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THE DINOFLAGELLATE OPPEL-ZONATION OF THE JURASSIC-LOWER CRETACEOUS SEQUENCE IN THE SVERDRUP BASIN, ARCTIC CANADA.

E.H. DAVIES

Canada

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Preface

The Sverdrup Basin, located in the Queen Elizabeth Islands, received sediments throughout the Mesozoic. Sedimentation was dominated by terrigenous clastics characterized by alternating transgressive and regressive phases.

With the expansion of exploration for hydrocarbons in the Arctic, there is a need to correlate and understand the evolution of this basin within a refined chronostratigraphic framework. Palynology, the study of the pollen of seed plants and spores, provides a tool for correlation and its applicability to subsurface studies has led to a reliance by the petroleum industry on this discipline to provide dating of strata. Six hundred and seventy-two samples from 12 surface and 3 subsurface sections were analyzed palynologically in the present study. A dinoflagellate cyst Oppel-zonation was recognized with 17 divisions that range from Toarcian or older to Valanginian and provide the most detailed palynological subdivision of the Mesozoic in the Arctic to date. Studies such as this provide the necessary geological framework to understand the evolution of the Sverdrup Basin with a view to facilitating the full development of its petroleum resources.

R.A. Price
Director General
Geological Survey of
Canada

OTTAWA, March 1983

Préface

Le bassin de Sverdrup, situé dans les fles Reine-Elisabeth, a été le théâtre d'un processus de sédimentation tout au long du Mésozoique. Les sédiments sont surtout constitués de roches détritiques terrigènes, et on y observe une alternance de transgressions et de régressions.

En raison de l'expansion de la recherche d'hydrocarbures dans l'Arctique, il est nécessaire d'inscrire l'étude des relations et de l'évolution de ce bassin dans un cadre chronostratigraphique mieux défini. La palynologie, l'étude du pollen des plantes à graines et des spores, est un agent de corrélation utile et, comme elle peut être appliquée à l'étude de processus de subsurface, l'industrie pétrolière s'en sert abondamment pour dater les couches. Les auteurs de cette étude ont soumis à des analyses palynologiques 672 échantillons prélevés dans 12 profils en surface et 3 profils en subsurface. Ils ont reconnu 17 zones Oppel de kystes de dinoflagellés, qui varient du Toarcien ou d'un étage plus ancien au Valanginien et qui forment la subdivision palynologique du Mésozoique la plus détaillée que l'on ait découverte à ce jour dans l'Arctique. Les études comme celle-là contribuent à établir le cadre géologique dont nous avons besoin pour comprendre l'évolution du bassin de Sverdrup et ainsi faciliter la mise en valeur des ressources pétrolières qu'il renferme.

R.A. Price
Directeur général
Commission geologique
du Canada

OTTAWA, mars 1983

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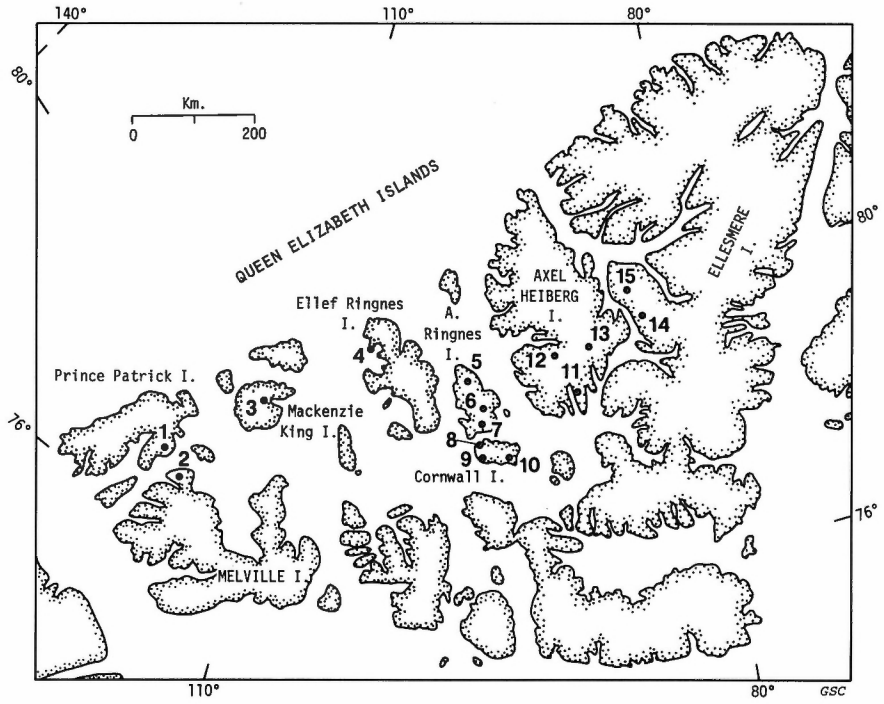

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Figure 1. Generalized section locations.

THE DINOFLAGELLATE OPPEL-ZONATION OF THE JURASSIC-LOWER CRETACEOUS SEQUENCE IN THE SVERDRUP BASIN, ARCTIC CANADA

Abstract

Jurassic to Lower Cretaceous samples from the Sverdrup Basin, Arctic Canada, contain abundant and well preserved dinoflagellate cysts. The stratigraphic interval studied comprises the Savik Formation – Jaeger Formation complex, the Awingak Formation – Ringnes Formation deltaic complex and the Deer Bay Formation – Mould Bay Formation deltaic complex; it is characterized by dominantly clastic sedimentation.

Seventeen dinoflagellate cyst Oppel-zones are recognized within the Lower Jurassic to Lower Cretaceous interval. The ages suggested by the assemblages of dinoflagellate cysts generally agree with those based on invertebrates and range from Toarcian or older to Late Valanginian or younger.

Sixty genera and 129 species of dinoflagellate cysts have been identified. Eighteen new species are described: *Apteodinium bucculiatum, ?Comparodinium cavum, Dapcodinium coalitum, Dapcodinium holotabulatum, ?Egmontodinium diminutum, Escharisphaeridia rudis, Glomodinium opeasatos, Glomodinium zabros, Hystrichodinium lanceatum, Lithodinia serrulata, Millioudodinium jubaris, Occisucysta thulia, Parvulodinium penitabulatum, Sentusidinium cuculliformis, Sentusidinium filiatum, Tanyosphaeridium magneticum, Tectatodinium laminatum and Trichodinium erinaceoides.*

Résumé

Des échantillons du Jurassique au Crétacé inférieur, prélevés dans le bassin de Sverdrup, Arctique canadien, contiennent des kystes de dinoflagellés abondants et bien conservés. L'intervalle stratigraphique étudié comprend le complexe des formations de Savik-Jaeger, le complexe deltaique des formations de Awingak-Ringnes et le complexe deltaique des formations de Deer Bay-Mould Bay. Il est caractérisé par une sédimentation surtout clastique.

Dix-sept zones Oppel de kystes de dinoflagellés sont identifiées au sein de l'intervalle Jurassique inférieur-Crétacé inférieur. Les âges suggérés par les assemblages de kystes de dinoflagellés concordent généralement avec ceux fondés sur les invertégrés; ils varient du Toarcien ou d'un étage plus ancien au Valanginien tardif ou à un étage plus récent.

On a identifié 60 genres et 129 espèces de kystes de dinoflagellés. Dix-huit nouvelles espèces sont décrites dans le texte: *Apteodinium bucculiatum, ?Comparodinium cavum, Dapcodinium coalitum, Dapcodinium holotabulatum, ?Egmontodinium diminutum, Escharisphaeridia rudis, Glomodinium opeasatos, Glomodinium zabros, Hystrichodinium lanceatum, Lithodinia serrulata, Millioudodinium jubaris, Occisucysta thulia, Parvulodinium penitabulatum, Sentusidinium cuculliformis, Sentusidinium filiatum, Tanyosphaeridium magneticum, Tectatodinium laminatum et Trichodinium erinaceoides.*

INTRODUCTION

The Sverdrup Basin is an elongate trough trending northeast across the seaward side of the Queen Elizabeth Islands in the Canadian Arctic. During the Jurassic to Early Cretaceous, 2200m of regressive sandstones and transgressive marine shales accumulated. The interval studied is represented by the Savik Formation through Deer Bay Formation and their correlatives.

The purpose of this study is to describe the dinoflagellate cysts of the Jurassic to Lower Cretaceous (Toarcian or older to Valanginian) of the Sverdrup Basin and to establish a detailed Oppel-zonation.

In nearly all previous palynological reports from the Sverdrup Basin only a small portion of the total dinoflagellate flora has been described. Since the account by Brideaux in 1975 on the status of dinoflagellate studies in the Canadian Arctic little more has been published. He stated that there is a need for a comprehensive taxonomic and biostratigraphic study of the Upper Jurassic to Lower Cretaceous of the Sverdrup Basin. This study attempts to fulfil this need.

Materials and Implementation

Sample Locations

Six hundred and seventy-two samples from the Sverdrup Basin were prepared and examined. These were obtained from Mobil Oil Canada Ltd., Elf Oil Canada Ltd., the Geological Survey of Canada, and sampling by the author during a one month field excursion with the Geological Survey of Canada.

From three subsurface sections in the southwestern portion of the basin, a total of 298 (289 cutting and 9 conventional core) samples were obtained. Three hundred and seventy-four samples were collected from 12 surface sections distributed across the central and northeastern portions of the basin.

Figure 1 gives the approximate location of each section.

Sample Preparation

The samples were processed using the hydrofluoric acid-oxidation method basically following that outlined in Barss and Williams (1973).

Curation of Materials

The illustrated specimens and type materials were deposited in the Royal Ontario Museum, Toronto, Ontario, except those from the Panarctic Sandy Point L-46 well samples which are deposited in type collections of the Geological Survey of Canada. Specimen co-ordinates are referenced according to the "England Finder" reference system with the right vertical and lower horizontal edges as the locating edges. The England Finder is available from Graticules Limited, Sovereign Way, Tonbridge, Kent, England.Section descriptions, sample locations and species occurrences charts may be obtained through the Geological Survey of Canada.

Acknowledgments

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Gratitude is also extended to Mobil Oil Canada Ltd. and Elf Oil Canada Ltd. for donating samples. Drafting and photography were ably performed by G.M. Grant and W.C. MacMillan (Geological Survey of Canada). Special thanks are given to M.S. Barss, J.P. Bujak and J.A. Jeletzky for reading the manuscript and offering constructive criticism.

My sincerest thanks are extended to Sara Joan Davies who assisted with the preparation of the manuscript.

BIOSTRATIGRAPHY

Previous Palynological Investigations

Results of detailed palynological investigations of Jurassic to Lower Cretaceous sequences in the Sverdrup Basin have not been published, although preliminary accounts are available.

By far the most comprehensive reports are those by Johnson (1973, 1974) and Johnson and Hills (1973) who described and correlated the dinoflagellate cyst floras from three sections of the Savik Formation and Awingak Formation on Bjarnason Island, Axel Heiberg Island and Ellesmere Island. These sections were characterized by poor preservation and low species diversities.

Brideaux and Fisher (1976) described a few Upper Jurassic to Lower Cretaceous dinoflagellate cyst species from the Mackenzie Delta region and western portion of the Sverdrup Basin. They attempted to outline an assemblage of dinoflagellate cysts typified by association with '*Pareodinia*' *borealis* (now *Paragonyaulacysta borealis*). No attempt was made to establish a biostratigraphic framework within the Sverdrup Basin; instead they emphasized the correlation of the *P. borealis* assemblage with European and Russian stages.

Van Helden (1977) described selected species from Lower to Middle Jurassic dinoflagellate cyst assemblages from the Wilkie Point Formation and Borden Island Formation from the southwest margin of the Sverdrup Basin on Prince Patrick Island.

Pocock (1976) presented a generalized preliminary zonation for the uppermost Jurassic to Lower Cretaceous of the Canadian Arctic. This zonation basically represents an expansion of earlier works (Pocock, 1970, 1972) which included material from the Awingak Formation and Deer Bay Formation on Amund Ringnes Island.

Felix (1975) described three Upper Triassic to possibly Lower Jurassic microfloral assemblages from the Heiberg Formation and Savik Formation on Reindeer Peninsula, Ellef Ringnes Island and erected a gross zonation.

Open File Reports 245 and 297 of the Geological Survey of Canada (1974, 1975) contain various palynological and micropaleontological reports on several wells from the Sverdrup Basin and the District of Mackenzie, compiled by Robertson Research Ltd. and Paleo Services Ltd. Geological Survey of Canada Open File Report 403 by Brideaux (1977b) contains range charts and occurrence charts of dinoflagellate cysts for two wells in the District of Mackenzie.

Zeiss (1977) published an abstract on the zonation of the Deer Bay Formation based on dinoflagellate cysts. Five assemblage zones were recognized from the Oxfordian to Hauterivian.

Le Blanc (*in* Souaya, 1976) listed the palynomorphs of the Jurassic and Cretaceous found in the Sun Gulf Gloval Linckens Island P-46 well, on Linckens Island.

McGregor (1965, 1970) catalogued in pictorial form, some Mesozoic terrestrial microfloras of the Mackenzie Delta region and the Sverdrup Basin. McGregor (*in* Christie 1964, p. 50, 51) listed Jurassic and Cretaceous palynomorphs from the Savik, Awingak and Deer Bay formations on northeastern Ellesmere Island.

Dörhöfer and Davies (1980) discussed the taxonomy, phylogeny and evolution of some rhaetogonyaulacacean, pareodiniacean and pseudoceratiacean forms from the Triassic to Lower Cretaceous of Arctic Canada and northwestern Germany.

Other palynological studies that are relevant to this study include the following (arranged in ascending stratigraphic order). Triassic microfloras from Arctic Canada have been described by Bujak (1973), Dunay and Fisher (1974), Fisher and Bujak (1975), Bujak and Fisher (1976) and Wiggins (1973). Some elements of the Lower Cretaceous terrestrial microfloras from the Isachsen Formation and Christopher Formation in the Sverdrup Basin were described by Hopkins (1971a, b, 1974) and Hopkins and Balkwill (1973). Brideaux and McIntyre (1973, 1975), Brideaux and Myhr (1976), Brideaux (1976a, b, 1977a), Brideaux and Fisher (1976), McIntyre (1974) and McIntyre and Brideaux (1980) described the marine and terrestrial microfloras from the Upper Jurassic to Lower Cretaceous of the Mackenzie Delta and Richardson Mountains region. Material from the Late Cretaceous on Ellef Ringnes Island was analyzed for dinoflagellates by Manum (1963), Manum and Cookson (1964), and Cookson and Manum (1964). Doerenkamp et al. (1976) described the Cretaceous and Tertiary microfloras from Banks Island.

Further publications of Arctic Mesozoic microfloras from areas outside Canada are listed below. Wiggins (1969, 1972, 1975) described selected dinoflagellate cysts from the Jurassic to Lower Cretaceous of Alaska. Sarjeant (1972) described two assemblages of dinoflagellate cysts from the Middle Jurassic of East Greenland. Bjaerke (1977a,b, 1978, 1980a,b), Bjaerke and Dypvik (1977), and Bjaerke et al. (1976) outlined dinoflagellate cyst assemblages from the Lower Cretaceous and Toarcian of Spitsbergen. Vozzhennikova (1967) described dinoflagellate cysts from the Upper Jurassic to Cretaceous of the Siberian Platform.

Other Paleontological Investigations

Macrofaunal studies of the Jurassic to Lower Cretaceous of the Sverdrup Basin have centred around three main investigators: H. Frebold, J.A. Jeletzky, and E. Kemper. Their faunal zonations are summarized in Figure 2; their taxonomy is used verbatim throughout the text.

Frebold, in a series of articles (1958, 1960, 1961, 1964a,b,c, 1975, *in* Stott, 1969) studied the Jurassic ammonites and pelecypods of the Sverdrup Basin.

Jeletzky (1965, 1966, 1969, 1970, 1971, 1973, 1979) concentrated on Jurassic and Cretaceous ammonites and species of *Buchia* of Arctic Canada. The material has mainly been derived from the Mackenzie Delta-Richardson Mountains region and to a lesser extent, the Sverdrup Basin. He was the first to employ species of *Buchia* to correlate with the European stages.

Jeletzky (1980) described belemnites from the Toarcian-Middle Bajocian of western and Arctic Canada.

Kemper (1975, 1977) and Kemper and Jeletzky (1979) have intensively studied the Valanginian (uppermost Deer Bay Formation) from Ellef Ringnes Island and Amund Ringnes Island, and from Mackenzie King Island. Frebold and Jeletzky identified faunas collected in investigations by Tozer (1963), Tozer and Thorsteinsson (1964), Stott (1969), Fortier et al. (1963), and Balkwill et al. (1977). A series of unpublished Geological Survey of Canada internal reports by Frebold were used in this study. Nearly all geological publications on the Jurassic and Cretaceous of the Sverdrup Basin refer to ages cited from the above works on invertebrate fossils.

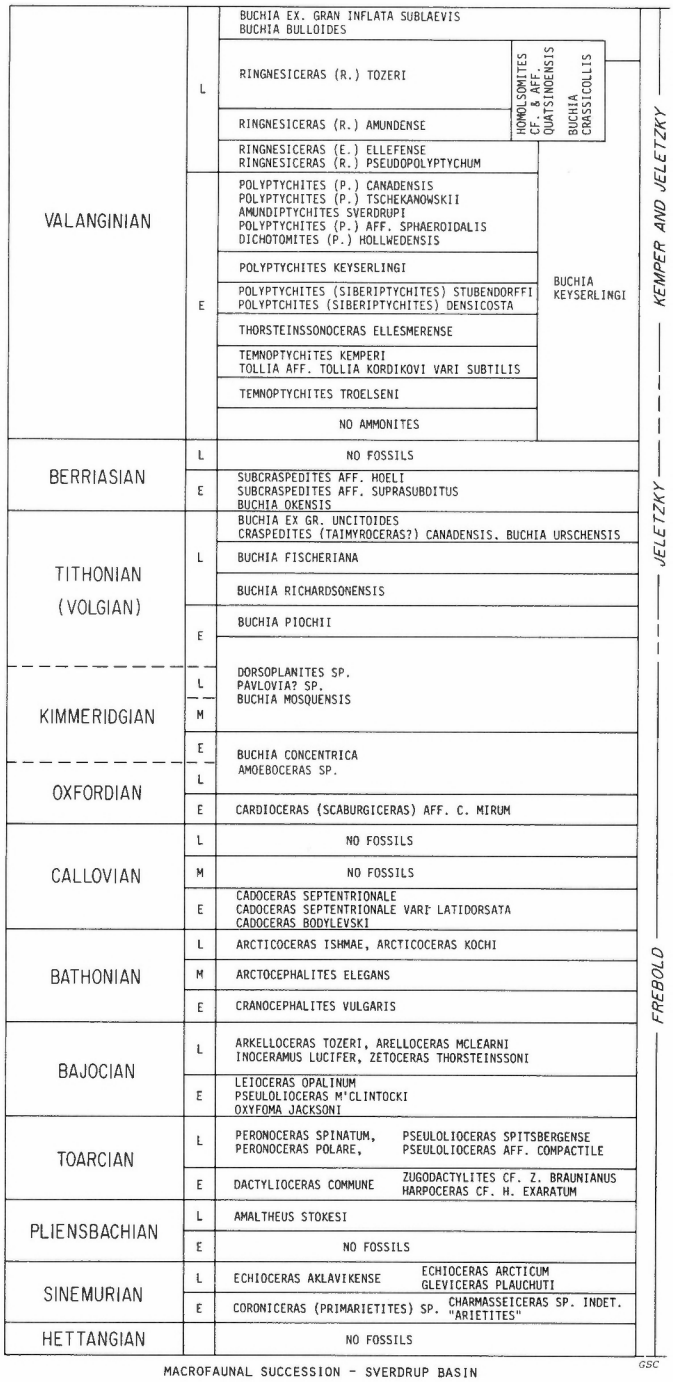


Figure 2. Macrofaunal succession of the Jurassic to Lower Cretaceous (Valanginian) of the Sverdrup Basin from various publications by Fredbold, Jeletzky and Kemper (*see* text for full citations).

Ichthyosaur remains have been found by Tozer and Thorsteinsson (1964) in the Mould Bay Formation on Prince Patrick Island and Mackenzie King Island.

Foraminiferal studies on Arctic Canada have been made by Souaya (1976) and Chamney (1968, 1969, 1971, 1973a,b). Souaya described the microfauna recovered from well cuttings of the Sun Gulf Gloval Linckens Island P-46 well on Linckens Island just off the southwest coast of Amund Ringnes Island. Chamney described the foraminifers close to the Cretaceous-Jurassic boundary in Arctic Canada.

Dinoflagellate Cyst Assemblage Composition

One hundred and thirty species of dinoflagellate cysts, ten green algal cyst species, twenty-five acritarch species and over two hundred and fifty species of spores and pollen have been identified from Jurassic to Lower Cretaceous strata of the Sverdrup Basin. In this paper, only the dinoflagellates and stratigraphically important green algal components are discussed.

Preservation and recovery were generally excellent. In areas of high thermal maturation, however, such as the thermally altered shales in the west and south of Axel Heiberg Island near South Strand Fjord and Glacier Fjord respectively, palynomorphs were not observed or were rare and usually poorly preserved.

These Sverdrup Basin microfloras have low in species diversity, typical of high latitude dinoflagellate assemblages (Davies and Norris,1980). The maximum number of species per sample was 24, found in the upper Savik on Reindeer Peninsula, Ellef Ringnes Island. There was an average of six species per sample, and a mode of five species per sample. Over the entire basin, a maximum of forty-five species existing at a single chronohorizon occurred in the Late Callovian or Early Oxfordian. Acavate proximate cyst types dominate strongly over other morphological groups of dinoflagellate cysts. Only in the uppermost part of the sequence are there abundant chorate cysts, usually belonging to the genus *Oligosphaeridium* (Davies and Norris,1980).

Dinoflagellate Cyst Oppel-Zonation

The Arctic fossil dinoflagellate cyst floras are characterized by assemblages of low diversity containing, for the most part, long ranging species. Abrupt changes in the floral composition are rare.

Owing to the lack of short ranging, recurrent species, zones are commonly discriminated by overlapping species ranges.

According to the International Stratigraphic Guide (Hedberg, 1976, p. 58) "The Oppel-zone may be defined as a zone characterized by an association or aggregation of *selected* taxons of restricted and largely concurrent range, chosen as indicative of approximate contemporaneity. Not all of the taxons considered diagnostic need be present at any one place for the zone to be legitimately identified. The lower part of the zone is commonly marked largely by the first appearance and its upper part by the last appearance of certain taxons. The body of the zone is marked largely by concurrences of the diagnostic taxons."

Seventeen dinoflagellate cyst Oppel-zones have been recognized within the Jurassic to Lower Cretaceous interval (Fig. 3). These are given formal names as well as alphabetic indices in order to facilitate reference. The indices correspond to those used in Davies and Norris (1980). The intervals in metres under "Distribution" correspond to those in the section descriptions (Davies, 1979) that may be obtained through the Geological Survey of Canada. Zones are described in ascending order. Zonal ranges of species are shown in Figure 4.

A. *Lithodinia serrulata* Oppel-Zone

Taxa Which Occur Solely Within The Zone. None.

Taxa Which Occur Within And Below The Zone. None (bottom of interval examined).

Taxa Which Occur Within And Above The Zone. *Comparodinium aquilonium, Dapcodinium coalitum, Dapcodinium holotabulatum, Dapcodinium semitabulatum, Glomodinium evittii, Lithodinia serrulata, Nannoceratopsis senex var. A, Nannoceratopsis senex* var. B, *Nannoceratopsis senex var. C, Scriniocassis weberi.*

Q	FROMEA ATLANTICA	?HAUTERIVIAN- LATE LATE VALANGINIAN
P	MUDERONGIA SIMPLEX	MIDDLE-LATE LATE VALANGINIAN
O	TANYOSPHAERIDIUM MAGNETICUM	EARLY LATE- EARLY VALANGINIAN
N	SENTUSIDINIUM CUCULLIFORMIS-PARAGONYAULACYSTA BOREALIS	BERRIASIAN
M	TRICHODINIUM ERINACEOIDES-HOROLOGINELLA SPINOSIGIBBEROSA	BERRIASIAN- LATE LATE TITHONIAN
L	PROLIXOSPHAERIDIUM SPISSUM-PARAGONYAULACYSTA CAPILLOSA	EARLY BERRIASIAN- LATE LATE TITHONIAN
K	MILLIOUDODINIUM JUBARIS	EARLY-LATE TITHONIAN
J	LANTERNA SATURNALIS-ESCHARISPHAERIDIA POCOCKII	EARLY LATE TITHONIAN- MIDDLE KIMMERIDGIAN
I	MILLIOUDODINIUM EHRENBERGII-GONYAULACYSTA DUALIS	EARLY-MIDDLE KIMMERIDGIAN
H	STEPHANELYTRON REDCLIFFENSE	OXFORDIAN- MIDDLE CALLOVIAN
G	PARAGONYAULACYSTA CALLOVIENSE	EARLY CALLOVIAN- LATE BATHONIAN
F	HYSTRYCHOGONYAULAX CLADOPHORA-NANNOCERATOPSIS SENEX VAR. A	LATE BATHONIAN
E	GLOMODINIUM TRIPARTITUM-COMPARODINIUM AQUILONIUM	MIDDLE BATHONIAN- LATE BAJOCIAN
D	WALLODINIUM ELONGATUM	EARLY BAJOCIAN
C	PHALLOCYSTA EUMEKES-DAPCODINIUM COALITUM	EARLY BAJOCIAN- TOARCIAN
B	SUSADINIUM SCROFOIDES-NANNOCERATOPSIS SENEX VAR. C	TOARCIAN
A	LITHODINIA SERRULATA	TOARCIAN OR ?PLIENSBACHIAN

GSC

Figure 3. Dinoflagellate Oppel-zonation for the Jurassic-Lower Cretaceous of the Sverdrup Basin.

Taxa Which Occur Within, Above And Below The Zone. None.

Distribution. Elf Jameson Bay C-31 804-960 m, Reindeer Peninsula 87 m, Elf Wilkins E-60 676-690 m, Skaare Anticline 37 m.

Remarks. This zone contains many forms in common with Oppel-Zone B. *Lithodinia serrulata* (Plate 9, fig. 1-6), *Nannoceratopsis senex, Dapcodinium* spp. and *Scriniocassis weberi* are abundant. *Comparodinium aquilonium* occurs infrequently near the top of the zone. This zone is distinguished by the presence of few dinoflagellate species. The succeeding zone is marked by the first appearance of several more species. Below Oppel-Zone A are typical Upper Triassic forms such as *Rhaetogonyaulax, Suessia, Sverdrupiella, Heibergella* and *Noricysta* described by Bujak and Fisher (1976).

Age. According to the ranges of dinoflagellate cyst species, the age of this zone is Toarcian or possibly Pliensbachian. However, within the interval Hettangian-Pliensbachian, there is a worldwide paucity of published studies on dinoflagellate cysts. Ranges of some dinoflagellate cysts, therefore, appear not to continue below the Toarcian. The age of this Oppel-zone appears, in fact, to include beds older than Toarcian because of the following biostratigraphic data.

Sediments attributed to the Borden Island Formation have been dated as Sinemurian by the presence of *Coroniceras (Primarietites)* sp. indet. on Borden Island (Frebold, 1960, 1975) and Ellef Ringnes Island (Frebold, 1975; Frebold *in* Stott, 1969). Similar Borden Island sediments are found in the Elf Jameson Bay C-31 and Elf Wilkins E-60 wells which contain assemblages from Oppel-Zone A. Higher portions of Oppel-Zone A in Elf Jameson Bay C-31 well may correspond to Upper Pliensbachian sediments on Prince Patrick Island and Axel Heiberg Island that contain *Amaltheus stokesi* (Frebold, 1975). The age of this zone is, therefore, tentatively Toarcian to possibly as old as Sinemurian.

B. *Susadinium scrofoides – Nannoceratopsis senex* var. C Oppel-Zone

Taxa Which Occur Solely Within The Zone. None

Taxa Which Occur Within And Below The Zone. *Nannoceratopsis senex var. C.*

Taxa Which Occur Within And Above The Zone. *Caligodinium aceras, ?Comparodinium cavum, Dapcodinium wapellense, Dingodinium minutum, Dodekovia syzygia, Microdinium opacum, Nannoceratopsis gracilis, Susadinium scrofoides.*

Taxa Which Occur Within, Above And Below The Zone. *Comparodinium aquilonium, Dapcodinium coalitum, Dapcodinium holotabulatum, Dapcodinium semitabulatum, Nannoceratopsis senex* var. A, *Scriniocassis weberi.*

Distribution. Elf Jameson Bay C-31 649-795 m, Elf Wilkins E-60 595-676 m, Reindeer Peninsula 88-107 m, Skaare Anticline 72-78 m.

Remarks. The base of this zone is distinguished by the first appearances of *S. scrofoides* (Plate 2, fig. 17) and *C. aceras*. Many other first appearances occur higher in the zone. *N. senex* var. C (Plate 6, fig. 20) has only been identified in Elf Jameson Bay C-31 and Panarctic Sandy Point L-46. *Dapcodinium wapellense* only occurs near the top of the zone.

Age. The age circumscribed by worldwide correlation of dinoflagellates appears to be Toarcian with the introduction of *S. scrofoides* and *C. aceras*. *M. opacum* suggests either a possible Bajocian age to the upper portions or a longer range for the species. Correlative sediments indicate an Early Toarcian age because they contain *Dactylioceras commune* on Prince Patrick Island, Cornwall Island and Borden Island (Frebold, 1960; Frebold *in* Greiner, 1963; Frebold *in* Tozer and Thorsteinsson, 1964). *Peronoceras spinatum*, *P. polare* and *Pseudoleoceras* aff. *compactile* have been found on Prince Patrick Island, Ellef Ringnes Island, Cornwall Island, Axel Heiberg Island and Ellesmere Island (Frebold, 1960; Frebold *in* Tozer, 1963; Frebold *in* Souther, 1963; Frebold *in* Stott, 1969). Toarcian sediments are, therefore, present in the basin and are probably represented in Oppel-Zone B. No macrofauna in situ have been collected from localities that may be directly related to Oppel-Zone B.

C. *Phallocysta eumekes – Dapcodinium coalitum* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Comparodinium perpunctatum, Parvulodinium penitabulatum, Scriniocassis pyrus.*

Taxa Which Occur Within And Below The Zone. *Dapcodinium coalitum, Dapcodinium wapellense, Lithodinia serrulata.*

Taxa Which Occur Within And Above The Zone. *Chytroeisphaeridia chytroeides, Ellipsoidictyum cinctum, Mendicodinium reticulatum, Phallocysta eumekes, Scriniocassis dictyotus.*

Taxa Which Occur Within, Above and Below The Zone. *Caligodinium aceras, Comparodinium aquilonium, Dapcodinium holotabulatum, Dapcodinium semitabulatum, Dingodinium minutum, Dodekovia syzygia, Glomodinium evittii, Nannoceratopsis gracilis, Nannoceratopsis senex var. A, Nannoceratopsis senex var. B, Scriniocassis weberi, Susadinium scrofoides.*

Distribution. Elf Jameson Bay C-31 566-649 m, Elf Wilkins E-60 485-595 m, Reindeer Peninsula 117-135 m, Skaare Anticline 93-126 m.

Remarks. The rare species *C. perpunctatum* (Plate 2, fig. 16) and *P. penitabulatum* (Plate 9, fig. 9-11, 13-15, 17-19) are restricted to Oppel-zone C. The base of this zone can be readily distinguished by the first appearance of *P. eumekes* (Plate 1, fig. 20). The last appearances of *D. coalitum* (Plate 1, fig. 1-8) and *D. wapellense* are limited to the lower portion of the zone. *E. cinctum* first appears in the upper portion but is rare, limiting its usefulness. *Lithodinia serrulata* is also rare in this zone.

Age. The dinoflagellate cysts of Oppel-Zone C indicate a Toarcian-Bajocian age. The first appearances of *E. cinctum, P. eumekes, S. dictyotus* and *C. chytroeides* occur within this interval. *Pseudolioceras m'clintocki* occurs in correlative beds on Vantage Point, Axel Heiberg Island (Tozer, 1963; Johnson and Hills, 1973) and has been dated by Frebold (1975) as Early Bajocian. *Leioceras opalinum* occurs in rocks correlative with the uppermost beds of this Oppel-zone in Ellef Ringnes Island and has been dated as Early Bajocian (Frebold *in* Stott, 1969). The age indicated by macrofaunas is in a large part Early Bajocian with the basal portions being possibly Toarcian.

D. *Wallodinium elongatum* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Wallodinium elongatum, ?Parvocysta cracens.*

Taxa Which Occur Within And Below The Zone. *?Comparodinium cavum, Dingodinium minutum, Dodekovia syzygia, Mendicodinium reticulatum.*

Taxa Which Occur Within And Above The Zone. *Chlamydophorella membranoides, ?Lithodinia cantrellii, Nannoceratopsis pellucida, Phallocysta eumekes.*

Taxa Which Occur Within, Above And Below The Zone. *Caligodinium aceras, Chytroeisphaeridia chytroeides, Comparodinium aquilonium, Dapcodinium holotabulatum, Dapcodinium semitabulatum, Ellipsoidictyum cinctum, Microdinium opacum, Nannoceratopsis gracilis, Nannoceratopsis senex var. A, Nannoceratopsis senex var. B, Scriniocassis dictyotus, Scriniocassis weberi, Susadinium scrofoides.*

Distribution. Elf Jameson Bay C-31 521-557 m, Elf Wilkins E-60 375-458 m, Reindeer Peninsula 135-150 m, northwestern Cornwall Island 78-110 m, Jaegar River 260-270 m, Skaare Anticline 126-154 m.

Remarks. This zone is distinguished by the presence of *Wallodinium elongatum* (Plate 2, fig. 9). *D. minutum* is generally restricted to this zone. The last appearance of *Phallocysta eumekes* occurs just above and most often delimits the top of the zone. *D. syzygia* extends only into the lower half of the zone.

Age. Oppel-Zone D is dated as Bajocian-Bathonian by the presence of *W. elongatum, N. pellucida*, and *D. semitabulatum*. The age of this zone may be dated as Early Bajocian by macrofauna through the presence of *Leioceras opalinum* near the base of the Oppel-zone on Ellef Ringnes Island (Frebold *in* Stott, 1969). No other macrofossils have been found that are directly correlative with this zone. Immediately above this zone, beds on Vantage Point, Axel Heiberg Island contain *Arkelloceras mclearni* which has been dated as Middle Bajocian (Frebold et al., 1967). The age for Oppel-Zone D, therefore, is most probably Early Bajocian.

E. *Glomodinium tripartitum – Comparodinium aquilonium* Oppel-Zone

Taxa Which Occur Solely Within The Zone. None.

Taxa Which Occur Within And Below The Zone. *Comparodinium aquilonium, Phallocysta eumekes.*

Taxa Which Occur Within And Above The Zone. *Glomodinium tripartitum, Lithodinia deflandrei.*

Taxa Which Occur Within, Above And Below The Zone. *Caligodinium aceras, Chytroeisphaeridia chytroeides, Dapcodinium holotabulatum, Dapcodinium semitabulatum, Microdinium opacum, Nannoceratopsis gracilis, Nannoceratosis senex var. A, Nannoceratosis senex var. B, Scriniocassis weberi, Susadinium scrofoides.*

Distribution. Elf Jameson Bay C-31 476-512 m, Reindeer Peninsula 160-181 m.

Remarks. The first appearances of *G. tripartitum* (Plate 2, fig. 22) and *L. deflandrei* mark the base of this zone. The last appearance of *C. aquilonium* (Plate 2, fig. 19) delimits the top of the zone. This zone is commonly absent in sequences containing disconformites, e.g. Elf Wilkins E-60.

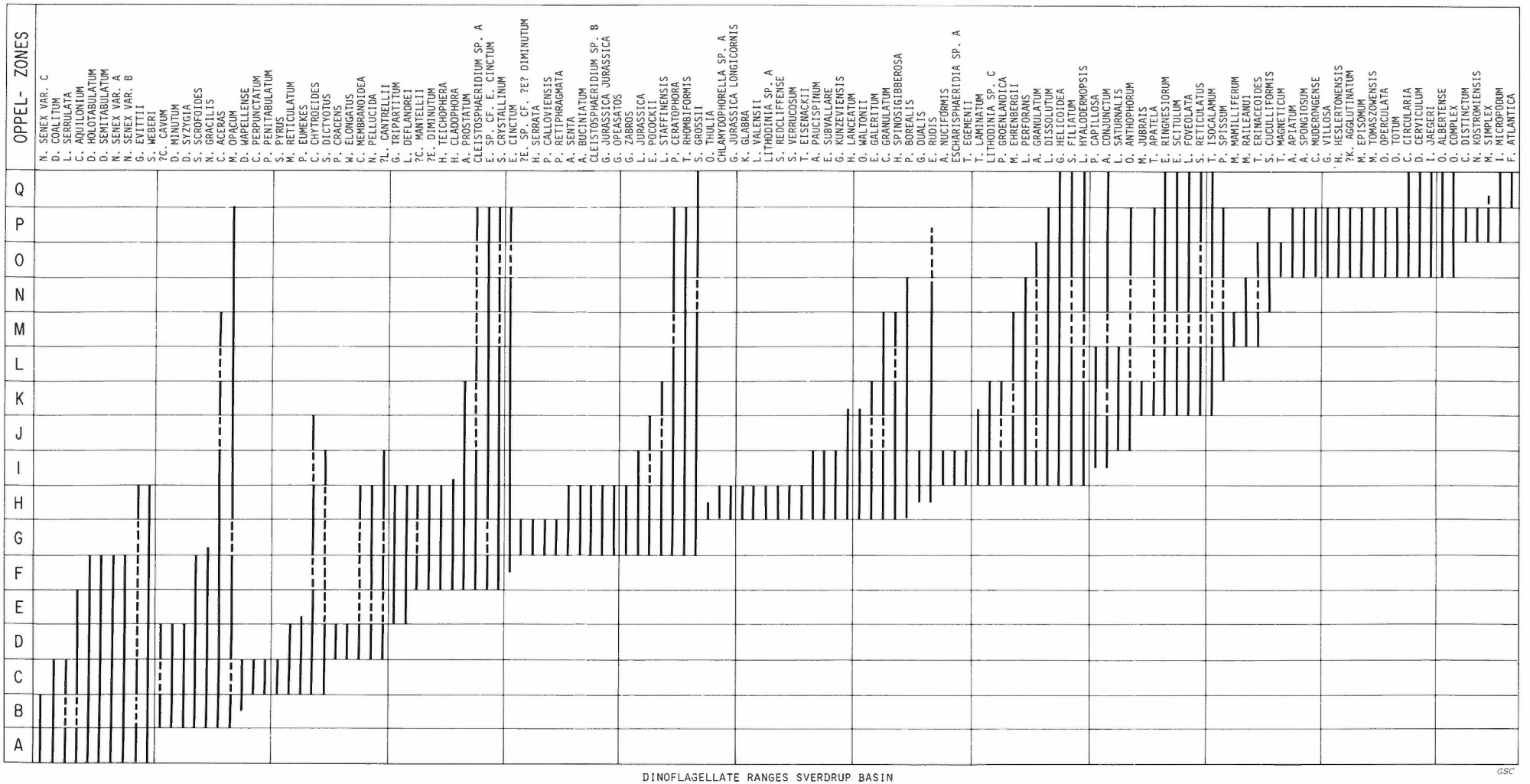


Figure 4. Dinoflagellate cyst Oppel-zonation. Species ranges are generalized within Oppel-zones. Dotted lines indicate questionable or interpolated occurrences.

Age. Oppel-Zone E may be dated as Late Bajocian-Bathonian by the presence of *G. tripartitum*, and *L. deflandrei*. Older forms such as *C. aquilonium, S. scrofoides, P. eumekes* (into the basal portions only), *S. senex* and *D. semitabulatum* continue to occur. The presence of *Arkelloceras mclearni* correlative with the base of Oppel-Zone E on Vantage Point indicates a Middle Bajocian age (Frebold *in* Tozer, 1963; Frebold, 1964a; Frebold et al., 1967). Higher in the section, correlative with the upper portions of Oppel-Zone E, the ammonite *Arctocephalites elegans* is present and indicative of a Middle Bathonian age (Frebold et al., 1967). This agrees with the dinoflagellate age assignment.

F. *Hystrichogonyaulax cladophora – Nannoceratopsis senex* var. A Oppel-Zone

Taxa Which Occur Solely Within The Zone. None.

Taxa Which Occur Within And Below The Zone. *Dapcodinium holotabulatum, Dapcodinium semitabulatum, Nannoceratopsis senex* var. A, *Nannoceratopsis senex* var. B, *Susadinium scrofoides*.

Taxa Which Occur Within And Above The Zone. *Atopodinium prostatum, ?Chytroeisphaeridia mantellii, Cleistosphaeridium* sp. A, *?Egmontodinium diminutum, Ellipsoidictyum* sp. cf. *E. cinctum, Heslertonia teichophera, Hystrichogonyaulax cladophora, Scriniodinium crystallinum*.

Taxa Which Occur Within, Above and Below The Zone. *Caligodinium aceras, Ellipsoidictyum cinctum, Glomodinium tripartitum, ?Lithodinia cantrellii, Lithodinia deflandrei, Microdinium opacum, Nannoceratopsis gracilis, Nannoceratopsis weberi*.

Distribution. Elf Jameson Bay C-31 430-476 m, North Amund Ringnes Dome 83 m, Central Amund Ringnes Dome 289 m, Skaare Anticline 133 m.

Remarks. A transition in the dominant, long-ranging species occurs within this zone, from an association of *Nannoceratopsis, Susadinium* and *Dapcodinium* in the Early-Middle Jurassic, to one of *Hystrichogonyaulax, Gonyaulacysta, Pareodinia and Lithodinia* in the Late Jurassic-Early Cretaceous. The first appearances of *H. cladophora* (Plate 4, fig. 11), *A. prostatum*, and/or *Cleistosphaeridium* sp. A delimit the base of the zone. The last appearances of *S. scrofoides, N. senex* var. A (Plate 6, fig. 18) and/or *D. holotabulatum* define the top. *N. gracilis* may on occasion range higher into the basal portions of Oppel-Zone G.

Age. The age of Oppel-Zone F based on dinoflagellate cyst assemblages, is Late Bajocian-Late Bathonian as indicated by the presence of *N. gracilis, G. tripartitum, ?L. cantrellii* and *L. deflandrei*. No macrofossils have been found in beds directly correlative with Oppel-Zone F. The Oppel-zone, however, is bracketed by the macrofauna *Arctocephalites elegans* of Oppel-Zone E and *Cadoceras bodylevski* (Lower Callovian) of Oppel-Zone G. The age of Oppel-Zone F is most probably Late Bathonian correlative with the ammonite zone *Arcticoceras ishmae* and *A. kochi* (Fig. 2; Frebold, 1961).

G. *Paragonyaulacysta calloviensis* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *?Egmontodinium* sp. cf. *?E. diminutum, Hystrichogonyaulax serrata, Paragonyaulacysta calloviensis, Paragonyaulacysta retiphragmata*.

Taxa Which Occur Within And Below The Zone. *Nannoceratopsis gracilis (in the basal portions of the zone).*

Taxa Which Occur Within And Above The Zone. *Acanthaulux senta, Apteodinium bucculiatum, Cleistosphaeridium* sp. B, *Escharisphaeridia pocockii, Glomodinium opeasatos, Glomodinium zabros, Gonyaulacysta jurassica jurassica, Lithodinia jurassica, Lithodinia staffinensis, Pareodinia ceratophora, Sirmiodinium grossii, Tubotuberella rhombiformis*.

Taxa Which Occur Within, Above And Below The Zone. *Atopodinium prostatum, Caligodinium aceras, Chytroeisphaeridia chytroeides, Cleistosphaeridium* sp. A, *?Egmontodinium diminutum, Ellipsoidictyum cinctum, Glomodinium tripartitum, Heslertonia teichophera, Hystrichogonyaulax cladophora, Lithodinia deflandrei, Nannoceratopsis pellucida, Scriniocassis weberi, Scriniodinium crystallinum*.

Distribution. Elf Jameson Bay C-31 311-421 m, North Amund Ringnes Dome 89-150 m, Central Amund Ringnes Dome 309-403 m, northwestern Cornwall Island 158 m, Jaeger River – upper 280-344 m (faulted repetition), – lower 80 m, Skaare Anticline 169-184 m, Blueman Cape 141-161 m, Fosheim Anticline 168-187 m.

Remarks. Oppel-Zone G can be readily identified by the presence of *P. calloviensis* (Plate 2, fig. 18) and/or *P. retiphragmata*. The base of this zone is marked by the last appearance of *N. gracilis* and the first appearances of *A. senta* and *S. grossii*. Common species are *Cleistosphaeridium* sp. A, *G. tripartitum, H. cladophora*, and *L. deflandrei*.

Age. The presence of *A. senta, B. pocockii, G. jurassica jurassica, G. tripartitum, H. teichophera, N. gracilis, P. calloviensis, S. grossii* and *T. rhombiformis* indicates an age of Late Bathonian-Early Callovian for Oppel-Zone G.The presence of the ammonites *Cadoceras bodylevski* near the base and *C. septentrionale* near the top at Central Amund Ringnes Dome and Vantage Point suggests an Early Callovian age (Frebold, 1961, 1964b; Frebold *in* Tozer, 1963; Frebold *in* Balkwill et al., 1977). This is in accord with the age based on dinoflagellate cysts.

H. *Stephanelytron redcliffense* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Sentusidinium verrucosum, Chlamydophorella* sp. A, *Gonyaulacysta jurassica longicornis, Kalyptea glabra, ?Lithodinia* sp. A, *Lithodinia valensii, Occisucysta thulia, Stephanelytron redcliffense, Tubotuberella eisenackii*.

Taxa Which Occur Within And Below The Zone. *Acanthaulax senta, Apteodinium bucculiatum, Chlamydophorella membranoidea, Cleistosphaeridium* sp. B, *?Chytroeisphaeridia mantellii, ?Egmontodinium diminutum, Glomodinium evittii, Glomodinium opeasatos, Glomodinium tripartitum, Glomodinium zabros, Gonyaulacysta jurassica jurassica, Heslertonia teichophera, Lithodinia deflandrei, Nannoceratopsis pellucida, Scriniocassis weberi*.

Taxa Which Occur Within And Above The Zone. *Adnatosphaeridium paucispinum, Cribroperidinium granulatum, Endoscrinium subvallare, Endoscrinium galeritum, Escharisphaerida rudis, Gonyaulacysta dualis, Gonyaulacysta kunzeviensis, Horologinella spinosigibberosa, Hystrichodinium lanceatum, Lithodinia* sp. A, *Ovoidinium waltonii, Paragonyaulacysta borealis*.

Taxa Which Occur Within, Above And Below The Zone. *Atopodinium prostatum, Caligodinium aceras, Chytroeisphaeridia chytroeides, Cleistosphaeridium sp. A, Ellipsoidictyum cinctum, Ellipsoidictyum sp. cf. E. cinctum, Escharisphaeridia pocockii, Hystrichogonyaulax cladophora, ?Lithodinia cantrellii, Lithodinia ju-*

rassica, Lithodinia staffinensis, Microdinium opacum, Pareodinia ceratophora, Scriniodinium crystallinum, Sirmiodinium grossii, Tubotuberella rhombiformis.

Distribution. Elf Jameson Bay C-31 247-302 m, Elf Wilkins E-60 320-348 m, Reindeer Peninsula 227-249 m, North Amund Ringnes Dome 210-270 m, Central Amund Ringnes Dome 121-221 m, northwestern Cornwall Island 168-280 m, Jaegar River – upper 315-330 m, – lower 80-138 m, Skaare Anticline 200-396 m, Blueman Cape 161-247 m, Fosheim Anticline 320-337 m, Glacier Fjord 590 m, Cape Ludwig 68-240 m.

Remarks. The base of this zone is marked by the first appearances of *P. borealis, O. waltonii, T. eisenackii* (Plate 4, fig. 9) and/or *E. galeritum*. Other stratigraphically important first appearances of species occur within this zone such as *G. dualis* near the middle, *E. rudis* near the top. The zone may be easily recognized by the presence of *K. glabra* and/or *S. redcliffense* (Plate 7, fig. 19, 20). The top of the zone is distinguished by the last appearances of *A. senta, Glomodinium* spp. and/or *G. jurassica*. *H. cladophora* ranges into the basal portions of Oppel-Zone I but its last appearance is often indicative of the top of Oppel-Zone H.

Age. The first appearances of a large number of dinoflagellate cysts including *C. granulatum, E. subvallare, G. dualis, G. jurassica longicornis, H. spinosigibberosa, K. glabra, P. borealis, S. redcliffense, S. verrucosum,* and the last appearances of *G. triparitum, G. jurassica jurassica, H. teichophera, L. deflandrei* and *N. pellucida* suggest a Callovian-Oxfordian age for Oppel-Zone H, possibly extending into the Early Kimmeridgian. Rocks correlative with beds just below the base of Oppel-Zone H on Vantage Point, Axel Heiberg Island contain the ammonite *Cadoceras septentrionale* (Frebold, 1964b; Frebold *in* Tozer, 1963) which is indicative of an Early Callovian age (Fig. 2). *Buchia concentrica* occurs in the base of Oppel Zone I on North Amund Ringnes Dome and is a Late Oxfordian-Early Kimmeridgian pelecypod (Jeletzky *in* Balkwill et al., 1977). The age therefore, ranges from Middle Callovian to Late Oxfordian to possible Kimmeridgian.

I. *Millioudodinium ehrenbergii – Gonyaulacysta dualis* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Apteodinium nuciforme, Sentusidinium* sp. A, *Tubotuberella egemenii.*

Taxa Which Occur Within And Below The Zone. *Adnatosphaeridium paucispinum, Endoscrinium subvallare, Gonyaulacysta dualis, Gonyaulacysta kunzeviensis, Hystrichogonyaulax cladophora* (in the basal portions of the zone), *?Lithodinia cantrellii, Lithodinia jurassica, Scriniocassis dictyotus.*

Taxa Which Occur Within And Above The Zone. *Apteodinium conjunctum* (in the upper portions of the zone), *Apteodinium granulatum, Gonyaulacysta helicoidea, Leptodinium hyalodermopsis, Leptodinium perforans, Millioudodinium ehrenbergii, Paragonyaulacysta capillosa* (in the upper portions of the zone), *Pareodinia groenlandica, Lithodinia* sp. C, *Lunatadinium dissolutum, Sentusidinium filiatum, Tectatodinium laminatum.*

Taxa Which Occur Within, Above And Below The Zone. *Atopodinium prostatum, Caligodinium aceras, Chytroeisphaeridia chytroiedes, Cleistosphaeridium* sp. A, *Cribroperidinium granulatum, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Endoscrinium galeritum, Escharisphaeridia rudis, Horologinella spinosigibberosa Hystrichodinium lanceatum, Lithodinia staffinensis, Microdinium opacum, Millioudodinium ehrenbengii, Ovoidinium waltonii, Paragonyaulacysta borealis, Pareodinia ceratophora, Scriniodinium crystallinum, Sirmiodinium grossii.*

Distribution. Elf Jameson Bay C-31 202-247 m, Elf Wilkins E-60 292 m, Reindeer Peninsula 252 m, North Amund Ringnes Dome 330-445 m, Central Amund Ringnes Dome 221-384 m, Jaegar River 187-203 m, Skaare Anticline 416-504 m, Blueman Cape 247-270, Fosheim Anticline 384-412 m, Glacier Fjord 590 m.

Remarks. The base of the zone is marked by the last appearance of *H. cladophora* and the first appearance of *M. ehrenbergii* (Plate 4, fig. 12). Generally the presence of *G. dualis* (Plate 4, fig. 10) typifies the zone although it may occasionally range lower into Oppel-Zone H. Within this zone are found the first appearances of *Apteodinium* spp., *G. helicoidea, L. dissolutum* and/or *L. hyalodermopsis*. The top of the zone is defined by the last appearance of *G. dualis* and the first appearance of *P. capillosa.*

Age. The presence of the dinoflagellate cysts *A. conjunctum, A. granulatum, A. nuciforme, A. paucispinum, E. galeritum, E. subvallare, G. dualis, G. helicoidea, H. spinosigibberosa, H. cladophora* (in the basal portions only), *L. hyalodermopsis, L. perforans, L. dissolutum, P. capillosa*, and *T. egemenii* indicates a Kimmeridgian age for Oppel-Zone I. The presence of the pelecypod *Buchia concentrica* in the lower portion of Oppel-Zone I on North Amund Ringnes Dome and Central Amund Ringnes Dome indicates a Late Oxfordian-Early Kimmeridgian age (Jeletzky *in* Balkwill et al., 1977). *Buchia mosquensis* occurs in the basal beds of Oppel-Zone J and is indicative of a Middle Kimmeridgian-early Late Tithonian age (Jeletzky *in* Balkwill et al., 1977). A probably Early-Middle Kimmeridgian age is assigned to this zone.

J. *Lanterna saturnalis – Escharisphaeridia pocockii* Oppel-Zone

Taxa Which Occur Solely Within The Zone. None.

Taxa Which Occur Within And Below The Zone. *Escharisphaeridia pocockii, Chytroeisphaeridia chytroeides.*

Taxa Which Occur Within And Above The Zone. *Lanterna saturnalis, Oligosphaeridium anthophorum.*

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium conjunctum, Atopodinium prostatum, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *cinctum, Escharisphaeridia rudis, Gonyaulacysta helicoidea, Horologinella spinosigibberosa, Hystrichodinium lanceatum, Leptodinium hyalodermopsis, Leptodinium perforans, Lithodinia sp. C, Lunatadinium dissolutum, Microdinium opacum, Millioudinium ehrenbergii, Ovoidinium waltonii, Paragonyaulacysta borealis, Paragonyaulacysta capillosa, Pareodinia ceratophora, Scriniodinium crystallinum, Sentusidinium filiatum, Sirmiodinium grossii, Tectatodinium laminatum, Tubotuberella rhombiformis.*

Distribution. Elf Jameson Bay C-31 165-202 m, Elf Wilkins E-60 237-265 m, Reindeer Peninsula 262 m, Central Amund Ringnes Island 500 m, Blueman Cape 293 m.

Remarks. This zone may be regarded as an interval-zone between Oppel-Zones I and K and is delimited by the last appearance of *G. dualis* and the first appearance of *P. capillosa* of Oppel-Zone I, and by the several first appearances of species found in Oppel-Zone K. It is also marked by a peak in abundance of *L. dissolutum*. The first appearances of *Lanterna saturnalis* (Plate 7, fig. 18) and *Oligosphaeridium anthophorum* and the last appearances of *Escharisphaeridia pocockii* (Plate 7, fig. 16) occur within this zone.

Age. The age based on dinoflagellate assemblages is assigned to the Kimmeridgian-early Late Tithonian because of the presence of

E. pocockii, C. chytroeides, L. saturnalis, O. anthophorum, H. spinosigibberosa (in the basal portions only) and *O. waltonii*. This is in accord with the presence of the pelecypod *Buchia mosquensis* on Central Amund Ringnes Dome (Jeletzky in Balkwill et al., 1977). The early Late Tithonian pelecypod *B. fischeriana* occurs in the lower portion of Oppel-Zone K on Central Amund Ringnes Dome (Jeletzky *in* Balkwill et al., 1977). A Middle Kimmeridgian-early Late Tithonian age is assigned to Oppel-Zone J.

K. *Millioudodinium jubaris* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Millioudodinium jubaris*.

Taxa Which Occur Within And Below The Zone. *Atopodinium prostatum, Endoscrinium galeritum, Hystrichodinium lanceatum* (in basal portions of the zone), *Lithodinia staffinensis, Lithodinia* sp. C, *Ovoidinium waltonii* (in basal portions of the zone), *Pareodinia groenlandica, Tectatodinium laminatum* (in basal portions of the zone).

Taxa Which Occur Within And Above The Zone. *Canningia ringnesiorum, Exochosphaeridium scitulum, Lecaniella foveolata, Schizosporis reticulatus, Tanyosphaeridium isocalamum* (rarely occurring), *Tubotuberella apatela*.

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium granulatum,Caligodinium aceras, Cribroperidinium granulatum, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Escharisphaeridia rudis, Gonyaulacysta helicoidea, Horologinella spinosigibberosa, Lanterna saturnalis, Leptodinium hyalodermopsis, Leptodinium perforans, Lunatadinium dissolutum, Microdinium opacum, Oligosphaeridium anthophorum, Paragonyaulacysta borealis, Paragonyaulacysta capillosa, Pareodinia ceratophora, Scriniodinium crystallinum, Sentusidinium filiatum, Sirmiodinium grossii, Tubotuberella rhombiformis*.

Distribution. Elf Jameson Bay C-31 128-156 m, Elf Wilkins E-60 155-210 m, Reindeer Peninsula 267 m, Central Amund Ringnes Dome 649-753 m, northwest Cornwall Island 1045 m, Jaegar River 240-252 m, Skaare Anticline 534-549 m, Fosheim Anticline 469-475 m, Cape Ludwig 700 m.

Remarks. This Oppel-zone is readily identified by the presence of a rare species, *Millioudodinium jubaris* (Plate 5, fig. 13-20). The base may be identified by the last appearance of *Tectatodinium laminatum* and the first appearances of *Lecaniella foveolata, C. ringnesiorum* or *Exochosphaeridium scitulum*. Rare lower occurrences of the chorate species *O. anthophorum* and *T. isocalamum* may be found. The top of the zone is distinguished by the last appearance of *Atopodinium prostatum*.

Age. Many Kimmeridgian and older forms are present in Oppel-Zone K. The green algal cyst *Lecaniella foveolata* is present and indicates a Berriasian or younger age. *C. ringnesiorum* suggests a Valanginian or younger age. Also the Lower Cretaceous form *T. isocalamum* occurs rarely within this zone, whereas *P. capillosa* limits the upper range of this zone to the Berriasian. Only a generalized assessment of late Late Kimmeridgian-Early Berriasian may be made based on dinoflagellate cyst assemblages. This interval also has few macrofaunal elements. *Buchia fischeriana* is present in the basal portion on Central Amund Ringnes Dome and indicates an early Late Tithonian age (Jeletzky *in* Balkwill et al., 1977). This zone is therefore assigned an early Late Tithonian age with the possibility of Early Berriasian in the uppermost portions.

L. *Prolixosphaeridium spissum – Paragonyaulacysta capillosa* Oppel-Zone

Taxa Which Occur Solely Within The Zone. None.

Taxa Which Occur Within And Below The Zone. *Lanterna saturnalis, Paragonyaulacysta capillosa*.

Taxa Which Occur Within And Above The Zone. *Prolixosphaeridium spissum, Trichodinium erinaceoides* (in the upper portions of the zone).

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium conjunctum, Canningia ringnesiorium, Cleistosphaeridium* sp. A, *Cribroperidinium granulatum, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Escharisphaeridia rudis, Exochosphaeridium scitulum, Gonyaulacysta helicoidea, Lecaniella foveolata, Leptodinium perforans, Lunatadinium dissolutum, Microdinium opacum, Millioudodinium ehrenbergii, Paragonyaulacysta borealis, Pareodinia ceratophora, Scriniodinium crystallinum, Sentusidinium filiatum, Sirmiodinium grossii, Tanyosphaeridium isocalamum, Tubotuberella rhombiformis*.

Distribution. Elf Jameson Bay C-21 119 m, Elf Wilkins E-60 128-146 m, North Amund Ringnes Dome 590 m, Central Amund Ringnes Dome 875-988 m, Cape Ludwig 1000-1030 m, Skaare Anticline 549-568 m, Fosheim Anticline 485-533 m, Glacier Fjord 1070 m.

Remarks. The base of this zone may be identified by the first appearance of *Prolixosphaeridium spissum* (Plate 6, fig. 22). The top of the zone may be distinguished by the last appearance of *Lanterna saturnalis* and/or *Paragonyaulacysta capillosa* (Plate 2, fig. 20). *Microdinium opacum, Sirmiodinium grossii* and *Tubotuberella rhombiformis* are abundant.

Age. The last appearance of *P. capillosa* indicates a Late Tithonian-Berriasian age for Oppel-Zone L. Kimmeridgian forms such as *C. granulatum, L. saturnalis* and *M. ehrenbergii*, are still present. There is a general lack of dinoflagellates within this zone making further division and detailed age assignments difficult. No macrofauna has been found in strata that may be directly correlated with Oppel-Zone L, but it may correspond to the zones of *Craspedites canadensis* and *Buschia urschensis* to *Subcraspedites* aff. *subditus* and *Buchia okensis* of the late Late Tithonian-Early Berriasian (Fig. 2) in the surface sections elsewhere in the Sverdrup Basin that have not been analyzed in this study.

M. *Trichodinium erinaceoides – Horologinella spinosigibberosa* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Millioudodinium mamilliferum*.

Taxa Which Occur Within And Below The Zone. *Caligodinium aceras, Cribroperidinium granulatum, Horologinella spinosigibberosa, Millioudodinium ehrenbergii*.

Taxa Which Occur Within And Above The Zone. *Trichodinium erinaceoides, Moesiodinium raileanui*.

Taxa Which Occur Within, Above And Below The Zone. *Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Escharisphaeridia rudis, Gonyaulacysta helicoidea, Leptodinium perforans, Lunatodinium dissolutum, Microdinium opacum, Paragonyaulacysta borealis, Prolixosphaeridium spissum, Scriniodinium crystallinum, Sirmiodinium grossii, Tubotuberella rhombiformis*.

Distribution. Elf Jameson Bay C-31 82-110 m, North Amund Ringnes Dome 820 m, Central Amund Ringnes Dome 1073 m, northwestern Cornwall Island 670 m, Skaare Anticline 580-626 m, Glacier Fjord 1130-1170 m, Fosheim Anticline 543-550 m.

Remarks. The base of this zone may be marked by the first appearances of the rare species *Trichodinium erinaceoides* (Plate 6, fig. 6-15) and *Moesiodinium raileanui* (Plate 6, fig. 23). *M. mamilliferum* (Plate 5, fig. 9) is confined to this zone but is extremely rare. *L. perforans, S. grossii* and *T. rhombiformis* are abundant. *P. borealis* is common. The top of the zone is defined by the last appearances of *Horologinella spinosigibberosa* and *M. ehrenbergii*.

Age. The presence of *M. mamilliferum* suggests a Tithonian or older age. The presence of *G. helicoidea* and *L. dissolutum* suggests a Late Tithonian or younger age. A Berriasian age is indicated by the absence of the species *P. capillosa* which appears lastly at the top of Oppel-Zone L. Although positive age assignments are not possible due to the paucity of macrofossils and dinoflagellate cysts, the Oppel-Zone M is tentatively assigned to the late Late Tithonian to Berriasian. The overlapping ages of Oppel-Zones L and M may indicate lateral facies change between the two.

N. *Sentusidinium cuculliformis – Paragonyaulacysta borealis* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *?Lithodinia* sp. B.

Taxa Which Occur Within And Below The Zone. *Leptodinium perforans, Moesiodinium raileanui, Paragonyaulacysta borealis* (rarely occurring in Oppel-Zone O).

Taxa Which Occur Within And Above The Zone. *Sentusidinium cuculliformis.*

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium conjunctum, Caligodinium aceras, Canningia ringnesiorum, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Escharisphaeridia dictydia, Escharisphaeridia rudis, Exochosphaeridium scitulum, Gonyaulacysta helicoidea, Lecaniella foveolata, Leptodinium hyalodermopsis, Lunatadinium dissolutum, Microdinium opacum, Pareodinia ceratophora, Schizosporis reticulata, Scriniodinium crystallinum, Tubotuberella rhombiformis.*

Distribution. Elf Jameson Bay C-31 28-73 m, Central Amund Ringnes Dome 1157 m, Fosheim Anticline 561-579 m, Glacier Fjord 1180-1200 m.

Remarks. This zone is an interval-zone and is therefore indistinguishable from Oppel-Zone M when only a few species are found. The base is defined by the first appearance of *S. cuculliformis* (Plate 10, fig. 1-4). The top is defined by the base of Oppel-Zone O; however, last appearances of *L. perforans* or *P. borealis* (Plate 2, fig. 21) are indications of the upper portions of the zone. *Sirmiodinium grossi, T. rhombiformis* and *Lunatadinium dissolutum* are the dominant microfloral elements.

Age. The first appearance of *S. cuculliformis* occurs at the base of Oppel-Zone N and indicates a Berriasian or younger age. *E. rudis* has not been found in strata younger than the Early Berriasian (Brideaux, 1977a). The presence of *L. foveolata* and *S. reticulata* also suggests a Berriasian or younger age. The last appearance of *P. borealis* near the top of the zone implies an Early Valanginian or older age. No macrofossils have been found that are directly correlative with this zone but it probably corresponds to the interval ranging from the *Subcraspedites* aff. *suprasubditus* Zone to the base of *Buchia keyserlingi* Zone of the Late Berriasian-earliest Valanginian (Jeletzky, 1969). *Temnoptychites kemperi* occurs near the base of Oppel-Zone O and indicates an upper limit of early Early Valanginian to Oppel-Zone N (Kemper, 1977). A Berriasian age is assigned to Oppel-Zone N.

O. *Tanyosphaeridium magneticum* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Tanyosphaeridium magneticum.*

Taxa Which Occur Within And Below The Zone. *Apteodinium granulatum, Trichodinium erinaceoides.*

Taxa Which Occur Within And Above The Zone. *Apteodinium apiatum, Apteodinium spongiosum, Canningia circularis, Cribroperidinium muderongense, Dingodinium cerviculum, Heslertonia heslertonensis, Gochteodinia villosa, Imbatodinium jaegeri, ?Kallosphaeridium agglutinatum, Millioudinium episomum, Muderongia tomaszowensis, Odontochitina operculata, Oligosphaeridium albertense, Oligosphaeridium complex, Oligosphaeridium totum.*

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium conjunctum, Canningia ringnesiorum, Ellipsoidictyum* sp. cf. *E. cinctum, Exochosphaeridium scitulum, Gonyaulacysta helicoidea, Lecaniella foveolata, Leptodinium hyalodermopsis, Lunatadinium dissolutum, Microdinium opacum, Oligosphaeridium anthophorum, Pareodinia ceratophora, Prolixosphaeridium spissum, Sentusidinium cuculliformis, Sentusidinium filiatum, Sirmiodinium grossii, Tanyosphaeridium isocalamum, Tubotuberella apatela, Tubotuberella rhombiformis.*

Distribution. Reindeer Peninsula 350 m, North Amund Ringnes Dome 960-1060 m, Central Amund Ringnes Dome 1320-1441 m, Jaegar River 975-988 m, Skaare Anticline 641-732 m, Blueman Cape 605-620 m, Fosheim Anticline 588 m.

Remarks. The base of this zone is marked by an influx of chorate species such as *Oligosphaeridium albertense*, O. *complex* and *O. totum*. Throughout the zone there is a rapid increase in the number of species that continue through the next two higher zones. The species *T. magneticum* (Plate 8, fig. 1-8, 11, 12) is distinctive and may range on occasion just into the base of Oppel-Zone P. Relatively few species have last appearances within this zone. A rare specimen of *P. borealis* has been found but may be attributed to reworking. The first appearance of pseudoceratiacean genera occurs within the zone, such as *Imbatodinium, Odontochitina* and *Muderongia.*

Age. Oppel-Zone O is assigned an Early to possibly Late Valanginian age by the first appearances of *I. jaegeri, O. operculata,* and *O. complex*. The youngest limit for this zone is not well defined. Hauterivian and Barremian forms such as *H. heslertonensis, C. muderongense, M. episomum, O. albertense*, and *O. totum* have their first appearances within this zone. The presence of *S. cuculliformis* implies a Valanginian or older age. The presence of the ammonite *Temnoptychites kemperi* between the defined boundaries of Oppel-Zones N and O and the presence of ammonites *Thorsteinssonoceras ellesmerense* and *Polyptychites (Siberiptychites) stubendorffi* in the North Amund Ringnes Dome within Oppel-Zone O suggests a Early Valanginian age (Kemper, 1977). Also included are the beds of *Polyptychites (Polyptychites) tschekanowskii* (late Early Valanginian age) and *Ringnesiceras (Ringnesiceras) pseudopolyptychum* (earliest Late Valanginian age) described by Kemper and Jeletzky (1979). This is in agreement with the age assignment based on dinoflagellate assemblages which together suggest an Early to early Late Valanginian age for Oppel-Zone O.

P. *Muderongia simplex* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Cyclonephelium distinctum, Muderongia simplex, Nelchinopsis kostromiensis.*

Taxa Which Occur Within And Below The Zone. *Apteodinium apiatum, A. spongiosum, Cleistosphaeridium* sp. A, *Cribroperidinium muderongense, Ellipsoidictyum cinctum, Ellipsoidictyum* sp. cf. *E. cinctum, Escharisphaeridia rudis, ?Kallosphaeridium agglutinatum, Gochteodinia villosa, Heslertonia heslertonensis, Lunatadinium dissolutum, Microdinium opacum, Millioudodinium episomum, Muderongia tomazsowensis, Odontochitina operculata, Oligosphaeridium anthophorum, Pareodinia ceratophora, Prolixosphaeridium spissum, Schizosporis reticulatus, Scriniodinium crystallinum, Sentusidinium cuculliformis, Tubotuberella rhombiformis.*

Taxa Which Occur Within And Above The Zone. *Imbatodinium micropodum.*

Taxa Which Occur Within, Above And Below The Zone. *Apteodinium conjunctum, Canningia circularia, Dingodinium cerviculum, Escharisphaeridia ringnesiorium, Exochosphaeridium scitulum, Gonyaulacysta helicoidea, Imbatodinium jaegeri, Lecaniella foveolata, Leptodinium hyalodermopsis, Oligosphaeridium albertense, Oligosphaeridium complex, Sirmiodinium grossii, Sentusidinium filiatum, Tanyosphaeridium isocalamum.*

Distribution. Reindeer Peninsula 372-402 m, North Amund Ringnes Dome 1104-1204 m, Central Amund Ringnes Dome 1450 m, east of Central Amund Ringnes Dome 30-87 m, Cape Ludwig 1300-1400 m, northwestern Cornwall Island 670-900 m, Skaare Anticline 740-870 m, Blueman Cape 649-654, Fosheim Anticline 610-628 m.

Remarks. The base of this zone is marked by the first appearance of *Muderongia simplex* (Plate 7, fig. 17) or *Imbatodinium micropodum*. Only one questionable specimen of *M. simplex* has been found above this zone. The presence of this species is most characteristic of this zone; however, *M. simplex* is known to range into the Barremian in other areas. The top of this zone is distinguished by the last appearances of several species, in particular *A. apiatum* and *A. spongiosum*. This zone has the second highest species diversity within the interval examined.

Age. The concurrence of *N. kostromiensis* and *S. cuculliformis* suggests a Valanginian age for Oppel-Zone P. The macrofossils present in Central Amund Ringnes Dome within Oppel-Zone P, *Ringnesiceras (Ringnesiceras) tozeri* beds and the *Ringnesiceras (R) amundense* beds described by Kemper and Jeletzky (1979), indicate a middle Late to late Late Valanginian age.

Q. *Fromea atlantica* Oppel-Zone

Taxa Which Occur Solely Within The Zone. *Fromea atlantica, Hystrichosphaeridium sp.*

Taxa Which Occur Within And Below The Zone. *Apteodinium conjunctum, Canningia circularis, Canningia ringnesiorum, Gonyaulacysta helicoidea, Imbatodinium jaergeri, Imbatodinium micropodum, Lecaniella foveolata, Leptodinium hyalodermopsis, Muderongia simplex* (questionable specimen), *Dingodinium cerviculum, Exochosphaeridium scitulum, Oligosphaeridium albertense, Oligosphaeridium complex, Pareodinia ceratophora, Sentusidinium filiatum, Sirmiodinium grossii, Tanyosphaeridium isocalamum.*

Taxa Which Occur Within And Above The Zone. Indeterminate (top of section studied).

Distribution. Reindeer Peninsula (provisionally) 897 m, North Amund Ringnes Dome 1239 m, Central Amund Ringnes Dome 1534-1553 m, east of Central Amund Ringnes Dome 25 m, Skaare Anticline 897 m, Blueman Cape 666-675 m.

Remarks. The base of the zone is marked by the large number of last appearances of species at the top of Oppel-Zone P. There are also many last appearances throughout the lower portions of the zone. The upper boundary is indistinct because of the facies change to the coarse clastic Isachsen Formation of marginal marine to nonmarine paleoenvironment. Due to the increase in terrestrial detritus, dinoflagellate recovery was poor, except for North Amund Ringnes Dome where the first appearance of *Fromea atlantica* (Plate 6, fig. 24, 25) occurs.

Age. Oppel-Zone Q is assigned a tentative age of late Late Valanginian to possibly Hauterivian. *Sirmiodinium grossii* ranges into Hauterivian and possibly younger strata. Most other species have ranges that continue higher into the middle Cretaceous. The latest Late Valanginian pelecypod, *Buchia* ex gr. *inflata sublaevis*, is present in Central Amund Ringnes Dome at the base of Oppel-Zone Q (Kemper, 1977). A positive age assignment cannot be given to the highest beds (60 m) of Oppel-Zone Q due to the scarcity of macrofossils (Kemper, 1975, 1977). The upper portions of Oppel-Zone Q may therefore be younger than Valanginian.

Comparisons with other Zonations

Five zonal schemes have been previously proposed for portions of the Jurassic and Lower Cretaceous of the Sverdrup Basin (Felix, 1975; Johnson, 1974; Johnson and Hills, 1973; Pocock, 1976; Zeiss, 1977; Doerenkamp et al.,1976). They are discussed below in ascending stratigraphic order.

Felix (1975)

Felix (1975, p. 116, pl. 2) listed ranges of species from the Savik Formation and Heiberg Formation based on Johnson and Hills (1973) and Felix's own work on outcrop and subsurface material distributed across the basin. He then compared palynologically three samples that he collected which were supposedly comparable to Stott's (1969) collections on Reindeer Peninsula, Ellef Ringnes Island. Stott's collections range from Early Toarcian to Bathonian as dated with macrofossils. The three samples were assigned to the Triassic by Felix when compared to his palynological range chart. He concluded therefore, that those samples were attributable to the Heiberg Formation. Contrary to this several samples collected for this present study were also derived from horizons comparable in age and location to Stott's collections and clearly show Oppel-Zones B (Toarcian) and younger. Considering the extensive faulting in the area, it seems probable that the collections of Felix (1975) were not identical to those made by Stott (1969).

Jurassic Range-Zonal Scheme of Johnson and Hills (1973)

Johnson and Hills (1973) and Johnson (1974) presented the first biostratigraphic zonation based on dinoflagellate cysts for the Jurassic of the Sverdrup Basin. This work was a significant contribution towards developing a comprehensive dinoflagellate cyst zonal scheme, in spite of the choice of a highly thermally degraded

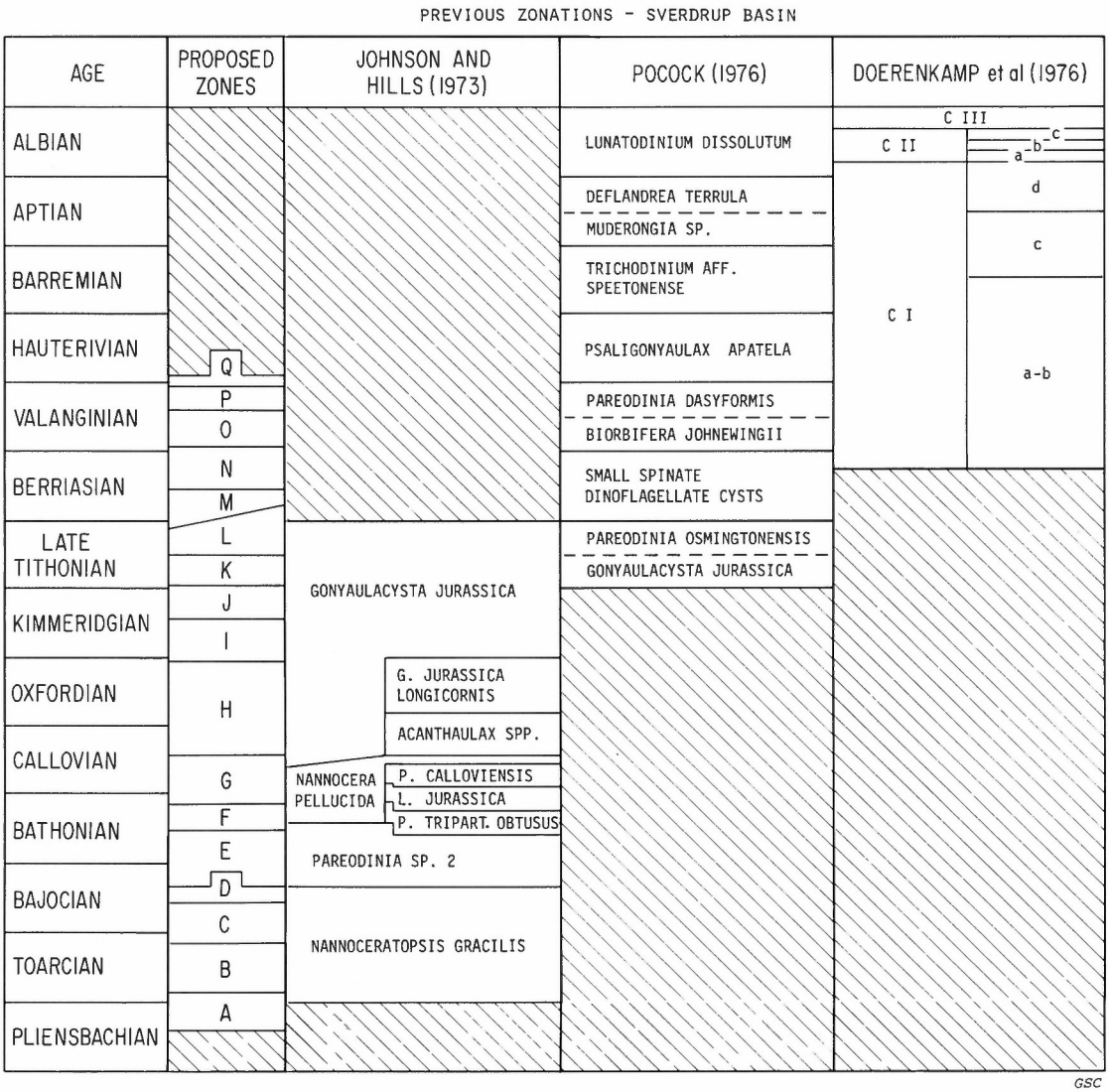


Figure 5. Previous Jurassic-Cretaceous dinoflagellate cyst zonations for Arctic Canada.

section (Vantage Point, western Axel Heiberg Island) on which to base this preliminary study. Johnson and Hills (1973) defined four range-zones, four range-subzones, one concurrentrange-zone and one peak-zone (Fig. 5). The following is a discussion of the potential of their zonal scheme and its relationship to the Oppel-zonation proposed herein.

***Nannoceratopsis gracilis* Range-Zone.** This zone occurs in higher stratigraphic horizons than was found by Johnson and Hills (1973). Concurrence of *N. gracilis* with *Nannoceratopsis pellucida* and *Glomodinium tripartitum* (alias *Pareodinia tripartitum)* is frequent. Within the *N. gracilis* Range-Zone, the many other species such as *Comparodinium aquilonium, Phallocysta eumekes,* and *Susadinium scrofoides*, found in Oppel-Zone B were not observed by Johnson and Hills (1973).

***Pareodinia* sp. 2 Range-Zone.** The generic assignment of this species is in question. From the poorly preserved material illustrated it may be attributable to *Glomodinium*, possibly G. *evittii* which has proved to be of limited biostratigraphic use because of its varied and infrequent occurrences.

***Nannoceratopsis pellucida* Range-Zone.** *N. pellucida* occurs erratically, in abundance at various stratigraphic levels within Oppel-Zones D to H and at a few geographical localities across the Sverdrup Basin. The establishment and recognition of this zone, therefore, is strongly dependent on paleoenvironmental and paleoecological factors.

***'Pareodinia' tripartitus* var. *obtusus* Subzone.** *Glomodinium tripartitum* is the name-species of this zone. In the present study it has been found to be highly variable in size and shape; therefore, the varieties as proposed by Johnson and Hills (1973) have not been recognized nor applied biostratigraphically. Morphological variation within this species has not been found to be stratigraphically controlled. *Glomodinium tripartitum* ranges through Oppel-Zones E to H and is used as a key species in recognition of the base of Oppel-Zone E and the top of Oppel-Zone H.

***Leiofusa jurassica* Peak Zone.** *L. jurassica* did not form a significant portion of the palynomorph assemblages in this study; therefore, the lateral extent of this peak zone does not appear to be extensive.

***Paragonyaulacysta calloviensis* Subzone.** This subzone is relatively well defined and may be compared directly to Oppel-Zone G where either *Paragonyaulacysta retiphragmata* or *P. calloviensis* may occur. Both species are rare, making it necessary to define Oppel-Zone G on more species than the above two.

***Gonyaulacysta jurassica* Range-Zone.** In the present study *G. jurassica* has been shown to range from Oppel-Zone G to H. The *G. jurassica* Range-Zone of Johnson and Hills (1973) overlaps with the top of their *Nannoceratopsis pellucida* Range-Zone and correlates with Oppel-Zones G to L. *Gonyaulacysta dualis*, a closely

related species, ranges from Oppel-Zones H to L. It appears that the range of *G. dualis* was probably incorporated into the concept of the *G. jurassica* Range-Zone, since the only significant difference between *G. jurassica* and *G. dualis* is a slight antapical pericoelar development in the latter. The erection of *G. dualis* as a separate species by Brideaux and Fisher (1976) postdates the Johnson and Hills study.

***Acanthaulax* spp. Subzone.** *Acanthaulax* sp. A and *Acanthaulax* sp. B of Johnson and Hills (1973) are considered to be within the species variation of *Acanthaulax senta* described by Drugg (1978). Variation between the above species is not stratigraphically controlled. The occurrence of *A. senta* is frequent and characterizes Oppel-Zones G to H; thus, it is a useful index species.

***Gonyaulacysta jurassica* var. *longicornis* Subzone.** A morphological continuum ranges from the slightly cavate *G. jurassica jurassica* through *G. jurassica longicornis* with an apical pericoel to *G. dualis* with both strongly developed apical and antapical pericoels; therefore, the delimitation of these forms is somewhat arbitrary. The subzone proposed by Johnson and Hills would be correlative with the upper portion of Oppel-Zone H.

Zonal schemes such as that of Johnson and Hills, based on range-zones of single species, tend to degenerate in chronostratigraphic significance when correlating and extrapolating to other stratigraphic sections. This develops because local species ranges are for the most part facies controlled (Shaw, 1964; Hedberg, 1976) and, therefore, such schemes are of limited use in chronostratigraphic applications.

Preliminary Assemblage Zones of Pocock (1976)

Pocock's (1976) preliminary zonation of the uppermost Jurassic and lower part of the Cretaceous outlined ten informal assemblage zones (Fig. 5). The five lower zones are roughly correlative to Oppel-Zones K-Q (Tithonian-Valanginian).

***Gonyaulacysta jurassica* Assemblage-Zone.** This lowest zone was said to range into the Tithonian; however, *G. jurassica* has not been found in strata of Tithonian age within the present study. Pocock (1976, Plate 1, fig. 1) illustrated a specimen of *G. jurassica* but stated that it was probably Oxfordian in age. Perhaps the forms found in the Tithonian are attributable to the closely related species, *G. dualis*.

***'Pareodinia osmingtonensis' (Paragonyaulacysta borealis)* Assemblage-Zone.** The establishment of this assemblage zone by Pocock was based on poorly preserved samples from only two localities. He restricted its range to the Tithonian; however, the species ranges into the upper beds of Oppel-Zone N and also ranges into the Berriasian according to Brideaux and Fisher (1976).

Small Spinate Dinoflagellate Cyst Zone. No distinctive interval of small spinate dinoflagellate cysts as reported by Pocock (1976, p. 103-104) has been recognized within Oppel-Zones L-N which are comparable in age to his 'intra-zone.' *Exochosphaeridium scitulum*, however, appears near the top of Oppel-Zone M and continues to the top of Oppel-Zone O and may be a component of his small spinate dinoflagellate cyst group. Perhaps *Trichodinium erinaceoides* from Oppel-Zones M-O is also a representative of this group.

***Biorbifera johnewingii* Assemblage Zone.** This zone could not be identified in the present study since no forms similar to *B. johnewingii* were recorded. The illustration of *B. johnewingii* by Pocock (1976, Plate 1, fig. 7) raises doubt as to its correct identification as it appears similar to an equatorial view of an apiculate trilete spore. No specimens of *Druggidium deflandrei* were found in Oppel-Zones M to O. Pocock's illustration of *D. deflandrei* (Plate 1, fig. 12) suggests that the species may be *Microdinium opacum*. In the present study *M. opacum* is often abundant within the Berriasian-Valanginian interval but is not indicative of a Berriasian age.

***'Pareodinia dasyforma'* (alias *Gochteodinia villosa*) Assemblage-Zone.** This assemblage-zone according to Pocock (1976, p. 105), has upper limits within the zone of *Buchia keyserlingi*. This statement contradicts both his range chart (textfigure 2, p. 106) where *'P. dasyforma'* ranges up into the Hauterivian, and the established range of *Buchia keyserlingi* (last appearance in the early Late Valanginian; Kemper, 1977; see Fig. 2). Equivalent zones would be Oppel-Zones O to P.

***'Psaligonyaulax apatela'* Assemblage-Zone.** This assemblage-zone is questionably defined as well. The specimen illustrated as *'P. apatela'* in Pocock (1976, Plate 1, fig. 8) has clear tabulation which is not within the variation of the species and is more likely *Tubotuberella rhombiformis*. Furthermore, Pocock states that the species ranges from the Upper Jurassic through the Hauterivian; such a long ranging species is of doubtful value in defining an assemblage zone with a supposedly short time interval. In fact, many samples examined in the present study from the Berriasian and Valanginian contain assemblages composed almost entirely of *T. rhombiformis*.

Younger Zones. Assessments of Pocock's younger zones are beyond the scope of this study.

Assemblage Zonation of Zeiss (1977)

Zeiss (1977) listed in abstract form five informal assemblage zones (A-E) from Oxfordian and older to Hauterivian and younger strata in the Sverdrup Basin. Comparison with the above Oppel-zonation is not possible due to the lack of published details.

Palynozones of Doerenkamp, Jardiné and Moreau (1976)

Doerenkamp et al. (1976) outlined an informal scheme of 'palynozones' using both miospores and dinoflagellate cysts for the Cretaceous-Tertiary strata on Banks Island and adjacent areas, including the western islands of the Sverdrup Basin (Mackenzie King, Prince Patrick, Melville,and Eglington islands). Assemblages from the Horton River area and Richardson Mountains were also considered. The lower zone CI (*Trilobosporites-Classopollis* zone) is characterized by *Trilobosporites, Concavissimisporites, Callialasporites* and *Cerebropollenites* with several species of *Cicatricosisporites* and *Plicatella* (*'Appendicisporites'*). Within this zone four subzones, CIa-d, were recognized. The lower two subzones, CIa-b, were recognized from the Mould Bay Formation and Isachsen Formation on Prince Patrick Island and Mackenzie King Island. These subzones appear approximately correlative with Oppel-Zones N-Q. The exact relationship between their zonal scheme and the present one cannot be determined since Doerenkamp et al. (1976) did not elaborate on details of the two lowermost subzones, concentrating instead on the Isachsen and younger formations. Some resemblance is apparent, however, between the microplankton of subzones CIIa,b and Oppel-Zones P and Q. Both have the following species in common: *Apteodinium maculatum, Imbatodinium jaegeri, Odontochitina operculata, Oligosphaeridium anthophorum* and *O. complex. Other species, however, such as Cyclonephelium eisenackii, Luxadinium propatulum* and *Pseudoceratium* cf. *P. pelliferum*, have not been found in the present study and most likely indicate the presence of younger strata in subzones CIIa-b than in Oppel-Zones P, or Q.

SYSTEMATICS OF NEW AND SELECTED TAXA

Classification

The suprageneric classification devised by Norris (1978a,b) is employed along with emendations made by Dörhöfer and Davies (1980) and Artzner et al. (1979).

Terminology

Descriptive terms used in this study are as outlined by Williams et al. (1978). Evitt et al. (1977) proposed several new terms and alterations. These are employed with the exception of the prefix 'para-' which has been assessed and rejected by Norris (1978a,b) and Dörhöfer and Davies (1980). New terminology proposed by Norris (1978a) and Dörhöfer and Davies (1980) is also employed. Round brackets are used instead of superscript bars to indicate compound opercular pieces in archeopyle notations (Norris, 1978a). The terminology for basic cyst morphotypes is used as in Artzner et al. (1979). A new term is introduced: *antennule* (a small antenna) referring to the distal termination of the apical horn when condensed into a solid process-like feature as in the holotype of *Glomodinium zabros* sp. nov.

Size measurements are given in the following convention:
minimum (mean) maximum

The International code of Botanical Nomenclature (Leningrad, 1975) is abbreviated as ICBN.

Systematic Descriptions

Division PYRRHOPHYTA Pascher
Class DINOPHYCEAE Fritsch
Order PERIDINIALES Haeckel
Suborder RHAETOGONYAULACINEAE Norris

Family RHAETOGONYAULACACEAE Norris emend. Dörhöfer and Davies
Genus *Dapcodinium* Evitt emend. Dörhöfer and Davies

1961a *Dapcodinium* Evitt, p. 996
1972 *Opaeopsomus* Evitt; Pocock, p. 96-97
1973 *Opaeopsomus* Pocock (auct. non Evitt); Lentin and Williams, p. 101
1980 *Dapcodinium* Evitt, 1961a emend. Dörhöfer and Davies, p. 23

Type Species. *Dapcodinium priscum* Evitt, 1961a

Dapcodinium coalitum sp. nov.
Plate 1, figures 1-8; Figure 6

1979 *Maturodinium* cf. *inornatum* Morgenroth, 1970; Wille and Gocht, 1979, Fig. 29/11a,b
1980 *Dapcodinium* sp. A Dörhöfer and Davies, Fig. 22-D
1980 *Dapcodinium semitabulatum* (Morgenroth) Dörhöfer and Davies (en pars.), Fig. 25-G.

Name Derivation. *Coalitum* (L: *coalescere* = to grow together, to merge) referring to the coalescent appearance of the granules.

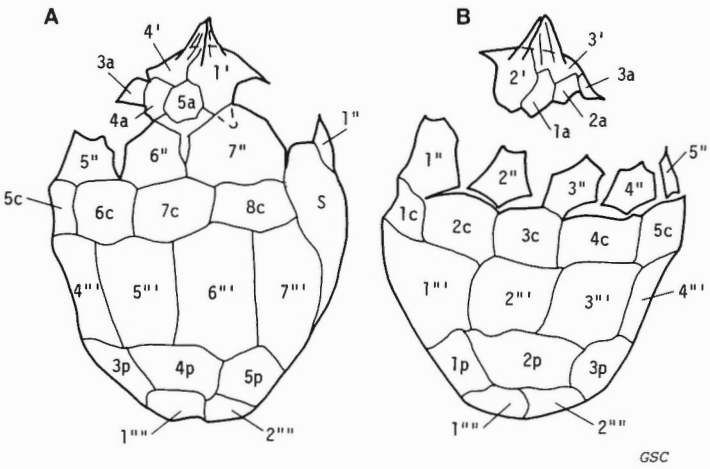


Figure 6. *Dapcodinium coalitum* sp. nov. holotype. A, Right lateral view; B, Left lateral view. Tabulation: 4',5a,7",8c,7"',5p,2"",1s. Archeopyle: 4A5I7P, disintegration type.

Type Stratum and Locality. Lower Savik Formation, 52 m below the top (cuttings sample) Elf Jameson Bay C-31 well, cuttings sample 587 m (1950 ft), Prince Patrick Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide JB 1950A, co-ordinates L36/2; Plate 1, figures 7, 8; ROM 36552
Size: length – 53 μm; breadth – 46 μm.

Diagnosis. A species of *Dapcodinium* with a short fibrous apical horn, rounded antapex, indistinct cingulum and a slightly invaginated sulcus. Ornament densely granulate, granules small and coalescent with rare short spines. Sutures are expressed by narrow pandasutural zones.
Tabulation: 4', 5a, 7", ?8c, 7"', 5p, 2"", ?s.
Archeopyle: (4A5I) + 7P, disintegration type.
Size: length – 45(49)57 μm; breadth – 33(45)54 μm (10 measured specimens).

Description. The shape is oblate with a proximate wall structure. The fibrous apical horn arises from all four apical plates and terminates raggedly (4-5 μm long). The granulate ornament is dense, so that the granules coalesce resulting in a spongy appearance. The sutures are apparent through a reduction in ornament. Up to five small processes (2 μm high) may form on the epicyst. The disintegration archeopyle may be found at various stages of development from being intact to the complete loss of all apical, intercalary and precingular plates.

Remarks. *D. priscum* and *D. wapellense* differ from *D. coalitum* in lacking ornament and in possessing only one antapical plate. *D. ornatum* differs in possessing only four intercalary plates and having smaller ornament.

Distribution. *D. coalitum* is present in Oppel-Zones A, B, and C, Toarcian or older to Early Bajocian.

Dapcodinium holotabulatum sp. nov.
Plate 1, figures 9-19; Figure 7

1980 *Dapcodinium* sp. B Dörhöfer and Davies, Fig. 22-G, I

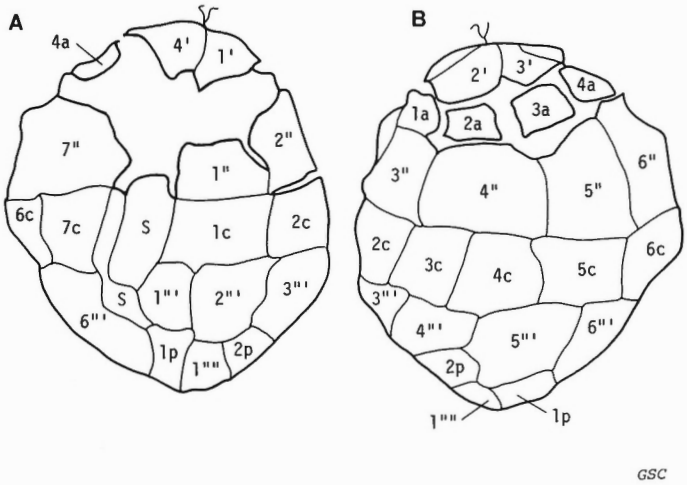


Figure 7. *Dapcodinium holotabulatum* sp. nov. holotype.
A, Ventral view; B, Dorsal view.
Tabulation: 4',4a,7",7c",6"',2p,1"",2s.
Archeopyle: 4A4I7Pa, disintegration type.

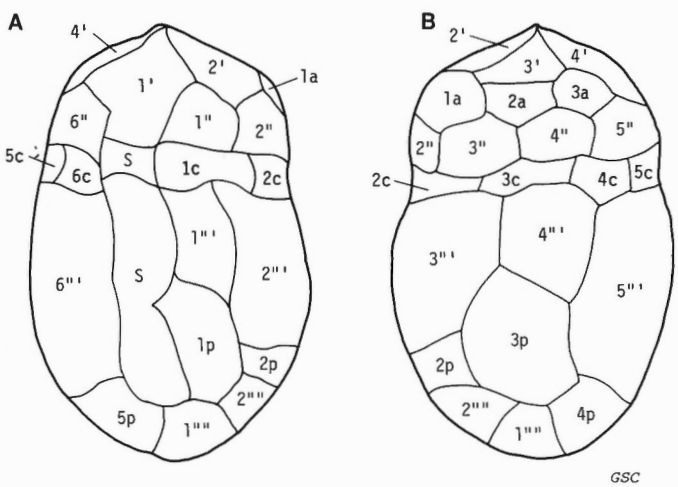


Figure 8. *?Egmontodinium diminutum* sp. nov. schematic drawing from holotype.
A, Ventral view; B, Dorsal view.
Tabulation: 4',3a,6",6c,6"',5p,2"",2s.
Archeopyle: 4A3I.

Name Derivation. *Holo* (Gk: *holos* = whole), *tabulatum* (L: *tabula* = plate), to refer to the presence of tabulation on the entire cyst.

Type Stratum and Locality. Savik Formation, 1.5-5 m below the top (well cuttings). Panarctic Sandy Point L-46 well, cuttings sample 573 m (1880 ft), District of Franklin, Northwest Territories, Canada.

Holotype. Slide SP 1880F, co-ordinates H42/0, Plate 1, figures 9-11; GSC #69359.
Size: length – 46 μm; breadth – 50 μm.

Diagnosis. A species of *Dapcodinium* with coarsely granulate surface. Sutures represented by lines of granules or spines. Small apical horn sometimes present. Cingulum of variable width.
Tabulation: 4', 4a, 7", 7c, 6"', 2p, 1"", 3s, 1pv.
Archeopyle: (4A) + 4I + $7P_{?a}$.
Size: length – 45(48) 55 μm; breadth – 37(43)55 μm (10 measured specimens).

Description. Proximate dinoflagellate cyst, almost spherical to slightly elongate. Short apical horn occasionally present; epicyst usually ruptured. Surface coarsely granulate. Sutures formed by densely aligned granules (less than 0.5 μm) with rare spines occasionally coalescing to form low ridges, up to 1 μm high.

Remarks. *D. semitabulatum* differs from *D. holotabulatum* by its incomplete tabulation, finer ornament and smaller size. *D. ornatum* differs in its smaller size and in that the sutures are marked by pandasutural zones.

Distribution. *D. holotabulatum* is present in Oppel-Zones A, B, C, D, E and F, Toarcian or older to Bathonian.

Genus *Egmontodinium* Gitmez and Sarjeant

1972 *Egmontodinium* Gitmez and Sarjeant, p. 228-231

Type Species. *Egmontodinium polyplacophorum* Gitmez and Sarjeant, 1972

?Egmontodinium diminutum sp. nov.
Plate 2, figures 4-8; Figure 8

Name Derivation. *Diminutum* (L: *diminutu(us)* = lessened) referring to the small size of the cyst.

Type Stratum and Locality. Savik Formation, approximately 175 m below the top. Sample ED 1009-1, Central Amund Ringnes Dome, Amund Ringnes Island, District of Franklin, Canada.

Holotype. Slide ED 1009-1A, co-ordinates Q39/2; Plate 2, figures 6-7; ROM 36635.
Size: length – 41 μm; breadth – 24 μm.

Diagnosis. Ellipsoidal proximate dinoflagellate cyst without apical or antapical horns. Ornament granulate to spinate, sutures marked by aligned and coalescent granules and spines usually larger than the fine intratabular ornament.
Tabulation: 4', 3a – 5a, 6", 6c, 6"', 5p, 2"", 3s with geniculate 2a plate boundaries.
Archeopyle: (4A3I) + $6P_a$.
Size: length – 25(34)45 μm; breadth – 22(25)33 μm (16 measured specimens).

Description. The posterior intercalary series is a circlet of plates with the dorsal 3p relatively large. The anterior intercalaries are variable with three, four or, infrequently, five which remain attached to the apical operculum. The operculum hinges on plate 1' at the sulcal notch but usually is found detached. Often the precingular plates develop accessory archeopyle sutures. The cingulum is slightly laevo-rotary, variable in width and often greater than one-fifth of the total length of the cyst. Sutural spines (less than 1.2 μm) are present.

Remarks. *Egmontodinium polyplacophorum* differs by its larger size (60-80 m), lack of granulation, and the development of delicate sutural crests. The archeopyle of this species develops by splitting through the intercalary plates whereas in *?E. diminutum* the intercalaries are removed entirely with the operculum. *?E. diminutum* is tentatively placed in *Egmontodinium* because it possesses a fewer number of anterior and posterior intercalary plates than the type species *E. polyplacophorum*.

Distribution. *?E. diminutum* is present in Oppel-Zones F, G and H, Late Bathonian to Oxfordian.

?Egmontodinium sp. cf. *?E. diminutum* sp. nov.
Plate 2, figures 1-3

Description. A species of questionable affinity to *Egmontodinium*. An ellipsoidal proximate cyst, without apical or antapical horns. Ornament densely granulate resulting in a spongy textured periphragm. Ornament reduced on the cingulum. Cingulum bounded by alignment of coalescent granules. Other sutural traces not defined. Archeopyle suture suggests a similar archeopyle to *?E.diminutum*, i.e. $(4A3I)+6P_a$.
Size: length – 27-29 μm; breadth – 21-22 μm (2 measured specimens).

Remarks. Only two specimens have been found; therefore, a new species is not erected. The overall shape, the wide cingulum, archeopyle, and size are similar to *?E. diminutum*. The ornament, however, is densely granulate and clearly distinguishes it as a separate species.

Distribution. *?E.* sp. cf. *?E. diminutum* is present in Oppel-Zone G, Late Bathonian to Early Callovian.

Family PHALLOCYSTACEAE Dörhöfer and Davies
Genus *Comparodinium* Morbey emend. Wille and Gocht

1975 *Comparodinium* Morbey, p. 43.
1979 *Comparodinium* Morbey emend. Wille and Gocht, p. 226-228.

Type Species. *Comparodinium koessenium* Morbey, 1975

?Comparodinium cavum sp. nov.
Plate 2, figures 10-15; Figure 9

Name Derivation. *Cavum* (L:*cavum* = hollow) referring to the cavate nature of the cyst.

Type Stratum and Locality. Lower Savik Formation (30 m below base of Jaeger Formation). Sample ED 1029-1, Reindeer Peninsula, Ellef Ringnes Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1029-1A; co-ordinates: 043/4, Plate 2, figures 10,11; ROM 36619.
Size: Length – 34 μm; breadth – 29 μm.

Diagnosis. A membranate dinoflagellate cyst species with a highly refractive autocyst, ovoidal in shape, and a thin hyaline ectophragm; with bifurcate processes grouped in apical, antapical and cingular locations, and thus developing three ectocoels in separate locations.
Tabulation: ?5', 3-?4a, 8", ?c, 8", 5p, 2"", ?s.
Archeopyle: $4A_{1-4}+3I_{1-3}$.
Size: length – 31(35)37 μm; breadth – 22(27)29 μm (7 measured specimens).

Description. The bifurcate processes are 2-3 μm long. The cingular processes form a double row which encircles the cyst. On well preserved specimens a thin ectophragm covers the processes creating three ectocoels corresponding to the groups of processes. The cingular ectocoel is widely separated from the polar ectocoels and occasionally may be reduced or faintly evident. Tabulation is indistinct, formed by faint lines on the periphragm and by archeopyle sutures. The archeopyle appears to be a disintegration type as defined by Dörhöfer and Davies (1980). Accessory sutures are found among both the intercalary plates and the precingular plates. A long narrow sulcus is present.

Remarks. *Comparodinium* includes species without cingular processes and ectocoels which are present, however, in *?C. cavum*; therefore the placement of this species in *Comparodinium* is tentative. The polar arrangement of the processes, the occasional reduction of the cingular processes and the similarity in archeopyle formation and tabulation indicate strong affinities to *Comparodinium*. *C. lineatum* possesses trabaculae and has close affinities to *?C. cavum*. The possession of the polar ectocoels and the intercalary plates is similar to *?Gillinia* sp. of Dodekova (1975); however, *?Gillinia* sp. of Dodekova (1975) does not have supporting processes. *Cleistosphaeridium* does not have ectocoels nor the alignment of processes shown by this species. *Chlamydophorella* possesses an entire enveloping ectophragm.

Distribution. *?C. cavum* is present in Oppel-Zones B and D, Toarcian to Bajocian.

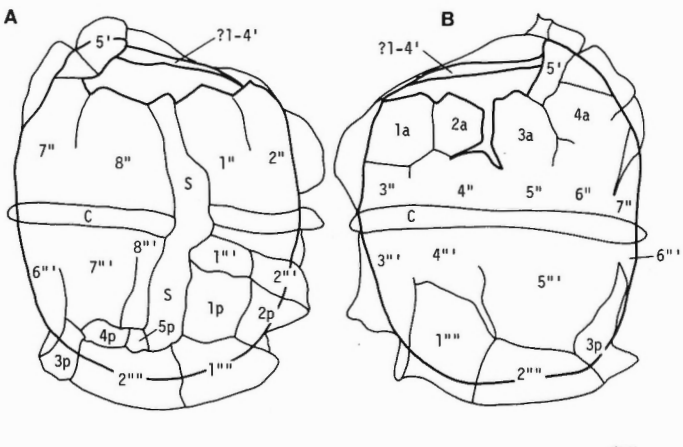


Figure 9. *?Comparodinium cavum* sp. nov. holotype.
A, Ventral view; B, Dorsal view.
Archeopyle: $4A_{1-4}+3I_{1-3}$.
Tabulation: ?5',3-?4a,8",?c,8"',5p,2"",?s.
Processes not shown.

Family PAREODINIACEAE Gocht emend. Dörhöfer and Davies
Genus *Glomodinium Dodekova*

1975 *Glomodinium* Dodekova, p. 26

Type Species. *Glomodinium reticulopilosum* Dodekova, 1975

Remarks. Stover and Evitt's (1978, p. 116-117) inclusion of this genus in *Pareodinia* (following Wiggins, 1975) is rejected. Dodekova (1975) and Dörhöfer and Davies (1980) concept for this genus as having a 3I archeopyle is retained.

Glomodinium evittii (Pocock) comb. nov.
Plate 3, figure 1

1972 *Tenua evittii* Pocock, p. 94, 95, Pl. 24, Fig. 6,8.
1975 *Pareodinia evittii* (Pocock 1972) Wiggins, p. 105, Pl. 3, Fig. 9.
1975 *Glomodinium evittii* (Pocock 1972) Dodekova (nomen nudum), p. 27.

Remarks. This species was improperly transferred from *Tenua* to *Glomodinium* by Dodekova (1975, p. 27) because there was no citation of the page number of the original description (ICBN, Article 33). It is herein correctly transferred. *G. evittii* differs from *G. tripartitum* by its granulate ornament, the latter being smooth. *G. reticulopilosum* differs by its more strongly developed and complex ornament, which comprises finely reticulate autophragm and a kalyptra structured with radial fibrils.

Distribution. *G. evittii* is present in Oppel-Zones A, C and H, Toarcian to Oxfordian.

Glomodinium opeasatos sp. nov.
Plate 3, figures 13-16; Figure 10

Name Derivation. *Opeas(atos)* (G:*Opeas* = awl) referring to the overall shape.

Type Stratum and Type Locality. Savik Formation 85 m below the base of the Awingak Formation. Sample ED 1009-3, Central Amund Ringnes Dome, Northwest Territories, Canada.

Holotype. Slide ED 1009-3A; co-ordinates O46/0, Plate 3, figure 13; ROM 36637.
Size: length – 133 μm; breadth – 42 μm.

Diagnosis. A species of *Glomodinium* ellipsoidal in shape with a long tapering apical horn (greater than 1/3 the total length of the cyst). The autophragm is smooth to finely pitted, occasionally covered with a kalyptra. No visible tabulation is present.
Archeopyle: 3I.
Size: length 90(114)133 μm; breadth 42(49)53 μm (five measured specimens).

Description. The apical horn length varies from 39 to 46 μm. It is narrow and tapers to a rounded point. A rudimentary antapical horn is occasionally developed as a slight bulge. The kalyptea is thin and more greatly developed over the apical horn in the holotype. An omphalos is often present. Faint tabulation traces may be discerned but they are too indistinct and discontinuous to resolve the pattern.

Remarks. *Glomodinium opeasatos* has a much longer apical horn than *G. tripartitum*, but, it is similar in all other respects, namely 3I archeopyle and smooth autophragm. *Pareodinia prolongata* Sarjeant, 1959 is similar; however, the main body is more global, the horn more slender and aculeate, and the exact mode of archeopyle formation (2I or 3I) is not known.

Distribution. This species is present in Oppel-Zones G and H, Late Bathonian to Oxfordian.

Glomodinium tripartitum (Johnson and Hills) comb. nov.
Plate 2, figure 22

1973 *Pareodinia tripartita* Johnson and Hills, p. 12, Pl. 2, Fig. 12-14, 17, 18.
1975 *Glomodinium tripartitus* (Johnson and Hills) Dodekova (nomen nudum), p. 27.

Remarks. Dodekova (1975) transferred *P. tripartita* Johnson and Hills to *Glomodinium*, but she did not cite the page, plate, or figure numbers; thus under ICBN, Article 33, the transfer was invalid. It is herein corrected.

Distribution. *G. tripartitum* is present in Oppel-Zones E,F,G and H, Late Bajocian to Oxfordian.

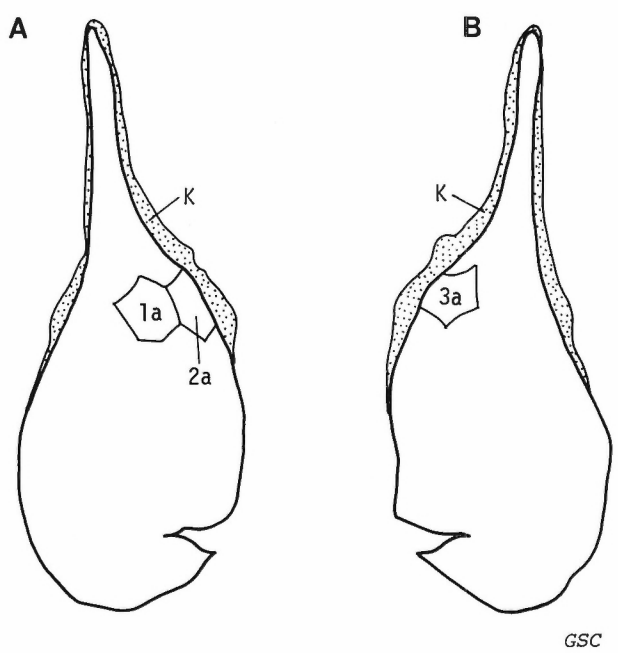


Figure 10. *Glomodinium opeasatos* sp. nov. holotype.
A, Left lateral view; B, Right lateral view.
K = kalyptra;
3I archeopyle and an elongated apical horn.

Glomodinium zabros sp. nov.
Plate 3, figures 2-12; Figure 11

1975 *Pareodinia* sp. A Wiggins, p. 108, Pl. 2, Fig. 6
1980 *Glomodinium* sp. Dörhöfer and Davies, Fig. 29A

Name Derivation. From Greek: *Zabros* = gluttonous, referring to the broad, robust shape.

Type Stratum and Locality. Upper Savik Formation 173 m above the base of the section, just below the contact with Awingak Formation. Sample ED 1009-7A. Central Amund Ringnes Dome, Northwest Territories, Canada.

Holotype. Slide ED 1009-7Aa; co-ordinates N48/0, Plate 3, figure 12; ROM 36641.
Size: length – 8 μm; breadth 50 μm.

Diagnosis. A species of *Glomodinium* with a prolate, lozenge to ellipsoidal shape and a sharply terminating apical horn. Two anterior hypotractal bulges may be present as indications of antapical and lateral horns. The ornament is densely granulate. Tabulation is not evident.
Archeopyle: 3I.
Size: length – 64(78)90 μm; breadth – 45(56)65 μm (ten measured specimens).

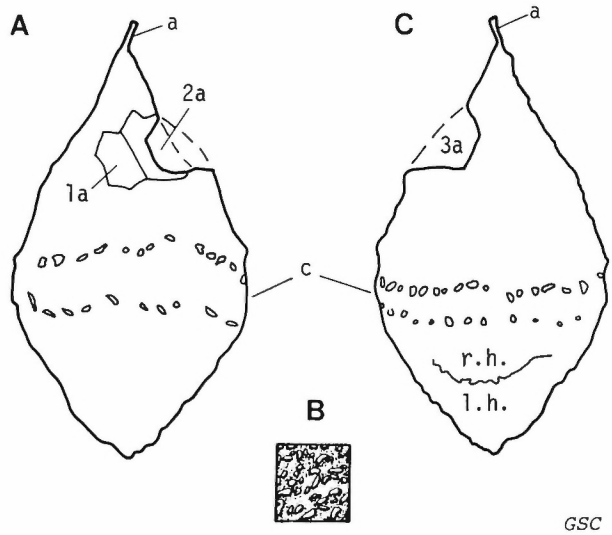
Description. The apical horn (9(14)19 μm in length) is conical beginning immediately anterior to the intercalary archeopyle and terminating in an antennule (3-6.5 μm in length) that is slightly enlarged distally. The rudimentary antapical horns are expressed by broad hypocystal bulges. The left antapical horn is generally more posteriorly displaced while the right antapical horn is often displayed as a conspicuous fold. The granules are coarse (0.5-1.5 μm in diameter), irregular in shape and aligned adcingularly. Compression is most often lateral.

Remarks. This species resembles *Gochteodinia verrucosa*; however, the ornament is less robust. In *Glomodinium zabros* there is a definite 3I archeopyle.

Distribution. *Glomodinium zabros* is present in Oppel-Zones G and H, Bathonian to Oxfordian. Possible other occurrences are from the Middle-Upper Jurassic of West Spitsbergen (Bjaerke and Dypvik, 1977; Bjaerke and Manum, 1977); and from the Upper Jurassic of Alaska (Wiggins, 1975).

Suborder GONYAULACYSTINEAE Norris
Family GONYAULACYSTACEAE Sarjeant and Downie emend. Sarjeant and Downie
Genus *Gonyaulacysta* Deflandre ex. Norris and Sarjeant emend. Stover and Evitt

1964 *Gonyaulacysta* Deflandre (nomen nudum), p. 5030.
1965 *Gonyaulacysta* Deflandre, 1964 ex. Norris and Sarjeant, p. 65
1966b *Gonyaulacysta* Deflandre, 1964 ex. Norris and Sarjeant, 1965
emend. Sarjeant, p. 7-8.
1978 *Gonyaulacysta* Deflandre, 1964 emend. Stover and Evitt, p. 157-160.



GLOMODINIUM ZABROS SP. NOV.

Figure 11. *Glomodinium zabros* sp. nov. holotype.
A, Left lateral view;
B, Ornamental pattern of irregular granules;
C, Right lateral view.
a = antennule;
c = cingulum bounded by larger granules.
r.h. = right antapical horn,
l.h. = left antapical horn. Archeopyle: $3I_{1-3}$.

Type Species. *Gonyaulacysta jurassica* (Deflandre, 1938) Norris and Sarjeant, 1965.

Gonyaulacysta kunzeviensis (Vozzhennikova) stat. nov.
Plate 4, figures 1-3; Figure 12

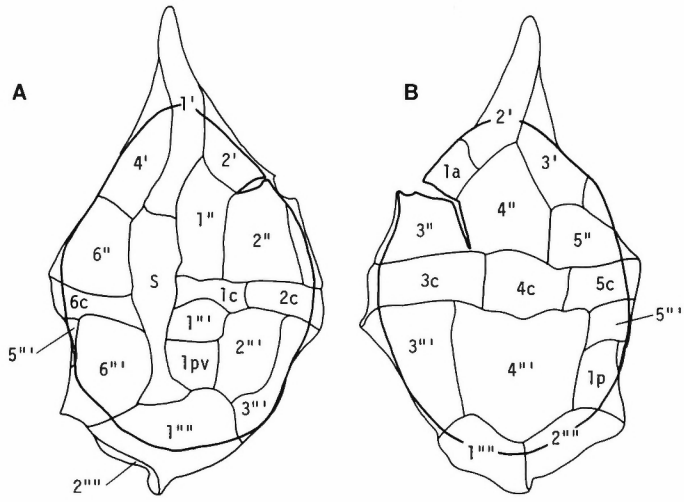
1967 *Gonyaulax perforans* (Cookson and Eisenack, 1958) var. *kunzeviensis* Vozzhennikova, p. 87, Pl. 27, Fig. 6; Pl. 30, Fig. 2; Pl. 33, Fig. 6.
1981 *Leptodinium perforans* sub sp. *kunzeviensis* Lentin and Williams, 1981.

Remarks. This species of *Gonyaulacysta* differs from *L. perforans* by the lack of perforations in the periphragm and sutural crests. There is also a stronger pericoel development in the antapical and apical regions.

Distribution. *G. kunzeviensis* is present in Oppel-Zones H and I, Late Callovian to Early Kimmeridgian. It has been recorded from the Valanginian of Russia (Vozzhennikova, 1967).

Genus *Millioudodinium Stover and Evitt.*

1978 *Millioudodinium* Stover and Evitt, p. 173-174.



GSC

Figure 12. *Gonyaulacysta kunzeviensis* (Vozzhennikova) comb. nov., stat. nov.
A, Ventral view; B, Dorsal view.
Tabulation: 4',la,6",6c,6"',lpv,2"",ls.
Archeopyle: P_3. Sutural crests are developed as folds in the pericoel.

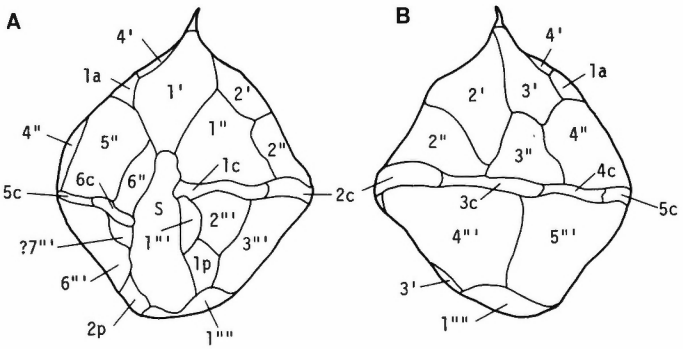


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Figure 13. *Millioudodinium jubaris* sp. nov. holotype.
A, Ventral view; B, Dorsal view.
Tabulation: 4',la,6",6c,7"',2p,l"",ls.

Type Species. *Millioudodinium fetchamense* Sarjeant, 1966

Millioudodinium jubaris sp. nov.
Plate 5, figures 13-20; Figure 13

Name Derivation. *Jubar(is)* (L:*jubar* = radiance of heavenly bodies) referring to the highly refractive autophragm that appears very bright.

Type Stratum and Type Locality. Mould Bay Formation, approximately 70 m above the base. Elf Wilkins E-60 well, cuttings sample at 210 m (690 ft), north-central Mackenzie King Island, Northwest Territories, Canada.

Holotype. Slide WI 690A, co-ordinates E48/3; Plate 5, figure 16; ROM 36428
Size: length – 67 μm; breadth – 60 μm.

Diagnosis. A species of *Millioudodinium* with a subrhombohedral outline and a short apical horn terminating in a pointed antennule. The autophragm is smooth and sutural ridges are unornamented.
Tabulation: 4', la, 6", 6c, 6"', 2p, 1"", la.
Archeopyle: P_3.
Size: length – 56(62)70 μm; breadth – 60(74)79 μm. (Five measured specimens). The length is difficult to measure due to the usual oblique apical compression.

Description. The apical horn is 4 m in length with a pointed antennule 3.5 μm long. The sutural ridges are low (0.5-1.0 μm). The cingulum is narrow (5 μm) and the sulcus is broad (11 μm). The autophragm is characteristically highly refractive, appearing very bright, especially along the sutural crests.

Remarks. This species differs from *Millioudodinium ambiguum* and *M. mamiliferum* since the latter are more ellipsoidal in shape and possess a granulate autophragm. *Leptodinium eumorphum, L. mirable, L. arcuatum* and *L. millioudii* are more robust in shape and lack the apical conical horn and antennule. *Impagiodinium white*; has higher perforated sutural crests. *Gonyaulacysta transparens* (Sarjeant, 1959) Sarjeant, 1969 is more ovoidal and less angular in shape than *M. jubaris*.

Distribution. *Millioudodinium jubaris* is confined to Oppel-Zone K, Early to Late Tithonian.

Genus *Occisucysta* Gitmez

1970 *Occisucysta* Gitmez, p. 267.

Type Species. *Occisucysta balia* Gitmez, 1970.

Occisucysta thulia sp. nov.
Plate 5, figures 1-8, 10-12; Figure 14

Name Derivation. *Thul(ia)* (L: *thule* = farthest north) referring to the type locality in the arctic.

Type Stratum and Type Locality. Upper Savik Formation, sample ED 1040-3, Jaegar River, eastern Cornwall Island, Northwest Territories, Canada.

Holotype. Slide ED 1040-3A, co-ordinates T37/2; Plate 5, figures 10, 11; ROM 36710.
Size: breadth 112 μm.

Diagnosis. A large oblate species of *Occisucysta* marked by denticulate crests and penitabular hair-like spines.
Tabulation: ?4', ?a, 6", 6c, ?"', ?"".
Archeopyle: P_3.
Size: length – 83(89)94 μm (3 measured specimens); breadth – 80(92)112 μm (Seven measured specimens).

Description. The hair-like spines (2-5 μm long) arise in penitabular bands around the periphery of the plates leaving the centre of the plates less ornamented. The sutural crests are 8 μm high. The cyst is usually polarly compressed and is oval in outline. When ventually compressed it has a rounded pentagonal outline with little or no apical horn development. It is often split epitractally.

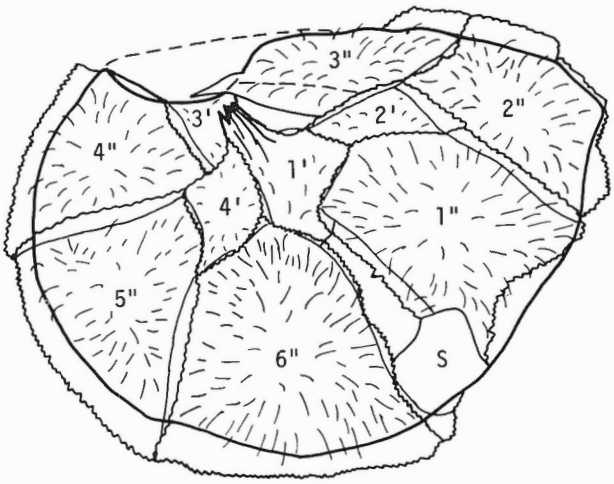


Figure 14. *Occisucysta thulia* sp. nov. apical view, epitractal tabulation 4', 6". Archeopyle: P_{3a}.

Remarks. The large size, the denticulate crests and the hair-like spines distinguish it from all other species of *Occisucysta*.

Distribution. This species is present in Oppel-Zone H (at the base).

Family APTEODINIACEAE Eisenack emend. Sarjeant and Downie

Genus *Apteodinium* Eisenack

1958 *Apteodinium* Eisenack, p. 385.

Type Species. *Apteodinium granulatum* Eisenack, 1958.

Apteodinium granulatum Eisenack

1958 *Apteodinium granulatum* Eisenack, p. 386, Pl. 23, Fig. 8-14.

Remarks. From the illustrations of the type specimen (Eisenack, 1958, Pl. 23, fig. 9) it appears that the periphragm and endophragm separate slightly in the apical and antapical regions. This separation was also found in some of the Arctic specimens. This species is typified by its densely granulate surface.

Distribution. *A. granulatum* is present in Oppel-Zones I, K, and O, Late Oxfordian to Early Valanginian, within the Sverdrup Basin.

Apteodinium bucculiatum sp. nov.
Plate 14, figures 13-18; Figure 15

Name Derivation. *Buccul(iatum)* (L:*buccula* = small cheeks) referring to the antapical bulges characteristic of this species.

Type Stratum and Locality. Wilkie Point Formation, 11-14 m above the base.Panarctic Sandy Point L-46 well, cuttings sample between 561-564 m (1840-1850 ft), Melville Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide SP 1840-1850B; co-ordinates J65/0; Plate 4, figures 13,14; GSC #69362.
Size: length – 81 μm; breadth – 67 μm.

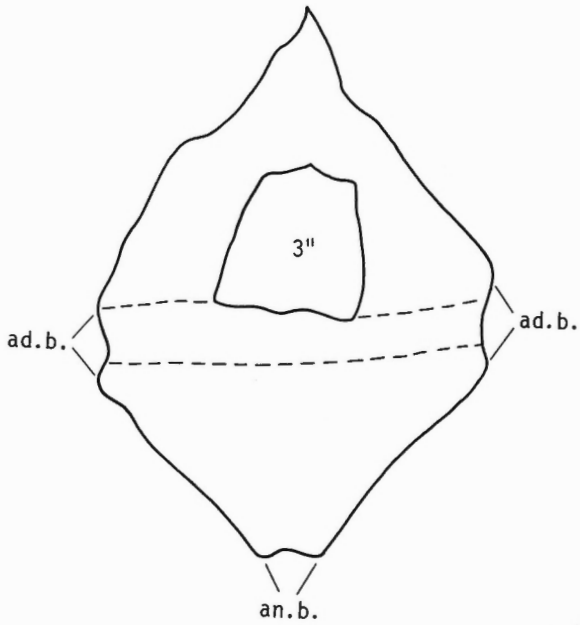


Figure 15. *Apteodinium bucculiatum* sp. nov., dorsal view. b. = adcingular bulges; an. b. = antapical bulges. Archeopyle: P_3; ad.

Diagnosis. Proximate dinoflagellate cysts, heart shaped with an elongated, pointed to roundly terminated apical horn and two antapical bulges. Ornament is granulate. Cingulum and tabulation usually not present or poorly defined. Archeopyle: P_3.
Size: length – 77(85)90 μm; breadth – 77(68)65 μm (six measured specimens).

Description. The granulation is more strongly developed at the apex, cingulum and antapex. The granulate elements are globular in shape and less than 1.0 μm (generally less than 0.5 μm) in diameter. A distinct omphalos is present at the cingular-ventral area. The cingulum is poorly defined, flanked by adcingular lateral bulges. Autophragm is less than 0.5 μm thick and thickened at the apex of the apical horn which is 16-25 μm long. The antapex has two small lateral bulges (5 μm high; 11 μm wide). Tabulation is indistinct or not visible. In the holotype, alignment of granules outlines a dorsal postcingular plate (?3'").

Remarks. This species is similar to *A. granulatum*, but is distinguished by its more distinct apical horn, and the presence of adcingular lateral bulges and two antapical bulges.

Distribution. *A. bucculiatum* is present in Oppel-Zones G and H, Callovian to Oxfordian.

Apteodinium conjunctum Eisenack and Cookson
Plate 4, figure 19

1958 *Apteodinium* sp. Eisenack, p. 387, Pl. 23, Fig. 15-18.
1960b *Apteodinium conjunctum* Eisenack and Cookson, p. 5, Pl. 1, Fig. 7-8.
1970 *Apteodinium maculatum* auct. non. Cookson and Eisenack, 1960; Gitmez, p. 280, Pl. 12, Fig. 8.
1972 *Apteodinium* cf. *maculatum* auct. non. Eisenack and Cookson 1960; Gitmez and Sarjeant, p. 231, Pl. 12, Fig. 6.

Remarks. This species is characterized by a clearly defined cingulum. The ornament, although not mentioned in the original descriptions, is clearly smooth, punctate or lightly granulate. The archeopyle is also quite large. It is distinguished from *A. maculatum* and *A. apiatum* by the lack of circular thickenings.

Distribution. *A. conjunctum* is present in Oppel-Zones I, J, L, N-Q, Late Oxfordian to Valanginian (possibly Hauterivian).

Genus *Chytroeisphaeridia* (Sarjeant) Downie and Sarjeant emend. Pocock

1962a *Leiosphaeridia (Chytroeisphaeridia)* Sarjeant, p. 492.
1964 *Chytroeisphaeridia* (Sarjeant, 1962a) Downie and Sarjeant, p. 102.
1972 *Chytroeisphaeridia* (Sarjeant, 1962a) emend. Pocock, p. 99-100.
1977 *Tapeinosphaeridium* Ioannides, Stavrinos and Downie, p. 461.
1979 *Chytroeisphaeridia* (Sarjeant, 1962a) emend. Davey, p. 211.

Type Species. *Chytroeisphaeridia chytroeides* Sarjeant, 1962a emend Davey, 1979.

Chytroeisphaeridia chytroeides Sarjeant, 1962a emend Davey, 1979
Plate 4, figure 20; Plate 8, figure 19

1962a *Leiosphaeridia (Chytroeisphaeridia) chytroeides* Sarjeant, p. 493, Pl. 70, Fig. 13, 16.
1964 *Chytroeisphaeridia chytroeides* (Sarjeant, 1962a); Downie and Sarjeant, p. 103.
1979 *Chytroeisphaeridia chytroeides* (Sarjeant, 1962a) Downie and Sarjeant, emend. Davey, p. 211-212

Remarks. Davey (1977, 1979) confirmed the presence of a precingular archeopyle in *C. chytroeides* and rejected the possibility of an apical archeopyle. After re-examining a number of specimens from the Sverdrup Basin, cysts with both precingular (Plate 4, fig. 20) and apical archeopyles (Plate 8, fig. 19) were found to have been grouped into C. chytroeides. Separation of the two types from the Sverdrup Basin awaits further study.

Distribution. *C. chytroeides* is present in Oppel-Zones C, D, E, G, H and J, Toarcian to Early Tithonian.

Genus *Tectatodinium Wall*

1967 *Tectatodinium pellitum* Wall, 1967.

Tectatodinium laminatum sp. nov.
Plate 6, figures 1-5, 21; Figure 16

Name Derivation. *Laminatum* (L: *laminat(us)* = layered) referring to the layered structure of the autophragm.

Type Stratum and Locality. Lower Wilkie Point Formation between 10-15 metres above the base. Panarctic Sandy Point L-46 well, cuttings sample from 561-564 m (1840-1850 ft), northwestern Melville Island, District of Franklin, Northwest Territories, Canada.

Holotype. SP 1840-1850B, co-ordinates V53/4, Plate 6, figure 21; GSC #69365.
Size: length – 39 μm; breadth – 31 μm.

Diagnosis. A species of *Tectatodinium* with a pronounced laminated autophragm, a distinct omphalos and loosely attached granules. An antapical horn is sometimes present.

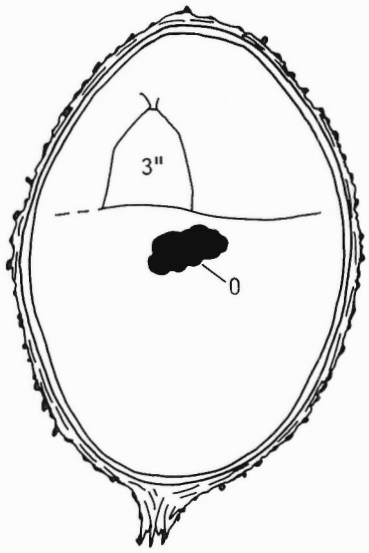


Figure 16. *Tectatodinium laminatum* sp. nov. dorsal view. Interpretive drawing of holotype, autophragm in optical cross-section, O = omphalos. Archeopyle: P_3.

Archeopyle: P_3.
Size: length -32(42)51 μm; breadth – 31(39)45 μm (10 measured specimens).

Description. The phragma is composed of two distinct layers appressed together. The endophragm is uniform, with a distinct omphalos (internal accumulation body) present equatorially on the inner surface. The ectophragm is composed of loosely compacted fibrils giving the cyst a laminated appearance in cross-section. The surface is undulating and covered by loosely attached, fine granules resulting in a hazy appearance. A short, raggedly terminating antapical horn (5 μm long) composed of ectophragmatic fibrils is occasionally developed. An angular apical inflection is sometimes present. Tabulation not evident; cingulum weakly defined.

Remarks. This species differs from *Tectatodinium pellitum* by its more loosely compacted ectophragmatic fibrils, more distinct and loosely attached granules, occasional presence of an antapical horn, distinct omphalos and smaller opercular plate. *?Tectatodinium granulatum* differs from *T. laminatum* by lacking the outer fibrils.

Distribution. *Tectatodinium laminatum* is present in Oppel-Zones I, J, and K (at base), Late Oxfordian to Late Tithonian.

Genus *Trichodinium* Eisenack and Cookson emend. Clarke and Verdier

1960 *Trichodinium* Eisenack and Cookson, p. 5.
1967 *Trichodinium* Eisenack and Cookson, 1960 emend. Clarke and Verdier, p. 18-19.

Type Species. *Trichodinium pellitum* Eisenack and Cookson, 1960.

Trichodinium erinaceoides sp. nov.
Plate 6, figure 6-15; Figure 17

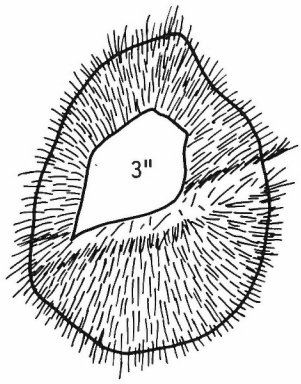


Figure 17. *Trichodinium erinaceoides* sp. nov., dorsal view of holotype. Archeopyle: P_3.

Name Derivation. *Erinaceoides* (L: *erinace(us)* – hedgehog) referring to hedgehog-like appearance of the sculpture.

Type Stratum and Locality. Upper Deer Bay Formation, near base. ED1032-1, Reindeer Peninsula, Ellef Ringnes Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1032-1A, co-ordinates T45/0, Plate 6, figures 6,7; ROM 36615.
Size: length – 22 μm; breadth – 18 μm.

Diagnosis. A species of *Trichodinium* with a dense covering of short hair-like spines (5-7 μm long) which obscure the cyst body. Two faint, narrow alignments of spines delimit the cingulum. A slight inflection in the cyst outline marks the apical horn; otherwise the shape is spherical.
Archeopyle: P_3.
Size: length – 21(23)26 μm; breadth – 18(20)24 μm (10 measured specimens).

Remarks. This species closely resembles *Trichodinium pellitum* (length – 48-64 μm; Eisenack and Cookson, 1960) except that it is much smaller. The minute size and the dense covering of spines inhibit further description.

Distribution. *Trichodinium erinaceoides* is present in Oppel-Zones L (at top), M and O, Late Tithonian to Early Valanginian.

Family *SPINIFERITACEAE* Sarjeant and Downie emend. Sarjeant and Downie emend. Norris
Genus *Hystrichodinium*

1935 *Hystrichodinium* Deflandre, p. 182
1961 *Heliodinium* Alberti, p. 33.
1966 *Heliodinium* Alberti, 1961 emend. Sarjeant, p. 142.
1967 *Hystrichodinium* Deflandre, 1935 emend. Clarke and Verdier, p. 37-38.

Type Species. *Hystrichodinium pulchrum* Deflandre, 1935.

?Hystrichodinium lanceatum sp. nov.
Plate 7, figures 1-12; Figure 18

Name Derivation. *Lanceatum* (L: *lancea* = lance) referring to the lance-shaped processes.

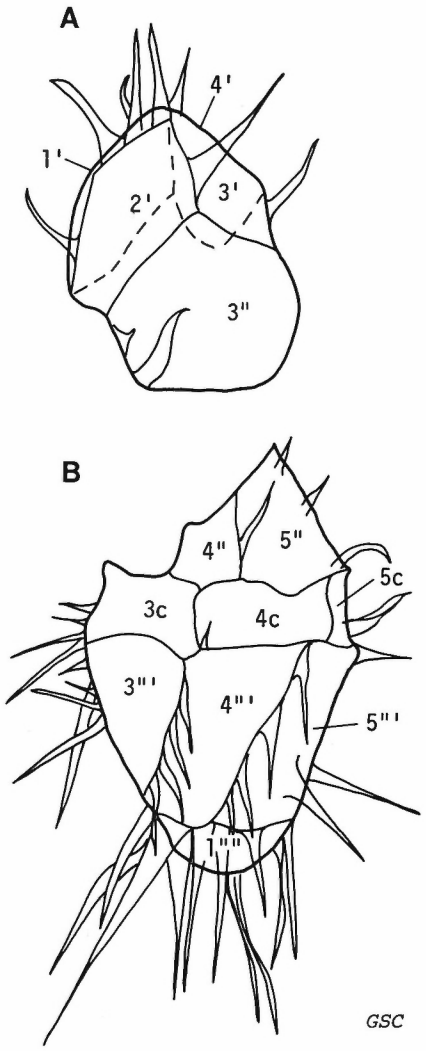


Figure 18. *?Hystrichodinium lanceatum* sp. nov.
A, operculum indicating archeopyle: $4A_{1-4}P_3$;
B, Right lateral view of holotype.

Type Stratum and Type Locality. Savik Formation (approximately 15 m from the top). ED 1028-4, North Amund Ringnes Dome, Amund Ringnes Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1028-4A, co-ordinates 042/1, Plate 7, figures 1,2; ROM 36760.
Size: length – 53 μm; breadth – 28 μm.

Diagnosis. An ellipsoid, spiniferate dinoflagellate cyst with a short teat-like apical horn and one or occasionally two antapical horns. Long ribbon-like processes arise from low sutural crests, tapering to sharp, lance-like terminations, rarely bifurcate. Surface granulate.
Tabulation: ?4', 6", 6"', ?0p, 1"".
Archeopyle: (AP_3).
Size: length – 32(49)59 μm; breadth 25(36)43 μm (10 measured specimens).

Description. The number of processes is variable. The processes (up to 24 μm long) are concentrated around the cingulum and the antapex, often developed over the antapical horn(s) as extensions to it. The periphragm is granulate to finely pitted giving a

spongy appearance; the endophragm is thick and smooth. Processes arise from the periphragm and some may be penitabular on the operculum (Plate 7, fig. 9-11). A precise apical tabulation could not be determined due to the folding of the processes and the spongy surface, however, isolated apical opercula indicate that four plates are involved. Poorly preserved specimens often have some of the periphragm and processes removed.

Remarks. *?Hystrichodinium lanceatum* is tentatively placed in the genus *Hystrichodinium* because the apical series is removed along with the 3" plate in archeopyle formation. *Hystrichodinium voigtii* (Alberti, 1961) Davey, 1974 is similar but differs by its well developed apical horn, low crests bordering the cingulum and processes arising from the apical horn position. *Hystrichodinium patriciae* (Neale and Sarjeant, 1962) Lentin and Williams, 1975 differs by its ovoidal endoblast and longer, more numerous processes.

Distribution. *?Hystrichodinium lanceatum* is present in Oppel-Zones H, I, J and K (at base), Late Callovian to Late Tithonian.

Family ENDOSCRINIACEAE Vozzhennikova emend. Sarjeant and Downie
Genus *Tubotuberella* Vozzhennikova

1967 *Tubotuberella* Vozzhennikova p. 197.
1977a *Glabridinium* Brideaux p. 35.
1977a *Dimidiadinium* Brideaux p. 37.
1977a *Tubotuberella* Vozzhennikova, 1967 emend. Brideaux p. 36.

Type Species. *Tubotuberella rhombiformis* Vozzhennikova, 1967.

Remarks. Brideaux (1977a) erected two superfluous genera, *Glabridinium* and *Dimidiadinium*, that differed from *Tubotuberella* only slightly in the development of the apical pericoel and sutural crests. The three genera constitute a coherent group and the variation among them is, in the writer's opinion, well within generic variability. Accordingly the following species are considered to belong to *Tubotuberella*:

T. rhombiformis Vozzhennikova, 1967
T. apatela (Cookson and Eisenack, 1960b) Ioannides et al., 1977
T. dangeardii (Sarjeant, 1968) Stover and Evitt, 1978
T. dentata Raynaud, 1978
T. egemenii (Gitmez, 1970) Stover and Evitt, 1978
T. eisenackii (Deflandre, 1938) Stover and Evitt, 1978
T. irregulare (Cookson and Eisenack, 1958) comb. nov.
T. lurida (Deflandre, 1938) comb. nov.
T. sphaerocephalis Vozzhennikova, 1967
T. uncinatum (Brideaux, 1977a) comb. nov.
T. whatleyi (Sarjeant, 1972) Stover and Evitt, 1978

Tubotuberella rhombiformis Vozzhennikova emend. Brideaux
Plate 4, figure 4

1967 *Tubotuberella rhombiformis* Vozzhennikova, p. 180, Pl. 101, Fig. 1-2; Pl. 102, Fig. 1-3; Pl. 104, Fig. 1-3.
1977a *Tubotuberella rhombiformis* Vozzhennikova, 1967 emend. Brideaux, p. 36.

Remarks. *T. rhombiformis* differs from *T. dangeardii* (Plate 4; fig. 8) in having a slightly more rounded apical horn (Brideaux, 1977a). The differences between these two species were not recognized early in this study since a continuous intergradation of these forms exists in material from the Sverdrup Basin and the elucidation by Brideaux (1977a) postdates the majority of this palynological analysis. No attempt has been made here to separate these forms for stratigraphic purposes. *Tubotuberella apatela* is almost identical to these forms and differs only in lacking tabulation traces. This subtle distinction may not be significant. *T. rhombiformis, T. dangeardii* and *T. apatela* may represent a single species which has variable development of the apical horn and tabulation traces.

Distribution. *T. rhombiformis* (including forms attributable to *T. dangeardii*) is present in Oppel-Zones G, H, I, J, K, L, M, N, 0 and P.

Tubotuberella apatela (Cookson and Eisenack) Ioannides, Stavrinos and Downie
Plate 4, figure 7

1960b *Scriniodinium apatela* Cookson and Eisenack, p. 249, Pl. 37, Fig. 12-13.
1966 *Psaligonyaulax apatela* (Cookson and Eisenack, 1960b) Sarjeant (nomen nudum) p. 138.
1969 *Psaligonyaulax apatela* (Cookson and Eisenack, 1960b) Sarjeant, p. 15.
1977 *Tubotuberella apatela* (Cookson and Eisenack, 1960b) Ioannides, Stavrinos and Downie p. 464.
1977a *Glabridinium apatelum* (Cookson and Eisenack, 1960b) Brideaux, p. 35.

Remarks. *T. apatela* is retained for specimens of *Tubotuberella* that lack sutural crests other than the characteristic antapical crests. In some reports (e.g. Pocock, 1976) it has not been distinguished from other species of *Tubotuberella*, especially *T. rhombiformis* with which there is a continuous intergradation.

Tubotuberella egemenii (Gitmez) Stover and Evitt
Plate 4, figures 5,6

1970 *Leptodinium egemenii* Gitmez, p. 272-274, Pl. 10, Fig. 5-6.
1978 *Tubotuberella egemenii* (Gitmez, 1970) Stover and Evitt, 1978, p. 197.

Remarks. This species was transferred to *Tubotuberella* since it possesses both apical and antapical pericoels and well developed antapical sutural crests.The resemblance of this species to *Tubotuberella apatela* and *T. rhombiformis* is striking, suggesting their affinity and possible synonomy. *T. egemenii* has a rounded apex with faint tabulation; *T. apatela* has an apical horn without tabulation; and *T. rhombiformis* has an apical horn with faint tabulation.

Distribution. *T. egemenii* is confined to Oppel-Zone I, Late Oxfordian to Early Kimmeridgian.

Tubotuberella irregularis (Cookson and Eisenack) comb. nov.

1958 *Wetzeliella irregularis* Cookson and Eisenack, p. 28-29, Pl. 10, Fig. 1-2.
1978 *?Endoscrinium irregulare* (Cookson and Eisenack, 1958) Stover and Evitt, p. 188.

Tubotuberella lurida (Deflandre, 1938) comb. nov.

1935 *Gymnodinium luridum* Deflandre, p. 166, Pl. 5, Fig. 4-6.
1970 *Endoscrinium luridum* (Deflandre, 1938) Gocht, p. 144-146.
1978 *Scriniodinium luridum* (Deflandre, 1938) Stover and Evitt p. 187.

Tubotuberella uncinatum (Brideaux) comb. nov.

1977a *Dimidiadinium uncinatum* Brideaux, p. 38, Pl. 15, Fig. 2-5, 7, 8.

Family SCRINIOCASSACEAE Sarjeant and Downie emend. Sarjeant and Downie
Genus *Scriniocassis* Gocht

1964 *Scriniocassis* Gocht, p. 121.

Type Species. *Scriniocassis weberi* Gocht, 1964.

Remarks. Following Gocht's (1964, p. 121) suggestion, *Scriniodinium dictyotum* was placed in *Scriniocassis* (Beju, 1971). Lentin and Williams (1973) recombined the subspecies of *S. dictyotum* that were designated by Gitmez (1970). *S. dictyotus osmingtonensis* is here placed in synonymy with *S. weberi* in accord with Article 56 ICBN. *S. dictyotus dictyotus, S. dictyotus papillatus* and *S. dictyotus pyrus* are raised to specific status.

Scriniocassis weberi Gocht
Plate 7, figure 13

1964 *Scriniocassis weberi* Gocht, p. 121, Pl. 17, Fig. 1-4.
1970 *Scriniodinium dictyotum osmingtonensis* Gitmez, p. 310-311, Pl. 1, Fig. 3; Pl. 8, Fig. 12.
1975 *Scriniocassis dictyotus osmingtonense* (Gitmez, 1970) Lentin and Williams, p. 2154.

Remarks. This species is characterized by the lack of an apical horn (Gocht, 1964; Gitmez, 1970). *Cyclodictyon* Cookson and Eisenack 1958 is characterized by a cingularly positioned pericoel. Pocock's (1972, p. 101) interpretation of this genus is therefore incorrect and his species *Cyclodictyon minor* is probably synonymous with *S. weberi*.

Distribution. *S. weberi* is present in Oppel-Zones A, B, C, D, E, F, G and H, Toarcian or older to Oxfordian.

Scriniocassis dictyotus (Cookson and Eisenack) Beju

1960b *Scriniodinium dictyotum* Cookson and Eisenack, p. 248-249, Pl. 37, Fig. 8, 9.
1970 *Scriniodinium dictyotum dictyotum* Cookson and Eisenack, 1960b; Gitmez, p. 310.
1971 *Scriniocassis dictyotus* (Cookson and Eisenack, 1960b) Beju, p. 299.
1975 *Scriniocassis dictyotus dictyotus* (Gitmez, 1970) Lentin and Williams, p. 2154.

Remarks. This species is characterized by the possession of a distinct, short, broadly based apical horn (Gitmez, 1970).

Distribution. *Scriniocassis dictyotus* is present in Oppel-Zones C, D and I, Toarcian to Early Kimmeridgian.

Scriniocassis papillatus (Gitmez) stat. nov.

1970 *Scriniodinium dictyotum papillatum* Gitmez, p. 311, Pl. 9, Fig. 11.
1970 *Scriniocassis weberi* Gocht, 1964; Morgenroth, p. 252, Pl. 12, Fig. 1,2.
1975 *Scriniocassis dictyotus papillatus* (Gitmez, 1970) Lentin and Williams, p. 2154.

Remarks. This species is characterized by the possession of a blunt teat-like apical horn (Gitmez, 1970).

Scriniocassis pyrus (Gitmez) stat. nov.
Plate 7, figure 14

1970 *Scriniodinium dictyotum pyrum* Gitmez, p. 311-312, Pl. 13, Fig. 1, 2; Pl. 10, Fig. 1.
1975 *Scriniocassis dictyotus pyrus* (Gitmez, 1970) Lentin and Williams, p. 2154.

Remarks. This species is characterized by a strong apical horn giving an overall pearshape (Gitmez, 1970).

Distribution. *S. pyrus* is present in Oppel-Zone C, Toarcian to Early Bajocian.

Suborder HYSTRICHOSPHAERIDIINEAE Norris
Family HYSTRICHOSPHAERIDIACEAE Evitt emend. Sarjeant and Downie emend. Norris
Genus *Tanyosphaeridium* Davey and Williams

1966 *Tanyosphaeridium* Davey and Williams, p. 98.

Type Species. *Tanyosphaeridium variecalamum* Davey and Williams, 1966.

Remarks. Specimens of *T. magneticum* sp. nov. and *T. isocalamum* intergrade with each other. As the processes become more concentrated around the apices of the cyst, fewer cingular processes are present. *Bourkidinium granulatum* represents the end member of this spectrum where the processes are entirely polarized lacking both cingular and precingular processes. Generic separation of these types from *Tanyosphaeridium* may be unwarranted.

Tanyosphaeridium isocalamum
(Deflandre and Cookson) Davey and Williams
Plate 8, figures 9,10; Figure 19

1955 *Hystrichosphaeridium isocalamus* Deflandre and Cookson, p. 272, Pl. 2, Fig. 7, 8.
1966 *Tanyosphaeridium isocalamus* (Deflandre and Cookson, 1955) Davey and Williams (nomen nudum), p. 100.
1969 *Tanyosphaeridium isocalamus* (Deflandre and Cookson, 1955) Davey and Williams, p. 7.
1971 *Tanyosphaeridium* sp. Singh, p. 344-345, Pl. 57, Fig. 7.
1971 *Tanyosphaeridium* sp. A. Brideaux, p. 39, Pl. 26, Fig. 71.
1975 *Tanyosphaeridium* sp. A. Brideaux, 1971; Brideaux and McIntyre, p. 31, Pl. 9, Fig. 11.

Remarks. The specimens of Singh (1971) and Brideaux (1971) are characterized by buccinate processes. The type specimen of *T. isocalamum* has blunt processes. Specimens from the Sverdrup Basin show variation between the two, namely buccinate, blunt and constricted processes, frequently on the same specimen (Fig. 19).

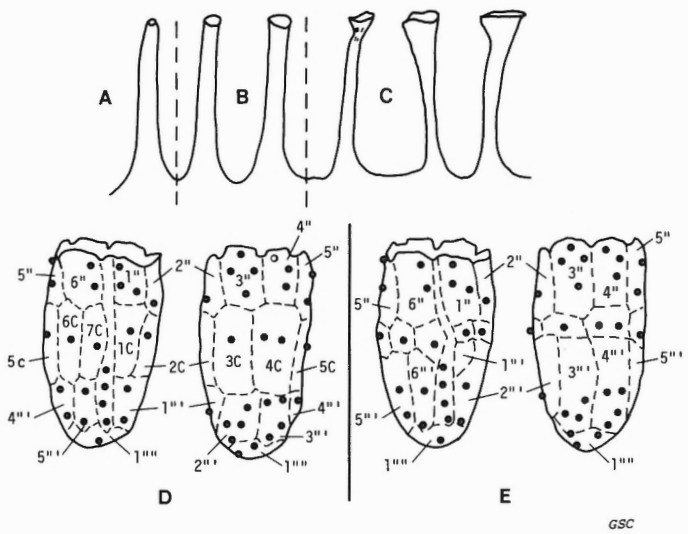


Figure 19. *Tanyosphaeridium isocalamum*
A, Constricted processes;
B, Blunt processes;
C, Buccinate processes;
D, Expanded cingular plate pattern;
E, Shortened cingular plate pattern.
Tabulation: 4',5",7c,5-6"',1"",s.

Thus, the flaring of distal ends of processes should be considered an infra-specific variation in *T. isocalamum*. The tabulation has been determined as: 4', 6", 6-7c, 5-6"', 1"6, ?s (Fig. 19). Since plates may have 1-4 processes each, difficulty arises on the hypotract where there are no sutures. The sulcus is expressed by a left lateral offset in the alignment of the cingular processes and by a meridinal row of processes. The actual size of the cingular plates relative to the adcingular plates is indeterminable since the adcingular processes are slightly polarized to the apices of the cyst (compare Fig. 19 D and E).

Distribution. *Tanyosphaeridium isocalamum* is present in Oppel-Zones O, P and Q, Valanginian to possibly Hauterivian, and rarely in Oppel-Zone K, Tithonian.

Tanyosphaeridium magneticum sp. nov.
Plate 8, figures 1-8,11,12; Figure 20

Name Derivation. *Magneticum* (L: *magneticus* = magnetic) referring to the polarized processes resembling lines of magnetic force around a bar magnet.

Type Stratum and Type Locality. Deer Bay Formation, 30m below the top. Sample ED 1004-3, Jaeger River, Cornwall Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1004-3F, co-ordinates T57/3, Plate 8, figure 7; ROM 36678.
Size: endoblast length – 33 μm; endoblast breadth – 20 μm; process length – 10-12 μm.

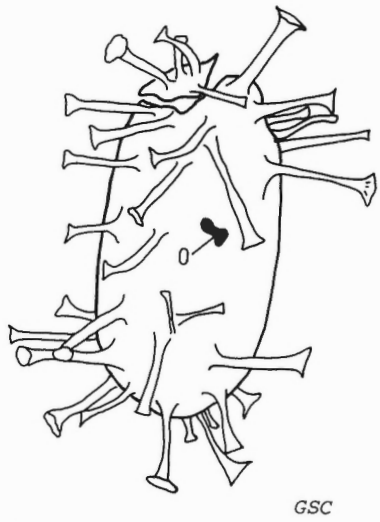


Figure 20. *Tanyosphaeridium magneticum* sp. nov., O = omphalos; Archeopyle: 4I.

Diagnosis. Chorate dinoflagellate cysts with an elongate ovoidal endoblast, granulate ornament, and entire to denticulate, cylindrical to buccinate, tubiform processes concentrated around the apices of the cyst (14-17 on each end).
Archeopyle: apical.
Size: length – 33(38)48 μm; breadth – 20(23)25 μm (10 measured specimens).

Description. The process terminations are variable and would not suffice for specific separation since on one specimen there may be two or three types of process termination. The processes are located at the apex and antapex of the cyst; 0-3 cingular processes are present. After archeopyle separation 3-6 processes remain near the edge of the archeopyle; therefore, 8-12 processes are removed in the operculum. The arrangement of processes resembles the lines of magnetic force around a bar magnet.

Remarks. *T. isocalamum* is very similar in size, shape, ornament and process types but differs by having more evenly spaced processes and a well developed cingular series. *T. vareicalamum* has well spaced processes with wide bases. *Bourkidinium granulatum* has fewer processes (9-15) on each end lacking all precingular and cingular processes, a slightly larger size (length – 35(46)62 μm; breadth – 20(24)29 μm) and tends to be more granulate than *T. magneticum*.

Distribution. *T. magneticum* is present in Oppel-Zones O and P (in the basal portions), Valanginian. McIntyre and Brideaux (1980) report this species as *Bourkidinium* sp. AE from the Valanginian of northern Richardson Mountains.

Family CLEISTOSPHAERIDIACEAE Sarjeant and Downie
Genus *Cleistosphaeridium* Davey, Downie, Sarjeant and Williams

1966 *Cleistosphaeridium* Davey et al., p. 168.

Type Species. *Cleistosphaeridium diversispinosum* Davey et al., 1966.

Remarks. Davey et al. (1966) erected the genus *Cleistosphaeridium* to include chorate cysts with typically over 50 processes and an apical archeopyle. A large range in variation among species has been incorporated into this genus. Many species overlap each other. The result is a conglomeration of taxa that warrants extensive research to resolve. In order to avoid extending the confusion the two following species are left for the present in open nomenclature.

Cleistosphaeridium sp. A.
Plate 8, figures 15-18

Description. A species of *Cleistosphaeridium* with a circular outline, densely covered by short (3-5 μm), narrow, bluntly or slightly buccinate terminating processes. Tabulation not evident. Omphalos frequently present.
Archeopyle: probably 4A as indicated by the angular outline.
Size: length – 46(52)55 μm; breadth – 38(47)55 μm (10 measured specimens).

Distribution. This species is present in Oppel-Zones F, G, H, I, L and P, Late Bathonian to Valanginian.

Cleistosphaeridium sp. B
Plate 8, figures 13-14

Description. A species of *Cleistosphaeridium* with a circular to subcircular outline, covered by 60-90 solid, conical to multifurcate processes (5-7 m long). Tabulation not apparent except for a slight alignment of processes bordering the cingulum.
Archeopyle: probably 4A as indicated by the angular outline.
Size: length – 48(51)54 μm; breadth – 30(38)45 μm (10 measured specimens).

Distribution. This species is present in Oppel-Zones G and H, Callovian to Oxfordian.

Family LITHODINIACEAE Norris
Genus *Ellipsoidictyum* Klement

1960 *Ellipsoidictyum* Klement, p. 78.

Type Species. *Ellipsoidictyum cinctum* Klement, 1960.

Ellipsoidictyum sp. cf. *E. cinctum* Klement, 1960
Plate 8, figure 20

Remarks. The reticulata ornament is highly variable in shape, size and number of lacuna. The specimens from the Sverdrup Basin tend to be characterized bysmaller, more numerous and more irregular lacuna than the holotype, and closely resemble the holotype of "*Dictyopyxidia areolata*" Cookson and Eisenack, 1960b (a junior synonym of *E. cinctum*).

Distribution. *E.* sp. cf. *E. cinctum* is present in Oppel-Zones F, H, I, J, K, L, M, N, O and P, Late Bathonian to Valanginian.

Genus *Lithodinia Eisenack emend. Gocht*

1935 *Lithodinia* Eisenack, p. 175.
1966 *Meiourogonyaulax* Sarjeant, p. 144-146.
1975 *Lithodinia* Eisenack, 1935 emend. Gocht, p. 353.

Lithodinia serrulata sp. nov.
Plate 9, figures 1-6, Figure 21

Name Derivation. *Serrulata* (L: *serrula* = diminutive of *serra* = saw) referring to the fine serrulation on the sutural crests.

Type Stratum and Type Locality. Savik Formation, approximately 91 m above the base. Elf Jameson Bay C-31 well, cuttings sample 911 m (3030 ft), Prince Patrick Island, District of Franklin, Northwest Territories, Canada.

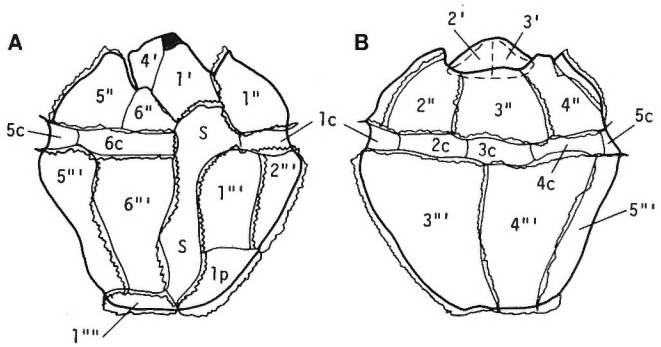
Holotype. Slide JB 3030A, co-ordinates: K27/4, Plate 9, figure 3,4; ROM 36586.
Size: length – 42 μm; breadth – 46 μm.

Diagnosis. Oblate, proximate dinoflagellate cysts. Autophragm thin, smooth to punctate or slightly granulate, often possessing remnants of a kalyptra. Tabulation marked by low, often indistinct, finely serrulated sutural crests.
Tabulation: ?4', 6", 6c, 6"', 1p, 1"".
Archeopyle: (?4A).
Size: length – 30(38)52 μm; breadth – 29(35)46 μm (20 measured specimens).

Description. Sutural crests are up to 1.5 m high. The sulcus is well defined and bordered by two crests with serrulated margins. The laevo-rotary cingulum is bordered by cingular crests up to 2 m high and tabulated by low non-serrulated ridges (approx. 0.5 μm high). The apex is terminated by a thickening. Tabulation within the apical series is poorly defined and not often visible; however, by the shape of the operculum four apical plates are suggested. The operculum is sometimes attached ventrally, or completely removed. The kalyptra when present gives the cyst a spongy appearance.

Remarks. This species is distinguished from other species of *Lithodinia* by its thin, low, hyaline serrulated crests, frequent possession of a kalyptra, the very thin transparent autophragm, and its small size.

Distribution. *Lithodinia serrulata* is present in Oppel-Zones A and C, Toarcian or older to Early Bajocian.



GSC

Figure 21. *Lithodinia serrulata* sp. nov.
A, Ventral view; B, Dorsal view of holotype.
Tabulation: ?4',6",6c,1p,1"",s.
Archeopyle: ?4A.

?Lithodinia sp. A
Plate 9, figure 20; Figure 22

Description. A questionable species of *Lithodinia* with an elongate body and low sutural ridges. Tabulation indicated by low sutural ridges. The hypotract is elongate and the epitract is short and conical. The cingulum is distinct and invaginated. Surface is irregularly granulate.
Tabulation: ?4', 2a, 6", ?c, 6"', 1p, 2"", 3s.
Archeopyle: A.
Size: length – 71 μm; breadth – 36 μm (one measured specimen).

Remarks. Only one specimen has been found. Since it possesses two intercalary plates and two antapical plates, it is tentatively placed in *Lithodinia*.

Distribution. *?Lithodinia* sp. A is present in Oppel-Zone H, Late Callovian to Oxfordian.

?Lithodinia sp. B
Plate 9, figures 7-8; Figure 23

Description. An oblate dinoflagellate cyst with granulate to rugulate ornamental elements that coalesce into an imperfect reticulum. Low sutural ridges formed by more densely fused and coarser ornamental elements. The cingulum is expressed by one distinct ridge.
Tabulation: 4', 3a, 6", 6"', 1p, 1"", s.
Archeopyle: $(4A)_a$ with accessory sutures among the apical, intercalary and precingular plates.
Size: length – 33 μm; breadth – 41 μm (one measured specimen).

Remarks. Only four specimens of this species have been found. Due to its unusual tabulation (4', 3a, 6", 6"', 1p, 1"", s) where there are two intercalary plates on the sinistral side and one on the dextral side separated by 3" and 4" plates, this species is provisionally placed in *Lithodinia*. Sarjeant (1976) reports a similar tabulation pattern in *?Meiourogonyaulax acanthosphaera*, differing by the possession of four intercalary plates, two on either side. This species also differs in the type of ornament. *?M. acanthosphaera* has coarse granules and short broad stubble-like spines, whereas *?Lithodinia* sp. B has rugulae coalescing into an imperfect reticulum.

Distribution. *?Lithodinia* sp. B is present in Oppel-Zone N, Late Berriasian to Early Valanginian.

Lithodinia sp. C
Plate 9, figures 12,16

Description. A species of *Lithodinia* with a rounded lozenge-shaped body. Periphragm, smooth, thin (less than 0.5 μm), closely appressed against the thicker (approximately 1 μm), smooth to punctate endophragm. High, serrated sutural crests are developed on the periphragm.
Tabulation: 4', 1a, 6", ?c, ?6"', 1"".
Archeopyle: $4A_a$.
Size: length – 55 μm; breadth – 47 μm (one measured specimen).

Remarks. Only one of six specimens that have been found is fairly well preserved. This species strongly resembles *Lithodinia valensii* except that it has periphragmatic differentiation and more well developed sutural crests.

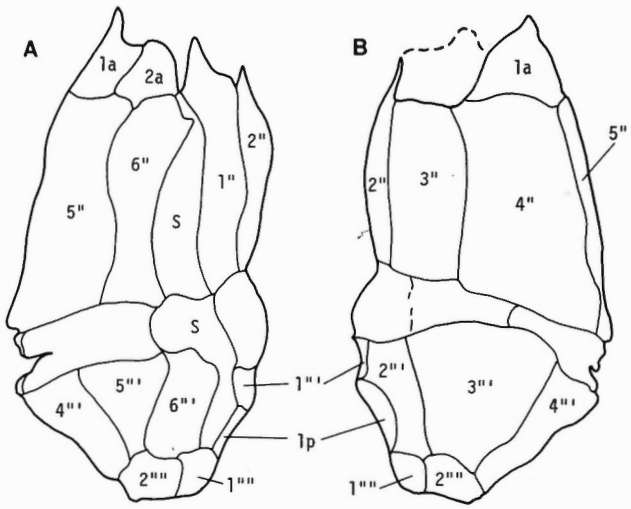


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Figure 22. *?Lithodinia* sp. A
Tabulation: ?4', 2a, 6", 6"', 1p, 2"", 2s.
Archeopyle: ?4A.

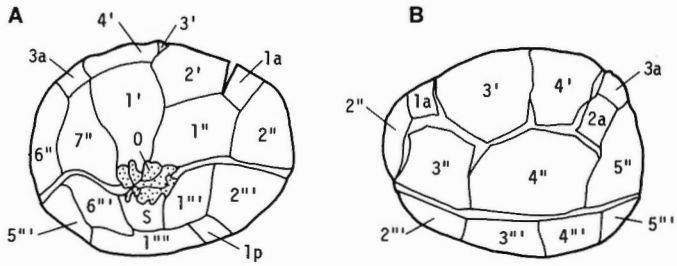

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Figure 23. *?Lithodinia* sp. B.
A, Ventral view; B, Dorsal view.
Tabulation: 4',3a,6",?c,6"',1p,1"",1s.
O = omphalos.

Distribution. *Lithodinia* sp. C is present in Oppel-Zones I, J and K, Late Oxfordian to Tithonian.

Genus *Parvulodinium Dodekova*

1975 *Parvulodinium* Dodekova, p. 29.

Type Species. *Parvulodinium clavatum* Dodekova, 1975.

Parvulodinium penitabulatum sp. nov.
Plate 9, figures 9-11, 13-15, 17-19; Figure 24

Name Derivation. *Peni-* (L: *penitus* = within), *tabulatum* (L: *tabulatus* = boarded, planked), referring to the penitabular arrangement of verrucae.

Type Stratum and Type Locality. Jaeger Member of the Savik Formation, one metre above the base. Sample ED 1030-4, Reindeer Peninsula, Ellef Ringnes Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1030-4A, co-ordinates P44/0, Plate 9, figures 9-11; ROM 36629.
Size: length – 41 μm; breadth – 30 μm.

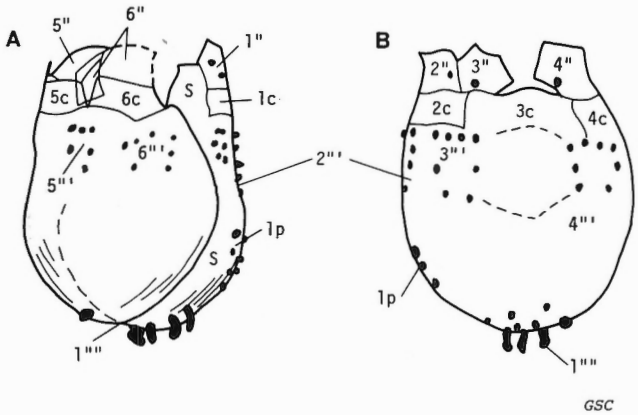

Figure 24. *Parvulodinium penitabulatum* sp. nov.
A, Ventral view of holotype; B, Dorsal view.
Tabulation: 6",6c,6"',lp,l"",s.
Archeopyle: 4AII.

Diagnosis. Elongate ellipsoidal dinoflagellate cyst with reticulate autophragm and penitabular verrucae. Sulcus indented, cingulum wide.
Tabulation formula: 4', 1a, 6", 6c, 6"', 1p, 1"", ?s.
Archeopyle: (4A) + 1I + $6P_{?a}$.
Size: length – 27(33)41 μm; breadth – 27(28)30 μm (six measured specimens).

Description. The reticulum has irregular sized circular to subcircular lumina. The penitabular verrucae (2 μm wide) are more elevated in the antapical region to form baculae (3 μm high). There are never more than three or four per plate boundary. The epitractal sutures are simple splits with one or two intratabular verrucae. The sulcus divides the hypotract into two lateral bulges. The apex is blunt, with a short pointed horn (5 μm long). The operculum consists of four apical plates as one piece, one intercalary plate where archeopyle development is initiated, and six precingular plates occasionally attached adcingularly.

Remarks. *Parvulodinium clavatum* differs from *P. penitabulatum* by its irregular and variable ornament and the lack of alignment along penitabular septa.

Distribution. *Parvulodinium penitabulatum* is confined to Oppel-Zone C, Toarcian to Early Bajocian.

Family BATIACASPHAERACEAE Dörhöfer and Davies
Genus *Escharisphaeridia* Erkmen and Sarjeant

1980 *Escharisphaeridia* Erkmen and Sarjeant, p. 62, 63

Type Species. *Escharisphaeridia pocockii* (Sarjeant, 1968) Erkmen and Sarjeant, 1980.

Escharisphaeridia rudis sp. nov.
Plate 10, figures 7, 10-18; Figure 25

1976a *Canningia* sp. C-29146 Brideaux, Pl. 23.1, Fig. 14.

Name Derivation. *Rudis* (L: *rudis* = rough) referring to the rough granulate ornament.

Type Stratum and Type Locality. Deer Bay Formation, the upper portions. Sample ED 1034-4, Station Bay near Reindeer Peninsula, Ellef Ringnes Island, District of Frankin, Northwest Territories, Canada.

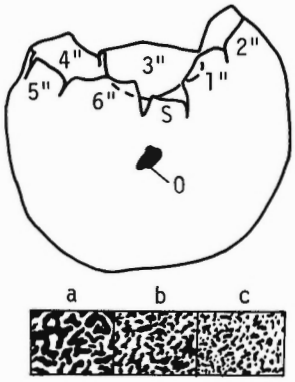

Figure 25. *Escharisphaeridia rudis* sp. nov.
O = omphalos; a-c, ornament variability,
Archeopyle: 4A.

Holotype. Slide ED 1034-4A, co-ordinates: P49/1, Plate 10, figure 13; ROM 36602.
Size: length – 69 μm; breadth – 70 μm.

Diagnosis. A species of *Escharisphaeridia* with a spherical to subspherical shape; thick wall; densely granulate ornament with a few large, scattered, irregular shaped tubercules.
Tabulation: as revealed by archeopyle sutures, 4', 6".
Archeopyle: (4A) with operculum occasionally hinged ventrally.
Size: length – 49(65)92 μm; breadth – 44(66)90 μm. (34 measured specimens).

Description. The autophragm is thick (1.5-2.5 μm). The granulate ornament has considerable variability from verrucate, rugulate, alveolate to imperfectly reticulate as the individual tubercules (1-3 μm in diameter) coalesce. Attempts to separate these variants into different taxa proved impossible due to the intergradation. An inward thickening, the omphalos, at the midventral area is usually present. The archeopyle often has accessory sutures between the precingular plates. No other tabulation is evident.

Remarks. *Sentusidinium cuculliformis, S. echinatum, S. pilosum, S. rioultii*, and *S. villerense* are distinguished from *E. rudis* by their possession of spinate processes. *?Canningia rotundata* is distinguished by its vermiculate ornament and short apical horn. *?Canningia circularia* is distinguished from *E. rudis* by its sharply terminating, less dense apiculate elements. *Canningia ringnesiorium* is distinguished by its less dense ornament and thinner autophragm. *E. pocockii* has finer, less dense ornament with a smaller size range (length – 38-45 μm, breadth – 50-55 μm) and a thinner autophragm.

Distribution. *E. rudis* is present in Oppel-Zones H, I, J, L, M, N and P, Late Callovian to Valanginian.

Escharisphaeridia sp. A.
Plate 10, figures 19-20

Description. A species of *Batiacasphaera* with a spherical to ovoidal shape, strongly rugulate ornament coalescing into an imperfect reticulum, and a thick wall (3 μm). Cingulum and sulcus not evident.
Archeopyle: 4A.
Size: 101 μm.

Remarks. Only two specimens have been found. This species may represent a large, thick walled variant of *E. rudis*.

Distribution. *Escharisphaeridia* sp. A is present in Oppel-Zone I, Late Oxfordian to Early Kimmeridgian, from the Elf Wilkins E-60 well at 289 m (960 ft) in the upper portions of the Savik Formation.

Genus *Sentusidinium* Sarjeant and Stover

1978 *Sentusidinium* Sarjeant and Stover, p. 49-50.

Type Species. *Sentusidinium rioultii* (Sarjeant, 1968) Sarjeant and Stover, 1978

Sentusidinium cuculliformis sp. nov.
Plate 10, figures 1-4; Figure 26

1976a *Tenua* sp. C-50864 Brideaux, p. 122, Pl. 23.2, Fig. 1.

Name Derivation. *Cucull(iformis)* (L: *cucullus* = hood) referring to the hood-like appearance of the operculum when attached ventrally.

Type Stratum and Type Locality. Deer Bay Formation, from the upper portions. Sample ED 1034-4, Station Bay near Reindeer Peninsula, Ellef Ringnes Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1034-4A; co-ordinates: U50/0; Plate 10, figures 3,4; ROM 36602.
Size: length – 72 μm; breadth – 75 μm; spine length – 9 μm.

Diagnosis. A species of *Sentusidinium* having a spherical to ovoidal shape; dense covering of sturdy spines which are complexly terminated and reduced or lacking along the cingulum.
The accessory sutures are weakly developed between the precingular plates.
Tabulation: only 4', 6" are evident.
Archeopyle: (4A)a + 6Pa, the ventrally attached operculum is often removed.
Size: length – 48(63)81 μm; breadth – 49(63)77 μm (19 measured specimens).

Description. The spines (3(7)16 μm long) are broadly based, tapering to acuminate, foliate, aculeate, capitate or acicular terminations. The spines are aligned adcingularly with coalescent bases. Other plate boundaries are also suggested by spine alignment but they are obscured by the spine density and inconsistence in alignment. The cingulum is positioned equatorially, dividing the cyst into two equal halves. Rarely, some precingular plates may be dislocated after archeopyle formation.

Remarks. *S. echinatum* is distinguished from *S. cuculliformis* by its more regularly spaced, simple spines and the lack of a distinct cingulum. *S. pilosum* has more widely spaced ornate to capitate spines with no cingulum evident. *S. rioultii* has similar ornament but more widely spaced, as does *S. villerense* which has narrower and shorter spines.

Distribution. *S. cuculliformis* is present in Oppel-Zones N, O and P, Berriasian to Valanginian.

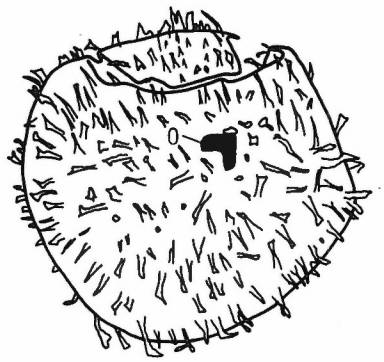

Figure 26. *Sentusidinium cuculliformis* sp. nov., holotype. Archeopyle: 4A; O-omphalos.

Sentusidinium filiatum sp. nov.
Plate 10, figures 5,6, 8-9; Figure 27

Name Derivation. *Filiatum* (L: *filiatus* = thread-like) referring to the thread-like spines.

Type Stratum and Type Locality. Upper Deer Bay Formation. Sample ED 1004, Jaegar River, east Cornwall Island, District of Franklin, Northwest Territories, Canada.

Holotype. Slide ED 1018-1A; co-ordinates M43/1; Plate 10, figure 8; ROM 36665.
Size: length – 61 μm; breadth – 63 μm.

Diagnosis. A species of *Sentusidinium* having a spherical to ovoidal shape covered with densely spaced, thread-like spines with no trace of a cingulum or sulcus.
Tabulation: No tabulation except for archeopyle sutures, 4', 6".
Archeopyle: (4A) often hinged ventrally with accessory sutures between the precingular plates occasionally developed.
Size: length – 52(61)70 μm; breadth – 35(56)65 μm (10 measured specimens).

Description. The dense, fine spines vary in length (2.5-7.5 μm), terminate simply and acutely and cover the cyst in a carpet-like fashion. There are no horns but rarely two small antapical bulges are evident. The cingulum and sulcus are not clearly defined but the presence of a distinct omphalos in the midventral region is frequent. Whole specimens occur frequently and appear as a densely spinate sphere.

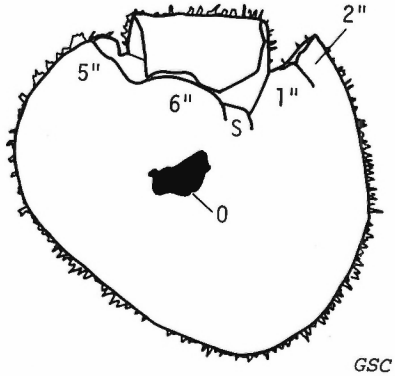

Figure 27. *Sentusidinium filiatum* sp. nov., holotype; O = omphalos. Archeopyle: 4A.

Remarks. *S. echinatum* has shorter and more widely spaced spinate ornament. *S. varispinosum* has longer, wider and hollow spines. *S. cuculliformis* has longer, more complexly terminating spines with a distinct cingulum and sulcus.

Distribution. *S. filiatum* is present in Oppel-Zones I, J, K, L, O, P and Q, Late Oxfordian to Valanginian (possibly Hauterivian).

Family MEMBRANILARNACIACEAE Eisenack emend. Sarjeant and Downie
Genus *Chlamydophorella* Cookson and Eisenack

1958 *Chlamydophorella* Cookson and Eisenack, p. 56.

Type Species. *Chlamydophorella nyei* Cookson and Eisenack, 1958.

Chlamydophorella sp. A
Plate 7, figure 15

Description. A species of *Chlamydophorella* with an ovoidal shape, short (1-3 μm), fine processes, densely arranged in 10-12 whorls, distally connected by a thin membrane. An omphalos is generally present, presumably in mid-ventral position.
Archeopyle: apical.
Size: length – 36 μm; breadth – 29 μm (one measured specimen).

Distribution. This species is confined to Oppel-Zone H, Late Callovian to Oxfordian.

Order NANNOCERATOPSIALES Piel and Evitt
Family NANNOCERATOPSITACEAE Gocht
Genus *Nannoceratopsis* Deflandre emend. Piel and Evitt

1938 *Nannoceratopsis* Deflandre, p. 183
1961b *Nannoceratopsis* Deflandre, 1938 emend. Evitt, p. 306.
1980 *Nannoceratopsis* Deflandre, 1938 emend. Piel and Evitt, 1980, p. 102.

Type Species. *Nannoceratopsis pellucida* Deflandre, 1938.

Nannoceratopsis gracilis Alberti emend. Evitt
Plate 6, figures 16,17

1961 *Nannoceratopsis gracilis* Alberti, p. 30, Pl. 7, Fig. 16, 17.
1961b *Nannoceratopsis deflandrei* Evitt, p. 308, Pl. 1, Fig. 1-14, Pl. 2, Fig. 1-29.
1962 *Nannoceratopsis gracilis* Alberti, 1961 emend. Evitt, p. 1129-1130.

Remarks. Within the *N. gracilis* complex four groups may be distinguished. 1. Those with a coarsely alveolate-reticulate autophragm; 2. Those with a granulate to finely alveolate autophragm; 3. Those with an unornamented smooth autophragm and an angular outline; 4. Those with an unornamented autophragm with a rounded shape. The coarsely alveolate-reticulate types are attributed to *N. gracilis*. The original description of *N. spiculata* indicates the presence of two antapical horns and a reticulate to alveolate structured autophragm. Specimens from the Sverdrup Basin have a gradation between one and two antapical horns. The type of *N. gracilis* clearly has two antapical horns and a reticulate autophragm (Alberti, 1961; Pl. 7, Fig. 17); therefore, *N. spiculata* is probably synonymous with *N. gracilis*. Van Helden (1977) attributed forms with alveolate-reticulate ornament to *N. gracilis* and erected a new species *N. senex* van Helden to accommodate cysts with finer ornament, namely micro-reticulate granulate to nearly smooth autophragms. *N. senex* includes the last three groups (2, 3, 4) of cysts and will be separated into three informal varieties, namely, A, B, and C respectively.

Distribution. *N. gracilis* is present in Oppel-Zones B, C, D, F and G (in the basal portions), Toarcian to Early Callovian.

Nannoceratopsis senex van Helden

1977 *Nannoceratopsis senex* van Helden, p. 16, Pl. 33.1, Fig. 1-9.

Remarks. This species is here divided into three informal varieties based on ornament and shape (Fig. 28-30).

Nannoceratopsis senex var. A
Plate 6, figure 18; Figure 28

Remarks. This variety of *N. senex* is characterized by granulate to micro-reticulate to alveolate ornament.
Size: length 39(61)80 μm; breadth – 34(51)69 μm (58 measured specimens).

Distribution. This variety is present in Oppel-Zones A, B, C, D, E and F, Toarcian or older to Bathonian.

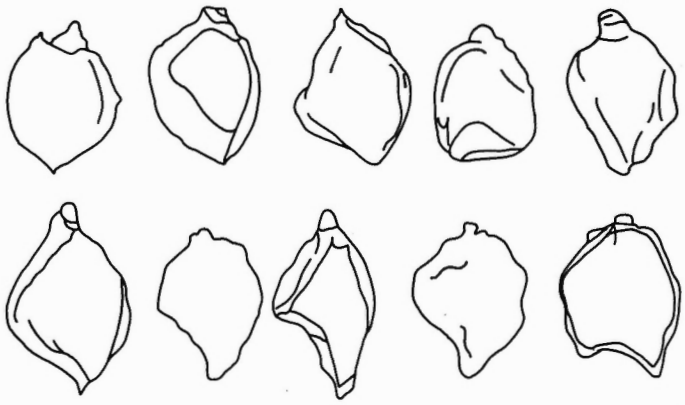

Figure 28. *Nannoceratopsis senex* var. A, illustrating variation in shape and antapical horn positions. GSC

Nannoceratopsis senex var. B
Plate 6, figure 19; Figure 29

Remarks. This variety of *N. senex* is characterized by a smooth to almost smooth autophragm and strong angularities at the three horn positions (1 apical and 2 antapical). The two antapical horns may occasionally be strongly developed but not as strongly as in *Nannoceratopsis plegas*.
Tabulation is not usually present.
Size: length – 44(63)80 μm; breadth – 27(42)55 μm (38 measured specimens).

Distribution. *N. senex* var. B. is present in Oppel-Zones A, C, D, E and F, Toarcian or older to Bathonian.

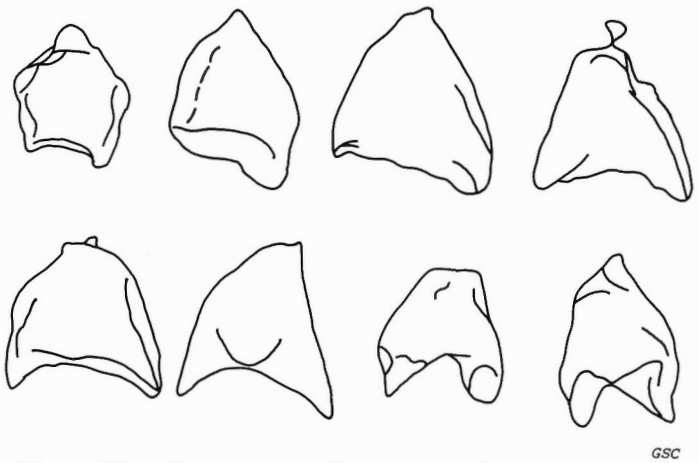

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Figure 29. *Nannoceratopsis senex* var. B, illustrating variation in shape and antapical horn positions.

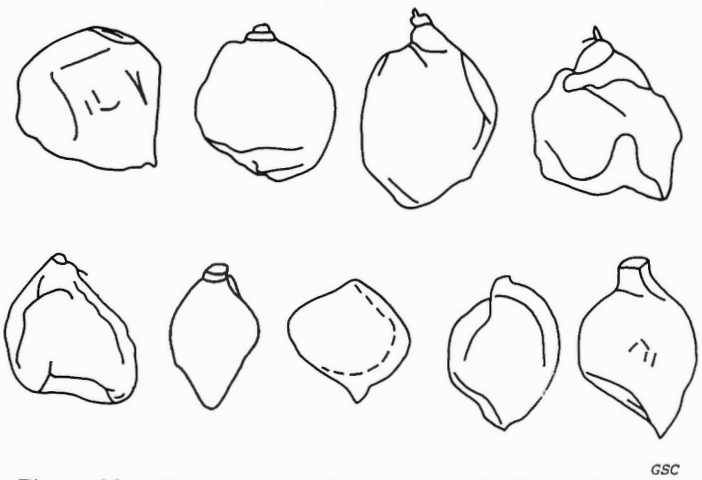

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Figure 30. *Nannoceratopsis senex* var. C, illustrating variation in shape and antapical horn positions.

Nannoceratopsis senex var. C
Plate 6, figure 20; Figure 30

Remarks. This variety of *N. senex* is similar to *N. senex* var. B except the tendency to develop horns is reduced, resulting in a rounded cyst outline.
Size: length – 48(61)80 μm; breadth 38(50)61 μm (45 measured specimens).

Distribution. *N. senex* var. C is present in Oppel-Zones A and B, Toarcian or older.

Incertae Familiae
Genus *Fromea* Cookson and Eisenack

1958 *Fromea* Cookson and Eisenack, p. 55.

Type Species. *Fromea amphora* Cookson and Eisenack, 1958.

Fromea atlantica (Habib) comb. nov.
Plate 6, figures 24-25

1972 *Tenua atlantica* Habib, p. 375, Pl. 4, Fig. 2, 5.
1977a *Fromea complicata* Brideaux, p. 18-19, Pl. 7, Fig. 1-6.
1978 *?Sentusidinium atlantica* (Habib, 1972) Stover and Evitt, p. 50

Remarks. The lozenge shape, finely granulate to scabrate autophragma, weakly developed cingulum and the small apical archeopyle characterize *F. atlantica*.

Distribution. This species is present in Oppel-Zone Q, Valanginian to possibly Hauterivian. It has been recorded from the Callovian-Oxfordian of the western North Atlantic (Habib, 1972) and from the Aptian-Albian of the District of Mackenzie (Brideaux, 1977b).

CONCLUSIONS

1. Well preserved high latitude dinoflagellate cyst assemblages have been recovered from the Jurassic to Lower Cretaceous of the Sverdrup Basin. One hundred and twenty-nine species have been identified, including 18 new species.
2. These high latitude assemblages are characterized by low diversities and dominated by proximate acavate cysts.
3. Seventeen dinoflagellate cyst Oppel-zones are recognized from the Toarcian or older to the Late Valanginian or younger and dated to substage level.

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APPENDIX
List of Species

Acanthaulax aculeata (Klement, 1960) Stover and Evitt, 1978
Acanthaulax senta Drugg, 1978
Adnatosphaeridium paucispinum (Klement, 1960) Gitmez and Sarjeant, 1972
Apteodinium apiatum McIntyre and Brideaux, 1980
Apteodinium bucculiatum sp. nov.
Apteodinium conjunctum Eisenack and Cookson, 1960
Apteodinium granulatum Eisenack, 1958
Apteodinium maculatum Eisenack and Cookson, 1960
Apteodinium nuciforme (Deflandre, 1938) Stover and Evitt, 1978
Apteodinium spongiosum McIntyre and Brideaux, 1980
Atopodinium prostatum Drugg, 1978

Bourkidinium granulatum Morgan, 1975

Caligodinium aceras (Manum and Cookson, 1964) Lentin and Williams, 1973
Canningia circularia Cookson and Eisenack, 1971
Canningia ringnesiorum Manum and Cookson, 1964
Canningia rotundata Cookson and Eisenack, 1961
Chlamydophorella membranoidea Vozzhennikova, 1967
Chlamydophorella sp. A
Chytroeisphaeridia chytroeides (Sarjeant, 1962a) Downie and Sarjeant, 1964
?Chytroeisphaeridia mantellii Gitmez and Sarjeant, 1972
Cleistosphaeridium sp. A
Cleistosphaeridium sp. B
Comparodinium aquilonium Dörhöfer and Davies, 1980
?Comparodinium cavum sp. nov.
Comparodinium lineatum Wille and Gocht, 1979
Comparodinium perpunctatum Wille and Gocht, 1979
Cribroperidinium granulatum (Klement, 1960) Stover and Evitt, 1978
Cribroperidinium muderongense (Cookson and Eisenack, 1958) Davey, 1969
Cyclonephelium distinctum Deflandre and Cookson, 1955
Cyclonephelium eisenackii Davey, 1969

Dapcodinium coalitum sp. nov.
Dapcodinium holotabulatum sp. nov.
Dapcodinium semitabulatum (Morgenroth, 1970) Dörhöfer and Davies, 1980
Dapcodinium wapellense (Pocock, 1972) Dörhöfer and Davies, 1980
Dingodinium cerviculum Cookson and Eisenack, 1958
Dingodinium minutum Dodekova, 1975
Dodekovia syzygia Dörhöfer and Davies, 1980

?Egmontodinium diminutum sp. nov.
?Egmontodinium sp. cf. ?E. diminutum
Ellipsoidictyum cinctum Klement, 1960
Ellipsoidictyum sp. cf. *E. cinctum Klement*, 1960
Endoscrinium subvallare (Sarjeant, 1962b) Lentin and Williams, 1973
Escharisphaeridia dictydia (Sarjeant, 1972) Erkmen and Sarjeant, 1980
Escharisphaeridia pocockii (Sarjeant, 1968) Erkmen and Sarjeant, 1980
Escharisphaeridia rudis sp. nov.
Escharisphaeridia sp. A.
Exochosphaeridium scitulum Singh, 1971

Fromea atlantica (Habib, 1972) comb. nov.

Glomodinium evittii (Pocock, 1972) comb. nov.
Glomodinium opeasatos sp. nov.
Glomodinium tripartitum (Johnson and Hills, 1973) Dörhöfer and Davies, 1980
Glomodinium zabros sp. nov.
Gochteodinia verrucosa (Vozzhennikova, 1967) Dörhöfer and Davies, 1980
Gochteodinia villosa (Vozzhennikova, 1967) Norris, 1978b
Gonyaulacysta dualis (Brideaux and Fisher, 1976) Stover and Evitt, 1978
Gonyaulacysta helicoidea (Eisenack and Cookson, 1960) Sarjeant, 1966
Gonyaulacysta jurassica (Deflandre, 1938) Norris and Sarjeant, 1965
G. jurassica jurassica (Deflandre, 1938) Norris and Sarjeant, 1965
G. jurassica longicornis (Deflandre, 1938) Lentin and Williams, 1973
Gonyaulacysta kunzeviensis (Vozzhennikova, 1967) stat. nov., comb. nov.
Gonyaulacysta transparens (Sarjeant, 1959) Sarjeant, 1969

Heslertonia heslertonensis (Neale and Sarjeant, 1962) Sarjeant, 1966
Heslertonia teichophera (Sarjeant, 1961) Sarjeant, 1976
Horologinella spinosigibberosa Brideaux and Fisher, 1976
Hystrichodinium lanceatum sp. nov.
Hystrichogonyaulax cladophora (Deflandre, 1938) Stover and Evitt, 1978
Hystrichogonyaulax serrata (Cookson and Eisenack, 1958) Stover and Evitt,1978

Imbatodinium jaejeri (Alberti, 1961) Dörhöfer and Davies, 1980
Imbatodinium micropodum (Eisenack and Cookson, 1960) Dörhöfer and Davies,1980
Impagidinium white (Sarjeant, 1966) Stover and Evitt, 1978

?Kallosphaeridium agglutinatum McIntyre and Brideaux, 1980
Kalyptea glabra (Cookson and Eisenack, 1958) Wiggins, 1975

Lanterna saturnalis Brideaux and Fisher, 1976
Lecaniella foveolata Singh, 1971
Leptodinium arcuatum Klement, 1960
Leptodinium eumorphum (Cookson and Eisenack, 1960b) Sarjeant, 1969
Leptodinium hyalodermopsis (Cookson and Eisenack, 1958) Stover and Evitt,1978
Leptodinium millioudii (Sarjeant, 1963) Sarjeant, 1969
Leptodinium mirable Klement, 1960
Leptodinium perforans (Cookson and Eisenack, 1958) Stover and Evitt, 1978
?Lithodinia cantrellii (Sarjeant, 1972) Gocht, 1975
Lithodinia deflandrei (Sarjeant, 1968) Gocht, 1975
Lithodinia jurassica Eisenack, 1935 emend. Gocht, 1975
Lithodinia serrulata sp. nov.
Lithodinia staffinensis (Gitmez, 1970) Gocht, 1975
Lithodinia valensii (Sarjeant, 1966) Gocht, 1975
?Lithodinia sp. A
?Lithodinia sp. B
Lithodinia sp. C
Lunatadinium dissolutum Brideaux and McIntyre, 1973
Luxadinium propatulum Brideaux and McIntyre, 1975

?Meiourogonyaulax acanthosphaera (Sarjeant, 1961) Sarjeant, 1976
Mendicodinium reticulatum Morgenroth, 1970
Microdinium opacum Brideaux, 1971
Millioudodinium ambiguum (Deflandre, 1939) Stover and Evitt, 1978
Millioudodinium ehrenbergii (Gitmez, 1970) Stover and Evitt, 1978
Millioudodinium episomum (Sarjeant, 1966) Stover and Evitt, 1978
Millioudodinium jubaris sp. nov.
Millioudodinium mamilliferum (Deflandre, 1939) Stover and Evitt, 1978
Moesiodinium raileanui Antonescu, 1974
Muderongia simplex Alberti, 1961
Muderongia tomaszowensis Alberti, 1961

Nannoceratopsis gracilis Alberti, 1961
Nannoceratopsis pellucida Deflandre, 1938
Nannoceratopsis plegas Drugg, 1978

Nannoceratopsis senex van Helden, 1977
Nannoceratopsis senex var. A
Nannoceratopsis senex var. B
Nannoceratopsis senex var. C
Nelchinopsis kostromiensis (Vozzhennikova, 1967) Wiggins, 1972

Occisucysta thulia sp. nov.
Odontochitina operculata (Wetzel, 1933) Deflandre and Cookson, 1955
Oligosphaeridium albertense (Pocock, 1962) Davey and Williams, 1969
Oligosphaeridium anthophorum (Cookson and Eisenack, 1958) Davey, 1969
Oligosphaeridium complex (White, 1842) Davey and Williams, 1966
Oligosphaeridium totum Brideaux, 1971
Ovoidinium waltonii (Pocock, 1972) Lentin and Williams, 1976

Paragonyaulacysta borealis (Brideaux and Fisher, 1976) Stover and Evitt,1978
Paragonyaulacysta calloviensis Johnson and Hills, 1973
Paragonyaulacysta capillosa (Brideaux and Fisher, 1976) Stover and Evitt,1978
Paragonyaulacysta retiphragmata Dörhöfer and Davies, 1980
Pareodinia ceratophora Deflandre, 1947 emend. Gocht, 1970
Pareodinia groenlandica Sarjeant, 1972
Parvocysta cracens Bjaerke, 1980
Parvulodinium clavatum Dodekova, 1975
Parvulodinium penitabulatum sp. nov.
Phallocysta eumekes Dörhöfer and Davies, 1980
Prolixosphaeridium spissum (McIntyre and Brideaux, 1980) Lentin and Williams, 1981
Pseudoceratium pelliferum Gocht, 1957

Schizocystia laevigata (Cookson and Eisenack, 1962)
Schizosporis reticulata Cookson and Dettmann, 1959 emend. Pierce, 1976
Scriniocassis dictyotus (Cookson and Eisenack, 1960b) Beju, 1971, stat. nov.
Scriniocassis pyrus (Gitmez, 1970) Lentin and Williams, 1977 stat. nov.
Scriniocassis weberi Gocht, 1964
Scriniodinium crystallinum (Deflandre, 1938) Klement, 1960
Sentusidinium cuculliformis sp. nov.
Sentusidinium echinatum (Gitmez and Sarjeant, 1972) Sarjeant and Stover,1978
Sentusidinium filiatum sp. nov.
Sentusidinium pilosum (Ehrenberg, 1843) Sarjeant and Stover, 1978
Sentusidinium rioultii (Sarjeant, 1968) Sarjeant and Stover, 1978
Sentusidinium varispinosum (Sarjeant, 1959) Sarjeant and Stover, 1978
Sentusidinium verrucosum (Sarjeant, 1968) Sarjeant and Stover, 1978
Sentusidinium villerense (Sarjeant, 1968) Sarjeant and Stover, 1978
Sirmiodinium grossii Alberti, 1961
Stephanelytron redcliffense Sarjeant, 1961
Susadinium scrofoides Dörhöfer and Davies, 1980

Tanyosphaeridium isocalamum (Deflandre and Cookson, 1955) Davey and Williams, 1969
Tanyosphaeridium magneticum sp. nov.
?Tectatodinium granulatum (Ioannides et al., 1977) Davey, 1979
Tectatodinium laminatum sp. nov.
Tectatodinium pellitum Wall, 1967
Trichodinium erinaceoides sp. nov.
Trichodinium pellitum Eisenack and Cookson, 1960
Tubotuberella apatela (Cookson and Eisenack, 1960b) Ioannides et al., 1977
Tubotuberella dangeardii (Sarjeant, 1968) Stover and Evitt, 1978
Tubotuberella dentata Raynaud, 1978
Tubotuberella egemenii (Gitmez, 1970) Stover and Evitt, 1978
Tubotuberella eisenackii (Deflandre, 1938) Stover and Evitt, 1978
Tubotuberella irregulare (Cookson and Eisenack, 1958) comb. nov.
Tubotuberella lurida (Deflandre, 1938) comb. nov.
Tubotuberella rhombiformis Vozzhennikova, 1967
Tubotuberella uncinatum (Brideaux, 1977b) comb. nov.
Tubotuberella whatleyi (Sarjeant, 1972) Stover and Evitt, 1978

Wallodinium elongatum (Beju, 1971) Duxbury, 1980

PLATES 1–10

A ten micron bar is illustrated in each figure. All specimens are deposited at the Royal Ontario Museum (ROM), Toronto, Ontario, except those from the Panarctic Sandy Point L-46 well sample which are deposited in type collections of the Geological Survey of Canada.

In the figure explanatory the species name is followed by the locality/slide number, the "England Finder" reference system co-ordinates, the optical system (IC = interference contrast; PC = phase contrast), figure descriptions, if needed, and the ROM or GSC collection number.

PLATE 1

Figures 1-8. *Dapcodinium coalitum* sp. nov.

1. ED 1029-1A, O43/4, IC, ROM 36619
2. JB 1950A, Q34/1, IC, ROM 36552
3. JB 1950A, C33/4, IC, dorsal focus, ROM 36552
4. JB 1950A, C33/4, IC, ventral focus, ROM 36552
5. ED 1030-4A, U44/4, IC, lateral view, ROM 36629
6. JB 1950A, P37/1, IC, lateral view, ROM 36552
7. JB 1950A, L36/2, IC, holotype, ROM 36552
8. JB 1950A, L36/2, PC, holotype, ROM 36552

Figures 9-19. *Dapcodinium holotabulatum* sp. nov.

9. SP 1880F, H42/0, PC, holotype, ventral focus, GSC #69359
10. SP 1880F, H42/0, IC, holotype, optical section, GSC #69359
11. SP 1880F, H42/0, IC, holotype, ventral focus, GSC #69359
12. ED 1030-4A, K48/4, IC, optical section, ROM 36629
13. ED 1030-4B, N39/3, IC, ventral focus, ROM 36629
14. ED 1030-4B, N39/3, IC, optical section, OP = operculum, ROM 36629
15. ED 1030-4B, N39/3, IC, dorsal focus, ROM 36629
16. ED 1030-4A, K48/4, IC, lateral focus, ROM 36629
17. ED 1030-4A, L45/0, IC, optical section, ROM 36629
18. ED 1030-4A, L45/0, IC, dorsal focus, ROM 36629
19. ED 1030-4A, L45/0, IC, ventral focus, ROM 36629

Figure 20. *Phallocysta eumekes*
ED 1031-4A, P37/3, IC, holotype, ROM 36631

PLATE 1

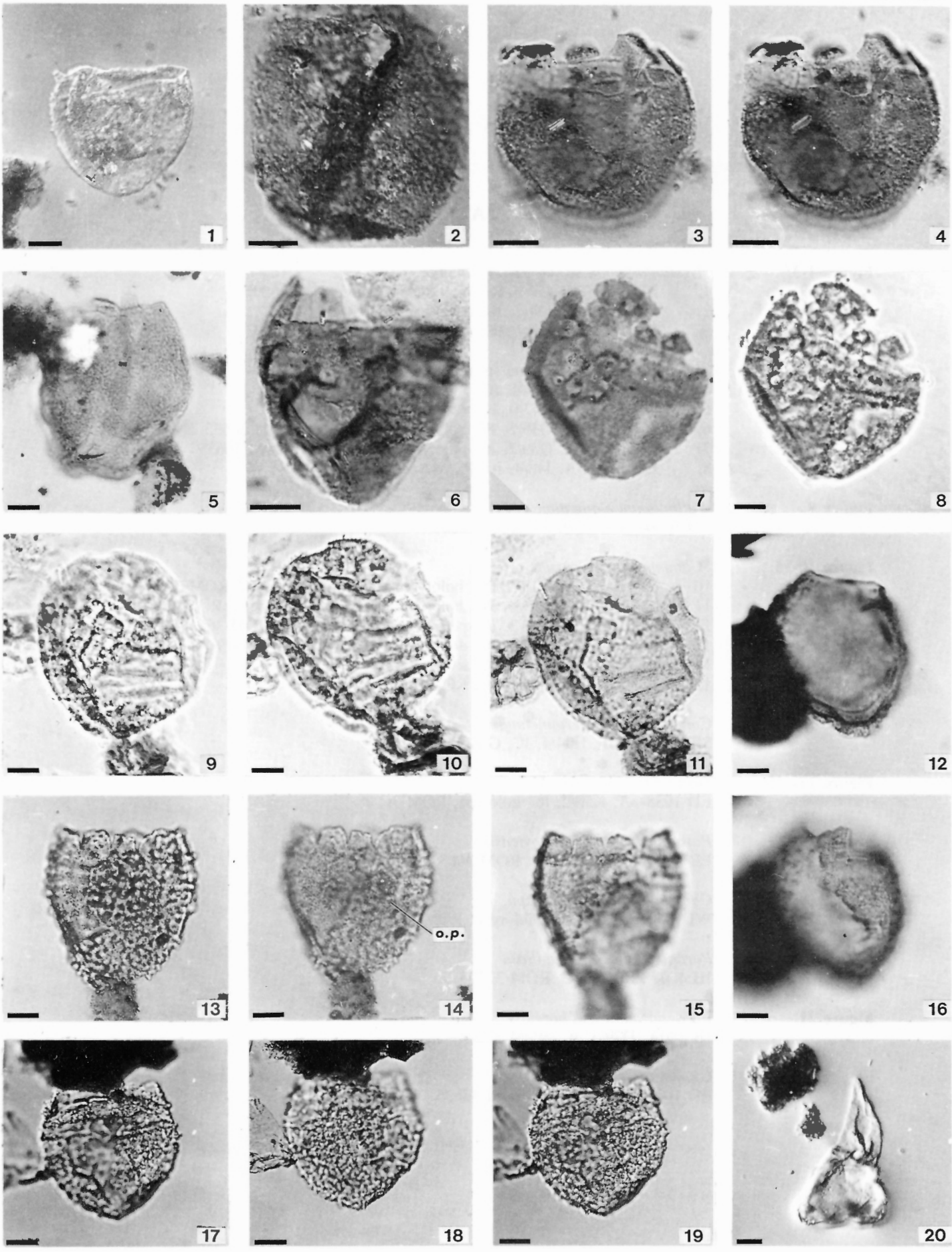


PLATE 2

Figure 1-3. *?Egmontodinium* sp. cf. *?E. diminutum*
1. ED 1007-3B, J54/2, IC, right lateral focus, ROM 36690
2. ED 1007-3B, J54/2, IC, optical section, ROM 36690
3. ED 1007-3B, J54/2, IC, left lateral focus, ROM 36690

Figure 4-8. *?Egmontodinium diminutum* sp. nov.
4. ED 1009-5A, S34/4, IC, ROM 36639
5. ED 1009-5A, R47/0, IC, ROM 36639
6. ED 1009-1A, Q39/2, IC, holotype, dorsal focus, ROM 36635
7. ED 1009-1A, Q39/2, IC, holotype, ventral focus, ROM 36635
8. ED 1009-5A, J40/4, IC, ROM 36639

Figure 9. *Wallodinium elongatum*
ED 1030-4A, T55/0, IC, ROM 36629

Figure 10-15. *?Comparodinium cavum*
10. ED 1029-1A, O43/4, PC, holotype, dorsal pericyst focus, ROM 36619
11. ED 1029-1A, O43/4, PC, holotype, dorsal endocyst focus, ROM 36619
12. ED 1029-1A, K54/3, IC, periphragm discontinuous, ROM 36619
13. ED 1029-1A, K54/3, IC, dorsal pericyst focus, ROM 36619
14. ED 1029-3A, B32/4, IC, ROM 36621
15. ED 1029-1A, H48/1, IC, ROM 36619

Figure 16. *Comparodinium perpunctatum*
SP 2330-2360F, H34/4, IC, GSC #69360

Figure 17. *Susadinium scrofoides*
ED 1038-2A, K50/2, IC, holotype, ROM 36598

Figure 18. *Paragonyaulacysta calloviensis*
ED 1009-3A, K37/1, IC, ROM 36637

Figure 19. *Comparodinium aquilonium*
WI 1950A, U36/0, IC, holotype, ROM 36470

Figure 20. *Paragonyaulacysta capillosa*
JB 450A, R36/0, IC, ROM 37203

Figure 21. *Paragonyaulacysta borealis*
JB 480A, D29/3, IC, ROM 37204

Figure 22. *Glomodinium tripartitum*
ED 1009-1A, J44/0, IC, ROM 36635

PLATE 2

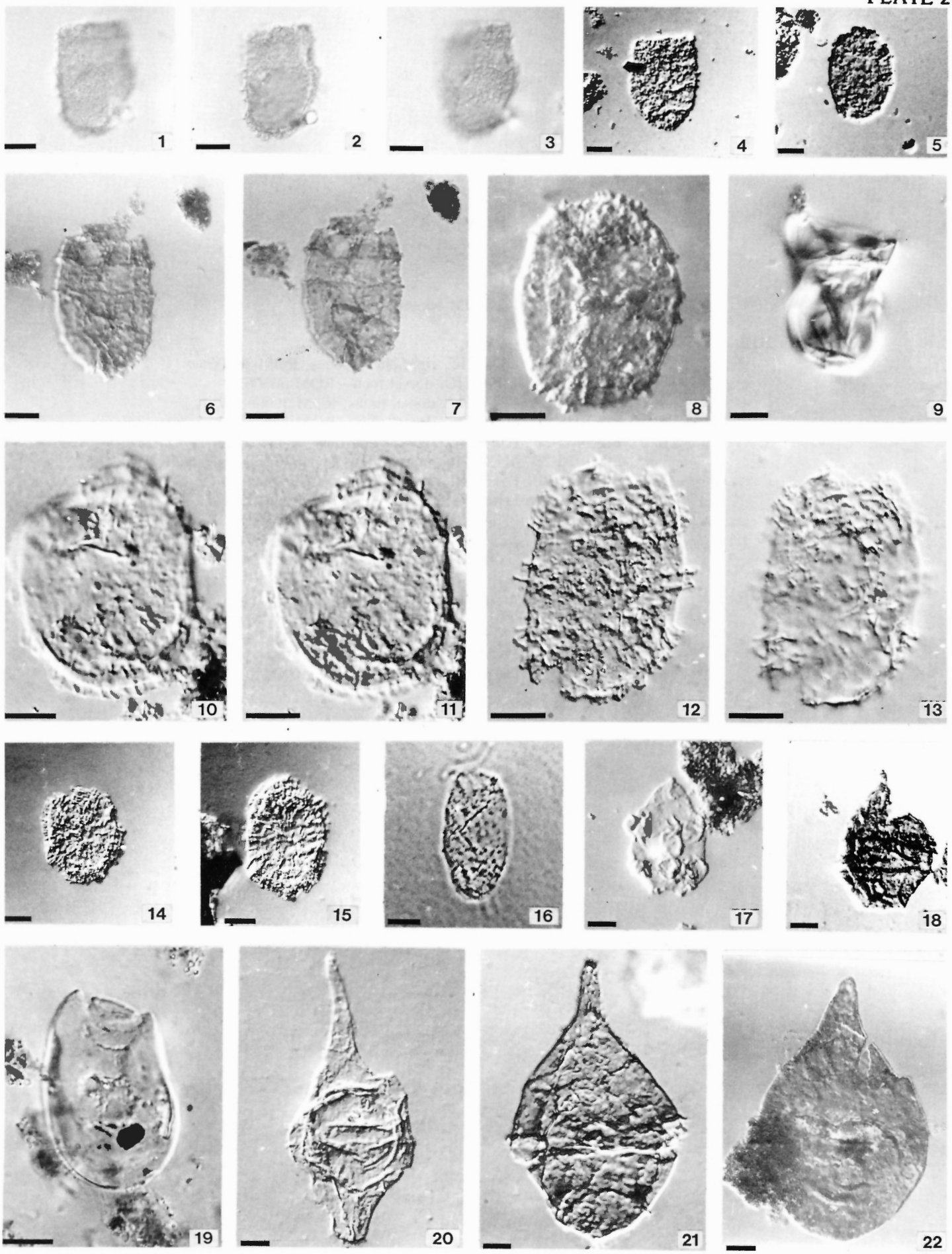


PLATE 3

Figure 1. *Glomodinium evittii*
ED 1035-2B, F33/0, IC, ROM 36606

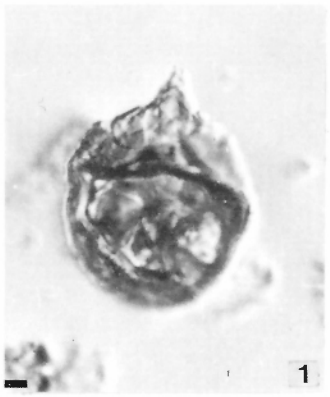
Figures 2-12. *Glomodinium zabros* sp. nov.

2. ED 1035-2B, P52/0, IC, right lateral focus, ROM 36606
3. ED 1035-2A, U39/2, IC, dorsal focus, ROM 36606
4. ED 1035-2A, L31/4, IC, dorsal focus, ROM 36606
5. ED 1035-2B, G44/0, IC, dorsal focus, ROM 36606
6. ED 1035-2B, P51/0, IC, right lateral view, ROM 36606
7. ED 1035-2B, M45/0, IC, lateral view, apical horn removed, ROM 36606
8. ED 1035-2B, P51/1, IC, ventral focus, ROM 36606
9. ED 1035-2A, O36/0, IC, lateral view, ROM 36606
10. ED 1040-3B, P33/3, IC, finer ornament, ROM 36710
11. ED 1040-3A, E39/2, IC, finer ornament, ROM 36710
12. ED 1009-7Aa, N48/0, IC, holotype, left lateral view, ROM 36641

Figure 13-16. *Glomodinium opeasatos* sp. nov.

13. ED 1009-3A, O46/0, IC, holotype, lateral view, ROM 36637
14. ED 1009-3A, C32/1, IC, lateral view, ROM 36637
15. ED 1009-3A, C32/1, PC, lateral view, ROM 36637
16. ED 1009-3A, O40/1, IC, dorsal focus, ROM 36637

PLATE 3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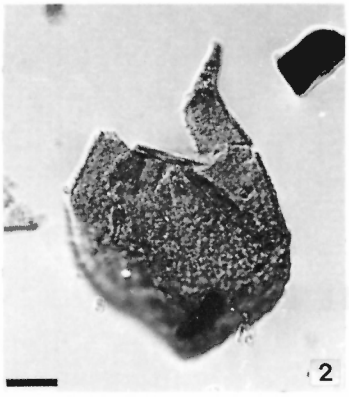
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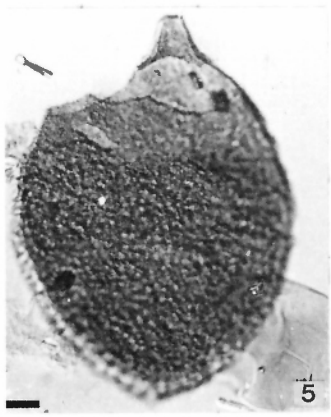
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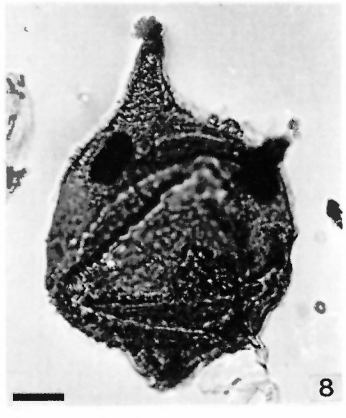
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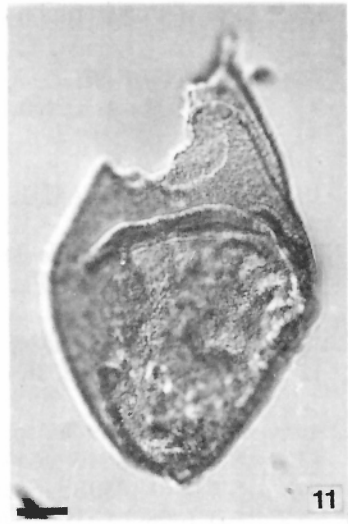
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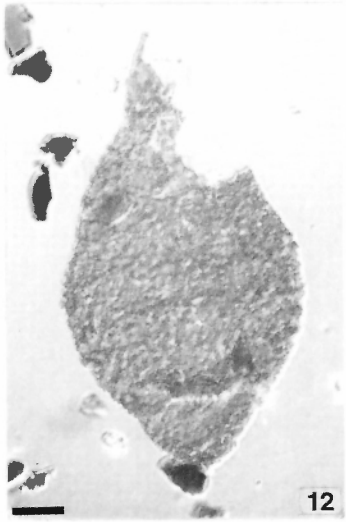
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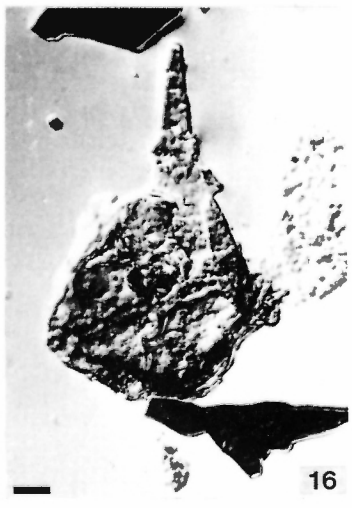

16

PLATE 4

Figure 1-3. *Gonyaulacysta kunzeviensis*
1. JB 1560A, S40/4, IC, medium ventral focus, ROM 36542
2. JB 1560A, S40/4, IC, dorsal focus, ROM 36542
3. JB 1560A, S40/4, IC, high ventral focus, ROM 36542

Figure 4. *Tubotuberella rhombiformis*
4. ED 1004-3G, P52/0, IC, ROM 36678

Figure 5, 6. *Tubotuberella egemenii*
5. SP 1220-1250G, E53/1, IC, GSC #69361
6. JB 510A, T68/4, IC, ROM 36542

Figure 7. *Tubotuberella apatela*
7. ED 1034-1A, J44/0, IC, ROM 36599

Figure 8. *Tubotuberella dangeardii*
8. ED 1050-2A, H44/0, IC, ROM 36733

Figure 9. *Tubotuberella eisenackii*
9. ED 1009-4A, C36/0, IC, ROM 36638

Figure 10. *Gonyaulacysta dualis*
10. ED 1008-8A, A42/1, IC, ROM 36698

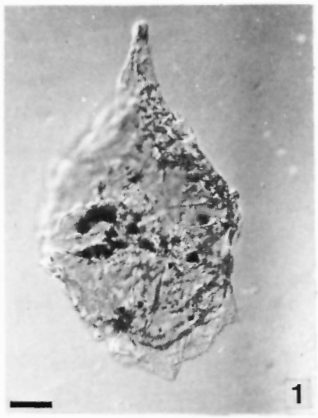
Figure 11. *Hystrichogonyaulax cladophora*
11. ED 1047-6A, H39/2, IC, ROM 36740

Figure 12. *Millioudodinium ehrenbergii*
12. JB 240A, U29/3, IC, ROM 36495

Figure 13-18. *Apteodinium bucculiatum* sp. nov.
13. SP 1840-1850B, J65/0, IC, holotype, focus on epicyst, GSC #69362
14. SP 1840-1850B, J65/0, IC, holotype, focus on hypocyst, GSC #69362
15. ED 1008-7A, J56/1, IC, ROM 36697
16. ED 1008-7A, J56/1, PC, ROM 36697
17. ED 1008-8A, D54/1, IC, ROM 36698
18. ED 1009-8A, L46/0, IC, ROM 36643

Figure 19. *Apteodinium conjunctum*
WI 420A, Q58/0, IC, ROM 36419

Figure 20. *Chytroeisphaeridia chytroeides*
ED 1047-7A, H47/4, IC, P_3 archeopyle, ROM 36741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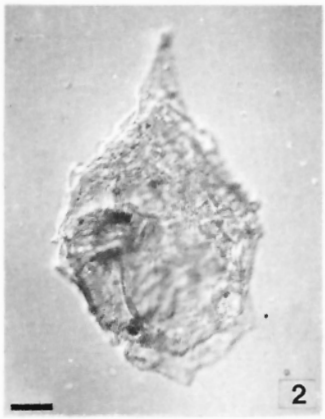
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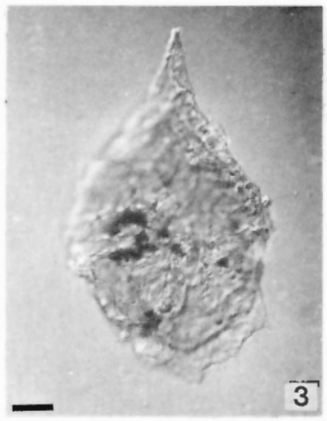
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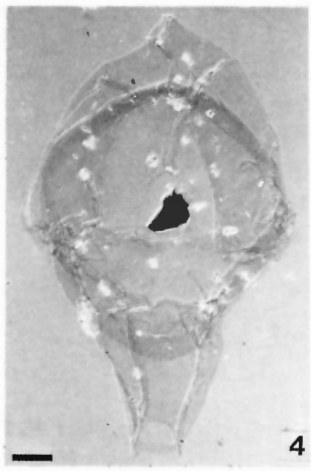
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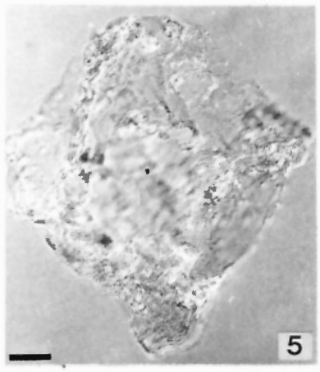
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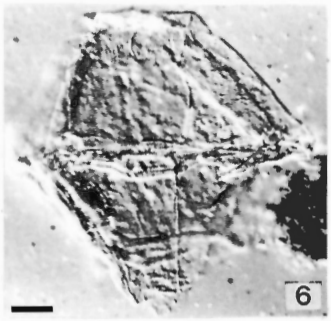
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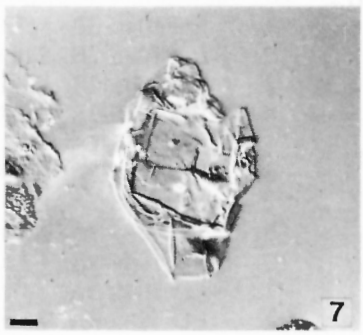
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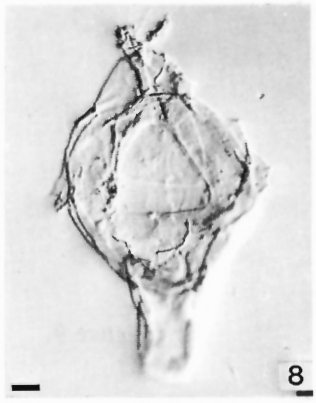
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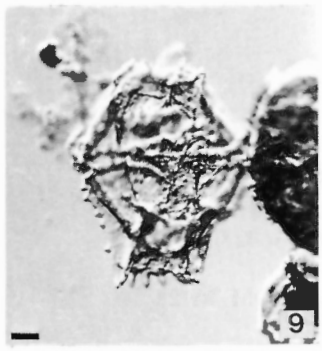
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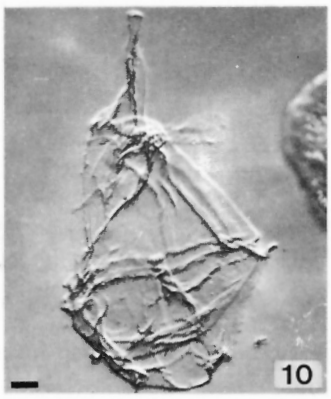
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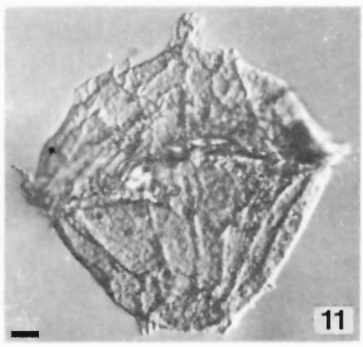
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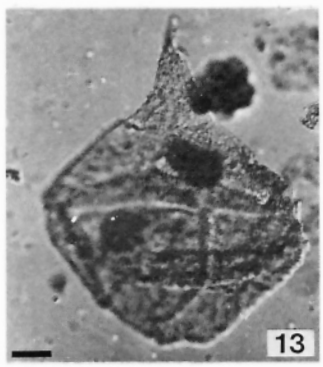
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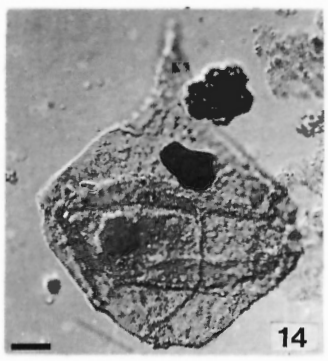
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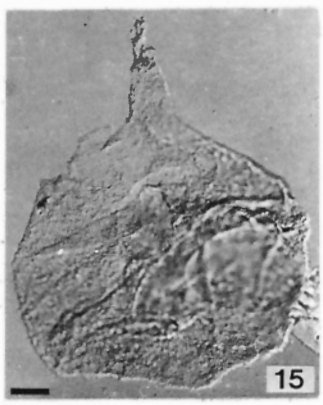
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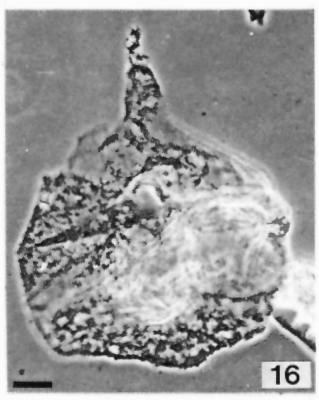
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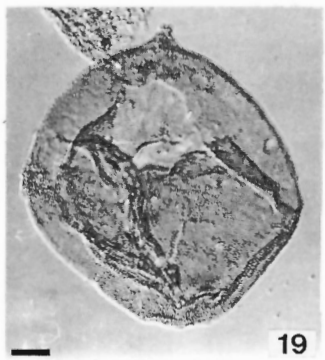
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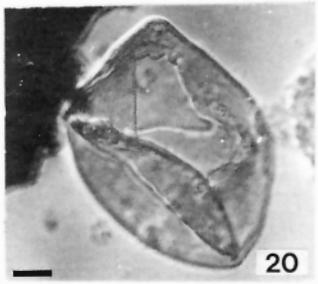
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PLATE 5

Figure 1-8, 10-12. *Occisucysta thulia* sp. nov.

1. ED 1040-3B, M32/2, IC, operculum, ROM 36710
2. ED 1035-2B, S48/0, IC, pericyst, ROM 36606
3. ED 1035-2B, M50/4, IC, pericyst, ROM 36606
4. ED 1035-2B, 040/0, IC, epicyst with hinged operculae (3",4"), ROM 36606
5. ED 1035-2A, R33/0, IC, lateral view, ROM 36606
6. ED 1035-2A, O26/0, PC, dorsal view, ROM 36606
7. ED 1035-2A, L34/3, IC, epicyst, ROM 36606
8. ED 1035-2A, N36/2, IC, epicyst, ROM 36606
10. ED 1040-3A, T37/2, PC, holotype, opical section, ROM 36710
11. ED 1040-3A, T37/2, IC, holotype, ROM 36710
12. ED 1035-3A, L31/3, IC, operculum, ROM 36607

Figure 9. *Millioudodinium mamilliferum*

9. JB 240A, R27/3, PC, ROM 36495

Figure 13-20. *Millioudodinium jubaris* sp. nov.

13. JB240A, K26/2, PC, lateral view, ROM 36495
14,15. JB240A, K26/2, IC, lateral views, ROM 36495
16. WI 690A, E48/3, IC, holotype, ventral focus, ROM 36428
17. WI 690A, C49/3, IC, ventral hypocystal focus, ROM 36428
18. WI 690A, H54/0, IC, dorsal focus on archeopyle, ROM 36428
19. WI 690A, F47/4, IC, ventral focus, ROM 36428
20. WI 690A, H58/4, IC, ventral focus, elongate specimen, ROM 36428

PLATE 5

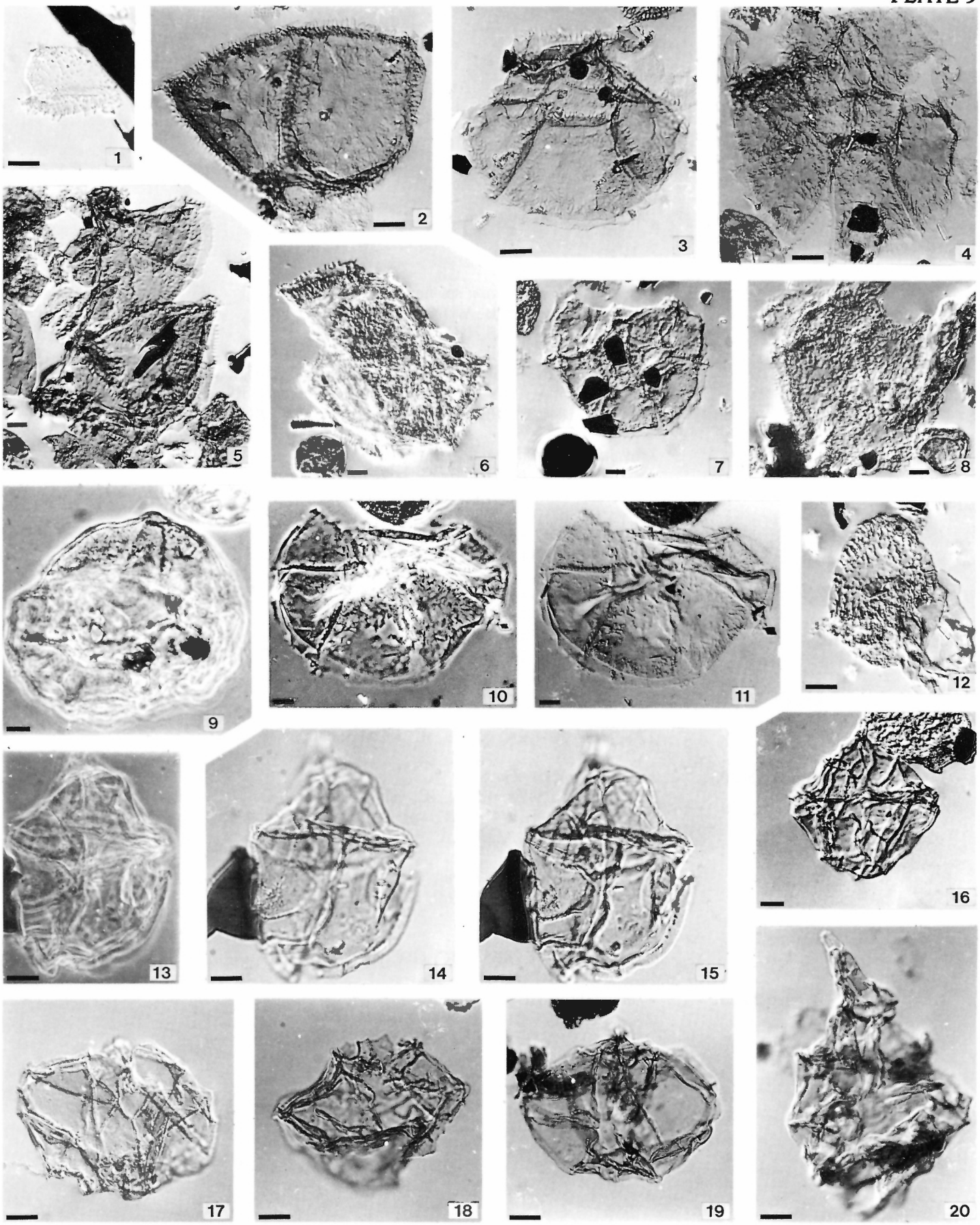


PLATE 6

Figure 1-5, 21 *Tectatodinium laminatum* sp. nov.

1. SP 1840-1850B, V51/0, IC, GSC #69363
2. SP 1840-1850B, G67/4, IC, GSC #69364
3. SP 1840-1850B, G62/4, IC, GSC #69364
4. JB 750A, 032/0, IC, optical section, ROM 36512
5. JB 750A, O32/0, IC, notice surface ornament, ROM 36512
21. SP 1840-1850B, V53/4, IC, holotype, GSC #69365

Figure 6-15. *Trichodinium erinaceoides* sp. nov.

6. ED 1032-1A, T45/0, IC, holotype, ROM 36615
7. ED 1032-1A, T45/0, PC, holotype, ROM 36615
8. ED 1032-1A, U51/0, IC, ROM 36615
9. ED 1032-1A, E46/2, IC, ROM 36615
10. ED 1032-1A, E46/2, PC, ROM 36615
11. ED 1032-1A, K40/1, IC, ROM 36615
12. ED 1032-1A, M37/0, IC, ROM 36615
13. ED 1032-1A, S47/4, IC, ROM 36615
14. ED 1032-1A, Q47/0, IC, ROM 36615
15. ED 1032-1A, M37/0, IC, ROM 36615

Figure 16-17. *Nannoceratopsis gracilis*

16. ED 1031-2A, R48/3, IC, ROM 36630
17. ED 1031-2A, M46/3, IC, ROM 36630

Figure 18-20. *Nannoceratopsis senex*

18. ED 1029-2A, L35/2, IC, var. A, ROM 36620
19. SP 1880F, N47/0, IC, var. B, ROM GSC #69366
20. JB 3030A, M26/0, IC, var. C, ROM 36586

Figure 22. *Prolixosphaeridium spissum,*

22. ED 1044-13A, M49/0, IC, ROM 36878

Figure 23. *Moesiodinium raileanui*

23. SP 1880F, R35/1, IC, GSC #69367

Figure 24-25. *Fromea atlantica*

24. ED 1028-21B, S43/3, IC, ROM 36777
25. ED 1028-21C, R52/3, IC, ROM 36805

PLATE 6

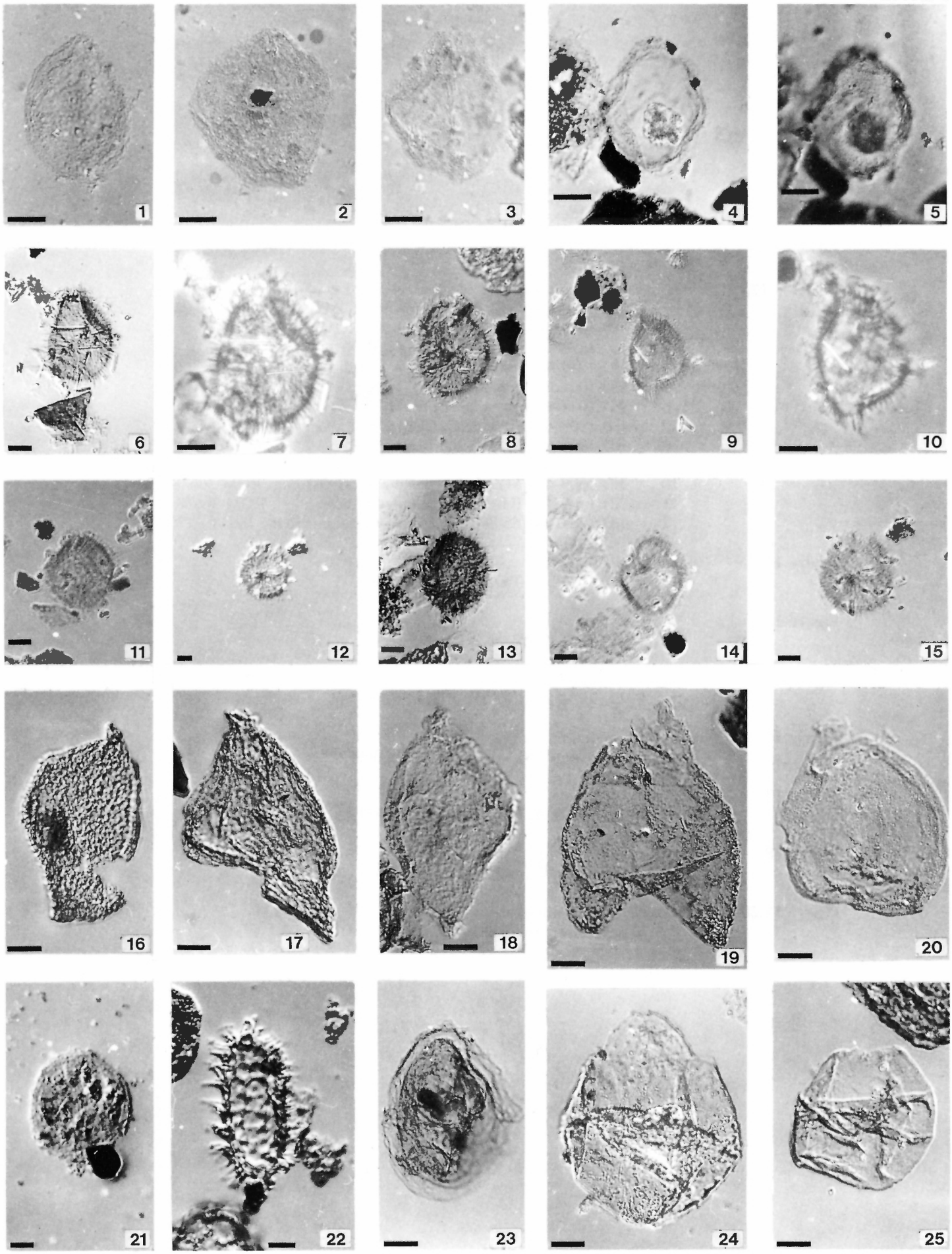


PLATE 7

Figure 1-12. *Hystrichodinium lanceatum* sp. nov.

1. ED 1028-4A, O42/1, IC, holotype, ROM 36760
2. ED 1028-4A, O42/1, PC, holotype, ROM 36760
3. ED 1009-4A, U40/4, IC, ROM 36638
4. ED 1009-4A, H41/4, PC, AP = opical operculum, ROM 36638
5. ED 1009-4A, O44/2, IC, ROM 36638
6. ED 1044-12A, U64/0, IC, ROM 36876
7. ED 1009-4A, U50/0, IC, ROM 36638
8. ED 1009-4A, M51/4, IC, ROM 36638
9. ED 1009-4A, M37/4, PC, precingular operculum, ROM 36638
10. ED 1009-4A, M37/4, IC, precingular operculum, ROM 36638
11. ED 1009-4A, R44/1, IC, precingular operculum, ROM 36638
12. ED 1009-4A, S50/4, PC, apical operculum, ROM 36638

Figure 13. *Scriniocassis weberi*

13. ED 1029-5A, T57/0, IC, ROM 36623

Figure 14. *Scriniodinium pyrus*

14. JB240A, U32/2, ROM 36495

Figure 15. *Chlamydophorella* sp. A.

15. ED 1044-13A, K46/0, ROM 36878

Figure 16. *Escharisphaeridia pocockii*

16. ED 1045-22A, V39/4, IC, ROM 36917

Figure 17. *Muderongia simplex*

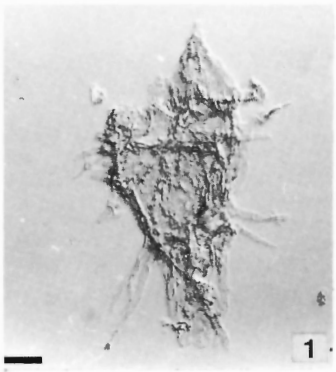
17. ED 1002-4A, J41/1, PC, ROM 36715

Figure 18. *Lanterna saturnalis*

18. JB 480A, D33/0, IC, ROM 37204

Figure 19,20. *Stephanelytron redcliffense*

19,20. ED 1009-7Aa, G43/0, IC, ROM 36641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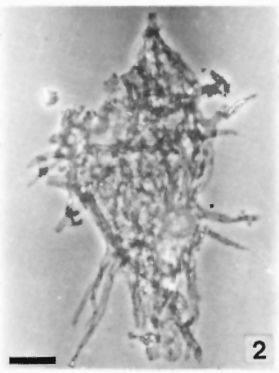
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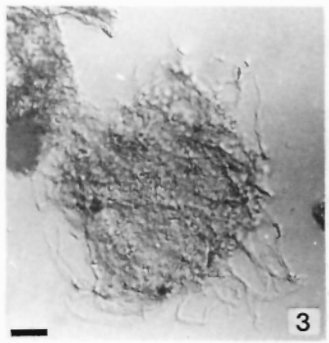
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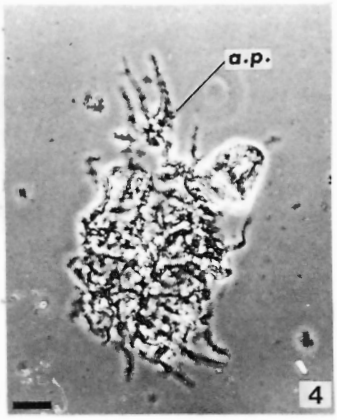

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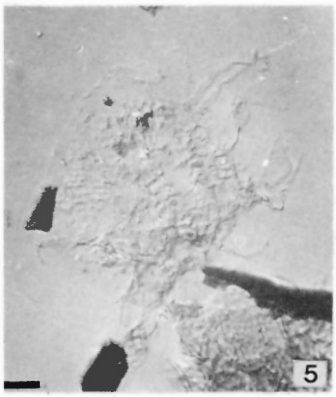
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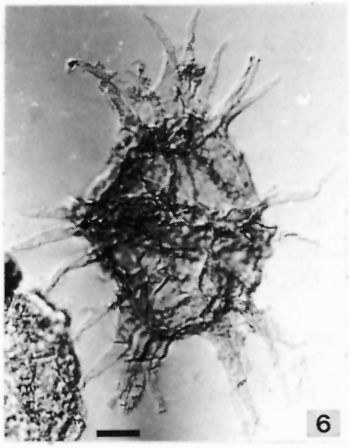
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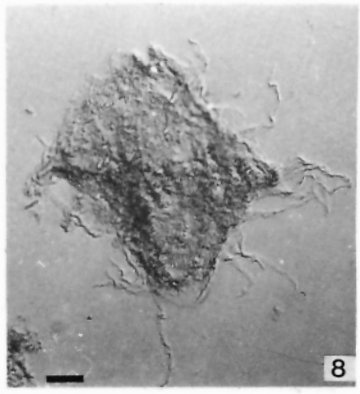
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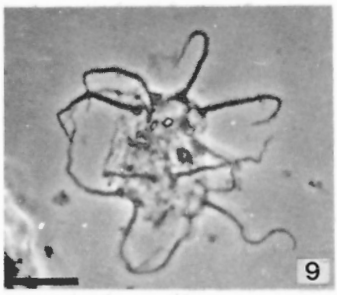
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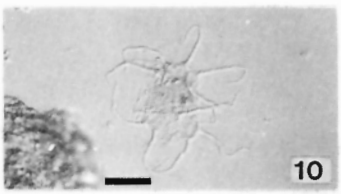
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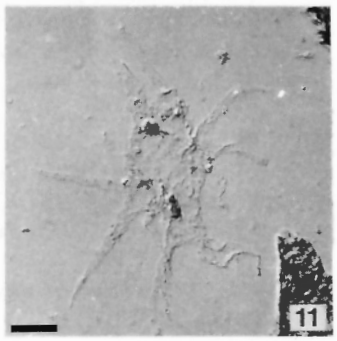
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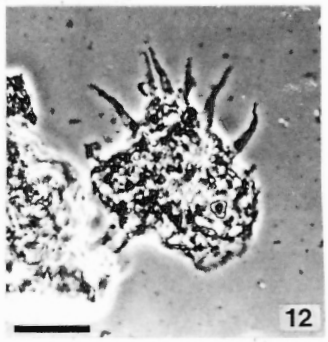
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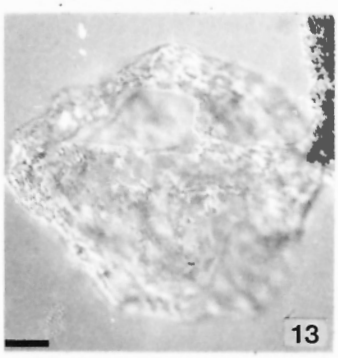
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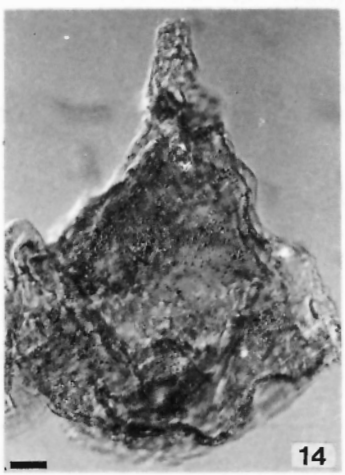
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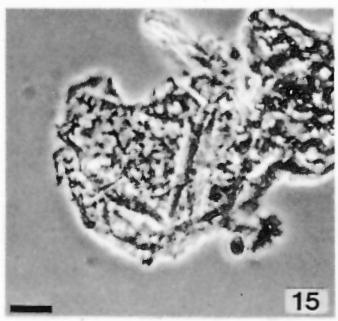
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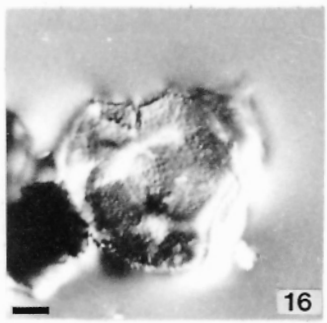
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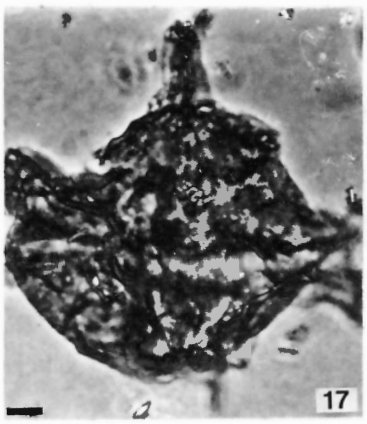
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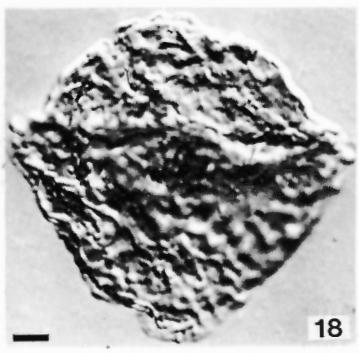
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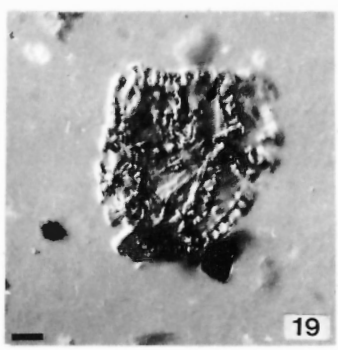
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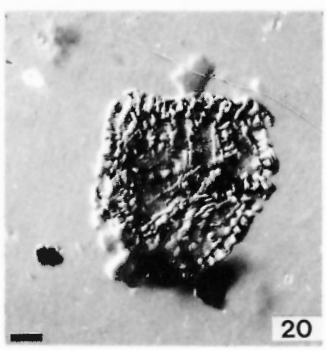
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PLATE 8

Figure 1-8, 11,12 *Tanyosphaeridium magneticum* sp. nov.
1. ED 1004-3F, T52/2, PC, 1 cingular process, ROM 36678
2. ED 1004-3G, K50/1, PC, 2 cingular processes, ROM 36678
3. ED 1004-3G, K50/1, IC, 2 cingular processes, ROM 36678
4. ED 1004-3F, O49/3, IC, 1 cingular process, ROM 36678
5. ED 1004-3G, H46/2, IC, 0 cingular processes, ROM 36678
6. ED 1004-3G, E57/2, IC, operculum ROM 36678
7. ED 1004-3F, T57/3, IC, holotype, 2 cingular processes, ROM 36678
8. ED 1004-3G, P51/2, IC, 1 cingular process, ROM 36678

11,12. ED 1004-3G, P51/2, PC, ROM 36678

Figure 9, 10. *Tanyosphaeridium isocalamum*
9. ED 1034-4A, Q53/2, IC, ROM 36602
10. ED 1034-4A, Q53/2, PC, ROM 36602

Figure 13-14. *Cleistosphaeridium* sp. B.
13. ED 1009-4A, R55/1, IC, ROM 36638
14. ED 1047-7A, N47/3, IC, ROM 36741

Figure 15-18. *Cleistosphaeridium* sp. A.
15. SP 550-580B, IC, M42/0, GSC #69368
16. SP 550-580B, PC, M42/0, GSC #69368
17. SP 550-580B, IC, 038/0, GSC #69369
18. SP 550-580B, PC, 038/0, GSC #69369

Figure 19. *"Chytroeisphaeridia chytroeides"* auct. non.
19. JB 930A, Q37/1, IC, apical archeopyle form, ROM 36518

Figure 20. *Ellipsoidictyum* sp. cf. *E. cinctum*
20. ED 1035-6A, F55/4, IC, ROM 36610

PLATE 8

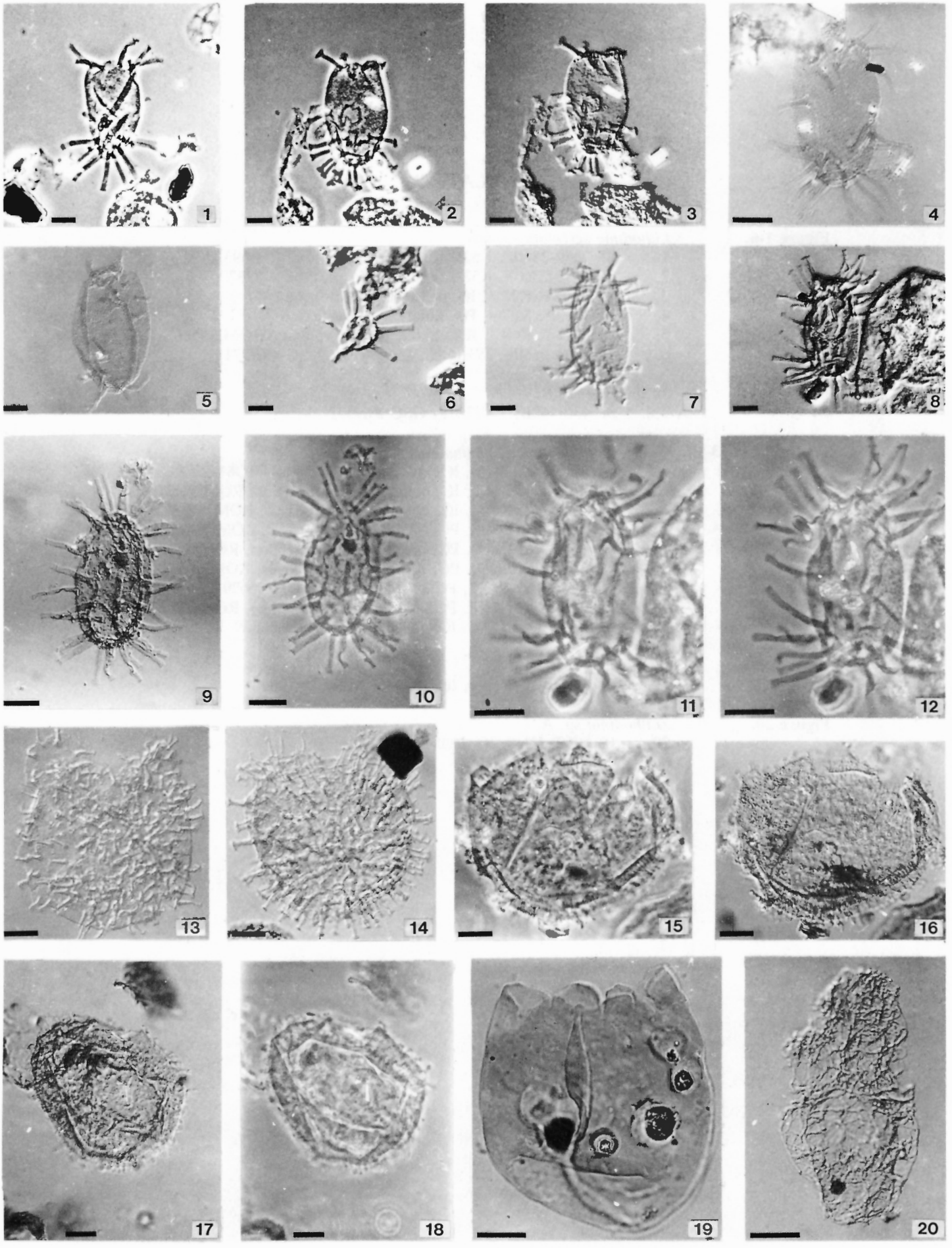


PLATE 9

Figure 1-6. *Lithodinia serrulata* sp. nov.

1. SP 2330-2360F, K52/1, hypotractal focus, GSC #69370
2. SP 2330-2360F, K52/1, epitractal focus, GSC #69370
3. JB 3030A, K27/4, IC, holotype, ROM 36586
4. JB 3030A, K27/4, PC, holotype, ROM 36586
5. JB 3030A, R40/3, IC, oblique dorsal hypotract, ROM 36586
6. SP 2330-2360F, J53/1, IC, apical view, GSC #69371

Figure 7-8. *?Lithodinia* sp. B,

7,8. SP 430-460B, T47/3, IC, GSC #69372

Figure 9-11, 13-15, 17-19. *Parvulodinium penitabulatum* sp. nov.

9. ED 1030-4A, P44/0, IC, holotype, dorsal focus, ROM 36629
10. ED 1030-4A, P44/0, IC, holotype, optical section, ROM 36629
11. ED 1030-4A, P44/0, IC, holotype, ventral focus, ROM 36629
13. ED 1030-4A, P44/0, PC, holotype, dorsal focus, ROM 36629
14. ED 1030-4A, P44/0, PC, holotype, optical section, ROM 36629
15. ED 1030-4A, P44/0, PC, holotype, ventral focus, ROM 36629
17. ED 1030-4A, N53/2, PC, 1" plate focus, ROM 36629
18. ED 1030-4A, N53/2, PC, anterior sulcal plate (as), ROM 36629
19. ED 1030-4A, N53/2, IC, ventral focus, ROM 36629

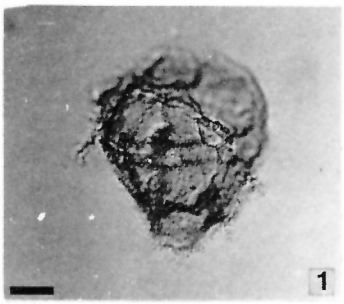
Figure 12,16. *Lithodinia* sp. C.

12,16. ED 1035-8A, K56/4, IC, ROM 36612

Figure 20. *?Lithodinia* sp. A

20. JB 1950, J36/0, IC, ROM 36552

PLATE 9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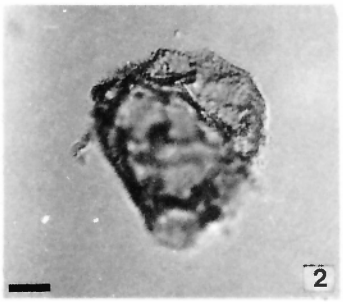
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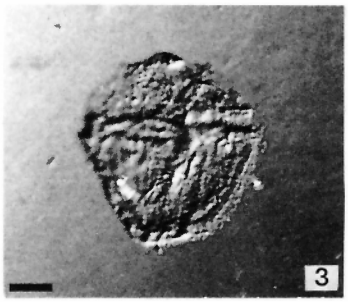
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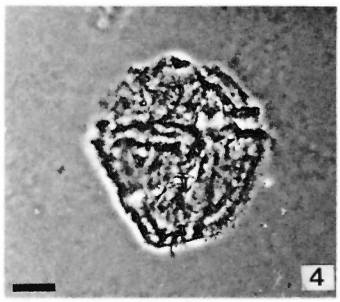
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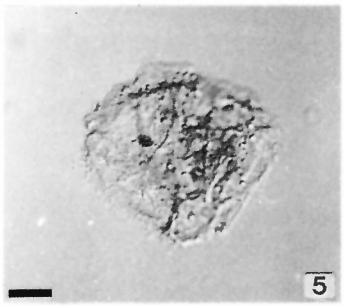
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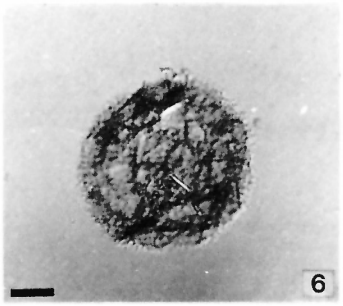
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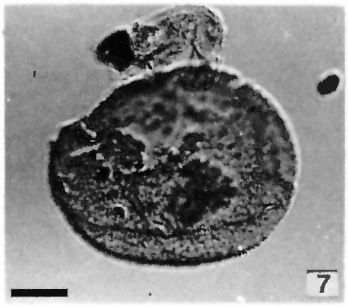
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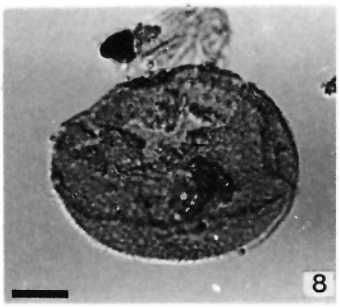
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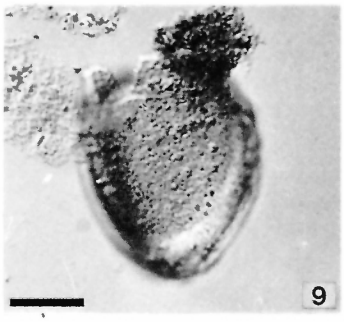
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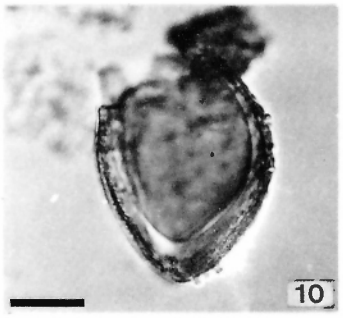
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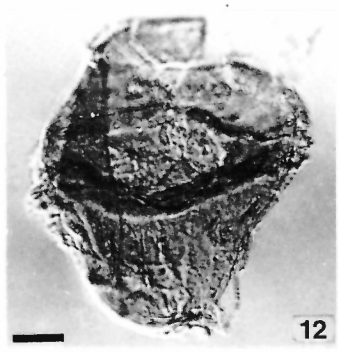
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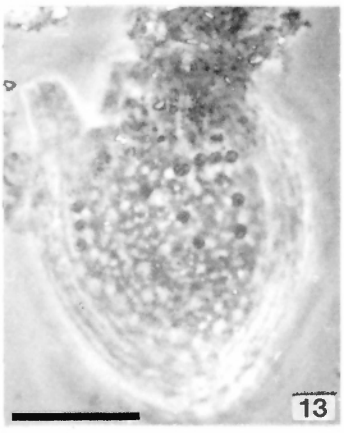
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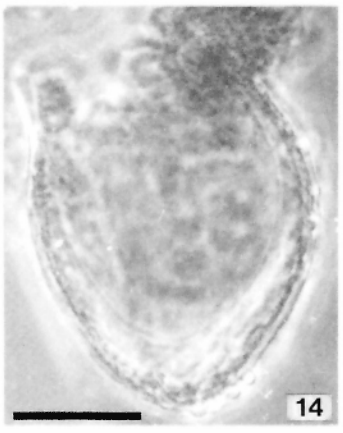
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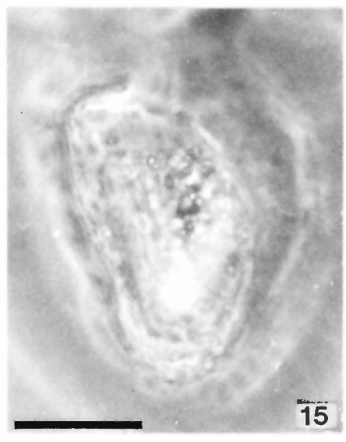
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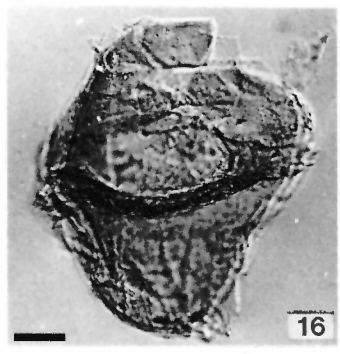
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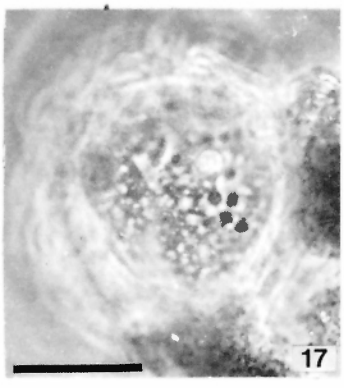
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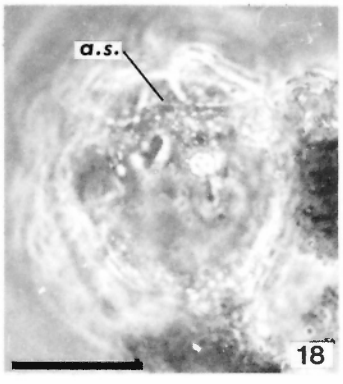

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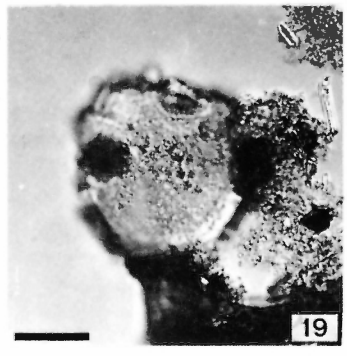
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PLATE 10

Figure 1-4. *Sentusidinium cuculliformis* sp. nov.

1. ED 1027-4A, Q31/1, IC, ROM 36669
2. ED 1034-4A, N43/0, IC, ROM 36602
3. ED 1034-4A, U50/0, IC, holotype, ROM 36602
4. ED 1034-4A, U50/0, PC, holotype, ROM 36602

Figure 5,6, 8-9. *Sentusidinium filiatum* sp. nov.

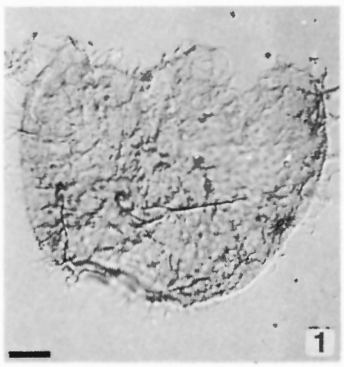
5. ED 1004-3A, L41/0, IC, ROM 36678
6. ED 1004-3F, M52/0, IC, ROM 36678
8. ED 1018-1A, M43/1, IC, holotype, ROM 36665
9. ED 1004-3A, G34/2, IC, ROM 36678

Figure 7, 10-18. *Escharisphaeridia rudis* sp. nov.

7. ED 1009-4A, O41/0, ROM 36638
10. ED 1034-4A, T39/0, ROM 36602
11. JB 240A, Q34/1, ROM 36495
12. ED 1035-2B, N38/4, ROM 36606
13. ED 1034-4A, P49/1, holotype, ROM 36602
14. ED 1034-4A, P34/3, ROM 36602
15. ED 1035-2B, P43/4, ROM 36606
16. ED 1009-17A, P41/0, ROM 36652
17. ED 1034-4A, P47/0, ROM 36602
18. ED 1034-4A, V37/2, ROM 36602

Figure 19,20. *Escharisphaeridia* sp. A

19. WI 960A, E34/0, IC, ROM 36437
20. WI 960A, X50/2, IC, ROM 36437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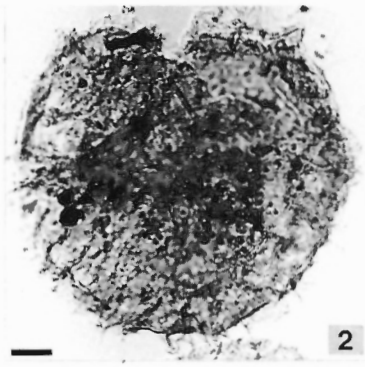
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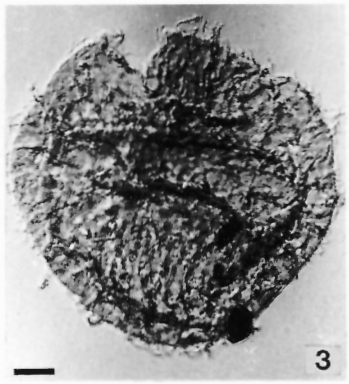
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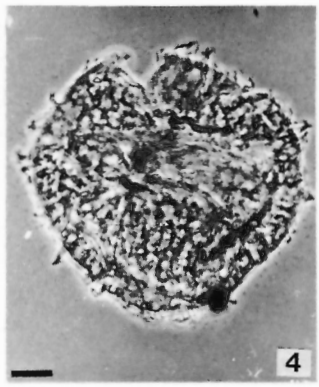
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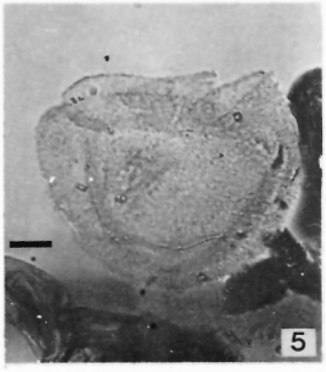
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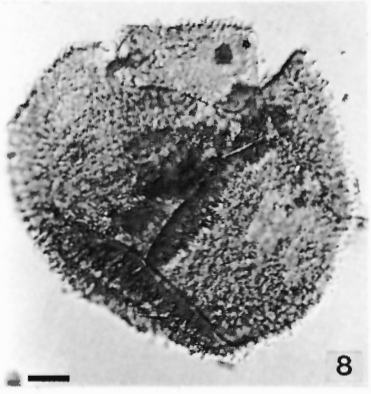
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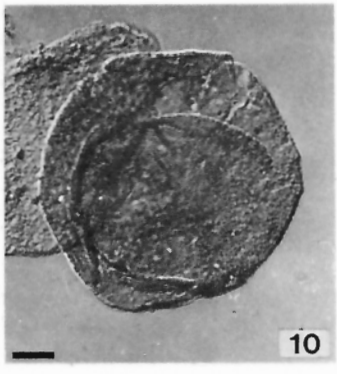
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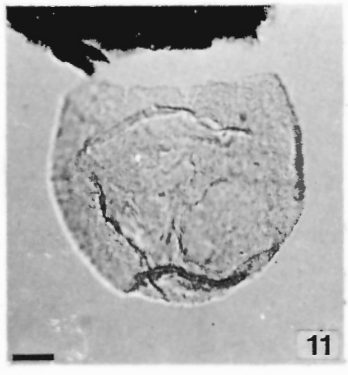
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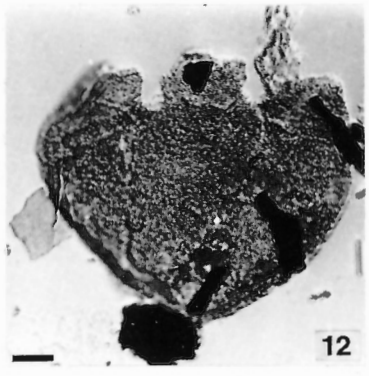
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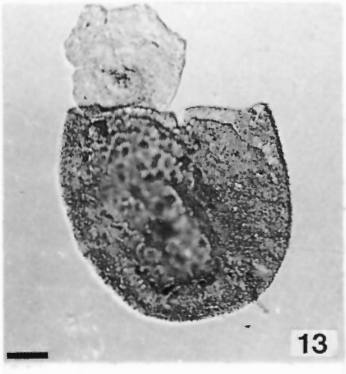
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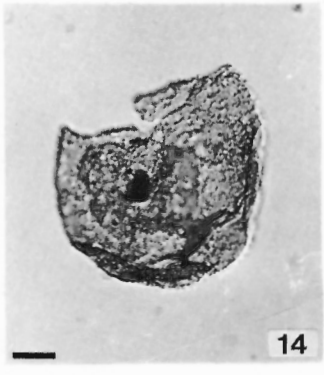
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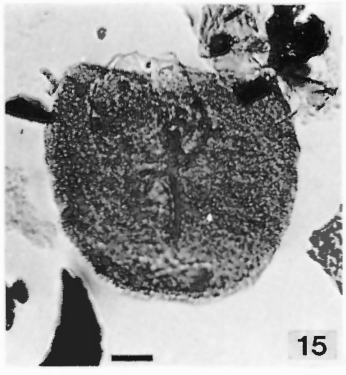
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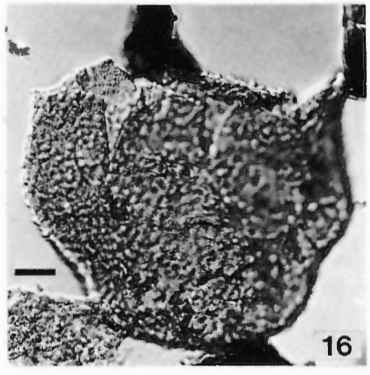
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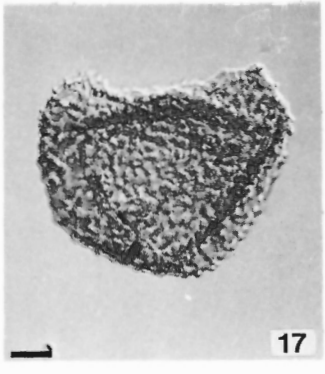
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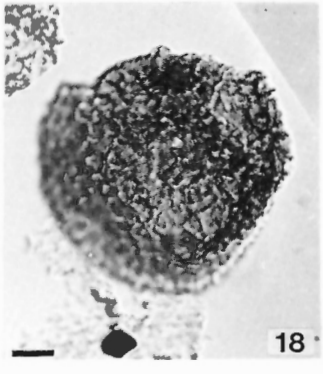
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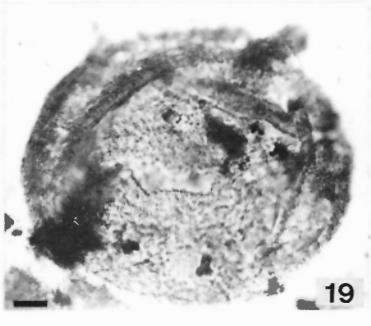
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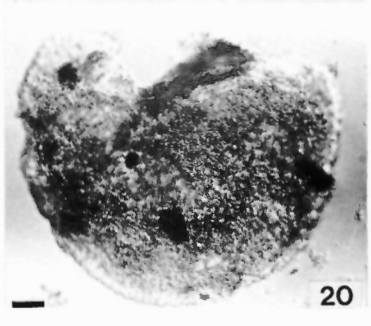
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