula are similar if not identical, except for species of *Chatangiella* in which the periopercula are monoplacoid and the endopercula are triplacoid. On species of *Ovoidinium* the archeopyles are combined apical and intercalary with polyplacoid, contiguous, free opercula. Paratabulation is commonly indicated incompletely; less frequently it is expressed completely by intratabular, pandasutural, or penitabular features of low relief. When sufficiently delineated, the paratabulation is peridiniacean and the dorsal epicystal pattern follows the hexa-style configuration.

Species

- Andalusiella* spp.
Cerodinium diebelii (Alberti 1959) Lentin & Williams 1987
Cerodinium speciosum (Alberti 1959) Lentin & Williams 1987
Chatangiella ditissima (McIntyre 1975) Lentin & Williams 1976
Chatangiella verrucosa (Manum 1963) Lentin & Williams 1976
Deflandrea oebisfeldensis Alberti 1959
Deflandrea phosphoritica 'complex'
Isabelidinium spp.
Lejeunecysta spp.
Lentini *serrata* Bujak in Bujak et al., 1980
Manumiella? cretacea (Cookson 1956) Bujak & Davies 1983
Ovoidinium cinctum (Cookson & Eisenack 1958) Davey 1970
Ovoidinium verrucosum (Cookson & Hughes 1964) Davey 1970
Palaeocystodinium golzowense Alberti 1961
Phthanoperidinium spp.
Selenopemphix spp.

Senegalinium spp.
Sumatradinium spp.
Trinovantedinium capitatum Reid 1977
Trithyrodinium spp.

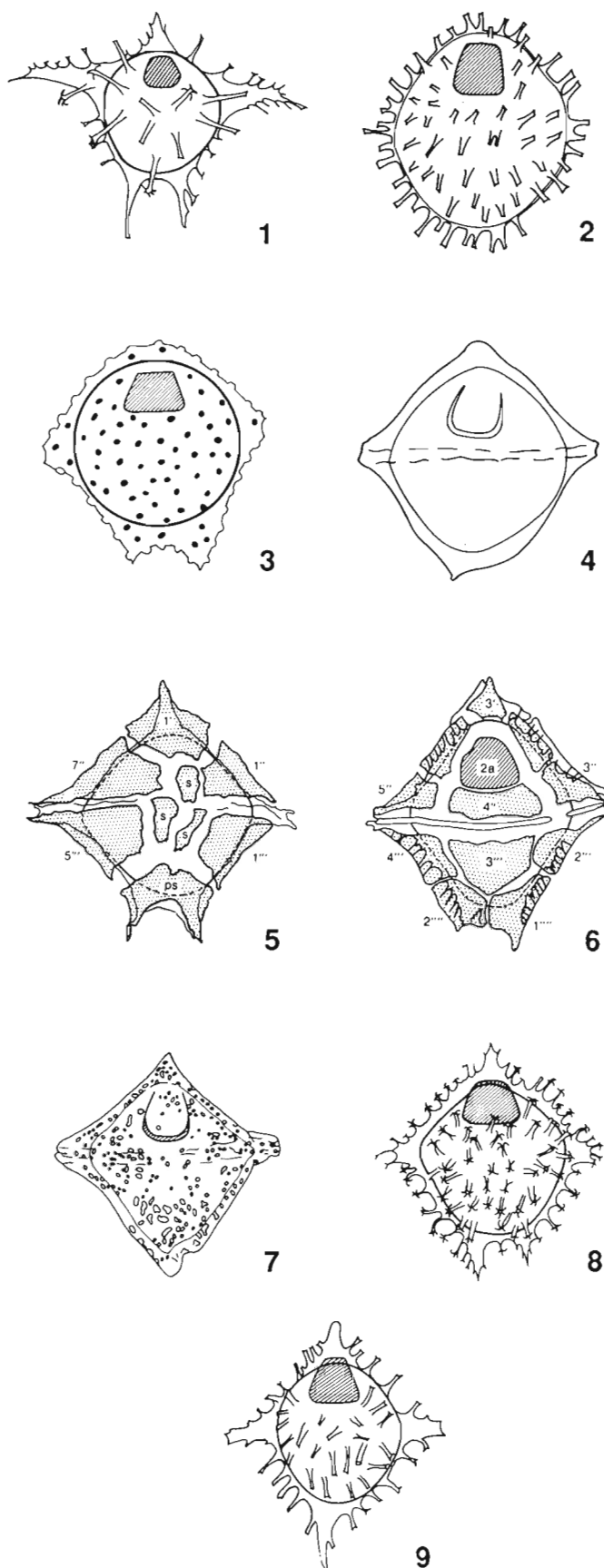
Comments and/or guides to identification

Specimens of *Lejeunecysta* spp. consist of a single wall layer (autophragm) that is often thin, commonly folded and generally smooth or faintly ornamented. In outline, specimens vary from roundly triangular to peridinioid. The middorsal intercalary archeopyle is centred longitudinally and its posterior margin is usually very close to the paracingulum. The same general features apply equally well to specimens of *Selenopemphix* spp. except that the archeopyles in *Selenopemphix* spp. are not centred longitudinally, but are offset to the left by about half the widths of the opercula. Specimens of *Trinovantedinium capitatum* are similar in shape to those of *Lejeunecysta* spp. and possess longitudinally-centred, middorsal intercalary archeopyles. However, they differ from *Lejeunecysta* spp. in having nontabular spines with capitate tips. Specimens of *Sumatradinium* spp. are ornamented with nontabular features of moderate to low relief and show little, if any, horn development antapically. Their intercalary archeopyles are centred longitudinally. Some specimens appear to have two wall layers whereas others evidently have only one wall layer. The remaining species in Group VII have two wall layers and with few exceptions, are clearly cavate.

Specimens of *Palaeocystodinium golzowense* are fusiform; their endocysts are elongate ellipsoidal and the pericysts are close to the endocysts except at their narrow ends, where the pericysts form long and narrow apical and antapical horns. Although small in size relative to the length of the endocysts, the archeopyle is longer than wide. Specimens of *Manumiella? cretacea* are bicavate, and the outlines of the pericysts are broadly elliptical with little or no indications of horns. The archeopyle is small and the operculum is adnate posteriorly. In contrast, specimens of *Isabelidinium* spp. are bicavate or circumcavate and are more elongate longitudinally than those of *Manumiella? cretacea*. In addition, horn development, although slight, is better in *Isabelidinium* spp. and the monoplacoid opercula may be adnate or free. Paracingula are not evident on specimens of *M.? cretacea* and *Isabelidinium* spp. On *Chatangiella ditissima* and *Chatangiella verrucosa* the paracingula are bordered anteriorly by seven discontinuous ridges and posteriorly by five discontinuous ridges. These anterior and posterior ridges are interpreted as representing the adcingular positions of the precingular and postcingular paraplates respectively. The periarcheopyles are omegaform, relatively wide and their opercula are monoplacoid; endopercula are triplacoid and the individual paraplates are more often than not in place. Both species are bicavate. *Chatangiella ditissima* has an elongate elliptical outline with short apical and left antapical horns and gently sloping antero-lateral margins. The periphragm is essentially smooth. The outline of *C. verrucosa* is somewhat quadrate with short apical and left antapical horns and prominent, angular "shoulders". Moreover, the periphragm surface is granulate to verrucate.

Specimens of *Andalusiella* spp. are cornucavate; the body is generally broadly ellipsoidal with an apical and a medial antapical horn of at best only moderate length. A short, spur-like protrusion extends from at or near the base of the antapical horn. The intercalary archeopyle is also of moderate size, about as wide as high, and its monoplacoid operculum is typically free, although the opercula are often in place. The archeopyles and opercula on *Senegalinium* spp. are like those on *Andalusiella* spp. However, *Senegalinium* spp. differs from *Andalusiella* spp. in being bicavate or possibly circumcavate, and in possessing two moderately to well-developed antapical horns. The horns of *Cerodinium speciosum* are usually longer than those on *Senegalinium* spp. and the antapical horns project more laterally. Also, traces of paratabulation are commonly discernible on the periphragm of *C. speciosum* and the archeopyle tends to be wider than on most specimens of *Senegalinium*. *Cerodinium diebelii* is cornucavate and its horns are long, narrow and evenly tapered. The endocysts are narrowly ellipsoidal. Longitudinal striae or very narrow folds cover most of the body, but they rarely extend beyond the limits of the endocyst. The archeopyle is large, relative to the body size, and is about as wide as it is high. Specimens of *Lentinia serrata* are characterized in having pyramidal epicysts that are larger than the hypocysts, short apical and antapical horns and exceptionally large archeopyles, which extends over an appreciable part of the dorsal epicystal surface. Clusters and/or scattered spinules, which may delineate the paratabulation, occur on the pericysts.

The type species of *Deflandrea*, *D. phosphoritica*, is one of the most commonly reported Paleogene species, and judging from the illustrations, one of the most varied. The more obvious variables include outline of the pericyst, size of endocyst and its relation to the pericyst, and the clarity and amount of ornamentation. The last also has a bearing on how well and how completely the paratabulation is expressed. The one constant feature among specimens of *D. phosphoritica* is the archeopyle and its attendant operculum. The archeopyle is middorsal and its operculum, which is typically free, is composed of both the periphragm and endophragm. These remain joined posteriorly but are separated anteriorly. In overall shape, the opercula are wider than high, and the perioperculum is higher than the endoperculum, however, the endoperculum is nearly always the thicker. Specimens most similar to the type material of *D. phosphoritica* are bicavate or circumcavate with relatively small endocysts; the epicysts are triangular in outline, and the hypocysts are widest a short distance below the paracingulum, then they narrow posteriorly and form two antapical horns separated by a medial posterior concavity. Intratabular clusters of minute conia separated by smooth pandasuturate areas define the peridiniacean paratabulation. Specimens of *Deflandrea oebisfeldensis* are similar to those of *D. phosphoritica*, but the former has a narrower outline, a more elongate epicyst, and the lateral sides of the hypocysts do not widen then narrow below the paracingulum. Instead the sides of the hypocysts are nearly straight and the median concavity is less concave. Thus, antapical horns are poorly developed.



The endocysts of *Trithyrodinium* spp. are usually subspherical and of moderate thickness, whereas the pericysts, which may form short apical and antapical horns, are typically thin, wrinkled or folded, and easily torn. Accordingly, many specimens of *Trithyrodinium* spp. consist of only the endocysts. These have intercalary archeopyles whose triplacoid opercula are disarticulated and free. Other indications of paratabulation are customarily lacking. The paratabulation on specimens of *Phthanoperidinium* spp. is expressed by penitabular, or parasutural features, or both, and is normally complete. The archeopyle is conventionally intercalary and the opercula may be monoplacoid (usually), or diplacoid, or triplacoid; occasionally, a keyhole shaped archeopyle is formed by the release of the middorsal intercalary and the subjacent precingular paraplates.

The final two species in the *DEFLANDREA* Group, *Ovoidinium cinctum* and *O. verrucosum*, are bicavate, elongate, with poor to moderate horn development, and have combined apical-intercalary archeopyles. The opercula are polyplacoid, consisting evidently of four apical and certainly of three intercalary paraplates, and they are contiguous and free. The periphragm on *O. cinctum* is smooth or faintly ornamented, and that of *O. verrucosum* is granulate to verrucate.

Group VIII: WETZELIELLA and allied forms

Group characteristics

Cysts in Group VIII (Fig. 16) are proximate to proximochoate, generally circumcavate and compressed dorsoventrally. Outlines are subcircular, quadrangular, to markedly peridinioid and with or without lateral (cingular) horns. The periphragm may be smooth, or ornamented with features of low relief, or have nontabular or intratabular clusters of processes. Archeopyles are intercalary, opercula are middorsal and monoplacoid, free or adnate anteriorly. When periarcheopyles and endoarcheopyles are discernible, the corresponding opercula are also monoplacoid. The paratabulation may be expressed incompletely by the archeopyle alone, or with the paracingulum, or it may be expressed completely by a combination of pandasutural and

Figure 16. Group VIII, *WETZELIELLA* Group.

All views of dorsal surfaces unless otherwise stated

1. *Apectodinium augustum* (T-93)
2. *Apectodinium homomorphum* (T-76)
3. *Dracodinium condylos* (T-79)
4. *Rhombodinium draco* (T-56)
- 5,6 *Kisselovia coleothrypta* 'complex' (T-63), ventral surface (5)
7. *Rhombodinium porosum* (T-71)
8. *Wetzeliella articulata* (T-64)
9. *Wetzeliella symmetrica* (T-47)

intratabular features, including simulate complexes. When complete, the paratabulation is peridiniacean with a quadra-style dorsal epicystal pattern.

Species

Apectodinium augustum (Harland 1979c) Lentin & Williams 1981

Apectodinium homomorphum 'complex'

Dracodinium condylos (Williams & Downie in Davey et al., 1966) Costa & Downie 1979

Kisselovia coleothrypta 'complex'

Rhombodinium draco Gocht 1955

Rhombodinium porosum 'complex'

Wetzeliiella articulata 'complex'

Wetzeliiella symmetrica 'complex'

Comments and/or guides to identification

The *WETZELIELLA* Group represents an important collection of species whose occurrences are restricted to the Paleogene. Components of the Group have also been used as the basis for, or as parts of, Tertiary dinoflagellate zonation. Separation of taxa at the generic level is fairly straightforward (see below), however, such is not the case for many of the approximately 70 species currently attributed to the Group. With few exceptions, the more commonly occurring species in the genera listed above tend to have variable, overlapping interspecific features which frequently make for difficult and tentative species identifications.

On specimens of *Apectodinium* the endophragm is very thin and characteristically appressed or very close to the slightly thicker periphragm. Accordingly, cavation is difficult to discern and may be confined to small areas beneath the horns (cornucavate). Species in the *Apectodinium homomorphum* 'complex' are of moderate size and vary in shape from broadly ellipsoidal with poorly developed horns to peridinioid; in most the horns are not prominent. In contrast, *Apectodinium augustum* is relatively large and has conspicuously long, well-developed horns of which the two lateral horns are much nearer the apex than the antapex. On specimens of *Wetzeliiella*, the endophragm and periphragm are of similar thickness and wall separation is usually circumcavate, occasionally strongly cornucavate. Specimens in the *Wetzeliiella articulata* 'complex' have two antapical horns (the left horn is longer than the right horn), whereas those in the *Wetzeliiella symmetrica* 'complex' have a single antapical horn located near the longitudinal midline. The length of the antapical horn varies considerably. On specimens of *Dracodinium condylos* the endophragm is appreciably thicker than the periphragm (a characteristic of all *Dracodinium* species), which is ornamented with rather equally-spaced, low, rounded verrucae. Most other species in the genus have processes. Specimens of *Kisselovia* differ from those of *Wetzeliiella* in having simulate intratabular clusters of processes whose distal ends are connected by a generally reticulate trabeculum or an incomplete ectophragm. The latter is present on specimens in the *Kisselovia coleothrypta* 'complex', and on well-preserved examples a complete peridiniacean paratabulation pattern is reflected

with admirable fidelity. With rare exceptions, species of *Apectodinium*, *Wetzeliiella*, *Dracodinium* and *Kisselovia* possess processes which are formed exclusively by the periphragm and are arranged in intratabular clusters or are seemingly randomly disposed. Specimens of *Rhombodinium* lack processes, but may be uniformly ornamented with features of low positive or negative relief. For example, the periphragm of *Rhombodinium draco* is smooth to very faintly ornamented, whereas on specimens in the *Rhombodinium porosum* 'complex' it is finely to coarsely perforate.

Group IX: *RHAETOGONYAULAX* and allied forms

Group characteristics

Cysts in Group IX (Fig. 17) are proximate to proximochorate with variously shaped bodies: these are subspherical, elongate, or subtriangular and with or without constricted cingula. The archeopyle types are apical, intercalary, or combined and the opercula vary from monoplacoid to polyplacoid. The precingular paraplates are generally camerate, and anterior intercalary paraplates, when present, are usually bicamrate. On species whose epicystal and hypocystal paratabulation is known, the number of apical paraplates varies from four to six (4'-6'). The number of the anterior intercalary paraplates varies from three to five (3a-5a) and seven precingular paraplates (7'') are always present. Two antapical paraplates are present. None of the genera and species in the *RHAETOGONYAULAX* Group has a paratabulation formula that conforms to the standard gonyaulacacean or peridiniacean models.

Species

Dapcodinium priscum Evitt 1961a emended Below 1987a

Mancodinium semitabulatum Morgenroth 1970 emended Below 1987b

Moesiodinium raileanui Antonescu 1974

Parvocysta spp.

Phallocysta eumekes Dörhöfer & Davies 1980 emended Below 1987a

Rhaetogonyaulax rhaetica (Sarjeant 1963) Loeblich & Loeblich 1968 emended Below 1987a

Susadinium spp.

Sverdrupiella spp.

Comments and/or guides to identification

The paratabulation formulae for the above listed genera and species are given below.

Dapcodinium priscum: 4', 4a, 7'', 6c, 7''', 2''', 1p

Mancodinium semitabulatum: 4', 4a, 7'', (not expressed on hypocyst)

Moesiodinium raileanui: unknown

Parvocysta spp.: unknown or uncertain

Phallocysta eumekes: unknown, formula given by Dörhöfer & Davies (1980) is unsubstantiated

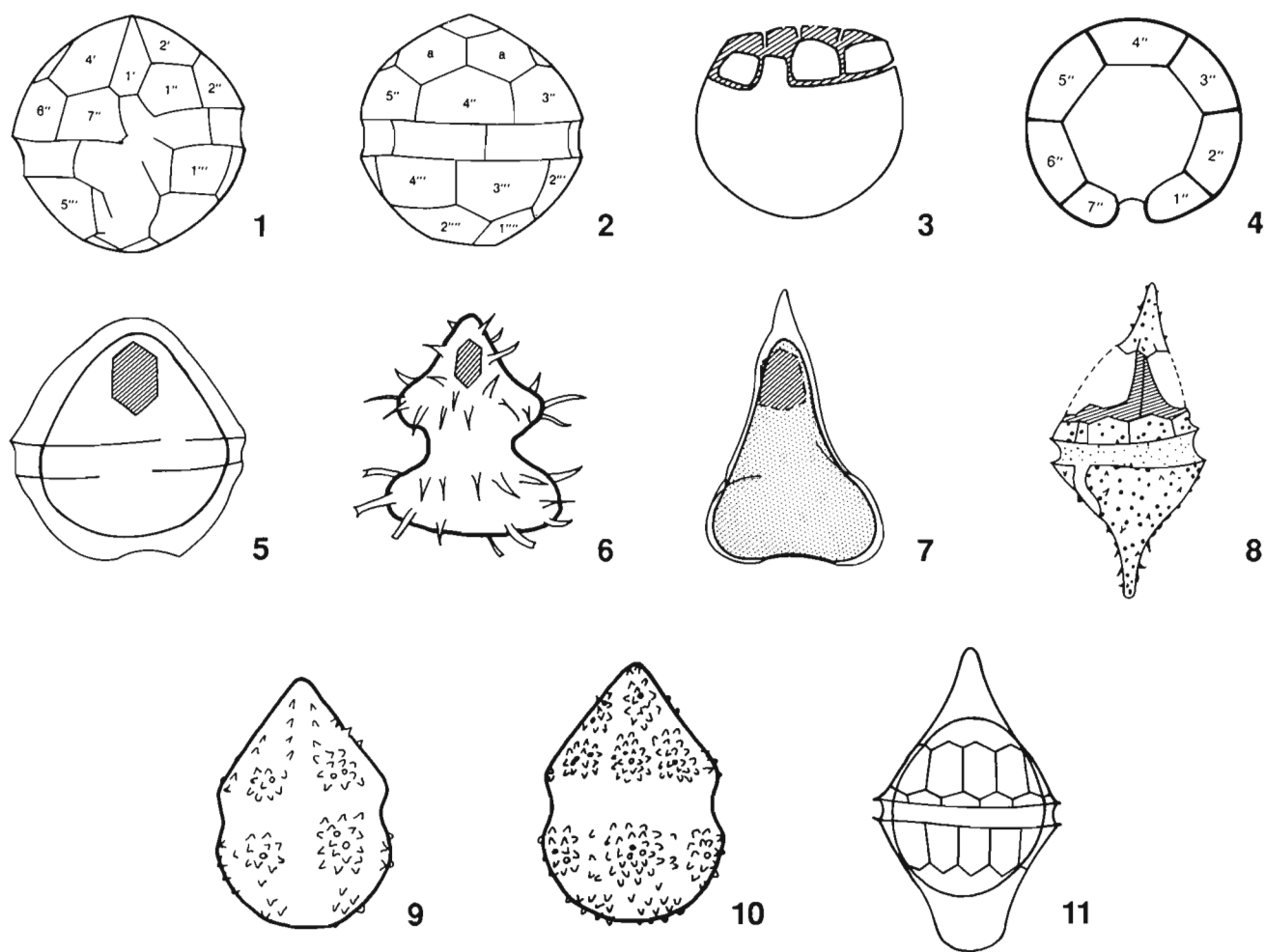
Rhaetogonyaulax rhaetica: 6', 5a, 7'', (not expressed on hypocyst)

Susadinium spp.: 5', 3a, 7'', 0c, 5''', 2''''

Sverdrupiella spp.: unknown

Within the *RHAETOGONYAULAX* Group, the least complex form is *Moesiodinium raileanui* which is circumcavate and has a faintly marked paracingulum and a monoplacoid bicamerate operculum. Specimens of *Phallocysta eumekes* vary from ovoidal to pear-shaped and lack indications of a paracingulum. Separation of the two wall layers is much greater anteriorly than posteriorly (essentially epicavate) and the operculum is apparently bicamerate and monoplacoid. The presence of diplacoid and triplacoid opercula and the complex paratabulation depicted by Dörhöfer and Davies (1980) remains unsubstantiated. *Parvocysta* spp. has a general pentagonal outline with an angular apex, which can be attenuated, and a generally constricted paracingular area. Various types of ornamentation are known, but only a single type is present on individual specimens, and opercula are bicamerate and monoplacoid.

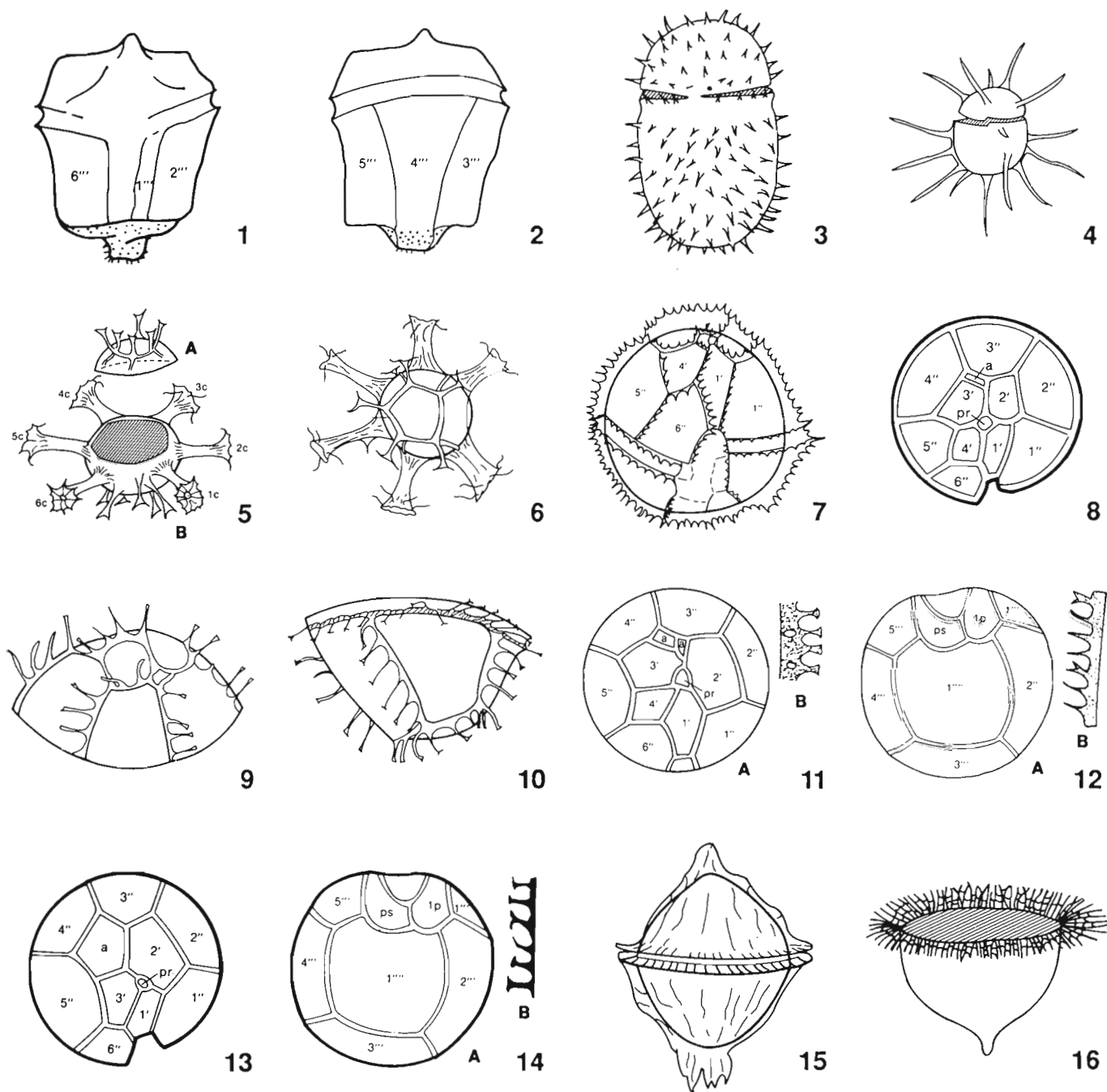
Other indications of paratabulation are lacking. Such is not the case with specimens of *Susadinium* spp., which are similarly shaped to those of *Parvocysta* spp. In *Susadinium* spp. local clusters of ornamentation or protrusions define the paratabulation cited above and the middorsal intercalary paraplate is bicamerate and the operculum is monoplacoid. Only the paratabulation of the epicyst is known for *Mancodinium semitabulatum* and because epicysts are commonly disarticulated, most specimens consist of only the hypocyst. Occasionally one or more of the precingular paraplates remains in place, but complete specimens are rare. Specimens of *Dapcodinium priscum* are subspherical, thin-walled and have the paratabulation indicated by parasutural markings. The type of archeopyle is uncertain, however, displaced apical and anterior intercalary paraplates have been observed. The subdivided



- 1,2 *Dapcodinium priscum* (J.-60), ventral and dorsal surfaces, respectively
 3,4 *Mancodinium semitabulatum* (J.-49), ventral and apical surfaces, respectively
 5. *Moesiodinium raileanui* (J.-53), dorsal surface
 6. *Parvocysta* sp. (J.-54), dorsal surface

7. *Phallocysta eumekes* (J.-52), dorsal surface
 8. *Rhaetogonyaulax rhaetica* (J.-61), ventral surface
 9,10 *Susadinium* sp. (J.-48), ventral and dorsal surfaces, respectively
 11. *Sverdrupiella* sp. (J.-64), dorsal surface

Figure 17. Group IX, *RHAETOGONYAULAX* Group.



1,2 *Bejuia polygonalis* (J.-46), ventral and dorsal surfaces, respectively

3. *Biorbifera johnewingii* (C-95), dorsal surface

4. *Cauca parva* (C-74), ventral surface

5A-B,6 *Callaiosphaeridium asymmetricum* (C-47), oblique apical surfaces and dorsal surface, respectively

7,8 *Ctenidodinium continuum* (J.-38), ventral surface with septa (7), epicystal surface without septa (8)

9,10 *Ctenidodinium elegantulum* (C-89), dorsal surfaces of epicyst (9) and hypocyst (10)

11A,B *Ctenidodinium ornatum* (J.-32), epicystal configuration (11A)

12A,B *Dichadogonyaulax? panneae* (C-99), hypocystal configuration (12A)

13,14A-B *Dichadogonyaulax culmula* (C-98), epicystal (13) and hypocystal (14A) configurations

15. *Glossodinium dimorphum* (J.-15), dorsal surface

16. *Wanaea* sp. (J.-35), lateral surface

Figure 18. Group X, CTENIDODINIUM Group.

paracingulum and the presence of four anterior and one posterior intercalary paraplates differentiate *D. priscum* from typical peridiniaceans.

Specimens of *Sverdrupiella* spp. vary in shape from biconical (spindle-shaped) to broadly ellipsoidal, and most tend to be longer than wide. The precingular paraplates are considerably shorter than the bicameral intercalary paraplates, and generally three or less of the latter may be released during archeopyle formation. Other indications of paratabulation are lacking and the various types of ornamentation are rarely conspicuous. Specimens of *Rhaetogonyaulax rhaetica* are also biconical and the paratabulation is expressed on the epicyst only. Its basic paratabulation is like that of *Sverdrupiella* spp., except that on *Rhaetogonyaulax rhaetica* the operculum is typically formed of more than three intercalary paraplates, and in some specimens all of the epicyst anterior to the precingular paraplates is involved in archeopyle formation.

Group X: CTENIDODINIUM and allied forms

Group characteristics

Cysts in Group X (Fig. 18) are proximate to proximochorate, acavate, and have variously shaped bodies: these are subspherical, ellipsoidal, subconical and subquadrate. The surface may be ornamented with nontabular, parasutural, intratabular or gonal features or a combination of such features. Additionally, the ornamentation may be confined to a specific area, for example, the paracingular area. Archeopyles are epicystal, combined apical and precingular, rarely combined apical, intercalary and precingular. When anterior intercalary paraplates are present, they are inconspicuous. Opercula are contiguous, may or may not indicate constituent paraplates, and are typically free. Paratabulation, when expressed, is gonyaulacacean with a standard sexiform hypocystal pattern.

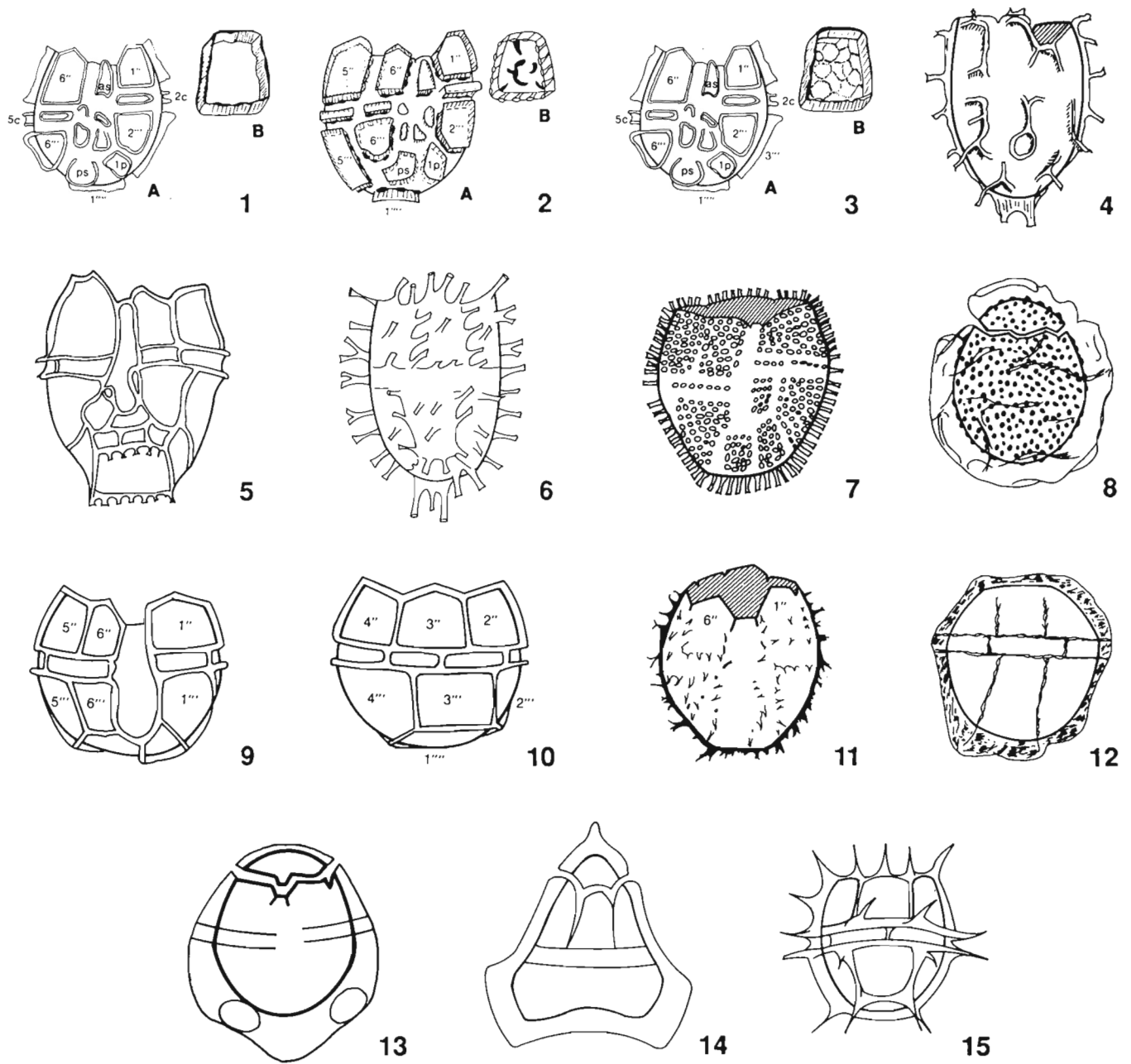
Species

Bejuia polygonalis (Beju 1983) Stover & Williams 1987
Biorbifera johnewingii Habib 1972 emended Below 1987a
Callaiosphaeridium asymmetricum (Deflandre & Courteville 1939) Davey & Williams in Davey et al., 1966
Cauca parva (Alberti 1961) Davey & Verdier 1971
Ctenidodinium continuum Gocht 1970b
Ctenidodinium elegantulum Millioud 1969 emended Below 1981
Ctenidodinium ornatum (Eisenack 1935) Deflandre 1938b
Dichadogonyaulax culmula (Norris 1965) Loeblich & Loeblich 1968
Dichadogonyaulax? pannea (Norris 1965) Sarjeant in Davey et al., 1969
Glossodinium dimorphum Ioannides et al., 1977
Wanaea spp.

Comments and/or guides to identification

The CTENIDODINIUM Group consists of some species in which the paratabulation is moderately well expressed (*Callaiosphaeridium asymmetricum* and species of *Ctenidodinium* and *Dichadogonyaulax*) and other species in which the paratabulation is virtually unexpressed or poorly expressed (*Bejuia*, *Biorbifera*, *Cauca*, *Glossodinium* and *Wanaea*). Considering the latter subgroup first, *Biorbifera johnewingii* is characteristically small, ellipsoidal and except for the paracingulum, is evenly ornamented with low relief features. Specimens of *Cauca parva*, whose bodies are also small, have relatively few, long, simple, thin-walled processes. The remaining forms in the subgroup lack processes. Specimens of *Glossodinium dimorphum* are somewhat biconical, with an obvious, digitate, antapical extension and relatively narrow paracingular bands. In contrast, specimens of *Wanaea* spp. have conical hypocysts and slightly concave (inverted saucer-shaped) epicysts. The hypocysts are commonly fringed paracingularly by a simple to complex, wide to narrow band, and have a nipple-like posterior protrusion. Except for the fringes, the epicysts and hypocysts are smooth or faintly ornamented. Specimens of *Bejuia polygonalis* are thin-walled, and therefore, are almost always torn, folded or otherwise distorted, so that specific identification rests mainly on recognizing the thickened antapical structure.

Separated epicysts and hypocysts of *Ctenidodinium* and/or *Dichadogonyaulax* are fairly easy to recognize in strewn mounts, but complete specimens of those genera can be mistaken for those of *Rhynchodiniopsis*. Epicysts of *Ctenidodinium* typically possess one or two minute intercalary paraplates, and a centred preapical structure which precludes contact of 2' and 4'. Epicysts of *Dichadogonyaulax* characteristically lack intercalary paraplates and have an off-centre preapical structure which allows contact of 2' and 3'. Species in both genera are defined mainly on the size (height), shape and complexity of the parasutural features. Prior to the treatment of Benson (1985) *Ctenidodinium* and *Dichadogonyaulax*, separation of the two genera was based on whether the two paracingular ridges were equally developed (*Dichadogonyaulax*) or unequally developed (*Ctenidodinium*). Benson and others (Lentin and Williams, 1973; Stover and Evitt, 1978) regarded the equal vs. the unequal development of paracingular structures as a variable feature without generic taxonomic significance, whereas Sarjeant (1966, 1975 and Woollam, 1983) continued to consider the differences in paracingular development as generically meaningful. The difference of opinion became moot when Benson (1985) redefined the genera on differences in the epicystal paratabulation. Although Benson's treatment improved the generic definitions, it, like previous analyses, failed to provide a means for separating the two genera on the basis of their hypocysts, which are almost identical.



All views of ventral surfaces unless otherwise stated (inserts included)

1A,B *Alisocysta circumtabulata* (T-94)

2A,B *Alisocysta margarita* (T-92)

3A,B *Alisocysta reticulata* (T-98)

4. *Egmontodinium spiratum* (J.-11)

5. *Egmontodinium polyplacophorum* (J.-13)

6. *Egmontodinium torynum* (C-97)

7. *Lanterna* sp. (J.-12)

8. *Leberidocysta chlamydata* (C-41)

9,10 *Lithodinia deflandrei* (J.-36), dorsal surface

11. *Lithodinia jurassica* (J.-39)

12. *Lithodinia stoveri* (C-87), dorsal surface

13. *Sirmiodiniopsis orbis* (J.-27)

14. *Sirmiodinium grossii* (C-86), dorsal surface

15. *Xiphophoridium alatum* (C-50), dorsal surface

Figure 19. Group XI, LITHODINIA Group.

Specimens of *Callaiosphaeridium asymmetricum* have six large, paracingular, intratabular processes whose bases are not connected. Apically and antapically, low parasutural ridges connect slender, gonial processes, and the hypocystal ridges outline a standard sexiform antapical paraplate.

Group XI: LITHODINIA and allied forms

Group characteristics

Cysts in Group XI (Fig. 19) are proximate to proximochorate, acavate or circumcavate, and with bodies whose outlines are subcircular, elliptical or roundly triangular. The archeopyles are typically apical and the opercula are tetraplacoid and contiguous. The paratabulation may be indicated by the archeopyle alone or with the paracingulum, but is expressed more commonly by parasutural or penitabular features. When sufficiently indicated the paratabulation is gonyaulacacean and the hypocystal pattern is standard sexiform. However, the hypocystal pattern evidently may be quinqueform on some species of *Alisocysta*.

Species

Alisocysta circumtabulata (Drugg 1967) Stover & Evitt 1978
Alisocysta margarita (Harland 1979a) Harland 1979a
Alisocysta reticulata (Damassa 1979) Stover & Evitt 1978
Egmontodinium expiratum Davey 1982
Egmontodinium polyplacophorum Gitmez & Sarjeant 1972
Egmontodinium torynum (Cookson & Eisenack 1960b) Davey 1979b
Lanterna spp.
Leberidocysta chlamydata (Cookson & Eisenack 1962) Stover & Evitt 1978
Lithodinia deflandrei (Sarjeant 1969) Gocht 1975
Lithodinia jurassica Eisenack 1935 emended Gocht 1975
Lithodinia stoveri (Millioud 1969) *comb. nov.*
Sirmiodiniopsis orbis Drugg 1978
Sirmiodinium grossii Alberti 1961 emended Warren 1973
Xiphophoridium alatum (Cookson & Eisenack 1962) Sarjeant *in* Davey et al., 1966

Comments and/or guides to identification

When evident, the paratabulation on forms in the *LITHODINIA* Group is expressed by parasutural or penitabular features and varies from partial to complete. The paratabulation is expressed least in *Leberidocysta chlamydata*, which consists of an ellipsoidal, granulate endocyst separated from, but enclosed by a thinner-walled periphragm. The apical archeopyle is the only indication of paratabulation. On specimens of *Sirmiodiniopsis orbis*, the paratabulation is expressed by the archeopyle and the paracingulum. A few relatively large holes are typically present in the hypocystal part of the periphragm. Such holes are lacking on specimens of *Sirmiodinium grossii*, whose outline varies from trilobate to subcircular and whose

operculum can include the middorsal precingular paraplate as well as the paraplates of the apical series. Species of *Egmontodinium* are ellipsoidal and possess isolated processes, processes connected by discontinuous parasutural ridges, and more or less continuous ridges. The processes on *Egmontodinium torynum* are about one-third the body diameter in length and may be close together or relatively widely spaced. *Egmontodinium expiratum* has fewer processes than *E. torynum* and some processes are connected proximally by low, longitudinal ridges. Parasutural ridges outline the paratabulation on specimens of *Egmontodinium polyplacophorum*.

The parasutural features on species of *Lithodinia* vary from interrupted rows of low-relief features (spinules, conical granulae, short processes) on *Lithodinia jurassica*, to low, continuous ridges on *L. deflandrei*, to low septa of unequal height and thickness on *L. stoveri*. Relatively high parasutural septa surmounted with simple acuminate projections, together with the apical archeopyle, delineate the paratabulation on *Xiphophoridium alatum*.

The areas of positive ornamentation on specimens of *Lanterna* spp., which occupy most of the cyst's surface, are separated by narrow, unornamented or less prominently ornamented, pandasuturate bands. Together, the pandasuturate and positively ornamented areas define the paratabulation. Penitabular ridges are present on all species of *Alisocysta*, and this feature serves to separate this genus from other genera included in the *LITHODINIA* Group. On *Alisocysta margarita*, the ridges are relatively low and the areas outlined by the ridges may have indistinct markings; on *Alisocysta circumtabulata*, the ridges are relatively high, and the enclosed intratabular areas are smooth or very faintly ornamented; and on *A. reticulata*, the ridges are of intermediate height and the enclosed areas are reticulate. The height of the muri is less than that of the penitabular ridges.

Group XII: MICRODINIUM and allied forms

Group characteristics

Cysts in Group XII (Fig. 20) are proximate to skolochorate and have subspherical to ellipsoidal bodies whose epicysts are slightly to markedly smaller than their hypocysts. Epicysts and hypocysts are usually separated by relatively wide paracingula. The paratabulation is indicated by low parasutural ridges or folds and simple gonial spines can be present. Intercalary paraplates may occur on the epicysts, the hypocysts consistently have six postcingular and two antapical paraplates, and lack posterior intercalary paraplates. All genera and species in the *MICRODINIUM* Group have partiform hypocystal patterns. Moreover, the first and last precingular paraplates are similar in size and shape and relatively large, and the posterior sulcal paraplate, when clearly delineated, is conspicuously larger than other sulcal paraplates. Archeopyles and opercula differ for each genus included in Group XII. The various paratabulation formulae and archeopyle types are presented below under Comments.

Species

Carpathodinium predae (Beju 1971) Drugg 1978

Cladopyxidium saeptum (Morgenroth 1968) Stover & Evitt 1978

Druggidium spp.

Eyachia prisca Gocht 1979

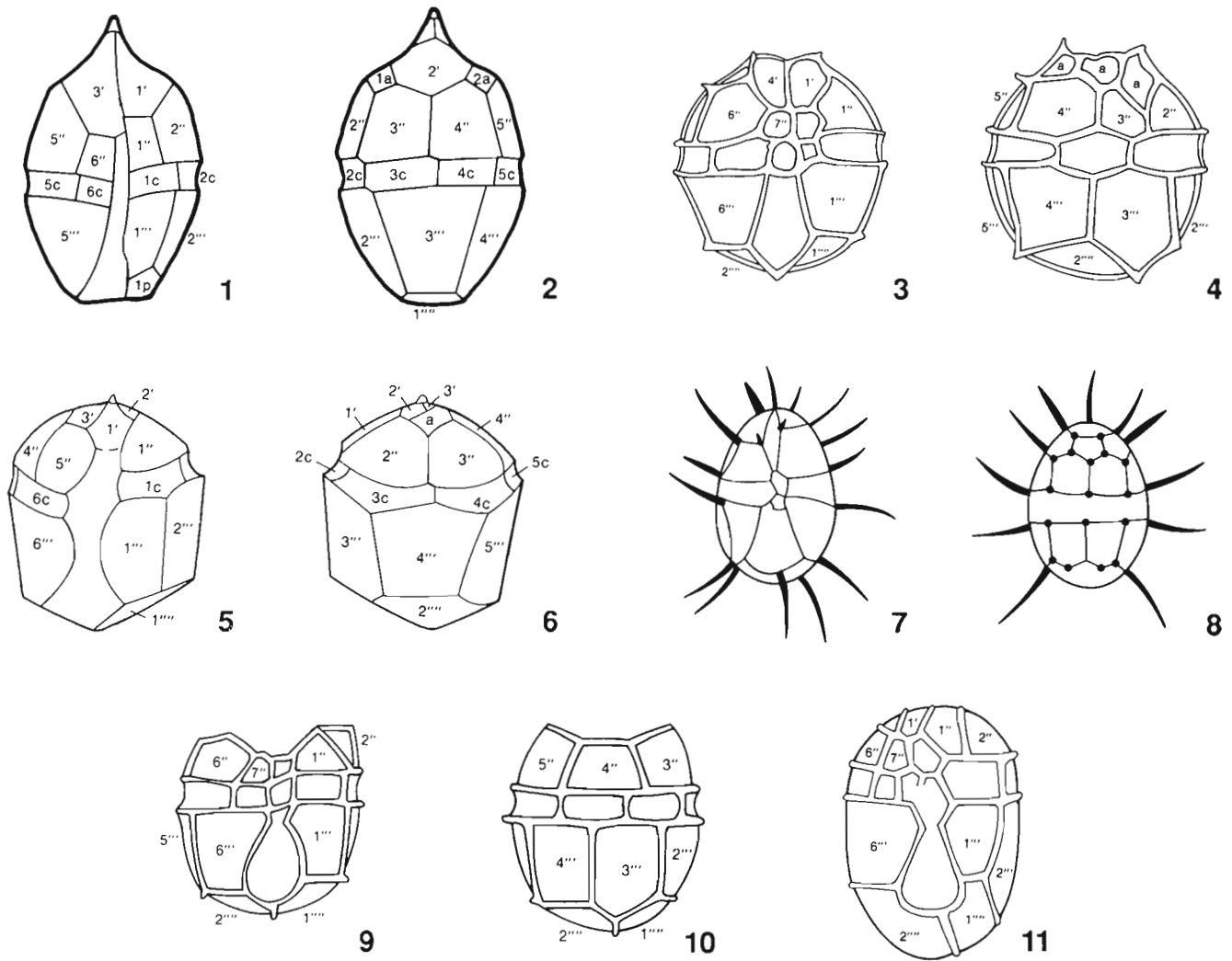
Luehndea spinosa Morgenroth 1970

Microdinium spp.

Comments

The paratabulation formulae and the type(s) of archeopyles and opercula for the above listed genera and species are presented below:

Carpathodinium predae: 3', 2a, 6'', ?6c, 6''', 2''''; the archeopyle is apical and the monoplacoid operculum (2') is free.



- 1,2 *Carpathodinium predae* (J.-37), ventral and dorsal surfaces, respectively
 3,4 *Cladopyxidium saeptum* (T-95), ventral and dorsal surfaces, respectively
 5,6 *Eyachia prisca* (J.-50), ventral and dorsal surfaces, respectively

- 7,8 *Luehndea spinosa* (J.-58), ventral and dorsal surfaces, respectively
 9,10 *Microdinium* sp. (T-96), ventral and dorsal surfaces, respectively
 11. *Druggidium* sp. (C-90), ventral surface

Figure 20. Group XII, MICRODINIUM Group.

Cladopyxidium saeptum: 4', 3a, 7'', 6c + tr, 6''', 2''', 3s; the archeopyle is apical and the diplacoid, contiguous operculum (2' + 3') is free.

Druggidium spp.: 4', 7'', 6c + tr, 6''', 2'''; the archeopyle is precingular and the diplacoid operculum is disarticulated and free.

Eyachia prisca: pr, 3', 1a, 5'', 26c, 6''', 2'''; archeopyle variable, combined apical, intercalary and precingular type [3A]+I+2P with two (most common) to four opercular pieces. Operculum is polyplacoid and the apical paraplates remain contiguous, others disarticulate.

Luehndea spinosa: 4', 3a, 6'', 0c, 6''', 2'''; archeopyle is epicystal with a polyplacoid, contiguous, free operculum.

Microdinium spp.: 4', 7'', 6c + tr, 6''', 2'''; archeopyle is apical, but may contain a preapical and possibly a small intercalary paraplate. The operculum is contiguous and free, occasionally adherent.

Forms included in the *MICRODINIUM* Group (except for *Luehndea*), have their paratabulation indicated by faint to prominent parasutural ridges. On the nominate genus, *Microdinium*, which diagnostically lacks epicystal intercalary paraplates posterior to the archeopyle margin, the ridges are usually clearly evident. Such is also the case with specimens of *Cladopyxidium saeptum*, which differ from those of *Microdinium* spp. in possessing three to four anterior intercalary paraplates posterior to the archeopyle and in having a diplacoid apical operculum. Specimens of *Druggidium* spp. are ellipsoidal and have precingular rather than apical archeopyles. Also ellipsoidal are specimens of *Carpathodinium predae* which, like *Cladopyxidium saeptum* has anterior intercalary paraplates, but has a monoplacoid apical operculum rather than a diplacoid operculum. *Eyachia prisca* is relatively large and its parasutural features may be only slightly elevated. In addition, its compound archeopyle may be formed by the release of two, three or four opercular pieces representing from two to six paraplates. The last species in the group, *Luehndea spinosa*, differs from the others in Group XII by having gonal spines and an epicystal archeopyle.

Group XIII: PALAEOPERIDINIUM and allied forms

Group characteristics

Cysts in Group XIII (Fig. 21) are proximate, dorso-ventrally flattened, and subcircular to peridinioid in outline with moderately to weakly developed horns. Cavation may be cornucavate or bicavate, very rarely circumcavate. The combined archeopyle always involves anterior intercalary and dorsal precingular paraplates and can also include a dorsal apical paraplate. Opercula are tetraplacoid or polyplacoid, contiguous or completely disarticulated, posteriorly adnate or free. Indications of peridiniacean paratabulation include the archeopyle, and when present, penitabular, pandasutural and intratabular features.

Species

Chichaouadinium vestitum (Brideaux 1971) Bujak & Davies 1983

Laciniadinium arcticum (Manum & Cookson 1964) Lentin & Williams 1980

Luxadinium propatulum Brideaux & McIntyre 1975

Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967

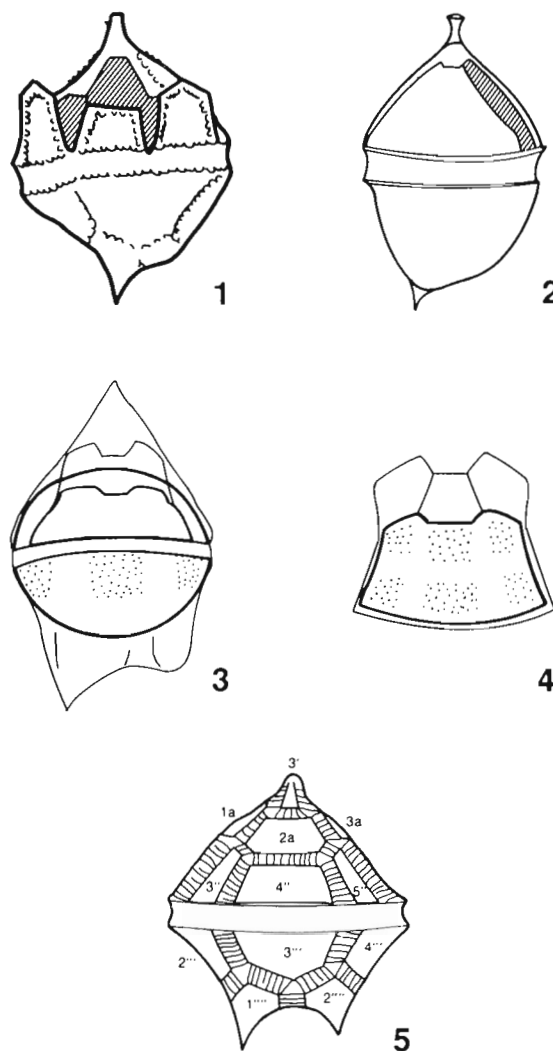


Figure 21. Group XIII, PALAEOPERIDINIUM Group.

1. *Chichaouadinium vestitum* (C-71), dorsal surface
2. *Laciniadinium arcticum* (C-30), dorsal surface
- 3,4. *Luxadinium propatulum* (C-72), dorsal surface and operculum, respectively
5. *Palaeoperidinium pyrophorum* (T-97), dorsal surface

Comments and/or guides to identification

The peridinioid outline and the pandasuturate bands are frequently the most conspicuous and diagnostic features on specimens of *Palaeoperidinium pyrophorum*. The polyplacoid operculum, which always involves the middorsal apical paraplate as well as three anterior intercalary and the three middorsal precingular paraplates, is commonly adherent cingularly but may be detached completely on occasional specimens. Similarly, a thin-walled endocyst can be present and well-preserved specimens faithfully reflect the peridiniacean paratabulation. On specimens of *Luxadinium propatulum* the paratabulation is reflected by intratabular clusters of small granulae or coni depicting the general positions of the precingular, postcingular and intercalary paraplates. The free, polyplacoid operculum comprises three anterior intercalary and three middorsal precingular paraplates. Specimens of *Luxadinium propatulum* are bicavate.

The opercula of *Laciniadinium arcticum* consist also of three anterior intercalary and three precingular paraplates, but specimens are cornucavate rather than bicavate, although the two wall layers may be difficult to distinguish. We prefer to retain the species *L. arcticum* in *Laciniadinium*. The assignment of *arcticum* to *Diconodinium* by Morgan (1980) was not based on observations of the type specimens, but rather on specimens from outside the type area. Examination of the type specimens of *L. arcticum* by S.B. Manum and G.L. Williams confirms that these possess combined intercalary-precingular archeopyles indicative of *Laciniadinium* and not the simple middorsal intercalary archeopyles characteristic of *Diconodinium*. Moreover, these type specimens lack an antapical horn positioned adjacent to the longitudinal axis.

The middorsal intercalary paraplates are characteristically free in specimens of *Chichaouadinium vestitum*, and the subjacent middorsal precingular paraplates are commonly separated laterally (but attached cingularly). Vague alignment of granulae or coni on the periphragm suggests a peridiniacean paratabulation and the presence of two wall layers is difficult to demonstrate in many specimens.

Group XIV: *BATOLADINIUM* and allied forms

Group characteristics

Cysts in Group XIV (Fig. 22) are proximate with elongate ellipsoidal bodies which can have apical and antapical protrusions or horns and can be covered by a loosely fitting periphragm. Although the precise type of archeopyle is uncertain, the opening is large and extends over an appreciable part of the ventral(?) surface. The archeopyle is presumably apical with slight indications of paratabulation shown along its margin; the principal archeopyle suture is strongly inclined, much nearer the anterior end dorsally than ventrally. The right and left archeopyle margins are asymmetrical and the presence of two paraplates along the posterior part of the left margin is suggested; the rest of the

archeopyle suture lacks indications of paraplates. The opercula are free, with the constituent components not being indicated.

Species

Aprobolocysta eilema Duxbury 1977

Batioladinium longicornutum (Alberti 1961) Brideaux 1975

Batioladinium micropodum (Eisenack & Cookson 1960)
Brideaux 1975

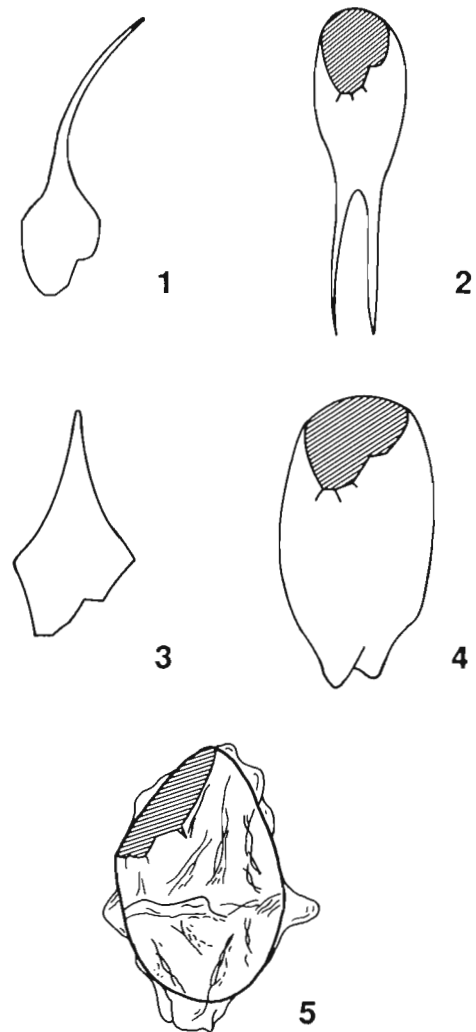


Figure 22. Group XIV, *BATIOLADINIUM* Group.

- 1,2 *Batioladinium longicornutum* (C-91), operculum and ventral surface, respectively
- 3,4 *Batioladinium micropodum* (C-75), operculum and ventral surface, respectively
- 5. *Aprobolocysta eilema* (C-80), oblique left lateral surface

Comment and/or guides to identification

The outstanding diagnostic feature of this small group is the strongly inclined archeopyle margin with its asymmetrical trace. Specimens of *Batioladinium micropodum* have relatively short antapical horns or protrusions and a short to moderate-length apical horn; those of *B. longicornutum* have long apical and antapical horns. Specimens of *Aprobolocysta eilema* lack horns and/or protuberances, but have loosely-fitting, commonly-folded periphragms. The periphragmal folds do not reflect paratabulation.

Group XV: PAREODINIA and allied forms

Group characteristics

Cysts in Group XV (Fig. 23) are proximate to proximochorate and have elongate ellipsoidal bodies with an apical protrusion. Surface ornamentation consists of low, nontabular features, or of spines. The body may be surrounded by a kalyptra. Archeopyles are intercalary; opercula are middorsal, monoplacoid, diplacoid or triplacoid (possibly polyplacoid also) and the individual paraplates are bicamrate, disarticulated and free. Other indications of paratabulation are characteristically lacking.

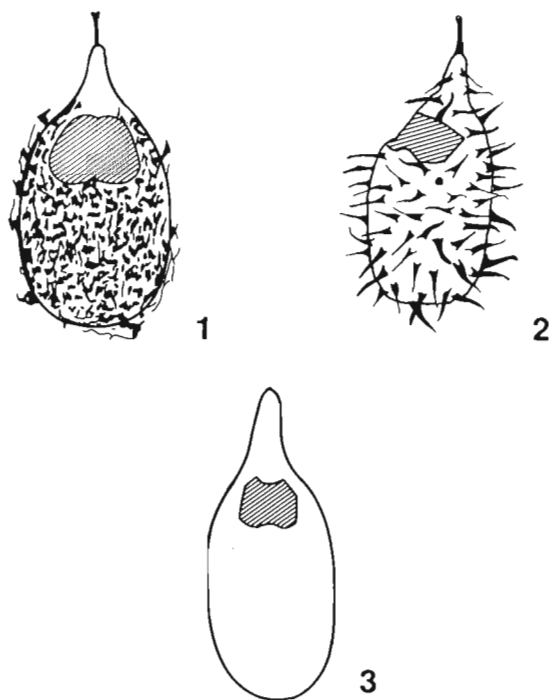


Figure 23. Group XV, PAREODINIA Group.

1. *Gochteodinia mutabilis* (J.-16), dorsal surface
2. *Gochteodinia villosa* (C-96), oblique right surface
3. *Pareodinia* sp. (C-58), dorsal surface

Species

Gochteodinia mutabilis (Riley in Fisher & Riley 1980) Davey 1982
Gochteodinia villosa (Vozzhennikova 1967) Norris 1978
Pareodinia spp.

Comments and/or guides to identification

Specimens of *Pareodinia* spp. are smooth or ornamented with features of low relief and generally have one to three bicamrate, intercalary paraplates whose release forms the archeopyle. Recently, specimens otherwise identical to those of *Pareodinia* have been found with as many as five or possibly six intercalary paraplates. Specimens of *Gochteodinia* differ from those of *Pareodinia* by being more strongly ornamented. *Gochteodinia villosa* has numerous, tapered, acuminate spines, whereas *G. mutabilis* has a scabrate-granulate to finely spinate ornamentation. The opercula of *Gochteodinia* are so far consistently diplacoid and bicamrate.

Group XVI: NANNOCERATOPSIS

Group characteristics

Group XVI (Fig. 24) consists of species of the genus, *Nannoceratopsis*, whose cysts have roughly triangular to roundly quadrate outlines with slightly to deeply concave

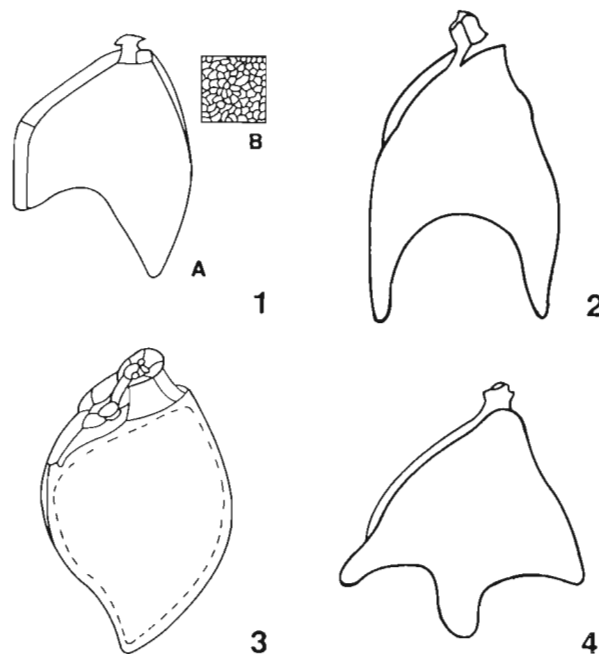


Figure 24. Group XVI, NANNOCERATOPSIS Group.

- All views of oblique left lateral surfaces
- 1A-B *Nannoceratopsis gracilis* (J.-45)
 2. *Nannoceratopsis pellucida* (J.-31)
 3. *Nannoceratopsis senex* (J.-56)
 4. *Nannoceratopsis tricerat* (J.-40)

posterior lateral margins. Specimens are flattened laterally; the epicysts are minute (typically less than about one-tenth the length of the entire specimens), relative to the size of the broad and generally longitudinally elongate hypocysts. Posterior horn development varies from two prominent horns to virtually none, and one of the two horns can be suppressed entirely. Low relief ornamentation commonly differs both within and among species. The archeopyle is a miniscule, cingular opening that faces the dorsal surface and is customarily not discernible with light microscopy.

Species

Nannoceratopsis gracilis Alberti 1961 emended Evitt 1962
Nannoceratopsis pellucida Deflandre 1938a emended Evitt 1961b

Nannoceratopsis senex van Helden 1977

Nannoceratopsis tricerias Drugg 1978

Comments

The archeopyle type and the paratabulation of *Nannoceratopsis* are known from a single publication (Piel and Evitt, 1980), a single collection of specimens, and an SEM study only. Those authors provided a paratabulation formula of pr, 5', 5'', 4c, and 4s for the epicyst, and 4H (using dinophysalean terminology) for the hypocyst. They compared the paratabulation of *Nannoceratopsis* to the tabulation of modern Peridiniales and Dinophysiales and concluded that the epicystal paratabulation suggests affinity with the Peridiniales, whereas the hypocystal paratabulation suggests affinity with the Dinophysiales. Because *Nannoceratopsis* accords completely with neither ordinal group, a separate Order, the Nannoceratopsiales, was erected for the reception of the single genus.

The illustration of the epicyst of *Nannoceratopsis senex* by Piel and Evitt (1980, especially p. 84, pl. 2, fig. a) shows that two of the apical paraplates (designated 1' and 2') fail to contact the preapical paraplate. We regard these paraplates as intercalary rather than apical; accordingly, a modified epicystal paratabulation formula of pr, 3', 2a, 5'', 4c and 4s is presented to reflect this interpretation.

Guides to identification

Species of *Nannoceratopsis* are separated mainly on differences in the shape of the hypocysts, with attention to the lengths and placement of the horns. In *N. pellucida*, the horns are more or less of equal length, separated by a deep concavity and with the ends of the horns relatively close together. Thus the hypocyst takes on the appearance of a pincer. In *N. gracilis* the ventral horn is reduced to a rounded bulge which is separated from the dorsal horn by a relatively shallow concavity. Further reduction of the ventral bulge results in loss of that protrusion and the retention of only the dorsal horn, which is characteristic of *N. senex*. Specimens of *N. tricerias* are characterized by having three antapical protrusions with the medial protrusion being longer than the adjacent ones. In general, ornamentation appears to be a poor

criterion for separating species and in samples where specimens of *Nannoceratopsis* are abundant, consistent separation of species, particularly *N. gracilis* and *N. senex*, may be difficult.

Group XVII: miscellaneous

Remarks

Species in Group XVII (Fig. 25-27) cannot be placed conveniently in one of the preceding groups; also, their morphological diversity precludes preparation of a meaningful synopsis of their characteristics. The genera and species included in Group XVII are listed below alphabetically within broad stratigraphic categories: Tertiary, Cretaceous and Triassic-Jurassic.

Species

Tertiary forms

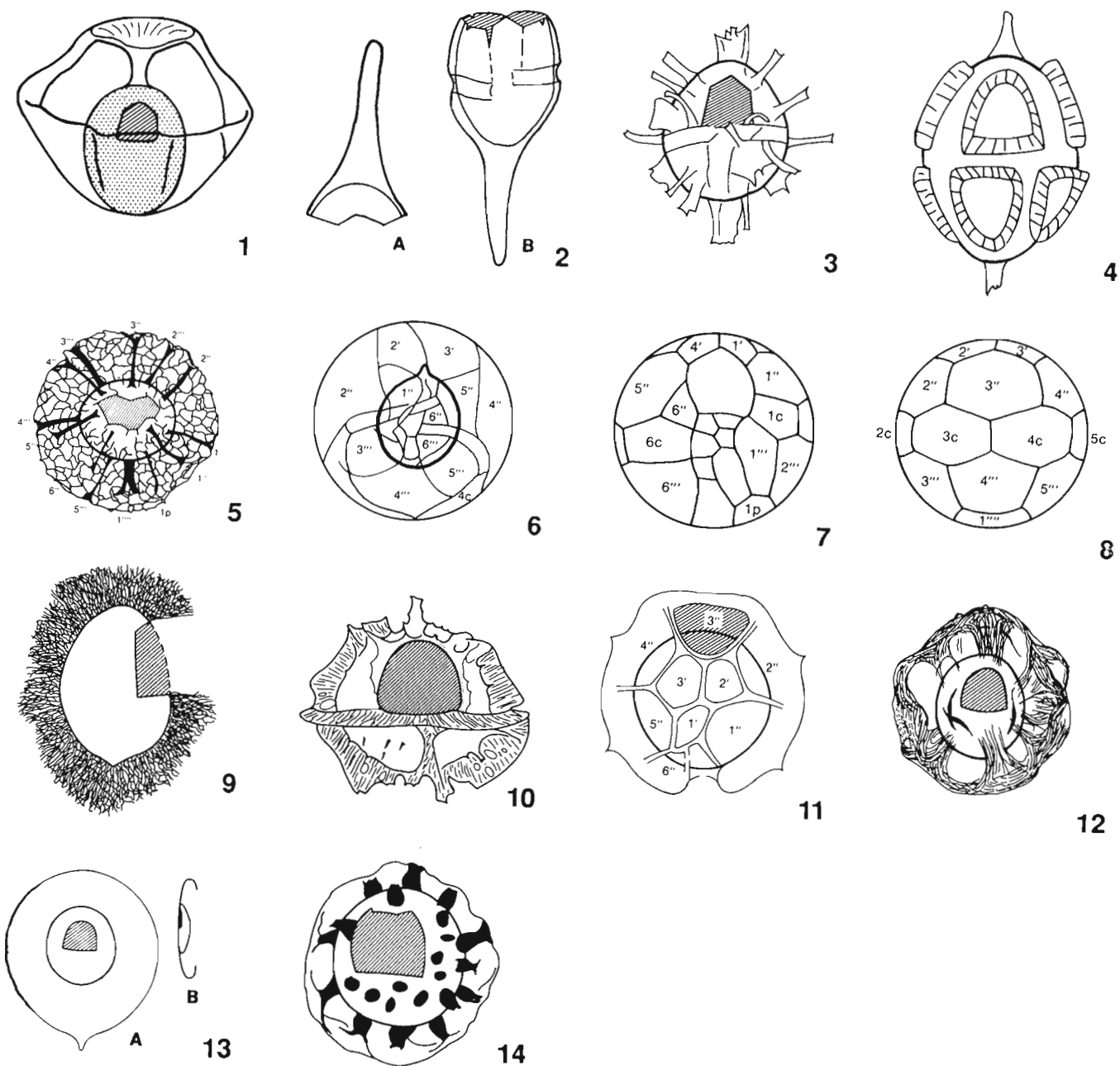
Amiculosphaera umbracula Harland 1979b
Biconidinium longissimum Islam 1983b
Conneximura fimbriata (Morgenroth 1968) May 1980
Danea californica (Drugg 1967) Stover & Evitt 1978
Eatonicysta ursulae (Morgenroth 1966a) Stover & Evitt 1978
Evittosphaerula paratabulata Manum 1979
Invertocysta tabulata Edwards 1984
Lanternosphaeridium spp.
Muratodinium fimbriatum (Cookson & Eisenack 1967) Drugg 1970
Pentadinium laticinctum Gerlach 1961 emended Benedek et al., 1982
Thalassiphora patula (Williams & Downie in Davey et al., 1966) Stover & Evitt 1978
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960 emended Benedek & Gocht 1981
Tuberculodinium vancampoeae (Rossignol 1962) Wall 1967

Cretaceous forms

Angustidinium acribes (Davey & Verdier 1971) Goodman & Evitt 1981 emended
Cannosphaeropsis utinensis O. Wetzel 1933b emended May 1980 emended Sarjeant 1985
Dinogymnium spp.
Epelidosphaeridia spinosa (Cookson & Hughes 1964) Davey 1969
Nelchinopsis kostromiensis (Vozzhennikova 1967) Wiggins 1972
Palaeohystrichophora infusorioides Deflandre 1935
Stephodinium coronatum Deflandre 1936a

Triassic-Jurassic forms

Geiselodinium inaeffectum Drugg 1978
Hebecysta brevicornuta Bujak & Fisher 1976
Liasidium variabile Drugg 1978
Noricysta spp.
Reutlingia gochtii Drugg 1967 emended Below 1987a
Suessia swabiana Morbey 1975 emended Below 1987a



1. *Amiculosphaera umbracula* (T-18), dorsal surface
- 2A,B *Biconidinium longissimum* (T-90), operculum (2A) and ventral surface (2B)
3. *Conneximura fimbriata* (T-102), dorsal surface
4. *Danea californica* (T-104), dorsal surface
5. *Eatonicysta ursulae* (T-80), apical surface
6. *Invertocysta tabulata* (T-16), dorsal surface

- 7,8 *Evittosphaerula paratabulata* (T-38), ventral and dorsal surfaces, respectively
9. *Lanternosphaeridium* sp. (T-88), left lateral surface
10. *Muratodinium fimbriatum* (T-78), dorsal surface
11. *Pentadinium laticinctum* (T-32), apical surface
12. *Thalassiphora patula* (T-84), dorsal surface
- 13A,B *Thalassiphora pelagica* (T-49), dorsal surface (13A)
14. *Tuberculodinium vancampoeae* (T-6), antapical surface

Figure 25. Group XVII, Miscellaneous, Tertiary forms.

Valvaeodinium lineatum (Wille and Gocht 1979) Below 1987b

Valvaeodinium punctatum (Wille and Gocht 1979) Below 1987b

Comments and/or guides to identification

Tertiary forms (Fig. 25)

Amiculosphaera umbracula. The funnel-like structure extending from the anterior end of the endocyst and the large openings in the epiperiphragm, together with the simple precingular archeopyle characterize this species.

Biconidinium longissimum. This fusiform cyst is relatively thick-walled so that the endophragm may be difficult to discern. Complete specimens are superficially similar to those of *Palaeocystodinium* and *Svalbardella*, but those genera have intercalary archeopyles rather than an apical archeopyle.

Conneximura fimbriata. The presence of intratabular and/or penitabular processes, high parasutural septa, especially on the dorsal surface, and a middorsal precingular archeopyle are diagnostic for this species. On the midventral area, the septa may form a relatively large-mesh reticulation.

Danea californica. The septa on this species are penitabular, lower than those on *Conneximura fimbriata*, and more clearly discernible. *Danea californica* has a simple precingular archeopyle.

Eatonicysta ursulae. This species can be perceived as essentially a specimen of *Areosphaeridium diktyoplokus* with an enclosing, imperfectly reticulate ectophragm. Complete specimens of *A. diktyoplokus* and *E. ursulae* possess 17 solid intratabular processes and apical archeopyles with tetraplacoid opercula.

Evittosphaerula paratabulata. The important particulars of this species consist solely of ribbon-like parasutural bands, whose arrangement reflects a gonyaulacacean paratabulation. However, the relative proportions and sizes of the individual paraplates differ from those of the standard model.

Invertocysta tabulata. In this species, the periphragm and endophragm are appressed ventrally and the periphragmal opening represents the middorsal precingular position. The paratabulation is fairly well delineated by low parasutural features.

Lanternosphaeridium spp. Specimens of this form consist of subspherical to ellipsoidal endocysts enclosed completely by loosely interwoven, fibrous membranes. Well defined indentations along the periphery of the membrane or other obvious indications of paratabulation, except for the middorsal precingular archeopyle, are usually lacking.

Muratodinium fimbriatum. The presence of relatively high, fibrous parasutural septa, only a single paracingular septum and a simple middorsal precingular archeopyle characterize this generally subspherical cyst.

Pentadinium laticinctum. This species, whose bodies are commonly compressed apically-antapically, has reduced paratabulation and is suturocavate.

Thalassiphora patula. The periphragm and endophragm of this species are appressed dorsally and radially-disposed fibroid connections extend outward from the endocyst. The archeopyle is a simple middorsal precingular opening.

Thalassiphora pelagica. This species lacks the radially-disposed fibroid connections of *T. patula*, and has a less coarsely ornamented periphragm. A periphragmal projection, when present, is usually antapical.

Tuberculodinium vancampoeae. This species is characterized by having numerous (29-36), clearly separated barrel-like tubercles between the anterior and posterior surfaces of the oblate cysts and a hypocystal archeopyle with triplacoid to polyplacoid opercula. The tubercles are arranged serially into four subparallel rows.

Cretaceous forms (Fig. 26)

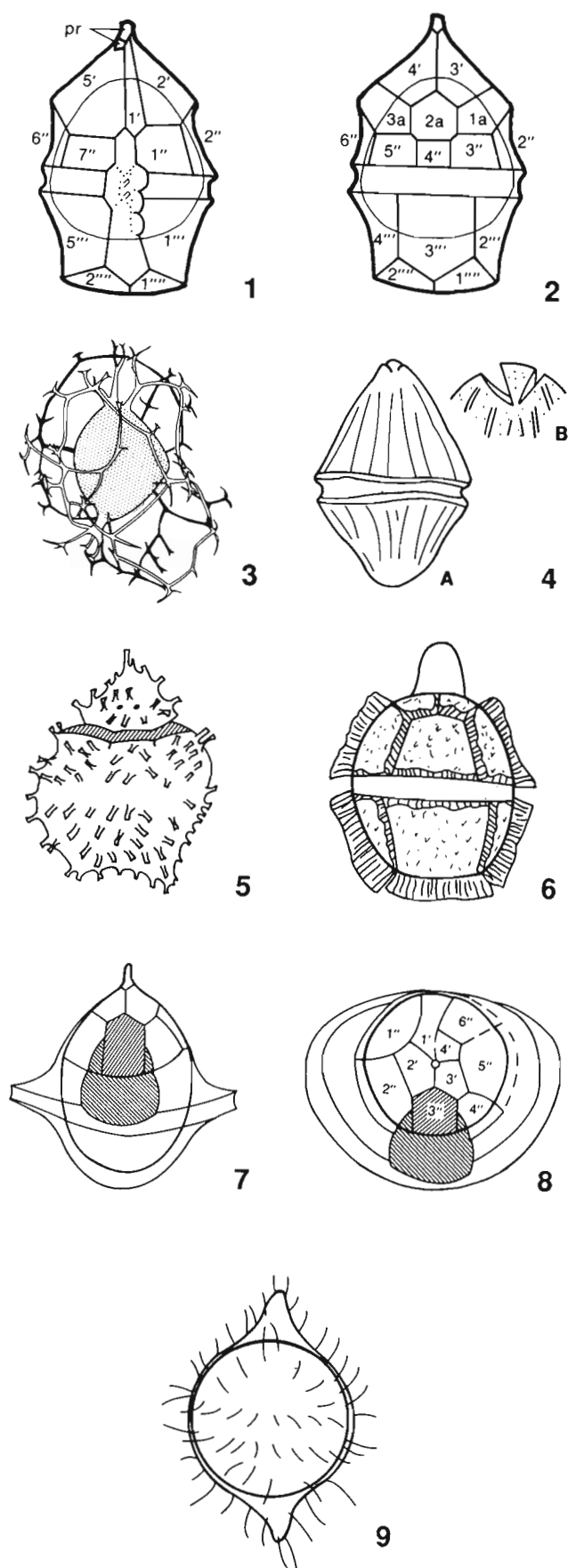
Angustidinium acribes. The paratabulation of this species appears unique as exemplified by the long and narrow first apical paraplate and the seven-sided middorsal intercalary paraplate. The hypocystal pattern on *A. acribes* is partiform.

Cannosphaeropsis utinensis. The small endocyst has very few connections to a much larger, open trabecular network. The triple junction intersections of the trabeculum consist of three trabeculae together with a triradiate structure with short branches (like the primary-branched tips of gonol *Spiniferites* processes) arranged 60 degrees to the trabeculae. Short cross-spines (like the primary branched tips of intergonal *Spiniferites* processes) occur along the trabeculae between triple junctions. The archeopyle, when discernible, is simple precingular.

Dinogymnium spp. Specimens are biconical to elongate ellipsoidal, smooth or with folds and/or plicae. Part of the specimen may be smooth whereas the other part is folded or plicated, or both. A paracingulum divides the cysts into equal to vastly disparate parts. The apical archeopyle is covered by a diamond-shaped operculum whose long axis is dorsal-ventral.

Epelidosphaeridia spinosa. This species is uniformly ornamented with short spines and the position of the paracingulum is usually evident. The archeopyle margin generally shows little angularity, which has led some to regard the archeopyle as combined apical and intercalary; others regard it as simply apical claiming that the operculum is too small to include both the apical and the intercalary paraplates.

Nelchinopsis kostromiensis. The thick wall with abundant radiate internal structures, whose slight difference in height along parasutures delineates the paratabulation, and the thin-walled apex characterize this species. The type of archeopyle is uncertain.



Palaeohystrichophora infusorioides. This typically bicavate cyst has a thin periphragm that is ornamented with sparse to numerous, hair-like projections. The hypocyst may have a single horn, typically located more or less in line with the longitudinal axis of the cyst, but some specimens have the antapical horn offset slightly to the left and still others have a weakly developed right protrusion. Specimens almost universally lack archeopyles.

Stephodinium coronatum. Specimens of this species are camocavate dorsally so that the periphragm and endophragm are attached ventrally. The paratabulation, which is expressed on the periphragm by parasutural features, is standard gonyaulacacean with a sexiform hypocystal pattern. The archeopyle is precingular and the periarcheopyle is enlarged.

Triassic-Jurassic forms (Fig. 27)

Geiselodinium inaffectum. The species is circumcavate, has short horns and indications of a paracingulum, but lacks an archeopyle.

Hebecysta brevicornuta. The species is relatively small and has two wall layers, which are close together except at the base of the apical horn and beneath the paracingular crests. The archeopyle is intercalary, with a diplacoid or triplacoid operculum.

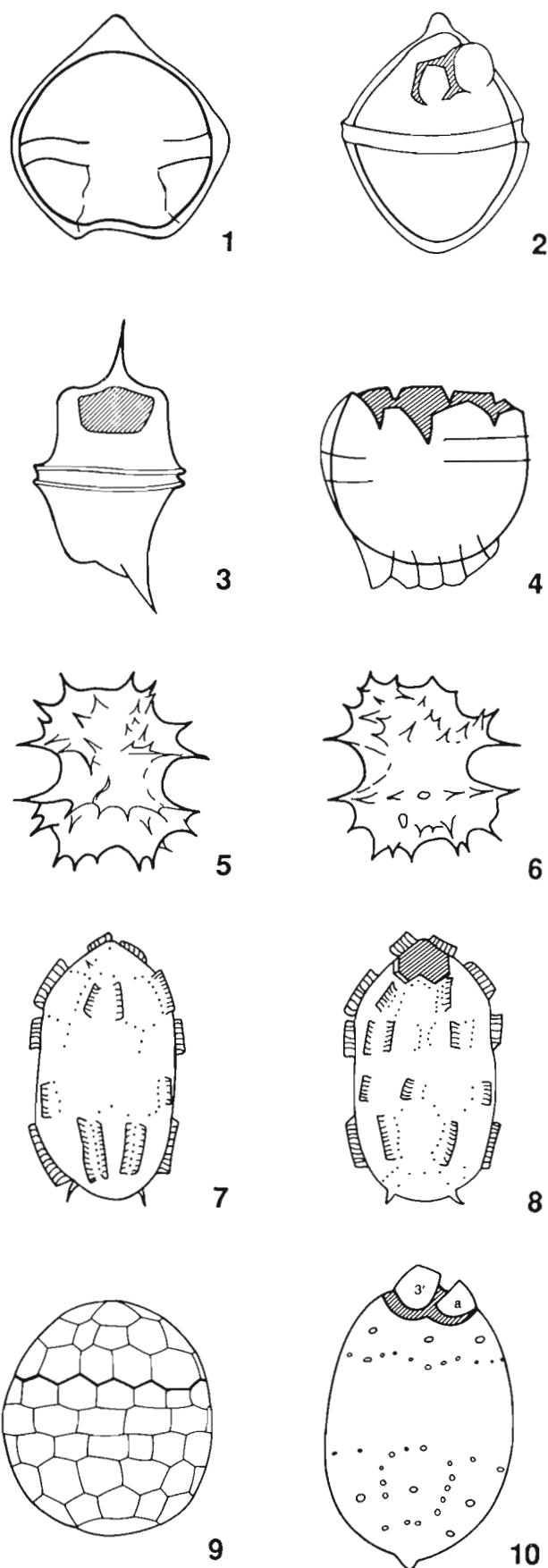
Liasidium variabile. The prominent apical and antapical horns, the comparatively large intercalary archeopyle, the presence of anterior "shoulders", and the lack of obvious ornamentation characterize this species. *Liasidium variabile* is the only dinoflagellate species known in which the right antapical horn is better developed than the left.

Noricysta spp. Species of this genus are relatively small, have two wall layers, of which the outer is often indistinct or incomplete and, an apical archeopyle. Cavation is poorly expressed.

Reutlingia gochtii. The outline of this species is similar to that of *Susadinium* and *Parvocysta* in having a constricted paracingular area. The spines on *R. gochtii* may be parasutural and the archeopyle is probably apical, but neither of these conditions is certain. In contrast, the presence of intercalary archeopyles on the other two genera is established.

Figure 26. Miscellaneous, Cretaceous forms.

- 1,2 *Angustidinium acribes* (C-81), ventral and dorsal surfaces, respectively
3. *Cannosphaeropsis utinensis* (C-29), orientation unknown
- 4A,B *Dinogymnium* sp. (C-27), dorsal surface (4A)
5. *Epelidosphaeridia spinosa* (C-63), ventral surface
6. *Nelchinopsis kostromiensis* (C-93), dorsal surface
- 7,8 *Stephodinium coronatum* (C-55), dorsal and epicystal configurations, respectively
9. *Palaeohystrichophora infusorioides* (C-34), dorsal surface



Suessia swabiana. The small cysts have about 65 to 85 polygonal paraplates arranged in eight or nine latitudinal series. Series at and adjacent to the equatorial area (paracingulum) usually have 12-13 paraplates per series; those away from the equatorial area generally possess fewer paraplates. The archeopyle suture follows the anterior margin of the precingular series and the polyplacoid opercula comprise the rest of the epitheca.

Valvaeodinium lineatum and *V. punctatum*. These species have elongate ellipsoidal bodies, wide paracingular areas and apical archeopyles with biplacoid opercula. The body of *V. punctatum* is smooth except for rather faint punctae, whereas that of *V. lineatum* has short fence-like longitudinal ridges that help define the paratabulation.

MORPHOLOGICAL COMPLEXES

Apectodinium homomorphum 'complex'

Three species are included in this complex: *Apectodinium homomorphum* (Deflandre & Cookson 1955) Lentin & Williams 1977b, *A. geometricum* (Pastiels 1948 *ex* Downie & Sarjeant 1965) Fensome et al., 1990 and *A. summisum* Harland 1979c. Fensome et al. (1990) pointed out that *Apectodinium patielsii* Lentin & Williams 1989 and *A. geometricum* have the same holotype, thus the former name is a taxonomic junior synonym of the latter. We also regard *Hystrichosphaeridium caiboense* Regali et al., 1974 and *Apectodinium folliculum* Islam 1983b as taxonomic junior synonyms of *A. homomorphum*. For details, see the next section captioned Taxonomic Considerations.

Areosphaeridium arcuatum 'complex'

Three species are included in this complex: *Areosphaeridium arcuatum* Eaton 1971, *A. multicornutum* Eaton 1971 and *A. pectiniforme* (Gerlach 1961) Stover & Evitt 1978. A detailed study of *Areosphaeridium* species by Stover, Williams and Eaton (1988) demonstrated that *A. multicornutum* and *A. pectiniforme*, contrary to the treatment by Sarjeant (1984b), are not conspecific.

Figure 27. Miscellaneous, Triassic-Jurassic forms.

1. *Geiselodinium inaffectum* (J.-20) 91, ventral surface
2. *Hebecysta brevicornuta* (J.-65), dorsal surface
3. *Liasidium variabile* (J.-59), dorsal surface
4. *Noricysta* sp. (J.-63), ventral surface
- 5,6 *Reutlingia gochtii* (J.-41), ventral and dorsal surfaces, respectively
- 7,8 *Valvaeodinium lineatum* (J.-57), ventral and dorsal surfaces, respectively
9. *Suessia swabiana* (J.-62), oblique right lateral surface
10. *Valvaeodinium punctatum* (J.-55), dorsal surface

***Chiropteridium mespilanum* ‘complex’**

This complex comprises forms currently assigned to *Chiropteridium mespilanum* (Maier 1959) Lentin & Williams 1973 and those that were previously attributed to that species or to one of the following species: *Chiropteridium galea* (Maier 1959) Sarjeant 1983, *C. dispersum* Gocht 1960, *C. partispinatum* (Gerlach 1961) Brosius 1963 and *Membranophoridium multispinatum* Gerlach 1961. Forms in the *Chiropteridium mespilanum* ‘complex’ are appreciably smaller than specimens of the type species, *C. lobospinosum* (Gocht in Weiler 1956) Gocht 1960.

***Cribrasperidium edwardsii* ‘complex’**

Problems in consistently identifying specimens of *Cribrasperidium edwardsii* (Cookson & Eisenack 1958) Davey 1969, *C. maderongense* (Cookson & Eisenack 1958) Davey 1969 and *C. orthoceras* (Eisenack 1958) Davey 1969 led us to treat these three species as a complex.

***Deflandrea phosphoritica* ‘complex’**

Included in the complex is the type species of *Deflandrea*, *D. phosphoritica* Eisenack 1938, together with its two subspecies, *D. phosphoritica* subsp. *phosphoritica* and *D. phosphoritica* subsp. *australis* Cookson & Eisenack 1961b, as well as the following five species: *Deflandrea dissoluta* Vozzhennikova 1967, *D. granulata* Menendez 1965, *D. heterophlycta* Deflandre & Cookson 1955, *D. intrasphaerula* Mao & Norris 1988 and *D. tribulosa* Islam 1983c.

***Gonyaulacysta cassidata* ‘complex’**

In addition to the nominate species, *Gonyaulacysta cassidata* (Eisenack & Cookson 1960) Sarjeant *in* Davey et al., 1966, the following five species are included in the complex: *Gonyaulacysta cretacea* (Neale & Sarjeant 1962) Sarjeant 1969, *G. diutina* Duxbury 1977, *G. helicoidea* (Eisenack & Cookson 1960) Sarjeant *in* Davey et al., 1966, *G. perforobusta* Duxbury 1977 and *G. teicha* Davey 1974.

***Kisselovia coleothrypta* ‘complex’**

Four species are included in this complex. They are: *Kisselovia clathrata* (Eisenack 1938) Lentin & Williams 1976, *K. coleothrypta* Williams & Downie *in* Davey et al., 1966, *K. columna* Michoux 1985 and *K. fasciata* (Rozan 1965) Costa & Downie 1979. On these species the incomplete ectophragms, whose outlines simulate those of the paraplates, are more or less continuous over the supporting intratabular processes. Species in which the processes are connected by trabeculae or a reticulum are excluded from the complex.

***Rhombodinium porosum* ‘complex’**

Rhombodinium perforatum (Jan du Chêne & Chateaufort 1975) Lentin & Williams 1977b and *R. porosum* Bujak 1979 are included in this complex. These forms are similar in shape and their periphragms may be finely to coarsely perforate. Forms with projections rather than perforations are not included in the complex.

***Wetzelialla articulata* ‘complex’**

Within this complex we include *Wetzelialla articulata* Eisenack 1938, *W. astra* Costa et al., 1978, *W. asteroides* Islam 1983b, *W. horrida* Jan du Chêne & Chateaufort 1975 and *W. meckelfeldensis* Gocht 1969. Stover and Evitt (1978) regarded *W. horrida* as a taxonomic junior synonym of *W. articulata*. However, examination of the type specimens by one of us (LES) revealed that *W. horrida* is not conspecific with *W. articulata*.

***Wetzelialla symmetrica* ‘complex’**

Wetzelialla symmetrica Weiler and the subspecies *W. symmetrica* subsp. *incisa* Gerlach 1961 are included in the complex together with *W. gochtii* Costa & Downie 1976. The close similarity between *W. symmetrica* subsp. *incisa* and *W. gochtii* suggests that the two forms may be conspecific.

TAXONOMIC CONSIDERATIONS

Discussions during and after the 1984 Course (see Introduction) led to questions concerning the taxonomy and/or ranges of certain genera and species. Adjustments in ranges are accounted for on the accompanying range charts. Similarly, most of the taxonomic concerns were addressed or adjusted in Lentin and Williams (1989). This section deals with a few remaining problems, of which the most involved concerns *Lithodinia* and *Meiourogoniaulax*.

Analysis of Lithodinia and Meiourogoniaulax

The morphological similarity of the dominantly Jurassic genera *Lithodinia* Eisenack 1935 and *Meiourogoniaulax* Sarjeant *in* Davey et al., 1966 prompted Gocht (1975, p. 353) to suppress *Meiourogoniaulax*. Because of procedural infractions concerning the valid transfer of species, actual suppression of the genus was not effected until the following year (Gocht, 1976, p. 334). However, Stover and Evitt (1978), after perusal of Gocht's 1975 restudy of *Lithodinia jurassica*, the type species, concluded that both genera merited recognition on the basis of opercular differences. Owing to this decision and despite efforts to the contrary by Fenton (1981, p. 250-251), both genera have been maintained (Lentin and Williams, 1981, 1985, 1989). We now realize that the separation of these genera based on whether the apical opercula are contiguous or disarticulated is unrealistic and impractical, especially because the vast majority of specimens lack opercula. Therefore, we retain *Lithodinia*, the senior taxonomic synonym.

Our analysis includes the presently accepted taxa in *Lithodinia* (5 species) and *Meiourogonaulax* (30 species and 1 subspecies) in Lentin and Williams (1989). To these we added a species of *Lithodinia* not included there. The results, derived from the study of literature information about the holotypes, are summarized below.

- a. Of the six species of *Lithodinia*, five are retained (*L. arcanitabulata*, *L. bathonica*, *L. borealis*, *L. jurassica* and *L. ? serrulata*); one species (*L. ? areolata*) is returned to its previous assignment (*Epiplosphaera*).
- b. Nineteen species of *Meiourogonaulax* are returned to *Lithodinia* (*M. ? acanthosphaera*, *M. araneosa*, *M. bulloidea*, *M. callomonii*, *M. caytonensis*, *M. cristulata*, *M. deflandrei*, *M. germanii*, *M. ? insolfigurata*, *M. pertusa*, *M. pila*, *M. psora*, *M. reticulata*, *M. ? riultii*, *M. ? staffinensis*, *M. stoveri*, *M. ? strongylos*, *M. ? superornata* and *M. valensii*).
- c. Seven species and one subspecies of *Meiourogonaulax* are transferred to *Lithodinia* as new combinations (*M. amlasis*, *M. bejui*, *M. ? diaphanis*, *M. maculata*, *M. mitra*, *M. pertusa* subsp. *heta*, *M. planoseptata* and *M. spongiosa*).
- d. Three species of *Meiourogonaulax* are transferred to genera other than *Lithodinia* (*M. cantrellii* to *Lanterna*, *M. dicrypta* to *Escharisphaeridia* and *M. sagera* to *Ellipsoidictyum*).
- e. *Meiourogonaulax decapitata* is treated as a taxonomic junior synonym of *M. valensii*.

Validation of the new assignments is presented under the heading Species following the emended description of *Lithodinia*.

LITHODINIA Eisenack 1935 emended

Taxonomic junior synonym

Meiourogonaulax Sarjeant in Davey et al., 1966, p. 144

Previous emendations

Eisenack & Klement 1964, p. 503

Gocht 1975, p. 353

Stover & Evitt 1978, p. 61

Discussion

The original description of *Lithodinia* (Eisenack, 1935) by today's standards is couched in very broad terms, yet was sufficiently detailed that its dinoflagellate affinity was readily verifiable. Nearly three decades later Eisenack and Klement (1964, p. 503) provided the first paratabulation formula for the genus (3', 6'', 6''', 1p, 1'''). Gocht (1975, p. 353) gave a more elaborate formula of 4', 6'', 0-7c, 5-7''', 0-2p, 0-1av, 0-1pv, 1'''' in part because he included in *Lithodinia* the species previously assigned to *Meiourogonaulax* and in part because he accepted the paratabulation formulae of the various species as initially presented. Stover and Evitt (1978)

offered a less complex formula of 4', 6'', 6c, 5''', 1p, 1'''' and 1 or more s. They also called attention to the disarticulation of the four apical paraplates. The emended description presented below allows for the apical operculum to be contiguous or disarticulated, the paratabulation to be of the general gonyaulacacean type with a standard sexiform hypocystal pattern.

Emended Description

SYNOPSIS

Cysts proximate, subspherical to roundly polygonal; paratabulation gonyaulacacean, indicated by generally low, continuous or discontinuous parasutural features, formula: 4', 6'', 0-6c, 5-6''', 1p, 1''', 0-1s, hypocystal pattern is standard sexiform; archeopyle apical, operculum tetraplacoid, contiguous or non-contiguous.

DESCRIPTION

Shape. Subspherical to roundly polygonal.

Wall Relationships. Autophragm only; SEM analysis reveals two wall layers that are not discernible with light microscopic techniques.

Wall Features. Parasutural features consist of generally low continuous and smooth or perforate or striate and of essentially uniform height, or discontinuous projections; latter isolated or joined proximally. Areas between parasutural features smooth or with features of low relief.

Archeopyle. Apical; operculum tetraplacoid, contiguous or disarticulated, free.

Paratabulation. Gonyaulacacean, expressed by parasutural features; formula: 4', 6'', 0-6c, 5-6''', 1p, 1''', 0-1s. Presence of anterior intercalary paraplates unconfirmed; hypocystal pattern standard sexiform.

Paracingulum. Subdivided and represented by six subrectangular paraplates, or undivided.

Parasulcus. Anterior position indicated by shallow to deep parasulcal notch; delimited laterally and posteriorly by continuous or discontinuous parasutural features; faint indications of subdivision may be discernible.

Size. Small to intermediate.

COMPARISON

Lithodinia differs from *Lanterna* Dodekova 1969 in having parasutural rather than pandasutural features and in lacking conspicuous ornamentation in the intratabular areas. *Cernicysta* Stover and Helby 1987d has a relatively large first postcingular paraplate, which is either absent or small on *Lithodinia*, and a middorsal hypocystal septum which *Lithodinia* lacks. *Cerbia* Below 1981 has penitabular features as well as a lenticular body with an offset parasulcal notch.

SPECIES

Type Species

Lithodinia jurassica Eisenack 1935, p. 175-177, pl. 4, figs. 5-10, text-figs. 1-14 emended Gocht 1975, p. 355. The holotype (Eisenack 1935, pl. 4, fig. 5; re-figured by Gocht (1975, figs. 22a-b) is from the Middle Jurassic (Callovian) of Germany.

Accepted Species

Lithodinia amlasis (Below 1981, p. 58, pl. 6, figs. 14-16b) *comb. nov.* The holotype (Below 1981, pl. 6, figs. 16a-b, as *Meiourogoniaulax amlasis*) is from the Lower Cretaceous (Hauterivian) of Morocco.

Lithodinia araneosa (Muir & Sarjeant 1978, p. 197-198, pl. 1, fig. 1, text-fig. 1) Riley 1979, p. 221. The holotype and only specimen illustrated is from the Middle Jurassic (Callovian) of Yorkshire, England.

Lithodinia arcanitabulata Brenner 1988, p. 61-63, pl. 18, figs. 3a-c, 4-5, text-fig. 20. The holotype (*ibid.*, pl. 18, fig. 4) is from the Upper Jurassic (Malm gamma) of Germany. An unusual feature of this species is that the interpreted sexiform paratabulation pattern shows relatively long contacts for 1'''/1p and 1'''/6'''.

Lithodinia bathonica Conway 1978, p. 349, pl. 2, figs. 4-5, 7-8. The holotype (*ibid.*, pl. 2, figs. 4-5) is from Middle Jurassic (Bathonian) strata in the Yinnon No.1 borehole, Israel.

Lithodinia bejui (Zotto et al., 1987, p. 199-202, pl. 1, figs. 1a-3, text-figs. 5a-c) *comb. nov.* The holotype (*ibid.*, pl. 1, figs. 1a-b, as *Meiourogoniaulax bejui*) is from Upper Jurassic (Kimmeridgian) strata in Deep Sea Drilling Project Site 100, North Atlantic Basin. In the tetraplacoid contiguous operculum, the paraplates labelled 2' and 4' by Zotto et al. (1987) are in substantial contact. As a result, the dorsal paraplate (3' of Zotto et al., 1987) becomes an anterior intercalary paraplate.

Lithodinia borealis (Sarjeant 1980, p. 123-124) Riley & Fenton 1980, p. 200. The holotype (Sarjeant 1972, pl. 5, fig. 3, text-fig. 5, as *Meiourogoniaulax decapitata*) is from the Middle Jurassic (Bathonian) of Greenland. This species and *L. callomonii* may be conspecific and *L. arkitos* Fenton 1981 is a taxonomic junior synonym (Riley and Fenton 1982).

Lithodinia bulloidea (Cookson and Eisenack 1960b, p. 247, pl. 37, fig. 11, text-figs. 4a-b) Gocht 1976, p. 334. The holotype and the only specimen illustrated in Cookson and Eisenack (1960b, as *Goniaulax bulloidea*) is from the Upper Jurassic (?Tithonian) of Australia.

Lithodinia callomonii (Sarjeant 1972, p. 31-33, pl. 5, fig. 5, text-fig. 6) Gocht 1976, p. 334. The holotype and the only specimen illustrated in Sarjeant (1972) is from the Middle Jurassic (Bathonian) of Greenland.

Lithodinia caytonensis (Sarjeant 1959, p. 330-332, pl. 13, fig. 1, text-fig. 1) Gocht 1976, p. 334. The holotype and the only specimen illustrated in Sarjeant (1959), is from the Middle Jurassic (Callovian) of Yorkshire, England.

Lithodinia cristulata (Sarjeant 1959, p. 332-334, pl. 13, fig. 2, text-fig. 2) Gocht 1976, p. 334. The holotype and the only specimen illustrated in Sarjeant (1959) is from the Middle Jurassic (Callovian) of Yorkshire, England.

Lithodinia decapitata (W. Wetzel 1967) Gocht 1976; see *L. valensii*.

Lithodinia deflandrei (Sarjeant 1968, p. 228-229, pl. 1, fig. 20; pl. 3, fig. 13, text-fig. 4) Gocht 1976, p. 334. The holotype (Sarjeant 1968, pl. 1, fig. 20, text-fig. 4) is from the Middle Jurassic (Callovian) of Normandy, France.

Lithodinia germanii (Beju 1971, p. 287-288, pl. 4, figs. 1-3, text-fig. 4) Gocht 1976, p. 334. The holotype (Beju 1971, pl. 4, fig. 1, text-fig. 4) is from the Jurassic (within a Callovian-Oxfordian interval, exact position not given) of the Carpathian Foreland, Rumania.

Lithodinia maculata (Backhouse 1988, p. 96, pl. 32, figs. 8-11, text-figs. 29a-b) *comb. nov.* The holotype (*ibid.*, figs. 9a-b, text-figs. 29a-b, as *Meiourogoniaulax maculata*) is from the Lower Cretaceous (Barremian) of Western Australia, Australia.

Lithodinia mitra (Dürr 1987, p. 74, 77, pl. 3, figs. a-b; pl. 4, figs. 3-6; pl. 6, figs. 1-3, 5) *comb. nov.* The holotype (*ibid.*, pl. 4, fig. 3, as *Meiourogoniaulax mitra*) is from the Upper Jurassic (Kimmeridgian) of Germany.

Lithodinia pertusa Duxbury 1977, p. 41-43, pl. 8, fig. 5. The holotype and only illustrated specimen is from the Lower Cretaceous (Hauterivian) of England. We interpret the paraplate labelled 7''' by Duxbury (1977) as a sulcal paraplate.

Lithodinia pertusa subsp. *heta* (Below 1981, p. 56-57, pl. 3, figs. 7a-8b; pl. 11, fig. 21; pl. 14, figs. 1-4, text-figs. 59-60) *comb. nov.* The holotype (*ibid.*, pl. 3, figs. 8a-b, as *Meiourogoniaulax pertusa* subsp. *heta*) is from the Lower Cretaceous (Hauterivian) of Morocco.

Lithodinia pila (Gitmez and Sarjeant 1972, p. 226-227, pl. 4, fig. 5; pl. 7, fig. 3, text-fig. 23) Gocht 1976, p. 334. The holotype (Gitmez and Sarjeant 1972, pl. 4, fig. 5, text-fig. 23) is from the Upper Jurassic (Kimmeridgian) of Dorset, England.

Lithodinia planoseptata (Riding 1987a, p. 262, fig. 9, nos. 9-12, fig. 13) *comb. nov.* The holotype (Riding 1987a, fig. 9, nos. 9-10, as *Meiourogoniaulax planoseptata*) is from the Middle Jurassic (Callovian) of Lincolnshire, England.

Lithodinia psora (Davey and Verdier 1974, p. 634, 636, pl. 92, figs. 8-9) Gocht 1976, p. 334. The holotype and the only specimen illustrated (as *Meiourogoniaulax psora*) is from the Lower Cretaceous (Aptian) of France.

Lithodinia reticulata (Dodekova 1975, p. 22-23, pl. 2, figs. 11-13, text-fig. 4) Gocht 1976, p. 334. The holotype (Dodekova 1975, pl. 2, figs. 11-12) is from the Middle Jurassic (Bathonian) of Bulgaria.

Lithodinia spongiosa (Smelror 1987, p. 230-232, figs. 5A-G, text-fig. 3) *comb. nov.* The holotype (Smelror 1987, fig. 5B, as *Meiourogonaulax spongiosa*) is from the Middle Jurassic (Callovian) of Franz Josef Land, arctic U.S.S.R.

Lithodinia stoveri (Millioud 1969, p. 429, pl. 3, figs. 1-3) Gocht 1976, p. 334. The holotype (Millioud 1969, pl. 3, figs. 1-2) is from the Lower Cretaceous (Hauterivian) of France.

Lithodinia valensii (Sarjeant in Davey et al., 1966, p. 145-146, pl. 15, fig. 7, text-fig. 37) Gocht 1976, p. 334. The holotype (Valensi 1955, pl. 2, figs. 12-13, and the only specimen which was re-illustrated by Sarjeant in Davey et al., 1966) is from the Middle Jurassic (Bathonian) of France. We concur with Fenton (1981, p. 253) that *L. decapitata* (W. Wetzel 1967) Gocht 1976 is a taxonomic junior synonym of *L. valensii*.

Provisionally accepted species

Lithodinia? diaphanis (Stevens 1987, p. 191-192, figs. 4A-K, 6-7) *comb. nov.* The holotype (*ibid.*, figs. 4A-D, 6, as *Meiourogonaulax diaphanis*) is from Lower Cretaceous (Barremian) strata in the Sirius-1 well, Exmouth Plateau, Western Australia, Australia. The provisional assignment takes into account the presence of a fairly prominent, hollow apical horn and the rectangular outline of the body. Neither feature is found on other species of *Lithodinia*.

Lithodinia? insulofigurata (Dodekova 1975, p. 21-22, pl. 2, figs. 4-5, 7-8, text-figs. 3a-c) Gocht 1976, p. 334. The holotype (Dodekova 1975, pl. 2, figs. 4-5) is from the Middle Jurassic (Bathonian) of Bulgaria. In consideration of the relatively wide parasutural (?pandasutural) features reported in the description, this species might be placed more appropriately in *Lanterna* Dodekova 1969. However, because features critical for a positive identification are not clearly evident in the illustrations in Dodekova (1975), we retain the form provisionally in *Lithodinia*.

Lithodinia? rioultii (Sarjeant 1968, p. 229) Gocht 1976, p. 334. The holotype (Sarjeant 1965, pl. 1, fig. 1, text-fig. 1 and the only illustrated specimen) is from the Middle Jurassic (Callovian) of Normandy, France. The provisional assignment expresses uncertainties about the paratabulation as interpreted by Sarjeant (1965, text-fig. 1). Unusual features include: the presence of an anterior intercalary paraplate (1a), the relationship and sizes of 1''' and 2''', and the fact that 2''' is in contact with 1'''.

Lithodinia? serrulata Davies 1983, p. 26, pl. 9, figs. 1-6, text-figs. 21A-B. The holotype (*ibid.*, pl. 9, figs. 3-4) is from Jurassic strata in the Elk Jameson Bay C31 well, Prince Patrick Island, Arctic Canada. Precise age and exact depth of the type stratum are not given. The paratabulation departs from the usual gonyaulacean style in that paraplate 1''' is large and wide and is as high longitudinally as 2'''; 6'' is subtriangular and substantially smaller than 5'' and the 3'''/4''' contact is middorsal.

Lithodinia? staffinensis (Gitmez 1970, p. 276-278, pl. 3, fig. 1, text-figs. 20A-B) Gocht 1976, p. 334. The holotype (Gitmez 1970, pl. 3, fig. 1, text-figs. 20A-B) and only illustrated specimen is from the Upper Jurassic (Kimmeridgian) of Scotland. The drawing by Gitmez shows three small posterior intercalary paraplates (labelled 1pv, 1p and 2p) rather than the customary single 1p paraplate.

Lithodinia? stronglylos (Sarjeant 1972, p. 35-37, pl. 4, fig. 7, text-fig. 7) Gocht 1976, p. 334. The holotype and only illustrated specimen is from the Middle Jurassic (Bathonian) of Greenland. The drawing by Sarjeant depicts a paratabulation formula which has: 7 cingular paraplates instead of 6, 7 postcingular paraplates rather than 5 or 6, and the 3'''/4''' parasutural boundary in a middorsal position.

Lithodinia? superornata (W. Wetzel 1967, p. 869, pl. 16, figs. 8a-b) Fenton 1981, p. 253 emended Sarjeant 1980, p. 124-125. The holotype (W. Wetzel 1967, pl. 16, figs. 8a-b and re-illustrated in Sarjeant 1980, pl. 1, figs. 2-3, text-fig. 4) is from the Middle Jurassic (Bajocian) of Germany. The relatively small epicyst and elongate hypocyst, resulting in the paracingulum being much nearer the apex than the antapex, coupled with deviations in the depicted paratabulation (for example, the presence of two posterior intercalary paraplates) are denoted by the provisional assignment.

Problematical Species

Lithodinia acanthosphaera (Sarjeant 1961, p. 94-95, pl. 13, fig. 14, text-fig. 4) Lentin and Williams 1977b, p. 100. The holotype (Sarjeant 1961 and the only illustrated specimen was re-illustrated in Sarjeant 1976, pl. 5, figs. 2, 4, when he transferred the species provisionally to *Meiourogonaulax*), is from the Upper Jurassic (Oxfordian) of Yorkshire, England. The species is not attributable to *Lithodinia* with any degree of certainty or confidence, and on the basis of the re-illustrations of the holotype, assignment to another genus is not obvious.

Reattributed species

Epiplosphaera areolata Klement 1960, p. 76-77, pl. 8, figs. 5-9; holotype, pl. 8, figs. 5-7 = *Lithodinia? areolata* (Klement 1960) Sarjeant 1984a, p. 166. We retain this species in *Epiplosphaera* because of the lack of definitive evidence about the paratabulation.

Lanterna cantrellii (Sarjeant 1972) *comb. nov.* = *Meiourogonaulax? cantrellii* Sarjeant 1972, p. 37-38, pl. 4, fig. 3; pl. 6, figs. 1-2, text-fig. 8: holotype and only specimen illustrated by Sarjeant. Pandasutural areas are clearly evident on the holotype together with bordering penitabular features.

Ellipsoidictyum sagemum (Duxbury 1980) *comb. nov.* = *Lithodinia sagemum* Duxbury 1980, pl. 13, figs. 6, 9, 12-13: holotype, figs. 6, 9, 12. The reticulate ornamentation precludes retention in *Lithodinia*.

Escharisphaeridia dicrypta (Gitmez and Sarjeant 1972) *comb. nov.* = *Meiourogonyaulax dicrypta* Gitmez and Sarjeant 1972, p. 225-226, pl. 7, fig. 6, text-fig. 20: holotype and only specimen illustrated by Gitmez and Sarjeant. This species was transferred from *Meiourogonyaulax* to *Lithodinia* by Gocht (1976, p. 334) and subsequently assigned by Below (1981, p. 31) to *Canningia* Cookson & Eisenack 1960b as emended Below 1981. However, Helby (1987, p. 324-325) rejected Below's treatment and retained the species in *Meiourogonyaulax*. Photomicrographs of the holotype fail to reveal parasutural features, hence our transfer of *M. dicrypta* to *Escharisphaeridia*.

DESCRIPTION OF *TECTATODINIUM* *GRANDE* SP. NOV.

Rex Harland thoughtfully advised one of us (LES) that the specimens we showed as *Tectatodinium pellitum* Wall 1967 during the 1984 Short Course were misidentified. These mistakenly identified, thick-walled forms are described below under the new name, *Tectatodinium grande*.

TECTATODINIUM Wall 1967, p. 112-113

Type Species.

Tectatodinium pellitum Wall 1967, p. 113, pl. 16, figs. 11-12.

Tectatodinium grande sp. nov.

or

Synonymy

Tectatodinium sp. 2 of Manum et al., 1989, pl. 20, figs. 3-4.

Description.

Cysts proximate, spherical or nearly so, and thick-walled. Wall consists of a thin (1.0 µm or less) endophragm that is faintly structured and appressed to a much thicker and more compact periphragm (3.0 to 3.5 µm) composed of rather densely-packed, short, sinuous fibroid threads. Archeopyle formed by the release of a 5-sided paraplate, presumably from a middorsal, precingular position; operculum monoplacoid and free. Other indications of dinoflagellate affinity such as paratabulation or the presence of a paracingulum or a parasulcus or horns are lacking. Cysts 32 to 45 µm in diameter.

Holotype

Specimen illustrated by Manum et al., 1989, pl. 20, figs. 3-4; diameter, 36 µm. Repository: Palaeontological Museum, University of Oslo, Oslo, Norway.

Type Locality and Stratum.

ODP Leg 104, Site 643A at the outer Vøring Plateau, Norwegian Sea; core 08-6, sample 48-50 cm at a depth of 70.28 m below the seafloor; Late Miocene (undifferentiated), probably Tortonian.

Comparison.

The very thick wall (about 4.0 µm) coupled with the compact, densely fibroid periphragm characterize *Tectatodinium grande*. *Tectatodinium minutum* Matsuoka 1983 has a thinner wall (about 2.0 µm) and is granular; the periphragm on *T. pellitum* Wall 1967 is also about one-half as thick as that of *T. grande* and is less dense; the wall in typical specimens of *T. psilatum* Wall & Dale in Wall et al., 1973 is smooth, and finally, the wall in *T. rugulatum* (Hansen 1977) McMinn 1988, which is as thick as that of *T. grande*, is less compact and rugulate.

Stratigraphic Range.

Latest Paleocene to Late Miocene.

SPECIES REATTRIBUTIONS AND SYNONYMS

Apectodinium folliculum Islam 1983b, p. 336-337, pl. 1, figs. 8-9; considered a taxonomic junior synonym of *Apectodinium homomorphum* (Deflandre & Cookson 1955) Lentin & Williams 1977b, emended Harland 1979c.

Hystrichosphaeridium caiboense Regali et al., 1974, p. 290, pl. 24, fig. 4; considered a taxonomic junior synonym of *Apectodinium homomorphum* (Deflandre & Cookson 1955) Lentin & Williams 1977b, emended Harland 1979c. Last previous assignment was to *Apectodinium*.

Trichodinium scarburghense *comb. nov.* = *Gonyaulacysta scarburghensis* Sarjeant 1964, p. 472-472 (Basonym = *Gonyaulax areolata* Sarjeant 1961, p. 95-96, pl. 13, fig. 13, text-fig. 5, *non Gonyaulax areolata* Kofoed & Michener 1911). Last previous assignment was to *Liesbergia*.

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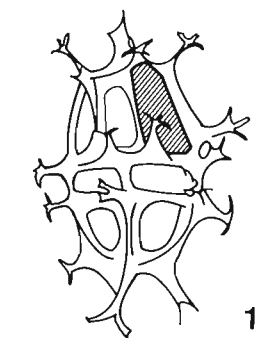
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PLATE 1

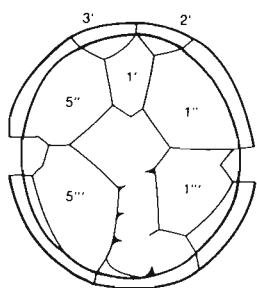
For plates 1-14, alphanumeric designation in brackets denotes the position of that taxon on one of the three range charts. T = Tertiary-Holocene range chart (no. 3), C = Cretaceous range chart (no. 2), J. = Triassic-Jurassic range chart (no. 1). In this and subsequent plates, the cross-hatching denotes the archeopyle.

- Figure 1.** *Spiniferites elongatus* (T-1). Holotype dimensions: central body length = 49 μm , central body width = 30 μm process length = 6-13 μm
- Figure 2.** *Impagidinium patulum* (T-2). Holotype dimensions: diameter about 55 μm
- Figure 3.** *Bitectatodinium tepikiense* (T-3). Holotype dimensions: diameter = 51 μm
- Figure 4.** *Trinovantedinium capitatum* (T-4). Holotype dimensions: length = 77 μm , width = 64 μm
- Figure 5.** *Spiniferites mirabilis* (T-5). Holotype dimensions: central body diameter = 52 μm by 44 μm
- Figure 6.** *Tuberculodinium vancampoe* (T-6). Holotype dimensions: diameter about 130 μm
- Figure 7.** *Selenopemphix* sp. (T-7). Dimensions of holotype of type species, *S. nephroides*: width = 76 μm
- Figure 8.** *Lejeunecysta* sp. (T-8). Dimensions of holotype of type species, *L. hyalina*: length = 93 μm , width = 93 μm
- Figure 9.** *Polysphaeridium zoharyi* (T-9). Holotype dimensions: diameter = 45 μm
- Figure 10.** *Lingulodinium machaerophorum* (T-10). Holotype dimensions: diameter about 50 μm
- Figure 11.** *Melitasphaeridium choanophorum* (T-11). Holotype dimensions: central body diameter about 30 μm
- Figure 12.** *Filisphaera filifera* (T-12). Range of type material: length = 45 to 60 μm , width = 45 to 56 μm
- Figure 13.** *Nematosphaeropsis lemniscata* (T-13). Range of type material: central body diameter = 23 x 28 μm to 37 x 41 μm , maximum process length = 21 to 32 μm
- Figure 14.** *Reticulosphaera actinocoronata* (T-14). Holotype dimensions: central body diameter = 14 μm
- Figure 15.** *Hystrichokolpoma rigaudiae* (T-15). Holotype dimensions: central body diameter = 33 μm
- Figure 16.** *Invertocysta tabulata* (T-16). Holotype dimensions: length = 90 μm
- Figure 17.** *Achomosphaera andalousiensis* (T-17). Holotype dimensions: central body diameter = 35 μm by 40 μm , process length = 15 μm
- Figure 18.** *Amiculosphaera umbracula* (T-18). Holotype dimensions: length = 80 μm , width = 86 μm
- Figure 19.** *Hystrichosphaeropsis obscura* (T-19). Holotype dimensions: central body diameter about 38 μm
- Figure 20.** *Spiniferites splendidus* (T-20). Holotype dimensions: central body length = 70 μm , central body width = 74 μm

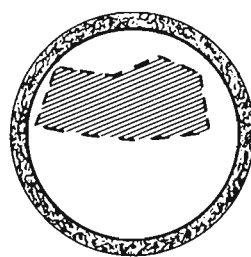
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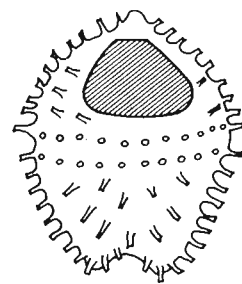
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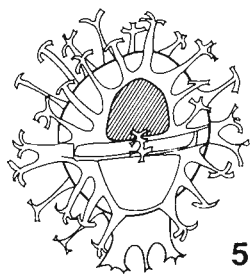
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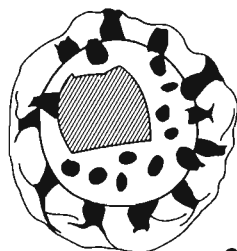
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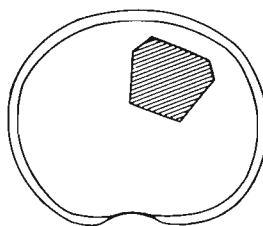
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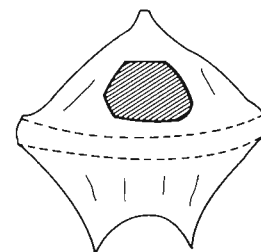
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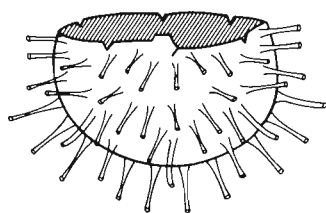
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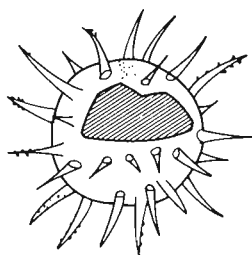
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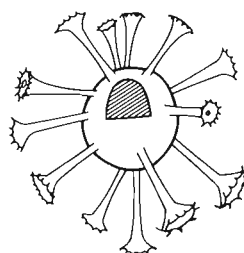
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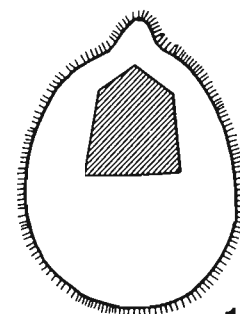
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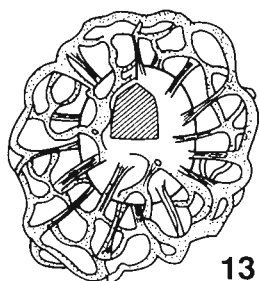
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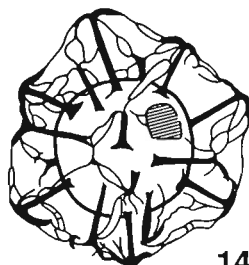
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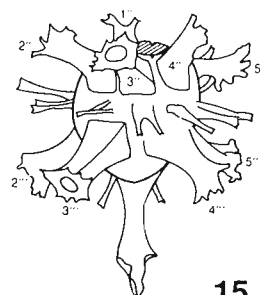
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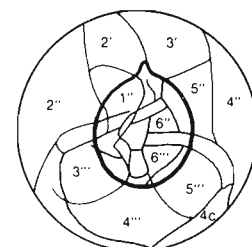
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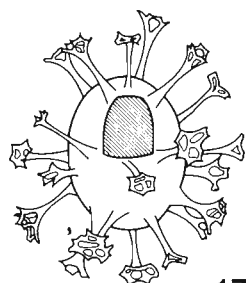
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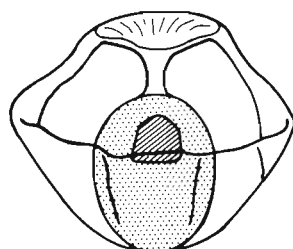
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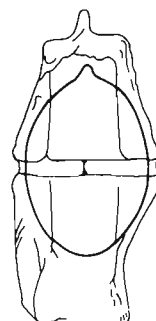
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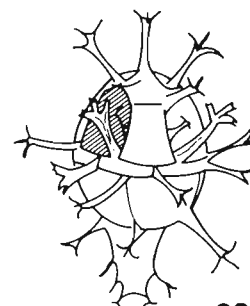
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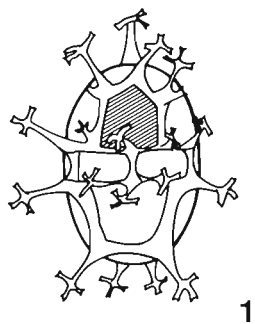


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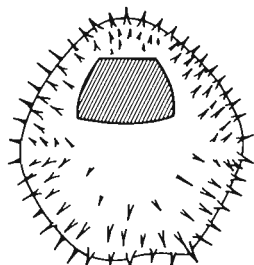
PLATE 2

- Figure 1.** *Spiniferites ellipsoideus* (T-21). Holotype dimensions: central body diameter = 40 μm by 27 μm , process length = 6-9 μm
- Figure 2.** *Sumatradinium* sp. (T-22). Range of type species, *S. hispidum*: length = 78 to 97 μm , width = 72 to 87 μm
- Figure 3.** *Labyrinthodinium truncatum* (T-23). Holotype dimensions: diameter = 25 μm , process length = 5 μm
- Figure 4.** *Impagidinium aquaeductum* (T-24). Holotype dimensions: overall length = 39 μm , overall width = 38 μm , central body length = 27 μm , central body width = 26 μm
- Figure 5.** *Dapsilidinium pseudocolligerum* (T-25). Range of type material: overall diameter = 60 to 92 μm , central body diameter = 36 to 45 μm , process length = 15 to 23 μm
- Figure 6.** *Palaeocystodinium golzowense* (T-26). Holotype dimensions: pericyst length = 130 μm , pericyst width = 38 μm
- Figure 7A,B** *Batiacasphaera sphaerica* (T-27). Range of type material: overall diameter = 32 to 40 μm
- Figure 8A,B** *Batiacasphaera micropapillata* (T-28). Holotype dimensions: diameter = 38 μm
- Figure 9.** *Systematophora placacantha* (T-29). Holotype dimensions: overall diameter about 100 μm
- Figure 10.** *Spiniferites pseudofurcatus* (T-30). Holotype dimensions: central body diameter = 66 μm
- Figure 11.** *Apteodinium australiense* (T-31). Range of type material: length = 102 to 105 μm , width = 87 to 105 μm
- Figure 12.** *Pentadinium laticinctum* (T-32). Holotype dimensions: overall diameter = 91 μm by 90 μm
- Figure 13.** *Achomosphaera allicornu* (T-33). Holotype dimensions: overall diameter = 157 μm , central body diameter = 65 μm by 67 μm
- Figure 14.** *Apteodinium spiridoides* (T-34). Holotype dimensions: length = 76 μm , width = 73 μm
- Figure 15.** *Cribroperidinium tenuitabulatum* (T-35). Holotype dimensions: length = 84 μm , width = 75 μm
- Figure 16.** *Chiropteridium mespilanum* (T-36). Holotype dimensions: overall diameter = 102 μm , central body diameter = 62 μm by 48 μm
- Figure 17.** *Distatodinium paradoxum* (T-37). Holotype dimensions: central body diameter = 58 μm by 27 μm
- Figure 18,19** *Evittosphaerula paratabulata* (T-38). Holotype dimensions: maximum diameter = 98 μm
- Figure 20.** *Homotryblium plectilum* (T-40). Holotype dimensions: central body diameter = 43 μm , process length = 14 μm

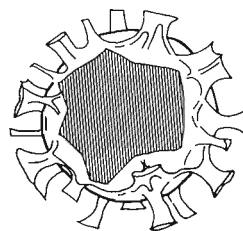
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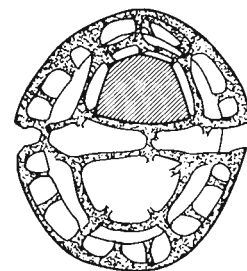
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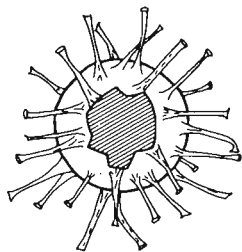
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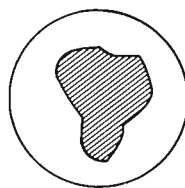
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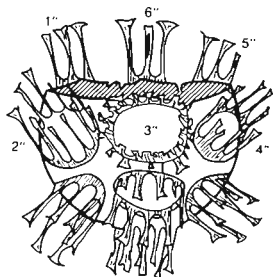
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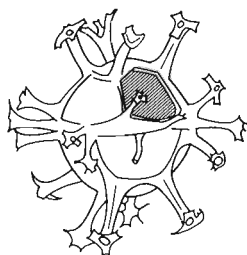
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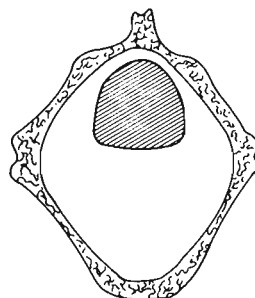
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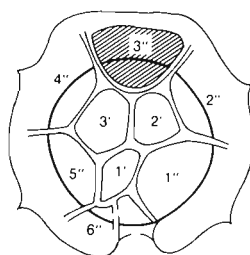
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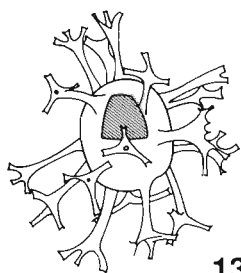
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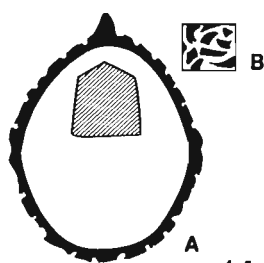
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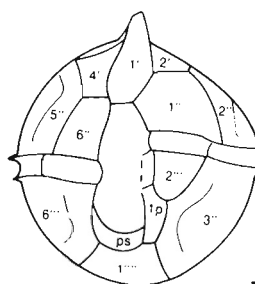
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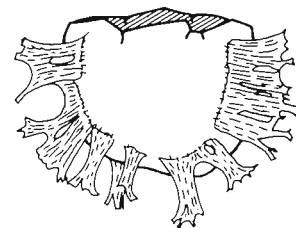
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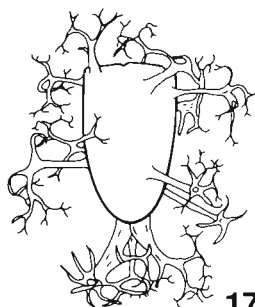
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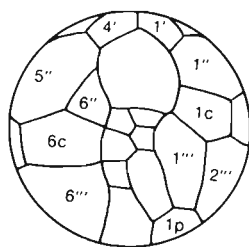
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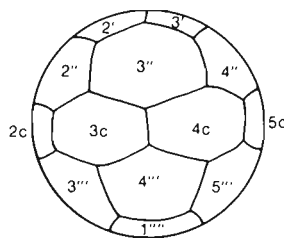
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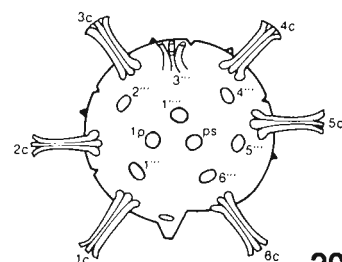
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PLATE 3

- Figure 1,2** *Homotryblium vallum* (T-39). Range of type material: overall diameter = 70 to 80 μ m, central body diameter = 47 to 53 μ m, process length = 13 to 20 μ m
- Figure 3.** *Cordosphaeridium cantharellum* (T-41). Holotype dimensions: central body diameter = 54 μ m
- Figure 4.** *Membranophoridium aspinatum* (T-42). Holotype dimensions: overall diameter = 93 by 110 μ m, central body diameter = 74 by 84 μ m
- Figure 5,6** *Hystriochokolpoma cinctum* (T-43). Holotype dimensions: central body diameter = 46 μ m
- Figure 7.** *Caligodinium amiculum* (T-44). Holotype dimensions: diameter = 68 by 64 μ m
- Figure 8.** *Impagidinium dispertitum* (T-46). Holotype dimensions: length = 62 μ m, width = 57 μ m
- Figure 9-11** *Deflandrea phosphoritica* (T-45). Holotype dimensions: pericyst length = 116 μ m
- Figure 12.** *Wetzeliiella symmetrica* (T-47). Holotype dimensions: pericyst length = 185 μ m, pericyst width = 175 μ m, endocyst length = 120 μ m, endocyst width = 114 μ m
- Figure 13.** *Tectatodinium grande* (T-48). Holotype dimensions: diameter = 36 μ m
- Figure 14A-B** *Thalassiphora pelagica* (T-49). Holotype dimensions: central body diameter = 81 by 69 μ m
- Figure 15,16** *Polysphaeridium congregatum* (T-50). Holotype dimensions: central body diameter = 52 by 50 μ m
- Figure 17,18** *Phthanoperidinium* spp. (T-51). Dimensions of holotype of type species, *P. amoenum*: length = 38 μ m, width = 35 μ m
- Figure 19.** *Corrudinium incompositum* (T-52). Holotype dimensions: length = 40 μ m, width = 40 μ m
- Figure 20.** *Areosphaeridium arcuatum* (T-53). Holotype dimensions: central body diameter = 40 by 53 μ m

PLATE 3

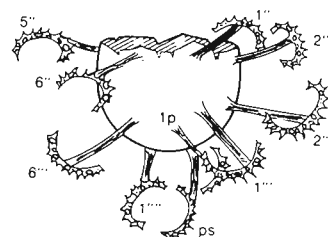
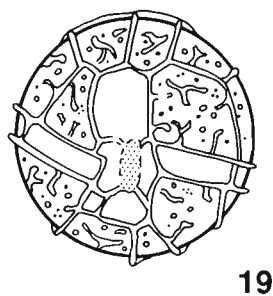
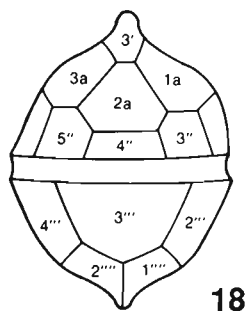
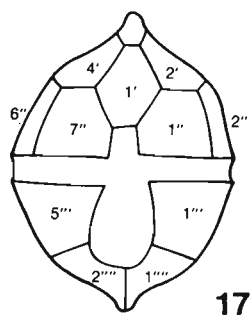
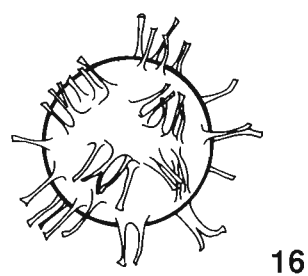
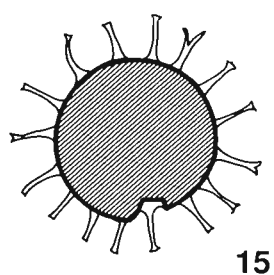
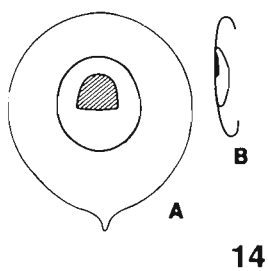
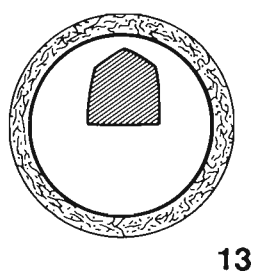
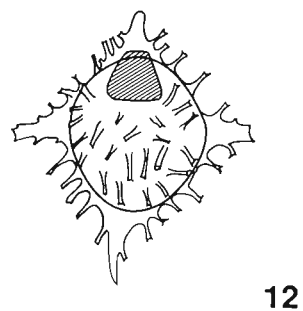
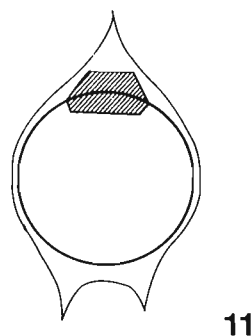
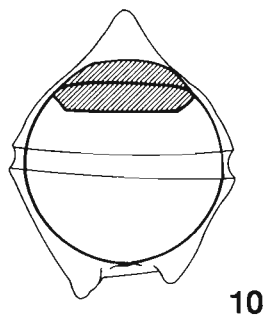
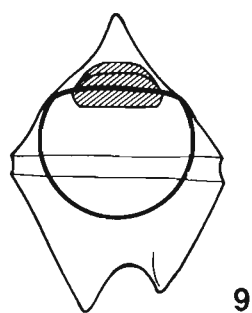
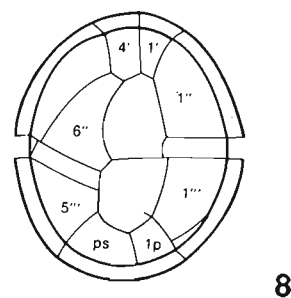
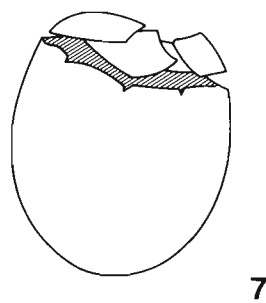
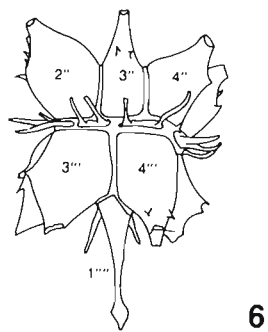
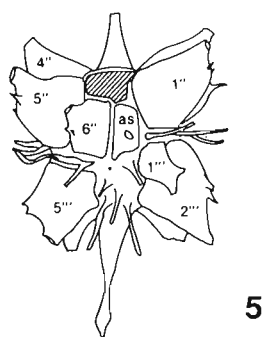
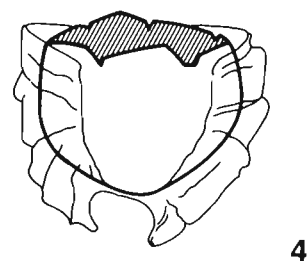
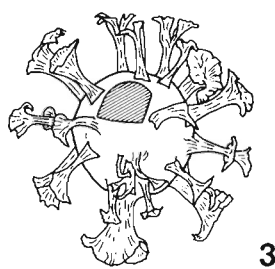
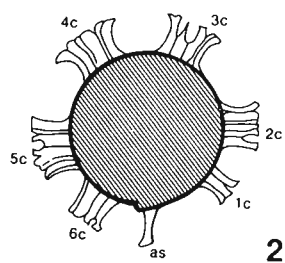
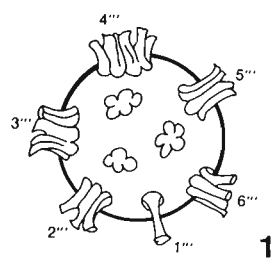
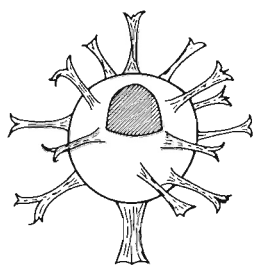
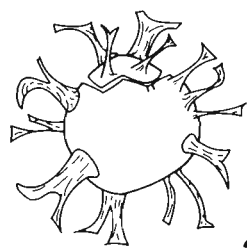


PLATE 4

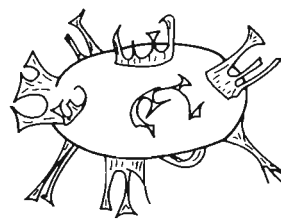
- Figure 1.** *Cordosphaeridium gracile* (T-54). Holotype dimensions: central body diameter = 77 μ m, process length = 46-52 μ m
- Figure 2,3** *Areoligera? semicirculata* (T-55). Range of type material: central body length = 45 μ m to 61 μ m, central body width = 42 to 56 μ m, central body height = 33 to 40 μ m, process length = 5 to 33 μ m
- Figure 4.** *Rhombodinium draco* (T-56). Holotype dimensions: pericyst length = 150 μ m, pericyst width = 158 μ m
- Figure 5.** *Samlandia chlamydophora* (T-57). Holotype dimensions: length = 86 μ m, width = 76 μ m
- Figure 6.** *Achilleodinium biformoides* (T-58). Holotype dimensions: central body diameter = 50 μ m
- Figure 7.** *Senegalinium* sp. (T-59). Dimensions of holotype of type species, *S. bicavatum*: overall length = 100 μ m, overall width = 65 μ m, endocyst length = 63.7 μ m, endocyst width = 65 μ m
- Figure 8.** *Fibrocysta axialis* (T-60). Holotype dimensions: overall width = 57 μ m, central body length = 71 μ m
- Figure 9.** *Cordosphaeridium fibrospinosum* (T-61). Holotype dimensions: central body diameter = 63 by 67 μ m, process length = 15 to 28 μ m
- Figure 10.** *Operculodinium divergens* (T-62). Holotype dimensions: overall diameter = 124 μ m, central body diameter = 71 μ m
- Figure 11,12** *Kisselovia coleothrypta* (T-63). Holotype dimensions: pericyst length = 122 μ m, pericyst width = 110 μ m
- Figure 13.** *Wetzeliiella articulata* (T-64). Holotype dimensions: pericyst length = 167 μ m
- Figure 14A,B** *Batiacasphaera compta* (T-65). Holotype dimensions: length = 75 μ m
- Figure 15.** *Areosphaeridium diktyoplokus* (T-66). Holotype dimensions: central body diameter = 48 μ m
- Figure 16.** *Cordosphaeridium funiculatum* (T-67). Holotype dimensions: central body diameter = 57 μ m
- Figure 17A-C,18** *Homotryblium tenuispinosum* (T-68). Holotype dimensions: central body diameter = 41 by 48 μ m
- Figure 19.** *Diphyes colligerum* (T-69). Holotype dimensions: central body diameter = 33 μ m
- Figure 20.** *Rhombodinium porosum* (T-71). Holotype dimensions: pericyst length = 138 μ m, pericyst width = 145 μ m



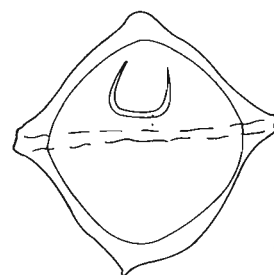
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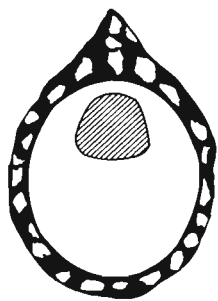
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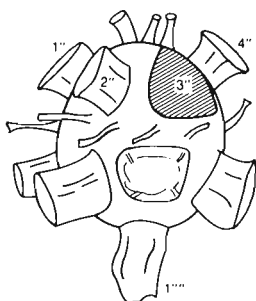
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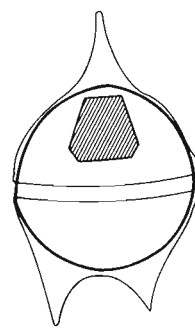
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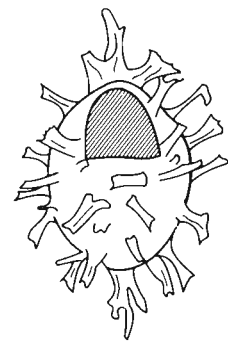
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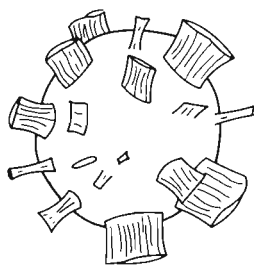
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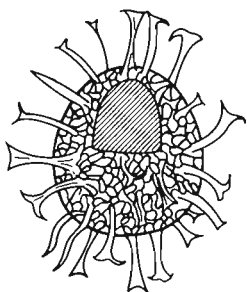
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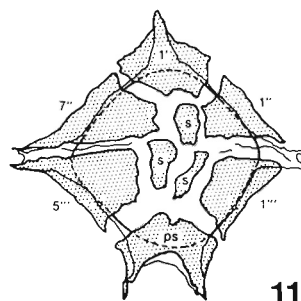
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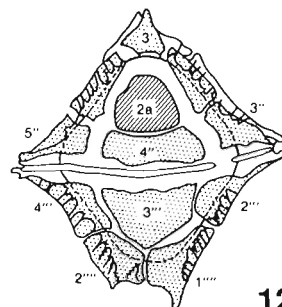
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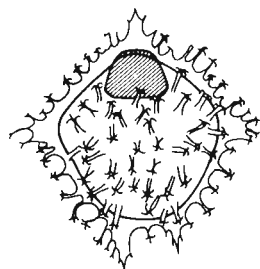
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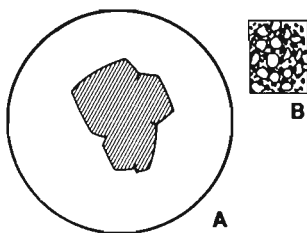
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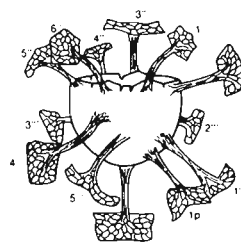
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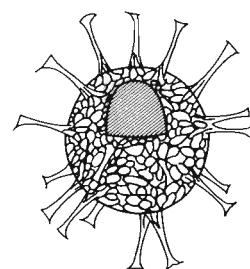
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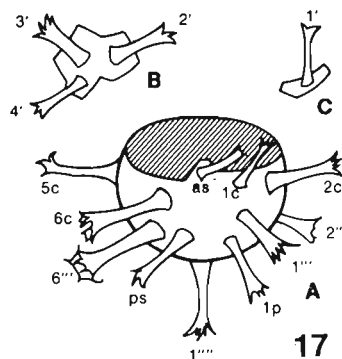
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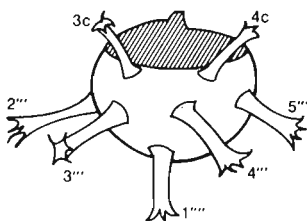
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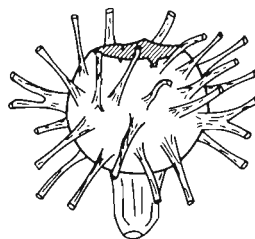
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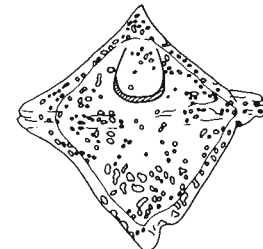
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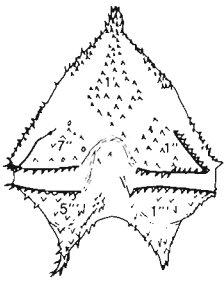


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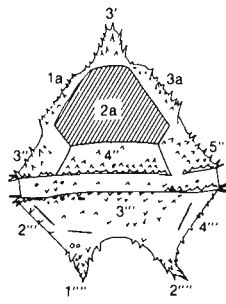
PLATE 5

- Figure 1,2** *Lentinia serrata* (T-70). Holotype dimensions: pericyst length = 52 μ m, pericyst width = 32 μ m
- Figure 3.** *Melitasphaeridium pseudorecurvatum* (T-72). Holotype dimensions: central body diameter = 34 μ m
- Figure 4.** *Glaphyrocysta exuberans* (T-73). Range of type material: overall diameter = 70 to 80 μ m, central body diameter = 40 to 70 μ m
- Figure 5,6** *Heteraulacacysta porosa* (T-74). Holotype dimensions: overall diameter = 85 by 91 μ m
- Figure 7.** *Adnatospaeridium multispinosum* (T-75). Holotype dimensions: central body diameter = 44 by 59 μ m
- Figure 8.** *Apectodinium homomorphum* (T-76). Holotype dimensions: overall diameter = 67 μ m
- Figure 9A-C** *Eocladopyxis peniculata* (T-77). Holotype dimensions: central body length = 38 μ m
- Figure 10.** *Muratodinium fimbriatum* (T-78). Holotype dimensions: overall length = 118 μ m, overall width = 104 μ m
- Figure 11.** *Dracodinium condylos* (T-79). Holotype dimensions: pericyst length = 122 μ m, pericyst width = 112.5 μ m
- Figure 12.** *Eatonicysta ursulae* (T-80). Holotype dimensions: central body diameter = 50 μ m
- Figure 13.** *Oligospaeridium complex* (T-81). Neotype dimensions: central body diameter = 35 μ m
- Figure 14.** *Areoligera senonensis* (T-82). Range of type material: overall diameter = 44 by 57 μ m
- Figure 15.** *Hystrichospaeridium tubiferum* (T-83). Holotype dimensions: central body diameter 33 by 34 μ m
- Figure 16.** *Thalassiphora patula* (T-84). Holotype dimensions: central body diameter = 75 by 80 μ m, process length up to 37 μ m
- Figure 17.** *Glaphyrocysta ordinata* (T-85). Holotype dimensions: central body diameter = 61 by 73 μ m
- Figure 18.** *Cerodinium speciosum* (T-86). Holotype dimensions: pericyst length = 120 μ m, pericyst width = 74 μ m
- Figure 19.** *Hystrichospaeridium salpingophorum* (T-87). Holotype dimensions: central body diameter = 42 by 37 μ m
- Figure 20.** *Lanternospaeridium* sp. (T-88). Range of type material of the type species, *L. lanosum*: central body length = 61 to 70 μ m, central body width = 45 to 53 μ m, overall length = 87 to 123 μ m, overall width = 50 to 98 μ m

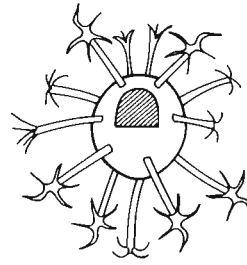
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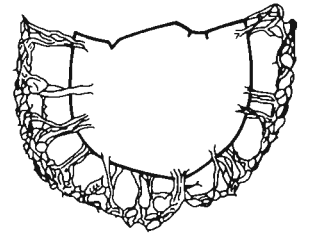
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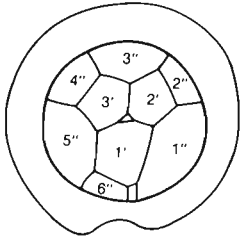
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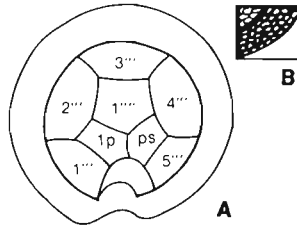
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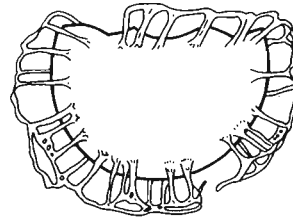
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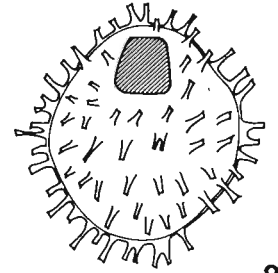
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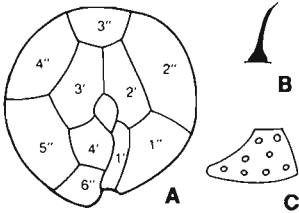
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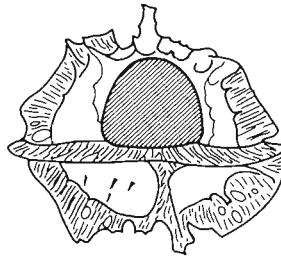
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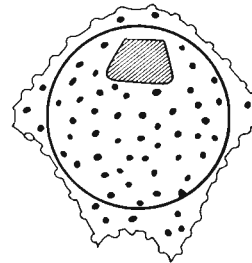
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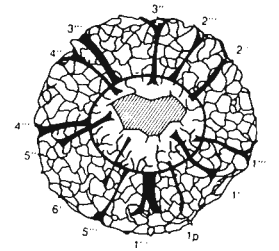
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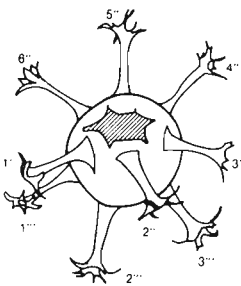
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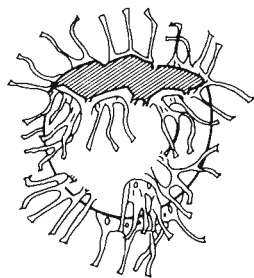
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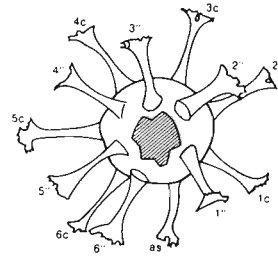
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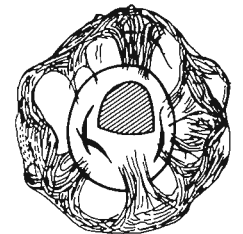
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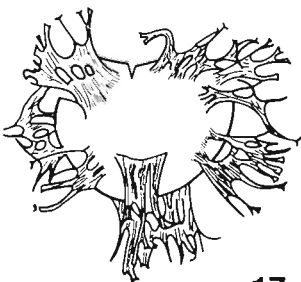
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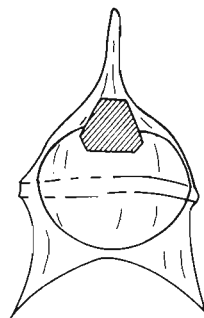
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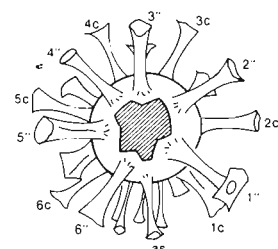
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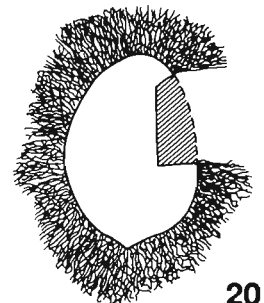
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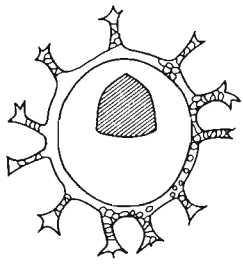


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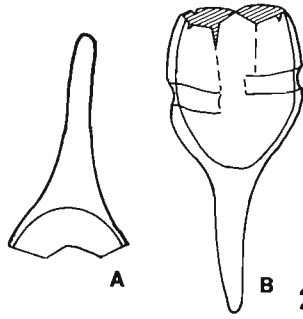
PLATE 6

- Figure 1.** *Spiniferites septatus* (T-89). Holotype dimensions: central body diameter = 57 μm
- Figure 2A,B** *Biconidinium longissimum* (T-90). Holotype dimensions: pericyst length = 140 μm , pericyst width = 51 μm , endocyst length = 57 μm , endocyst width = 49 μm
- Figure 3.** *Deflandrea oebisfeldensis* (T-91). Holotype dimensions: pericyst length = 150 μm , pericyst width = 88 μm
- Figure 4A,B** *Alisocysta margarita* (T-92). Holotype dimensions: length = 44 μm , width = 40 μm
- Figure 5.** *Apectodinium augustum* (T-93). Holotype dimensions: pericyst length (excluding horns) = 63.75 μm , pericyst width (excluding horns) = 66.25 μm
- Figure 6A,B** *Alisocysta circumtabulata* (T-94). Range of type material: length = 37 to 47 μm , width = 36-47 μm
- Figure 7,8** *Cladopyxidium saeptum* (T-95). Holotype dimensions: 16 by 18 μm
- Figure 9,10** *Microdinium* sp. (T-96). Dimensions of holotype of type species, *M. ornatum*: length = 29 μm , width = 27 μm
- Figure 11.** *Palaeoperidinium pyrophorum* (T-97). Holotype dimensions: length = 92 μm , width = 74 μm
- Figure 12A,B** *Alisocysta reticulata* (T-98). Average range of type material: length = 55 μm , width = 51 μm
- Figure 13.** *Trithyrodinium* sp. (T-99). Dimensions of holotype of type species, *T. evittii*: pericyst length = 90 μm , pericyst width = 78 μm
- Figure 14.** *Carpatella cornuta* (T-100). Holotype dimensions: length = 114 μm , width = 90 μm
- Figure 15.** *Andalusiella* spp. (T-101). Dimensions of holotype of type species, *A. mauthei*: pericyst length = 152 μm , endocyst length = 101 μm , endocyst width = 82 μm
- Figure 16.** *Conneximura fimbriata* (T-102). Holotype dimensions: length 118 μm , width = 104 μm
- Figure 17.** *Senoniasphaera inornata* (T-103). Holotype dimensions: overall length (with operculum) = 118 μm , overall width = 100 μm
- Figure 18.** *Danea californica* (T-104). Range of type material: length = 61 to 103 μm , width = 44 to 66 μm
- Figure 19,20** *Hystriochokolpoma bulbosum* (T-105). Dimensions of specimens examined by Morgenroth (1968): maximum body length = 31 to 43 μm , maximum body width = 25 to 33 μm , process length = 6-31 μm

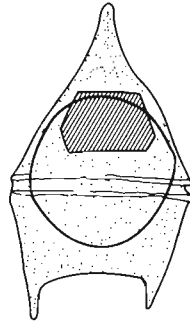
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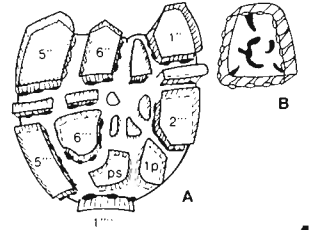
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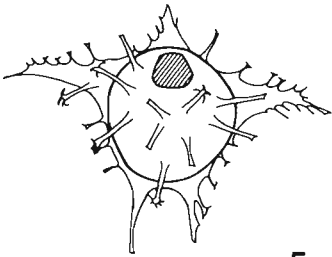
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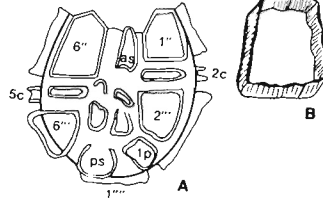
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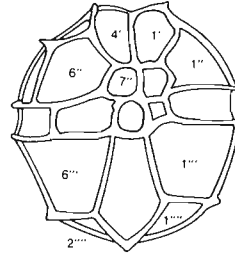
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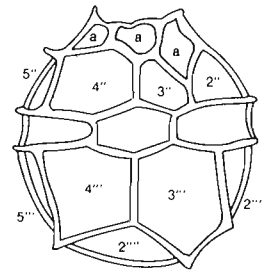
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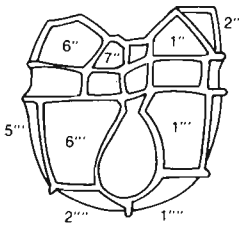
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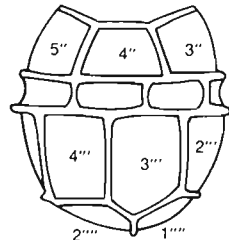
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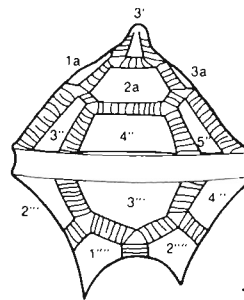
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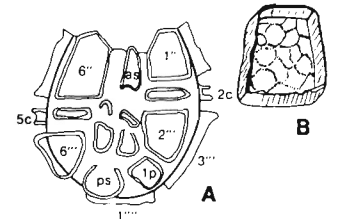
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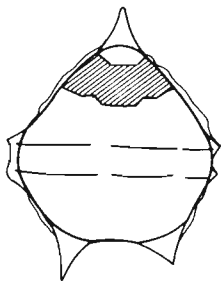
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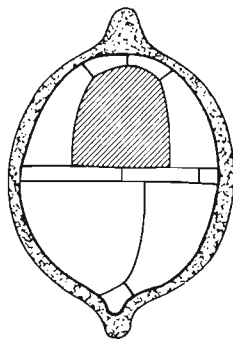
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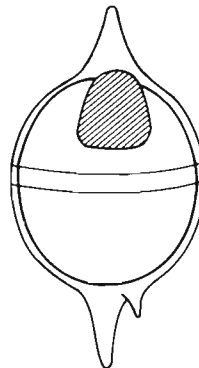
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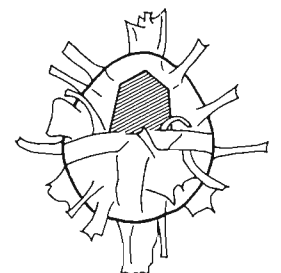
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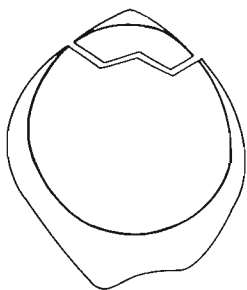
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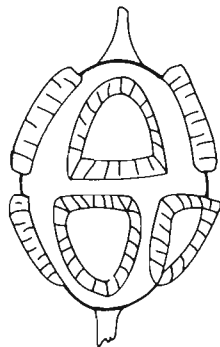
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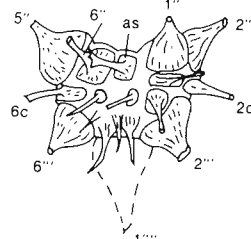
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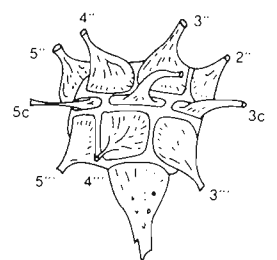
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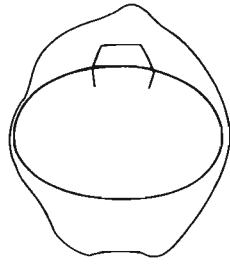
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PLATE 7

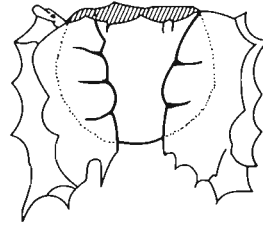
- Figure 1.** *Cerodinium diebelii* (T-106). Holotype dimensions: pericyst length = 180 μm , pericyst width = 44 μm
- Figure 2.** *Manumiella cretacea* (T-107). Holotype dimensions: pericyst length = 55 μm , pericyst width = 52 μm
- Figure 3,4** *Palynodinium grallator* (C-25). Holotype dimensions: overall diameter (with processes) = 106 μm
- Figure 5.** *Spongodinium delitiense* (T-108). Dimensions of specimens examined by Deflandre (1936b): length = 75 to 130 μm , width = 70 to 112 μm
- Figure 6.** *Triblastula utinensis* (C-26). Range of type material: length = 100 to 112 μm , width = 45 to 50 μm
- Figure 7A,B.** *Dinogymnium* sp. (C-27). Dimensions of holotype of type species, *D. acuminatum*: length = 91 μm , width = 61 μm
- Figure 8.** *Circulodinium distinctum* (C-28). Holotype dimensions: central body diameter = 77 μm
- Figure 9.** *Cannosphaeropsis utinensis* (C-29). Holotype dimensions: overall length = 116 μm , overall width = 88 μm , central body length = 44 μm , central body width = 36 μm
- Figure 10.** *Laciniadinium arcticum* (C-30). Holotype dimensions: length = 71 μm , width = 45 μm
- Figure 11.** *Isabelidinium* sp. (C-31). Dimensions of holotype of type species, *I. korajonense*: pericyst length = 71 μm , pericyst width = 52 μm
- Figure 12.** *Xenascus* sp. (C-32). Dimensions of holotype of type species, *X. ceratioides*: pericyst length = 172 μm
- Figure 13.** *Tanyosphaeridium variecalamum* (C-33). Holotype dimensions: central body length = 34 μm , central body width = 14 μm , process length = 12 to 16 μm
- Figure 14.** *Palaeohystrichophora infusorioides* (C-34). Holotype dimensions: overall length (without processes) = 35 μm , overall width (without processes) = 23 μm
- Figure 15,16** *Odontochitina operculata* (C-35). Holotype dimensions: pericyst length = 210 μm , pericyst width = 170 μm
- Figure 17.** *Coronifera oceanica* (C-36). Holotype dimensions: overall diameter = 90 x 81 μm , central body diameter = 57 x 48 μm
- Figure 18.** *Hystrichodinium* spp. (C-37). Dimensions of holotype of type species, *H. pulchrum*: central body diameter = 31 μm
- Figure 19A,B** *Aldorfia deflandrei* (C-38). Holotype dimensions: overall length = 52 μm , overall width = 40 μm
- Figure 20.** *Hystrichosphaeropsis ovum* (C-40). Holotype dimensions: central body diameter = 35 x 41 μm



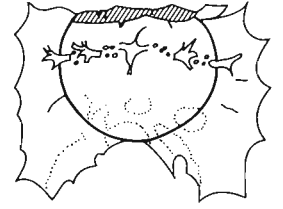
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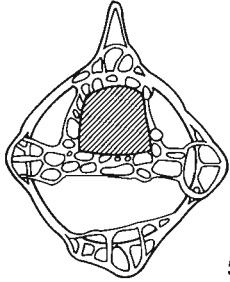
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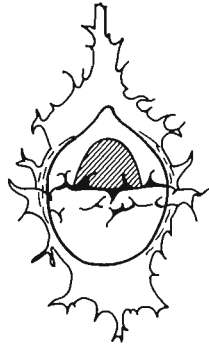
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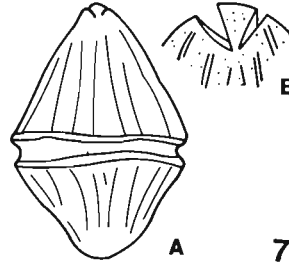
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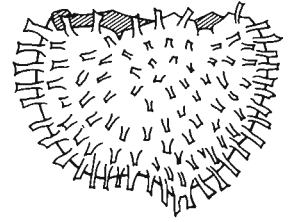
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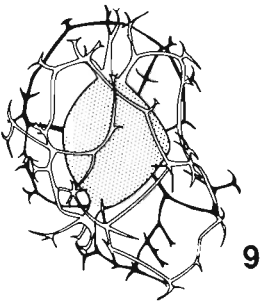
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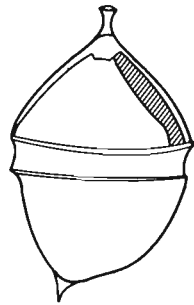
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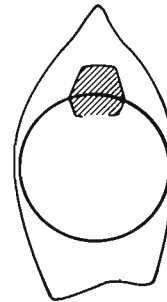
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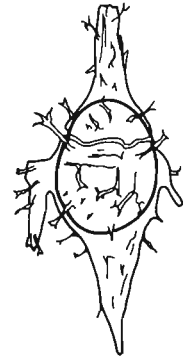
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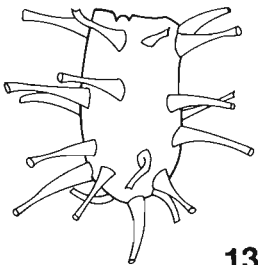
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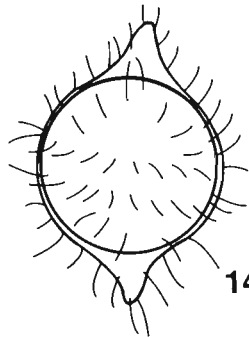
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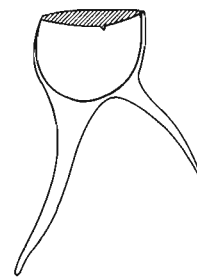
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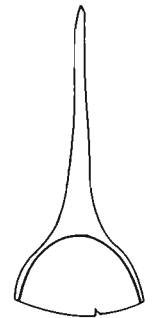
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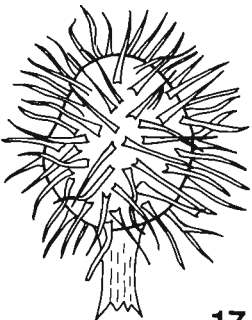
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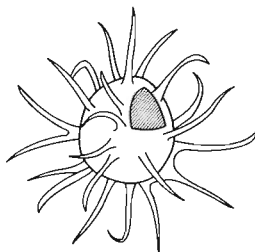
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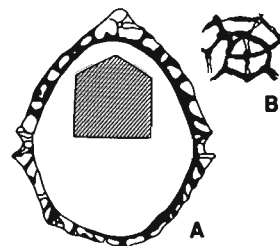
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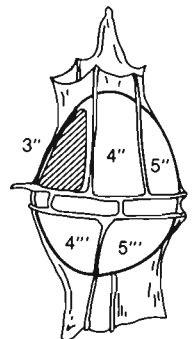
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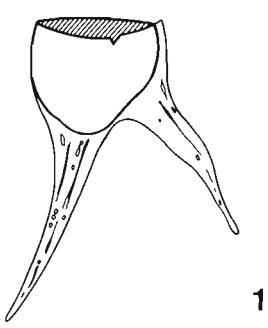
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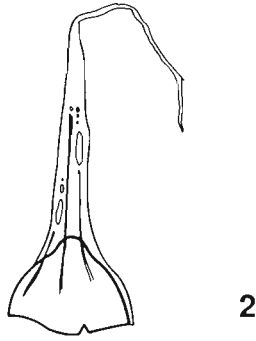
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PLATE 8

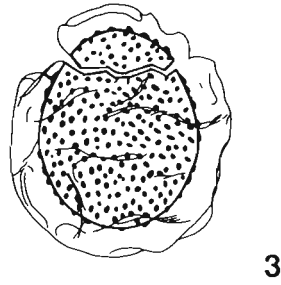
- Figure 1,2** *Odontochitina costata* (C-39). Holotype dimensions: pericyst length = 522 μm , central body diameter = 88 μm
- Figure 3.** *Leberidocysta chlamydata* (C-41). Holotype dimensions: overall length = 75 μm , overall width = 76 μm , central body length = 60 μm , central body width = 50 μm
- Figure 4.** *Chatangiella verrucosa* (C-42). Holotype dimensions: pericyst length = 134 μm , pericyst width = 83 μm
- Figure 5.** *Trichodinium castanea* (C-43). Holotype dimensions: overall length = 89 μm , overall width = 73 μm , apical horn length = 11 μm
- Figure 6.** *Chatangiella ditissima* (C-44). Holotype dimensions: pericyst length = 147 μm , pericyst width = 80 μm , endocyst length = 53 μm
- Figure 7.** *Surculosphaeridium? longifurcatum* (C-45). Holotype dimensions: central body diameter = 41 μm , process length = 20 μm
- Figure 8.** *Kleithriasphaeridium loffrense* (C-46). Holotype dimensions: central body diameter = 48 x 49 μm , process length = 31 to 34 μm
- Figure 9A,B,10** *Callaiosphaeridium asymmetricum* (C-47). Holotype dimensions: central body diameter = 40 μm , process length = 22 to 34 μm
- Figure 11.** *Pervosphaeridium? truncigerum* (C-48). Holotype dimensions: central body diameter = 42 μm
- Figure 12.** *Psaligonyaulax deflandrei* (C-49). Holotype dimensions: pericyst length = 75 μm , pericyst width = 44 μm , endocyst length = 35 μm , endocyst width = 40 μm
- Figure 13.** *Xiphophoridium alatum* (C-50). Holotype dimensions: overall length = 125 μm , overall width = 96 μm , length (not including ornamentation) = 70 μm , width (not including ornamentation) = 52 μm
- Figure 14.** *Odontochitina porifera* (C-51). Holotype dimensions: pericyst length = 208 μm , pericyst width = 78 μm
- Figure 15.** *Heterosphaeridium difficile* (C-52). Holotype dimensions: diameter = 91 μm , process length = 25 μm
- Figure 16.** *Chlamydophorella ambigua* (C-53). Range of type material: overall diameter = 27 to 28 μm , central body diameter = 20 to 22 μm
- Figure 17.** *Stiphrosphaeridium anthophorum* (C-54). Holotype dimensions: overall diameter = 210 μm , central body diameter = 70 μm , process length = 50 μm
- Figure 18,19** *Stephodinium coronatum* (C-55). Holotype dimensions: equatorial diameter of pericyst = 72 μm , endocyst diameter = 43 x 55 μm
- Figure 20.** *Florentinia mantellii* (C-56). Holotype dimensions: central body diameter = 41 x 42 μm



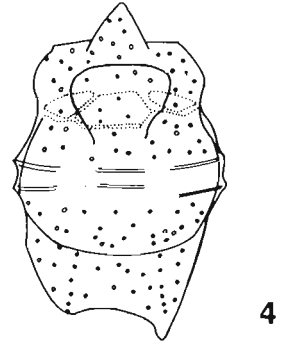
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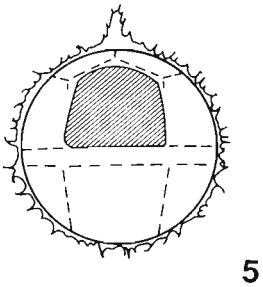
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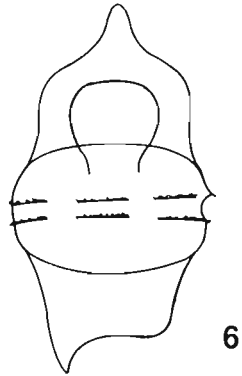
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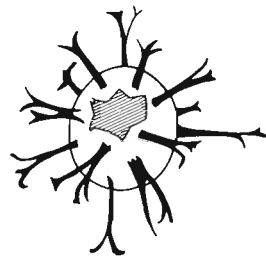
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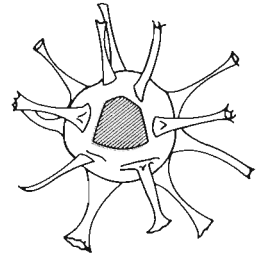
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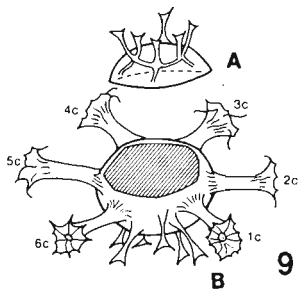
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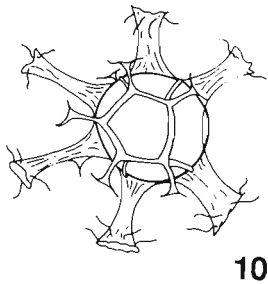
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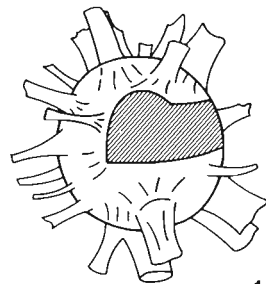
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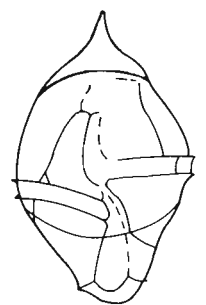
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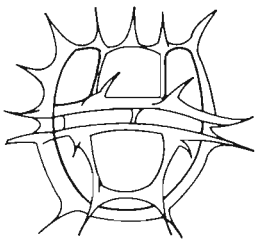
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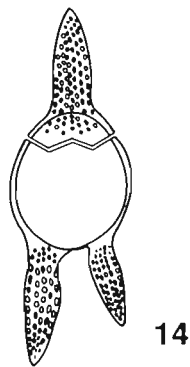
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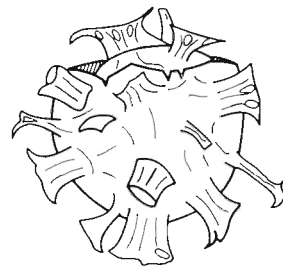
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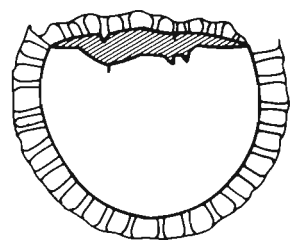
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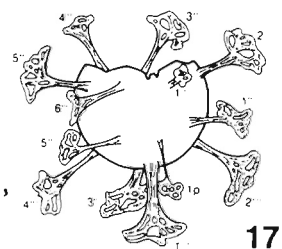
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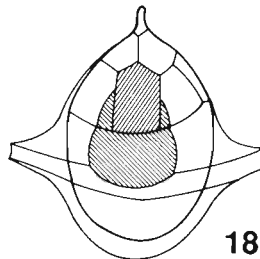
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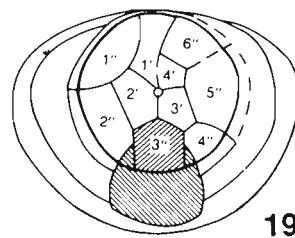
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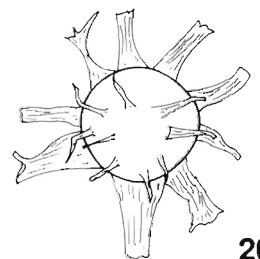
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PLATE 9

- Figure 1.** *Scriniodinium? campanulum* (C-57). Holotype dimensions: overall length = 104 μm , overall width = 91 μm
- Figure 2.** *Pareodinia* sp. (C-58). Dimensions of holotype of type species, *P. ceratophora*: overall length = 78 μm , overall width = 38 μm
- Figure 3.** *Litosphaeridium siphoniphorum* (C-59). Holotype dimensions: overall diameter = 76 μm
- Figure 4.** *Cribroperidinium edwardsii* (C-60). Holotype dimensions: length = 143 μm , width = 125 μm
- Figure 5.** *Florentinia cooksoniae* (C-61). Holotype dimensions: central body length = 67 μm , central body width = 50 μm , process length = 14 to 28 μm
- Figure 6.** *Prolixosphaeridium parvispinum* (C-62). Holotype dimensions: central body length = ca. 40 μm , central body width = ca. 28 μm
- Figure 7.** *Epelidosphaeridia spinosa* (C-63). Holotype dimensions: overall length = 55 μm , overall width = 46 μm
- Figure 8.** *Kiokansium williamsii* (C-64). Holotype dimensions: overall length = 82 μm , overall width = 62 μm , central body length = 65 μm , central body width = 37 μm , process length = 12 to 18 μm
- Figure 9.** *Ovoidinium verrucosum* (C-65). Holotype dimensions: overall length = 52 μm , overall width = 32 μm
- Figure 10.** *Vesperopsis* sp. (C-66). Dimensions of type species, *V. mayi*: overall length = 88 to 120 μm , overall width = 64 to 96 μm
- Figure 11.** *Ovoidinium cinctum* (C-67). Range of type material: pericyst length = 81 to 118 μm , pericyst width = 52 to 66 μm , endocyst diameter = 52 to 66 μm by 45 to 57 μm
- Figure 12.** *Apteodinium granulatum* (C-68). Holotype dimensions: length = 75 μm , width = 64 μm , horn = 12 μm
- Figure 13.** *Gonyaulacysta cassidata* (C-69). Holotype dimensions: overall length = 83 μm , overall width = 52 μm
- Figure 14.** *Litosphaeridium arundum* (C-70). Holotype dimensions: overall diameter = 42 μm , central body diameter = 28 μm
- Figure 15.** *Chichaouadinium vestitum* (C-71). Holotype dimensions: length = 71 μm , width = 51 μm
- Figure 16.** *Pseudoceratium polymorphum* (C-73). Holotype dimensions: diameter = 81 μm
- Figure 17,18** *Luxadinium propatulum* (C-72). Holotype dimensions: pericyst length = 70 μm , pericyst width = 62 μm , endocyst length = 61 μm , endocyst width = 62 μm
- Figure 19.** *Cauca parva* (C-74). Holotype dimensions: central body length (with operculum) = 25 μm , central body width = 30 μm , process length = 12 to 22 μm
- Figure 20.** *Protoellipsodinium* sp. (C-76). Dimensions of holotype of type species, *P. spinocristatum*: central body length = 37 μm , central body width = 19 μm , maximum process length = 6 μm

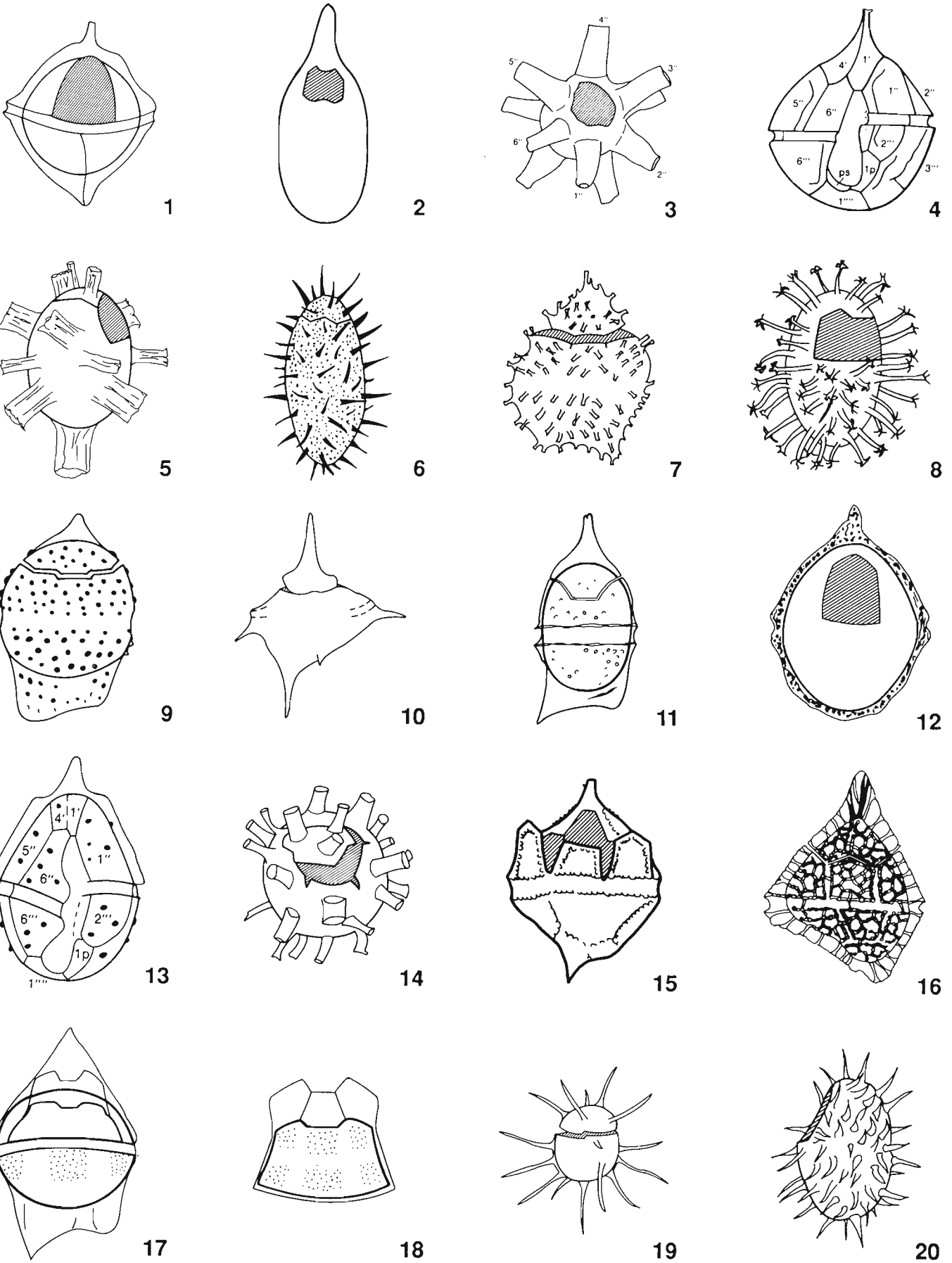


PLATE 10

Figure 1,2 *Batioladinium micropodum* (C-75). Holotype dimensions: pericyst length = 100 μm , pericyst width = 47 μm

Figure 3. *Gardodinium trabeculosum* (C-77). Holotype dimensions: central body length = 74 μm , central body width = 62 μm , apical horn length about 16 μm

Figure 4. *Hystichosphaerina schindewolfii* (C-78). Holotype dimensions: central body diameter = 65 μm , process length = 24 to 27 μm

Figure 5. *Discorsia nanna* (C-79). Holotype dimensions: central body diameter = 24 μm , process length = 10 to 14 μm

Figure 6. *Aprobolocysta eilema* (C-80). Holotype dimensions: length = 73 μm , width = 46 μm

Figure 7,8 *Angustidinium acribes* (C-81). Holotype dimensions: overall length = 27 μm , overall width = 22 μm

Figure 9,10 *Cerbia tabulata* (C-82). Holotype dimensions: overall length (without operculum) = 57 μm , overall width = 72 μm

Figure 11. *Muderongia tetracantha* (C-83). Holotype dimensions: pericyst length = 147 μm

Figure 12. *Achomosphaera? neptuni* (C-84). Holotype dimensions: diameter = 88 μm

Figure 13. *Pseudoceratium pelliferum* (C-85). Holotype dimensions: overall length = 132 μm , overall width = 59 μm

Figure 14. *Sirmiodinium grossii* (C-86). Holotype dimensions: pericyst length = 91 μm , pericyst width = 86 μm

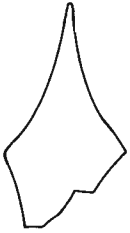
Figure 15. *Lithodinia stoveri* (C-87). Holotype dimensions: overall length = 78 μm , overall width = 72 μm

Figure 16. *Phoberocysta neocomica* (C-88). Holotype dimensions: pericyst length = 118 μm , pericyst width = 97 μm

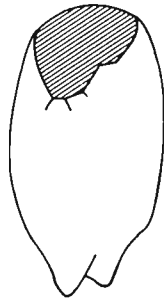
Figure 17,18 *Ctenidodinium elegantulum* (C-89). Holotype dimensions: overall diameter = 83 x 78 μm

Figure 19,20 *Batioladinium longicornutum* (C-91). Holotype dimensions: overall length = 241 μm , overall width = 35 μm , apical horn length = 96 μm , length of two antapical horns = 61 μm and 63 μm

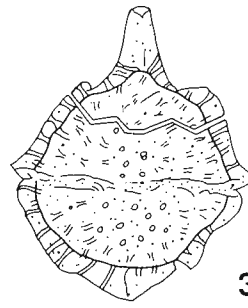
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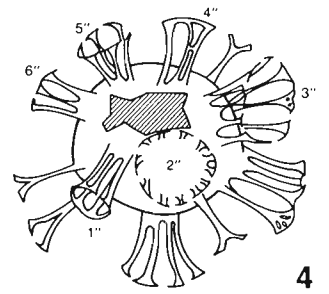
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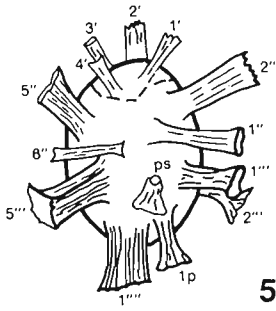
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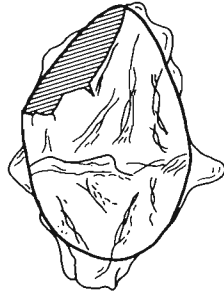
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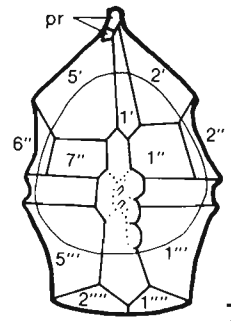
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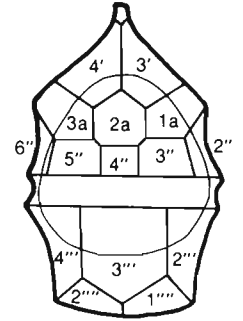
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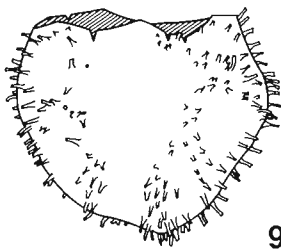
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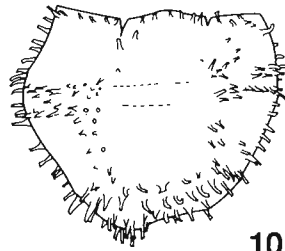
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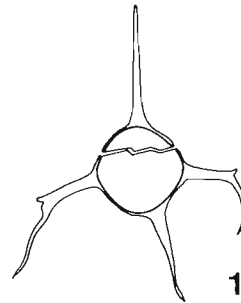
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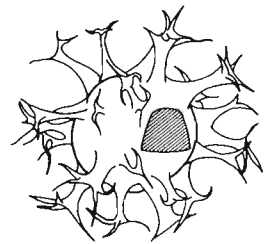
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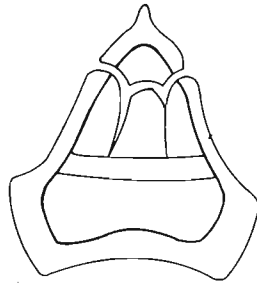
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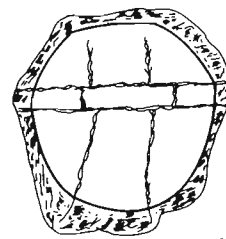
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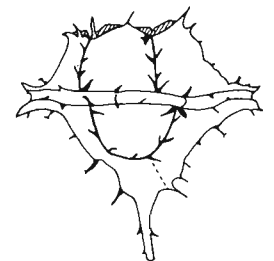
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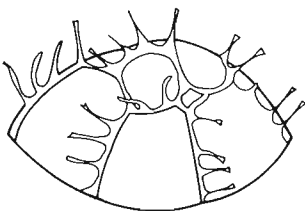
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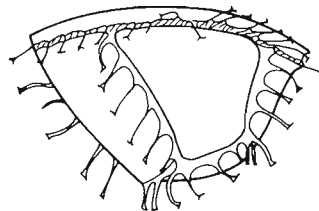
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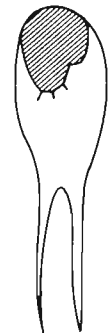
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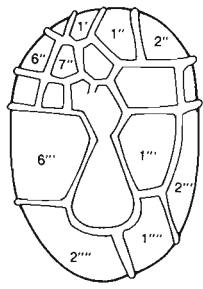


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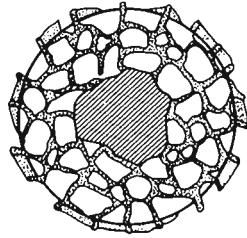
PLATE 11

- Figure 1.** *Druggidium* sp. (C-90). Dimensions of holotype of type species, *D. apicopaucicum*: length = 39 μm , width = 23 μm
- Figure 2.** *Cassiculosphaeridia magna* (C-92). Holotype dimensions: central body diameter = 72 x 92 μm , maximum crest height = 7 μm
- Figure 3.** *Nelchinopsis kostromiensis* (C-93). Holotype dimensions: overall length = 61.8 μm , overall width = 50.6 μm
- Figure 4.** *Muderongia simplex* (C-94). Holotype dimensions: pericyst length = 151 μm , pericyst width = 121 μm
- Figure 5.** *Biorbifera johnewingii* (C-95). Holotype dimensions: length = 28 μm , width = 19 μm
- Figure 6.** *Gochteodinia villosa* (C-96). Holotype dimensions: overall length = 108 μm , overall width = 30 μm
- Figure 7.** *Egmontodinium torynum* (C-97). Holotype dimensions: central body length = 68 μm , central body width = 33 μm , process length to 10 μm
- Figure 8A,B** *Dichadogonyaulax pannea* (C-99). Holotype dimensions: equatorial diameter = 57 μm
- Figure 9,10A,B** *Dichadogonyaulax culmula* (C-98). Holotype dimensions: equatorial diameter = 40 μm
- Figure 11.** *Tubotuberella apatela* (C-100). Holotype dimensions: pericyst length = 120 μm , pericyst width = 58 μm , endocyst length = 80 μm , endocyst width = 58 μm
- Figure 12.** *Egmontodinium expiratum* (J.-11). Holotype dimensions: length (not including apical paraplates) = 64 μm , width = 40 μm , process length = 10 μm
- Figure 13.** *Lanterna* sp. (J.-12). Dimensions of holotype of type species, *L. bulgarica*: central body length = 73 μm , central body width = 73 μm , process length = 6 μm
- Figure 14.** *Egmontodinium polyplacophorum* (J.-13). Holotype dimensions: length = 76 μm , width = 58 μm
- Figure 15.** *Senoniasphaera jurassica* (J.-14). Holotype dimensions: overall length = 85 μm , overall width = 72 μm , central body length = 73 μm , central body width = 66 μm
- Figure 16.** *Glossodinium dimorphum* (J.-15). Range of type material: overall length = 94 to 135 μm , overall width = 90 to 117 μm
- Figure 17.** *Gochteodinia mutabilis* (J.-16). Holotype dimensions: overall length = 80 μm , overall width = 40 μm , apical horn length = 17 μm
- Figure 18.** *Oligosphaeridium patulum* (J.-17). Range of type material: overall diameter = 79.2 to 110.4 μm , central body diameter = 40.8 to 64.8 μm , process length = 19.2 to 38.4 μm
- Figure 19,20** *Occisucysta balios* (J.-18). Holotype dimensions: overall length = 60 μm , overall width = 60 μm

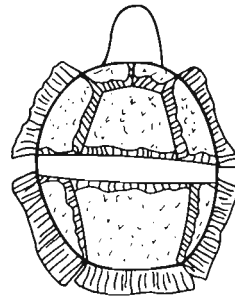
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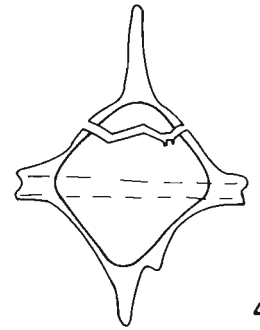
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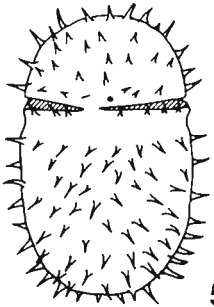
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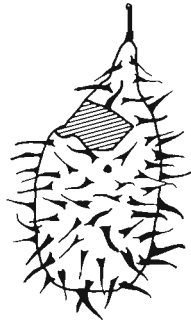
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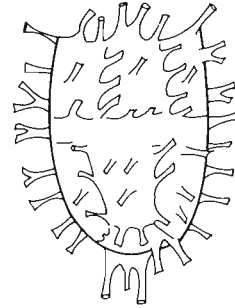
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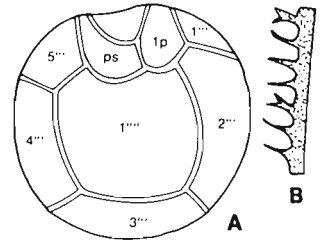
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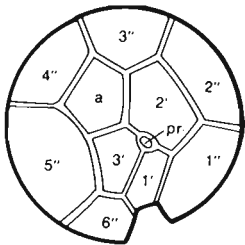
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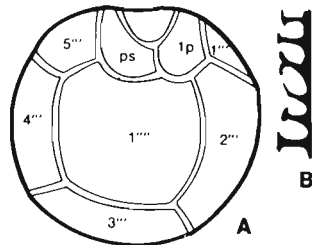
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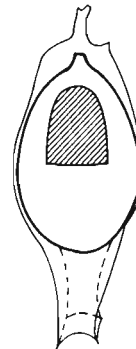
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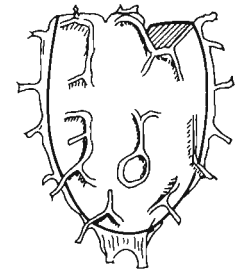
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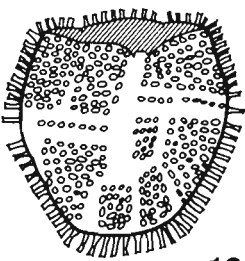
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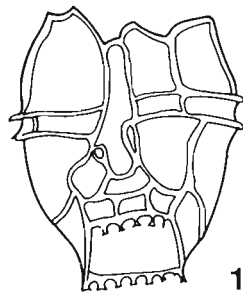
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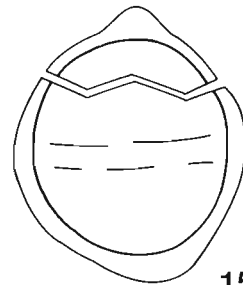
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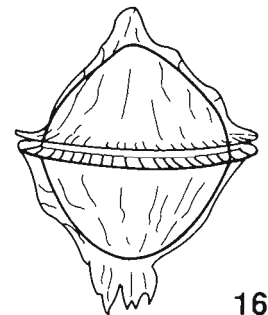
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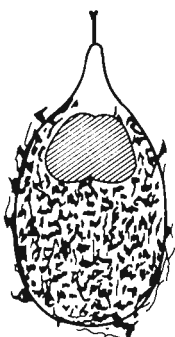
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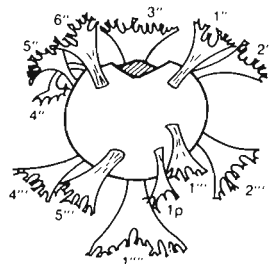
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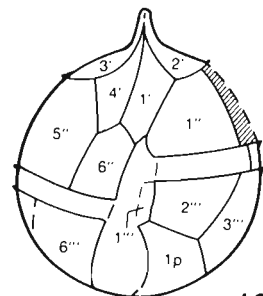
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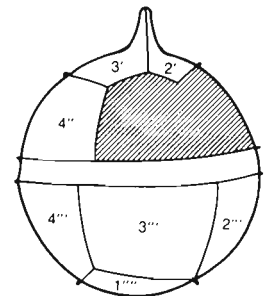
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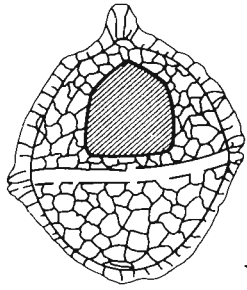


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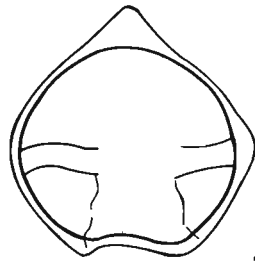
PLATE 12

- Figure 1.** *Scriniocassis dictyota* (J.-19). Holotype dimensions: overall length = 109 μm , overall width 95 μm
- Figure 2.** *Geiselodinium inaeffectum* (J.-20). Holotype dimensions: central body diameter = 55 μm
- Figure 3.** *Scriniodinium luridum sensu* Deflandre (1938b) (J.-21). Holotype dimensions: overall diameter = 69 x 68 μm
- Figure 4A,B** *Rhynchodiniopsis cladophora* (J.-22). Holotype dimensions: overall diameter = 95 x 95 μm
- Figure 5.** *Ellipsoidictyum cinctum* (J.-23). Holotype dimensions: overall diameter = 66 μm , overall width = 52 μm
- Figure 6,7** *Gonyaulacysta jurassica* (J.-24). Holotype dimensions: overall length = 80 μm , overall width = 57 μm
- Figure 8.** *Stephanelytron* sp. (J.-25). Dimensions of holotype of type species, *S. redcliffense*: overall length = 50 μm , overall width = 40 μm , maximum body length = 36 μm , maximum body width = 30 μm , height of corona = 10 μm
- Figure 9.** *Valensiella* sp. (J.-26). Range of type material of type species, *V. ovulum*: overall length = 55 to 65 μm , overall width = 44 to 55 μm , central body length = 48 to 55 μm , central body width = 37 to 45 μm
- Figure 10.** *Sirmiodiniopsis orbis* (J.-27). Holotype dimensions: overall length = 62 μm , overall width = 62 μm
- Figure 11.** *Scriniodinium crystallinum* (J.-28). Holotype dimensions: overall length = 92 μm , overall width = 85 μm
- Figure 12.** *Gonyaulacysta eisenackii* (J.-29). Range of type material: length = 65 to 80 μm , width = 57-60 μm
- Figure 13,14** *Rigaudella aemula* (J.-30). Holotype dimensions: central body diameter = 30 x 42 μm , total diameter = 62 x 75 μm
- Figure 15.** *Nannoceratopsis pellucida* (J.-31). Holotype dimensions: overall length = 88 μm , overall width = 45 μm
- Figure 16A,B** *Ctenidodinium ornatum* (J.-32). Holotype dimensions: central body diameter = 75 μm
- Figure 17.** *Compositosphaeridium polonicum* (J.-33). Holotype dimensions: central body diameter = 62 μm
- Figure 18.** *Trichodinium scarburghense* (J.-34). Holotype dimensions: overall length = 155 μm , overall width = 125 μm , apical horn length = 25 μm
- Figure 19,20** *Lithodinia deflandrei* (J.-36). Holotype dimensions: overall length (without operculum) = 47 μm , overall width = 50 μm

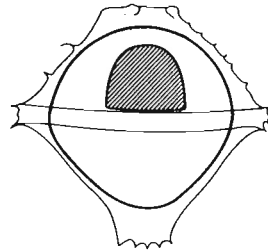
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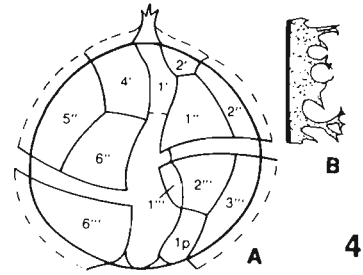
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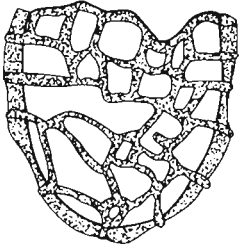
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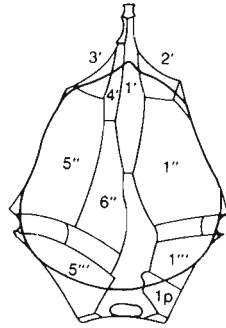
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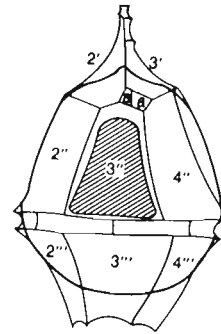
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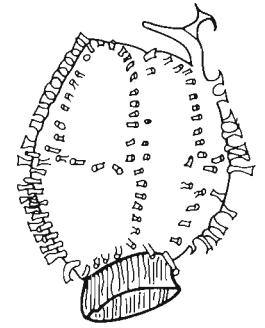
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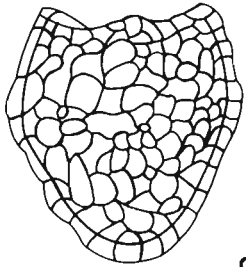
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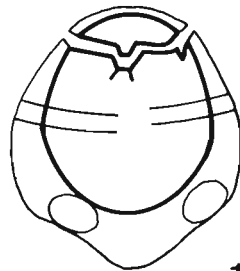
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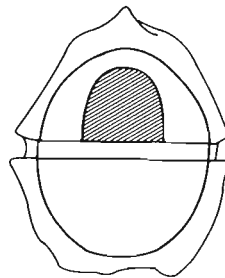
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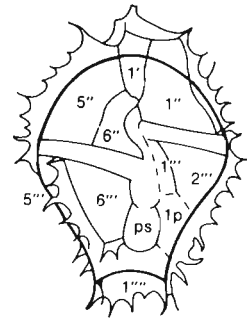
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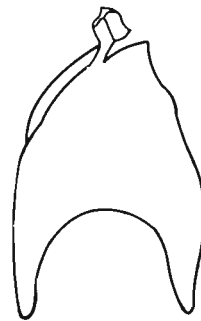
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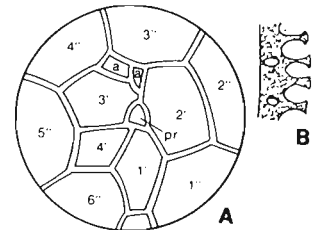
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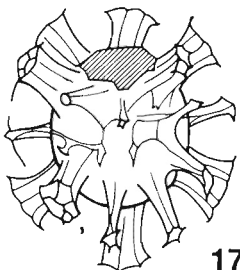
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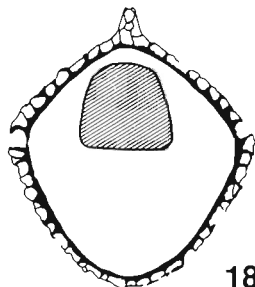
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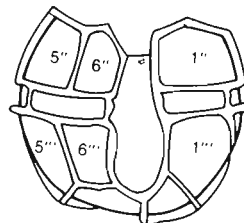
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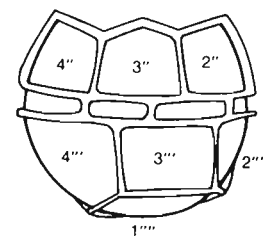
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PLATE 13

- Figure 1,2** *Carpathodinium predae* (J.-37). Range of type material: overall length = 56 to 74 μm , overall width = 33 to 46 μm
- Figure 3,4** *Ctenidodinium continuum* (J.-38). Holotype dimensions: overall diameter = 89 x 90 μm
- Figure 5.** *Wanaea* sp. (J.-35). Dimensions of holotype of type species, *W. spectabilis*: overall diameter = 110 μm by 84 μm , cingular fringe = 8 μm
- Figure 6.** *Lithodinia jurassica* (J.-39). Holotype dimensions: diameter = 66 x 63 μm
- Figure 7,8** *Reutlingia gochtii* (J.-41). Holotype dimensions: overall length = 34 μm , overall width = 32 μm
- Figure 9.** *Nannoceratopsis tricerias* (J.-40). Holotype dimensions: overall length = 62 μm
- Figure 10.** *Scrinodinium luridum sensu* Gocht (1970b) (J.-42). Holotype dimensions: overall diameter = 69 x 68 μm
- Figure 11A,B** *Aldorfia aldorfensis* (J.-43). Holotype dimensions: length = 79 μm , width = 65 μm
- Figure 12.** *Rhynchodiniopsis? regalis* (J.-44). Holotype dimensions: overall length = 78 μm , overall width = 73 μm
- Figure 13A,B** *Nannoceratopsis gracilis* (J.-45). Holotype dimensions: overall length = 78 μm , overall width = 52 μm
- Figure 14,15** *Bejuia polygonalis* (J.-46). Range of type material: length = 65 to 96 μm , width = 58 to 94 μm
- Figure 16.** *Apteodinium syzygium* (J.-47). Holotype dimensions: length = 30 μm
- Figure 17,18** *Susadinium* sp. (J.-48). Dimensions of holotype of type species, *S. scrofoides*: length = 38 μm
- Figure 19,20** *Mancodinium semitabulatum* (J.-49). Holotype dimensions: width = 39 μm

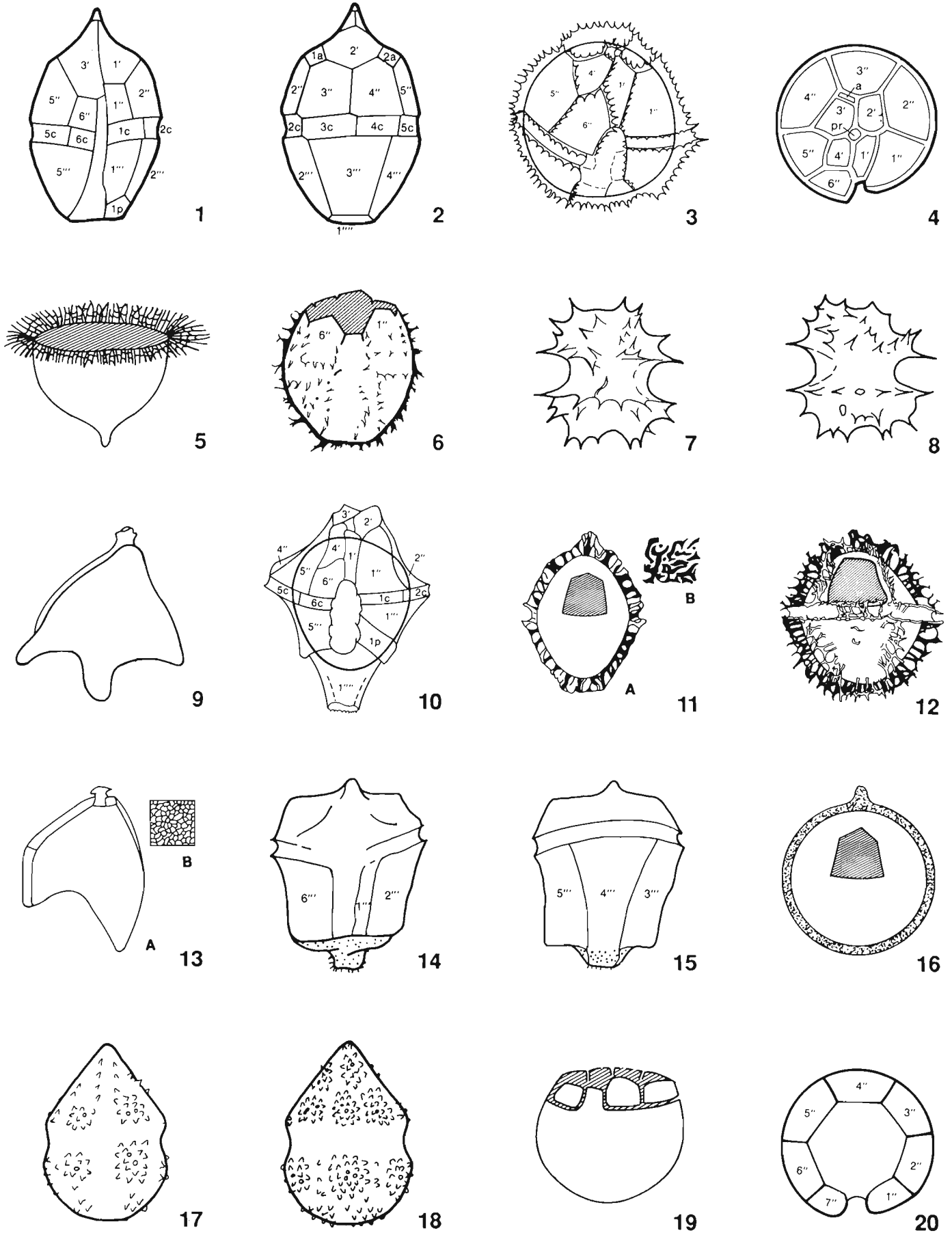
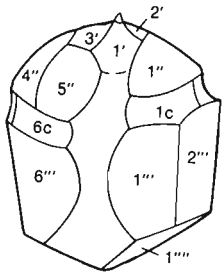
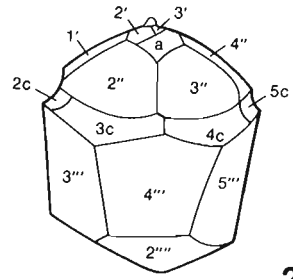


PLATE 14

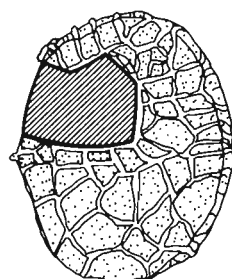
- Figure 1,2** *Eyachia prisca* (J.-50). Holotype dimensions: length = 75 μm , width = 83 μm
- Figure 3.** *Scriniocassis weberi* (J.-51). Holotype dimensions: overall length = 58 μm , overall width = 49 μm
- Figure 4.** *Phallocysta eumekes* (J.-52). Holotype dimensions: overall length = 64 μm
- Figure 5.** *Moesiodinium raileanui* (J.-53). Holotype dimensions: pericyst length = 34 μm , pericyst width = 32 μm , endocyst diameter = 25 μm
- Figure 6.** *Parvocysta* sp. (J.-54). Range of type species, *P. bullula*: length = 22 to 35 μm , width = 20 to 31 μm
- Figure 7.** *Valvaeodinium punctatum* (J.-55). Holotype dimensions: length = 53 μm , width = 34 μm
- Figure 8.** *Nannoceratopsis senex* (J.-56). Holotype dimensions: overall length = 86 μm , overall width = 55 μm
- Figure 9,10** *Valvaeodinium lineatum* (J.-57). Holotype dimensions: length = 35 μm , width = 21 μm
- Figure 11,12** *Luehndea spinosa* (J.-58). Holotype dimensions: central body length = 36 μm , central body width = 28 μm , process length = 12 to 14 μm
- Figure 13.** *Liasidium variabile* (J.-59). Holotype dimensions: overall length = 91 μm , overall width = 65 μm
- Figure 14,15** *Dapcodinium priscum* (J.-60). Range of type material: diameter = 25 to 30 μm
- Figure 16.** *Rhaetogonyaulax rhaetica* (J.-61). Holotype dimensions: overall length = 65 μm , overall width = 40 μm
- Figure 17.** *Suessia swabiana* (J.-62). Holotype dimensions: overall length = 47 μm , overall width = 41 μm
- Figure 18.** *Noricysta* sp. (J.-63). Dimensions of holotype of type species, *N. fimbriata*: length = 45 μm , width = 40 μm , maximum height of crests = 5 μm
- Figure 19.** *Sverdrupiella* sp. (J.-64). Dimensions of holotype of type species, *S. septentrionalis*: pericyst length = 103 μm , pericyst width = 58 μm , endocyst length = 54 μm , endocyst width = 49 μm
- Figure 20.** *Hebecysta brevicornuta* (J.-65). Holotype dimensions: length = 53 μm , width = 47 μm



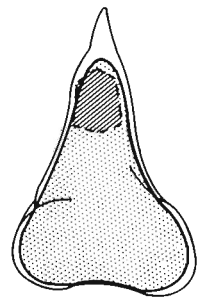
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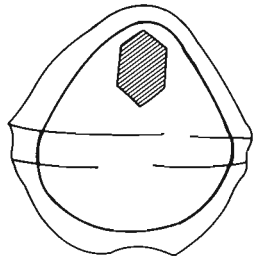
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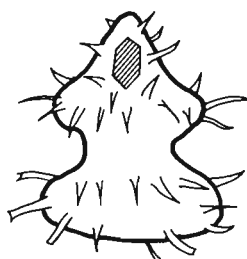
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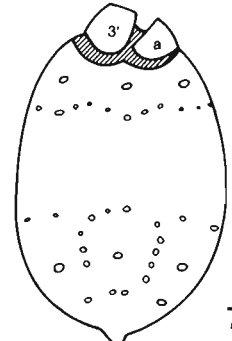
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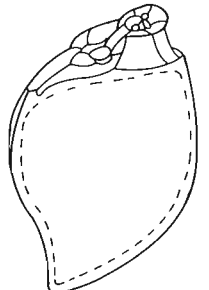
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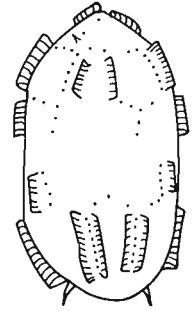
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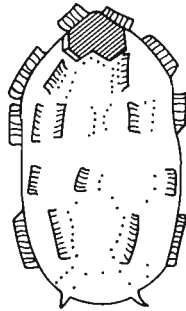
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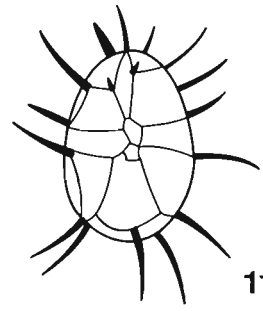
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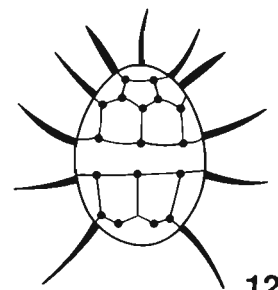
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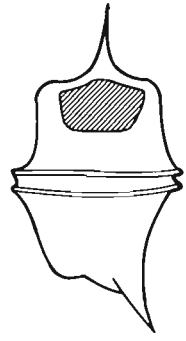
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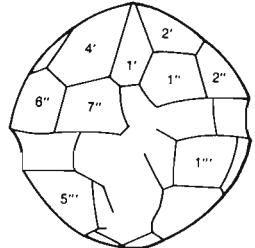
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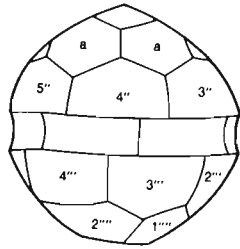
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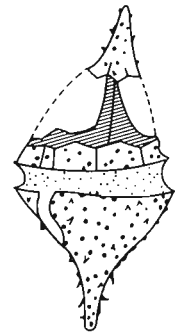
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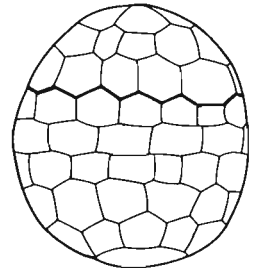
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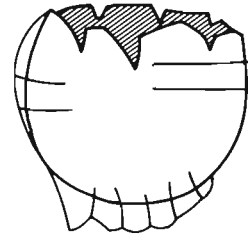
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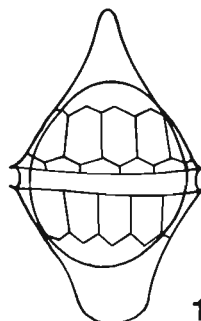
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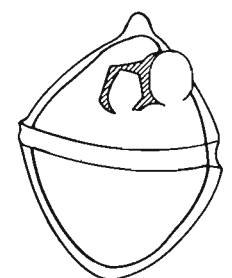
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APPENDIX A

Composition of morphological groups

Group No.	Group Name	Subgroup	Included Taxa
I	<i>BATIACASPHAERA-TECTATODINIUM</i>	<i>BATIACASPHAERA</i>	<i>Batiacasphaera compta</i> <i>Batiacasphaera micropapillata</i> <i>Batiacasphaera sphaerica</i> <i>Caligodinium amiculum</i> <i>Cassiculosphaeridia magna</i> <i>Chlamydomphorella ambigua</i> <i>Ellipsoidictyum cinctum</i> <i>Gardodinium trabeculosum</i> <i>Labyrinthodinium truncatum</i> <i>Stephanelytron</i> spp. <i>Valensiella</i> spp.
		<i>TECTATODINIUM</i>	<i>Aldorfia aldorfensis</i> <i>Aldorfia deflandrei</i> <i>Apteodinium australiense</i> <i>Apteodinium granulatum</i> <i>Apteodinium spiridoides</i> <i>Apteodinium syzygium</i> <i>Bitectatodinium tepikiense</i> <i>Carpatella cornuta</i> <i>Filisphaera filifera</i> <i>Samlandia chlamydomphora</i> <i>Scrinocassis dictyotus</i> <i>Scrinocassis weberi</i> <i>Tectatodinium grande</i> <i>Trichodinium castanea</i> <i>Trichodinium scarburghense</i>
II	<i>IMPAGIDINIUM-GONYAULACYSTA</i>	<i>IMPAGIDINIUM</i>	<i>Corrudinium incompositum</i> <i>Cribroperidinium edwardsii</i> complex <i>Cribroperidinium tenuitabulatum</i> <i>Impagidinium aquaeductum</i> <i>Impagidinium dispertitum</i> <i>Impagidinium patulum</i> <i>Occisucysta balios</i> <i>Rhynchodiniopsis cladophora</i> <i>Rhynchodiniopsis? regalis</i> <i>Spongodinium delitiense</i>
		<i>GONYAULACYSTA</i>	<i>Gonyaulacysta cassidata</i> complex <i>Gonyaulacysta eisenackii</i> <i>Gonyaulacysta jurassica</i> <i>Hystrichosphaeropsis obscura</i> <i>Hystrichosphaeropsis ovum</i> <i>Psaligonyaulax deflandrei</i> <i>Scriniodinium? campanula</i> <i>Scriniodinium crystallinum</i> <i>Scriniodinium luridum</i> sensu Deflandre (1938) <i>Scriniodinium luridum</i> sensu Gocht (1970) <i>Triblastula utinensis</i> <i>Tubotuberella apatela</i>

Appendix A (cont'd.)

Group No.	Group Name	Subgroup	Included Taxa
III	CORDOSPHAERIDIUM- HYSTRICHOSPHAERIDIUM	CORDOSPHAERIDIUM	<i>Achilleodinium biformoides</i> <i>Achomosphaera alcicornu</i> <i>Achomosphaera andalousiensis</i> <i>Achomosphaera? neptuni</i> <i>Cordosphaeridium cantharellum</i> <i>Cordosphaeridium fibrospinosum</i> <i>Cordosphaeridium funiculatum</i> <i>Cordosphaeridium gracile</i> <i>Coronifera oceanica</i> <i>Fibrocysta axialis</i> <i>Florentinia cooksoniae</i> <i>Florentinia mantellii</i> <i>Hystrichodinium</i> spp. <i>Kiokansium williamsii</i> <i>Kleithriasphaeridium loffrense</i> <i>Lingulodinium machaerophorum</i> <i>Melitasphaeridium choanophorum</i> <i>Melitasphaeridium pseudorecurvatum</i> <i>Nematosphaeropsis lemniscata</i> <i>Operculodinium divergens</i> <i>Pervosphaeridium? truncigerum</i> <i>Protoellipsodinium</i> spp. <i>Reticulatosphaera actinocoronata</i> <i>Spiniferites ellipsoideus</i> <i>Spiniferites elongatus</i> <i>Spiniferites mirabilis</i> <i>Spiniferites pseudofurcatus</i> <i>Spiniferites septatus</i> <i>Spiniferites splendidus</i>
		HYSTRICHOSPHAERIDIUM	<i>Adnatosphaeridium multispinosum</i> <i>Areosphaeridium arcuatum complex</i> <i>Areosphaeridium diktyoplokus</i> <i>Compositosphaeridium polonicum</i> <i>Dapsilidinium pseudocolligerum</i> <i>Diphyes colligerum</i> <i>Discorsia nanna</i> <i>Distatodinium paradoxum</i> <i>Heterosphaeridium difficile</i> <i>Hystrichokolpoma bulbosum</i> <i>Hystrichokolpoma cinctum s.l.</i> <i>Hystrichokolpoma rigaudiae</i> <i>Hystrichosphaeridium salpingophorum</i> <i>Hystrichosphaeridium tubiferum</i> <i>Hystrichosphaerina schindewolfii</i> <i>Litosphaeridium arundum</i> <i>Litosphaeridium siphoniphorum</i> <i>Oligosphaeridium complex</i> <i>Oligosphaeridium patulum</i> <i>Prolixosphaeridium parvispinum</i> <i>Rigaudella aemula</i> <i>Stiphrosphaeridium anthophorum</i> <i>Surculosphaeridium? longifurcatum</i> <i>Systematophora placacantha</i> <i>Tanyosphaeridium variecalamus</i>

Appendix A (cont'd.)

Group No.	Group Name	Subgroup	Included Taxa
IV	<i>HETERAULACACYSTA</i>		<i>Eocladopyxis peniculata</i> <i>Heteraulacacysta porosa</i> <i>Homotryblum plectilum</i> <i>Homotryblum tenuispinosum</i> <i>Homotryblum vallum</i> <i>Polysphaeridium congregatum</i> <i>Polysphaeridium zoharyi</i>
V	<i>MUDERONGIA</i>		<i>Muderongia simplex</i> <i>Muderongia tetracantha</i> <i>Odontochitina costata</i> <i>Odontochitina operculata</i> <i>Odontochitina porifera</i> <i>Phoberocysta neocomica</i> <i>Pseudoceratium pelliferum</i> <i>Pseudoceratium polymorphum</i> <i>Vesperopsis</i> spp. <i>Xenascus</i> spp.
VI	<i>GLAPHYROCYSTA</i>		<i>Areoligera?</i> <i>semicirculata</i> <i>Areoligera senonensis</i> <i>Cerbia tabulata</i> <i>Chiropteridium mespilanum</i> complex <i>Circulodinium distinctum</i> <i>Glaphyrocysta exuberans</i> <i>Glaphyrocysta ordinata</i> <i>Membranophoridium aspinatum</i> <i>Palynodinium grallator</i> <i>Senoniasphaera inornata</i> <i>Senoniasphaera jurassica</i>
VII	<i>DEFLANDREA</i>		<i>Andalusiella</i> spp. <i>Cerodinium diebelii</i> <i>Cerodinium speciosum</i> <i>Chatangiella ditissima</i> <i>Chatangiella verrucosa</i> <i>Deflandrea oebisfeldensis</i> <i>Deflandrea phosphoritica</i> complex <i>Isabelidinium</i> spp. <i>Lejeunecysta</i> spp. <i>Lentinia serrata</i> <i>Manumiella?</i> <i>cretacea</i> <i>Ovoidinium cinctum</i> <i>Ovoidinium verrucosum</i> <i>Palaeocystodinium golzowense</i> <i>Phthanoperidinium</i> spp. <i>Selenopemphix</i> spp. <i>Senegalinium</i> spp. <i>Sumatradinium</i> spp. <i>Trinovantedinium capitatum</i> <i>Trithyrodinium</i> spp.
VIII	<i>WETZELIELLA</i>		<i>Apectodinium augustum</i> <i>Apectodinium homomorphum</i> complex <i>Dracodinium condylos</i> <i>Kisselovia coleothrypta</i> complex <i>Rhombodinium draco</i> <i>Rhombodinium porosum</i> complex <i>Wetzelietta articulata</i> complex <i>Wetzelietta symmetrica</i> complex

Appendix A (cont'd.)

Group No.	Group Name	Subgroup	Included Taxa
IX	<i>RHAETOGONYAULAX</i>		<i>Dapcodinium priscum</i> <i>Mancodinium semitabulatum</i> <i>Moesiodinium raileanui</i> <i>Parvocysta</i> spp. <i>Phallocysta eumekes</i> <i>Rhaetogonyaulax rhaetica</i> <i>Susadinium</i> spp. <i>Sverdrupiella</i> spp.
X	<i>CTENIDODINIUM</i>		<i>Bejuia polygonalis</i> <i>Biorbifera johnewingii</i> <i>Callaiosphaeridium asymmetricum</i> <i>Cauca parva</i> <i>Ctenidodinium continuum</i> <i>Ctenidodinium elegantulum</i> <i>Ctenidodinium ornatum</i> <i>Dichadogonyaulax culmula</i> <i>Dichadogonyaulax? pannea</i> <i>Glossodinium dimorphum</i> <i>Wanaea</i> spp.
XI	<i>LITHODINIA</i>		<i>Alisocysta circumtabulata</i> <i>Alisocysta margarita</i> <i>Alisocysta reticulata</i> <i>Egmontodinium expiratum</i> <i>Egmontodinium polyplacophorum</i> <i>Egmontodinium torynum</i> <i>Lanterna</i> spp. <i>Leberidocysta chlamydata</i> <i>Lithodinia deflandrei</i> <i>Lithodinia jurassica</i> <i>Lithodinia stoveri</i> <i>Sirmiodiniopsis orbis</i> <i>Sirmiodinium grossii</i> <i>Xiphophoridium alatum</i>
XII	<i>MICRODINIUM</i>		<i>Carpathodinium predae</i> <i>Cladopyxidium saeptum</i> <i>Druggidium</i> spp. <i>Eyachia prisca</i> <i>Luehndea spinosa</i> <i>Microdinium</i> spp.
XIII	<i>PALAEOPERIDINIUM</i>		<i>Chichaouadinium vestitum</i> <i>Laciniadinium arcticum</i> <i>Luxadinium propatulum</i> <i>Palaeoperidinium pyrophorum</i>
XIV	<i>BATIOLADINIUM</i>		<i>Aprobolocysta eilema</i> <i>Batioladinium longicornutum</i> <i>Batioladinium micropodum</i>
XV	<i>PAREODINIA</i>		<i>Gochteodinia mutabilis</i> <i>Gochteodinia villosa</i> <i>Pareodinia</i> spp.
XVI	<i>NANNOCERATOPSIS</i>		<i>Nannoceratopsis gracilis</i> <i>Nannoceratopsis pellucida</i> <i>Nannoceratopsis senex</i> <i>Nannoceratopsis tricerias</i>

Appendix A (cont'd.)

Group No.	Group Name	Subgroup	Included Taxa
XVII	MISCELLANEOUS	TERTIARY FORMS	<i>Amiculosphaera umbracula</i> <i>Biconidinium longissimum</i> <i>Conneximura fimbriata</i> <i>Danea californica</i> <i>Eatonicysta ursulae</i> <i>Evittosphaerula paratabulata</i> <i>Invertocysta tabulata</i> <i>Lanternosphaeridium</i> spp. <i>Muratodinium fimbriatum</i> <i>Pentadinium laticinctum</i> <i>Thalassiphora patula</i> <i>Thalassiphora pelagica</i> <i>Tuberculodinium vancampoae</i>
		CRETACEOUS FORMS	<i>Angustidinium acribes</i> <i>Cannosphaeropsis utinensis</i> <i>Dinogymnium</i> spp. <i>Epelidosphaeridia spinosa</i> <i>Nelchinopsis kostromiensis</i> <i>Palaeohystrichophora infusorioides</i> <i>Stephodinium coronatum</i>
		TRIASSIC-JURASSIC FORMS	<i>Geiselodinium inaffectum</i> <i>Hebecysta brevicornuta</i> <i>Liasidium variabile</i> <i>Noricysta</i> spp. <i>Reutlingia gochti</i> <i>Suessia swabiana</i> <i>Valvaeodinium lineatum</i> <i>Valvaeodinium punctatum</i>

APPENDIX B

Alphabetic listing of northern hemisphere dinoflagellates,
their morphological group assignments and range chart locations
(J = Triassic-Jurassic; K = Cretaceous; T = Tertiary-Holocene)

Group	Name	Chart & Position
A		
III	<i>Achilleodinium biformoides</i>	T (58)
III	<i>Achomosphaera alcicornu</i>	T (33)
III	<i>Achomosphaera andalousensis</i>	T (17)
III	<i>Achomosphaera? neptunii</i>	K (84)
III	<i>Adnatosphaeridium multispinosum</i>	T (75)
I	<i>Aldorfia aldorfensis</i>	J (43)
I	<i>Aldorfia deflandrei</i>	K (38)
XI	<i>Alisocysta circumtabulata</i>	T (94); K (8)
XI	<i>Alisocysta margarita</i>	T (92)
XI	<i>Alisocysta reticulata</i>	T (98); K (9)
XVII	<i>Amiculosphaera umbracula</i>	T (18)
VII	<i>Andalusiella</i> spp.	T (101); K (17)
XVII	<i>Angustidinium acribes</i>	K (81)
VIII	<i>Apectodinium augustum</i>	T (93)
VIII	<i>Apectodinium homomorphum</i> 'complex'	T (76)
XIV	<i>Aprobolocysta eilema</i>	K (80)
I	<i>Apteodinium australiense</i>	T (31)
I	<i>Apteodinium granulatum</i>	K (68)
I	<i>Apteodinium spiridoides</i>	T (34)
I	<i>Apteodinium syzygium</i>	J (47)
VI	<i>Areoligera? semicirculata</i>	T (55)
VI	<i>Areoligera senonensis</i>	T (82); K (12)
III	<i>Areosphaeridium arcuatum</i> 'complex'	T (53)
III	<i>Areosphaeridium diktyoplokus</i>	T (66)
B		
I	<i>Batiacasphaera compta</i>	T (65)
I	<i>Batiacasphaera micropapillata</i>	T (28)
I	<i>Batiacasphaera sphaerica</i>	T (27)
XIV	<i>Batioladinium longicornutum</i>	K (91)
XIV	<i>Batioladinium micropodum</i>	K (75)
X	<i>Bejuia polygonalis</i>	J (46)
XVII	<i>Biconidinium longissimum</i>	T (90)
X	<i>Biorbifera johnewingii</i>	K (95)
I	<i>Bitectatodinium tepikiense</i>	T (3)

Appendix B (cont'd.)

Group	Name	Chart & Position
C		
I	<i>Caligodinium amiculum</i>	T (44)
X	<i>Callaiosphaeridium asymmetricum</i>	K (47)
XVII	<i>Cannosphaeropsis utinensis</i>	K (29)
I	<i>Carpatella cornuta</i>	T (100)
XII	<i>Carpathodinium predae</i>	J (37)
I	<i>Cassiculosphaeridia magna</i>	K (92)
X	<i>Cauca parva</i>	K (74)
VI	<i>Cerbia tabulata</i>	K (82)
VII	<i>Cerodinium diebelii</i>	T (106); K (20)
VII	<i>Cerodinium speciosum</i>	T (86); K (4)
VII	<i>Chatangiella ditissima</i>	K (44)
VII	<i>Chatangiella verrucosa</i>	K (42)
XIII	<i>Chichaouadinium vestitum</i>	K (71)
VI	<i>Chiropteridium mespilanum</i> 'complex'	T (36)
I	<i>Chlamydophorella ambigua</i>	K (55)
VI	<i>Circulodinium distinctum</i>	K (28); J (5)
XII	<i>Cladopyxidium saeptum</i>	T (95); K (5)
III	<i>Compositosphaeridium polonicum</i>	J (33)
XVII	<i>Conneximura fimbriata</i>	T (102); K (10)
III	<i>Cordosphaeridium cantharellum</i>	T (41)
III	<i>Cordosphaeridium fibrospinosum</i>	T (61); K (7)
III	<i>Cordosphaeridium funiculatum</i>	T (67)
III	<i>Cordosphaeridium gracile</i>	T (54); K (18)
III	<i>Coronifera oceanica</i>	K (36)
II	<i>Corrudinium incompositum</i>	T (52)
II	<i>Cribroperidinium edwardsii</i> 'complex'	K (60)
II	<i>Cribroperidinium tenuitabulatum</i>	T (35)
X	<i>Ctenidodinium continuum</i>	J (38)
X	<i>Ctenidodinium elegantulum</i>	K (89)
X	<i>Ctenidodinium ornatum</i>	J (32)
D		
XVII	<i>Danea californica</i>	T (104)
IX	<i>Dapcodinium priscum</i>	J (60)
III	<i>Dapsilidinium pseudocolligerum</i>	T (25)
VII	<i>Deflandrea oebisfeldensis</i>	T (91); K (1)
VII	<i>Deflandrea phosphoritica</i> 'complex'	T (45)
X	<i>Dichadogonyaulax culmula</i>	K (98); J (1)
X	<i>Dichadogonyaulax? pannea</i>	K (99); J (6)
XVII	<i>Dinogymnium</i> spp.	K (27)
III	<i>Diphyes colligerum</i>	T (69); K (3)

Appendix B (cont'd.)

Group	Name	Chart & Position
III	<i>Discorsia nanna</i>	K (79)
III	<i>Distatodinium paradoxum</i>	T (37)
VI	<i>Dracodinium condylos</i>	T (79)
XII	<i>Druggidium</i> spp.	K (90)
E		
XVII	<i>Eatonicysta ursulae</i>	T (80)
XI	<i>Egmontodinium expiratum</i>	J (11)
XI	<i>Egmontodinium polyplacophorum</i>	J (13)
XI	<i>Egmontodinium torynum</i>	K (97)
I	<i>Ellipsoidictyum cinctum</i>	J (23)
IV	<i>Eocladopyxis peniculata</i>	T (77)
XVII	<i>Epelidosphaeridia spinosa</i>	K (63)
XVII	<i>Evittosphaerula paratabulata</i>	T (38)
XII	<i>Eyachia prisca</i>	J (50)
F		
III	<i>Fibrocysta axialis</i>	T (60)
I	<i>Filisphaera filifera</i>	T (12)
III	<i>Florentinia cooksoniae</i>	K (61)
III	<i>Florentinia mantellii</i>	K (56)
G		
I	<i>Gardodinium trabeculosum</i>	K (77)
XVII	<i>Geiselodinium inaffectum</i>	J (20)
VI	<i>Glaphyrocysta exuberans</i>	T (73)
VI	<i>Glaphyrocysta ordinata</i>	T (85)
X	<i>Glossodinium dimorphum</i>	J (15)
XV	<i>Gochteodinia mutabilis</i>	J (16)
XV	<i>Gochteodinia villosa</i>	K (96); J (2)
II	<i>Gonyaulacysta cassidata</i> 'complex'	K (69); J (7)
II	<i>Gonyaulacysta eisenackii</i>	J (29)
II	<i>Gonyaulacysta jurassica</i>	J (24)
H		
XVII	<i>Hebecysta brevicornuta</i>	J (65)
IV	<i>Heteraulacacysta porosa</i>	T (74)
III	<i>Heterosphaeridium difficile</i>	K (52)
IV	<i>Homotryblum plectilum</i>	T (40)
IV	<i>Homotryblum tenuispinosum</i>	T (68)
IV	<i>Homotryblum vallum</i>	T (39)
III	<i>Hystrichodinium</i> spp.	K (37); J (4)
III	<i>Hystrichokolpoma bulbosum</i>	T (105)
III	<i>Hystrichokolpoma cinctum</i> s.l.	T (43)
III	<i>Hystrichokolpoma rigaudiae</i>	T (15)

Appendix B (cont'd.)

Group	Name	Chart & Position
III	<i>Hystrichosphaeridium salpingophorum</i>	T (87); K (13)
III	<i>Hystrichosphaeridium tubiferum</i>	T (83); K (23)
III	<i>Hystrichosphaerina schindewolfii</i>	K (78)
II	<i>Hystrichosphaeropsis obscura</i>	T (19)
II	<i>Hystrichosphaeropsis ovum</i>	K (40)
I		
II	<i>Impagidinium aquaeductum</i>	T (24)
II	<i>Impagidinium dispertitum</i>	T (46)
II	<i>Impagidinium patulum</i>	T (2)
XVII	<i>Invertocysta tabulata</i>	T (16)
VII	<i>Isabelidinium</i> spp.	K (31)
J-K		
III	<i>Kiokansium williamsii</i>	K (64)
VIII	<i>Kisselovia coleothrypta</i> 'complex'	T (63)
III	<i>Kleithriasphaeridium loffrense</i>	K (46)
L		
I	<i>Labyrinthodinium truncatum</i>	T (23)
XIII	<i>Laciniadinium arcticum</i>	K (30)
XI	<i>Lanterna</i> spp.	J (12)
XVII	<i>Lanternosphaeridium</i> spp.	T (88); K (14)
XI	<i>Leberidocysta chlamydata</i>	K (41)
VII	<i>Lejeunecysta</i> spp.	T (8)
VII	<i>Lentinia serrata</i>	T (70)
XVII	<i>Liasidium variabile</i>	J (59)
III	<i>Lingulodinium machaerophorum</i>	T (10)
XI	<i>Lithodinia deflandrei</i>	J (36)
XI	<i>Lithodinia jurassica</i>	J (39)
XI	<i>Lithodinia stoveri</i>	K (87)
III	<i>Litosphaeridium arundum</i>	K (70)
III	<i>Litosphaeridium siphoniphorum</i>	K (59)
XII	<i>Luehndea spinosa</i>	J (58)
XIII	<i>Luxadinium propatulum</i>	K (72)
M		
IX	<i>Mancodinium semitabulatum</i>	J (49)
VII	<i>Manumiella?</i> <i>cretacea</i>	T (107); K (16)
III	<i>Melitasphaeridium choanophorum</i>	T (11)
III	<i>Melitasphaeridium pseudorecurvatum</i>	T (72)
VI	<i>Membranosphaeridium aspinatum</i>	T (42)
XII	<i>Microdinium</i> spp.	T (96); K (22)
IX	<i>Moesiodinium raileanui</i>	J (53)
V	<i>Muderongia simplex</i>	K (94); J (3)
V	<i>Muderongia tetracantha</i>	K (83)
XVII	<i>Muratodinium fimbriatum</i>	T (78)

Appendix B (cont'd.)

Group	Name	Chart & Position
N		
XVI	<i>Nannoceratopsis gracilis</i>	J (45)
XVI	<i>Nannoceratopsis pellucida</i>	J (31)
XVI	<i>Nannoceratopsis senex</i>	J (56)
XVI	<i>Nannoceratopsis triceras</i>	J (40)
XVII	<i>Nelchinopsis kostromiensis</i>	K (93)
III	<i>Nematosphaeropsis lemniscata</i>	T (13)
XVII	<i>Noricysta</i> spp.	J (63)
O		
II	<i>Occisucysta balios</i>	J (18)
V	<i>Odontochitina costata</i>	K (39)
V	<i>Odontochitina operculata</i>	K (35)
V	<i>Odontochitina porifera</i>	K (51)
III	<i>Oligosphaeridium complex</i>	T (81); K (24)
III	<i>Oligosphaeridium patulum</i>	J (17)
III	<i>Operculodinium divergens</i>	T (62)
VII	<i>Ovoidinium cinctum</i>	K (67)
VII	<i>Ovoidinium verucosum</i>	K (65)
P-Q		
VII	<i>Palaeocystodinium golzowense</i>	T (26)
XVII	<i>Palaeohystrichophora infusorioides</i>	K (34)
XIII	<i>Palaeoperidinium pyrophorum</i>	T (97); K (11)
VI	<i>Palynodinium grallator</i>	K (25)
XV	<i>Pareodinia</i> spp.	K (58); J (10)
IX	<i>Parvocysta</i> spp.	J (54)
XVII	<i>Pentadinium laticinctum</i>	T (32)
III	<i>Pervosphaeridium? truncigerum</i>	K (48)
IX	<i>Phallocysta eumekes</i>	J (52)
V	<i>Phoberocysta neocomica</i>	K (88)
VII	<i>Phthanoperidinium</i> spp.	T (51)
IV	<i>Polysphaeridium congregatum</i>	T (50)
IV	<i>Polysphaeridium zoharyi</i>	T (9)
III	<i>Prolixosphaeridium parvispinum</i>	K (62)
III	<i>Protoellipsodinium</i> spp.	K (76)
II	<i>Psaligonyaulax deflandrei</i>	K (49)
V	<i>Pseudoceratium pelliferum</i>	K (85)
V	<i>Pseudoceratium polymorphum</i>	K (73)
R		
III	<i>Reticulatosphaera actinocoronata</i>	T (14)
XVII	<i>Reutlingia gochtii</i>	J (41)
IX	<i>Rhaetogonyaulax rhaetica</i>	J (61)

Appendix B (cont'd.)

Group	Name	Chart & Position
VIII	<i>Rhombodinium draco</i>	T (56)
VIII	<i>Rhombodinium porosum</i> 'complex'	T (71)
II	<i>Rhynchodiniopsis cladophora</i>	J (22)
II	<i>Rhynchodiniopsis? regalis</i>	J (44)
III	<i>Rigaudella aemula</i>	J (30)
S		
I	<i>Samlandia chlamydophora</i>	T (57)
I	<i>Scrinocassis dictyota</i>	J (19)
I	<i>Scrinocassis weberi</i>	J (51)
II	<i>Scriniodinium? campanula</i>	K (57)
II	<i>Scriniodinium crystallinum</i>	J (28)
II	<i>Scriniodinium luridum sensu</i> Deflandre	J (21)
II	<i>Scriniodinium luridum sensu</i> Gocht	J (42)
VII	<i>Selenopemphix</i> spp.	T (7)
VII	<i>Senegalinium</i> spp.	T (59); K (15)
VI	<i>Senoniasphaera inornata</i>	T (103); K (2)
VI	<i>Senoniasphaera jurassica</i>	J (14)
XI	<i>Sirmiodiniopsis orbis</i>	J (27)
XI	<i>Sirmiodinium grossii</i>	K (86); J (9)
III	<i>Spiniferites ellipsoideus</i>	T (21)
III	<i>Spiniferites elongatus</i>	T (1)
III	<i>Spiniferites mirabilis</i>	T (5)
III	<i>Spiniferites pseudofurcatus</i>	T (30)
III	<i>Spiniferites septatus</i>	T (89)
III	<i>Spiniferites splendidus</i>	T (20)
II	<i>Spongodinium delitiense</i>	T (108); K (19)
I	<i>Stephanelytron</i> spp.	J (25)
XVII	<i>Stephodinium coronatum</i>	K (55)
III	<i>Stiphrosphaeridium anthophorum</i>	K (54)
XVII	<i>Suessia swabiana</i>	J (62)
VII	<i>Sumatradinium</i> spp.	T (22)
III	<i>Surculosphaeridium? longifurcatum</i>	K (45)
IX	<i>Susadinium</i> spp.	J (48)
IX	<i>Sverdrupiella</i> spp.	J (64)
III	<i>Systematophora placacantha</i>	T (29)
T		
III	<i>Tanyosphaeridium variecalamus</i>	K (33)
I	<i>Tectatodinium grande</i>	T (48)
XVII	<i>Thalassiphora patula</i>	T (84)
XVII	<i>Thalassiphora pelagica</i>	T (49); K (6)
II	<i>Triblastula utinensis</i>	K (26)
I	<i>Trichodinium castanea</i>	K (43)
I	<i>Trichodinium scarburghense</i>	J (34)
VII	<i>Trinovantedinium capitatum</i>	T (4)
VII	<i>Trithyrodinium</i> spp.	T (99); K (21)
XVII	<i>Tuberculodinium vancampoae</i>	T (6)
II	<i>Tubotuberella apatela</i>	K (100); J (8)

Appendix B (cont'd.)

Group	Name	Chart & Position
U-V		
I	<i>Valensiella</i> spp.	J (26)
XVII	<i>Valvaeodinium lineatum</i>	J (57)
XVII	<i>Valvaeodinium punctatum</i>	J (55)
V	<i>Vesperopsis</i> spp.	K (66)
W		
X	<i>Wanaea</i> spp.	J (35)
VIII	<i>Wetziella articulata</i> 'complex'	T (64)
VIII	<i>Wetziella symmetrica</i> 'complex'	T (47)
X-Y-Z		
V	<i>Xenascus</i> spp.	K (32)
XI	<i>Xiphophoridium alatum</i>	K (50)

APPENDIX C

Northern hemisphere stratigraphic ranges of dinoflagellate
taxa as shown on the Tertiary-Holocene range chart (no. 3)

Name	Top Ma	Base Ma
<i>Achilleodinium biformoides</i>	31.0	53.0
<i>Achomosphaera alcornu</i>	12.0	56.0
<i>Achomosphaera andalusiensis</i>	1.4	13.0
<i>Adnatosphaeridium multispinosum</i>	39.4	52.0
<i>Alisocysta circumtabulata</i>	57.0	in Cret.
<i>Alisocysta margarita</i>	54.0	63.0
<i>Alisocysta reticulata</i>	59.0	in Cret.
<i>Amiculosphaera umbracula</i>	3.5	14.0
<i>Andalusiella</i> spp.	60.2	in Cret.
<i>Apectodinium augustum</i>	54.0	55.0
<i>Apectodinium homomorphum</i> 'complex'	41.0	55.0
<i>Apteodinium australiense</i>	12.0	45.0
<i>Apteodinium spiridoides</i>	13.0	27.0
<i>Areoligera?</i> <i>semicirculata</i>	31.0	36.0
<i>Areoligera senonensis</i>	49.0	in Cret.
<i>Areosphaeridium arcuatum</i> 'complex'	30.0	48.0
<i>Areosphaeridium diktyoplokus</i>	36.0	49.0
<i>Batiacasphaera compta</i>	36.0	40.0
<i>Batiacasphaera micropapillata</i>	10.2	30.0
<i>Batiacasphaera sphaerica</i>	10.2	23.0
<i>Biconidinium longissimum</i>	53.0	54.0
<i>Bitectatodinium tepikiense</i>	0.0	25.2
<i>Caligodinium amiculum</i>	22.0	66.5
<i>Carpatella cornuta</i>	60.2	66.5
<i>Cerodinium diebelii</i>	62.0	in Cret.
<i>Cerodinium speciosum</i>	51.0	in Cret.
<i>Chiropteridium mespilanum</i> 'complex'	13.0	45.0
<i>Cladopyxidium saeptum</i>	58.0	in Cret.
<i>Conneximura fimbriata</i>	60.2	in Cret.
<i>Cordosphaeridium cantharellum</i>	22.0	44.0
<i>Cordosphaeridium fibrospinosum</i>	33.0	in Cret.
<i>Cordosphaeridium funiculatum</i>	36.0	49.0
<i>Cordosphaeridium gracile</i>	30.0	in Cret.
<i>Corrudinium incompositum</i>	30.0	41.0
<i>Cribroperidinium tenuitabulatum</i>	13.0	44.0
<i>Danea californica</i>	62.0	66.5
<i>Dapsilidinium pseudocolligerum</i>	7.0	42.0
<i>Deflandrea oebisfeldensis</i>	53.0	in Cret.
<i>Deflandrea phosphoritica</i> 'complex'	23.0	54.0
<i>Diphyes colligerum</i>	36.0	in Cret.
<i>Distatodinium paradoxum</i>	14.0	32.0
<i>Dracodinium condylos</i>	48.0	51.0

Appendix C (cont'd.)

Name	Top Ma	Base Ma
<i>Eatonicysta ursulae</i>	48.0	53.0
<i>Eocladopyxis peniculata</i>	42.0	58.0
<i>Evittosphaerula paratabulata</i>	16.2	29.0
<i>Fibrocysta axialis</i>	33.0	37.0
<i>Filisphaera filifera</i>	1.0	8.0
<i>Glaphyrocysta exuberans</i>	38.0	54.0
<i>Glaphyrocysta ordinata</i>	51.0	59.0
<i>Heteraulacacysta porosa</i>	39.4	42.0
<i>Homotryblum plectilum</i>	16.2	41.0
<i>Homotryblum tenuispinosum</i>	36.0	52.0
<i>Homotryblum vallum</i>	16.2	30.0
<i>Hystrichokolpoma bulbosum</i>	62.0	66.5
<i>Hystrichokolpoma cinctum s.l.</i>	22.0	53.0
<i>Hystrichokolpoma rigaudiae</i>	1.0	51.0
<i>Hystrichosphaeridium salpingophorum</i>	51.0	in Cret.
<i>Hystrichosphaeridium tubiferum</i>	49.0	in Cret.
<i>Hystrichosphaeropsis obscura</i>	3.5	27.0
<i>Impagidinium aquaeductum</i>	7.0	15.2
<i>Impagidinium dispersitum</i>	26.0	42.0
<i>Impagidinium patulum</i>	0.0	17.0
<i>Invertocysta tabulata</i>	1.4	12.0
<i>Kisselovia coleothrypta 'complex'</i>	35.0	51.0
<i>Labyrinthodinium truncatum</i>	7.0	13.0
<i>Lanternosphaeridium spp.</i>	51.0	in Cret.
<i>Lejeunecysta spp.</i>	0.0	44.0
<i>Lentinia serrata</i>	37.0	43.0
<i>Lingulodinium machaerophorum</i>	0.0	54.0
<i>Manumiella? cretacea</i>	62.0	in Cret.
<i>Melitasphaeridium choanophorum</i>	0.5	22.0
<i>Melitasphaeridium pseudorecurvatum</i>	38.0	52.0
<i>Membranophoridium aspinatum</i>	22.0	36.0
<i>Microdinium spp.</i>	58.0	in Cret.
<i>Muratodinium fimbriatum</i>	44.0	52.0
<i>Nematosphaeropsis lemniscata</i>	1.0	36.0
<i>Oligosphaeridium complex</i>	48.0	in Cret.
<i>Operculodinium divergens</i>	34.0	42.0
<i>Palaeocystodinium golzowense</i>	8.0	38.0
<i>Palaeoperidinium pyrophorum</i>	58.0	in Cret.
<i>Pentadinium laticinctum</i>	12.0	50.0
<i>Phthanoperidinium spp.</i>	28.0	51.0
<i>Polysphaeridium congregatum</i>	28.0	40.0
<i>Polysphaeridium zoharyi</i>	0.0	51.0
<i>Reticulatosphaera actinocoronata</i>	1.0	36.0
<i>Rhombodinium draco</i>	31.0	41.0
<i>Rhombodinium porosum 'complex'</i>	38.0	40.0

Appendix C (cont'd.)

Name	Top Ma	Base Ma
<i>Samlandia chlamydophora</i>	31.0	51.0
<i>Selenopemphix</i> spp.	0.0	43.0
<i>Senegalinium</i> spp.	31.0	in Cret.
<i>Senoniasphaera inornata</i>	60.2	in Cret.
<i>Spiniferites ellipsoideus</i>	4.0	19.0
<i>Spiniferites elongatus</i>	0.0	8.0
<i>Spiniferites mirabilis</i>	0.0	27.0
<i>Spiniferites pseudofurcatus</i>	10.2	in Cret.
<i>Spiniferites septatus</i>	52.0	66.5
<i>Spiniferites splendidus</i>	4.0	7.0
<i>Spongodinium delitiense</i>	64.0	in Cret.
<i>Sumatradinium</i> spp.	6.3	30.0
<i>Systematophora placacantha</i>	10.2	45.0
<i>Tectatodinium grande</i>	27.0	54.0
<i>Thalassiphora patula</i>	50.0	53.0
<i>Thalassiphora pelagica</i>	27.0	in Cret.
<i>Trinovantedinium capitatum</i>	0.0	25.2
<i>Trithyrodinium</i> spp.	59.0	in Cret.
<i>Tuberculodinium vancampoe</i>	0.0	27.0
<i>Wetziella articulata</i> 'complex'	35.0	53.0
<i>Wetziella symmetrica</i> 'complex'	27.0	41.0

APPENDIX D

Northern hemisphere stratigraphic ranges of dinoflagellate taxa as shown on the Cretaceous range chart

Name	Top Ma	Base Ma
<i>Achomosphaera? neptuni</i>	109.0	129.0
<i>Aldorfia deflandrei</i>	74.0	96.0
<i>Alisocysta circumtabulata</i>	in Tert.	76.0
<i>Alisocysta reticulata</i>	in Tert.	76.0
<i>Andalusiella</i> spp.	in Tert.	79.0
<i>Angustidinium acribes</i>	102.5	107.0
<i>Aprobolocysta eilema</i>	101.0	123.0
<i>Apteodinium granulatum</i>	94.0	126.0
<i>Areoligera senonensis</i>	in Tert.	77.0
<i>Batioladinium longicornutum</i>	114.0	120.0
<i>Batioladinium micropodum</i>	96.0	127.0
<i>Biorbifera johnewingii</i>	120.0	131.0
<i>Callaiosphaeridium asymmetricum</i>	79.0	118.0
<i>Cannosphaeropsis utinensis</i>	70.0	83.0
<i>Cassiculosphaeridia magna</i>	114.0	127.0
<i>Cauca parva</i>	96.0	114.0
<i>Cerbia tabulata</i>	107.0	115.0
<i>Cerodinium diebelii</i>	in Tert.	86.0
<i>Cerodinium speciosum</i>	in Tert.	70.0
<i>Chatangiella ditissima</i>	78.0	88.0
<i>Chatangiella verrucosa</i>	75.0	89.0
<i>Chichaouadinium vestitum</i>	96.0	101.0
<i>Chlamyдохorella ambigua</i>	88.0	118.0
<i>Circulodinium distinctum</i>	67.0	132.0 Jur.
<i>Cladopyxidium saeptum</i>	in Tert.	70.0
<i>Conneximura fimbriata</i>	in Tert.	76.0
<i>Cordosphaeridium fibrospinosum</i>	in Tert.	72.0
<i>Cordosphaeridium gracile</i>	in Tert.	79.0
<i>Coronifera oceanica</i>	73.0	119.0
<i>Cribroperidinium edwardsii</i> 'complex'	91.0	126.0
<i>Ctenidodinium elegantulum</i>	113.0	126.0
<i>Deflandrea oebisfeldensis</i>	in Tert.	68.0
<i>Dichadogonyaulax culmula</i>	128.0	132.0 Jur.
<i>Dichadogonyaulax? panneae</i>	128.0	132.0 Jur.
<i>Dinogymnium</i> spp.	66.5	90.0
<i>Diphyes colligerum</i>	in Tert.	69.0
<i>Discorsia nanna</i>	99.0	122.0
<i>Druggidium</i> spp.	113.0	131.0
<i>Egmontodinium torynum</i>	128.0	131.0
<i>Epelidosphaeridia spinosa</i>	93.0	96.0
<i>Florentinia cooksoniae</i>	92.0	101.0
<i>Florentinia mantellii</i>	90.0	117.0
<i>Gardodinium trabeculosum</i>	98.0	120.0
<i>Gochteodinia villosa</i>	120.0	132.0 Jur.
<i>Gonyaulacysta cassidata</i> 'complex'	94.0	132.0 Jur.
<i>Heterosphaeridium difficile</i>	86.0	91.0
<i>Hystrichodinium</i> spp.	73.0	132.0 Jur.

Appendix D (cont'd.)

Name	Top Ma	Base Ma
<i>Hystrichosphaeridium salpingophorum</i>	in Tert.	77.0
<i>Hystrichosphaeridium tubiferum</i>	in Tert.	111.0
<i>Hystrichosphaerina schindewolfii</i>	99.0	118.0
<i>Hystrichosphaeropsis ovum</i>	74.0	98.0
<i>Isabelidinium</i> spp.	71.0	90.0
<i>Kiokansium williamsii</i>	94.0	99.0
<i>Kleithriasphaeridium loffrense</i>	78.0	108.0
<i>Laciniadinium arcticum</i>	71.0	83.0
<i>Lanternosphaeridium</i> spp.	in Tert.	77.0
<i>Leberidocysta chlamydata</i>	74.0	108.0
<i>Lithodinia stoveri</i>	112.0	119.0
<i>Litosphaeridium arundum</i>	95.0	107.0
<i>Litosphaeridium siphoniphorum</i>	91.0	99.0
<i>Luxadinium propatulum</i>	96.0	101.0
<i>Manumiella? cretacea</i>	in Tert.	78.0
<i>Microdinium</i> spp.	in Tert.	101.0
<i>Muderongia simplex</i>	118.0	132.0 Jur.
<i>Muderongia tetracantha</i>	108.0	125.0
<i>Nelchinopsis kostromiensis</i>	116.5	127.0
<i>Odontochitina costata</i>	74.0	96.0
<i>Odontochitina operculata</i>	72.0	117.0
<i>Odontochitina porifera</i>	86.0	89.0
<i>Oligosphaeridium complex</i>	in Tert.	126.0
<i>Ovoidinium cinctum</i>	94.0	115.0
<i>Ovoidinium verrucosum</i>	94.0	102.5
<i>Palaeohystrichophora infusorioides</i>	72.0	95.0
<i>Palaeoperidinium pyrophorum</i>	in Tert.	76.0
<i>Palynodinium grallator</i>	66.5	77.0
<i>Pareodinia</i> spp.	90.0	132.0 Jur.
<i>Pervosphaeridium? truncigerum</i>	82.0	89.0
<i>Phoberocysta neocomica</i>	112.0	128.0
<i>Prolixosphaeridium parvispinum</i>	92.0	120.0
<i>Protoellipsodinium</i> spp.	97.0	117.0
<i>Psaligonyaulax deflandrei</i>	84.0	100.0
<i>Pseudoceratium pelliferum</i>	110.2	129.0
<i>Pseudoceratium polymorphum</i>	96.0	111.0
<i>Scriniodinium? campanula</i>	90.0	131.0
<i>Senegalinium</i> spp.	in Tert.	77.0
<i>Senoniasphaera inornata</i>	in Tert.	68.0
<i>Sirmiodinium grossii</i>	111.0	132.0 Jur.
<i>Spongodinium delitiense</i>	in Tert.	79.0
<i>Stephodinium coronatum</i>	89.0	101.0
<i>Stiphrosphaeridium anthophorum</i>	88.0	128.0
<i>Surculosphaeridium? longifurcatum</i>	78.0	107.0
<i>Tanyosphaeridium variecalamus</i>	71.0	123.0
<i>Thalassiphora pelagica</i>	in Tert.	70.0
<i>Triblastula utinensis</i>	66.5	83.0
<i>Trichodinium castanea</i>	75.0	128.0
<i>Trithyrodinium</i> spp.	in Tert.	98.0
<i>Tubotuberella apatela</i>	128.0	132.0 Jur.
<i>Vesperopsis</i> spp.	94.0	114.0
<i>Xenascus</i> spp.	71.0	114.0
<i>Xiphophoridium alatum</i>	85.0	98.0

APPENDIX E

Northern hemisphere stratigraphic ranges of dinoflagellate taxa as shown on the Triassic-Jurassic range chart (no. 1)

Name	Top Ma	Base Ma
<i>Aldorfia aldorfensis</i>	156.0	166.0
<i>Apteodinium syzygium</i>	161.0	183.0
<i>Bejuia polygonalis</i>	160.0	167.0
<i>Carpathodinium predae</i>	151.0	166.0
<i>Circulodinium distinctum</i>	in Cret.	139.0
<i>Compositosphaeridium polonicum</i>	147.0	157.0
<i>Ctenidodinium continuum</i>	151.0	166.0
<i>Ctenidodinium ornatum</i>	146.0	166.0
<i>Dapcodinium priscum</i>	198.0	212.0
<i>Dichadogonyaulax culmula</i>	in Cret.	135.0
<i>Dichadogonyaulax? panneae</i>	in Cret.	140.0
<i>Egmontodinium expiratum</i>	131.0	134.0
<i>Egmontodinium polyplacophorum</i>	133.0	139.0
<i>Ellipsoidictyum cinctum</i>	140.0	164.0
<i>Eyachia prisca</i>	169.0	182.0
<i>Geiselodinium inaeffectum</i>	140.0	143.0
<i>Glossodinium dimorphum</i>	134.0	149.0
<i>Gochteodinia mutabilis</i>	135.0	140.0
<i>Gochteodinia villosa</i>	in Cret.	135.0
<i>Gonyaulacysta cassidata</i> 'complex'	in Cret.	147.0
<i>Gonyaulacysta eisenackii</i>	144.0	166.0
<i>Gonyaulacysta jurassica</i>	140.0	164.0
<i>Hebecysta brevicornuta</i>	216.0	218.0
<i>Hystrichodinium</i> spp.	in Cret.	137.0
<i>Lanterna</i> spp.	131.0	146.0
<i>Liasidium variabile</i>	194.0	197.0
<i>Lithodinia deflandrei</i>	150.0	164.0
<i>Lithodinia jurassica</i>	153.0	166.0
<i>Luehndea spinosa</i>	186.0	188.0
<i>Mancodinium semitabulatum</i>	168.0	193.0
<i>Moesiodinium raileanui</i>	172.0	180.0
<i>Muderongia simplex</i>	in Cret.	136.0
<i>Nannoceratopsis gracilis</i>	158.0	191.0
<i>Nannoceratopsis pellucida</i>	145.0	165.0
<i>Nannoceratopsis senex</i>	177.0	189.0
<i>Nannoceratopsis tricerat</i>	153.0	187.0
<i>Noricysta</i> spp.	210.0	218.0
<i>Occisucysta balios</i>	136.0	146.0
<i>Oligosphaeridium patulum</i>	136.0	141.0
<i>Pareodinia</i> spp.	in Cret.	183.0
<i>Parvocysta</i> spp.	177.0	182.0
<i>Phallocysta eumekes</i>	171.0	187.0

Appendix E (cont'd.)

Name	Top Ma	Base Ma
<i>Reutlingia gochtii</i>	153.0	154.0
<i>Rhaetogonyaulax rhaetica</i>	207.0	216.0
<i>Rhynchodiniopsis cladophora</i>	140.0	158.0
<i>Rhynchodiniopsis? regalis</i>	157.0	165.0
<i>Rigaudella aemula</i>	145.0	158.0
<i>Scrinocassis dictyota</i>	138.0	161.0
<i>Scrinocassis weberi</i>	169.0	188.0
<i>Scriniodinium crystallinum</i>	144.0	153.0
<i>Scriniodinium luridum sensu Deflandre</i>	140.0	154.0
<i>Scriniodinium luridum sensu Gocht</i>	156.0	165.0
<i>Senoniasphaera jurassica</i>	134.0	145.0
<i>Sirmiodiniopsis orbis</i>	143.0	157.0
<i>Sirmiodinium grossii</i>	in Cret.	158.0
<i>Stephanelytron</i> spp.	142.0	154.0
<i>Suessia swabiana</i>	210.0	216.0
<i>Susadinium</i> spp.	163.0	188.0
<i>Sverdrupiella</i> spp.	213.0	216.0
<i>Trichodinium scarburghense</i>	149.0	155.0
<i>Tubotuberella apatela</i>	in Cret.	156.0
<i>Valensiella</i> spp.	142.0	178.0
<i>Valvaeodinium lineatum</i>	183.0	188.0
<i>Valvaeodinium punctatum</i>	177.0	188.0
<i>Wanaea</i> spp.	149.0	167.0

APPENDIX F

Tops and bases of Tertiary-Holocene dinoflagellates for specific ages

	T = Top, B = Base, X = Pre-Tertiary Base
Age:	0.0 Ma Holocene
	T <i>Bitectatodinium tepikiense</i>
	T <i>Impagidinium patulum</i>
	T <i>Lejeunecysta</i> spp.
	T <i>Lingulodinium machaerophorum</i>
	T <i>Polysphaeridium zoharyi</i>
	T <i>Selenopemphix</i> spp.
	T <i>Spiniferites elongatus</i>
	T <i>Spiniferites mirabilis</i>
	T <i>Trinovantedinium capitatum</i>
	T <i>Tuberculodinium vancampoe</i>
Age:	0.5 Ma Pleistocene
	T <i>Melitasphaeridium choanophorum</i>
Age:	1.0 Ma Pleistocene
	T <i>Filisphaera filifera</i>
	T <i>Hystrichokolpoma rigaudiae</i>
	T <i>Nematosphaeropsis lemniscata</i>
	T <i>Reticulosphaera actinocoronata</i>
Age:	1.4 Ma Pleistocene
	T <i>Achomosphaera andalousiensis</i>
	T <i>Invertocysta tabulata</i>
Age:	1.7 Ma Pleistocene - Pliocene Boundary
Age:	2.0 Ma Pliocene
Age:	3.5 Ma Pliocene
	T <i>Amiculosphaera umbracula</i>
	T <i>Hystrichosphaeropsis obscura</i>
Age:	4.0 Ma Pliocene
	T <i>Spiniferites ellipsoideus</i>
	T <i>Spiniferites splendidus</i>
Age:	5.2 Ma Pliocene - Late Miocene Boundary (Messinian)
Age:	6.3 Ma Late Miocene (Messinian)
	T <i>Sumatradinium</i> spp.

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

Age:	7.0 Ma Late Miocene (Tortonian)
T	<i>Dapsilidinium pseudocolligerum</i>
T	<i>Impagidinium aquaeductum</i>
T	<i>Labyrinthodinium truncatum</i>
B	<i>Spiniferites splendidus</i>
Age:	8.0 Ma Late Miocene (Tortonian)
T	<i>Palaeocystodinium golzowense</i>
B	<i>Filisphaera filifera</i>
B	<i>Spiniferites elongatus</i>
Age:	9.0 Ma Late Miocene (Tortonian)
Age:	10.2 Ma Late Miocene - Middle Miocene Boundary (Serravallian)
T	<i>Batiacasphaera sphaerica</i>
T	<i>Batiacasphaera micropapillata</i>
T	<i>Spiniferites pseudofurcatus</i>
T	<i>Systematophora placacantha</i>
Age:	11.0 Ma Middle Miocene (Serravallian)
Age:	12.0 Ma Middle Miocene (Serravallian)
T	<i>Achomosphaera alcornu</i>
T	<i>Apteodinium australiense</i>
T	<i>Pentadinium laticinctum</i>
B	<i>Invertocysta tabulata</i>
Age:	13.0 Ma Middle Miocene (Serravallian)
T	<i>Apteodinium spiridoides</i>
T	<i>Chiropteridium mespilum</i> 'complex'
T	<i>Cribroridinium tenuitabulatum</i>
B	<i>Achomosphaera andalusiensis</i>
B	<i>Labyrinthodinium truncatum</i>
Age:	14.0 Ma Middle Miocene (Serravallian)
T	<i>Distatodinium paradoxum</i>
B	<i>Amiculosphaera umbracula</i>
Age:	15.2 Ma Middle Miocene (Langhian)
B	<i>Impagidinium aquaeductum</i>
Age:	16.2 Ma Middle Miocene - Early Miocene Boundary (Burdigalian)
T	<i>Evittosphaerula paratabulata</i>
T	<i>Homotryblum plectilum</i>
T	<i>Homotryblum vallum</i>
Age:	17.0 Ma Early Miocene (Burdigalian)
B	<i>Impagidinium patulum</i>

Appendix F (cont'd.)

	T = Top, B = Base, X = Pre-Tertiary Base	
Age:	18.0 Ma Early Miocene (Burdigalian)	
Age:	19.0 Ma Early Miocene (Burdigalian)	
	B	<i>Spiniferites ellipsoideus</i>
Age:	20.0 Ma Early Miocene (Aquitanian)	
	T	<i>Cordosphaeridium cantharellum</i>
Age:	21.0 Ma Early Miocene (Aquitanian)	
Age:	22.0 Ma Early Miocene (Aquitanian)	
	T	<i>Caligodinium amiculum</i>
	T	<i>Hystriocholpoma cinctum s.l.</i>
	T	<i>Membranophoridium aspinatum</i>
	B	<i>Melitasphaeridium choanophorum</i>
Age:	23.0 Ma Early Miocene (Aquitanian)	
	T	<i>Deflandrea phosphoritica</i> 'complex'
	B	<i>Batiacasphaera sphaerica</i>
Age:	24.0 Ma Early Miocene (Aquitanian)	
Age:	25.2 Ma Early Miocene - Late Oligocene Boundary (Chattian)	
	B	<i>Bitectatodinium tepikiense</i>
	B	<i>Trinovantedinium capitatum</i>
Age:	26.0 Ma Late Oligocene (Chattian)	
	T	<i>Impagidinium dispersitum</i>
Age:	27.0 Ma Late Oligocene (Chattian)	
	T	<i>Tectatodinium grande</i>
	T	<i>Thalassiphora pelagica</i>
	T	<i>Wetzelilla symmetrica</i> 'complex'
	B	<i>Apteodinium spiridoides</i>
	B	<i>Hystriosphaeopsis obscura</i>
	B	<i>Spiniferites mirabilis</i>
	B	<i>Tuberculodinium vancampoe</i>
Age:	28.0 Ma Late Oligocene (Chattian)	
	T	<i>Phthanoperidinium</i> spp.
	T	<i>Polysphaeridium congregatum</i>
Age:	29.0 Ma Late Oligocene (Chattian)	
	B	<i>Evittosphaerula paratabulata</i>

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

Age:	30.0 Ma Late Oligocene - Early Oligocene Boundary (Rupelian)
	T <i>Areosphaeridium arcuatum</i> 'complex'
	T <i>Cordosphaeridium gracile</i>
	T <i>Corrudinium incompositum</i>
	B <i>Batiacasphaera micropapillata</i>
	B <i>Homotryblum vallum</i>
	B <i>Sumatradinium</i> spp.
Age:	31.0 Ma Early Oligocene (Rupelian)
	T <i>Achilleodinium biformoides</i>
	T <i>Areoligera? semicirculata</i>
	T <i>Rhombodinium draco</i>
	T <i>Samlandia chlamydophora</i>
	T <i>Senegalinium</i> spp.
Age:	32.0 Ma Early Oligocene (Rupelian)
	B <i>Distatodinium paradoxum</i>
Age:	33.0 Ma Early Oligocene (Rupelian)
	T <i>Cordosphaeridium fibrospinosum</i>
	T <i>Fibrocysta axialis</i>
Age:	34.0 Ma Early Oligocene (Rupelian)
	T <i>Operculodinium divergens</i>
Age:	35.0 Ma Early Oligocene (Rupelian)
	T <i>Kisselovia coleothrypta</i> 'complex'
	T <i>Wetzelilla articulata</i> 'complex'
Age:	36.0 Ma Early Oligocene - Late Eocene Boundary (Priabonian)
	T <i>Areosphaeridium diktyoplokus</i>
	T <i>Batiacasphaera compta</i>
	T <i>Cordosphaeridium funiculatum</i>
	T <i>Diphyes colligerum</i>
	T <i>Homotryblum tenuispinosum</i>
	B <i>Areoligera? semicirculata</i>
	B <i>Membranophoridium aspinatum</i>
	B <i>Nematosphaeropsis lemniscata</i>
	B <i>Reticulatosphaera actinocoronata</i>
Age:	37.0 Ma Late Eocene (Priabonian)
	T <i>Lentinia serrata</i>
	B <i>Fibrocysta axialis</i>
	B <i>Palaeocystodinium golzowense</i>
Age:	38.0 Ma Late Eocene (Priabonian)
	T <i>Glaphyrocysta exuberans</i>
	T <i>Melitasphaeridium pseudorecurvatum</i>
	T <i>Rhombodinium porosum</i> 'complex'

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

Age: 39.4 Ma Late Eocene - Middle Eocene Boundary (Bartonian)

T *Adnatosphaeridium multispinosum*

T *Heteraulacacysta porosa*

Age: 40.0 Ma Middle Eocene (Bartonian)

B *Batiacasphaera compta*

B *Polysphaeridium congregatum*

B *Rhombodinium porosum* 'complex'

Age: 41.0 Ma Middle Eocene (Bartonian)

T *Apectodinium homomorphum* 'complex'

B *Corrudinium incompositum*

B *Homotryblidium plectilum*

B *Rhombodinium draco*

B *Wetzelilla symmetrica* 'complex'

Age: 42.0 Ma Middle Eocene (Lutetian)

T *Eocladopyxis peniculata*

B *Dapsilidinium pseudocolligerum*

B *Heteraulacacysta porosa*

B *Impagidinium dispertitum*

B *Operculodinium divergens*

Age: 43.0 Ma Middle Eocene (Lutetian)

B *Lentinia serrata*

B *Selenopemphix* spp.

Age: 44.0 Ma Middle Eocene (Lutetian)

T *Muratodinium fimbriatum*

B *Cordosphaeridium cantharellum*

B *Cribroperidinium tenuitabulatum*

B *Lejeunecysta* spp.

Age: 45.0 Ma Middle Eocene (Lutetian)

B *Apteodinium australiense*

B *Chiropteridium mespilanum* 'complex'

B *Systematophora placacantha*

Age: 46.0 Ma Middle Eocene (Lutetian)

Age: 47.0 Ma Middle Eocene (Lutetian)

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

- Age: 48.0 Ma Middle Eocene (Lutetian)
T *Dracodinium condylos*
T *Eatonicysta ursulae*
T *Oligosphaeridium complex*
B *Areosphaeridium arcuatum* 'complex'
- Age: 49.0 Ma Middle Eocene - Early Eocene Boundary (Ypresian)
T *Areoligera senonensis sensu* Gocht
T *Hystriosphæridium tubiferum*
B *Areosphaeridium diktyoplokos*
B *Cordosphaeridium funiculatum*
- Age: 50.0 Ma Early Eocene (Ypresian)
T *Thalassiphora patula*
B *Pentadinium laticinctum*
- Age: 51.0 Ma Early Eocene (Ypresian)
T *Cerodinium speciosum*
T *Glaphyrocysta ordinata*
T *Hystriosphæridium salpingophorum*
T *Lanternosphaeridium* spp.
B *Dracodinium condylos*
B *Hystriocholpoma rigaudiae*
B *Kisselovia coleothrypta* 'complex'
B *Phthanoperidinium* spp.
B *Polysphaeridium zoharyi*
B *Samlandia chlamydophora*
- Age: 52.0 Ma Early Eocene (Ypresian)
T *Spiniferites septatus*
B *Adnatosphaeridium multispinosum*
B *Homotryblum tenuispinosum*
B *Melitasphaeridium pseudorecurvatum*
B *Muratodinium fimbriatum*
- Age: 53.0 Ma Early Eocene (Ypresian)
T *Biconidinium longissimum*
T *Deflandrea oebisfeldensis*
B *Achilleodinium biformoides*
B *Eatonicysta ursulae*
B *Hystriocholpoma cinctum s.l.*
B *Thalassiphora patula*
B *Wetzelilla articulata* 'complex'

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

Age: 54.0 Ma Early Eocene - Late Paleocene Boundary (Thanetian)

T *Alisocysta margarita*
T *Apectodinium augustum*
B *Biconidinium longissimum*
B *Deflandrea phosphoritica* 'complex'
B *Glaphyrocysta exuberans*
B *Lingulodinium machaerophorum*
B *Tectatodinium grande*

Age: 55.0 Ma Late Paleocene (Thanetian)

B *Apectodinium augustum*

Age: 56.0 Ma Late Paleocene (Thanetian)

B *Achomosphaera alcornu*
B *Apectodinium homomorphum* 'complex'

Age: 57.0 Ma Late Paleocene (Thanetian)

T *Alisocysta circumtabulata*

Age: 58.0 Ma Late Paleocene (Thanetian)

T *Cladopyxidium saeptum*
T *Microdinium* spp.
T *Palaeoperidinium pyrophorum*
B *Eocladopyxis peniculata*

Age: 59.0 Ma Late Paleocene (Thanetian)

T *Alisocysta reticulata*
T *Trithyrodinium* spp.
B *Glaphyrocysta ordinata*

Age: 60.2 Ma Late Paleocene - Early Paleocene Boundary (Danian)

T *Andalusiella* spp.
T *Carpatella cornuta*
T *Conneximura fimbriata*
T *Senoniasphaera inornata*

Age: 61.0 Ma Early Paleocene (Danian)

Age: 62.0 Ma Early Paleocene (Danian)

T *Cerodinium diebelii*
T *Danea californica*
T *Hystriochokolpoma bulbosum*
T *Manumiella? cretacea*

Appendix F (cont'd.)

T = Top, B = Base, X = Pre-Tertiary Base

- Age: 63.0 Ma Early Paleocene (Danian)
 B *Alisocysta margarita*
- Age: 64.0 Ma Early Paleocene (Danian)
 T *Spongodinium delitiense*
- Age: 65.0 Ma Early Paleocene (Danian)
- Age: 66.0 Ma Early Paleocene (Danian)
- Age: 66.5 Ma Early Paleocene - Late Cretaceous Boundary
 B *Caligodinium amiculum*
 B *Carpatella cornuta*
 B *Danea californica*
 B *Hystrichokolpoma bulbosum*
 B *Spiniferites septatus*

Species that continue into the Maastrichtian

- X *Alisocysta circumtabulata*
 X *Alisocysta reticulata*
 X *Andalusiella* spp.
 X *Areoligera senonensis*
 X *Cerodinium diebelii*
 X *Cerodinium speciosum*
 X *Cladopyxidium saeptum*
 X *Conneximura fimbriata*
 X *Cordosphaeridium fibrospinosum*
 X *Cordosphaeridium gracile*
 X *Deflandrea oebisfeldensis*
 X *Diphyes colligerum*
 X *Hystrichosphaeridium salpingophorum*
 X *Hystrichosphaeridium tubiferum*
 X *Lanternosphaeridium* spp.
 X *Manumiella?* *cretacea*
 X *Microdinium* spp.
 X *Oligosphaeridium* complex
 X *Palaeoperidinium pyrophorum*
 X *Senegalinium* spp.
 X *Senoniasphaera inornata*
 X *Spiniferites pseudofurcatus*
 X *Spongodinium delitiense*
 X *Thalassiphora pelagica*
 X *Trithyrodinium* spp.

APPENDIX G

Tops and bases of Cretaceous dinoflagellates for specific ages

T = Top, B = Base, X = Post-Cretaceous Top, Y = Pre-Cretaceous Base

Age: 66.5 Ma Early Tertiary - Late Cretaceous Boundary (Early Paleocene-Maastrichtian Boundary)

Species that continue from the Tertiary

- X *Alisocysta circumtabulata*
- X *Alisocysta reticulata*
- X *Andalusiella* spp.
- X *Areoligera senonensis*
- X *Cerodinium diebelii*
- X *Cerodinium speciosum*
- X *Cladopyxidium saeptum*
- X *Conneximura fimbriata*
- X *Cordosphaeridium fibrospinosum*
- X *Cordosphaeridium gracile*
- X *Deflandrea oebisfeldensis*
- X *Diphyes colligerum*
- X *Hystrichosphaeridium salpingophorum*
- X *Hystrichosphaeridium tubiferum*
- X *Lanternosphaeridium* spp.
- X *Manumiella?* *cretacea*
- X *Microdinium* spp.
- X *Oligosphaeridium complex*
- X *Palaeoperidinium pyrophorum*
- X *Senegalinium* spp.
- X *Senoniasphaera inornata*
- X *Spongodinium delitiense*
- X *Thalassiphora pelagica*
- X *Trithyrodinium* spp.

Species whose last appearance is in the Late Maastrichtian

- T *Circulodinium distinctum*
- T *Dinogymnium* spp.
- T *Palynodinium grallator*
- T *Triblastula utinensis*

Age: 68.0 Ma Late Cretaceous (Late Maastrichtian)

- B *Deflandrea oebisfeldensis*
- B *Senoniasphaera inornata*

Age: 69.0 Ma Late Cretaceous (Late Maastrichtian)

- B *Diphyes colligerum*

Age: 70.0 Ma Late Cretaceous (Late Maastrichtian)

- B *Cerodinium speciosum*
- B *Cladopyxidium saeptum*
- B *Thalassiphora pelagica*

Age: 71.0 Ma Late Cretaceous (Late Maastrichtian-Early Maastrichtian Boundary)

- T *Cannosphaeropsis utinensis*

Appendix G (cont'd.)

Age:	72.0 Ma Late Cretaceous (Early Maastrichtian)
T	<i>Isabelidinium</i> spp.
T	<i>Laciniadinium arcticum</i>
T	<i>Tanyosphaeridium variecalamus</i>
T	<i>Xenascus</i> spp.
B	<i>Cordosphaeridium fibrospinosum</i>
Age:	73.0 Ma Late Cretaceous (Early Maastrichtian)
T	<i>Odontochitina operculata</i>
T	<i>Palaeohystrichophora infusorioides</i>
Age:	74.0 Ma Late Cretaceous (Early Maastrichtian-Late Campanian Boundary)
T	<i>Coronifera oceanica</i>
T	<i>Hystrichodinium</i> spp.
Age:	75.0 Ma Late Cretaceous (Late Campanian)
T	<i>Aldorfia deflandrei</i>
T	<i>Hystrichosphaeropsis ovum</i>
T	<i>Leberidocysta chlamydata</i>
T	<i>Odontochitina costata</i>
Age:	76.0 Ma Late Cretaceous (Late Campanian)
T	<i>Chatangiella verrucosa</i>
T	<i>Trichodinium castanea</i>
B	<i>Alisocysta circumtabulata</i>
B	<i>Alisocysta reticulata</i>
B	<i>Conneximura fimbriata</i>
B	<i>Palaeoperidinium pyrophorum</i>
Age:	77.0 Ma Late Cretaceous (Late Campanian)
B	<i>Areoligera senonensis</i>
B	<i>Hystrichosphaeridium salpingophorum</i>
B	<i>Lanternosphaeridium</i> spp.
B	<i>Palynodinium grallator</i>
B	<i>Senegalinium</i> spp.
Age:	78.0 Ma Late Cretaceous (Late Campanian-Early Campanian Boundary)
B	<i>Manumiella? cretacea</i>
Age:	79.0 Ma Late Cretaceous (Early Campanian)
T	<i>Chatangiella ditissima</i>
T	<i>Kleithriasphaeridium loffrense</i>
T	<i>Surculosphaeridium? longifurcatum</i>
B	<i>Andalusiella</i> spp.
B	<i>Cordosphaeridium gracile</i>
B	<i>Spongodinium delitiense</i>
Age:	80.0 Ma Late Cretaceous (Early Campanian)
T	<i>Callaiosphaeridium asymmetricum</i>
Age:	81.0 Ma Late Cretaceous (Early Campanian)

Appendix G (cont'd.)

Age:	82.0 Ma Late Cretaceous (Early Campanian)
Age:	83.0 Ma Late Cretaceous (Early Campanian)
	T <i>Pervosphaeridium? truncigerum</i>
	B <i>Cannosphaeropsis utinensis</i>
	B <i>Laciniadinium arcticum</i>
	B <i>Triblastula utinensis</i>
Age:	84.0 Ma Late Cretaceous (Early Campanian-Santonian Boundary)
Age:	85.0 Ma Late Cretaceous (Santonian)
	T <i>Psalignonyaulax deflandrei</i>
Age:	86.0 Ma Late Cretaceous (Santonian)
	T <i>Xiphophoridium alatum</i>
	B <i>Cerodinium diebelii</i>
Age:	87.0 Ma Late Cretaceous (Santonian)
	T <i>Heterosphaeridium difficile</i>
	T <i>Odontochitina porifera</i>
Age:	88.0 Ma Late Cretaceous (Santonian-Coniacian Boundary)
	B <i>Chatangiella ditissima</i>
Age:	89.0 Ma Late Cretaceous (Coniacian-Turonian Boundary)
	T <i>Chlamydophorella ambigua</i>
	T <i>Stiphrosphaeridium anthophorum</i>
	B <i>Chatangiella verrucosa</i>
	B <i>Odontochitina porifera</i>
	B <i>Pervosphaeridium? truncigerum</i>
Age:	90.0 Ma Late Cretaceous (Turonian)
	T <i>Stephodium coronatum</i>
	B <i>Dinogymnium</i> spp.
	B <i>Isabelidinium</i> spp.
Age:	91.0 Ma Late Cretaceous (Turonian)
	T <i>Florentinia mantellii</i>
	T <i>Pareodinia</i> spp.
	T <i>Scriniodinium? campanula</i>
	B <i>Heterosphaeridium difficile</i>
Age:	92.0 Ma Late Cretaceous (Turonian-Cenomanian Boundary)
	T <i>Cribroperidium edwardsii</i> 'complex'
	T <i>Litosphaeridium siphoniphorum</i>
Age:	93.0 Ma Late Cretaceous (Cenomanian)
	T <i>Florentinia cooksoniae</i>
	T <i>Prolixosphaeridium parvispinum</i>

Appendix G (cont'd.)

Age:	94.0 Ma Late Cretaceous (Cenomanian)
T	<i>Epelidosphaeridia spinosa</i>
Age:	95.0 Ma Late Cretaceous (Cenomanian)
T	<i>Apteodinium granulatum</i>
T	<i>Gonyaulacysta cassidata</i> 'complex'
T	<i>Kiokansium williamsii</i>
T	<i>Ovoidinium cinctum</i>
T	<i>Ovoidinium verrucosum</i>
T	<i>Vesperopsis</i> spp.
B	<i>Palaeohystrichophora infusorioides</i>
Age:	96.0 Ma Late Cretaceous - Early Cretaceous Boundary (Cenomanian-Late Albian Boundary)
T	<i>Litosphaeridium arundum</i>
B	<i>Aldorfia deflandrei</i>
B	<i>Epelidosphaeridia spinosa</i>
B	<i>Odontochitina costata</i>
Age:	97.0 Ma Early Cretaceous (Late Albian)
T	<i>Batioladinium micropodum</i>
T	<i>Cauca parva</i>
T	<i>Chichaouadinium vestitum</i>
T	<i>Luxadinium propatulum</i>
T	<i>Pseudoceratium polymorphum</i>
Age:	98.0 Ma Early Cretaceous (Late Albian)
T	<i>Protoellipsodinium</i> spp.
B	<i>Hystrichosphaeropsis ovum</i>
B	<i>Trithyrodinium</i> spp.
B	<i>Xiphophoridium alatum</i>
Age:	99.0 Ma Early Cretaceous (Late Albian-Middle Albian Boundary)
T	<i>Gardodinium trabeculosum</i>
B	<i>Kiokansium williamsii</i>
B	<i>Litosphaeridium siphoniphorum</i>
Age:	100.0 Ma Early Cretaceous (Middle Albian)
T	<i>Discorsia nanna</i>
T	<i>Hystrichosphaerina schindewolfii</i>
B	<i>Psaligonyaulax deflandrei</i>
Age:	101.0 Ma Early Cretaceous (Middle Albian)
B	<i>Chichaouadinium vestitum</i>
B	<i>Florentinia cooksoniae</i>
B	<i>Luxadinium propatulum</i>
B	<i>Microdinium</i> spp.
B	<i>Stephodinium coronatum</i>
Age:	102.5 Ma Early Cretaceous (Middle Albian-Early Albian Boundary)
T	<i>Aprobolocysta eilema</i>
B	<i>Ovoidinium verrucosum</i>

Appendix G (cont'd.)

Age:	104.0 Ma	Early Cretaceous (Early Albian)
	T	<i>Angustidinium acribes</i>
Age:	105.0 Ma	Early Cretaceous (Early Albian)
Age:	106.0 Ma	Early Cretaceous (Early Albian)
Age:	107.0 Ma	Early Cretaceous (Early Albian)
	B	<i>Angustidinium acribes</i>
	B	<i>Litosphaeridium arundum</i>
	B	<i>Surculosphaeridium? longifurcatum</i>
Age:	108.0 Ma	Early Cretaceous (Early Albian-Late Aptian Boundary)
	T	<i>Cerbia tabulata</i>
	B	<i>Kleithrasphaeridium loffrense</i>
	B	<i>Leberidocysta chlamydata</i>
Age:	109.0 Ma	Early Cretaceous (Late Aptian)
	T	<i>Muderongia tetracantha</i>
Age:	110.2 Ma	Early Cretaceous (Late Aptian-Early Aptian Boundary)
	T	<i>Achomosphaera? neptuni</i>
Age:	111.0 Ma	Early Cretaceous (Early Aptian)
	T	<i>Pseudoceratium pelliferum</i>
	B	<i>Hystriosphæridium tubiferum</i>
	B	<i>Pseudoceratium polymorphum</i>
Age:	112.0 Ma	Early Cretaceous (Early Aptian)
	T	<i>Sirmiodinium grossii</i>
Age:	113.0 Ma	Early Cretaceous (Early Aptian-Barremian Boundary)
	T	<i>Lithodinia stoveri</i>
	T	<i>Phoberocysta neocomica</i>
Age:	114.0 Ma	Early Cretaceous (Barremian)
	T	<i>Ctenidodinium elegantulum</i>
	T	<i>Druggidium</i> spp.
	B	<i>Cauca parva</i>
	B	<i>Vesperopsis</i> spp.
	B	<i>Xenascus</i> spp.
Age:	115.0 Ma	Early Cretaceous (Barremian)
	T	<i>Batioladinium longicornutum</i>
	T	<i>Cassiculosphaeridia magna</i>
	B	<i>Cerbia tabulata</i>
	B	<i>Ovoidinium cinctum</i>
Age:	116.0 Ma	Early Cretaceous (Barremian)
Age:	116.5 Ma	Early Cretaceous (Barremian-Hauterivian Boundary)

Appendix G (cont'd.)

Age:	117.0 Ma Early Cretaceous (Hauterivian)
T	<i>Nelchinopsis kostromiensis</i>
B	<i>Florentinia mantellii</i>
B	<i>Odontochitina operculata</i>
B	<i>Protoellipsodinium</i> spp.
Age:	118.0 Ma Early Cretaceous (Hauterivian)
B	<i>Callaiosphaeridium asymmetricum</i>
B	<i>Chlamydophorella ambigua</i>
B	<i>Hystriosphera schindewolfii</i>
Age:	119.0 Ma Early Cretaceous (Hauterivian)
T	<i>Muderongia simplex</i>
B	<i>Coronifera oceanica</i>
B	<i>Lithodinia stoveri</i>
Age:	120.0 Ma Early Cretaceous (Hauterivian)
B	<i>Batioladinium longicornutum</i>
B	<i>Gardodinium trabeculosum</i>
B	<i>Prolixosphaeridium parvispinum</i>
Age:	121.0 Ma Early Cretaceous (Hauterivian-Late Valanginian Boundary)
T	<i>Biorbifera johnewingii</i>
T	<i>Gochteodinia villosa</i>
Age:	122.0 Ma Early Cretaceous (Late Valanginian)
B	<i>Discorsia nanna</i>
Age:	123.0 Ma Early Cretaceous (Late Valanginian)
B	<i>Aprobolocysta eilema</i>
B	<i>Tanyosphaeridium variecalamus</i>
Age:	124.0 Ma Early Cretaceous (Late Valanginian-Early Valanginian Boundary)
Age:	125.0 Ma Early Cretaceous (Early Valanginian)
B	<i>Muderongia tetracantha</i>
Age:	126.0 Ma Early Cretaceous (Early Valanginian)
B	<i>Apteodinium granulatum</i>
B	<i>Cribroperidinium edwardsii</i> 'complex'
B	<i>Ctenidodinium elegantulum</i>
B	<i>Oligosphaeridium complex</i>
Age:	127.0 Ma Early Cretaceous (Early Valanginian)
B	<i>Batioladinium micropodum</i>
B	<i>Cassiculosphaeridia magna</i>
B	<i>Nelchinopsis kostromiensis</i>

Appendix G (cont'd.)

Age:	128.0 Ma Early Cretaceous (Early Valanginian-Ryazanian Boundary)
B	<i>Phoberocysta neocomica</i>
B	<i>Stiphrosphaeridium anthophorum</i>
B	<i>Trichodinium castanea</i>
Age:	129.0 Ma Early Cretaceous (Ryazanian)
T	<i>Dichadogonyaulax culmula</i>
T	<i>Dichadogonyaulax? pannea</i>
T	<i>Egmontodinium torynum</i>
T	<i>Tubotuberella apatela</i>
B	<i>Achomosphaera? neptuni</i>
B	<i>Pseudoceratium pelliferum</i>
Age:	130.0 Ma Early Cretaceous (Ryazanian)
Age:	131.0 Ma Early Cretaceous - Late Jurassic Boundary (Ryazanian-Portlandian Boundary)
B	<i>Biorbifera johnewingii</i>
B	<i>Druggidium</i> spp.
B	<i>Egmontodinium torynum</i>
B	<i>Scrinioidinium? campanula</i>
Age:	132.0 Ma Species that continue into the Late Jurassic (Portlandian)
X	<i>Circulodinium distinctum</i>
X	<i>Dichadogonyaulax culmula</i>
X	<i>Dichadogonyaulax? pannea</i>
X	<i>Gochteodinia villosa</i>
X	<i>Gonyaulacysta cassidata</i> 'complex'
X	<i>Hystrichodinium</i> spp.
X	<i>Muderongia simplex</i>
X	<i>Pareodinia</i> spp.
X	<i>Sirmiodinium grossii</i>
X	<i>Tubotuberella apatela</i>

APPENDIX H

Tops and bases of Triassic-Jurassic dinoflagellates for specific ages

T = Top, B = Base, X = Post-Jurassic top

Age: 131.0 Ma Early Cretaceous - Late Jurassic Boundary (Ryazanian-Portlandian Boundary)

Species that continue from the Cretaceous

- X *Circulodinium distinctum*
- X *Dichadogonyaulax culmula*
- X *Dichadogonyaulax? panneae*
- X *Gochteodinia villosa*
- X *Gonyaulacysta cassidata* 'complex'
- X *Hystrichodinium* spp.
- X *Muderongia simplex*
- X *Pareodinia* spp.
- X *Sirmiodinium grossii*
- X *Tubotuberella apatela*

Age: 132.0 Ma Late Jurassic (Portlandian)

- T *Egmontodinium expiratum*
- T *Lanterna* spp.

Age: 133.0 Ma Late Jurassic (Portlandian)

Age: 134.0 Ma Late Jurassic (Portlandian)

- T *Egmontodinium polyplacophorum*
- B *Egmontodinium expiratum*

Age: 135.0 Ma Late Jurassic (Portlandian)

- T *Glossodinium dimorphum*
- T *Senoniasphaera jurassica*
- B *Dichadogonyaulax culmula*
- B *Gochteodinia villosa*

Age: 136.0 Ma Late Jurassic (Portlandian-late Kimmeridgian Boundary)

- T *Gochteodinia mutabilis*
- B *Muderongia simplex*

Age: 137.0 Ma Late Jurassic (Late Kimmeridgian)

- T *Occisucysta balios*
- T *Oligosphaeridium patulum*
- B *Hystrichodinium* spp.

Age: 138.0 Ma Late Jurassic (Late Kimmeridgian)

Age: 139.0 Ma Late Jurassic (Late Kimmeridgian)

- T *Scrinocassis dictyota*
- B *Circulodinium distinctum*
- B *Egmontodinium polyplacophorum*

Appendix H (cont'd.)

Age:	140.0 Ma	Late Jurassic (Late Kimmeridgian-early Kimmeridgian Boundary)
B		<i>Dichadogonyaulax? pannea</i>
B		<i>Gochteodinia mutabilis</i>
Age:	141.0 Ma	Late Jurassic (Early Kimmeridgian)
T		<i>Ellipsoidictyum cinctum</i>
T		<i>Geiselodinium inaffectum</i>
T		<i>Gonyaulacysta jurassica</i>
T		<i>Rhynchodiniopsis cladophora</i>
T		<i>Scriniodinium luridum sensu</i> Deflandre
B		<i>Oligosphaeridium patulum</i>
Age:	142.0 Ma	Late Jurassic (Early Kimmeridgian)
Age:	143.0 Ma	Late Jurassic (Early Kimmeridgian)
T		<i>Stephanelytron</i> spp.
T		<i>Valensiella</i> spp.
B		<i>Geiselodinium inaffectum</i>
Age:	144.0 Ma	Late Jurassic (Early Kimmeridgian)
T		<i>Sirmiodiniopsis orbis</i>
Age:	145.0 Ma	Late Jurassic (Early Kimmeridgian-late Oxfordian Boundary)
T		<i>Gonyaulacysta eisenackii</i>
T		<i>Scriniodinium crystallinum</i>
B		<i>Senoniasphaera jurassica</i>
Age:	146.0 Ma	Late Jurassic (Late Oxfordian)
T		<i>Nannoceratopsis pellucida</i>
T		<i>Rigaudella aemula</i>
B		<i>Lanterna</i> spp.
B		<i>Occisucysta balios</i>
Age:	147.0 Ma	Late Jurassic (Late Oxfordian-middle Oxfordian Boundary)
T		<i>Ctenidodinium ornatum</i>
B		<i>Gonyaulacysta cassidata</i> 'complex'
Age:	148.0 Ma	Late Jurassic (Middle Oxfordian)
T		<i>Compositosphaeridium polonicum</i>
Age:	149.0 Ma	Late Jurassic (Middle Oxfordian)
B		<i>Glossodinium dimorphum</i>
Age:	150.0 Ma	Late Jurassic (Middle Oxfordian-early Oxfordian Boundary)
T		<i>Trichodinium scarburghense</i>
T		<i>Wanaea</i> spp.
Age:	151.0 Ma	Late Jurassic (Early Oxfordian)
T		<i>Lithodinia deflandrei</i>

Appendix H (cont'd.)

Age:	152.0 Ma Late Jurassic - Middle Jurassic Boundary (Early Oxfordian-late Callovian Boundary)
T	<i>Carpathodinium predae</i>
T	<i>Ctenidodinium continuum</i>
Age:	153.0 Ma Middle Jurassic (Late Callovian)
B	<i>Scriniodinium crystallinum</i>
Age:	154.0 Ma Middle Jurassic (Late Callovian-middle Callovian Boundary)
T	<i>Lithodinia jurassica</i>
T	<i>Nannoceratopsis tricerias</i>
T	<i>Reutlingia gochtii</i>
B	<i>Scriniodinium luridum sensu</i> Deflandre
B	<i>Stephanelytron</i> spp.
Age:	155.0 Ma Middle Jurassic (Middle Callovian-early Callovian Boundary)
B	<i>Reutlingia gochtii</i>
B	<i>Trichodinium scarburghense</i>
Age:	156.0 Ma Middle Jurassic (Early Callovian)
B	<i>Tubotuberella apatela</i>
Age:	157.0 Ma Middle Jurassic (Early Callovian-late Bathonian Boundary)
T	<i>Aldorfia aldorfensis</i>
T	<i>Scriniodinium luridum sensu</i> Gocht
B	<i>Compositosphaeridium polonicum</i>
B	<i>Sirmiodiniopsis orbis</i>
Age:	158.0 Ma Middle Jurassic (Late Bathonian)
T	<i>Rhynchodiniopsis? regalis</i>
B	<i>Rhynchodiniopsis cladophora</i>
B	<i>Rigaudella aemula</i>
B	<i>Sirmiodinium grossii</i>
Age:	159.0 Ma Middle Jurassic (Late Bathonian)
T	<i>Nannoceratopsis gracilis</i>
Age:	160.0 Ma Middle Jurassic (Late Bathonian)
Age:	161.0 Ma Middle Jurassic (Late Bathonian-early Bathonian Boundary)
T	<i>Bejuia polygonalis</i>
B	<i>Scriniocassis dictyota</i>
Age:	162.0 Ma Middle Jurassic (Early Bathonian)
T	<i>Apteodinium syzygium</i>
Age:	163.0 Ma Middle Jurassic (Early Bathonian)

Appendix H (cont'd.)

Age:	164.0 Ma	Middle Jurassic (Early Bathonian)
	T	<i>Susadinium</i> spp.
	B	<i>Ellipsoidictyum cinctum</i>
	B	<i>Gonyaulacysta jurassica</i>
	B	<i>Lithodinia deflandrei</i>
Age:	165.0 Ma	Middle Jurassic (Early Bathonian-late Bajocian Boundary)
	B	<i>Nannoceratopsis pellucida</i>
	B	<i>Rhynchodiniopsis? regalis</i>
	B	<i>Scriniodinium luridum sensu</i> Gocht
Age:	166.0 Ma	Middle Jurassic (Late Bajocian)
	B	<i>Aldorfia aldorfensis</i>
	B	<i>Carpathodinium predae</i>
	B	<i>Ctenidodinium continuum</i>
	B	<i>Ctenidodinium ornatum</i>
	B	<i>Gonyaulacysta eisenackii</i>
	B	<i>Lithodinia jurassica</i>
Age:	167.0 Ma	Middle Jurassic (Late Bajocian-middle Bajocian Boundary)
	B	<i>Bejuia polygonalis</i>
	B	<i>Wanaea</i> spp.
Age:	168.0 Ma	Middle Jurassic (Middle Bajocian)
Age:	169.0 Ma	Middle Jurassic (Middle Bajocian-early Bajocian Boundary)
	T	<i>Mancodinium semitabulatum</i>
Age:	170.0 Ma	Middle Jurassic (Early Bajocian)
	T	<i>Eyachia prisca</i>
	T	<i>Scriniocassis weberi</i>
Age:	171.0 Ma	Middle Jurassic (Early Bajocian-late Aalenian Boundary)
Age:	172.0 Ma	Middle Jurassic (Late Aalenian)
	T	<i>Phallocysta eumekes</i>
Age:	173.0 Ma	Middle Jurassic (Late Aalenian-middle Aalenian Boundary)
	T	<i>Moesiodinium raileanui</i>
Age:	174.0 Ma	Middle Jurassic (Middle Aalenian)
Age:	175.0 Ma	Middle Jurassic (Middle Aalenian)
Age:	176.0 Ma	Middle Jurassic (Middle Aalenian)
Age:	177.0 Ma	Middle Jurassic (Middle Aalenian-early Aalenian Boundary)

Appendix H (cont'd.)

Age:	178.0 Ma Middle Jurassic (Early Aalenian)
T	<i>Nannoceratopsis senex</i>
T	<i>Parvocysta</i> spp.
T	<i>Valvaeodinium punctatum</i>
B	<i>Valensiella</i> spp.
Age:	179.0 Ma Middle Jurassic - Early Jurassic Boundary (Early Aalenian-late Toarcian Boundary)
Age:	180.0 Ma Early Jurassic (Late Toarcian)
B	<i>Moesiodinium raileanui</i>
Age:	181.0 Ma Early Jurassic (Late Toarcian)
Age:	182.0 Ma Early Jurassic (Late Toarcian)
B	<i>Eyachia prisca</i>
B	<i>Parvocysta</i> spp.
Age:	183.0 Ma Early Jurassic (Late Toarcian)
B	<i>Apteodinium syzygium</i>
B	<i>Pareodinia</i> spp.
Age:	183.5 Ma Early Jurassic (Late Toarcian-early Toarcian Boundary)
T	<i>Valvaeodinium lineatum</i>
Age:	184.0 Ma Early Jurassic (Early Toarcian)
Age:	185.0 Ma Early Jurassic (Early Toarcian)
Age:	186.0 Ma Early Jurassic (Early Toarcian-late Pliensbachian Boundary)
Age:	187.0 Ma Early Jurassic (Late Pliensbachian)
T	<i>Luehndea spinosa</i>
B	<i>Nannoceratopsis tricerias</i>
B	<i>Phallocysta eumekes</i>
Age:	188.0 Ma Early Jurassic (Late Pliensbachian)
B	<i>Luehndea spinosa</i>
B	<i>Scriniocassis weberi</i>
B	<i>Susadinium</i> spp.
B	<i>Valvaeodinium lineatum</i>
B	<i>Valvaeodinium punctatum</i>
Age:	189.0 Ma Early Jurassic (Late Pliensbachian-early Pliensbachian Boundary)
B	<i>Nannoceratopsis senex</i>
Age:	190.0 Ma Early Jurassic (Early Pliensbachian)
Age:	191.0 Ma Early Jurassic (Early Pliensbachian)
B	<i>Nannoceratopsis gracilis</i>

Appendix H (cont'd.)

Age:	192.0 Ma	Early Jurassic (Early Pliensbachian)
Age:	193.0 Ma	Early Jurassic (Early Pliensbachian) B <i>Mancodinium semitabulatum</i>
Age:	194.0 Ma	Early Jurassic (Early Pliensbachian-late Sinemurian Boundary)
Age:	195.0 Ma	Early Jurassic (Late Sinemurian) T <i>Liasidium variable</i>
Age:	196.0 Ma	Early Jurassic (Late Sinemurian)
Age:	197.0 Ma	Early Jurassic (Late Sinemurian) B <i>Liasidium variable</i>
Age:	198.0 Ma	Early Jurassic (Late Sinemurian-early Sinemurian Boundary)
Age:	199.0 Ma	Early Jurassic (Early Sinemurian) T <i>Dapcodinium priscum</i>
Age:	200.0 Ma	Early Jurassic (Early Sinemurian)
Age:	201.0 Ma	Early Jurassic (Early Sinemurian-late Hettangian Boundary)
Age:	202.0 Ma	Early Jurassic (Late Hettangian)
Age:	203.0 Ma	Early Jurassic (Late Hettangian)
Age:	204.0 Ma	Early Jurassic (Late Hettangian)
Age:	205.0 Ma	Early Jurassic (Late Hettangian-early Hettangian Boundary)
Age:	206.0 Ma	Early Jurassic (Early Hettangian)
Age:	207.0 Ma	Early Jurassic (Early Hettangian)
Age:	208.0 Ma	Early Jurassic (Early Hettangian) T <i>Rhaetogonyaulax rhaetica</i>
Age:	209.0 Ma	Early Jurassic (Early Hettangian)
Age:	210.0 Ma	Early Jurassic - Late Triassic Boundary (Hettangian-Rhaetian Boundary)
Age:	211.0 Ma	Late Triassic (Rhaetian) T <i>Noricysta</i> spp. T <i>Suessia swabiana</i>
Age:	212.0 Ma	Late Triassic (Rhaetian) B <i>Dapcodinium priscum</i>

Appendix H (cont'd.)

Age:	213.0 Ma	Late Triassic (Rhaetian)
Age:	214.0 Ma	Late Triassic (Rhaetian)
	T	<i>Sverdrupiella</i> spp.
Age:	215.0 Ma	Late Triassic (Rhaetian-Norian Boundary)
Age:	216.0 Ma	Late Triassic (Norian)
	B	<i>Rhaetogonyaulax rhaetica</i>
	B	<i>Suessia swabiana</i>
	B	<i>Sverdrupiella</i> spp.
Age:	217.0 Ma	Late Triassic (Norian)
	T	<i>Hebecysta brevicornuta</i>
Age:	218.0 Ma	Late Triassic (Norian)
	B	<i>Hebecysta brevicornuta</i>
	B	<i>Noricysta</i> spp.

APPENDIX I

Ma	Relative geological ages (Haq et al., 1987)		Ma	Relative geological ages (Haq et al., 1987) (cont'd.)	
000.0	Recent		052.0	Early Eocene	(Ypresian)
000.5	Pleistocene		053.0	Early Eocene	(Ypresian)
001.0	Pleistocene		054.0	Early Eocene	(Ypresian)
001.4	Pleistocene		055.0	Late Paleocene	(Thanetian)
001.7	Pliocene		056.0	Late Paleocene	(Thanetian)
002.0	Pliocene		057.0	Late Paleocene	(Thanetian)
003.5	Pliocene		058.0	Late Paleocene	(Thanetian)
004.0	Pliocene		059.0	Late Paleocene	(Thanetian)
005.2	Pliocene		060.2	Late Paleocene	(Thanetian)
006.3	Late Miocene	(Messinian)	061.0	Early Paleocene	(Danian)
007.0	Late Miocene	(Tortonian)	062.0	Early Paleocene	(Danian)
008.0	Late Miocene	(Tortonian)	063.0	Early Paleocene	(Danian)
009.0	Late Miocene	(Tortonian)	064.0	Early Paleocene	(Danian)
010.2	Late Miocene	(Tortonian)	065.0	Early Paleocene	(Danian)
011.0	Middle Miocene	(Serravallian)	066.0	Early Paleocene	(Danian)
012.0	Middle Miocene	(Serravallian)	066.5	Early Paleocene	(Danian)
013.0	Middle Miocene	(Serravallian)	<u>Base of Cenozoic/Top of Mesozoic (Cretaceous)</u>		
014.0	Middle Miocene	(Serravallian)	067.0	Late Cretaceous	(Late Maastrichtian)
015.2	Middle Miocene	(Serravallian)	068.0	Late Cretaceous	(Late Maastrichtian)
016.2	Middle Miocene	(Langhian)	069.0	Late Cretaceous	(Late Maastrichtian)
017.0	Early Miocene	(Burdigalian)	070.0	Late Cretaceous	(Late Maastrichtian)
018.0	Early Miocene	(Burdigalian)	071.0	Late Cretaceous	(Late Maastrichtian)
019.0	Early Miocene	(Burdigalian)	072.0	Late Cretaceous	(Early Maastrichtian)
020.0	Early Miocene	(Burdigalian)	073.0	Late Cretaceous	(Early Maastrichtian)
021.0	Early Miocene	(Aquitania)	074.0	Late Cretaceous	(Early Maastrichtian)
022.0	Early Miocene	(Aquitania)	075.0	Late Cretaceous	(Late Campanian)
023.0	Early Miocene	(Aquitania)	076.0	Late Cretaceous	(Late Campanian)
024.0	Early Miocene	(Aquitania)	077.0	Late Cretaceous	(Late Campanian)
025.2	Early Miocene	(Aquitania)	078.0	Late Cretaceous	(Late Campanian)
026.0	Late Oligocene	(Chattian)	079.0	Late Cretaceous	(Early Campanian)
027.0	Late Oligocene	(Chattian)	080.0	Late Cretaceous	(Early Campanian)
028.0	Late Oligocene	(Chattian)	081.0	Late Cretaceous	(Early Campanian)
029.0	Late Oligocene	(Chattian)	082.0	Late Cretaceous	(Early Campanian)
030.0	Late Oligocene	(Chattian)	083.0	Late Cretaceous	(Early Campanian)
031.0	Early Oligocene	(Rupelian)	084.0	Late Cretaceous	(Early Campanian)
032.0	Early Oligocene	(Rupelian)	085.0	Late Cretaceous	(Santonian)
033.0	Early Oligocene	(Rupelian)	086.0	Late Cretaceous	(Santonian)
034.0	Early Oligocene	(Rupelian)	087.0	Late Cretaceous	(Santonian)
035.0	Early Oligocene	(Rupelian)	088.0	Late Cretaceous	(Santonian)
036.0	Early Oligocene	(Rupelian)	089.0	Late Cretaceous	(Coniacian)
037.0	Late Eocene	(Priabonian)	090.0	Late Cretaceous	(Turonian)
038.0	Late Eocene	(Priabonian)	091.0	Late Cretaceous	(Turonian)
039.0	Late Eocene	(Priabonian)	092.0	Late Cretaceous	(Turonian)
039.4	Middle Eocene	(Bartonian)	093.0	Late Cretaceous	(Cenomanian)
040.0	Middle Eocene	(Bartonian)	094.0	Late Cretaceous	(Cenomanian)
041.0	Middle Eocene	(Bartonian)	095.0	Late Cretaceous	(Cenomanian)
042.0	Middle Eocene	(Lutetian)	096.0	Late Cretaceous	(Cenomanian)
043.0	Middle Eocene	(Lutetian)	097.0	Early Cretaceous	(Late Albion)
044.0	Middle Eocene	(Lutetian)	098.0	Early Cretaceous	(Late Albion)
045.0	Middle Eocene	(Lutetian)	099.0	Early Cretaceous	(Late Albion)
046.0	Middle Eocene	(Lutetian)	100.0	Early Cretaceous	(Middle Albion)
047.0	Middle Eocene	(Lutetian)	101.0	Early Cretaceous	(Middle Albion)
048.0	Middle Eocene	(Lutetian)	102.5	Early Cretaceous	(Middle Albion)
049.0	Middle Eocene	(Lutetian)	104.0	Early Cretaceous	(Early Albion)
050.0	Early Eocene	(Ypresian)			
051.0	Early Eocene	(Ypresian)			

Appendix I (cont'd.)

Ma	Relative geological ages (Haq et al., 1987) (cont'd.)		Ma	Relative geological ages (Haq et al., 1987) (cont'd.)	
105.0	Early Cretaceous	(Early Albian)	157.0	Middle Jurassic	(Early Callovian)
106.0	Early Cretaceous	(Early Albian)	158.0	Middle Jurassic	(Late Bathonian)
107.0	Early Cretaceous	(Early Albian)	159.0	Middle Jurassic	(Late Bathonian)
108.0	Early Cretaceous	(Early Aptian)	160.0	Middle Jurassic	(Late Bathonian)
109.0	Early Cretaceous	(Late Aptian)	161.0	Middle Jurassic	(Late Bathonian)
110.0	Early Cretaceous	(Late Aptian)	162.0	Middle Jurassic	(Early Bathonian)
111.0	Early Cretaceous	(Early Aptian)	163.0	Middle Jurassic	(Early Bathonian)
112.0	Early Cretaceous	(Early Aptian)	164.0	Middle Jurassic	(Early Bathonian)
113.0	Early Cretaceous	(Early Aptian)	165.0	Middle Jurassic	(Early Bajocian)
114.0	Early Cretaceous	(Barremian)	166.0	Middle Jurassic	(Late Bajocian)
115.0	Early Cretaceous	(Barremian)	167.0	Middle Jurassic	(Late Bajocian)
116.0	Early Cretaceous	(Barremian)	168.0	Middle Jurassic	(Middle Bajocian)
116.5	Early Cretaceous	(Barremian)	169.0	Middle Jurassic	(Middle Bajocian)
117.0	Early Cretaceous	(Hauterivian)	170.0	Middle Jurassic	(Early Bajocian)
118.0	Early Cretaceous	(Hauterivian)	171.0	Middle Jurassic	(Early Bajocian)
119.0	Early Cretaceous	(Hauterivian)	172.0	Middle Jurassic	(Late Aalenian)
120.0	Early Cretaceous	(Hauterivian)	173.0	Middle Jurassic	(Late Aalenian)
121.0	Early Cretaceous	(Hauterivian)	174.0	Middle Jurassic	(Middle Aalenian)
122.0	Early Cretaceous	(Late Valanginian)	175.0	Middle Jurassic	(Middle Aalenian)
123.0	Early Cretaceous	(Late Valanginian)	176.0	Middle Jurassic	(Middle Aalenian)
124.0	Early Cretaceous	(Late Valanginian)	177.0	Middle Jurassic	(Middle Aalenian)
125.0	Early Cretaceous	(Early Valanginian)	178.0	Middle Jurassic	(Early Aalenian)
126.0	Early Cretaceous	(Early Valanginian)	179.0	Middle Jurassic	(Early Aalenian)
127.0	Early Cretaceous	(Early Valanginian)	180.0	Early Jurassic	(Late Toarcian)
128.0	Early Cretaceous	(Early Valanginian)	181.0	Early Jurassic	(Late Toarcian)
129.0	Early Cretaceous	(Ryazanian)	182.0	Early Jurassic	(Late Toarcian)
130.0	Early Cretaceous	(Ryazanian)	183.0	Early Jurassic	(Late Toarcian)
131.0	Early Cretaceous	(Ryazanian)	183.5	Early Jurassic	(Late Toarcian)
<u>Base of Cretaceous/Top of Jurassic</u>			184.0	Early Jurassic	(Early Toarcian)
132.0	Late Jurassic	(Portlandian)	185.0	Early Jurassic	(Early Toarcian)
133.0	Late Jurassic	(Portlandian)	186.0	Early Jurassic	(Early Toarcian)
134.0	Late Jurassic	(Portlandian)	187.0	Early Jurassic	(Late Pliensbachian)
135.0	Late Jurassic	(Portlandian)	188.0	Early Jurassic	(Late Pliensbachian)
136.0	Late Jurassic	(Portlandian)	189.0	Early Jurassic	(Late Pliensbachian)
137.0	Late Jurassic	(Late Kimmeridgian)	190.0	Early Jurassic	(Early Pliensbachian)
138.0	Late Jurassic	(Late Kimmeridgian)	191.0	Early Jurassic	(Early Pliensbachian)
139.0	Late Jurassic	(Late Kimmeridgian)	192.0	Early Jurassic	(Early Pliensbachian)
140.0	Late Jurassic	(Late Kimmeridgian)	193.0	Early Jurassic	(Early Pliensbachian)
141.0	Late Jurassic	(Early Kimmeridgian)	194.0	Early Jurassic	(Early Pliensbachian)
142.0	Late Jurassic	(Early Kimmeridgian)	195.0	Early Jurassic	(Late Sinemurian)
143.0	Late Jurassic	(Early Kimmeridgian)	196.0	Early Jurassic	(Late Sinemurian)
144.0	Late Jurassic	(Early Kimmeridgian)	197.0	Early Jurassic	(Late Sinemurian)
145.0	Late Jurassic	(Early Kimmeridgian)	198.0	Early Jurassic	(Late Sinemurian)
146.0	Late Jurassic	(Late Oxfordian)	199.0	Early Jurassic	(Early Sinemurian)
147.0	Late Jurassic	(Late Oxfordian)	200.0	Early Jurassic	(Early Sinemurian)
148.0	Late Jurassic	(Middle Oxfordian)	201.0	Early Jurassic	(Early Sinemurian)
149.0	Late Jurassic	(Middle Oxfordian)	202.0	Early Jurassic	(Late Hettangian)
150.0	Late Jurassic	(Middle Oxfordian)	203.0	Early Jurassic	(Late Hettangian)
151.0	Late Jurassic	(Early Oxfordian)	204.0	Early Jurassic	(Late Hettangian)
152.0	Late Jurassic	(Early Oxfordian)	205.0	Early Jurassic	(Late Hettangian)
153.0	Middle Jurassic	(Late Callovian)	206.0	Early Jurassic	(Late Hettangian)
154.0	Middle Jurassic	(Late Callovian)	207.0	Early Jurassic	(Early Hettangian)
155.0	Middle Jurassic	(Middle Callovian)	208.0	Early Jurassic	(Early Hettangian)
156.0	Middle Jurassic	(Early Callovian)	209.0	Early Jurassic	(Early Hettangian)
			210.0	Early Jurassic	(Early Hettangian)

Appendix I (cont'd.)

Ma	Relative geological ages (Haq et al., 1987) (cont'd.)		Ma	Relative geological ages (Haq et al., 1987) (cont'd.)	
<u>Base of Jurassic/Top of Triassic</u>					
211.0	Late Triassic	(Rhaetian)	226.0	Late Triassic	(Carnian)
212.0	Late Triassic	(Rhaetian)	227.0	Late Triassic	(Carnian)
213.0	Late Triassic	(Rhaetian)	228.0	Late Triassic	(Carnian)
214.0	Late Triassic	(Rhaetian)	229.0	Late Triassic	(Carnian)
215.0	Late Triassic	(Rhaetian)	230.0	Late Triassic	(Carnian)
216.0	Late Triassic	(Norian)	231.0	Late Triassic	(Carnian)
217.0	Late Triassic	(Norian)	232.0	Middle Triassic	(Ladinian)
218.0	Late Triassic	(Norian)	233.0	Middle Triassic	(Ladinian)
219.0	Late Triassic	(Norian)	234.0	Middle Triassic	(Ladinian)
220.0	Late Triassic	(Norian)	235.0	Middle Triassic	(Ladinian)
221.0	Late Triassic	(Norian)	236.0	Middle Triassic	(Ladinian)
222.0	Late Triassic	(Norian)	237.0	Middle Triassic	(Anisian)
223.0	Late Triassic	(Norian)	238.0	Middle Triassic	(Anisian)
224.0	Late Triassic	(Carnian)	239.0	Middle Triassic	(Anisian)
225.0	Late Triassic	(Carnian)	240.0	Early Triassic	(Scythian)

