



This is to certify that the

thesis entitled

Taxonomic and Stratigraphic Significance
of Dinoflagellates and Acritarchs of the
Navarro Group (Maestrichtian) from East
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presented by

James B. Zaitzeff

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of the requirements for

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ABSTRACT

TAXONOMIC AND STRATIGRAPHIC SIGNIFICANCE OF DINOFLAGELLATES AND ACRITARCHS OF THE NAVARRO GROUP (MAESTRICHTIAN) FROM EASTCENTRAL AND SOUTHWEST TEXAS

by James B. Zaitzeff

Analysis of dinoflagellates and acritarchs from a composite surface section near Austin, Texas, and a subsurface cored section in Frio County, Texas, has revealed an abundant and varied microplankton assemblage. Eighty-one species distributed among 35 genera are recorded. Four genera and thirty-nine species are described as new. The vertical distribution of these species permits a zonation of the Navarro rocks in the Austin area. The widespread geographic occurrence of several species and their high relative abundance in samples from the two sections studied permits the use of some species for correlation of the two sections. It is concluded that pollen-spore/microplankton ratios in the Austin composite section are useful for determining relative water depths or possibly distance from shore. The former interpretation is supported by the foraminiferal composition.

Comparative observations of microplankton assemblages from other areas indicate that the Corsicana and Kemp Formations in the Austin area and the Escondido and Olmos Formations in Frio County have assemblages that closely resemble that of the Red Bank Formation (Maestrichtian) of New Jersey, whereas the Neylandville Formation assemblage contains many species which have been described elsewhere from older rocks.

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NAVARRO GROUP (MAESTRICHTIAN) FROM
EASTCENTRAL AND SOUTHWEST TEXAS

By

James B. Zaitzeff

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Sincere appreciation and thanks are also extended to Dr. W. R. Evitt of the Department of Geology, Stanford University and to Dr. Graham Williams of the Pan American Petroleum Corporation, Research Center, Tulsa, Oklahoma, for their examination of many of the slides and illustrations used in this study and suggestions concerning some aspects of the morphology and taxonomy of a number of the dinoflagellate species.

The writer also expresses thanks here to Shell Oil Company for assistance given in providing sample locality data for the Austin, Texas composite section, and also to the Humble Oil and Refining Company for providing the sub-surface cored section of the Navarro group from Frio County, Texas.

Recognition and appreciation is extended to the Society of the Sigma Xi for a Grant-In-Aid and to the Office of the Dean of the College of Natural Science, Michigan State University, for a grant matching the Sigma Xi Award, for support of field and laboratory work during the course of the study.

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INTRODUCTION

Purpose and Scope

Numerous rock samples from the Navarro group have been shown to contain abundant acid insoluble entities, i.e., paleomicroplankton, pollen and spores. The purpose of this study is to report on the occurrences of dinoflagellates and acritarchs from selected outcrop sections, and cores of subsurface rocks of the Navarro group of eastcentral and southwest Texas, and to demonstrate that vertical successions of distinctive dinoflagellate and acritarch assemblages can be of aid in the biostratigraphic zonation and correlation of rocks comprising the Navarro group in this area.

Two essentially complete sections of the Navarro group were analyzed. The first, a composite section of Navarro rocks, is in the vicinity of Austin, Texas, and is based on several outcrop localities and supplemented by sections from two cores. The total thickness of this composite section is approximately 550 feet. The second section analyzed is a subsurface cored sequence consisting of Escondido and Olmos rocks from the northwest part of Frio County, Texas. The section is approximately 1100 feet. The two sections are 160 miles apart.

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Previous Work

There are relatively few published works describing dinoflagellates from Upper Cretaceous and Tertiary rocks from North America. There are no major Maestrichtian assemblages from North America described in the literature to date, except Drugg's very recent report (Drugg, 1967) of the Upper Moreno Formation of California, which appeared after the present study had been completed. One must rely primarily on European and Australian works for assemblage comparisons. Tasch (1964) described an Albian assemblage from Kansas, though his taxonomic treatment is inadequate and not used here. Other North American works which include some descriptions and illustrations of dinoflagellate assemblages are: Singh (1964) and Leopold (1964) though both of these describe materials from Cretaceous rocks of older age than Maestrichtian, and Stanley (1964) which describes forms from the Paleocene of South Dakota, of which many species appear to be conspecific with Navarro forms.

European and Australian Mesozoic dinoflagellate studies are more extensive. Davey and others (1966); Downie (1957); Neale and Sarjeant (1962); Cookson and Hughes (1964); Deflandre (1937, 1938, 1947, 1952); Klement (1960); Eisenack (1959); and Wetzel (1933, 1961) have contributed significantly to the knowledge of Mesozoic dinoflagellates.

I. GEOLOGY

Nomenclature and Stratigraphic Relations

The Navarro Group, formerly classed as a Formation, includes the youngest Cretaceous rocks in the Gulf Coast, the upper part of the Gulfian Series, (Figs. 1, 2). The existence of Upper Cretaceous rocks in Texas was first recognized by Shumard (1863) to which he applied the name "Navarro beds." His type section was located somewhere in Navarro County, and may have been a composite of several sections, but he did not specify the locations of the type locality through Chatfield Point and Corsicana are frequently mentioned as fossil localities in his text, and one or both may be portions of the type locality. Synonyms of the Navarro in the literature are: Glauconitic Division or Greensand Division, Ripley Group, Exogyra costata Assemblage Zone clays, Webberville Formation and the Pulliam Formation.

The Navarro Group has been subdivided into four formations in Navarro, Kaufman, and Hunt Counties, where it is most completely developed. These formations are in ascending order; Neylandville marl, Nacatoch sand, Corsicana marl, and Kemp clay. This classification was adopted for use by the United States Geological Survey and appears on the geological map of Texas issued by the United States Geological Survey in 1937.

EUROPE		EAST - CENTRAL TEXAS		
MONT- LANDEN- IAN	PALEOCENE SERIES	MIDWAY GROUP	WILLS POINT FORMATION	
			KINCAID FORMATION	
MAESTRICHtian	UPPER CRETACEOUS (GULF) SERIES	NAVARRO GROUP	KEMP CLAY	
			CORSICANA MARL	
			NACATOK SAND	
			NEYLANDVILLE MARL	
TAYLOR MARL		(UPPER PART)		
		PECAN GAP CHALK MEMBER WOLFE CITY SAND MEMBER		
		(LOWER PART)		
CONIAC-SANTON- IAN			AUSTIN CHALK	
TURONIAN			EAGLE FORD SHALE	
CENOMAN- IAN			WOODBINE SAND	

FIG.1. GENERALIZED SECTION SHOWING THE POSITION OF THE NAVARRO GROUP IN THE UPPER CRETACEOUS (GULF) SERIES, IN EAST-CENTRAL TEXAS. (AFTER STEPHENSON, 1941)

COMPOSITE SECTION OF UPPER CRETACEOUS AND PALEOCENE ROCKS IN THE VICINITY OF AUSTIN, TEXAS

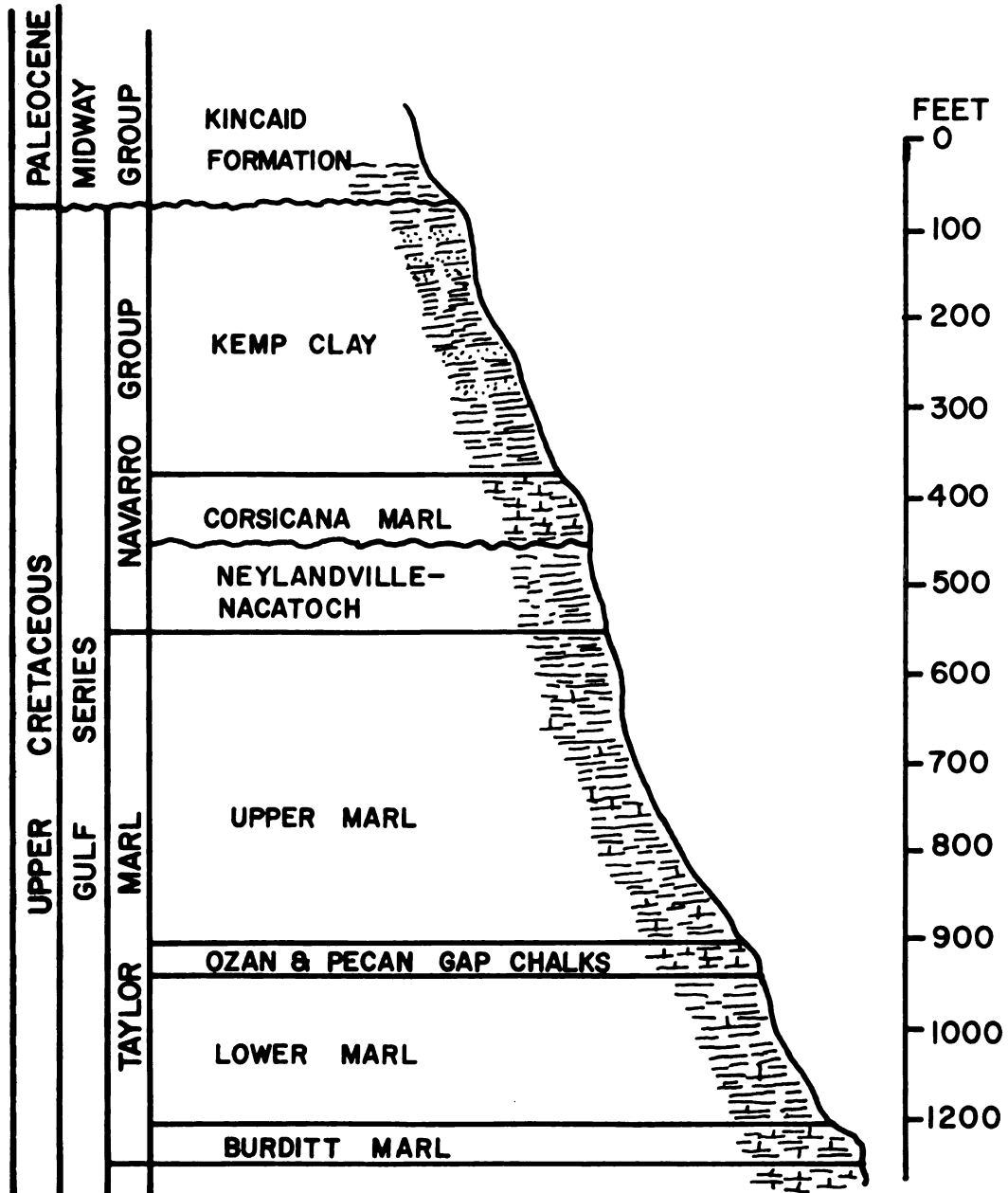


FIG. 2. SHOWS COMPOSITE SECTION OF UPPER CRETACEOUS AND PALEOCENE ROCKS IN THE VICINITY OF AUSTIN, TEXAS. (AFTER, PETE ROSE, SHELL OIL COMPANY UNPUBLISHED REPORT)

Southwest of Navarro County, and westward, the Kemp Formation changes, along its strike, into rocks of different lithology, to which the name Escondido Formation is given. The lithologic change is gradational from the Kemp and the separation of these two formations is rather arbitrary.

Invertebrate fossils near the base of the Navarro Group in Bexar and Medina Counties and near the base of the Escondido Formation farther west in Medina County indicate that the age of basal beds there is approximately equivalent to the middle of the Navarro in Navarro, Hunt and Kaufman Counties in northeastern Texas. This indicates the existence of an unconformity at the base of both the Navarro Group and Escondido Formation in the Bexar-Medina Counties area. This unconformity between the Navarro and underlying Taylor marl continues westward between the Anacacho limestone and the overlying Escondido Formation, but in Maverick County (Rio Grande Embayment area) the stratigraphic gap represented by the unconformity is in part filled-in by the non-marine beds, originally known as the "coal series," but now defined as the Olmos Formation. In Maverick County, the Olmos is overlain by the Escondido. The Olmos overlies the San Miguel (Senonian) which may be at least in part equivalent to the Anacacho limestone farther east.

The Navarro Group of central and northeastern Texas and the Escondido Formation of the southwestern part of the state are unconformably overlain by various overlapping

Tertiary Formations of Midway or Wilcox age. The amount of time represented by the hiatus between the uppermost Navarro or Escondido and the overlying Tertiary is unknown but it is probably a long interval.

It has been stated by Stephenson (1927) and others, that at different places on the outcrop, Navarro of different ages appears beneath the overlapping Tertiary strata. Stephenson (1927) points out that the upper part of the Escondido Formation is probably younger than the uppermost beds of the Navarro Group in central and northeastern Texas, but that these younger rocks were formed well within the limits of the Mesozoic Era. At the present time the zonation of the Navarro in the surface and subsurface is insufficiently supported in the literature to give a clear answer to the question. The difference of age of the surface deposits of the Navarro at different localities, may be in part due to differing amounts of material being removed from the top of the Cretaceous at various places, some now exposed in the outcrop, or that perhaps the sea retreated earlier in some areas than in others.

The Exogyra costata zone, a major faunal zone of Upper Cretaceous age, extending from New Jersey to the Rio Grande and beyond into Mexico, is co-extensive with the strata of the Navarro group and its equivalent strata. The species Exogyra cancellata Stephenson, is restricted to the lower part of the Exogyra costata Zone and forms a much

thinner zone having the same areal extent as the Exogyra costata Zone. In Texas, the Neylandville marl is co-extensive with the Exogyra cancellata Zone.

General Features of the Navarro Group

The Navarro Group is exposed at the surface in a belt up to 23 miles in width, extending from Red River Valley, in Bowie County, where it attains its greatest width (Fig. 3).

The marls, clays, and sands comprising the Navarro Group weather to gray and black soils and subsoils that blanket and partly conceal the formations, or alter their appearance, except where there are fresh exposures. The exposures of greatest thickness occur along banks and bluffs of streams, and occasionally good outcrops are also found in gullies, road and railroad cuts, and along ditches and near water tanks. Because of the covering by weathered materials, differentiation and mapping of the various formations and accurate stratigraphic placement of outcrop samples often becomes difficult and sometimes impossible. The four formations of the group have been differentiated and mapped, though in a highly generalized fashion, for the most part.

The sediments comprising the marine rocks of the Navarro Group were deposited in waters probably not exceeding 100 fathoms (Stephenson, 1942) but for the most part, deep enough to escape appreciable disturbance by wave action.

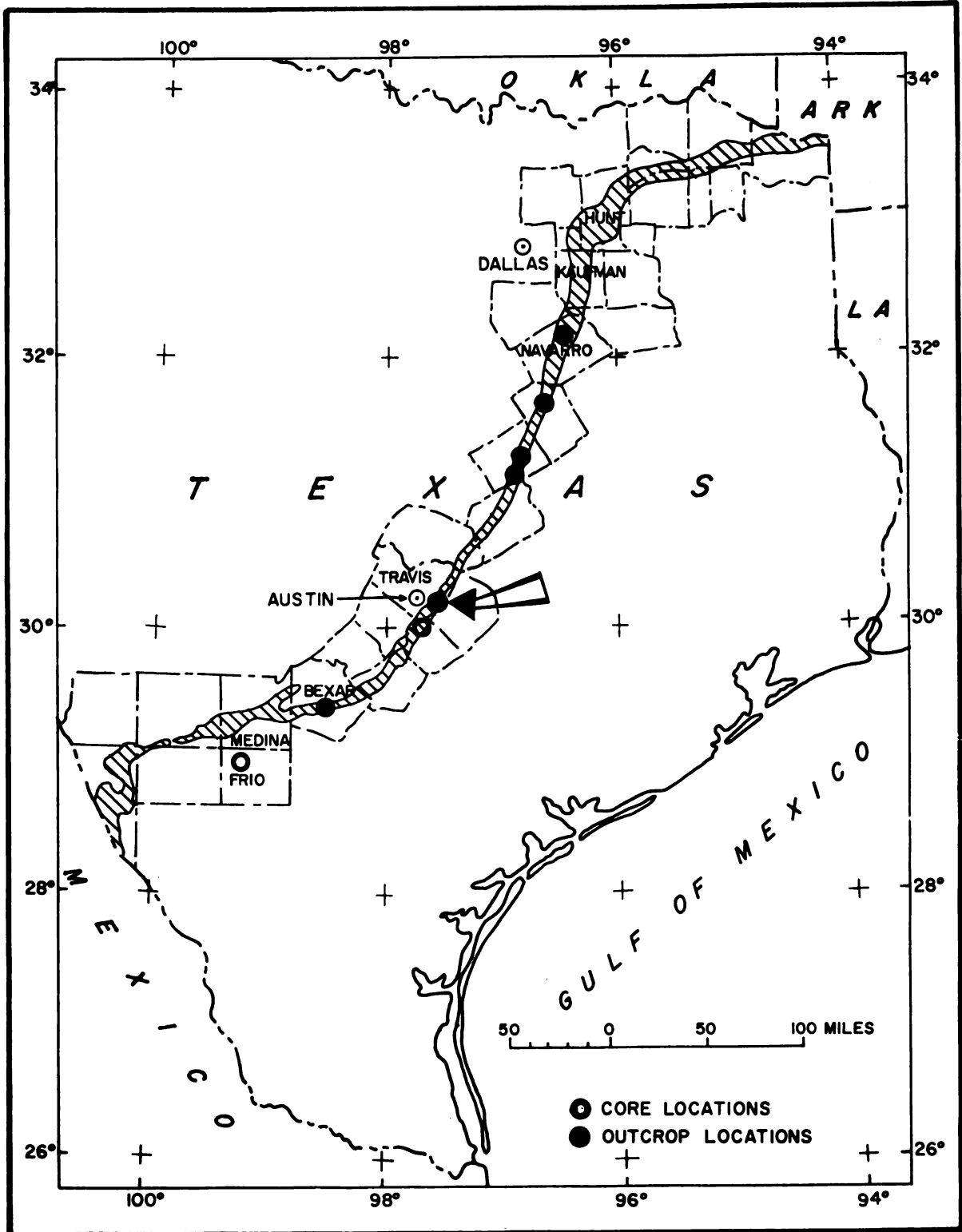


FIG. 3 MAP SHOWING THE BELT OF OUTCROP OF THE NAVARRO GROUP IN TEXAS, AND SECTION LOCATION.

The rocks consist dominantly of massive bedded marls, chalky marls, clays, and sands with subordinate indurated concretionary masses or layers cemented with calcareous carbonate. Bentonite forms a minor though well distributed, part of the group. The aggregate thickness of the Navarro sediments now exposed anywhere in the outcrop is estimated to be 550 to 750 feet or more, but down-dip in the subsurface the group thickens appreciably, to over 1000 feet.

In Maverick County, the Escondido Formations, equivalent to the Kemp clay in age, attains thicknesses in outcrop of 550 to 750 feet. The Escondido here consists of dark clays and marls, interbedded with limestones, shales and sandstones of quite variable thickness and areal distribution. In the area of outcrop of the Olmos Formation in Maverick County, it ranges in thickness from a few feet to 400 or 500 feet. The formation consists largely of non-marine clays, shales and sandstones, and seams of coal. Along Olmos Creek, in Maverick County, rocks of irregularly stratified sandstones and clays containing ferruginous concretions and silicified wood are exposed. The small beds of sand and clay usually are not constant laterally, but are interfingering lenses.

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II. DINOFLAGELLATE AND ACRITARCH

CONSIDERATIONS

Modern Dinoflagellate Morphology

The dinoflagellates are flagellated Protista, characterized by having two flagella. One flagellum is rather elongate, usually extending posteriorly with reference to the direction of motion. The second emerges from the same part as the first, i.e., on the ventral surface, and lies in a circumferential transverse groove, called the girdle, in which it moves in an undulating fashion. The girdle is usually, but not always, more or less spiral, so that its left end is more posterior than the right end when the organism is seen from the ventral side. In a number of forms, however, there is no displacement of the girdle, so that the two ends are opposite, though separated, from each other. The longitudinal flagellum is in a somewhat less well-defined and usually broader longitudinal furrow, the sulcus. Both girdle and sulcus are almost always provided with distinct lips. The girdle and sulcus are distinctly morphologic features of the dinoflagellates, thus making the group on the whole very easy to recognize. Many species of the dinoflagellates possess only a protective flexible pellicle, but others have a well-defined porous theca, composed of

cellulose. In the modern genus, Prorocentrum, the theca is simple, whereas in Ceratium, and most other modern thecate genera, it is composed of numerous sculptured plates, whose arrangement and sculpture are of considerable importance in the differentiation of species.

Reproduction is largely asexual, by means of binary fission, and this may in some species result in temporary chains of individuals. The division is simple longitudinal or oblique. When individuals divide, the two halves regenerate new halves. Conjugation similar to that occurring in some of the green algae has been observed in Ceratium and other types of sexual reproduction have also been described. Another method of multiplication, in some cases, is the formation of a cyst, within which, the protoplast of the organism is concentrated. Such a cyst may subsequently divide to form two or more individuals. Some genera as Ceratium are capable of producing resting spores which allow survival during adverse conditions. Usually during binary fission in the unarmoured dinoflagellates, a typical cyst is formed, for apparently the organisms require protection and rest during this critical period. The cyst is usually very delicate, so that the protoplast easily emerges from it, though in some forms the cyst is tough and resistant.

Various dinoflagellates possess holophytic, saprophytic, holozoic, and mixed nutritions, and in some instances different types of nutrition are known to occur even among

different species of the same genus. In the genus Gymnodinium, for example, G. brevis is strictly holophytic, and G. incisum is holozoic, but G. fulgens has been observed to contain both chromatophores and food vacuoles, showing that it has mixed nutritions. A number of species, including G. aureum, appear to be saprophytic.

Fossil Dinoflagellate Morphology

The current classification of living dinoflagellate species is based principally on their tabulation (plate arrangement) and the character of the motile cell. Descriptive morphologic terms used for modern dinoflagellates have been used in the descriptions of those fossils thought to be dinoflagellates. There has been much discussion of the alternate concepts that fossil dinoflagellates are, in most instances, dinoflagellate cysts, or that they are in fact, the motile theca, i.e., the whole body, of dinoflagellates. Some workers consider that fossil dinoflagellates are not the remains of the motile theca and that all fossil dinoflagellates recognized to date are dinoflagellate cysts. Evitt (1965) was strongly in favor of this concept, but later (in press), has come to the conclusion that there is not yet sufficient evidence, at least in some cases, e.g., fossil Gymnodinium, to warrant a conclusive decision at this time. Many species of some genera from the Upper Cretaceous rocks, particularly Peridinium and Gymnodinium, which lack

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true archeopyles and show none of the other characteristics of cysts, have been considered to be the motile theca of the organisms. Some species of fossil Gymnodinium studied by Evitt (in press) and some specimens of G. nelsonense and G. sp. 2, which I have studied, are shown to possess a particular opening at the apex of the epitheca (epittract), which can be considered to be analagous to an archeopyle. Although, as Evitt has stated (in press), the presence of wall canals in specimens of fossil Gymnodinium (which may imply open communication between the contents of the cyst and the surrounding water) seems inconsistent with the interpretation of a cyst.

Although little is known of the encystment of modern dinoflagellates, there is considerable evidence accumulating that at least most of the fossils recognized as dinoflagellates are morphologically cysts rather than motile thecae. If we are then truly dealing with fossil dinoflagellate cysts rather than the preserved motile theca, the use of morphologic terms applied to the modern dinoflagellate theca would therefore not be appropriate. New structures may be characteristic of some cysts which have no counterpart in the motile cell. Therefore the continued use of thecal terms to describe cysts would lead to confusion. Davey and others (1966) have suggested several morphologic terms for cysts which, at the present time seem appropriate, and are here used (see Appendix A).

Perhaps a reasonable direction of study in determining critical morphologic features of cysts would have to come through studies of cultures and the examination of cysts and their associated theca from the modern seas and recent bottom sediments. Evitt (1964) has shown that different extant species of Gonyaulax produce morphologically different cysts, and these, in no sense, resemble the original thecae in which they were enclosed. In some forms, both recent and fossil, the resting cyst will take on the aspect of its theca. It is difficult to assign a modern dinoflagellate cyst to a species or genus, which is founded on the living motile stage, let alone to be able to make such an assignment to a fossil cyst.

There are a number of reasons for postulating that it is usually the cyst and not the motile theca of dinoflagellates which is observed in the fossil state. These are stated below:

1. There is in some fossil dinoflagellate species the possibility of a "non-functional" girdle, which is incapable of containing a flagellum because of high membranes or ridges which divide the girdle into polygonal fields. Hystrichosphaera furcata, Gonyaulax jurassica and Wetzeliella sp. are thought to possess such a "non-functional" girdle. In many species of Gonyaulax the field boundaries, including those that cross the girdle, are provided with membranes that rise perpendicularly from the cyst.

2. External appendages or processes of many dinoflagellate tests, such as Hystsrichosphaera and Hystrichosphaeridium, are probably more logically interpreted as supporting features which developed between the wall of the motile theca and the wall of the cyst. External processes are less commonly observed on the motile theca.

3. An archeopyle, a more or less uniformly shaped, precisely located and oriented opening on the test of some fossils, which corresponds to a specific location in the structure of modern tabulate dinoflagellates, is characteristic of some fossil dinoflagellates. It is formed by the loss of either a single plate or group of plates (plate field), which allows the release or extrusion of the cell contents. An orifice of this type, which produces the archeopyle in the cysts of fossil or modern dinoflagellates, is unknown in the theca of modern forms. The cell contents, in living forms, escapes from the motile theca, by the opening of the theca along some of the many sutures between thecal plates.

4. Evitt (1966) stated that the modern dinoflagellate theca, which is composed of cellulose, is destroyed on boiling in acetolysis mixture, and a milder treatment in heated sodium hypochlorite reduces the plates to an unrecognizable mass, whereas the modern cyst withstands these treatments. It is possible that the thecae of living

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dinoflagellates, upon death or encystment, were destroyed by natural processes of decay and degradation.

5. There is a distinct flagellar pore present in the sulcal region of the ventral surface of the motile theca in modern forms. In fossil forms, these are not observed.

6. In the fossil state, in most dinoflagellates, there is a two-layered wall. Most modern forms do not appear to possess a double wall. Several extant species of cysts referable to the genus Peridinium were described by Wall (1965). Some of the specimens he described have a single wall; others double walls. Whether the single-wall type of cyst is derived from the double-wall type through decay, is not known.

Classification of Dinoflagellates

It is the consensus of modern biological interpretation that dinoflagellates are algae. They are a group of unicellular organisms, some of which contain chlorophyll and are vagile and predatory. The botanical classification is followed in this thesis for the fossil dinoflagellates. This classification of the fossil dinoflagellates today generally conforms to botanical rules and taxonomic practice.

Deflandre, in his work on fossil dinoflagellates, has classed them as Dinophyceae. Russian workers, Naumova and Timofeev, regard all hystrichospheres as plants, for taxonomic purposes. The question as to whether fossil dinoflagellates should be classed, for nomenclatural purposes, in

the animal or plant kingdoms has been adequately discussed by Downie, Williams and Sarjeant (1961) and Evitt (1963). They all agree that it is preferable to treat them under the botanical code.

Classification of Acritarchs

The classification of the acritarchs used in this thesis is that suggested by Downie, Evitt, and Sarjeant (1963). This is primarily an "artificial" grouping of genera of unknown biological relationships into morphologically similar categories. The International Code of Botanical Nomenclature is followed. The precise affinities of the acritarchs to algae, protozoans, protistans and the interrelationships of these groups themselves are in varying degrees of uncertainty. For practical purposes, acritarchs and other miscellaneous planktonic microfossils of organic composition and uncertain affinity should be dealt with under the same code as the dinoflagellates, and are referable to form genera and species.

Paleoecology and Ecology of Dinoflagellates

Paleomicroplanktonic entities are recorded in rocks from Precambrian to Recent. Forms attributed to the Dinophyceae have been reported (Tasch, 1963) from rocks of Permian age but there remains some question of the identification of these as palynomorphs and the author here has not examined them. The Dinophyceae are common in many of the

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marine deposits from middle Jurassic and younger rocks. Today they are known to occur in marine, brackish, and fresh waters. There are very few records of fossil freshwater forms (Churchill and Sarjeant, 1962), and in practically all instances, fossil dinoflagellates are considered to be indicators of marine environments.

The paleoecology of dinoflagellates is, as yet, little understood. It is only recently that modern dinoflagellate distribution, and even the distribution of many other groups of phytoplankton have become more than superficially understood. Obviously, in the understanding of fossil dinoflagellate distributions, one must draw from the knowledge obtained in the study of living forms. It is possible that with the advances in techniques of culturing phytoplankton, it may soon be possible to relate information derived from cultured populations to biogeographical problems in natural marine environments. A satisfactory knowledge of the underlying biogeographical factors can be obtained by combining floristic studies with studies of cultured populations of dinoflagellates. Thus, the results of such experimental studies, may serve in interpreting dynamics of various species of phytoplankton in their natural environment.

In the modern seas, the dinoflagellates rank second to the diatoms in the production of organic matter (Raymont, 1963). Occasionally, in response to unusually favorable

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growing conditions, dinoflagellates may develop in profusion to form a "bloom." Dinoflagellates appear to flourish in warmer areas. They attain their greatest development in the lower latitudes. They may be the major element in the plankton for long periods of time. In the middle and high latitudes, they sometimes occur in abundance during the summer.

The dinoflagellates are capable of feeble swimming, and this may be of ecological significance in enabling them to utilize dilute nutrients in the water, and by making possible a better orientation to light. The spatial distribution of dinoflagellates, as well as other phytoplankton, can be thought of as three dimensional, consisting of a latitudinal, longitudinal and a depth or vertical component. The distribution of dinoflagellates is governed by essentially the same variables that effect their abundance; salinity temperature, and nutrients. It is usually difficult to single out the most important factor in a given situation. Variations in these conditions can singly or in combination effect the morphology of individual species. For example, Chatton (1952) has noted that in warm waters some species have a tendency to develop spines and horns, which are usually absent or poorly developed in cold water forms. Fritsch (1948) states that in the oceanic plankton the naked forms are abundant, whereas the neritic plankton is far richer in armoured forms. There are few dinoflagellates that are shore dwellers, but occasionally species of

Gymnodinium occur in the near-shore environment. The length of horns of Ceratium trichoceros is apparently regulated in some way by temperature, and perhaps by this mechanism it is able to regulate itself to the viscosity and specific gravity of the water. The thickness of the cellulosic plates also seems to vary with the temperature of the water.

Ceratium platysome shows differences in shape of its horns, the flatter forms being typical of the variety living in warmer sub-tropical waters and the less-flattened horns being characteristic of colder seas. It is assumed that dinoflagellates are relatively free of the effects of bottom conditions.

III. METHODS

Sample Preparation Techniques

Preparation of the Navarro shales and calcareous clay shales for microscopic analysis were carried out in a procedure similar to standard palynological maceration for the study of acid insoluble micro-organisms. To release the organic entities from the enclosing matrix, samples were treated according to the following procedure.

1. Dry 200 gram sample in oven in 80°C for 24 hours
2. Crush sample into small fragments and mix thoroughly
3. Weigh 5 gram aliquot
4. Treat 5 gram aliquot with 10% HCl for 10 minutes for removal of carbonates
5. Wash residue
6. Treat residue with 70% HF for 24 hours for removal of silicates
7. Wash residue 3 times by centrifugation
8. Treat residue with Schulze solution for 10-20 minutes
9. Wash residue 3 times by centrifugation
10. Treat residue with 10% NH₄OH for 5-8 minutes
11. Wash residue 3 times by centrifugation

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12. Mix residue in a dilute solution of Alcojet* for further reaction with humic material and removal of silt-size particles; centrifuge in Alcojet solution.
13. Wash residue 3 times by centrifugation
14. Perform specific gravity separation on residue using zinc chloride (sp. gr. 1.90)
15. Stain with Safrinin O.

Residues are stored in an aqueous solution of glycerin and phenol.

Sample Analysis

Four slides of each residue were made. One entire slide was examined in detail and types were recorded and established. A total of 5,000 dinoflagellates and acritarchs were observed in some instances on the first slide. A second slide was used to insure random sampling, for the determination of relative abundance of the individual species. Relative abundance of species were determined by the recording of not less than 200, where specimens were rare, and a minimum of 500 where specimens were abundant. Also recorded were the relative abundance of pollen and spore groups or genera such as: bisaccates, Proteacidites, Classopollis, triporates, tricolpates, Ephedra, and Sphagnum.

*Alcojet - a patented detergent manufactured by Alconox Inc., New York, New York.

IV. SYSTEMATIC DESCRIPTIONS

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE Downie, Evitt and
Sarjeant, 1963

Genus Micrhystridium Deflandre, 1937, emend.
Downie and Sarjeant, 1963

Type species: M. (al. Hystrichosphaera) inconspicuum
(Deflandre, 1935) Cretaceous; France.

Discussion: Micrhystridium is distinguished from Balti-sphaeridium on the size of the test. The two genera express two different size modes. The mean and modal diameter of the test of Micrhystridium is less than 20 microns. Balti-sphaeridium has a mean and modal diameter greater than 20 microns. The 20 micron size differentiation is purely an artificial dividing line, though Downie and Sarjeant (1963) consider the genera to express two natural size modes. Species formerly attributed to Micrhystridium with distally open tabular processes have been transferred to Hystrichosphaeridium, and those whose surfaces are divided into fields by crests have been transferred to Cymatiosphaera.

Micrhystridium fragile Deflandre, 1947
Pl. 1, Figs. 1-4

1947. Micrhystridium fragile Deflandre: p. 8, text-figs. 13-18. Middle Jurassic; France.

Discussion: Micrhystridium fragile is restricted to specimens that have processes with narrow bases and generally spherical tests. Variation in number, length of processes, and shape of test amongst individual specimens of this species can exist. Processes are hollow, relatively long and slender, tapering towards closed distal tips. Process cavity communicates with test interior, though cavity does not extent to distal extremities of the processes.

Dimensions: Average range of 4 specimens: diameter of test 16 to 21 microns; length of processes 10 to 16 microns.

Remarks/Relationships: Williams (1963) reports this species from the London Clay, Eocene, of England. It has also been recorded from the Middle Jurassic of France (Deflandre, 1947d; Valensi, 1947, 1954) and the Upper Jurassic of Britain (Sarjeant, 1959, 1960, 1961a). This species has little stratigraphic value because of its long stratigraphic range.

Occurrence: M. fragile is common in the Neylandville and Corsicana Formations; rare in the Kemp Formation, Austin composite section; rare in the Olmos and Escondido Formations, Frio County, Texas.

Micrhystridium stellatum Deflandre, 1945
Pl. 1, Figs. 5-7

1945. Micrhystridium stellatum Deflandre: p. 65, pl. 3, figs. 16-19, Middle Silurian; France.

Discussion: Navarro specimens of M. stellatum vary somewhat in shape of test and in process number and length. Processes are usually greater than or equal to the diameter of the test; 14-16 processes per test. Processes are simple, solid, straight or curved, acuminate or capitate distally.

Dimensions: Average range of 5 specimens: diameter of test 15 to 20 microns; length of processes 15 to 25 microns.

Remarks/Relationships: Micrhystridium stellatum is described from the Wenlockian of France (Deflandre, 1945a) and Britain (Downie, 1959), and the Devonian of France (Deunff, 1954) Belgium (Stockmans and Williere, 1960, 1962a, 1962b) Canada (Staplin, 1961) and (Cramer, 1964), the Permian of Britain (Wall and Downie, 1963), the Middle Jurassic of France (Valensi, 1953) and the Upper Jurassic of Britain (Sarjeant, 1959, 1960c, 1961a). Williams (1963) records the first Tertiary occurrence of this species from the London Clay, Eocene of Britain.

Occurrence: M. stellatum commonly occurs in the Corsicana Formation; rare in the Neylandville Formation in the Austin composite section.

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Genus Baltisphaeridium Eisenack 1958, emend.
Downie and Sarjeant 1963

Type species: B. (al. Ovum hispidum) longispinosum
(Eisenack, 1931) Silurian; Baltic.

Baltisphaeridium hirsutum (Ehrenberg, 1838)
Pl. 1, Figs. 8-8a

1838. Baltisphaeridium hirsutum (as Xanthidium) (Ehrenberg);
pl. 1, fig. 13, Cretaceous; Germany

Discussion: One specimen referable to B. hirsutum was
observed from the Navarro material. The species is conspic-
uous from the surface pattern of the shell.

Dimensions: Diameter of central body 57 x 60 microns;
length of processes 20 to 25 microns.

Remarks/Relationships: B. hirsutum is reported from the
Cretaceous of Germany (Ehrenberg, 1883) and the Cenomanian
of Britain (Cookson and Hughes, 1964).

Occurrence: Rare in Corsicana Formation, Austin composite
section.

Baltisphaeridium sp. 1 sp. nov.
Pl. 1, Figs. 9-11

Diagnosis: Central body sub-circular to elliptical, possess-
ing widely separated processes. Processes acuminate, solid;
number of processes, 10-14. Wall of central body smooth.

Holotype: Pb. 4632, slide s-2, coord. 41.8 x 108.0; Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 60 by 50 microns; length of processes 30 to 33 microns. Average range of 3 specimens: diameter of central body 55 to 63 by 50 to 55 microns; length of processes 10 to 33 microns.

Remarks/Relationships: The central body of specimens of this species is subject to folding and distortion. The small number of processes and their distinctly acuminate character make this species readily identifiable. A pylome is not observed in any of the specimens examined. The species is restricted to the Neylandville Formation and may be stratigraphically significant in the Austin composite section.

Occurrence: Common in the Neylandville Formation, Austin composite section.

Baltisphaeridium sp. 2 sp. nov.
Pl. 2, Figs. 3-4a

Diagnosis: Central body elongate, possessing numerous solid, thin, hair-like sinuous processes. Wall of central body finely granular.

Holotype: Pb. 4513, slide 5, coord. 33.8 x 94.2; Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 35 microns; width of central body 17 microns; length of processes 10 to 15 microns. Average range of 3 specimens: length of central body 29 to 35 microns; width of central body 17 to 20 microns; length of processes 8 to 12 microns.

Remarks/Relationships: Baltisphaeridium sp. 2 is somewhat similar to Baltisphaeridium pilosum (Ehrenberg, 1943) in shape of central body and in bearing slender processes, but B. sp. 2 is much smaller in size and the processes are not hollow as in B. pilosum. Baltisphaeridium sp. 2 is close to B. sp. 3 in size and shape of central body, and in wall ornamentation, but differs from that species in character of the process. B. sp. 2 usually occurs in abundance when encountered in a sample.

Occurrence: Abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; rare in Escondido Formation, Frio County, Texas.

Baltisphaeridium sp. 3 sp. nov.
Pl. 2, Figs. 1-2b

Diagnosis: Central body elongate, possessing numerous solid, short, straight processes which are truncate distally. Wall of central body finely granular.

Holotype: Pb 4647, slide 2, coord. 31.5 x 101.2; Kemp Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 33 microns; width of central body 17 microns; length of processes 6 to 7 microns. Average range of 4 specimens: length of central body 30 to 34 microns; width of central body 15 to 18 microns; length of processes 4 to 7 microns.

Remarks/Relationships: Baltisphaeridium sp. 3 is similar to B. sp. 2 in size and shape of central body, but the processes of this species are not hair-like as in B. sp. 2. The morphologic features of this species are relatively simple, and the short truncate processes make it readily distinguishable from B. sp. 2. This species appears to be restricted to the Kemp Formation and it may prove to be a marker for the upper part of the formation.

Occurrence: Common in the Kemp Formation, Austin composite section.

Subgroup HERKOMORPHITAE

Genus Cymatiosphaera O. Wetzel, 1933

Type species: C. radiata O. Wetzel, 1933, Cretaceous; Germany.

Cymatiosphaera radiata O. Wetzel, 1933
Pl. 2, Figs. 5-9

1933. Cymatiosphaera radiata O. Wetzel: p. 27, pl. 4, fig. 9, Senonian; Germany.

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Discussion: The holotype of C. radiata from the north German Senonian flint has not been examined by the writer, but specimens here referable to that species seem to fit reasonably well the circumscribed limits of the species.

Dimensions: Average range of 6 specimens: overall diameter 40 to 45 microns.

Remarks/Relationships: C. radiata has been described by O. Wetzel (1933) from a north German Senonian flint. The species also has been recorded from the Albian and Cenomanian of Australia, Cookson and Eisenack (1960).

Occurrence: Abundant in Neylandville and Corsicana Formations; common in Kemp Formation, Austin composite section; common in Olmos and Escondido Formations, Frio County, Texas.

Subgroup Uncertain

Genus Palaeostomocystis Deflandre, 1935

Type Species: Palaeostomocystis reticulata Deflandre, 1935, Cretaceous; France.

Palaeostomocystis sp. 1 sp. nov.
Pl. 3, Figs. 3-8

Diagnosis: Test ellipsoidal, both sides rather evenly convex, narrowing towards a slightly sunken pylome at the apex. Wall slightly thickened around pylome. Wall extra-vermiculate.

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Holotype: Pb 4504, slide 5, coord. 43.8 x 95.5; Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test, 31 microns, width of test, 20 microns. Range of 4 specimens: length of test 27 to 32 microns; width of test 17 to 21 microns.

Remarks/Relationships: Palaeostomocystis sp. 1 is similar to P. apiculata Cookson and Eisenack (1960) from the Campanian of Australia in shape and nature of pylome. Palaeostomocystis sp. 1 differs from that species in not possessing spinules in the anterior and posterior regions, in being smaller in size, and in possessing an ornamented shell membrane.

Occurrence: Common in Neylandville Formation; abundant in Corsicana Formation, Austin composite section; rare in Olmos and Escondido Formations, Frio County, Texas.

Class CHLOROPHYCEAE

Family Uncertain

Genus Palambages O. Wetzel, 1961

Type species: Palambages morulosa O. Wetzel, 1961. Upper Cretaceous; Europe.

Discussion: The genus Palambages was first described in 1961, for those colonies or spherical bodies composed of many oval cells. Comparable colonies and a new species have since been recorded from Maestrichtian deposits in Poland

(H. Gorka, 1963) and three forms, Palambages Forma A, Forma B and Forma C, are described by Manum and Cookson (1964) from the lower Upper Cretaceous deposits in Graham and Ellef Ringes Islands, Arctic Canada. The present knowledge of the morphologic characteristics of this genus does not support assignment of this genus to the dinoflagellates at the present time. The stratigraphic range of the genus is known only to be in the Upper Cretaceous.

Palambages Forma A Manum and Cookson, 1964

Pl. 2, Figs. 10-12

Pl. 3, Fig. 2

1964. Palambages Forma A Manum and Cookson: p. 24, pl. VII, figs. 3-6. Cretaceous; Graham Island, Arctic Canada.

Discussion: The number of cells per colony is variable in specimens observed from the Navarro Group. The walls of the cells are finely to coarsely granular.

Dimensions: Range of 8 specimens: overall diameter 40 to 55 microns.

Remarks/Relationships: Palambages Forma A is described by Manum and Cookson (1964) from the lower Upper Cretaceous deposits in Graham and Ellef Ringes Island, Arctic Canada. Cookson (1965) reports this species from the lower Upper and Upper Cretaceous (Senonian) of south Australia.

Occurrence: Abundant in Neylandville Formation; common in Corsicana and Kemp Formations, Austin composite section.

Palambages deflandrei Gorka, 1963
Pl. 3, Fig. 1

1963. Palambages deflandrei Gorka: p. 76, pl. XI, fig. 2.
Upper Cretaceous (Maestrichtian); Poland.

Discussion: This species is characterized by clusters of oval, membranous cells with peripheral openings. Wall granular.

Dimensions: Range of 3 specimens: overall diameter 45 to 60 microns.

Remarks/Relationships: Palambages deflandrei and Palambages Forma A are the only two species of the genus observed in the Navarro Group. In spite of the nondescript morphologies of these two species, they are easily distinguishable from each other.

Occurrences: Rare in Neylandville Formation; common in Corsicana and Kemp Formations, Austin composite section; rare in Olmos and Escondido Formations, Frio County, Texas.

Class DINOPHYCEAE

Discussion: The Class Dinophyceae embraces all fossil dinoflagellates and the typical hystrichospheres. Downie, Evitt and Sarjeant (1963) define hystrichospheres as fossils identified as dinoflagellates that are generally similar to Hystrichosphaera; that is, forms with a spherical to ellipsoidal or lenticular central body which bears several to

many more or less spine-like radiating processes. The four criteria considered most critical by Evitt (1961) in demonstrating dinoflagellate affinity are:

1. Presence of a transverse furrow, with or without a longitudinal furrow.
2. Evidence of tabulation by alignment or grouping of ridges or processes according to the plate arrangement of typical thecate dinoflagellates.
3. Presence of an archeopyle.
4. Overall shape; an extreme "peridinioid" outline is indicative of dinoflagellate affinities, but it should not be considered conclusive without supporting evidence.

On the basis of these criteria, Evitt (1963) proposed two new dinoflagellate families, the Hystrichosphaeridiaceae and Areoligeraceae and the emendation of the family Hystrichosphaeraceae (O. Wetzel). These families are based on the shape of the test, the type of symmetry, the position of the processes relative to the plates, and the nature of the archeopyle.

Family Hystrichosphaeridiaceae Evitt

Genus Oligosphaeridium Davey and Williams in
Davey et al., 1966 (p. 70)

Type species: Xanthidium tubiferum complex White, 1842.

Upper Cretaceous; England.

Oligosphaeridium complex (White) emend. Davey
and Williams in Davey et al., 1966
Pl. 3, Fig. 12

1842. Oligosphaeridium (al. Xanthidium tubiferum) complex
White: p. 39, pl. 4, div. 3, fig. 11. Upper Cretaceous;
England.

Discussion: Specimens referable to O. complex from the
Navarro Group conform in every respect to the specific
description of the species. Processes 17-18 in number
(12-13 remain when the epithema is absent).

Dimensions: Range of 5 specimens: diameter of central body
31 to 37 microns; length of processes 28 to 32 microns.

Remarks/Relationships: Oligosphaeridium complex has been
recorded from the Upper Cretaceous of England (White, 1842,
1844a), Belgium (Lejuene-Carpentier, 1940), France (Firtion,
1952; Valensi, 1955b), Germany (Eisenack, 1958c; Gocht,
1959), the London Clay, Eocene of Britain (Davey et al.,
1966), the Neocomian of Germany (Gocht, 1959) and the Lower
and Upper Cretaceous of Australia (Deflandre and Cookson,
1955; and Cookson and Eisenack, 1958). I have also seen

this species in the Rocky Mountain Upper Cretaceous strata. The species, therefore, has a worldwide distribution.

Occurrence: Rare in Neylandville Formation; common in Corsicana Formation; rare in Kemp Formation of the Austin composite section; rare in Olmos and Escondido Formations, Frio County, Texas.

Genus Tanyosphaeridium Davey and Williams
in Davey et al., 1966 (p. 98)

Type species: Tanyosphaeridium variecalamum Davey and Williams in Davey et al., 1966. Upper Cretaceous (Cenomanian); England.

Tanyosphaeridium sp. 1 sp. nov.
Pl. 5, Figs. 4-4a, 6-7

Diagnosis: Central body elongate, composed of thin endophragm and finely granular periphragm. Processes consist of smooth periphragm. The processes are oval in cross section, long, slender, hollow, and do not communicate with the interior of the central body. Processes with fairly broad base proximally; distally, processes open and greatly expanded and with entire margins. Precingular fields bear two processes. Archeopyle apical, edges not zig-zag; defined by margins of 6 precingular fields. Cingulum does not possess processes. Number of processes, 25-32.

Holotype: Pb 4518, slide 4, coord. 32.2 x 89.3; Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 34 microns; width of central body, 23 microns; length of processes 16 to 18 microns.

Remarks/Relationships: Tanyosphaeridium sp. 1 is closest to T. variecalamum Davey and Williams (Davey et al., 1966) but differs from that species in having processes that are more greatly expanded distally, and in width-length ratio of the central body. T. sp. 1 is shorter and wider in the many specimens observed. Tanyosphaeridium sp. 1 is similar to T. isocalamus Deflandre and Cookson (1955) in outline, and in bearing long slender processes, but the processes in that species have clearly truncate apices which are not expanded distally. That species also differs in having a punctate wall. T. sp. 1 occurs in the Red Bank Formation (Maestrichtian) of New Jersey.

Occurrence: Abundant in Corsicana; common in Kemp Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Tanyosphaeridium sp. 2 sp. nov.
Pl. 5, Fig. 5

Diagnosis: Central body ellipsoidal-elongate, composed of thin endophragm and a thin, finely granular periphragm. Processes consist of smooth periphragm. The processes are oval to elliptical in cross section; long, slender. Processes taper distally from a fairly broad base. Distally processes are truncate and not expanded. Archeopyle apical;

margin not zig-zag, defined by margins of 6 precingular fields. Precingular fields bear one or two processes.

Number of processes 25-31.

Holotype: Pb 4632, slide s-1, coord. 34.2 x 99.2; Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 31 microns; width 25 microns; length of processes average 10 to 13 microns. Range of 6 specimens: length of central body 27 to 34 microns; width of central body 22 to 26 microns; length of processes 9 to 14 microns.

Remarks/Relationships: Tanyosphaeridium sp. 2 is similar to T. variecalamum Davey and Williams (Davey et al., 1966) in bearing truncate processes and in general shape of the central body. It differs from that species in having a consistently wider central body. T. sp. 2 is restricted to the Neylandville Formation in the Austin composite section, and may prove to be of stratigraphic importance locally.

Occurrence: Common in Neylandville Formation, Austin composite section.

Genus Polysphaeridium Davey and Williams
in Davey et al., 1966 (p. 91)

Type species: Polysphaeridium subtile Davey and Williams in Davey et al., 1966, Eocene (Ypresian); England.

Polysphaeridium sp. 2 sp. nov.
Pl. 4, Figs. 8-10

Diagnosis: Central body subcircular, consisting of relatively thick endophragm and thin finely reticulate periphragm. Processes numerous short, tapering slightly distally. Processes truncate distally, and with denticulate apices. The processes are composed of finely fibrous periphragm.

Holotype: Pb 4632, slide 4, coord. 32.2 x 107.2; Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: Diameter of central body 51 by 57 microns; length of processes, 5.7 to 6 microns. Range of 3 specimens: diameter of central body 50 to 55 microns by 55 to 58 microns; length of processes 5 to 8 microns.

Occurrence: Common in Neylandville Formation, Austin composite section; rare in Olmos Formation, Frio County, Texas.

Polysphaeridium sp. 1 sp. nov.
Pl. 6, Figs. 8, 10

Diagnosis: Central body subspherical, consisting of thin smooth endophragm and periphragm. Processes numerous, long, slender, tubular; circular to elliptical in cross section. Processes taper distally and are somewhat constricted before flaring abruptly at the extremities. Distal margins of process entire, slightly recurved.

Holotype: Pb 4518, slide 2, coord. 35.7 x 90.2; Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: Diameter of central body 57 by 58 microns; length of processes 18 to 20 microns. Range of 3 specimens: diameter of central body 55 to 60 microns; length of process 15 to 22 microns.

Remarks/Relationships: Polysphaeridium sp. 1 is similar to Polysphaeridium sp. 3 in wall character and termination of processes, though, in this species the processes are of greater length. The thin-walled character of this species is subject to distortion and folding. Tabulation has not been determined.

Occurrence: Rare in Neylandville Formation; common in Corsicana Formation; rare in Kemp Formation, Austin composite section; rare in Olmos and Escondido Formations, Frio County, Texas.

Polysphaeridium sp. 3 sp. nov.
Pl. 5, Figs. 8-10
Pl. 6, Fig. 1

Diagnosis: Central body spherical to subspherical, possessing a thin smooth endophragm and periphragm. Processes numerous, tubular, nearly circular in cross-section. Processes taper slightly distally and flare abruptly rather markedly at extremities. Distal margins of processes entire. The archeopyle was not observed.

Holotype: Cp-1, slide s-1, coord, 43.4 x 97.7; Kemp Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 30 by 32 microns; length of processes 6 to 8 microns. Range of 4 specimens: diameter of central body 29 to 33 microns; length of processes 6 to 9 microns.

Remarks/Relationships: The thin wall of the central body of this species is subject to folding and distortion. The spherical, thin-walled central body and greatly expanded process tips makes the species easily recognizable. P. sp. 3 is similar to P. sp. 1 in having a somewhat spherical thin-walled central body and in possessing greatly expanded process tips, though the processes of P. sp. 3 are more numerous than in that species and are shorter in length. P. sp. 3 appears to have a restricted distribution in the upper part of the Kemp Formation, and may prove to be a marker fossil for that part of the Navarro.

Occurrence: Common in Kemp Formation, Austin composite section.

Polysphaeridium sp. 4 sp. nov.
Pl. 6, Figs. 9, 11

Diagnosis: Central body subspherical, consisting of thin endophragm and thin, finely granular periphragm. Processes very numerous, tubular, subspherical in cross-section; processes taper slightly toward extremities, truncate and expanded slightly distally.

Holotype: Pb 4575, slide 3, coord. 47.5 x 101.8. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 28 by 35 microns; length of processes 10 to 12 microns. Range of 3 specimens: diameter of central body 30 to 35 microns; length of processes 9 to 12 microns.

Remarks/Relationships: Polysphaeridium sp. 4 is similar to sp. 1 in size and wall structure, but differs in having the greatly distal expanded processes. Tabulation has not been determined. Archeopyle was not observed.

Occurrence: Common in Neylandville Formation, Austin Composite section.

Genus Hystrichosphaeridium Deflandre 1937, emend.
Davey and Williams in Davey et al., 1966 (p. 55)

Type species: Hystrichosphaeridium (Xanthidium) tubiferum (Ehrenberg), 1838. Upper Cretaceous; Germany.

Hystrichosphaeridium tubiferum (Ehrenberg), emend.
Davey and Williams in Davey et al., 1966 (p. 56)
Pl. 3, Figs. 9-11
Pl. 4, Figs. 1-3

1838. Hystrichosphaeridium tubiferum (Ehrenberg): pl. 1, fig. 16. Senonian; Germany.

Discussion: The specimens here referred to H. tubiferum conform to the specific description of the type species. The processes of the Navarro forms usually number 29-30.

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and are of various diameters. The sulcal processes are reduced in diameter and length. The reflected tabulation is 4 apical, 6 precingular, 6 cingular, 5 postcingular, 1 posterior intercalary, 1 antapical plates. The archeopyle is usually always identifiable.

Dimensions: Range of 5 specimens: diameter of central body 37 to 43 microns; length of processes 17 to 25 microns.

Remarks/Relationships: Hystrichosphaeridium tubiferum is recorded from the Senonian of Germany by Ehrenberg (1838a), Ypresian of Belgium, Pastiels (1948), the Oligocene of Germany, Gocht (1952); Brosius (1963), the Oligocene to Middle Miocene of Germany, Gerlach (1961), the London Clay, Eocene of Britain, Davey et al. (1966).

Occurrence: Abundant in Corsicana Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Hystrichosphaeridium stellatum Maier, 1959
Pl. 4, Figs. 4-4a

1959. Hystrichosphaeridium stellatum Maier: p. 320-1, pl. 33, figs. 3-4. Oligocene; Germany.

Discussion: The morphology of the specimens from Texas tend to vary somewhat from the type material of Maier. They do compare well with those specimens from Albian to Cenomanian deposits of Western Australia, referred to by Cookson and Eisenack (1962), and the Upper Gault and Greensand

(Cenomanian) of Britain described by Cookson and Hughes (1964). Because of distinctive difference in age of the Texas and European forms and those from Australia, there is possibly an unrecognizable specific difference from Maier's material.

Dimensions: Range of 3 specimens: diameter of central body 34 to 40 microns; length of processes 13 to 19 microns.

Remarks/Relationships: Hystrichosphaeridium stellatum is recorded from the Oligocene-Middle Miocene of Northwest Germany (Maier, 1959), and the Albian-Cenomanian of Australia (Cookson and Eisenack, 1962).

Occurrence: Common in Corsicana Formation, Austin composite section.

Hystrichosphaeridium patulum Davey and
Williams in Davey et al., 1966 (p. 60)
Pl. 5, Figs. 1-3

1966. Hystrichosphaeridium patulum Davey and Williams in Davey et al.: p. 60, pl. 10, fig. 5. Paleocene; Britain.

Discussion: Specimens referred to H. patulum closely conform to the specific description and illustration of that species.

Dimensions: Range of 6 specimens: diameter of central body 14 to 16 microns; length of processes 5 to 7 microns.

Remarks/Relationships: Hystrichosphaeridium patulum is recorded from the London Clay, Eocene of Britain, Davey et al. (1966).

Occurrence: Common in Corsicana Formation, Austin composite section. Rare in Escondido Formation, Frio County, Texas.

Hystrichophaeridium sp. 1 sp. nov.
Pl. 7, Figs. 1-4

Diagnosis: Central body spherical, consisting of moderately thick endophragm and thin striate periphragm. Processes consist of fibrous periphragm. Processes taper from a broad base and are truncate distally; distal margins of processes denticulate.

Holotype: Pb 4670, slide 1, coord. 45.5 x 96.2. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 30 microns; length of processes 15 to 17 microns. Range of 3 specimens: diameter of central body 30 to 35 microns; length of processes 15 to 18 microns.

Remarks/Relationships: the striate periphragm of the central body and the fibrous nature of the processes characterize this species.

Occurrence: Common in Neylandville Formation, Austin composite section.

Hystrichosphaeridium sp. 2 sp. nov.
Pl. 7, Figs. 5-7

Diagnosis: Central body subcircular. Processes wide, short, and taper distally from a broad base; elliptical in cross-section. Periphragm punctate. Archeopyle margin zig-zag.

Holotype: Pb 4632, slide s-2, coord. 35.3 x 92.0. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 37 by 45 microns; length of processes 7 to 8 microns. Average dimensions of 6 measured specimens: diameter of central body 35 by 40 microns; length of processes 6 to 8 microns.

Remarks/Relationships: the short processes with broad bases distinguish this species from others in the genus. In some, the processes appear to be closed distally.

Occurrence: Rare in Neylandville Formation, Austin composite section.

? Hystrichosphaeridium sp. 3 sp. nov.
Pl. 6, Figs. 2-7

Diagnosis: Central body subspherical to elliptical, bearing numerous pairs of slender rod-like processes which are surrounded by a thin membranous-like structure; membranous structure also extending to tips of neighboring processes.

Holotype: Pb 4521-S, slide 2-A. coord. 38.0 x 90.8.

Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body, 67 by 57 microns; length of processes 7 microns. Range of 4 specimens: diameter of central body 68 to 75 by 55 to 67 microns; length of processes 6 to 8 microns.

Remarks/Relationships: This species is placed questionably in Hystrichosphaeridium. The processes are numerous and are distally covered with a thin membrane which tends to surround the central body. The archeopyle position has not been determined.

Occurrence: Common in Corsicana Formation, Austin composite section.

Genus Cleistosphaeridium Davey et al, 1966 (p. 166)

Type species: Cleistosphaeridium diversispinosum Davey et al., 1966, Eocene; England.

Cleistosphaeridium sp. 1. sp. nov.

Pl. 7, Figs. 8-9

Pl. 8, Figs. 1-2

Diagnosis: Central body spherical with finely granular wall, and bearing numerous solid, dagger-like processes. Processes closed distally, acuminate; some bifid or blunt. Archeopyle apical, with zig-zag margins, which is formed by 6(?) precingular plate-fields. Length of processes traversed by slender fibrils. Possibly two processes per precingular plate fields.

Holotype: Pb 4542, slide 1, coord. 31.0 x 92.8. Kemp Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 43 microns; length of processes 17 to 19 microns. Range of 6 specimens:

diameter of central body 39 to 45 microns; length of processes 15 to 22 microns.

Remarks/Relationships: Processes appear regularly arranged, but the tabulation is not determinable. C. sp. 1 is similar to C. disjunctum Davey et al. (1966) in size and granular central body, though the processes of C. sp. 1 appear to be solid. The processes of C. sp. 1 are characterized by slender longitudinal fibrils, which are not described in C. disjunctum. The length of the processes is usually constant in an individual.

Occurrence: Common in Corsicana Formation; rare in Kemp Formation Austin composite section; rare in Escondido Formation, Frio County, Texas.

Forma F Gen. nov.

Diagnosis: Chorate cysts with spherical to subspherical central body possessing two types of processes. There are numerous fine processes usually closed distally covering the central body, and a single large hollow antapical process which is open distally. Archeopyle precingular, margin undulating, not zig-zag.

Type species: Forma F. sp. 1 sp. nov. Corsicana Formation (Maestrichtian), Austin composite section.

Remarks/Relationships: This genus is similar to Diphyes Cookson (1965) in possessing two types of processes, but

differs from that genus in having a precingular rather than apical archeopyle. The precingular archeopyle and large antapical processes enable orientation of specimens of this species. The smaller processes are simple, slender, and usually taper distally, and are usually closed distally.

Forma F sp. l Gen. et sp. nov.

Pl. 8, Figs. 3-10

Diagnosis: Subspherical to spherical central body. Endophragm thin; periphragm thin, with sinuous, fine striations. Central body covered with numerous filamentous or hair-like processes which taper distally to a narrow point from a broad base, which are usually closed distally; some are open. Large antapical process hollow, open distally and with distal margin denticulate.

Holotype: Pb 4519, slide 6, coord. 36.7 x 104.5. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 45 by 50 microns; length of filamentous processes 18 to 22 microns; length of antapical process 20 microns; width 10 microns. Range of 8 specimens: diameter of central body 42 to 58 microns; length of processes 15 to 27 microns.

Remarks/Relationships: This species closely approximates the figured specimen of Hystrichosphaeridium monstrosum Tasch et al. (1964), though no mention is made of ornamentation of the central body in the specific description nor of

archeopyle position. The illustrated specimen also does not show two opposite, large, polar processes as originally described. This interpretation probably is due to a misinterpretation of the morphology by Tasch. The writer has examined samples from Tasch's study area, and specimens of these forms show a precingular archeopyle and only one polar process. Davey et al. (1966) incorrectly refer H. monstrosum to the genus Diphyes. H. monstrosum should be reassigned to Forma F.

Occurrence: Common in Corsicana Formation, Austin composite section; rare in Escondido Formation, Frio County, Texas.

Genus Diphyes Cookson, 1965, emend. Davey and Williams in Davey et al., 1966 (p. 95)

Type species: Diphyes (Hystrichosphaeridium) colligerum (Deflandre & Cookson), 1955, Eocene; Australia.

Diphyes colligerum (Deflandre & Cookson) emend.
Davey and Williams in Davey et al., 1966
Pl. 9, Figs. 1-2

1955. D. (al. Hystrichosphaeridium) colligerum Deflandre & Cookson: p. 278, pl. 7, fig. 3.

Discussion: The specimens D. colligerum are in rather close agreement to the emended specific description by Cookson (1965, p. 86). The nature of the distal portion of the smaller processes though, appears to be in doubt. Cookson states that it is impossible to trace the cavity along the

whole length of the appendages owing to the narrowness of their distal portions and the relative thickness of their walls, though the cavities do appear to communicate with that of the shell. The processes of specimens observed and illustrated here do not communicate with the interior of the central body as is stated in the holotype description.

Davey et al. (1966) state that the process of this species in their material do not open to the interior. It is quite difficult to determine in even well-preserved specimens from the Navarro if the distal extremities are open or closed. They taper to a very narrow terminal end, and are bluntly-pointed, slightly capitate, but not tubular. The smaller processes are less cylindrical at the bases, and taper to a more narrow point than those illustrated in the type specimen. The processes also appear to be more flexuous and are traversed by very fine fibrils, in the Navarro forms.

Stanley (1965, p. 231, pl. 24, figs. 7, 8) illustrates a specimen which he considers conspecific with H. colligerum. Stanley's specimens appear to have a close affinity to or are conspecific with forms observed in the Navarro.

Dimensions: Range of 3 specimens: Diameter of central body 35 by 40 microns; length of filamentous processes 14 to 16 microns.

Remarks/Relationships: Diphyes colligerum is reported from the Upper Cretaceous and Eocene of Australia and in England from the Eocene (Davey et al., 1966). Stanley (1965) reports the species from the Paleocene of South Dakota.

Occurrence: Common in Corsicana Formation; rare in Kemp Formation, Austin composite section.

Genus Forma A Gen. nov.

Diagnosis: Chorate cysts with spherical to subspherical central body. Processes numerous, of various sizes, intratabular, solid or hollow. Archeopyle precingular, polygonal; formed by loss of ep. hema consisting of a single plate field bearing several processes; margin never zig-zag.

Type species: Forma A sp. 1 sp. nov. Corsicana Formation (Maestrichtian), Austin composite section.

Remarks/Relationships: This genus is somewhat similar to Cordosphaeridium Eisenack in having processes composed of elongated fibrous strands, and that the archeopyle is formed from loss of one field and has a polygonal outline with angular corners. The archeopyle of Cordosphaeridium is apical. In some specimens of the species of Forma A, the archeopyle may appear to be apical due to differential compression, but in inflated specimens, it can be shown to be definitely precingular. The number and size of processes can vary considerably within the genus, but are usually constant within a species. A fused polar appendage is usually present just anterior to the archeopyle.

Forma A sp. 1 Gen. et sp. nov.

Pl. 9, Fig. 12

Pl. 10, Figs. 1-10

Diagnosis: Central body subspherical composed of smooth endophragm and fibrous periphragm, from which the processes arise. Processes numerous, slender, hollow, oval in cross-section. Processes taper from a broader base, then flare distally; with recurved denticulate terminal ends. Wall of processes traversed by slender fibrils which extend from apex to base. The fibrils extend from the central body where they form a faint linear-reticulate pattern. There are 7-9 processes per field.

Holotype: Pb 4504, slide 5, coord. 38.4 x 92.7. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 57 by 57 microns; length of processes 15 to 17 microns. Range of 6 specimens: diameter of central body 50 to 60 microns; length of processes 13 to 20 microns.

Remarks/Relationships: Forma A sp. 1 is similar to Forma A sp. 2 and Forma A sp. 3 in having a fibrous periphragm. Forma A sp. 1 is close to Forma A sp. 2, but is distinguished from that species in having a thicker endophragm and being larger in size. In some samples Forma A sp. 1 occurs in great abundance and may dominate the assemblage. This abundance may prove to be of value in local correlations.

Occurrence: Rare in Neylandville Formation; abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Olmos and Escondido Formations, Frio County, Texas.

Forma A sp. 2 Gen. et sp. nov.
Pl. 11, Figs. 1-3a
Pl. 12, Figs. 1-3

Diagnosis: Central body subspherical, composed of smooth relatively thick endophragm and fibrous periphragm, from which the processes arise. Processes numerous, slender, tubular, oval in cross-section. Processes taper from a broad base then flare distally, and with aculeate tips which sometimes are recurved. Wall of processes traversed by slender fibrils which extend from apex to base. The fibrils extend from the central body where they form a linear-reticulate pattern. There are 3-5 processes per field.

Holotype: Pb 4513, slide 3, coord. 38.6 x 99.0. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 74 by 80 microns; length of processes 29 to 30 microns. Average dimensions of 5 specimens: diameter of central body 70 to 82 microns; length of processes 26 to 33 microns.

Remarks/Relationships: Forma A sp. 2 is closest to Forma A sp. 1, though it is distinguished from that species in having a thicker endophragm, is larger in size, and possesses fewer processes per field.

Occurrence: Rare in Neylandville Formation; common in Corsicana Formation, Austin composite section.

Forma A sp. 3 Gen. et sp. nov.
Pl. 9, Figs. 3-11

Diagnosis: Central body subspherical, composed of smooth endophragm and fibrous periphragm, from which the processes arise. Processes densely cover the central body. Processes short acuminate, usually closed distally; some open. Wall of processes traversed by slender fibrils which extend from apex to base. The fibrils extend from the central body where they form a finely linear-reticulate pattern. Number of processes per field not determined, but very numerous.

Holotype: Jc-40, slide 3, coord. 41.3 x 98.3. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 68 by 70 microns; length of processes 2.8 to 3.0 microns. Average dimensions of several specimens: diameter of central body 52 by 70 microns; length of processes 2 to 4 microns.

Remarks/Relationships: This species is similar to Forma A sp. 1 in size, outline and ornamentation of periphragm, though Forma A sp. 3 is easily distinguished by its small processes.

Occurrence: Abundant in Corsicana Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Genus Cordosphaeridium Eisenack, 1963 emend. Davey and Williams in Davey et al., 1966 (p. 83)

Type species: Cordosphaeridium (Hystrichosphaeridium)

inodes (Klumpp) 1953. Eocene; Germany.

Cordosphaeridium inodes (Klump, 1953)
Pl. 4, Figs. 5-7

1953. Cordosphaeridium (al. Hystrichosphaeridium) inodes (Klump) p. 391, pl. 18, figs. 1-2. Eocene; Germany.

Discussion: The Navarro forms referred to Cordosphaeridium inodes conform to the specific description of the species given by Klumpp.

Dimensions: Range of 5 specimens; diameter of central body 51 to 60 microns; length of processes 20 to 24 microns.

Remarks/Relationships: Cordosphaeridium inodes has been previously recorded from the Eocene of Germany (Klump, 1953) and Victoria (Deflandre and Cookson, 1955), the middle Eocene and middle Miocene of Northwest Germany (Gerlack, 1961) and the upper Oligocene of Germany (Brosius, 1963), the Cannon Ball Member, Fort Union Formation of South Dakota (Stanley, 1965), the Eocene of Britain (Davey et al., 1966).

Occurrence: Common in Corsicana Formation; common in Kemp Formation, Austin composite section; common Escondido Formation, Frio County, Texas.

Cordosphaeridium fibrospinosum Davey and Williams
 in Davey et al., 1966 (p. 86)
 Pl. 12, Figs. 4-5a
 Pl. 13, Fig. 1

1966. Cordosphaeridium fibrospinosum Davey and Williams in
 Davey et al.: p. 86, pl. 5, fig. 5, Eocene; Britain.

Discussion: Navarro specimens of this species closely conform to the description and illustration given by Davey et al. (1966).

Dimensions: Range of 4 specimens: diameter of central body 65 to 70 microns. Length of processes 28 to 32 microns.

Remarks/Relationships: Stanley (1965, p. 231, pl. 25, figs. 1-6) illustrates specimens which he refers to Hystrichosphaeridium inodes Klumpp. His illustration and description is close to C. fibrospinosum and to the Navarro specimens observed here, and probably should not be assigned to H. inodes.

Occurrence: Abundant in Corsicana Formation; abundant in Kemp Formation Austin composite section; common in Escondido Formation, Frio County, Texas.

Cordosphaeridium sp. 1 sp. nov.
 Pl. 13, Figs. 2-4

Diagnosis: Central body subspherical, composed of smooth endophragm and fibrous periphragm. The periphragm forms numerous broad relatively short processes which consist of slender fibrils which run from the apex to the base.

Processes are open and slightly expanded distally; elliptical in cross-section. Outline of archeopyle polygonal.

Holotype: Pb 4632, slide s-5, coord. 36.7 x 101.8. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 60 microns; length of processes 17 to 20 microns. Average dimensions of 3 specimens; diameter of central body 55 to 67 microns; length of processes 15 to 20 microns.

Remarks/Relationships: This species is close to Cordosphaeridium fibrospinosum Davey et al., 1966, but differs in having shorter and less wide processes. C. sp. 1 is restricted to the Neylandville Formation in the Austin composite section, and may be considered as an index species of that formation on the basis of our present evidence.

Occurrence: common in Neylandville Formation, Austin composite section.

Genus Callaiosphaeridium Davey and Williams
in Davey et al., 1966 (p. 103)

Type species: Hystrichosphaeridium asymmetricum Deflandre & Courteville, 1939. Upper Cretaceous; France.

Callaiosphaeridium cf. asymmetricum
(Deflandre & Courteville)
Pl. 13, Figs. 5-7

Discussion: Navarro specimens referable here to C. asymmetricum agree in most respects to the specific description given by Deflandre & Courteville (1939).

Dimensions: Average range of 3 specimens: diameter of central body 45 to 50 microns; length of cingular processes 15 to 22 microns.

Remarks/Relationships: Davey et al. (1966) illustrate Cenomanian forms assigned to C. asymmetricum which possess an elevation of the ribs joining the hypotractal processes to form quite well-developed septa. In the Navarro forms the septa are not as greatly developed. The Navarro forms also differ from the Cenomanian forms in that the postcingular processes are not as well-developed. The aculei of specimens observed here is very well developed and are recurved. C. cf. asymmetricum is restricted to the Neylandville Formation in the Austin composite section, and may prove to be a marker species.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Genus Systematophora Klement, 1960

Type species: Systematophora areolata Klement, 1960. Upper Jurassic (Kimmeridgian); Germany.

Systematophora sp. 1 sp. nov.

Pl. 13, Figs. 8-10

Pl. 14, Figs. 1-3

Diagnosis: Central body spherical, composed of two layers. Endophragm thicker than periphragm, the latter giving rise to the processes. Processes intratabular, annular, taeniate,

slender, solid. Processes, in some, entire to approximately the mid-point along their length and then becoming bifurcate. Process tips acuminate, bifid or trifid. Reflected tabulation 6 precingular, 5 postcingular, 2 posterior intercalary, 1 antapical. Periphragm finely verrucose. Archeopyle margin not zig-zag, somewhat circular; re-entrant angle between fields moderate, shallow.

Holotype: Pb 4505, slide 1, coord. 45.8 x 109.0. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 68 microns; length of processes 14 to 16 microns. Average dimensions of 4 specimens: diameter of central body 68 to 74 microns; length of processes 12 to 17 microns.

Remarks/Relationships: Entire specimens and those without an epithema are observed in the Navarro material. The forms here agree somewhat to S. areolata Klement in size and outline of the archeopyle margin, but differ in having shorter and thinner processes.

Occurrence: Abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Family Hystrichosphaeraceae Evitt

Genus Hystrichosphaera O. Wetzel, 1933, emend. Davey and Williams in Davey et al., 1965 (p. 29)

Type species: Hystrichosphaera (Xanthidium) ramosa (Ehrenberg), 1838. Upper Cretaceous (Senonian); Germany.

Hystrichosphaera ramosa (Ehrenberg, 1838), emend. Davey and Williams in Davey et al., 1965 (p. 32)
Pl. 14, Figs. 7-11

1838. Hystrichosphaera ramosa (Ehrenberg) (al Xanthidium ramosum), pl. 1, fig. 14. Upper Cretaceous, Germany.

Discussion: Navarro specimens referable to H. ramosa have the characteristics of the description of the species. Central body possesses zonal and sutural processes. Processes are solid, usually long and slender. Gonial processes, trifurcate, wall smooth.

Dimensions: Range of 4 specimens: diameter of central body 46 to 52 microns; length of processes up to 16 microns.

Remarks/Relationships: This species is recorded from the Cenomanian of Britain, Cookson and Hughes (1964). Davey et al. (1966) state that it has been recorded as H. furcata from the Oxfordian by Deflandre (1938) and by Sarjeant (1960). Pleistocene occurrences have been recorded by Fries (1951) and Rossignol (1964).

Occurrences: Common in Corsicana and Kemp Formations, Austin composite section; rare in Escondido and Olmos Formations, Frio County, Texas.

Hystrichosphaera ramosa var. 1 var. nov.
Pl. 14, Figs. 9-11

Diagnosis: Hystrichosphaera ramosa var. 1 conforms to the emended diagnosis of H. ramosa by Davey and Williams (1966), though is distinct from other Navarro specimens referable to the species in possessing a distinctly punctate to reticulate wall. Processes solid, slender, trifurcate distally; cyst-like features extend entire length of processes; cysts more developed in some specimens than others.

Holotype: Pb 4514, slide 1, coord. 30.8 x 87.0. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 43 microns; range of processes 7 to 10 microns. Average range of 4 specimens: diameter of central body 40 to 48 microns; length of processes 6 to 10 microns.

Remarks/Relationships: H. ramosa var. 1 occurs in all Formations of the Austin and Frio sections. It occurs in large numbers near the top of the Corsicana Formation and in the upper Kemp Formation, Austin composite section. It also occurs commonly near the top of the Escondido Formation, Frio County. The distinctly punctate to reticulate wall and cyst-like features of the processes makes this type easily identifiable.

Occurrence: Rare Neylandville Formation, abundant in Corsicana and Kemp Formations, Austin composite section; rare Olmos Formation, abundant Escondido Formation, Frio County.

Hystriichosphaera sp. 1 sp. nov.
Pl. 15, Figs. 7-9

Diagnosis: Test ellipsoidal, composed of thin endophragm and periphragm. Periphragm smooth to finely granular. Processes appear solid, are broad at the bases and taper towards the tips; distally processes closed, usually bifurcate or trifurcate. Web-like membrane interconnects some adjacent processes near their bases. Girdle or sulcus not distinct. Archeopyle not observed.

Holotype: Pb 4518, slide-1, coord. 34.2 x 104.8. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 46 microns; width of test 38 microns. Range of 3 specimens: length of test 38 to 52 microns; width of test 31 to 39 microns.

Remarks/Relationships: The web-like membrane interconnecting adjacent processes near their bases distinguish this species from others observed in the Navarro group.

Occurrence: Common Corsicana Formation, Austin composite section.

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Hystrichosphaera sp. 2 sp. nov.
Pl. 14, Figs. 4-6

Diagnosis: Test ellipsoidal. Wall thin, smooth to finely punctate. Processes thin, short bifurcate or trifurcate distally. Girdle and sulcus not clearly discernible.

Archeopyle seldom identifiable.

Holotype: Cp-1 slide s-1, coord. 34.3 x 94.2. Kemp Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 41 microns; width of test 41 microns; length of processes up to 7 microns. Range of 4 specimens: length of test 40 to 46 microns; width of test 40 to 43 microns; length of processes, up to 10 microns.

Remarks/Relationships. This species is closely similar to the Navarro specimens referable to H. ramosa var. 1 in test outline and in possessing a punctate wall, though this species has a thinner wall and the punctations are not as coarse.

Occurrence: Rare in Corsicana Formation; abundant in Kemp Formation, Austin composite section.

Hystrichosphaera sp.
Pl. 15, Figs. 4-6a

Diagnosis: Test ellipsoidal. Wall moderately thick, smooth to finely punctate. Processes arise from low, thin sutures which reflect plate boundaries. Processes short, thin; those at juncture of fields usually trifurcate distally. Girdle clearly discernible. Archeopyle usually present.

Dimensions: Range of 2 specimens: length of test, 46 to 51 microns; width of test, 44 to 46 microns.

Genus Achomosphaera Evitt, 1963

Type species: A. (al. Hystrichosphaeridium) ramulifera (Deflandre, 1937a), Upper Cretaceous; France.

Achomosphaera ramulifera (Deflandre),
Evitt, 1963
Pl. 15, Figs. 1-3

1937. Achomosphaera (al. Hystrichosphaeridium) ramulifera, (Deflandre, 1937), p. 74, pl. 15, figs. 5-6. Upper Cretaceous; France.

Discussion: The Navarro forms attributed to A. ramulifera do not differ appreciably from the type description. The wall surface in the Navarro forms is finely to coarsely granular, and the processes split and unite near their tips forming a cyst-like structure.

Dimensions: Range of 3 specimens: diameter of central body 35 to 46 microns; length of processes up to 16 microns.

Remarks/Relationships: A. ramulifera is described by Deflandre (1937) from the Upper Cretaceous of France. The species is also recorded from the Ypresian of Belgium (Pastiels, 1948), the upper Oligocene-middle Miocene of Germany (Gerlach, 1961) and the upper Oligocene of Germany (Brosius, 1963) and from the London Clay, Eocene of Britain (Davey et al, 1966).

Occurrence: Rare in Neylandville Formation; common in Corsicana Formation; rare in Kemp Formation; Austin composite section; rare in Escondido and Olmos Formations, Frio County, Texas.

Genus Cannosphaeropsis O. Wetzel 1932a

Type species: Cannosphaeropsis utinensis O. Wetzel, 1933.
Cretaceous; Baltic.

Cannosphaeropsis cf. fenestrata Deflandre &
Cookson, 1955
Pl. 15, Figs. 10-11

1965. Cannosphaeropsis fenestrata Deflandre & Cookson:
p. 283, pl. 3, fig. 2, text-fig. 43. Upper Cretaceous
(Senonian); Australia.

Discussion: The Navarro forms referable to C. fenestrata compare fairly well to the specific description given by Deflandre & Cookson. The Navarro forms have smaller shells and the enveloping network is not perforated and is finer than in the type material. Specimens here compare more closely with the specimens of C. fenestrata illustrated by Cookson & Eisenack (1955), pl. VII, figs. 1-3.

Dimensions: Range of 4 specimens: diameter of central body 31 to 46 microns.

Remarks/Relationships: C. cf. fenestrata does not occur in abundance in any samples, but when found is in an index form

of Zone A of the Austin composite section.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Family Areoligeraceae Evitt

Genus Cyclonephelium Deflandre & Cookson,
1955, emend. Williams and Downie
in Davey et al., 1966 (p. 223)

Type species: Cyclonephelium compactum Deflandre & Cookson,
1955. Lower to Upper Cretaceous; Australia.

Cyclonephelium sp. 1 sp. nov.
Pl. 16, Figs. 1-3a

Diagnosis: Central body nearly circular in outline, with indented base. Two small antapical convexities suggesting antapical horns, one of which is more prominent than the other. Circumferential area on dorsal surface with thin elongate processes which are interconnected distally, connecting processes of adjacent plates. Ventral central area devoid of processes. Sulcal notch prominent, offset. Processes on dorsal central area. Postcingular fields of dorsal central area with annular process complex. Cingulum on dorsal surface delineated by processes. Processes rise from the periphragm and consist of annular or linear groupings of processes which tend to indicate a regular distribution. Archeopyle outlined by 6 precingular fields. Processes on precingular fields 2, 3 and 4 form annular

complexes; precingular field 6 always without processes; processes sometimes on field number 1. Processes solid taeniate, complexity united distally. The processes usually arise singly, proximately.

Holotype: Pb 4501, slide 1-A, coord. 38.3 x 107.0. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 60 by 69 microns; length of processes 15 to 35 microns. Average dimensions of 8 specimens: diameter of central body 65 to 75 microns; length of processes 15 to 38 microns.

Remarks/Relationships: C. sp. 1 appears to be quite similar to illustrations of C. exuberans, pl. V, figs. 11-12, given by Pastiels (1948) from the Eocene of Belgium, but the Navarro specimens are much larger in size than that species.

Occurrence: Rare in Neylandville Formation; abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Olmos and Escondido Formations, Frio County, Texas.

Cyclonephelium sp. 2 sp. nov.

Pl. 17, Figs. 2-6a

Pl. 18, Fig. 1

Diagnosis: Central body nearly circular in outline, with slightly indented base; antapical convexities suggesting antapical horns, one more prominent than the other. Circumferential area of ventral surface with processes formed from

the periphragm. Processes elongate and complexly interconnected distally. Processes interconnected from adjacent plates. Central areas of dorsal and ventral surfaces free of processes. Subequal edges of precingular plates are indicated by the angulations of the archeopyle margin, resulting from 6 precingular fields. Precingular fields 3 and 6 never possessing processes; processes on precingular fields 1 and 5 intratabular; precingular fields 2 and 3 are larger than 1 and 6. Few stray processes are present on the periphery of the dorsal surface. Sulcal notch, prominent, offset.

Holotype: JC-40, slide 1, coord. 46.0 x 95.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body, 79 by 65 microns; length of processes 25 microns. Average range of 5 specimens; diameter of central body 75 to 80 microns; length of processes up to 31 microns.

Remarks/Relationships: Cyclonephelium sp. 1 occurs in abundance in some samples of the Corsicana Formation, Austin composite section. This species is somewhat similar to C. pastielsi Deflandre & Cookson (1955) in outline, and process arrangement, but C. sp. 1 is much larger in size than the type material of C. pastielsi.

Occurrence: Common in Corsicana Formation; rare in Kemp Formation, Austin Texas composite section; common in Escondido Formation, Frio County, Texas.

Cyclonephelium sp. 3 sp. nov.

Pl. 16, Figs. 4-7

Pl. 17, Figs. 1-1a

Diagnosis: Central body nearly circular in outline; apical region tapers to a small short protruberance. Circumferential area of ventral surface with lace-like frill. Wall of central body finely punctate. Archeopyle margin showing 6 precingular fields.

Holotype: Nav. 11, slide 1, coord. 43.3 x 104.0. Corsicana Formation (Maestrichtian), Quarry of Whitsell Brick Company, Corsicana, Texas.

Dimensions: Holotype: diameter of central body 78 by 80 microns. Average range of 3 specimens: diameter of central body 72 to 80 microns.

Remarks/Relationships: This species is somewhat similar to C. vitilare, Cookson (1965), from the Paleocene of Australia, in outline, and in possessing a perforated circumferential membrane. Though in C. sp. 3 the perforations are not as coarse as in C. vitilare and do not appear to be the result of fusion of low, much-branched ridges.

Occurrence: Rare in Corsicana Formation, Austin composite section.

Cyclonephelium cf. divaricatum

Davey et al., 1966

Pl. 20, Figs. 1-6

1966. Cyclonephelium divaricatum Davey et al., 1966;
p. 223, pl. 25, fig. 1, text-fig. 60. Eocene; Britain.

Discussion: Navarro specimens referable to C. divaricatum conform closely to the description given by Davey et al., 1966. The Navarro forms differ in that the surface of the central body is smooth, whereas the London Clay forms have a finely reticulate central body.

Dimensions: Range of 5 specimens: diameter of central body 65 to 70 microns; length of processes up to 16 microns.

Remarks/Relationships: Cyclonephelium cf. divaricatum is recorded from the Eocene, London Clay Formation of Britain (Davey et al., 1966). This form appears to be restricted to the upper part of the Kemp Formation in the Austin composite section, and may be an indicator for that part of the Navarro.

Occurrence: Common in Kemp Formation, Austin composite section.

Genus Tenua Eisenack 1958b

Type species: T. hystrix Eisenack 1958b, p. 410, pl. 23, figs. 1-4, text-fig. 10. Aptian, Germany.

Tenua sp. 1 sp. nov.
Pl. 18, Figs. 4-5

Diagnosis: Test subspherical in outline, one side of antapex attenuated into a small, rounded protruberance. Processes intratabular; processes densely cover test; processes solid, tabular, slightly expanded proximally distally, and with blunt apices. Precingular fields 3, 4, 5 larger than 1, 2 and 6. Cingulum helicoidal.

Holotype: Pb 4632, slide s-2, coord. 39.3 x 104.2. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length (excluding epithema) 78 microns; width 93 microns. Range of 3 specimens: length 75 to 80 microns; width 85 to 94 microns.

Remarks/Relationships: The tabular processes distinguish this species from others described in the genus.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Tenua cf. hystrix Eisenack, 1958
Pl. 18, Figs. 2-3

1958. Tenua hystrix Eisenack, 1958, p. 410, pl. 23, figs. 1-4. Aptian; Germany

Discussion: The writer has not seen the holotype of this species, but the illustration and description given by Eisenack appear comparable to the Navarro forms. The test is covered with densely distributed short rod-like

projections. In specimens observed here, boundaries between plates are not marked and thus the tabulation is not indicated.

Dimensions: Range of 2 specimens: length 82-90 microns; width 77-84 microns.

Remarks/Relationships: Tenua hystrix is described by Eisenack (1958b) from the Lower Cretaceous (Aptian) deposits from Germany. Only a few specimens of this species were observed from the Neylandville Formation and it was not recognized elsewhere in the Navarro Group.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Genus Areoligera Lejeune-Carpentier, 1938
emend. Williams and Downie in
Davey et al, 1966 (p. 227-228)

Type species: A. senonensis Lejeune-Carpentier, 1938b.
Upper Cretaceous (Senonian), Belgium.

Areoligera senonensis Lejeune-
Carpentier, 1938
Pl. 19, Figs. 1-3

1938. Areoligera senonensis Lejeune-Carpentier: B164-6,
text-figs. 1-3. Upper Cretaceous; Belgium.

Discussion: Excellently preserved specimens of A. senonensis are observed from the Navarro material. Processes on dorsal surface reflect 3 precingular fields bearing soleate

processes; 3 postcingular fields, one soleate and two annular. One antapical field bearing annular processes. Antapex with two protruberences, the largest lying beneath the sulcal notch.

Dimensions: Range of 3 specimens: diameter of central body from 62 to 70 microns to 65 to 72 microns.

Remarks/Relationships: A. senonensis is recorded from the Senonian of Belgium, Lejeune-Carpentier (1938), the Paleocene of South Dakota, Stanley (1965), the Eocene of Britain, Davey et al. (1966), and the Maestrichtian of New Jersey, Evitt (1961).

Occurrence: Abundant in Corsicana Formation; common in Kemp Formation; Austin composite section; rare in Escondido and Olmos Formations, Frio County, Texas.

Areoligera sp. 1 sp. nov.
Pl. 19, Figs. 4-9

Diagnosis: Central body flat with subcircular outline. The six precingular and four postcingular fields bearing soleate processes which rise from the periphragm. Processes short, usually not united distally; erect, acuminate, bifid or trifid distally. Length of processes rarely exceeding one-third the diameter of central body. Antapex of central body usually with a single small protruberance.

Holotype: Pb 4505, slide 1, coord. 28.7 x 102.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 60 microns; width of central body 57 microns; length of processes up to 14 microns. Range of 5 specimens: length of central body 60 to 65 microns; width of central body 55 to 65 microns; length of processes 8 to 15 microns.

Remarks/Relationships: Areoligera sp. 1 sp. nov. is somewhat similar to Areoligera senonensis in tabulation, though in this species the processes are much more reduced in size.

Occurrence: Abundant in Corsicana Formation, Austin composite section; rare in Olmos Formation, Frio County, Texas.

Areoligera sp. 2 sp. nov.
Pl. 18, Figs. 6-9

Diagnosis: Central body subspherical in outline. Wall finely punctate. Processes arise singly or in pairs; circumferential processes are on both dorsal and ventral surfaces; processes on dorsal surface appear to be linear. Precingular plate 1 with linear processes; 3 with soleate processes.

Holotype: Pb. 4504, slide 2, coord. 44.0 x 86.5. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 68 microns; width 68 microns. Range of 5 specimens: diameter of central body 62 to 65 microns.

Remarks/Relationships: This species appears to be closest to Areoligera coronata (O. Wetzel), but the author has not

examined the holotype to make a more precise identification.

Occurrence: Abundant in Corsicana Formation; common in Kemp Formation; Austin composite section.

Genus Forma B Gen. nov.

Diagnosis: Dorso-ventrally flattened cysts. Central body oval in outline, the apex with a slight prominence suggesting an apical horn; antapical outline with two convexities with a depression between suggesting antapical horns. Circumferential areas of dorsal and ventral surfaces with surrounding membrane. Ventral and dorsal central areas not covered with membrane. Archeopyle apical. Sulcal notch offset.

Type species: Forma B sp. 1 sp. nov. Corsicana Formation (Maestrichtian) Austin composite section.

Remarks/Relationships: This genus is somewhat similar to Tenua, yclonephelium and Areoligera in that they all are dorso-ventrally flattened, have an apical archeopyle, and an offset sulcal notch.

Forma B sp. 1 Gen. et sp. nov.
Pl. 20, Figs. 7-8b

Diagnosis: Central body subspherical. Apex tapering to a slight prominence; antapical outline with two convexities. Surrounding membrane attached to circumferential areas of dorsal and ventral surfaces. Membrane attached to ventral surface with a few fine stray processes.

Holotype: Pb 4509, slide 3, coord. 36.8 x 106.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: diameter of central body 63 by 52 microns. Average range of 5 specimens: diameter of central body 60 to 65 microns by 50 to 55 microns.

Remarks/Relationships: This species occurs abundantly in the upper portion of the Corsicana Formation and from samples from the Olmos Formation, and is used as a horizon marker species.

Occurrence: Abundant in Corsicana Formation, Austin composite section, common in Escondido Formation, Frio County, Texas.

Family Hystrichodiniaceae Deflandre

Genus Heliodinium Alberti, 1961 emend. Sarjeant
in Davey et al., 1966

Type species: Heliodinium voigti Alberti: p. 33, pl. 8, figs. 1-5. Lower Cretaceous (Barremian); Germany.

Heliodinium cf. voigti Alberti, 1961, emend.
Sarjeant in Davey et al., 1966 (p. 142)

1961. Heliodinium voigti Alberti: p. 33, pl. 8, figs. 1-5. Lower Cretaceous; Germany.

1966. H. voigti (Alberti, 1961) emend. Sarjeant in Davey et al., 1966: p. 142-144, pl. 16, fig. 2, text-fig. 36.

Discussion: Specimens referable to H. voighti from the Navarro material are rare and poorly preserved, and distorted in most instances. The processes are dagger-like and flexible; distal ends are simple, usually acuminate. The surface of most specimens appears smooth. Tabulation was not determined.

Dimensions: Range of 3 specimens: length of central body 40 to 60 microns; width of central body 35 to 46 microns; length of processes up to 22 microns.

Remarks/Relationships: H. voighti is originally described from the Lower Cretaceous (Upper Barremian) of Germany by Alberti (1961). Davey et al. (1966) report it from the Upper Cretaceous (basal Cenomanian) of Britain.

Occurrence: Rare in the Neylandville Formation, Austin composite section.

Family Gymnodiniaceae Bergh

Genus Gymnodinium Stein, 1878 emend. Kofoid
and Swezy, 1921

Type species: (based on extant type species.)

Discussion: Non-tabulate ellipsoidal to biconical fossil tests without processes; with more or less equatorial cingulum; with sulcus mostly in the hypothecal portion; presently assigned to the genus Gymnodinium. These features conform to the circumscribed limits of the modern genus

Gymnodinium. Whether the fossil forms of the genus represent cysts or the free-living stage is not yet certain. Evitt, personal communication has proposed a new genus Dinogymnium for typical fossil "Gymnodinium." The features distinguishing Dinogymnium from modern Gymnodinium are a chemically resistant wall, small apical archeopyle, and wall partly or completely penetrated by minute canals. These features, except for the wall canals, indicate a cyst interpretation of fossil Gymnodinium, and possibly indicate a mode of encystment different than in other fossil dinoflagellates.

Gymnodinium nelsonense Cookson, 1956
Pl. 21, Figs. 10-13a
Pl. 22, Figs. 1-2

1956. Gymnodinium nelsonense Cookson: p. 183-4, pl. 1, figs. 8-11. Upper Cretaceous; Australia.

Discussion: The Navarro forms attributed to G. nelsonense agree to the type description of the species. An opening at the apex of the epitract, which is here considered to be analogous to an archeopyle, is observed in nearly all specimens examined.

Dimensions: Range of 5 specimens: length of test 68 to 75 microns; width of test 30 to 35 microns.

Remarks/Relationships: In several samples of the Neylandville Formation G. nelsonense occurs in great abundance, and

dominates the assemblage. This large occurrence of individuals may have stratigraphic significance in local correlations. G. nelsonense is reported from the Cannonball Marine Member, Paleocene, from South Dakota by Stanley (1966). Cookson and Eisenack (1957) state that the range of the species is from Campanian to Lower Maestrichtian in Australia.

Occurrence: Abundant in Neylandville Formation; rare in Corsicana Formation, Austin composite section; rare in Olmos Formation, Frio County, Texas.

Gymnodinium westralium Cookson
and Eisenack, 1958
Pl. 22, Figs. 3-6

1958. Gymnodinium westralium Cookson and Eisenack, pp. 25-26, pl. 1, fig. 9. Upper Cretaceous; Australia.

Discussion: Navarro specimens of Gymnodinium westralium possess a thin wall which is subject to distortions and folding. The girdle is well-defined by a central deep indentation. This species is somewhat similar to Gymnodinium hetercostatum Deflandre, in shape and size, though G. westralium appears to have more deeply incised furrows than G. heterocostatum.

Dimensions: Range of 5 specimens: length of test 45 to 58 microns; diameter of test 22 to 31 microns.

Remarks/Relationships: G. westralium is previously recorded from the Campanian and Lower Maestrichtian of Australia and also the Senonian and Cenomanian to Lower Turonian of Australia.

Occurrence: Common in Kemp Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Gymnodinium digitus Deflandre, 1935
Pl. 22, Figs. 7-11

1935. Gymnodinium digitus Deflandre: p. 225, text-figs. 7-8. Upper Cretaceous; France.

Discussion: The Navarro forms assigned to G. digitus compare closely with the specific description of the species given by Deflandre, though the specimens here have a more broadly rounded antapex and stronger development of longitudinal folds. The wall is finely granular and is penetrated by minute canals which tend to be arranged longitudinally. In end view the Navarro specimens are ventrally-dorsally plano-convex.

Dimensions: Range of 10 specimens: length of test 58 to 62 microns; width of test 18 to 22 microns.

Remarks/Relationships: An archeopyle or apical opening is observed in many of the Navarro specimens. In some samples the species occurs in great abundance or in clusters, and tends to dominate the assemblage. Whether this abundant

occurrence represents fossil dinoflagellate "blooms" is not certain.

Occurrence: Abundant in Neylandville Formation; rare in Corsicana Formation, Austin composite section.

Gymnodinium sp. 1 sp. nov.
Pl. 21, Figs. 1-4

Diagnosis: Test biconical. Hypotract blunt, broadly rounded at apex; epittract more narrowly rounded. Hypotract with short, narrow, longitudinal sulcus; wall not folded. Epittract with longitudinal folds. Wall punctate, Cingulum narrow, well defined; divides test into approximately two equal halves. Archeopyle small.

Holotype: Jc-7, slide 2-A, coord. 43.4 x 104.5. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 34 microns; width of test 25 microns. Average dimensions of 8 specimens: length of test 30 to 35 microns; width of test 25 to 28 microns.

Remarks/Relationships: This species is similar to G. cretaceum in general outline and size, but differs in having longitudinal folds on the epittract. Also in this species the hypotract apex is more broadly rounded than in G. cretaceum. A small opening at the apex of the epittract is suggested as being analogous to an archeopyle.

Occurrence: Abundant in Corsicana Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Gymnodinium sp. 2 sp. nov.
Pl. 21, Figs. 6-9

Diagnosis: Test fusiform, consisting of a single wall. Cingulum distinct, narrow, deeply indented, dividing the test into approximately equal halves. Test expanded in mid-area. Epittract and hypottract with crenulated longitudinal folds more or less equally developed on both halves. Test wall with fine granules which extend along a linear trend to the apices. Wall penetrated with minute canals which tend to be most obvious on the epithema and cingulum. Archeopyle relatively large.

Holotype: Jc-7, slide 3-B, coord. 30.8 x 93.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 88 microns; width of test 58 microns. Average dimensions of 4 specimens: length of test 85 to 90 microns; width of test 55 to 60 microns.

Remarks/Relationships: All of the Navarro specimens of this species observed possess an opening at the apex of the epittract analagous to an archeopyle. The epithema is attached in practically all specimens. This species is close to Gymnodinium westralium and G. heterocostatum in outline, possessing longitudinal folds and having minute wall canals as in G. westralium, but differs from both of these species in being much larger in size.

Occurrence: Common in Corsicana Formation, Austin composite section.

Gymnodinium sp. 3 sp. nov.
Pl. 22, Figs. 12-14

Diagnosis: Test elongate; epitract and hypotract approximately equal in length. Antapex bilobed. Wall covered with fine granules which tend to be arranged longitudinally, and penetrated with minute canals. Epitract with longitudinal folds; hypotract with reduced number of folds or none at all. Cingulum narrow, well-defined.

Holotype: Pb 4675, slide 1, coord. 37.4 x 84.3. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 60 microns; width of test 22 microns. Range of 3 specimens: length of test 58 to 65 microns; width of test 22 to 26 microns.

Remarks/Relationships: Gymnodinium sp. 3 is distinct from all previously described species of fossil Gymnodinium in the possession of a bilobed antapex. The bilobed character in this species is more developed in some specimens than in others, but is always identifiable in the species. G. sp. 3 is similar to Navarro specimens of Gymnodinium digitus in elongate outline, minute wall canals, granular test, and longitudinal folds, but is easily distinguished by its bilobed antapex. G. sp. 3 is found in stratigraphically lower samples than G. digitus, and whether G. digitus is an evolutionary development or environmental development from G. sp. 3 is not known. It is thought that G. sp. 3 will prove to be of stratigraphic value with further work. No

archeopyle has been observed in the examined specimens.

Examples of modern Gymnodinium which possess bilobed antapical ends are: G. sulcatum, G. mirabile, G. incisum and G. wilczeki.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Gymnodinium sp. 4 sp. nov.
Pl. 23, Figs. 1-2

Diagnosis: Test elongate, epitract and hypotract broadly rounded. Wall smooth to finely striate. Cingulum broad, poorly defined.

Holotype: Pb 4675, slide 1, coord. 34.0 x 83.3. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 60 microns, width of test 30 microns. Average range of 3 specimens: length of test 55 to 62 microns; width of test 27 to 30 microns.

Remarks/Relationships: the broadly rounded apices and relatively simple morphologic features make this species easily recognizable.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Gymnodinium sp.
Pl. 21, Fig. 5

Discussion: G. sp. is represented by one specimen from the Corsicana Formation of the Austin composite section. It is similar in shape and size to G. sp. 1 sp. nov., but differs in possessing rather sinuous longitudinal folds on both the epitract and hypotract.

Dimensions: Length 35 microns; width 27 microns.

Occurrence: Rare in Kemp Formation, Austin composite section.

Genus Diconodinium Eisenack and Cookson, 1960

Type species: D. (al Palaeohystrichophora) multispinum
(Deflandre and Cookson, 1955), Senonian; Western Australia.

Diconodinium sp. 1 sp. nov.
Pl. 23, Figs. 3-4

Diagnosis: Test biconical, Cingulum approximately equatorial. Test consists of a single wall; wall very thin, covered with fine granules. Antapex angular truncate, one side prolonged into short tapered point. Cingulum incised, probably heliocoid.

Holotype: Pb 4508, slide 3, coord. 28.3 x 90.8. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 40 microns; width of test 26 microns. Average range of 3 specimens: length of test 38 to 40 microns; width of test 24 to 27 microns.

Remarks/Relationships: Diconodinium sp. 1 is readily distinguished from other species of the genus by its small size and finely granular wall.

Occurrence: Abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Family Gonyaulacaceae Lindemann

Genus Gonyaulax Diesing

Type species: (Modern genus and type species.)

Gonyaulax sp. 1 sp. nov.
Pl. 23, Figs. 5-8

Diagnosis: Test ellipsoidal, with short apical horn. No indication of antapical horns. Capsule ellipsoidal, in close contact with outer wall. Reflected plate boundaries indicated by low distinct ridges. Cingulum narrow, well-defined, strongly spiral. Wall smooth or finely granular.

Holotype: Pb 4509, slide s-1, coord. 49.0 x 93.7. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 93 microns; width of test 87 microns. Range of 5 specimens: length of test 90 to 95 microns; width of test 82 to 88 microns.

Remarks/Relationships: This species occurs commonly throughout the Navarro Group in the Austin and Frio sections. Its most abundant occurrence is in the Corsicana Formation, in

the Austin composite section. This species also occurs in the Red Bank Formation of New Jersey.

Occurrence: Common in Neylandville Formation; abundant in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Olmos and Escondido Formations, Frio County, Texas.

Family Pseudoceratiaceae Eisenack

Genus Odontochitina Deflandre, 1935

Type species: O. (al. Ceratium) operculata (O. Wetzel, 1932) Deflandre and Cookson, 1955. Upper Cretaceous; Baltic.

Discussion: The emendation of this genus would be in order, though the author has not examined sufficient material for an emendation at the present time. Specimens referable to the genus Odontochitina should include those forms with globular tests, possessing three horns. One horn is apical and another antapical; a third horn is postcingular (Evitt, personal communication), rising from the test from an area just below the equator. Apical rupture divides the test into two unequal parts. Margin of archeopyle with clefts suggesting field margins, but no other indication of tabulation. Cingulum not defined. Capsule close to test wall, except in areas of horns.

Odontochitina striatoperforata
Cookson and Eisenack, 1962
 Pl. 24, Figs. 7-8

1962. Odontochitina striatoperforata Cookson & Eisenack:
 p. 490, pl. 3, fig. 16. Upper Albian to Cenomanian;
 Australia.

Dimensions: Range of 3 specimens: length of central body
 38 to 50 microns; width of central body 42 to 60 microns;
 length of horns 75 to 82 microns.

Remarks/Relationships: Several specimens referable to this
 species have been found, though none of them with epithema
 attached. The Navarro forms possess the perforated horns as
 described by Cookson and Eisenack, but the linear striations
 on the horns are more faint in the Navarro specimens. O.
striatoperforata is restricted to the Neylandville Formation
 in the Austin composite section; therefore its presence in a
 sample may be stratigraphically important. O. striatoper-
forata is reported from the Albian and Cenomanian of Austra-
 lia by Cookson and Eisenack (1962) and from the Upper Cre-
 taceous of Graham Island, Arctic Canada. Evitt (1961, pl. 6,
 figs. 15, 16) illustrates a similar form from the Senonian
 of West Pakistan.

Occurrence: Rare in Neylandville Formation, Austin compos-
 ite section.

Genus Forma C. Gen. nov.

Diagnosis: Chorate cysts. Test usually ellipsoidal and possessing two different types of processes. Three large processes, one apical and one antapical; a third process is postcingular. Several smaller processes reflect the main plates of the test. Archeopyle apical; margins irregular or zig-zag. Large process open or closed distally; small processes closed distally.

Type species: Forma C sp. 1 sp. nov. Corsicana Formation (Maestrichtian) Austin composite section.

Remarks/Relationships: Evitt (1961, pl. 6. fig. 9) illustrates this genus as Forma H. He states its relationship to Odontochitina in possessing a cyst within a cyst; having apical, antapical, and postcingular horn (personal communication); and also its relationship with Hystrichosphaeridium in having the ends of the processes flared.

Forma C sp. 1 Gen. et sp. nov.
Pl. 24, Figs. 1-6

Diagnosis: Test ellipsoidal, periphragm smooth, giving rise to the processes. Capsule ellipsoidal, penetrated by minute canals and in close contact with periphragm except in areas of apical and antapical horns. Smaller processes reflect field boundaries and are solid, closed distally and possess slightly flared tips. Apical processes open distally and with denticulate margin.

Holotype: Pb 4675, slide 1, coord. 40.8 x 88.0. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of central body 69 microns; width of central body 58 microns.

Remarks/Relationships: Forma C sp. 1 is restricted to the Neylandville Formation in the Austin composite section and is not observed in the Frio County section. In some samples this species is relatively abundant and their unusual morphology makes them readily identifiable. Only a few complete specimens were observed; the majority of the forms are found with the epithema detached. The epithema is observed commonly in samples containing the main body.

Occurrence: Common in Neylandville Formation, Austin composite section.

Family Deflandreaceae Eisenack

Genus Deflandrea Eisenack 1938, emend. Williams and Downie in Davey et al., 1966 (p. 231)

Type species: Deflandrea phosphoritica Eisenack, 1938.

Oligocene; East Prussia.

Deflandrea acuminata Cookson & Eisenack, 1958
Pl. 25, Figs. 5-7

1958. Deflandrea acuminata Cookson & Eisenack: p. 27, pl. 4, figs. 5-8. Cenomanian - Lower Turonian; Australia.

Dimensions: Range of 4 specimens: length of test 62 to 77 microns; width of test 38 to 46 microns; length of capsule 39 to 51 microns; width of capsule 31 to 38 microns.

Remarks/Relationships: This species has been previously recorded from the Cenomanian to lower Turonian of western Australia. It seems to be restricted to the Neylandville Formation, Austin composite section.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Deflandrea cooksoni Alberti, 1959
Pl. 25, Figs. 8-9, 12

1959. Deflandrea cooksoni Alberti: p. 97, pl. 9, figs. 1-6. Upper Cretaceous; Germany.

Dimensions: Average range of 5 specimens: overall length of test 78 to 84 microns; overall width of test 46 to 53 microns.

Remarks/Relationships: The wall of the Navarro forms of this species are medium thick, and probably brittle, as many specimens are subject to fracturing. There appears to be much morphologic variation among the Navarro specimens, though all probably belong to this species. Alberti (1959) described D. cooksoni from the Senonian of Germany, and it is known to occur in the Red Bank Formation (Maestrichtian), of New Jersey.

Occurrence: Common in the Corsicana Formation, Austin composite section; rare in Escondido Formation, Frio County, Texas.

Deflandrea microgranulata Stanley, 1965
Pl. 27, Figs. 1-2

1965. Deflandrea microgranulata Stanley: p. 219, pl. 19, figs. 4-6, Paleocene; South Dakota.

Dimensions: Average range of 4 specimens: overall length 51 to 60 microns; overall width 41 to 48 microns.

Remarks/Relationships: Deflandrea microgranulata is reported by Stanley (1965) from the Paleocene of South Dakota.

Occurrence: Common in Corsicana Formation; common in Kemp Formation, Austin composite section; common in Escondido Formation, Frio County, Texas.

Deflandrea magnifica Stanley, 1965
Pl. 29, Fig. 7
Pl. 30, Figs. 1-4

1965. Deflandrea magnifica Stanley: p. 218, pl. 20, figs. 1-6. Paleocene; South Dakota.

Discussion: Navarro specimens referable to D. magnifica closely conform to the description given by Stanley (1965).

Dimensions: Range of 6 specimens: overall length 65 to 93 microns; overall width 53 to 92 microns.

Remarks/Relationships: This species is previously reported from the Paleocene of South Dakota by Stanley (1965). Specimens of D. magnifica from the Corsicana Formation in the Austin composite section are almost always larger in size than those observed from the Frio County, Texas subsurface section.

Occurrence: Common in Corsicana Formation; abundant in Kemp Formation, Austin composite section; abundant in Escondido Formation, Frio County, Texas.

Deflandrea pannucea Stanley, 1965
Pl. 28, Figs. 3-4
Pl. 29, Figs. 1-3

1965. Deflandrea pannucea Stanley: p. 220, pl. 22, figs. 1-4, 8-10. Paleocene; South Dakota.

Discussion: The Navarro specimens of Deflandrea pannucea conform to the circumscribed limits of the specific description given by Stanley (1965), though the Navarro forms are larger in size.

Dimensions: Range of 8 specimens: outer shell length 120 to 146 microns; width 62 to 95 microns; capsule length 53 to 77 microns; width 60 to 93 microns; length of apical horn 22 to 38 microns.

Remarks/Relationships: Deflandrea pannucea has been previously described from the Paleocene of South Dakota by Stanley (1965). The species is easily recognized by its

longitudinally folded periphragm. Specimens of this species studied from the Neylandville Formation of the Austin composite section are consistently larger in size than those observed from the Corsicana Formation. The Neylandville specimens also have less attenuated horns.

Occurrence: Common in Neylandville Formation; common in Kemp Formation; Austin composite section; common in Olmos and Escondido formations, Frio County, Texas.

Deflandrea micracantha, Cookson
& Eisenack, 1960
Pl. 25, Figs. 10-11

1960. Cookson and Eisenack: p. 3, pl. 1, fig. 9. Upper Cretaceous; Australia.

Discussion: Specimens referable to D. micracantha from the Navarro material closely conform to the description given by Cookson & Eisenack though the Navarro forms are somewhat smaller in size.

Dimensions: Range of 2 specimens: overall length 82 to 85 microns; overall width 53 to 60 microns.

Remarks/Relationships: D. micracantha is described from the Campanian of Australia. The wall of the Navarro form is relatively thick and subject to fracturing.

Occurrence: Rare in Neylandville Formation, Austin composite section.

? Deflandrea sp. 1 sp. nov.
Pl. 30, Figs. 7-8a

Diagnosis: Test pentagonal in outline, consisting of one wall. Wall finely granular. Apical horn short, narrowly rounded at apex. Antapical horns non-divergent, short, narrowly rounded at apices, and sometimes poorly developed. Cingulum indicated by transverse folding of the wall at mid-region. Epithema consisting of three trapezodial fields.

Holotype: Pb 4501, slide 4-A, coord. 28.2 x 90.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: length of test 69 microns; width of test 53 microns. Average range of 4 specimens: length 69 to 74 microns; width 51 to 60 microns.

Remarks/Relationships: This species is placed questionably in the genus Deflandrea because of the absence of a capsule, though possessing all the other characteristics of the genus. The species is common in the Corsicana and Kemp formations, and in all instances, the specimens observed have only one wall.

Occurrence: Common in Corsicana Formation; common in Kemp Formation, Austin composite section; rare in Escondido Formation, Frio County, Texas.

Deflandrea sp. 2 sp. nov.
Pl. 26, Figs. 1-8

Diagnosis: Test pentagonal in outline. Periphragm covered with tiny spinules which show a tendency to be locally aligned in indistinct rows, probably reflecting field boundaries. Capsule large, smooth, fills enclosing test except in area of apical and antapical horns. Cingulum sinistral, well-defined; margins with tiny spinules. Archeopyle large, approximately hexagonal in outline, with rounded corners.

Holotype: Pb. 4504, slide G-1, coord. 35.3 x 104.2. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: outer shell length 115 microns, width 69 microns, capsule length 69 microns, width 68 microns; length of apical horn 30 microns. Range of 5 specimens: outer shell length 63 to 115 microns; width 53 to 75 microns.

Remarks/Relationships: Deflandrea denticulata Alberti (1959) from the Paleocene-Lower Eocene of Germany is quite close to this species. Deflandrea sp. 2 differs from the German material in possessing much smaller spines.

Occurrence: Common in Corsicana Formation; rare in Kemp Formation, Austin composite section.

Deflandrea sp. 3 sp. nov.
Pl. 29, Figs. 4-6

Diagnosis: Test pentagonal in outline, composed of smooth endophragm and periphragm. Capsule large, ovoidal in outline, in close contact with outer wall except in areas of

apical and antapical horns. Cingulum helicoidal; margin beaded. Archeopyle rhomboidal.

Holotype: JC-40, slide 4, coord. 46.7 x 95.5. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: outer shell length 124 microns, width 78 microns; capsule length 69 microns, width 70 microns. Range of 4 specimens: outer shell length 115 to 125 microns, width 67 to 70 microns; capsule length 68 to 70 microns, width 67 to 70 microns; length of apical horn up to 31 microns.

Remarks/Relationships: Deflandrea sp. 3 is close to D. obliquipes, Deflandre & Cookson (1955) in outline and possessing smooth walls, but this species differs in having the margins of the cingulum ornamented with beads, not having a punctate wall, and possessing a rhomboidal rather than a triangular archeopyle. The antapical horns in this species are also less divergent than in D. obliquipes. D. sp. 3 is easily recognized by its smooth wall and rhomboidal archeopyle.

Occurrence: Common in Corsicana Formation, Austin composite section.

Deflandrea sp. 4 sp. nov.
Pl. 27, Figs. 8-10
Pl. 28, Figs. 1-2

Diagnosis: Test fusiform, expanded at mid-area. Endophragm in close contact with periphragm except in areas of apical

and antapical horns. Apical and antapical horns attenuated into relatively short tapered points. Periphragm coarsely granular. Archeopyle large, triangular; not always distinct.

Holotype: Pb 4677, slide 1, coord. 47.5 x 96.3. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: overall length 144 microns, overall width 78 microns; length of central body 100 microns; width of central body 78 microns. Range of 5 specimens: overall length 140 to 170 microns; overall width 74 to 78 microns; length of central body 78 to 115 microns; width 72 to 78 microns.

Remarks/Relationships: Deflandrea sp. 4 is distinct from other described species of Deflandrea in outline and ornamentation of periphragm. In some specimens the archeopyle is difficult to distinguish if the archeopyle of the capsule is closely associated with the outer wall. Deflandrea sp. 4 is restricted to the Neylandville Formation and is a marker species for zone A.

Occurrence: Common in Neylandville Formation, Austin composite section.

Deflandrea sp. 5 sp. nov.
Pl. 27, Figs. 3-4

Diagnosis: Test subquadrate, composed of thin, smooth endophragm and periphragm. Capsule in close contact with outer wall, except in areas of apical and antapical horn.

Apical horn short, with blunt tip. Antapical area attenuated into small, pointed protruberance. Archeopyle triangular.

Holotype: Pb. 4673, slide 2, coord. 42.8 x 106.2. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: overall length 63 microns; overall width 36 microns. Range of 3 specimens; overall length 51 to 63 microns; overall width 34 to 40 microns.

Remarks/Relationships: The outer and inner walls of this species are very thin and best studied with phase contrast microscopy. Its small size and distinctive outline distinguish it from other species of the genus.

Occurrence: Common in Neylandville Formation, Austin composite section.

Deflandrea sp. 6 sp. nov.
Pl. 27, Figs. 5-7

Diagnosis: Test subquadrate in outline; composed of smooth endophragm and periphragm which bears small tubercles that are somewhat aligned in a regular fashion. Tubercles are most dense at the mid-area or capsular region. Apex tapers to short blunt point. Antapex angular, truncate on side prolonged into a short horn. Archeopyle broadly rounded at anterior. Epithema attached posteriorly.

Holotype: Pb. 4632, slide 3 coord. 38.0 x 100.2. Neylandville Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: overall length 72 microns; overall width 47 microns; length of central body 38 microns; width 46 microns. Range of 4 specimens: overall length 54 to 73 microns; overall width 46 to 48 microns.

Remarks/Relationships: Deflandrea sp. 6 is similar to Deflandrea balmei in general outline and tubercular ornamentation. This species differs in shape in archeopyle. D. sp. 6 is restricted to the Neylandville Formation of the Austin composite section and should prove to be stratigraphically important.

Occurrence: Common in Neylandville Formation, Austin composite section.

Genus Svalbardella Manum, 1960

Type species: Svalbardella cooksoniae Manum, 1960. Lower Tertiary; Spitsbergen.

Svalbardella cf. lidiae (Gorka, 1963)

Pl. 30, Figs. 9-9a

Pl. 31, Fig. 1

1963. Liofusa lidiae Gorka: p. 37, pl. 5, fig. 6.
Maestrichtian; Poland.

Discussion: Specimens referable to S. lidiae in the Navarro appear quite close to Leiofusa lidiae Gorka (1963) from the Maestrichtian of Poland, though in the description of that species it is stated that there is no internal capsule. The

illustrated figure appears to indicate an internal capsule which is attenuated into the horns. Therefore, it would be best to assign this species to Svalbardella. The endophragm and periphragm of the Navarro specimens are smooth. The archeopyle was not observed in any of the specimens examined, and the internal capsule does not extend into the horns as is indicated in L. lidiae. The horns of the Navarro material are attenuated into long tapered points, and the antapical horn is in some bifurcate.

Dimensions: Range of 5 specimens: overall length 160 to 187 microns; overall width 45 to 53 microns.

Remarks/Relationships: Svalbardella lidiae ranges throughout the Navarro group but it is abundant in the Kemp and Escondido Formations. This species was originally described from the Maestrichtian of Poland, Gorka (1963).

Occurrence: Common in Neylandville and Corsicana Formations; abundant in Kemp Formation, Austin composite section; abundant in Escondido Formation; rare in Olmos Formation, Frio County, Texas.

Family Apteodiniaceae Eisenack

Genus Apteodinium Eisenack, 1958

Type species: Apteodinium granulatum Eisenack, 1958.

Aptian; Germany.

Apteodinium sp. 1 sp. nov.
Pl. 30, Figs. 5-6

Diagnosis: Test oval in outline, composed of smooth endophragm and finely granular periphragm. Epitract terminated by short blunt horn; hypotract apex attenuated into two short horns; cingulum distinct; dextal. Archeopyle polygonal. Capsule in close contact with outer wall.

Holotype: Pb. 4506, slide 3, coord. 46.5 x 87.3. Corsicana Formation (Maestrichtian), Austin composite section.

Dimensions: Holotype: overall length 75 microns; overall width 58 microns. Range of 3 specimens: overall length 70 to 78 microns; overall width 55 to 60 microns.

Remarks/Relationships: Apteodinium sp. 1 is similar to A. conjunctum Eisenack & Cookson (1960) in outline and in possessing a short apical horn, but it differs from that species in having a central body and a helicoid cingulum.

Occurrence: Common in Corsicana Formation, Austin composite section.

DINOFLAGELLATES of UNCERTAIN AFFINITY

Genus Palaeohystrichophora Deflandre, 1934
 emend. Deflandre and Cookson, 1955

Type species: Palaeohystrichophora infusorioides Deflandre,
 1934. Cretaceous, France.

Palaeohystrichophora infusorioides
 Deflandre, 1934
 Pl. 31, Fig. 4

1934. Palaeohystrichophora infusorioides Deflandre: p. 967,
 fig. 8. Cretaceous; France.

Discussion: Navarro specimens referable to P. infusorioides
 compare closely with the specific description and illustration
 given by Deflandre. The test is biconical, consisting
 of thin, smooth endophragm and thin periphragm which bears
 widely spaced fairly long hair-like processes. The endo-
 phragm nearly fills the periphragm laterally.

Dimensions: Range of 2 specimens: overall length 42 to 45
 microns; overall width 30 to 33 microns.

Remarks/Relationships: P. infusorioides is reported from
 the Upper Cretaceous of France by Deflandre (1934) the Upper
 Cretaceous (Cenomanian to Lower Turonian) of Australia
 (Cookson and Eisenack, 1958), and the Senonian-Campanian of
 Western Australia (Cookson and Eisenack, 1960). This spe-
 cies is restricted to the Neylandville Formation in the
 Austion composite section.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Palaeohystrichophora sp. 1 sp. nov.
Pl. 31, Figs. 5-7

Diagnosis: Test biconical, composed of smooth endophragm and periphragm densely covered with short, fine, hair-like processes. Capsule circular to elliptical in outline, usually filling outer wall laterally, except in apical and antapical areas. Cingulum well-defined by thin marginal ridges. Two antapical horns, one of which is larger than the other.

Holotype: Pb. 4579, slide 1, coord. 47.0 x 92.5. Olmos Formation (Maestrichtian); Frio County, Texas.

Dimensions: Holotype: overall length 60 microns; overall width 42 microns. Range of 4 specimens: overall length 58 to 73 microns; overall width 40 to 43 microns.

Remarks/Relationships: P. sp. 1 is distinguished from P. infusorioides in having two antapical horns, and by its more numerous and shorter hair-like processes.

Occurrence: Common in Olmos Formation, Frio County, Texas.

Genus Hexagonifera

Type species: Hexagonifera glabra Cookson and Eisenack, 1961. Upper Cretaceous; Victoria, Australia.

Hexagonifera sp. 1 sp. nov.
Pl. 31, Figs. 2-3

Diagnosis: Test oval to spherical in outline; wall moderately thick. Surface covered with coarse granules of variable size.

Holotype: Pb. 4515, slide 1, coord. 36.8 x 102.2. Corsicana Formation (Maestrichtian); Austin composite section.

Dimensions: Holotype: diameter of test 31.0 microns.

Range of 5 specimens: diameter of test 26-34 microns.

Remarks/Relationships: Specimens in the Navarro material referable to Hexagonifera are within the limits of the genus. Only dorso-ventrally flattened specimens were observed and thus it is difficult to determine whether the pylome is six-sided or polygonal in outline. The small size and distinct ornamentation distinguish this species from others described in the genus.

Occurrence: Common in Neylandville Formation; abundant in Corsicana Formation; rare in Kemp Formation, Austin composite section.

Genus Gillinia Cookson and Eisenack, 1960

Type species: Gillinia hymenophora, 1960, p. 12, pl. 3, figs. 4-6. Senonian; western Australia.

Gillinia hymenophora Cookson & Eisenack, 1960
Pl. 31, Fig. 8

1960. Gillinia hymenophora Cookson & Eisenack, p. 12,
pl. 3, figs. 4-6. Senonian; western Australia.

Discussion: The Navarro specimen referable to G. hymenophora agrees closely with the description and illustration given by Cookson and Eisenack.

Dimensions: overall length 27 microns; overall width 20 microns.

Remarks/Relationships: One specimen of G. hymenophora was observed in the Navarro material. The species is previously recorded from the Senonian of Western Australia.

Occurrence: Rare in Neylandville Formation, Austin composite section.

Genus Spinidinium Cookson and Eisenack, 1962

Type species: Spinidinium grossi Alberti, 1961. Upper Hauterivian to Upper Barremian, North Germany.

Spinidinium cf. densispinatum Stanley, 1965

1965. Spinidinium densispinatum Stanley: p. 226, pl. 21, figs. 1-5. Paleocene; South Dakota.

Discussion: Navarro specimens referable to S. densispinatum are close to the description and illustration given by Stanley (1965).

Dimensions: Range of 3 specimens; overall length 50 to 60 microns; overall width 40 to 50 microns.

Remarks/Relationships: S. densispinatum is reported by Stanley (1965) from the Paleocene of South Dakota. This species is very abundant in samples near the base of the Olmos Formation, Frio County, Texas.

Occurrence: Abundant in Frio County section, Frio County, Texas.

STRATIGRAPHIC AND PALEONTOLOGIC
CONSIDERATIONS

List of Species in the Austin
Composite Section

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE

Micrhystridium fragile
Micrhystridium stellatum
Baltisphaeridium hirsutum
Baltisphaeridium sp. 1 sp. nov.
Baltisphaeridium sp. 2 sp. nov.
Baltisphaeridium sp. 3 sp. nov.

Subgroup HERKOMORPHITAE

Cymatiosphaera radiata

Subgroup Uncertain

Palaeostomocystis sp. 1 sp. nov.

Class CHLOROPHYCEAE

Family Uncertain

Palambages deflandrei
Palambages Forma A

Class DINOPHYCEAE

Family HYSTRICHOSPHAERIDIACEAE

Hystrichosphaeridium patulum
Hystrichosphaeridium stellatum
Hystrichosphaeridium tubiferum
? Hystrichosphaeridium sp. 3 sp. nov.
Hystrichosphaeridium sp. 1 sp. nov.
Hystrichosphaeridium sp. 2 sp. nov.

Polysphaeridium sp. 1 sp. nov.
Polysphaeridium sp. 2 sp. nov.
Polysphaeridium sp. 3 sp. nov.
Polysphaeridium sp. 4 sp. nov.
Cordosphaeridium fibrospinosum
Cordosphaeridium inodes
Cordosphaeridium sp. 1 sp. nov.
Oligosphaeridium complex
Tanyosphaeridium sp. 1 sp. nov.
Tanyosphaeridium sp. 2 sp. nov.
Cleistosphaeridium sp. 1 sp. nov.
Forma F. sp. 1 Gen. et sp. nov.
Forma A sp. 1 Gen. et sp. nov.
Forma A sp. 2 Gen. et sp. nov.
Forma A sp. 3 Gen. et sp. nov.
Diphyes cf. colligerum
Callaiosphaeridium assymmetricum
Systematophora sp. 1 sp. nov.

Family HYSTRICHOSPHAERACEAE

Achomosphaera ramulifera
Hystrichosphaera ramosa var. 1
Hystrichosphaera ramosa
Hystrichosphaera sp.
Hystrichosphaera sp. 1
Hystrichosphaera sp. 2
Cannosphaeropsis fenestrata

Family AREOLIGERACEAE

Areoligera senonensis
Areoligera sp. 1 sp. nov.
Areoligera sp. 2 sp. nov.
Cyclonephelium divaricatum
Cyclonephelium sp. 1 sp. nov.
Cyclonephelium sp. 2 sp. nov.
Cyclonephelium sp. 3 sp. nov.
Forma B. sp. 1 Gen. et sp. nov.
Tenua cf. hystrix
Tenua sp. 1 sp. nov.

Family HYSTRICHODINIACEAE

Heliodinium cf. voigti

Family GYMNODINIACEAE

Diconodinium sp. 1 sp. nov.
Gymnodinium digitus
Gymnodinium nelsonense
Gymnodinium westralium
Gymnodinium sp. 1 sp. nov.
Gymnodinium sp. 2 sp. nov.
Gymnodinium sp. 3 sp. nov.
Gymnodinium sp. 4 sp. nov.
Gymnodinium sp.

Family GONYAULACACEAE

Gonyaulax sp. 1 sp. nov.

Family PSEUDOCERATIACEAE

Odontochitina striatoperforata
 Forma C. sp. 1 gen. et sp. nov.

Family DEFLANDREACEAE

Deflandrea acuminata
Deflandrea cooksoni
Deflandrea magnifica
Deflandrea microgranulata
Deflandrea pannucea
 ? Deflandrea sp. 1 sp. nov.
Deflandrea sp. 2 sp. nov.
Deflandrea sp. 3 sp. nov.
Deflandrea sp. 4 sp. nov.
Deflandrea sp. 5 sp. nov.
Deflandrea sp. 6 sp. nov.
Svalbardella lidiae

Family APTEODINIACEAE

Apteodinium sp. 1 sp. nov.

Family Uncertain

Hexagonifera sp. 1 sp. nov.
Palaeohystrichophora infusorioides
Spinidinium sp.

List of Species in the
Frio Section

Group ACRITARCHA

Subgroup ACANTHOMORPHITAE

Micrhystridium fragile
Baltisphaeridium sp. 2 sp. nov.

Subgroup HERKOMORPHITAE

Cymatiosphaera radiata

Subgroup Uncertain

Paleostomocystis sp. 1 sp. nov.

Class CHLOROPHYCEAE

Family Uncertain

Palambages deflandrei
Palambages Forma A

Class DINOPHYCEAE

Family HYSTRICHOSPHAERIDIACEAE

Hystrichosphaeridium patulum
Hystrichosphaeridium tubiferum
Hystrichosphaeridium sp. 3 sp. nov.
Polysphaeridium sp. 1 sp. nov.
Polysphaeridium sp. 2 sp. nov.
Cordosphaeridium inodes
Cordosphaeridium fibrospinosum
Tanyosphaeridium sp. 1 sp. nov.
Oligosphaeridium complex
Systematophora sp. 1 sp. nov.
Forma A sp. 1 Gen. et sp. nov.
Forma A sp. 2 Gen. et sp. nov.
Forma A sp. 3 Gen. et sp. nov.
Forma F sp. 1 Gen. et sp. nov.
Cleistosphaeridium sp. 1 sp. nov.

Family HYSTRICHOSPHAERACEAE

Achomosphaera ramulifera
Hystrichosphaera ramosa var. 1
Hystrichosphaera ramosa

Family AREOLIGERACEA

Cyclonephelium sp. 1 sp. nov.
Cyclonephelium sp. 2 sp. nov.
Cyclonephelium sp. 3 sp. nov.
 Forma B sp. 1 Gen. et sp. nov.
Areoligera senonensis
Areoligera sp. 2 sp. nov.
Areoligera sp. 1 sp. nov.

Family GYMNODINIACEAE

Gymnodinium nelsonense
Gymnodinium westralium
Gymnodinium sp. 1 sp. nov.
Diconodinium sp. 1 sp. nov.

Family GONYAULACACEAE

Gonyaulax sp. 1 sp. nov.

Family DEFLANDRACEAE

Deflandrea cooksoni
Deflandrea magnifica
Deflandrea microgranulata
Deflandrea pannucea
 ? Deflandrea sp. 1 sp. nov.
Svalbardella lilidae

Family Uncertain

Palaeohystrichophora sp. 1 sp. nov.
Spinidinium cf. densispinatum

Zonation and Correlations

Zonation of the Austin Section

Eighty-one species of dinoflagellates and acritarchs have been recognized in rocks of the Navarro group in the Austin section in this study. The vertical distributions of 68 selected species are recorded on the range chart (Fig. 4). The Neylandville and Corsicana Formations contain a number of species which, based on data presented here, appear to have restricted ranges, whereas the Kemp Formation contains many species that are common to the Corsicana and Neylandville Formations as well. The Kemp has few if any restricted forms. There are 14 species that continue from the Neylandville through the Corsicana and Kemp Formations, and several of these have known occurrences in the Tertiary rocks from other areas. The dinoflagellate - acritarch Zones are based on the qualitative nature of the assemblages. The characteristics of the Zones are discussed below.

Zone A--Zone A includes the Neylandville Formation in the sampled area. There are a total of 40 species recognized here in the Neylandville Formation, 18 of which are also common to the Corsicana and Kemp Formations here. The top of Zone A is marked by the uppermost (youngest) occurrence of 18 species. Seven of these 18 species whose range here terminates at the top of Zone A (Odontochitina striatoperforata, Heliodinium cf. voigti, Callaiosphaeridium

FIG. 4 VERTICAL DISTRIBUTION OF SOME DINOFLAGELLATE AND ACRITARCH SPECIES NEAR AUSTIN, TEXAS.

asymmetricum, Deflandrea verrucosa, Cannosphaeropsis fenestrata, Gymnodinium digitus, Deflandrea acuminata) were described in earlier literature from older rocks in other areas. None of these seven or Paleohystrichophora infusorioides, which occur in the lower part of Zone A here, have been previously recorded from rocks as young as the Maestrichtian.

Although the Zone is rather rich in species, the number of individuals found in all, except a few species, is low in abundance. Gymnodinium digitum, G. nelsonense and Heliodinium sp. when present in a sample, usually occur in great abundance. The Zone is characterized in part by the abundance of these three species. The following species are considered good indicators of Zone A, whether they are found singly or in combination: Heliodinium sp., Forma C sp. 1, Odontochitina striatoperforata, Deflandrea sp. 6, Cannosphaeropsis fenestrata, Deflandrea acuminata. The division between Zone A and Zone B should prove to be of time stratigraphic significance on a regional as well as local basis. The sharp contrast in the dinoflagellate assemblage between the Zones is probably indicative of an unconformity at the top of the Neylandville Formation, and the difference is not interpreted as facies controlled.

Zone B--Zone B is characterized by a great diversity and abundance of species. The bottom of the Zone is marked

by the upper range of several forms described here from Zone A. The bottom of Zone B is also marked by the occurrence of 24 new forms, which are also indicated in Fig. 4. The top of the Zone is marked by the youngest occurrence of several species (see Fig. 4). The species *Forma B* sp. 1, *Forma A* sp. 1, *Forma A* sp. 3, *Diconodinium* sp. 1, *Cordosphaeridium fibrospinosum* and *Tanyosphaeridium* sp. 1 usually occur in abundance in samples throughout the Zone.

Zone C--The bottom of Zone C is marked by the highest occurrence of several species (see Fig. 4). The top of the Zone is not defined in the Austin composite section as the section was not sampled higher than the top of the Kemp Formation in this area. The youngest occurrence of species first appearing here is not known and many of the forms previously described in the literature and found here, are known to occur in younger sediments. There are a few species which appear to be markers for the upper part of the Zone, though, again their uppermost range is not determined here. These species are *Cyclonephelium divaricatum*, *Baltisphaeridium* sp. 3 and *Gymnodinium westralium*.

Correlation of the Navarro Group, Austin and Frio Sections

Figures 6-11 show relative abundance percentages of selected dinoflagellate species used to correlate the two sections studied. Figure 12, a composite of this information,

shows 6 horizons which can be identified in both sections; five horizons are based on positions of maximum occurrence of different species and one horizon represents the uppermost occurrence of the genus Palaeohystrichophora.

The upper limit of range of Palaeohystrichophora is taken as the horizon at the top of a zone which occurs near the base of the sections. Palaeohystrichophora sp. 1 sp. nov., is very abundant in the lowermost samples of the Frio section, and is not found above the 4254 foot depth in that well (Fig. 5). Palaeohystrichophora infusorioides was recorded on the basis of a few specimens from the top of the Neylandville Formation in the Austin section and did not occur in younger strata there.

Three horizons are defined which divide the Corsicana Formation into two zones in the Austin composite section and the same horizons are present in equivalent positions in the Frio County section. The base of the Corsicana is marked by a high occurrence of Cyclonephelium sp. 1 sp. nov., where it represents 60 percent of the dinoflagellate assemblage (Fig. 6). This high abundance is reflected in samples from the Olmos Formation, Frio County. The next horizon differentiated is represented by the maximum abundance of Forma A sp. 1 (Fig. 7), which is also observed in samples from the Olmos Formation. A third horizon is differentiated near the top of the Corsicana Formation and in

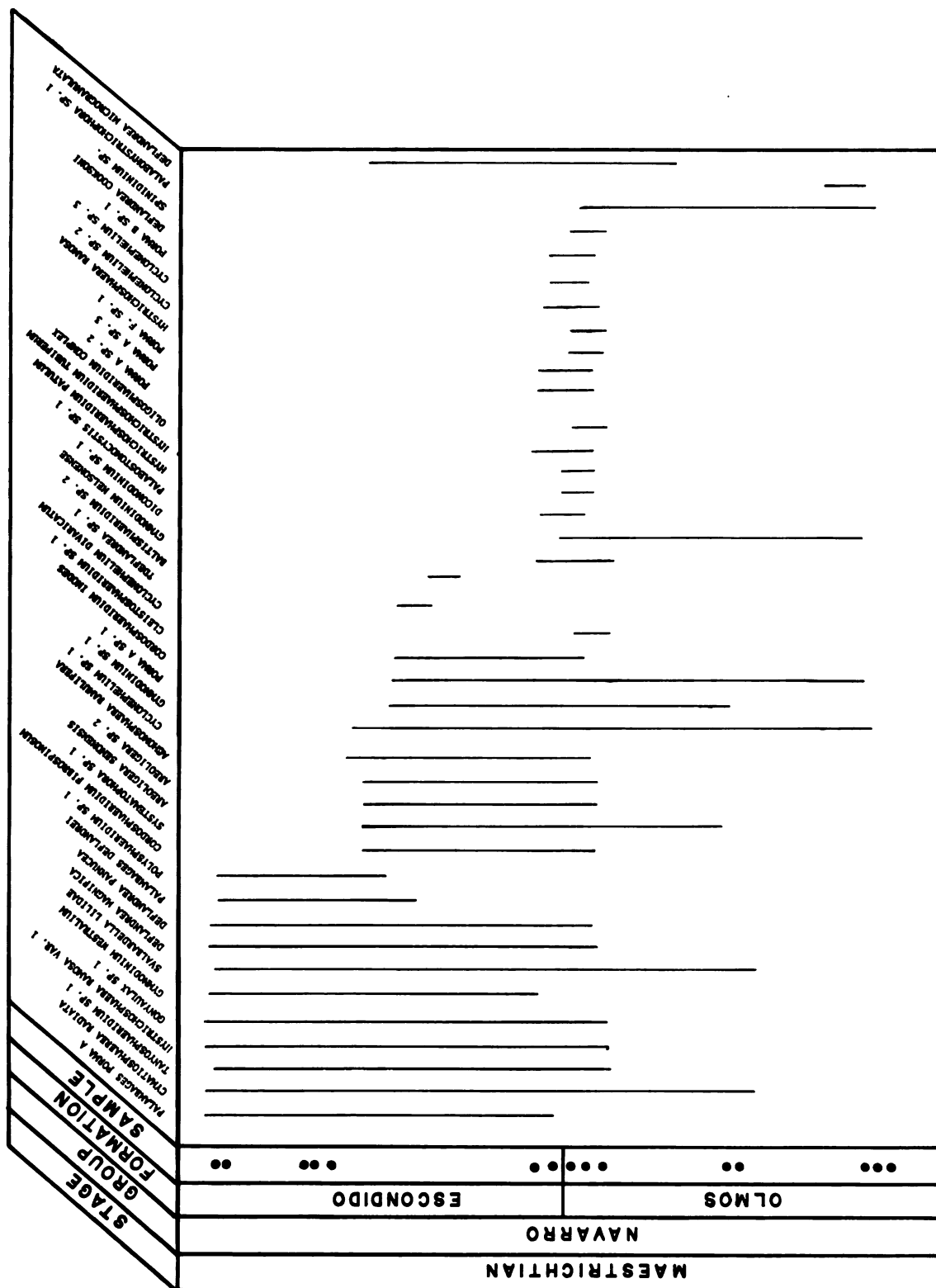


FIG. 5 VERTICAL DISTRIBUTION OF SOME DINOFLAGELLATE AND ACRITARCH SPECIES, FRIO COUNTY, TEXAS.

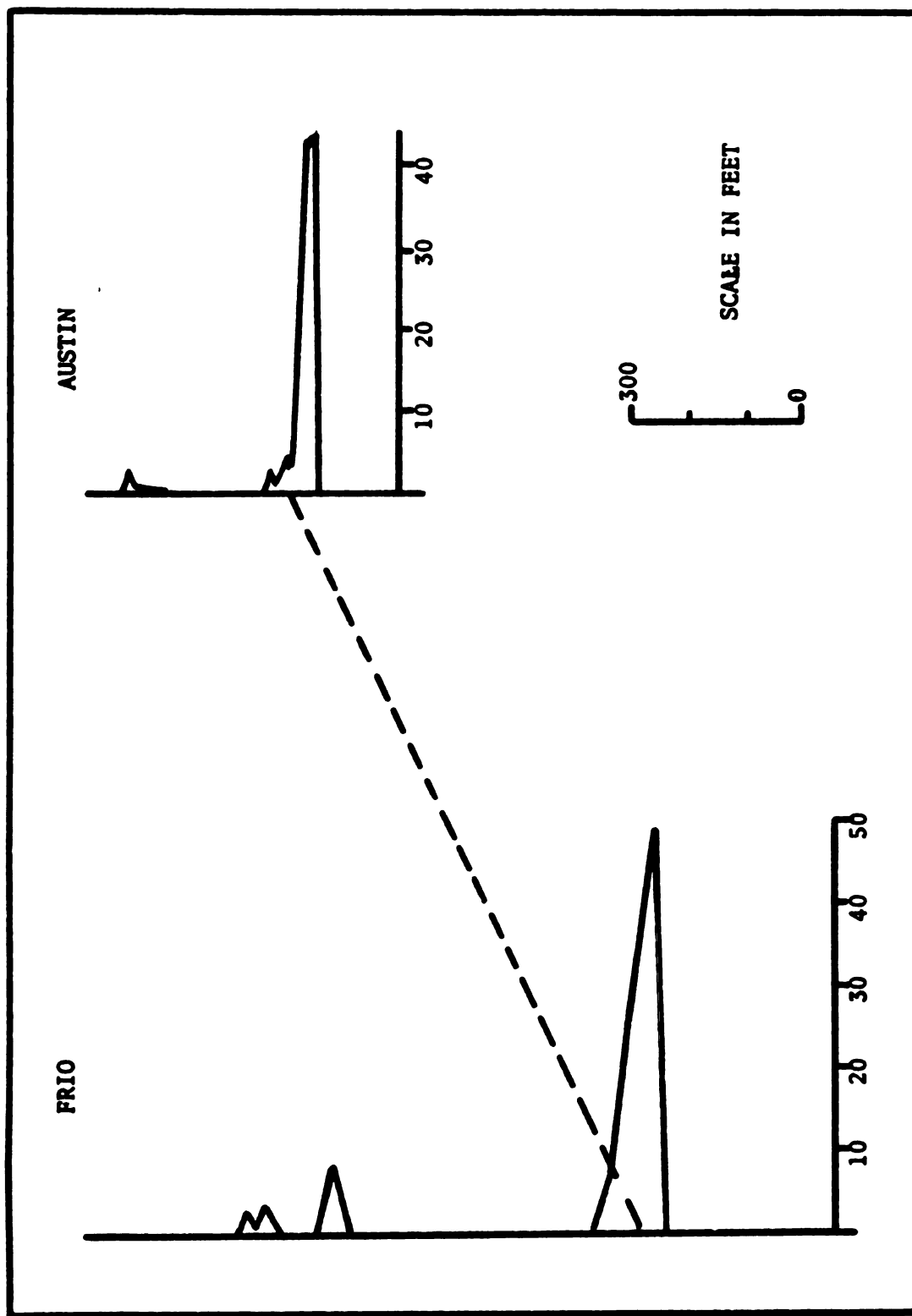


FIGURE 6. RELATIVE ABUNDANCE OF *CYCLONEPHELIUM* SP. 1 SHOWN AS PERCENTAGE OF MICROPLANKTON SUM IN THE AUSTIN AND FRIO SECTIONS. LINES INDICATE CORRELATIONS.

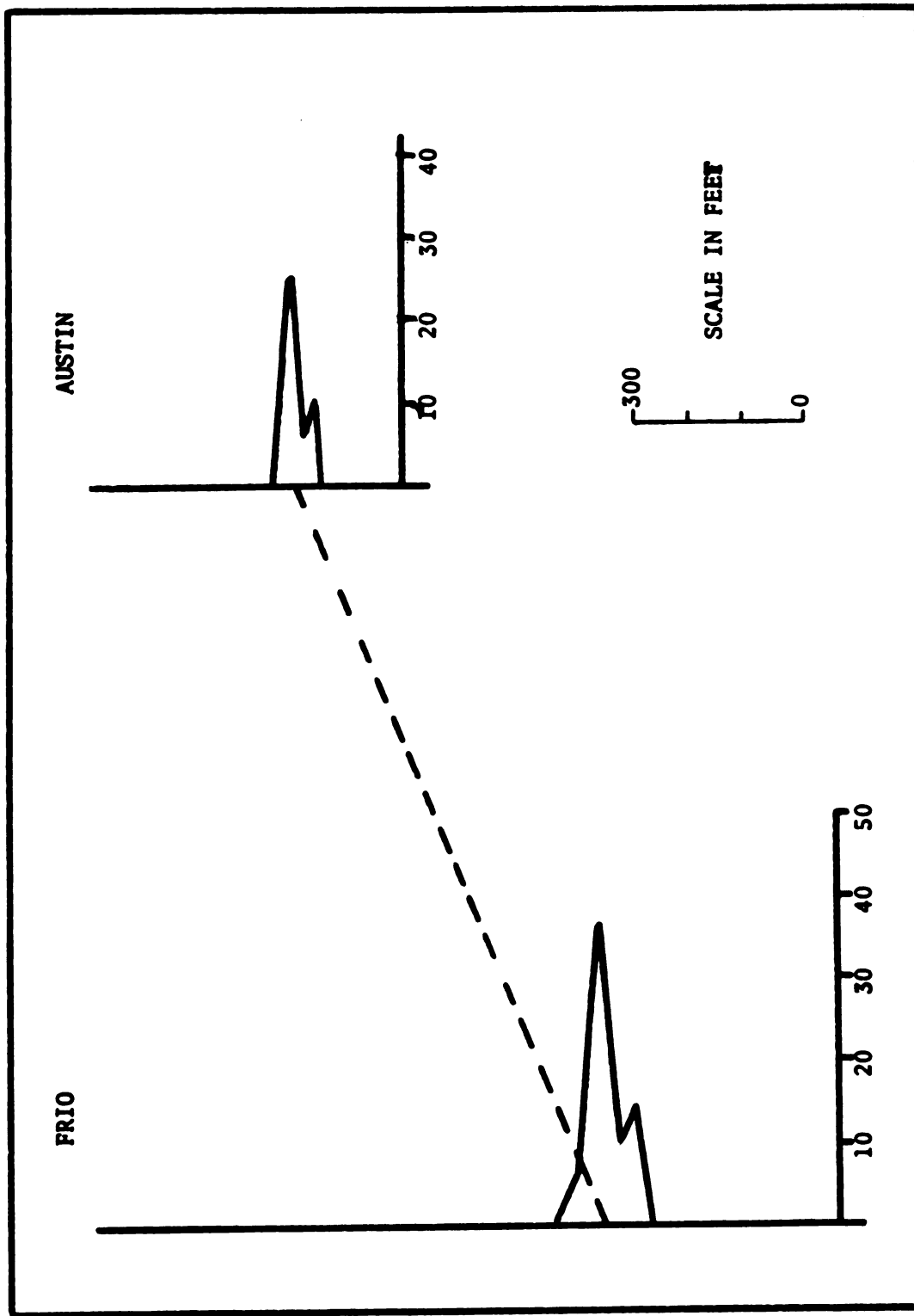


FIGURE 7. RELATIVE ABUNDANCE OF FORM A SP. 1 SHOWN AS PERCENTAGE OF MICROPLANKTON SUM IN THE AUSTIN AND FRIO SECTIONS. LINES INDICATE CORRELATIONS.

samples from the Olmos Formation. This horizon is indicated by maximum occurrence of *Forma B. sp. 1* (Fig. 8).

The Kemp Formation in the Austin section is marked by two horizons that can also be identified in the Escondido Formation in Frio County. The lower, is represented by a maximum occurrence of *Deflandrea magnifica* (Fig. 9) and is associated with high occurrence of *Svalbardella lilidae* (Fig. 10). Samples near the top of the Kemp and Escondido Formations contain a high abundance of *Hystrichosphaera* cf. *furcata* (Fig. 11) which is here taken to represent a correlative horizon.

These proposed correlations based on positions of maximum occurrence of single species are considered valid within the Navarro Group and are reliable horizon indicators on a local or regional scope.

In establishing these horizons, floods of occurrence of a single species can be used as a criterion for their recognition and particularly where occurrences are repetitive in a vertical sequence, trends of the microplankton spectra should be matched, and the associated species considered.

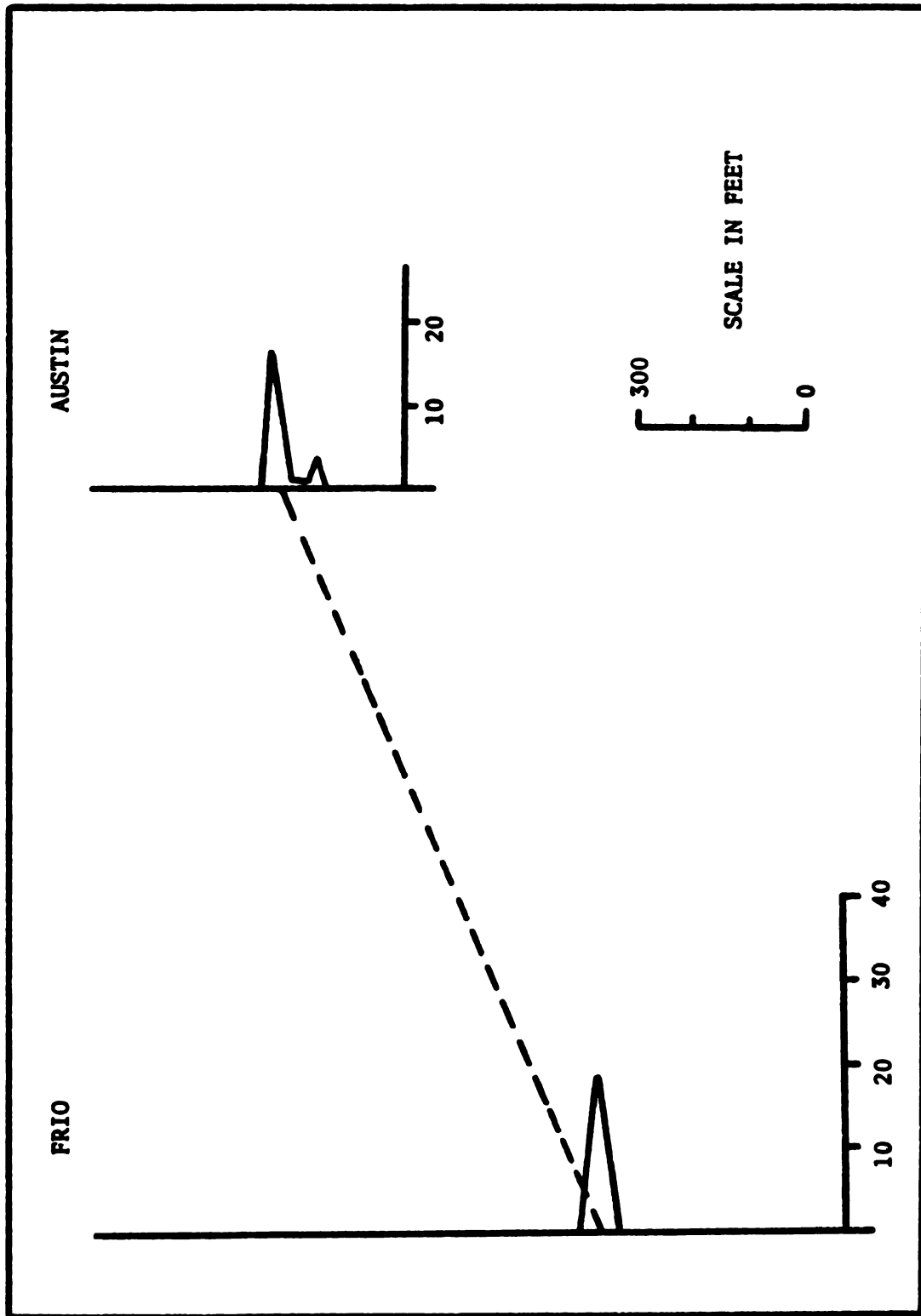


FIGURE 8. RELATIVE ABUNDANCE OF FORM B SP. 1 SHOWN AS PERCENTAGE OF MICROPLANKTON SUM IN THE AUSTIN AND FRIO SECTIONS. LINE INDICATES CORRELATIONS.

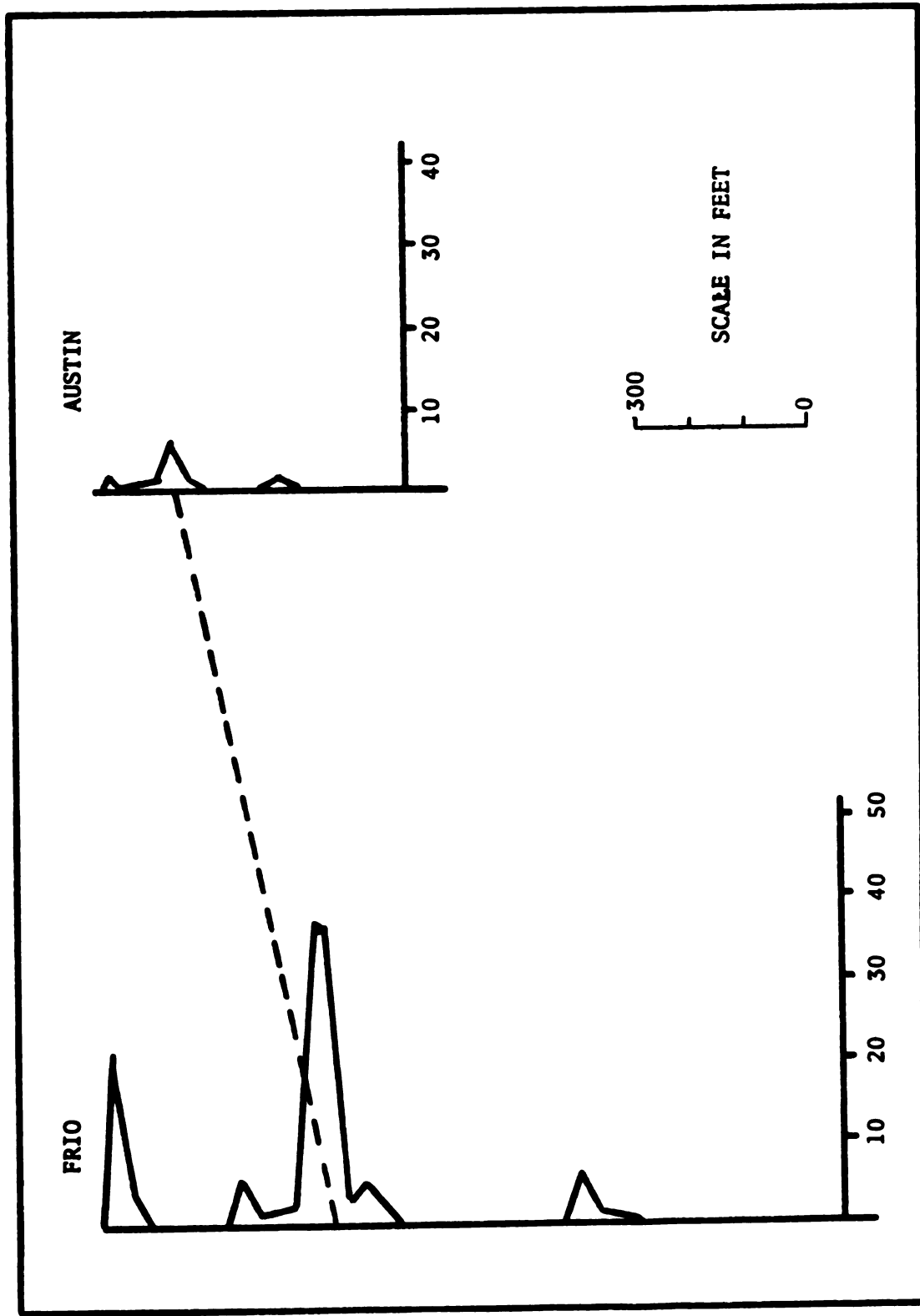


FIGURE 9. RELATIVE ABUNDANCE OF *DEILANDREA MAGNIFICA* SHOWN AS PERCENTAGE OF MICROPLANKTON SUM IN THE AUSTIN AND FRIO SECTIONS. LINE INDICATES CORRELATIONS.

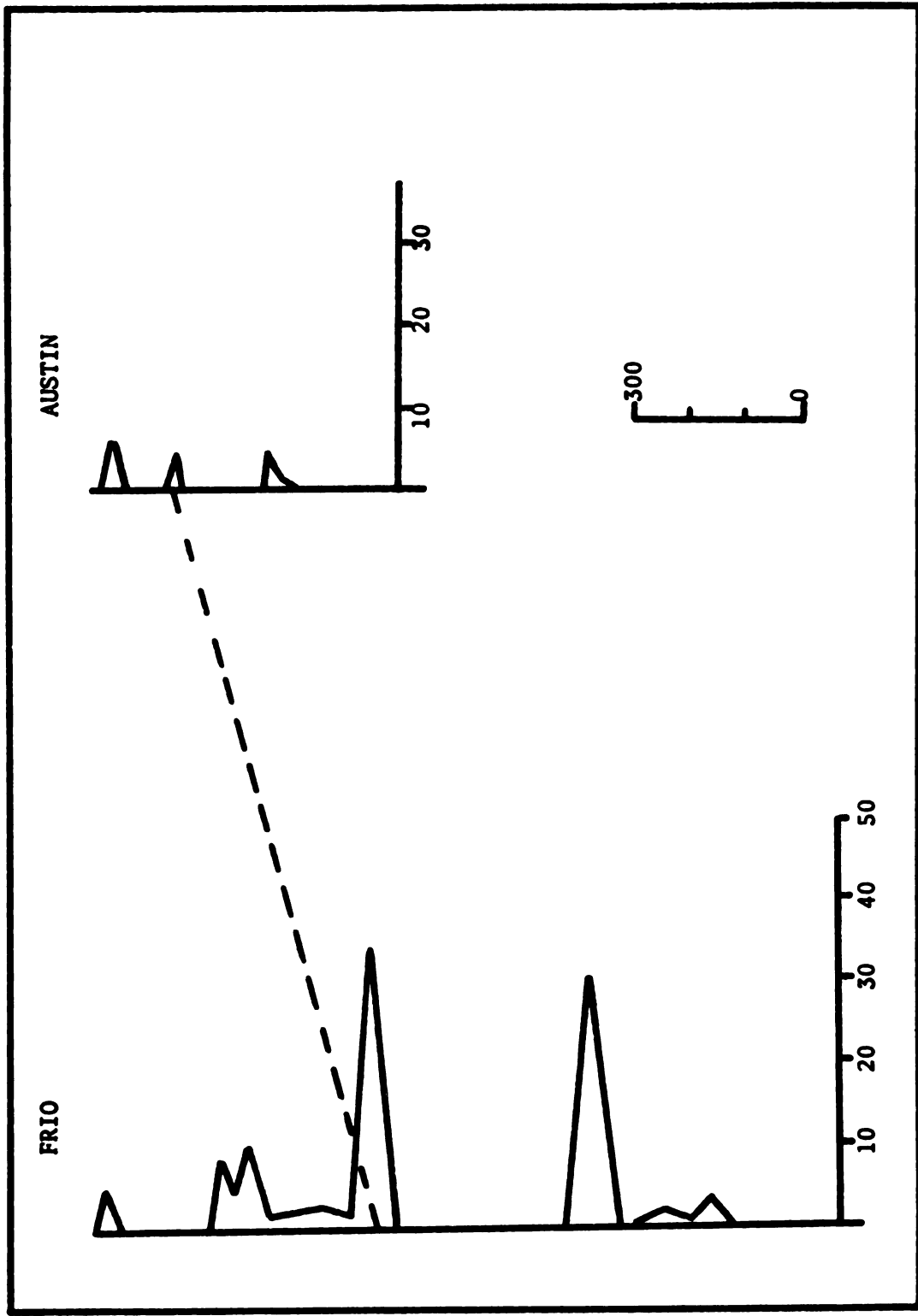


FIGURE 10. RELATIVE ABUNDANCE OF *SVALBARDELLA LIDIAE* SHOWN AS PERCENTAGE OF MICROPLANKTON SUM IN THE AUSTIN AND FRIO SECTIONS. LINE INDICATES CORRELATIONS.

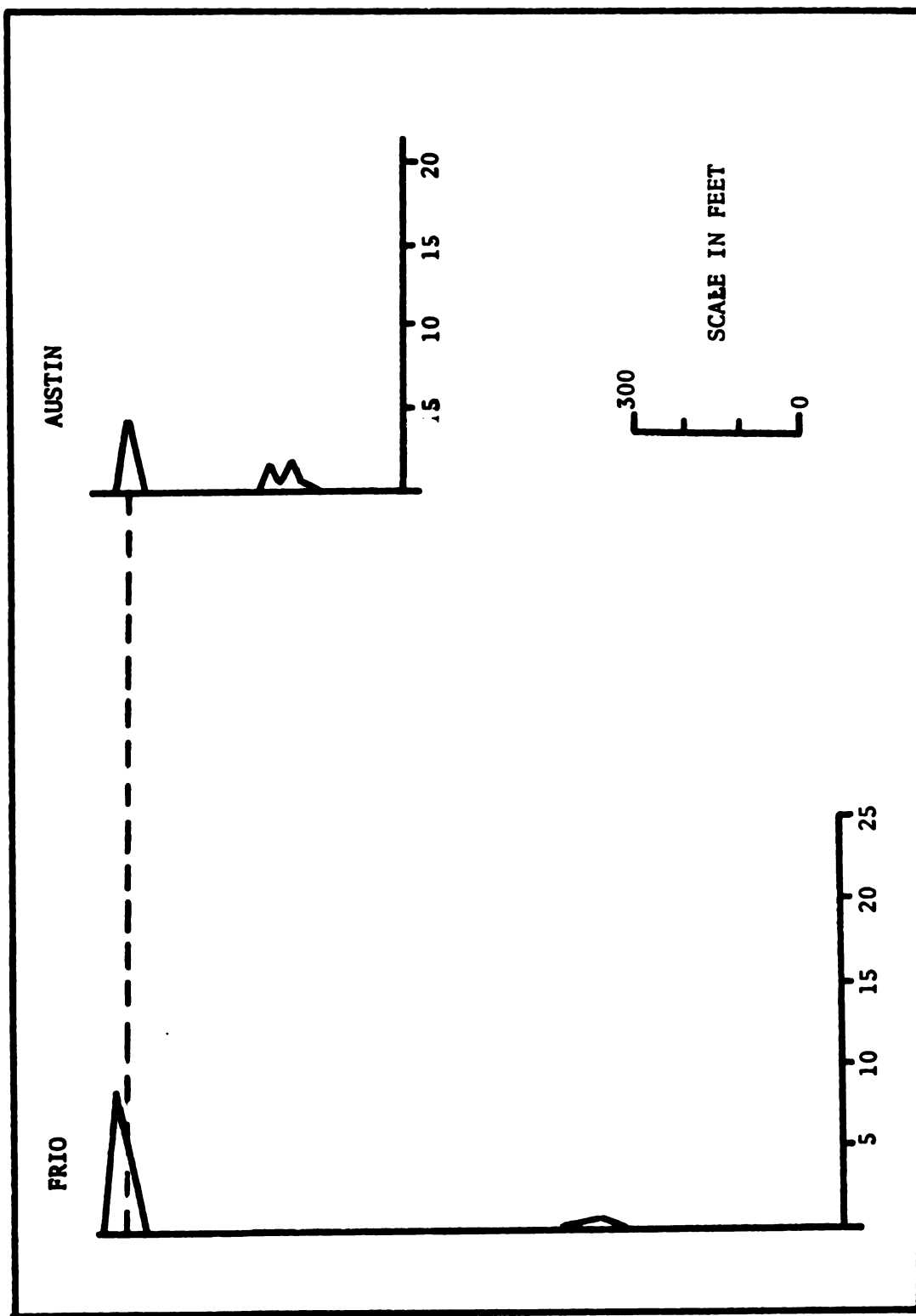


FIGURE 11. RELATIVE ABUNDANCE OF HYSTRICHOSSPHAERA RAMOSA VAR. 1 SHOWN AS PERCENTAGE OF MICROPLANKTON IN THE AUSTIN AND FRIO SECTIONS. LINE INDICATES CORRELATIONS.

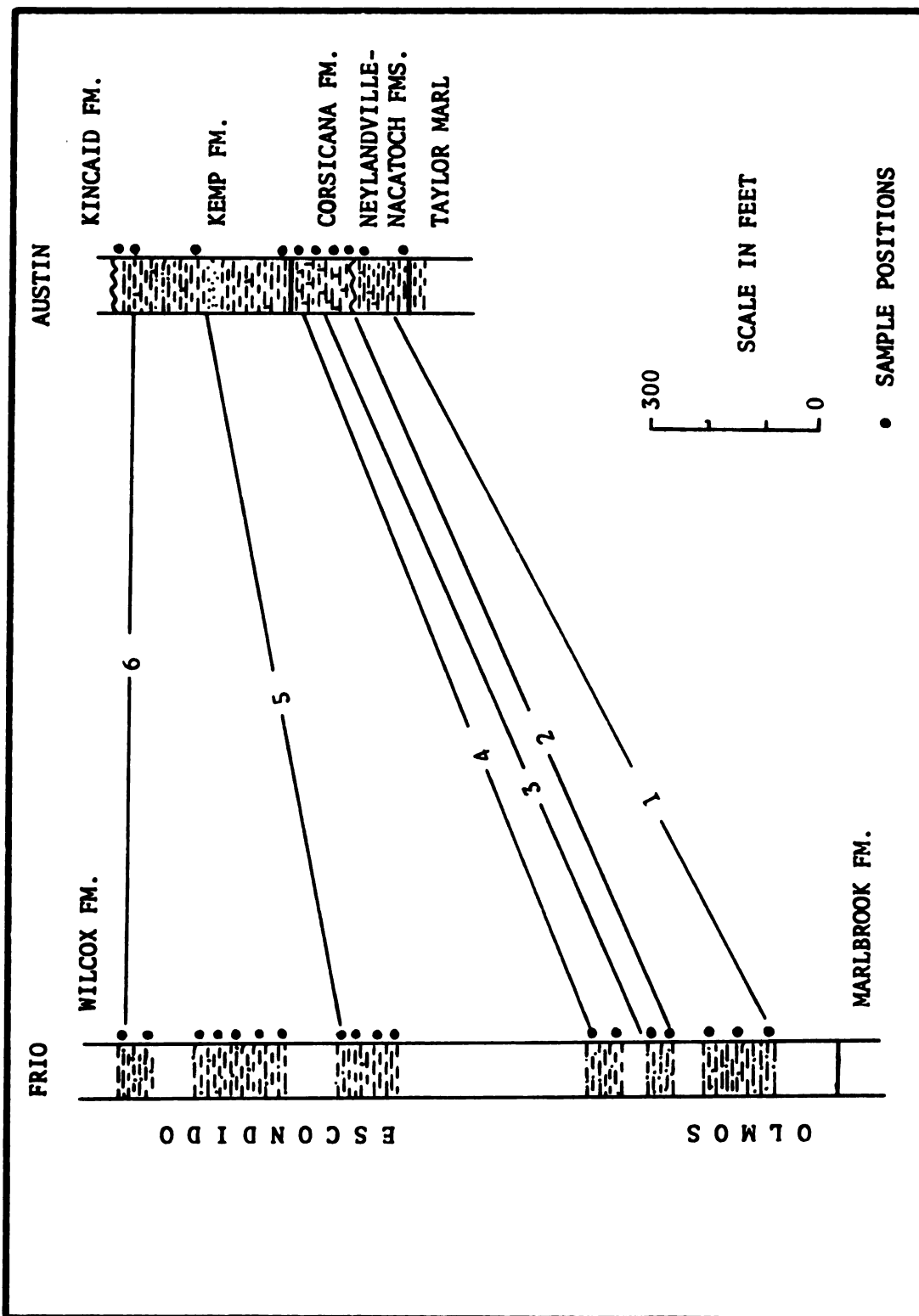


FIGURE 12. CORRELATIVE HORIZONS IN FRIO AND AUSTIN SECTIONS. (1) PALAEOHYSTRICOPHORA
 (2) CYCLONEPHELIUM SP. 1 (3) FORMA A SP. 1 (4) FORMA B SP. 1 (5) DEFLANDREA MAGNIFICA
 (6) HYSTRICOPHAERA RAMOSA VAR. 1.

Dinoflagellate - Acritarch Comparisons
with Other Areas

The lithologic dissimilarities of the Austin and Frio sections seem to imply dissimilar environments of deposition, though the comparison of overall dinoflagellate and acritarch assemblage characteristics from both sections shows extensive similarity. There are 81 species recorded from the Austin section. Of the 43 planktonic palynomorphs in the Frio section, 41 are common among the 81 in the Austin section. Two species, Spinidinium cf. densispinatum and Paleohystrichophora sp. 1 sp. nov. are recorded only from the Frio section. The Austin assemblage is more diverse in species, and the species are represented by larger numbers of individuals. The similarity of the assemblage of the Frio section to the assemblage in the Austin section, i.e., with 41 of the 43 dinoflagellate and acritarchs of the Frio section present in the Austin section, is striking when it is recognized that the two sections are approximately 160 miles apart.

In the Austin section, the limited vertical range and the assemblage composition of the palynomorphs allows differentiation of at least three zones. Zone A appears to support the previous paleontological interpretation, based on foraminifera, that the foram assemblage in the Neylandville Formation is dissimilar to the foram assemblages present in the other formations of the Navarro Group.

Frizzel (1954) states that the Neylandville foraminiferal assemblage shows 41 species in common with the Taylor marl, and the Navarro Group; and 38 additional species in common with the Taylor marl alone; 9 species are found in common with the other formations of the Navarro, and 2 species are restricted to the Neylandville Formation.

Although analysis of the microplankton of the Taylor marl was beyond the scope of this study, there are several species that have previously been described from other areas which occur in the Neylandville in the Austin section, whose ranges do not extend above the Neylandville Formation, and are recorded from rocks of the same and older ages from other areas. One of these species is Odontochitina striatoperforata, which is reported from the Upper Albian to Cenomanian of Australia. This species is also reported from the Cretaceous deposits of Graham Island, Arctic Canada. A form similar to the Navarro specimens referable to O. striatoperforata was figured by Evitt (1961, pl. 6, figs. 15-16) from a West Pakistan Senonian deposit. Deflandrea acuminata has been previously reported from Cenomanian to Lower Turonian deposits of Australia. Cannosphaeropsis fenestrata has been described from the Cenomanian, Senonian, Aptian and Albian rocks of Australia. Palaeohystrichophora infusorioides has been reported from Cenomanian to lower Turonian of Australia. Callaiosphaeridium cf. asymmetricum

was described from the Senonian of France; Cenomanian of Britain; and the Hauterivian and lower and middle Barremian of Yorkshire.

A study of the Neylandville microplankton shows there is possibly closer relationship of the Zone B assemblage to the Taylor than to the Navarro. There are a total of 22 species, the ranges of which appear to not extend above the Neylandville rocks and, as indicated above, occur in rocks of equivalent or older ages elsewhere.

In comparing the Navarro dinoflagellate assemblage with other North American material, the Navarro assemblage, primarily of the Corsicana, Kemp, Escondido and Olmos Formations, appears to most closely compare with that of the Red Bank (Maestrichtian) of New Jersey. Although there is no published taxonomic work on the Red Bank Formation, except for a few species illustrated by Evitt (1961), I had the opportunity to examine some of the material from that formation in Dr. Evitt's laboratory and make a few comparisons. Preliminary analysis indicates that there are several species which are probably conspecific with those in the Red Bank formation. Forms in the Navarro which are also found in the Red Bank are: *Forma A* sp. 1 sp. nov., *Deflandrea cooksoni*, *Areoligera senonensis*, *Deflandrea* sp. 3 sp. nov., *Gonyaulax* sp. 1 sp. nov., *Tanyosphaeridium* sp. 1 sp. nov., *Polysphaeridium* sp. 1 sp. nov., *Baltisphaeridium* sp. 2 sp. nov., and *Cyclonephelium* sp. 1 sp. nov.

Stanley (1965) described a very late Cretaceous and Paleocene pollenspore and dinoflagellate assemblage from South Dakota, and illustrated several species which are closely related to the Navarro forms. Navarro taxa common to those described and illustrated in this work are: Deflandrea microgranulata, Deflandrea magnifica, Deflandrea pannucea, Diphyes cf. colligerum, Hystriosphæridium tubiferum, Cordosphaeridium inodes, and Spinidinium cf. densispinatum. These species all occur in the Cannonball member (Paleocene) according to Stanley. Drugg (1967) in his work on the Upper Moreno Formation of California, illustrates a few species that are in common with the Navarro forms. These are: Spinidinium densispinatum, Micrhystridium fragile, and Deflandrea magnifica. He illustrates specimens: pl. 1, figs. 4-5, which he refers to Gymnodinium nelsonense, which appear to be quite close to Gymnodinium sp. 2 sp. nov. described here. In the opinion of the author, Drugg's specimens do not appear to be close to the type species described and illustrated by Cookson (1956).

Paleoecologic Interpretations

As stated previously, the lithologic dissimilarities of the two sections studied indicates different environments of deposition. The Frio County section consists dominantly of dark gray, slightly calcareous arenaceous shales interbedded with sand sequences. Most of the samples made

available for the study also contained abundant plant debris visible to the naked eye. Lithologically, the Austin section consists primarily of a medium-gray, fine-grained, calcareous clay-shale.

In the Austin composite section of the Navarro, the proportion of pollen and spores varies vertically in the strata comprising the group. Several workers have postulated that there is a correlation between number (absolute frequency) of pollen and spores in a sample and the distance from shore. Upshaw (1964) suggests that the determination of abundance ratios between microplanktonic organisms and entities of terrestrial origin would provide a qualitative means of estimating the relative distance from shore of sedimentary samples. Using this ratio he was able to define marine and non-marine zones in the Frontier Formation of Wyoming.

A study of this type of ratio in the Austin section (Fig. 13) indicates that there are successive variations of this ratio upward through the Navarro. These are here interpreted as indicating relative distance from shore, or possibly water depth, thus suggesting transgressive and regressive phases of the Navarro Sea in this area. These various marine conditions are indicated in Fig. 13.

The lower portion of the Corsicana is considered to be deeper marine or farther off-shore than any sections of the Neylandville-Nacatoch or Kemp Formations. The highest

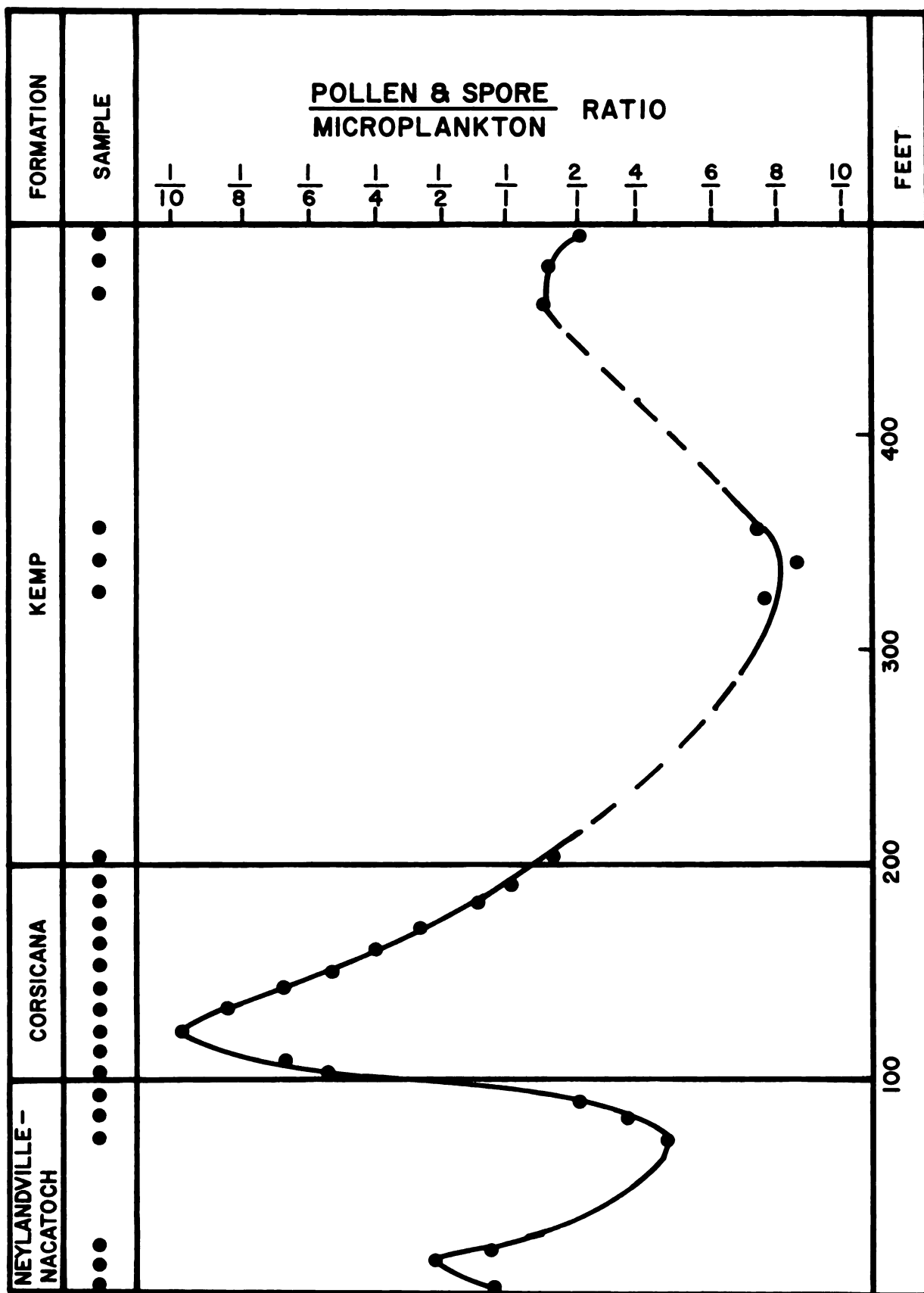


FIG. 13

pollen-spore/microplankton ratio occurs in the middle portions of the Neylandville and Kemp Formations, suggesting two regressions of the sea. The top of the Kemp and the top and bottom of the Neylandville-Nacatoch are marked by transgressions. There are several factors which may tend to invalidate such an interpretation, notably changes in prevailing winds and currents, differing amounts of water runoff contributing land derived material to the depositional basin, and the proximity of vegetation to the coast (Muller, 1959; Cross, Thompson and Zaitzeff, 1967, p. 520). Analysis of benthonic and planktonic foraminifera assemblages and planktonic/benthonic ratios in respect to determining relative water depth, closely correlates with the relative depth of water indicated by the pollen-spore/microplankton ratio (William N. Orr, personal communication).

Sections of the Austin and Frio sections are marked by floods or high occurrences of individual species that tend to dominate some samples. Whether or not these represent fossil dinoflagellate "blooms" would be speculative. Samples from the Neylandville Formation in the Austin area are dominated by the species Gymnodinium nelsonense and Gymnodinium digitus. The base of the Corsicana Formation and samples from the Olmos Formation in Frio County are marked by high occurrences of Cyclonephelium sp. 1 sp. nov. and Forma A sp. 1 sp. nov. The significance of these for correlative purposes has been discussed.

The occurrence of 41 species in common to both sections suggests that these forms were widespread geographically and existed in diverse environments of deposition.

PALEONTOLOGIC AND STRATIGRAPHIC CONCLUSIONS

Palynologic examination of the Navarro Group sediments from eastcentral and southwest Texas has revealed an abundant and varied dinoflagellate-acritarch assemblage. Analysis of the fossil assemblages indicates that some species have a restricted vertical distribution and the relative abundance of species varies vertically within the group at both localities. These characters aid in the zonation, correlation, and the interpretation of environment of deposition of the rocks.

Establishment of assemblages or types showing sequential variations in relative abundance is useful. The occurrence of unusually large numbers of particular species is considered to have time-stratigraphic significance and such occurrences can be used as horizon markers or point correlations. Five such horizons have been recognized here and are used as the basis for establishing five correlative horizons in the two sections.

Precise taxonomic interpretation of individual species is essential to this type of study and considerations of the effect of environment on the morphology of individual species as well as genetic factors, is requisite to good stratigraphic application or interpretation.

Comparisons of the Navarro assemblage with assemblages reported in other works indicate that the Corsicana, Kemp, Olmos, and Escondido Formations have a close affinity with the Red Bank Formation (Maestrichtian) of the New Jersey, whereas the Neylandville-Nacatoch Formations (undifferentiated) from the Austin composite section contains a quite dissimilar assemblage, and it appears to represent an older age than the other formations. Many of the genera and species of the Neylandville-Nacatoch are referable to Senonian and older rocks.

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APPENDICES

APPENDIX A

GLOSSARY OF DINOFLAGELLATE TERMINOLOGY¹ (Figs. 1-15)

ACRITARCH	Non-cellular organic microfossil of unknown affinity possessing a spherical, ellipsoidal, discoidal, fusiform or polygonal body that may or may not bear spines, septa, etc.
ANTAPEX	The area of the hypotract other than the post-equatorial fields, the ventral fields and the posterior intercalary field if present. If tabulation cannot be discerned, the antapex is defined as that part of the hypotract furthest from the girdle (Fig. 2b).
ANTAPICAL FIELDS	The field or fields making up the antapex on the hypotheca (Fig. 2b).
ANTAPICAL PLATES	The plates making up the antapex on the hypotheca (Fig. 1b).
ANTERIOR	Towards, or nearest to, the apex in dinoflagellates.
ANTERIOR INTER-CALARY FIELDS	Fields on the dorsal surface of the epitract that lie between the apical series and pre-equatorial series of fields (Fig. 2b).
ANTERIOR INTER-CALARY PLATES	Plates between the pre-equatorial plates and the apical plates (Fig. 1b).

¹This glossary, with only slight modification, has been prepared by Dr. Graham Williams, Pan American Petroleum Corporation Research Center, Tulsa, Oklahoma, and is used here with his permission.

APEX	The area of the epitract other than the pre-equatorial fields and the anterior intercalary fields when present. If tabulation is not discernable, the apex is defined as that area of epitract furthest from the girdle (Fig. 2b).
APICAL ARCHEOPYLE	An archeopyle resulting from the loss of one or more apical fields (Figs. 4, 12).
APICAL FIELDS	The fields making up the apex on the epitract (Fig. 2).
APICAL HORN	The pointed extension of the apex.
APICAL PLATES	The plates making up the apex on the epitheca (Fig. 1).
ARCHEOPYLE	An opening in a dinoflagellate cyst usually more or less polygonal, with shape and position related to the field pattern; occasionally rounded or apparently irregular (Figs. 2b, 3, 4, 5, 6).
BORDER	The line or zone along which adjacent fields meet or are inferred to meet in a dinoflagellate cyst (Fig. 5).
BORDER PROCESS	A process originating on a border (Fig. 5).
DINOFLAGELLATE CYST	The organic walled cyst, fossilized or not, of a dinoflagellate. It usually possesses a bilayered wall and is characterized by one or more of the following features: (1) cingulum, (2) archeopyle, (3) tabulation, (4) a peridinioid outline, (5) an apical horn.
DEXTRAL CINGULUM	When the right termination of the cingulum is nearer the apex than the left (Fig. 9).
CINGULUM	Equatorial zone separating the epitract from the hypotract (Fig. 2)
DORSAL	Side opposite the ventral side.
ENDOCOEL	The cavity enclosed by the endophragm (Fig. 3).

ENDOPHRAGM	The inner wall layer of a dinoflagellate cyst which possess two or more wall layers (Fig. 2a).
EPITHECA	The portion of the theca in a free living armored dinoflagellate which is anterior to the transverse furrow. It includes the apical, anterior intercalary (if present) and pre-equatorial plates (Fig. 1b).
EPITHEMA	The field or fields whose removal gives rise to the archeopyle. It can be partly attached to or completely detached from the margin of the archeopyle (Figs. 2b, 7).
EPITRACT	The portion of a dinoflagellate cyst anterior to the girdle, often characterized by an apical horn (Fig. 2a).
EPITRACTAL ARCHEOPYLE	An archeopyle formed by rupture immediately anterior to the cingulum. This results in the major part of the epitract becoming detached from the rest of the dinoflagellate cyst (Fig. 6).
EQUATORIAL ARCHEOPYLE	An archeopyle formed by breakage along and within the cingulum. This separates the main body into roughly equal halves.
FIELD	Fundamental area dividing the main body into series of distinct units, each field maintaining a consistent position and relation to the other fields (Fig. 2).
GONAL PROCESS	A process originating at the point of intersection of borders (Fig. 5).
HELICOID CINGULUM	When the girdle is either sinistral or dextral (Fig. 8, 9).
HYPOTHECA	The portion of the theca in a free living armored dinoflagellate which is posterior to the transverse furrow. It includes the post-equatorial posterior intercalary and antapical plates and most of the venter (Fig. 1b).

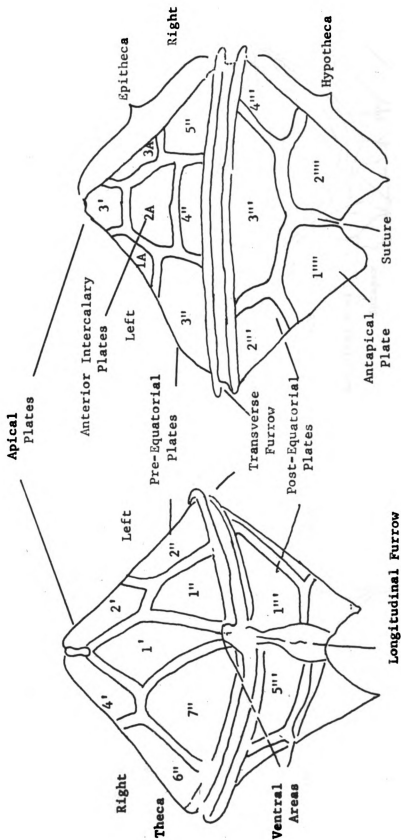
HYPOTRACT	The portion of a dinoflagellate cyst posterior to the cingulum, often characterized by one or more horns (Fig. 2b).
HYSTRICHOSPHERE	A general descriptive term for dinoflagellate cysts with a more or less spherical main body bearing several processes of one sort or another, that can be open, closed, hollow or solid.
INTERCALARY ARCHEOPYLE	An archeopyle resulting from the loss of one or more anterior intercalary fields (Figs 2b, 3).
INTRATABULAR PROCESS	A process originating from the area enclosed by the borders of an individual field (Fig. 4).
LEFT AND RIGHT	Left and right of a dinoflagellate cyst or free living stage is defined conventionally with the ventral side down and the anterior end directed forward.
LONGITUDINAL FURROW	In a free living dinoflagellate, the furrow posterior to the longitudinal flagellar pore (Fig. 1a).
MAIN BODY	The portion of a dinoflagellate cyst where the endophragm and periphragm are in contact. It excludes the processes of septa that are part of the periphragm.
MID-DORSAL LINE	In dinoflagellates an imaginary line which runs from the apex to the antapex on the ventral surface and divides the ventral surface into two usually more or less equal, areas (Fig. 11).
MID-VENTRAL LINE	In dinoflagellates an imaginary line which runs from the apex to the antapex on the ventral surface and divides the ventral surface into two, usually more or less equal areas (Fig. 12).
NON-TUBULAR PROCESS	A process whose position on the main body is apparently unrelated to tabulation.

PERICOEL	Cavity and cavities lying between the endophragm and periphragm (Fig. 3).
PERIPHHRAGM	The outer wall layer of a dinoflagellate cyst which possesses a bilayered wall (Fig. 2a).
PHRAGMA	The wall of a dinoflagellate cyst. It comprises the endophragm and periphragm (Fig. 4).
PLATE	Area of division of the theca in a free living form delineated by sutures (Fig.
PLATE OR FIELD FORMULA	Symbolic representation of tabulation using the following conventional abbreviations (Figs. 1, 2): ' apical " precingular ' " postcingular c cingulum " " antapical a anterior intercalary p posterior intercalary v ventral plates or fields.
POST-CINGULAR FIELDS	A series of fields on the hypotract that are adjacent to the cingulum (Fig. 2).
POST-CINGULAR PLATES	Row of plates closest to transverse furrow in hypotheca.
POSTERIOR	Towards, or nearest to, the anterior in dinoflagellates (Fig. 3).
POSTERIOR INTER-CALARY FIELDS	Fields or field on the ventral surface of the hypotract that lie between the post-cingular series and antapical fields (Fig. 15).
POSTERIOR INTER-CALARY PLATES	Plates between postcingular plates and antapical fields.
PRECINGULAR ARCHEOPYLE	An archeopyle resulting from the loss of one or more pre-equatorial fields (Fig. 5).
PRE-EQUATORIAL FIELDS	A series of fields on the epitract that are adjacent to the cingulum (Fig. 2).

PRE-EQUATORIAL PLATES	Row of plates closest to transverse furrow in epithema.
PROCESS COMPLEX	A distinctive arrangement of several intratabular processes, either free or united by alignment in various ways, e.g., the process complexes in <u>Areoligera</u> or <u>Systematophora</u> .
PYLOME	A regular opening in the wall of an acritarch.
SEPTUM	Raised or thickened portion of the periphragm along a border (Fig. 5).
SINISTRAL CINGULUM	When the left termination of the cingulum is nearer the apex than the right (Fig. 8).
SUTURE	The junction between adjacent plates in a free living dinoflagellate along which separation may occur (Fig. 1).
TABULATION	Number and arrangement of fields in a dinoflagellate cyst, or plates in a free living dinoflagellate (Figs. 1, 2).
TEST	The overall form assumed by the periphragm of a dinoflagellate cyst (Figs. 3, 13b).
THECA	The outer covering of cellulose or some closely related substance that encloses the cell in a free living dinoflagellate (Fig. 1a).
UNSPIRALED CINGULUM	When the left and right terminations of the girdle are not offset on the ventral surface (Fig. 10).
VENTER	In a dinoflagellate cyst, the area often depressed, lying between the left and right terminations of the cingulum and the first and last fields of the pre- and post-equatorial series. Bounded anteriorly by the apical fields, posteriorly by the antapical fields (Fig. 2a).

VENTRAL	Side of a dinoflagellate containing the longitudinal furrow or venter.
VENTRAL AREA	In a free living dinoflagellate, the depressed area lying between the left and right terminations of the transverse furrow and the first and last plates of the pre- and post-equatorial series. Bounded anteriorly by the apical plates, posteriorly by the antapical plates (Fig. 1a).
VENTRAL FIELDS	Fields occurring on the venter.
VENTRAL NOTCH	A commonly occurring notch on the margin of an apical archeopyle in line with the venter (Fig. 4).
VENTRAL TONGUE	A projection on the archeopyle margin representing the anterior part of the venter in forms with an epitrectal or equatorial archeopyle (Fig. 6).

FREE LIVING FORM PERIDINIUM SP.



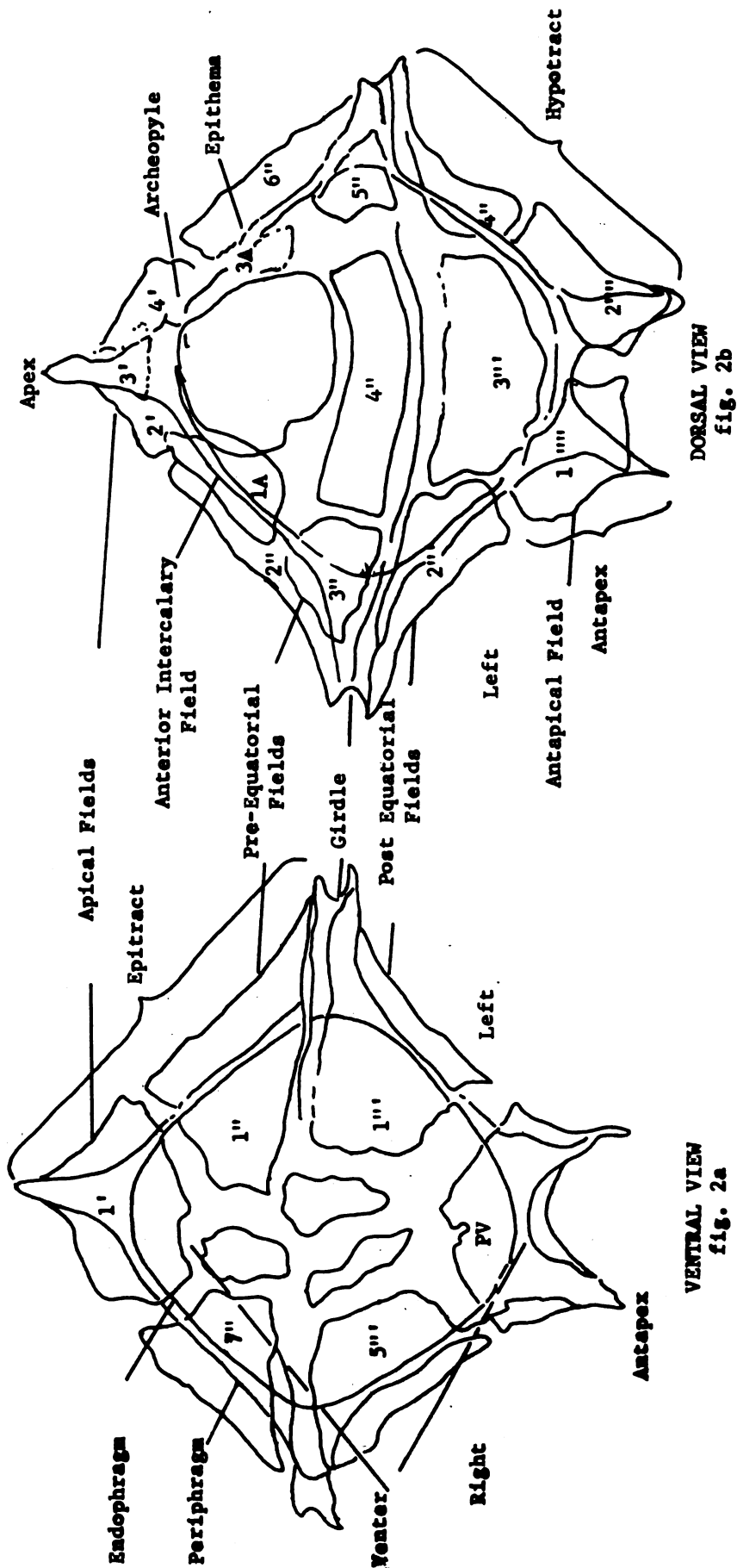
DORSAL VIEW

fig. 1b

VENTRAL VIEW

fig. 1a

DINOFLAGELLATE CYST. WETZELIELLA SP.



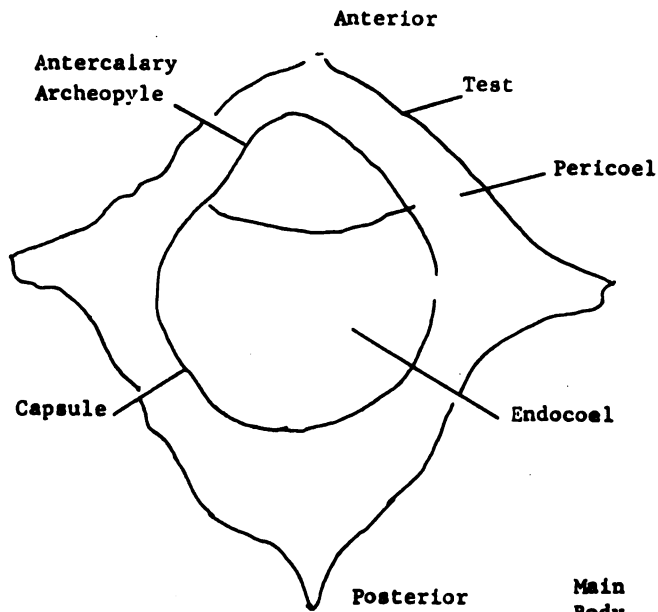
WETZELIELLA SP.

fig. 3

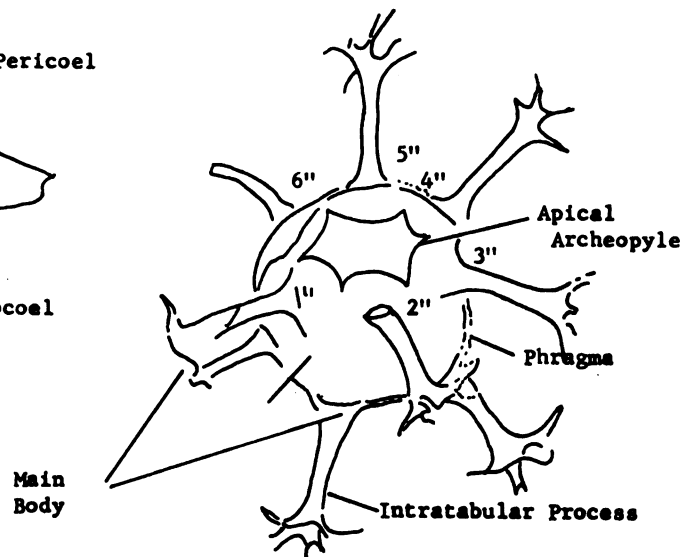
HYSTRICHOSPHAERIDIUM SP.

fig. 4

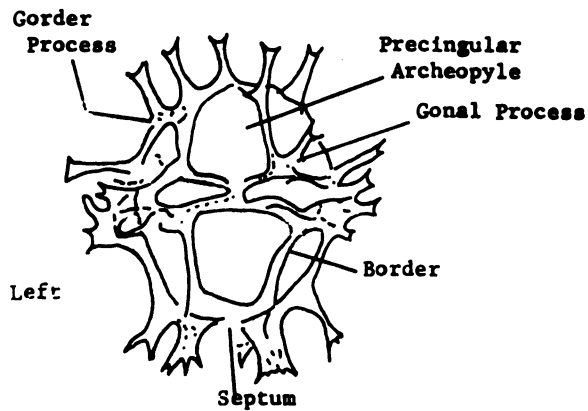
HYSTRICHOSPHAERA SP.

fig. 5

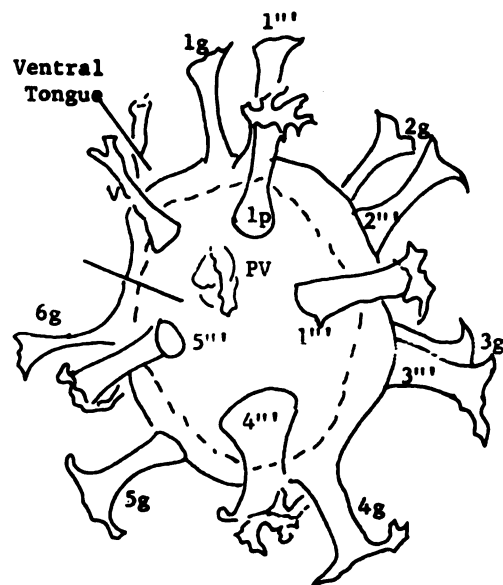
HOMOTRYBLIUM SP.

fig. 6

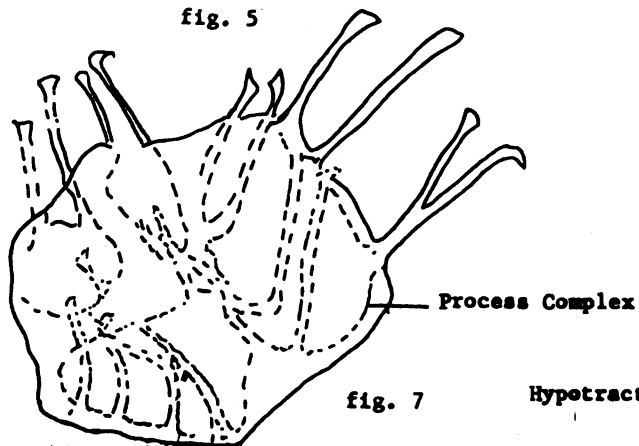


fig. 7

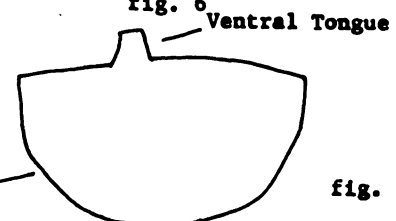
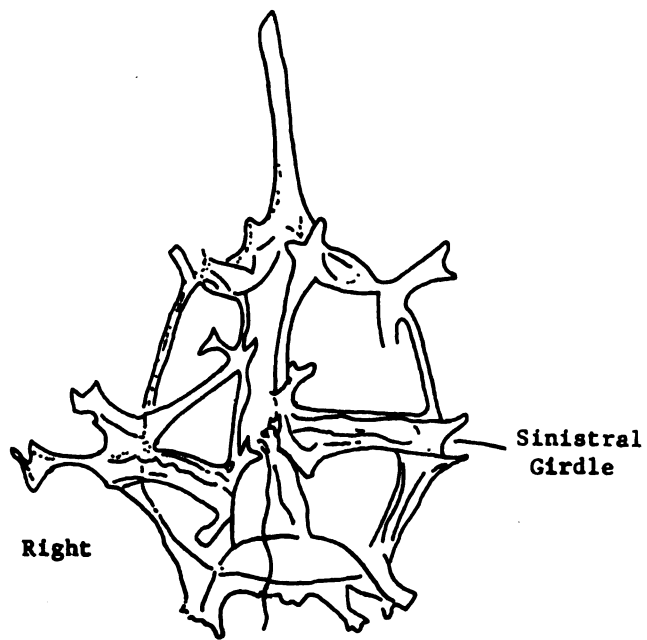
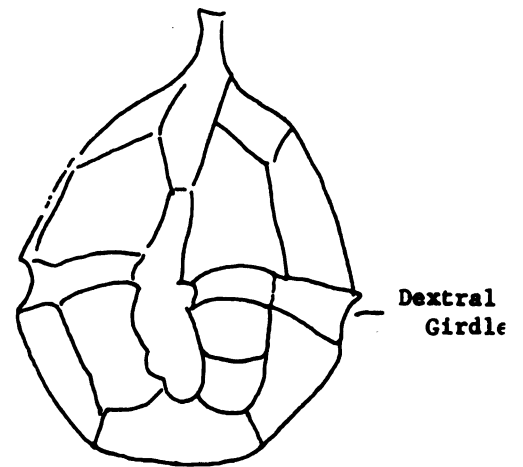


fig. 6b



HYSTRICHOSPHAERA SP.

fig. 8



HYPOTHETICAL DINO

fig. 9

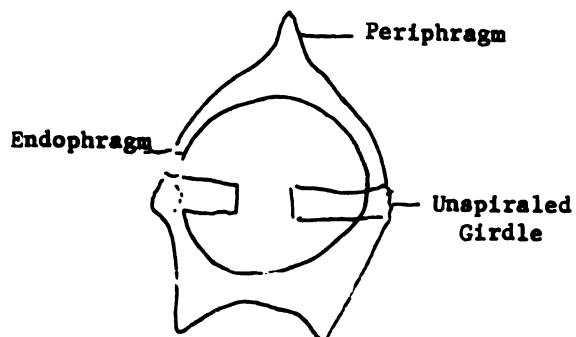


fig. 10

DEFLANDREA

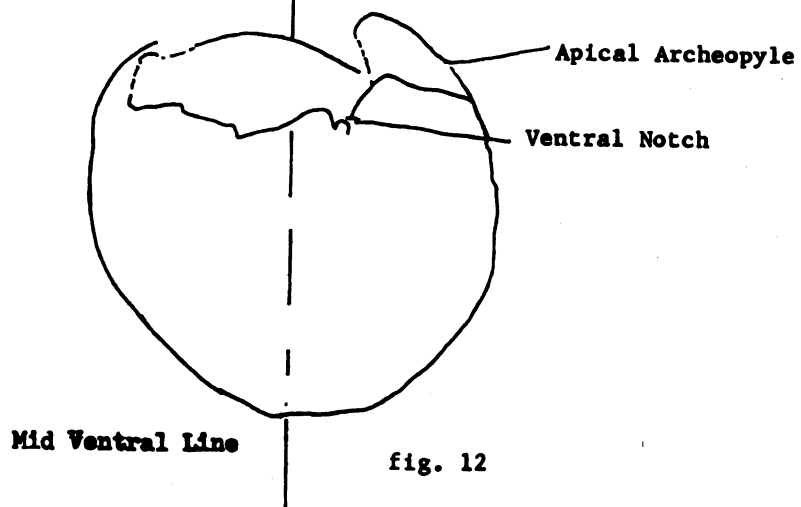


fig. 12

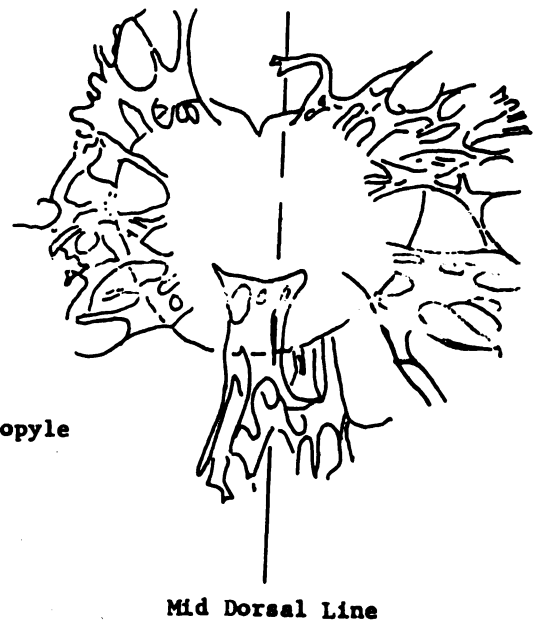


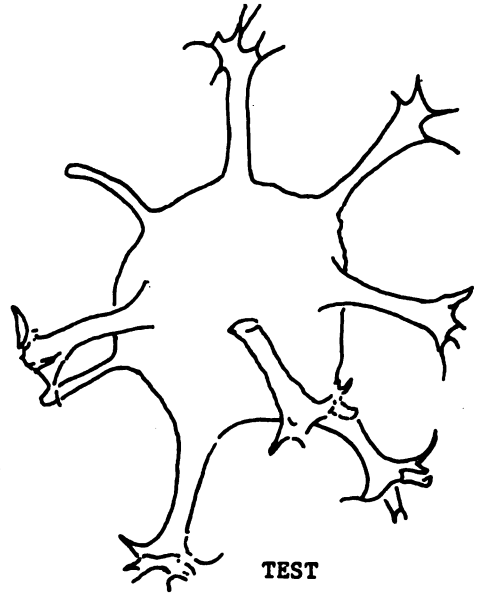
fig. 11



HYSTRICHOSPHEARIDIUM SP.

MAIN BODY

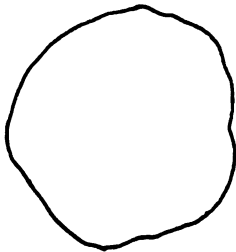
fig. 13a



TEST

HYSTRICHOSPHAERIDIUM SP.

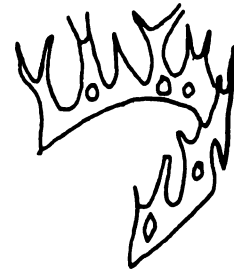
fig. 13b



CAPSULE

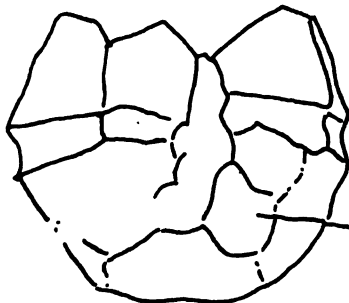
HYSTRICHOSPHAERIDIUM SP.

fig. 13c



PROCESS COMPLEX

fig. 14



Posterior
Intercalary
Field

fig. 15

APPENDIX B

SAMPLE LOCALITIES

Section in the Vicinity of Austin, Texas

Corsicana Formation

Travis County; Jones' Crossing Section. 1/4 mile downstream (east) from highway bridge (U.S. 71) over Onion Creek. Section begins at lowest exposed stratum in creek bed and extends eastward up steep, high, bluff. Kemp Formation present at top of section (bright yellow clay). Total thickness 90 feet.

Kemp Formation

Travis County; A.B. Beddow Ranch Section. Bluff of Colorado River about 1 mile due north of Garfield, Texas. Base of sections is about 50 feet above highest part of the Jones' Crossing section. Total section 40 feet.

Travis County; type locality of the Littig conglomerate, near Littig, Texas. Upper Kemp and Kincaid Formation collected from cut in west side of road leading south from Littig. Cut is 1.85 miles, by road, from railroad-crossing in Littig. Upper Kemp also collected in brick clay-pit on east side of road leading south from Littig. (Road leading into pit is 1.75 miles from railroad crossing in Littig.)

Neylandville Formation

Travis County; Gilleland Creek Section. Taylor marl-Neylandville Formation. Section measured on SW bank of Gilleland Creek 3.35 miles SSW of Manor on State Highway 973. Section begins in bank of creek 200 feet west of middle bridge (in three bridge sequence) and passes SW beside highway along NW side of road cut.

Frio County Section

Humble Oil and Refining Company, Frank Doering #1 well, located 13-1/2 miles NW of Dilley, Texas in Frio County. Top of the Navarro at 3050 feet. Bottom of the Navarro at 4370 feet. Total cored sequence 3102'-4272'.

PLATES

EXPLANATION OF PLATES

PLATE 1

- 1-4 Microhystridium fragile, 1 x500, 1a-4 x1250.
5-7 Microhystridium stellatum, x500.
8-8a Baltisphaeridium hirsutum, 8 x500, 8a x1250 showing striate wall.
9-11 Baltisphaeridium sp. 1 sp. nov., 9 holotype x500.

PLATE 2

- 1-2 Baltisphaeridium sp. 3 sp. nov., 1-1a holotype x500, 2-2a x500, 1b, 2b x1250.
3-4 Baltisphaeridium sp. 2 sp. nov., 4 holotype x500, 3 x500, 4a x1250.
5-9 Cymatiosphaera radiata, 5, 8, 9, x1250, 5a, 5b, 6, 7 x500.
10-12 Palambages Forma A, x500.

PLATE 3

- 1 Palambages deflandrei, x500.
2 Palambages Forma A, x500.
3-8 Palaeostomocystis sp. 1 sp. nov., 3 holotype x1250, 4-8 x1250.
9-12 Hystrichosphaeridium tubiferum, x500. Photographed by phase contrast.
12 Oligosphaeridium complex, x500.

PLATE 4

- 1-3 Hystrichosphaeridium tubiferum, x500. Photographed by phase contrast.
4-4a Hystrichosphaeridium stellatum, x500.
5-7 Cordosphaeridium nodes, x500. 5 shows precingular archeopyle.
8-10 Polysphaeridium sp. 2 sp. nov., 9 holotype x500, 8, 10 x500.

PLATE 5

- 1-3 Hystrichosphaeridium patulum, 1 x1250, 1a, 3 x500. Photographed by phase contrast.
4-4a Tanyosphaeridium sp. 1 sp. nov., 4-4a holotype, 4 x1250, 4a x500. Photographed by phase contrast.
6-7

- 5 Tanyosphaeridium sp. 2 sp. nov. holotype x500.
 Photographed by phase contrast.
- 8-10a Polysphaeridium sp. 3 sp. nov., 9 holotype x1250,
 10 x1250, 8, 10a x500. 9 and 10 enlarged to
 show flared processes tips with entire margins.
 Photographed by phase contrast.

PLATE 6

- 1 Polysphaeridium sp. 3 sp. nov. x500. Photographed
 by phase contrast.
- 2-7 Hystrichosphaeridium sp. 3 sp. nov. x500. Photo-
 graphed by phase contrast.
- 8,10-10a Polysphaeridium sp. 1 sp. nov. 10 holotype x500,
 8 x500, 10a x1250 enlarged to show greatly
 flared processes tips.
- 9-9a,11 Polysphaeridium sp. 4 sp. nov., 9-9a holotype,
 9 x500, 9a x1250, 11 x1250. Photographed by
 phase contrast.

PLATE 7

- 1-4 Hystrichosphaeridium sp. 1 sp. nov., 2 holotype
 x500, 1 x500, 1a x1250, 3-4 x500. Note figrilar
 processes structure in 1a.
- 5-7 Hystrichosphaeridium sp. 2 sp. nov., 5-5a holotype
 x500 and x1250. 5a x1250 shows apical archeopyle
 with zig-zag margin.
- 8-9 Cleistosphaeridium sp. 1 sp. nov., 8-8b holotype,
 8-8a x500, 8b x1250 showing apical archeopyle
 with zig-zag margin.

PLATE 8

- 1-2 Cleistosphaeridium sp. 1 sp. nov., x500, 1-1a
 showing apical view with epithema attached, also
 illustrates capitata character of distal extrem-
 ities in some processes. Photographed by phase
 contrast.
- 3-10 Forma F sp. 1 Gen et sp. nov., 10 holotype x500,
 wall ruptured to form precingular archeopyle;
 margins of large antapical processes denticulate.

PLATE 9

- 1-2 Diphyes cf. colligerum, 1 x1250 showing flat
 acuminate processes; 1a-2 x500.
- 3-11 Forma A sp. 3 Gen. et sp. nov., 5 holotype x500;
 3, 4-11 x500; 9 epithema.
- 12 Forma A sp. 1 Gen. et sp. nov., x500.

PLATE 10

- 1-10 Forma A sp. 1 Gen. et sp. nov., 2-2a holotype x500; 1, 3-6, 8, 9-10 x500; showing fused processes above archeopyle x1250; 8a shows detail of linear reticulate endophragm x1250; 1-2a, 4 illustrate apparent apical position of archeopyle due to compaction; 5, 8-10 inflated specimens.

PLATE 11

- 1-3a Forma A sp. 2 Gen. et sp. nov., 1-1b holotype x500 showing precingular archeopyle and fused appendage; 2-3a x500.

PLATE 12

- 1-3 Forma A sp. 2 Gen. et sp. nov., x500.
4-5a Cordosphaeridium fibrospinosum x500, 5a photographed by phase contrast.

PLATE 13

- 1 Cordosphaeridium fibrospinosum, x500. Photographed by phase contrast.
2-4 Cordosphaeridium sp. 1 sp. nov., 2 holotype x500; 3-4 x500.
5-7 Callaiosphaeridium cf. asymmetricum, x500; 5-5a medial view showing 6 large cingular processes with aculei well-developed. 5-6 photographed by phase contrast.
8-10 Systematophora sp. 1 sp. nov., x500; 9 view of apical archeopyle; 10 complete specimen.

PLATE 14

- 1-3 Systematophora sp. 1 sp. nov., x500; 1-1a, 3 entire specimens; 2 specimen with detached epithema.
4-6 Hystrichosphaera sp. 2 x500.
7-8 Hystrichosphaera ramosa, x500.
9-11 Hystrichosphaera ramosa var, 1, 9a, 11 x500; 9 x1250 showing punctate wall and cyst character of processes.

PLATE 15

- 1-2 Achomosphaera ramulifera 1-2 x500, 1a x1250 showing granular wall, cyst-like structure near distal part of processes, and trifurcate extremity. Photographed by phase contrast.
4-6a Hystrichosphaera sp.

- 7-9 Hystrichsphaera sp. 1 sp. nov.
10-11 Cannosphaeropsis fenestrata, x500.

PLATE 16

- 1-3a Cyclonephelium sp. 1 sp. nov., x500; 1-1a photographed by phase contrast, complete specimen; 3-3a complete specimen; 2-2a holotype.
4-7 Cyclonephelium sp. 3 sp. nov., x500; 4-5 complete specimens; 6-6a shows margins of apical archeopyle; 6 photographed by phase contrast.

PLATE 17

- 1-1a Cyclonephelium sp. 3 sp. nov. holotype x500.
 Photographed by phase contrast.
2-6a Cyclonephelium sp. 2 sp. nov., x600; 6-6a holotype;
 2, 4, 6 photographed by phase contrast.

PLATE 18

- 1 Cyclonephelium sp. 2 sp. nov. x500.
2-3 Tenua hystrix, x500.
4-5 Tenua sp. 1 sp. nov., x500; 4 holotype.
6-9 Areoligera sp. 2 sp. nov., x500; 7-7a photographed
 by phase contrast.

PLATE 19

- 1-3a Areoligera senonensis, x500; 1-1a dorsal and
 ventral view of same specimen with open archeopyle.
4-9 Areoligera sp. 1 sp. nov., x500; 6-6a dorsal and
 ventral view of same specimen with attached
 epithema. 6-9 photographed by phase contrast.

PLATE 20

- 1-6 Cyclonephelium divaricatum, x500; 4a photographed
 by phase contrast.
7-8b Forma B sp. 1 Gen. et sp. nov., 7-8a x500 showing
 6 apical archeopyle delineated by 6 precingular
 fields; 8b x1250 showing fine hair-like processes
 attached to membranous-like structure on ventral
 surface of central body; 7a, 8a, 8b, photographed
 by phase contrast.

PLATE 21

- 1-4 Gymnodinium sp. 1 sp. nov., x1250; 2, 2-2a, 4 showing small apical archeopyle; 2a photographed by phase contrast.
 5 Gymnodinium sp., x1250.
 6-9 Gymnodinium sp. 4 sp. nov., x500; 7, 9 shows apical archeopyle.
 10-13a Gymnodinium nelsonense, 10-13 x500; 13a x1250 shows apical archeopyle, photographed by phase contrast.

PLATE 22

- 1-2 Gymnodinium nelsonense, x500.
 3-6 Gymnodinium westralium, x500. 3-4, 6 photographed by phase contrast.
 7-11 Gymnodinium digitus, x1250.

PLATE 23

- 1-2 Gymnodinium sp. 4 sp. nov., x1250.
 3-4 Diconodinium sp. 1 sp. nov., x1250. 4 photographed by phase contrast.
 5-8 Gonyaulax sp. 1 sp. nov., x500. 7-7a photographed by phase contrast.

PLATE 24

- 1-6 Forma C sp. 1 Gen. et sp. nov., x500; 4 holotype, entire specimen; 1, 3, 6, specimens with detached epithema; 2, 5 epithema bearing large processes.
 7-8 Odontochitina striatoperforata, x500, specimens with detached epithema.

PLATE 25

- 1-4a Heliodinium cf. voigti, x500. Photographed by phase contrast.
 5-7 Deflandrea acuminata, x500. Photographed by phase contrast.
 8-9, 12 Deflandrea cooksoni, x500.
 10-11 Deflandrea micracantha, x500.

PLATE 26

- 1-8 Deflandrea sp. 2 sp. nov., x500; 1, 2-4, 6-8 photographed by phase contrast; specimens illustrate size variations amongst individuals; 1-3 from Kemp Formation, 4-8 from Corsicana Formation, Austin composite section. 6 holotype; 1, 2-5, 6-8, photographed by phase contrast.

PLATE 27

- 1-2 Deflandrea microgranulata, x500. 2 photographed by phase contrast.
- 3-4 Deflandrea sp. 5 sp. nov., x500. Photographed by phase contrast. 4 holotype, shows partly detached epithema and slight protruberance of central body into antapical processes.
- 5-7 Deflandrea sp. 6 sp. nov., x500. 5-6 shows epithema attached posteriorly, and rounded anterior portion of archeopyle.
- 8-10 Deflandrea sp. 4 sp. nov., x500. 8, 10 photographed by phase contrast to show granulate wall ornamentation and triangular archeopyle with rounded corners. 5 holotype.

PLATE 28

- 1-2 Deflandrea sp. 4 sp. nov., x500. 1 photographed by phase contrast.
- 3-4 Deflandrea pannucea, x500, photographed by phase contrast. Specimens show longitudinal wrinkles and triangular archeopyle.

PLATE 29

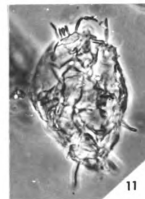
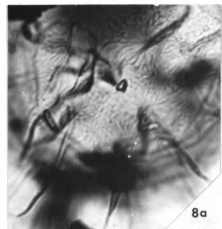
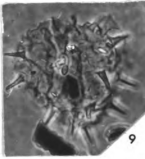
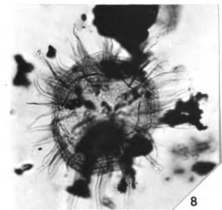
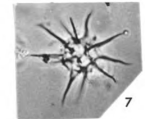
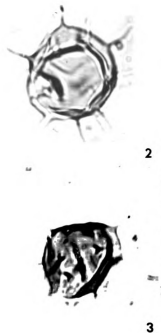
- 1-3 Deflandrea pannucea, x500. Photographed by phase contrast.
- 4-6 Deflandrea sp. 3 sp. nov., x500. 4, 5, 6 photographed by phase contrast. 4 holotype.
- 7 Deflandrea magnifica, x500. Photographed by phase contrast.

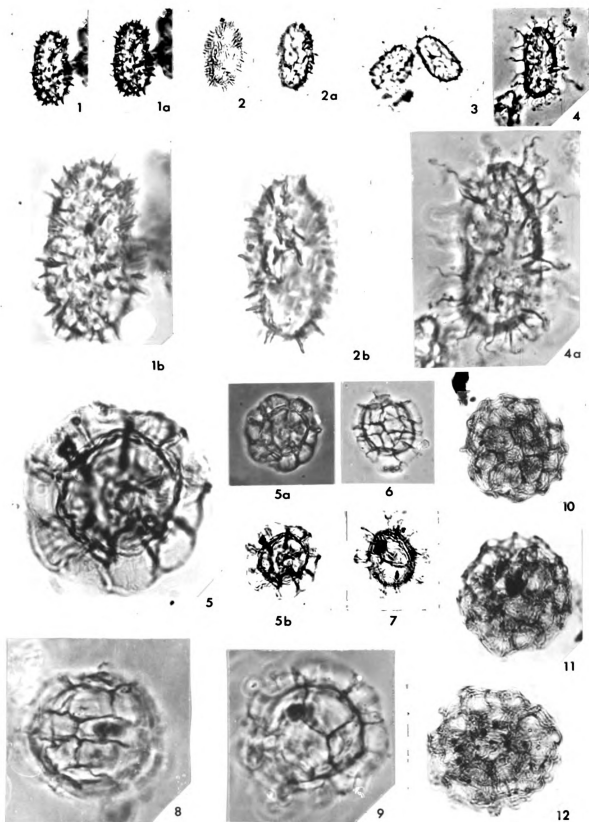
PLATE 30

- 1-4 Deflandrea magnifica, x500; 1 photographed by phase contrast. Figures 3-4 show smaller specimens from Escondido Formation, Frio County, Texas.
- 5-6 Apteodinium sp. 1 sp. nov., x500. Photographed by phase contrast. 5 holotype shows large precingular archeopyle and with internal capsule in close contact with outer wall.
- 7-8a ? Deflandrea sp. 1 sp. nov., x500. 7a, 8a photographed by phase contrast to show archeopyle formed by loss of three plates.
- 9-9a Svalbardella lidiae, x500. 9 photographed by phase contrast.

PLATE 31

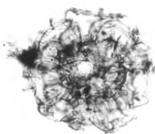
- 1 Svalbardella lidiae, x500. Photographed by phase
 contrast.
- 2-3 Hexagonifera sp. 1 sp. nov., x1250.
- 4 Paleohystrichophora infusorioides, x500. Photo-
 graphed by phase contrast.
- 5-9 Palaeohystrichophora infusorioides, x500. Photo-
 6a x1250 shows fine hair-like processes.







1



2



3



4



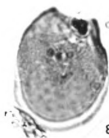
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6



7



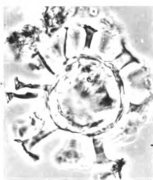
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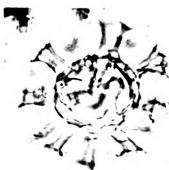
9



9a



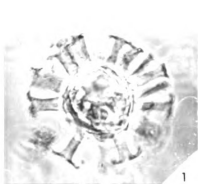
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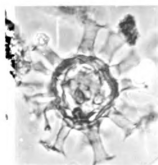
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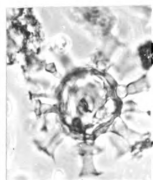
12



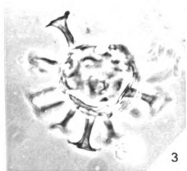
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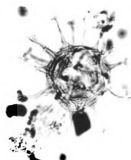
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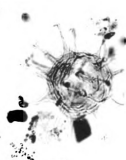
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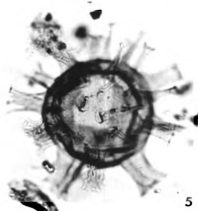
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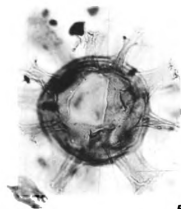
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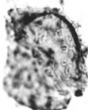
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5



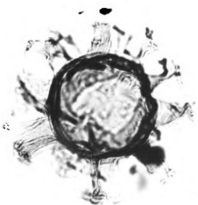
5a



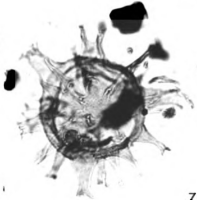
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9



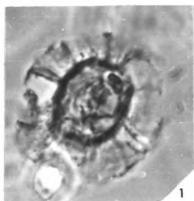
6



7



10



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1a



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4



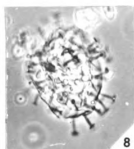
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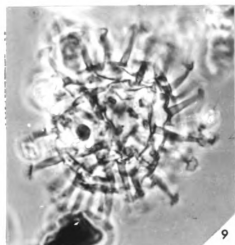
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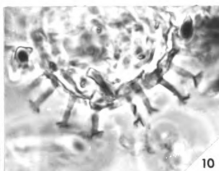
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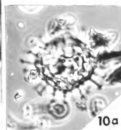
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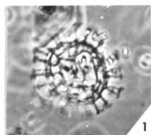


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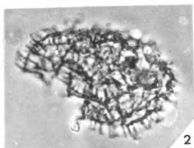


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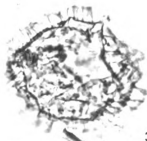




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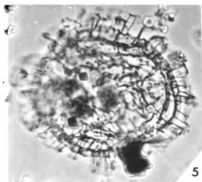
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3



4



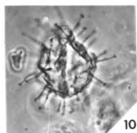
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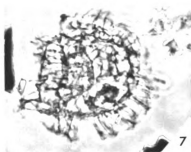
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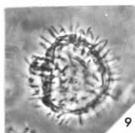
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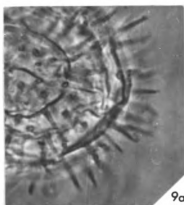
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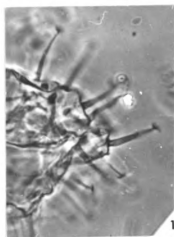
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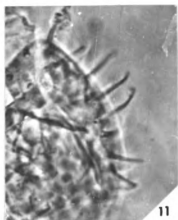
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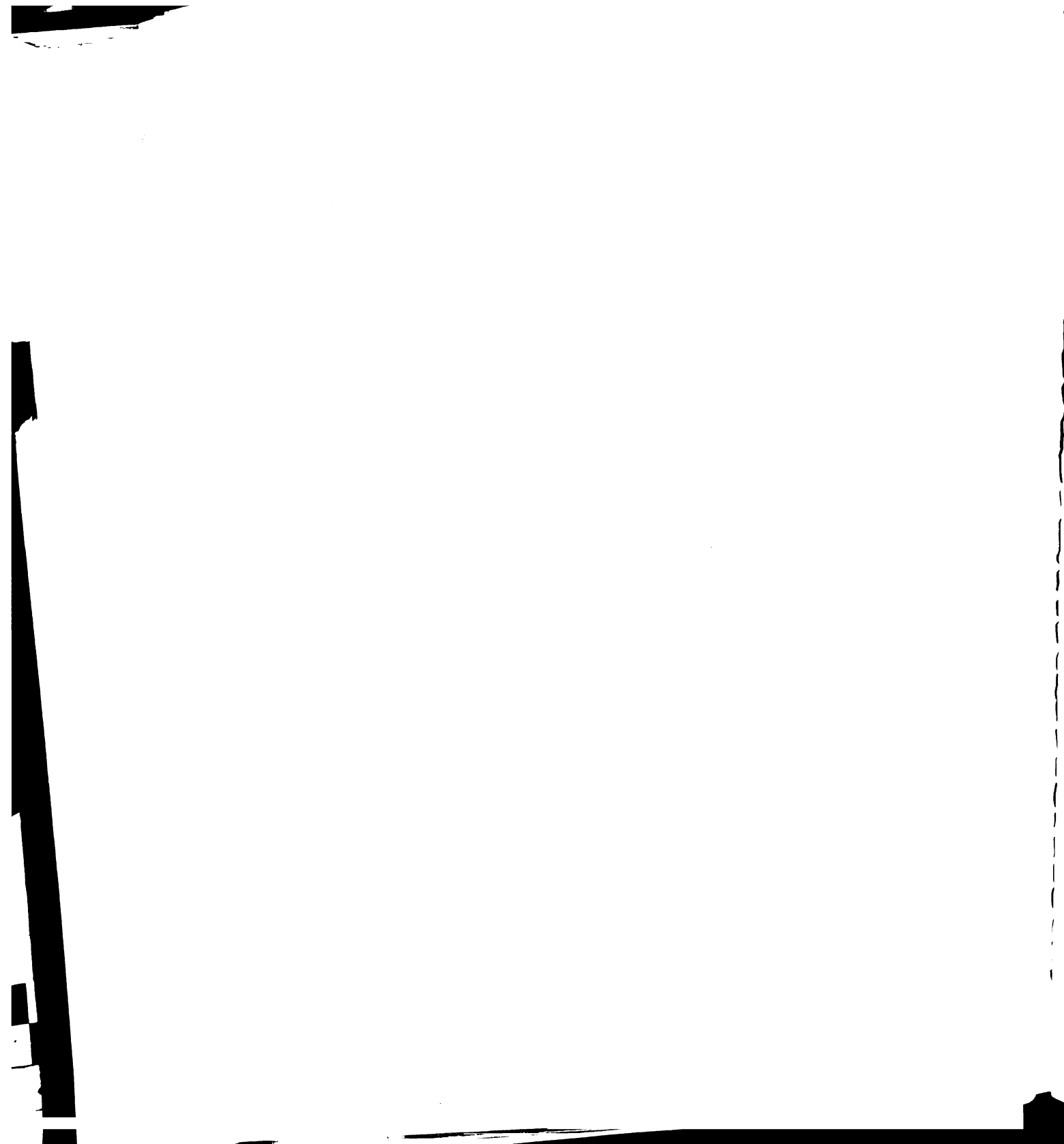
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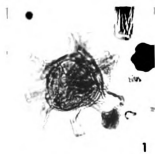


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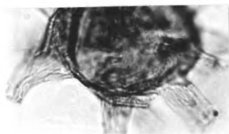


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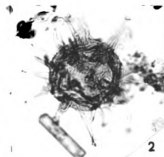




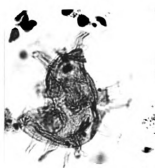
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1a



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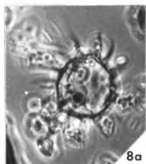
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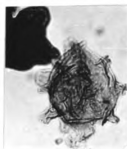
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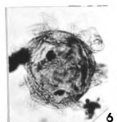
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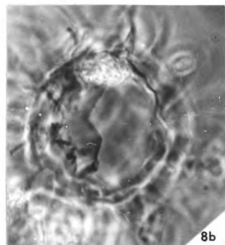
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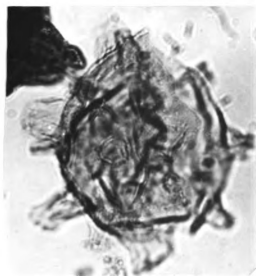
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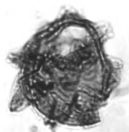
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8b



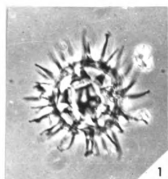
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7



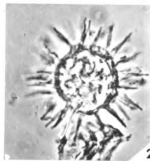
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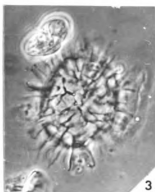
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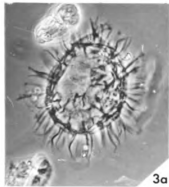
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2



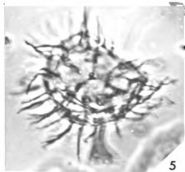
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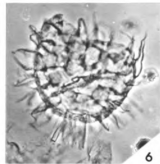
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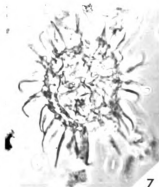
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5



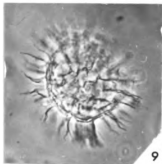
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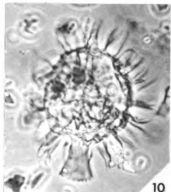
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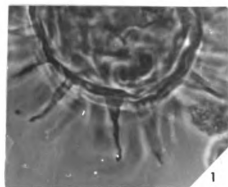
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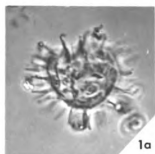
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10



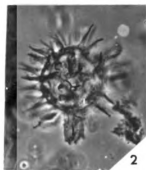
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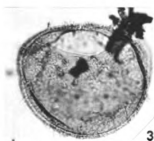
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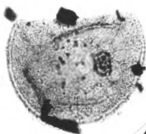
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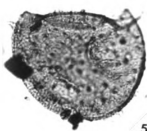
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3



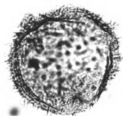
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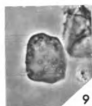
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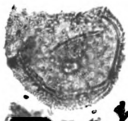
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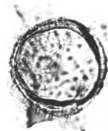
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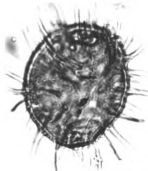
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11

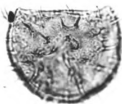


12

PLATE 9



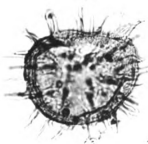
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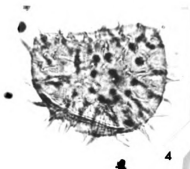
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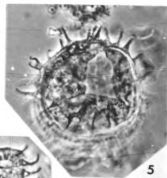
2a



3



4



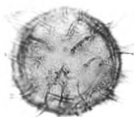
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6



7



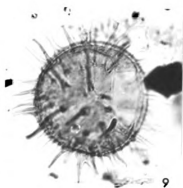
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8a



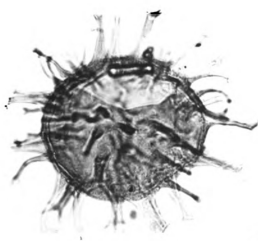
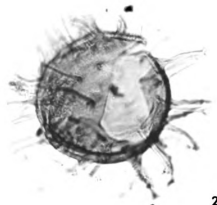
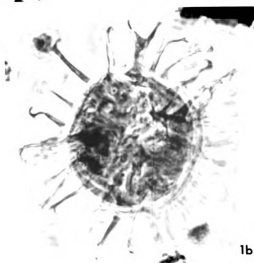
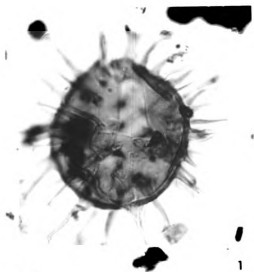
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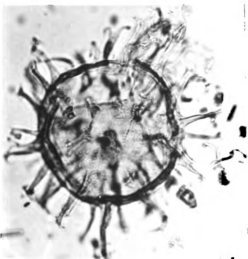


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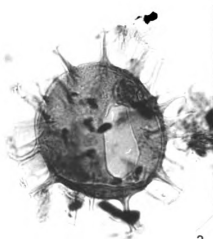


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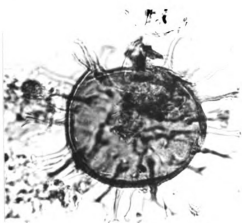




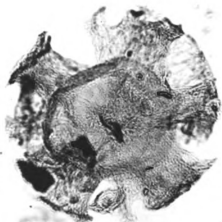
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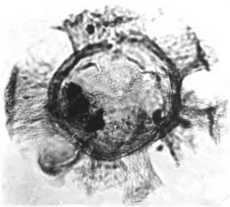
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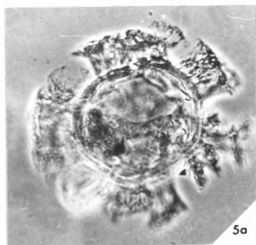
3



4



5



5a

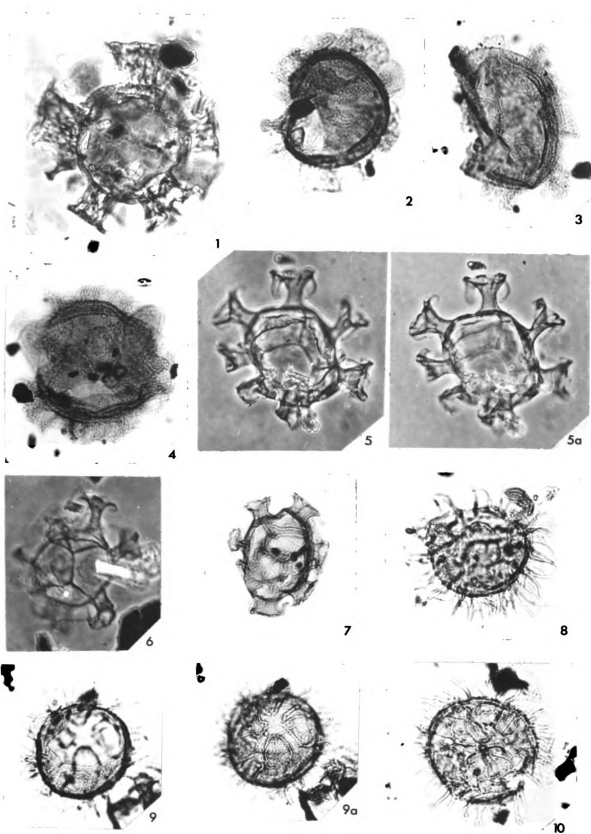
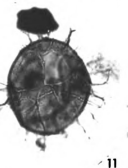
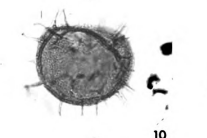
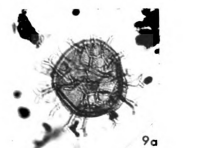
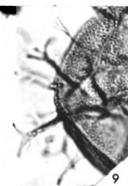
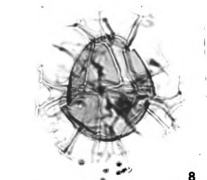
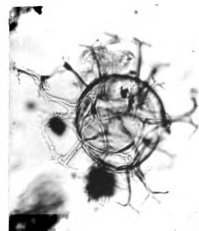
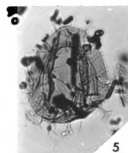
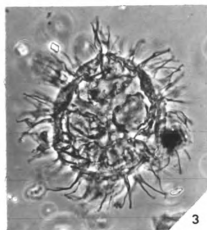
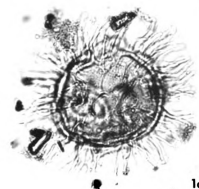
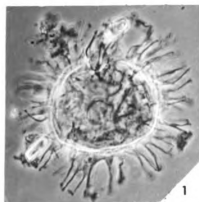
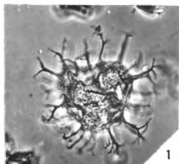
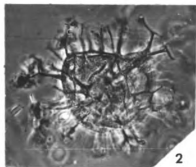


PLATE 13

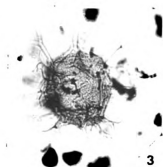




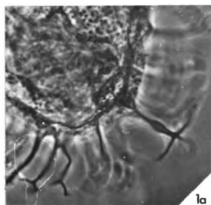
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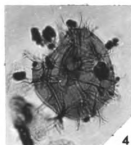
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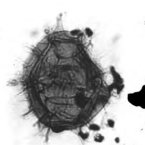
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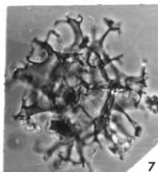
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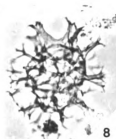
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5



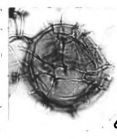
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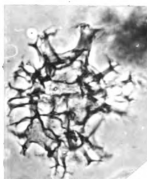
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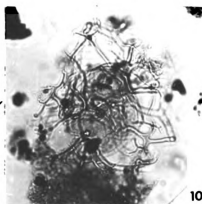
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6a



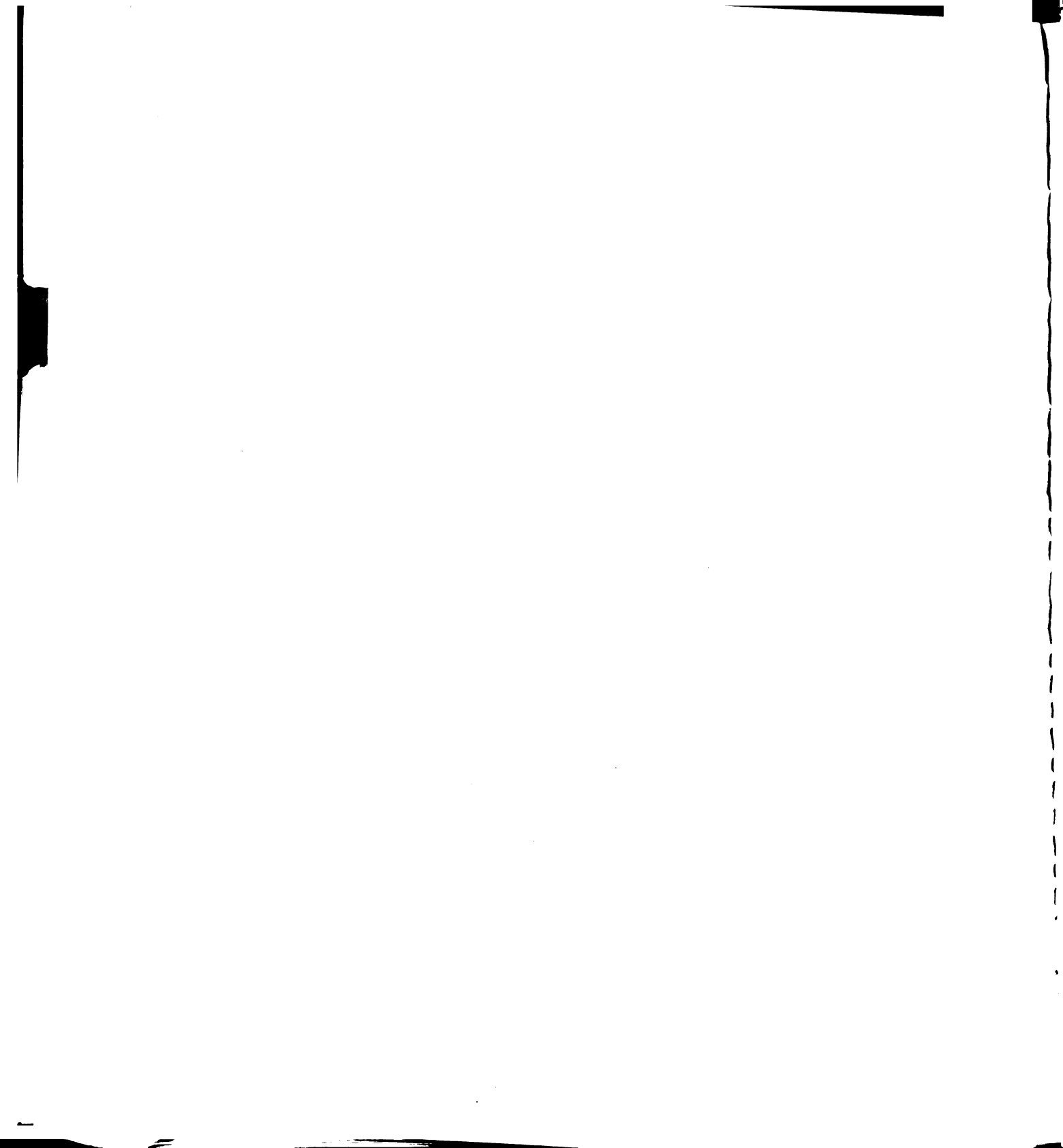
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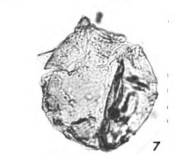
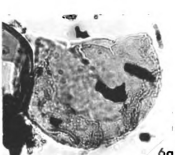
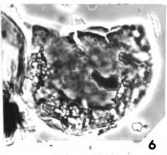
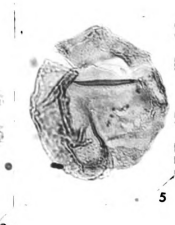
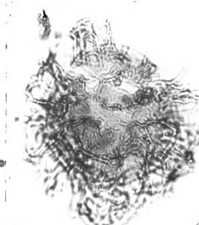
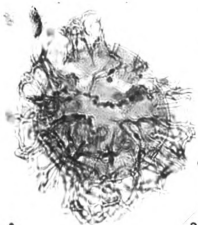
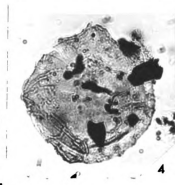
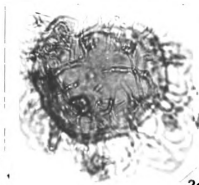
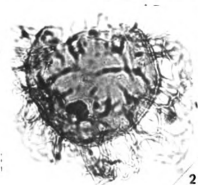
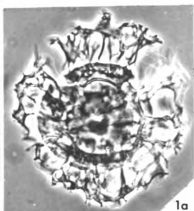
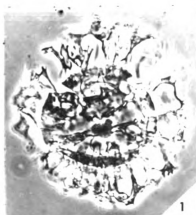


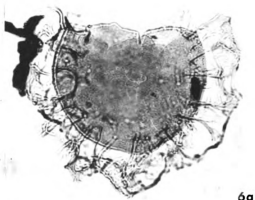
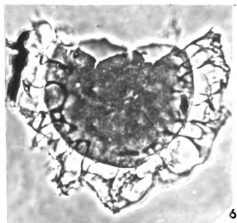
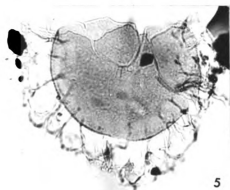
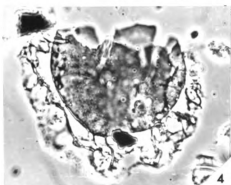
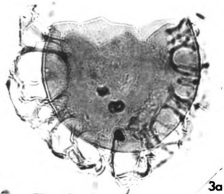
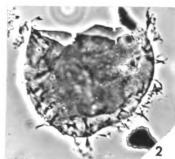
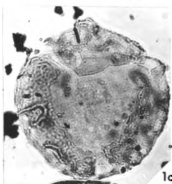
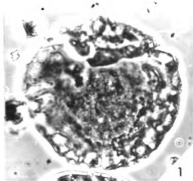
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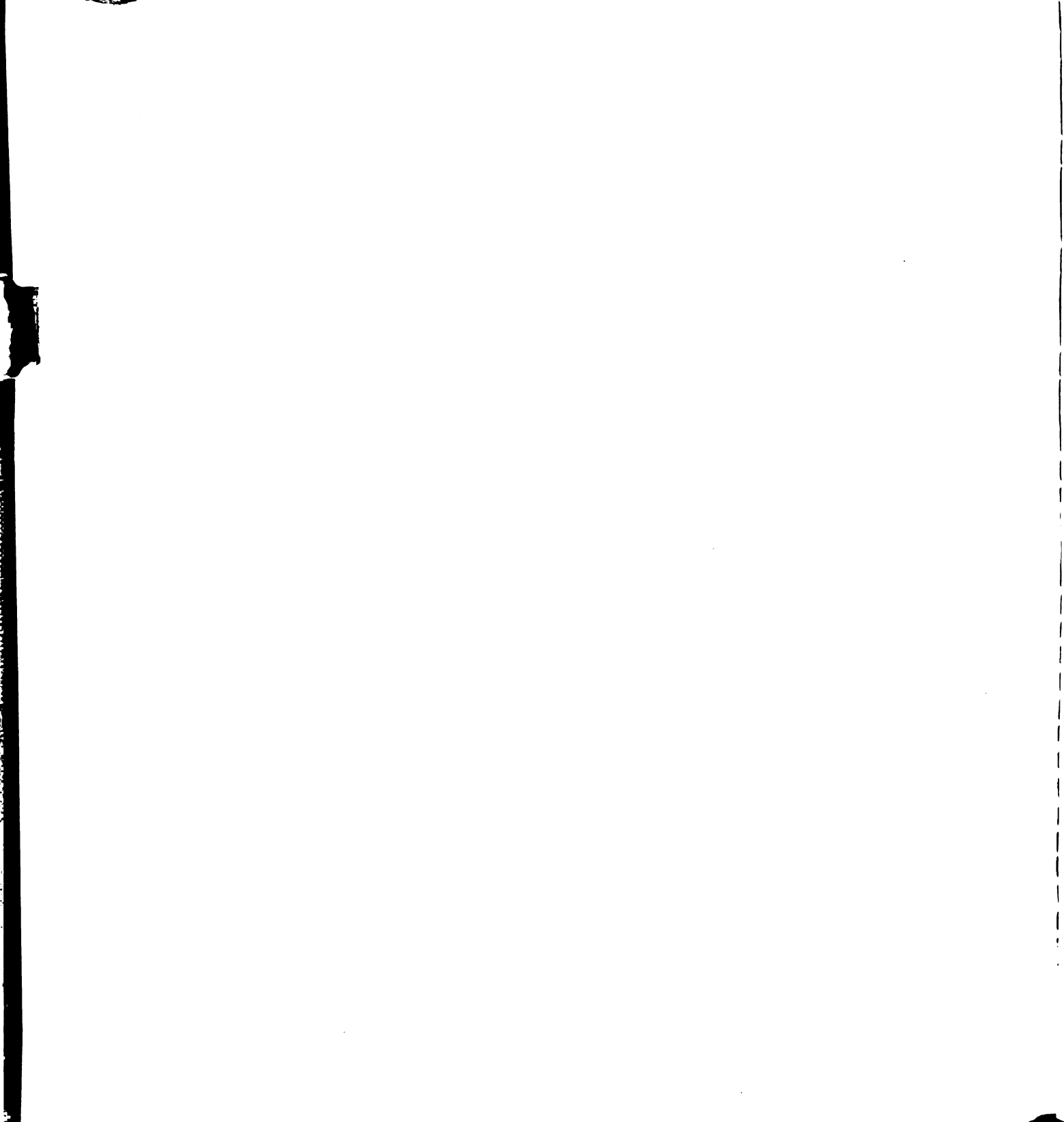


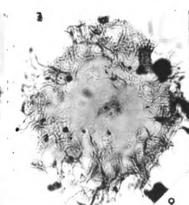
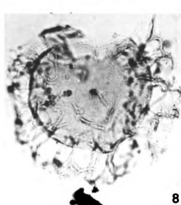
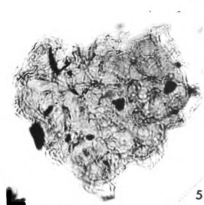
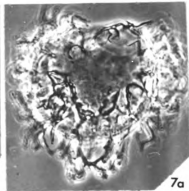
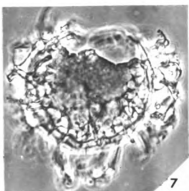
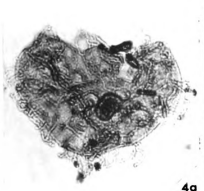
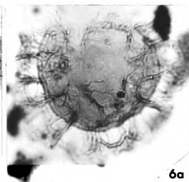
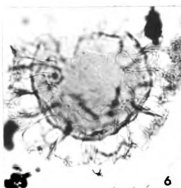
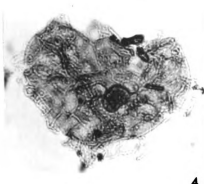
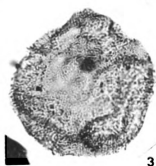
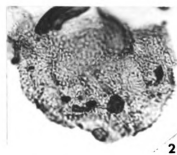
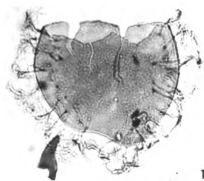
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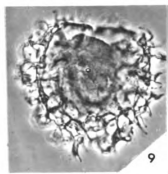
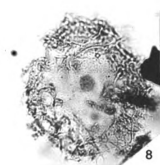
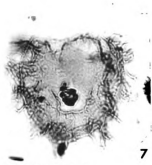
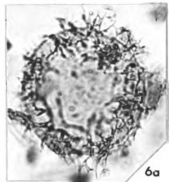
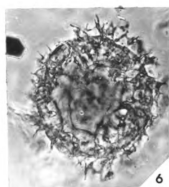
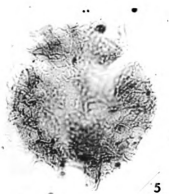
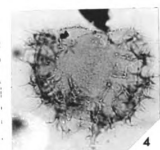
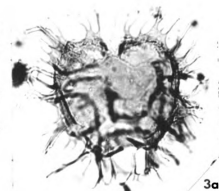
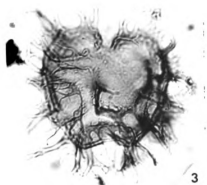
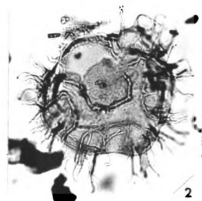
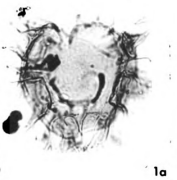
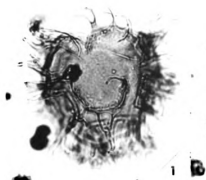




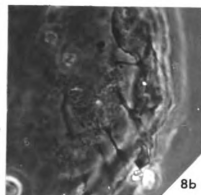
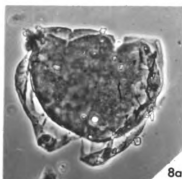
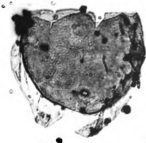
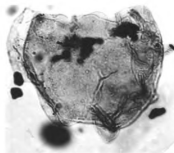
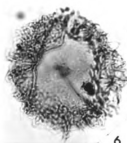
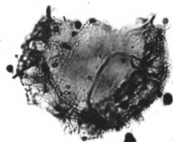
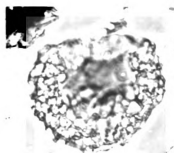
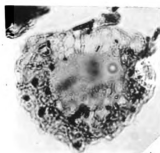
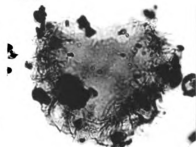
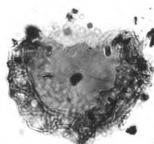
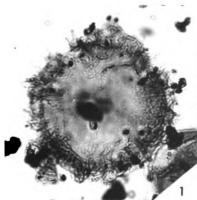












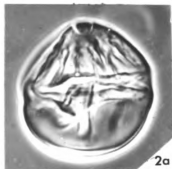




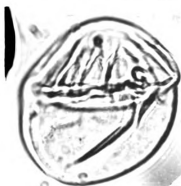
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2



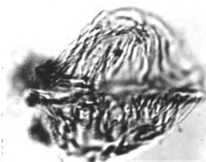
2a



3



4



5



6



7



8



10



9



11



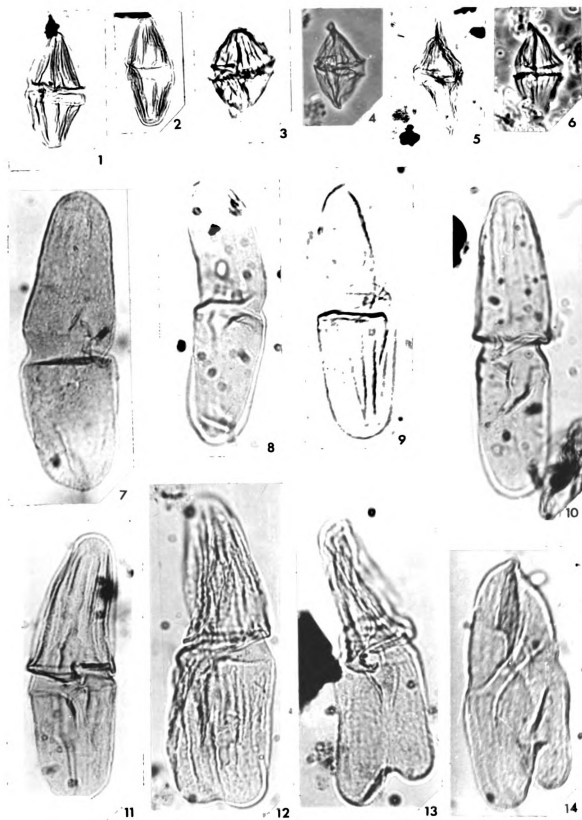
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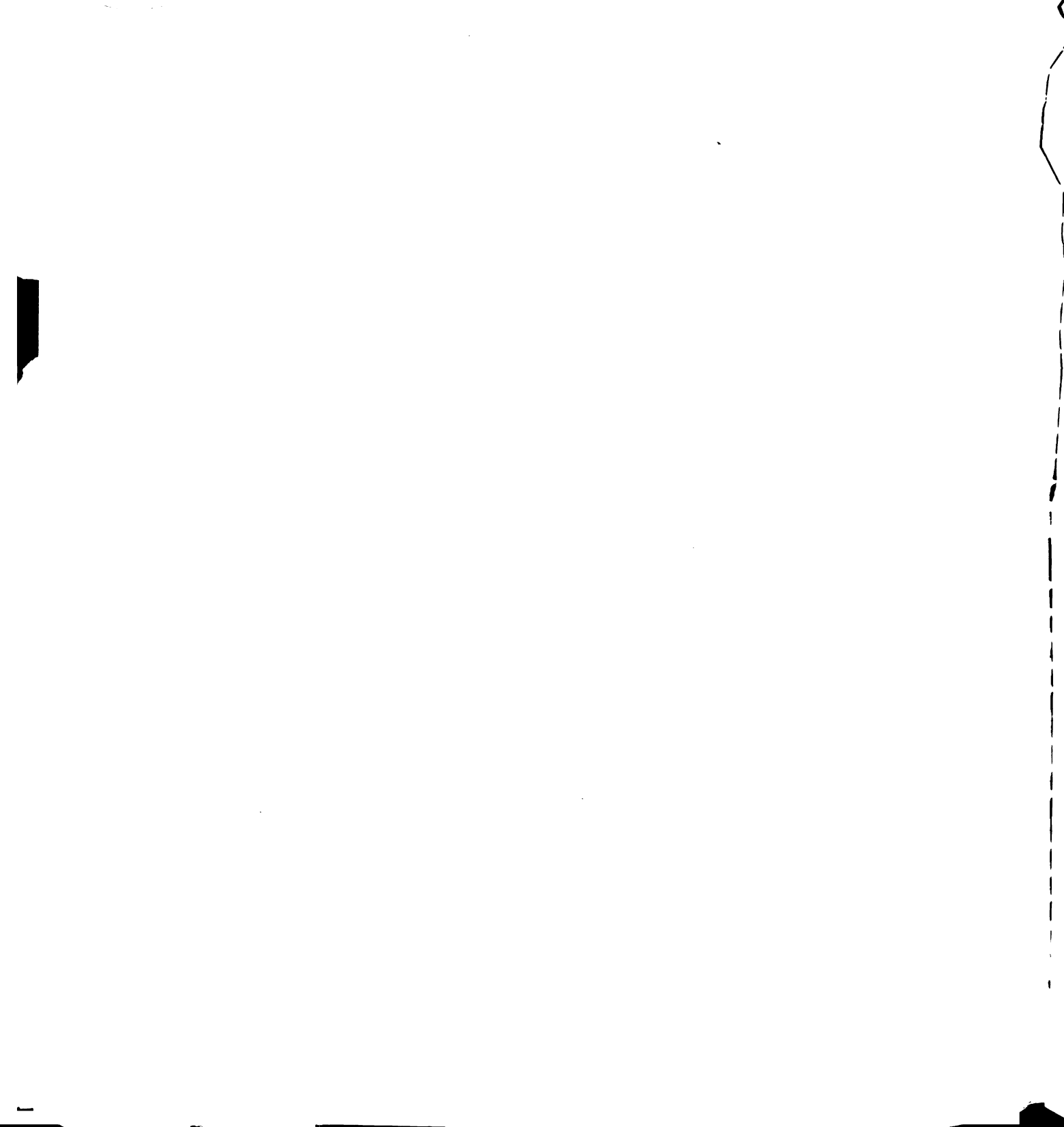


13



13a







1



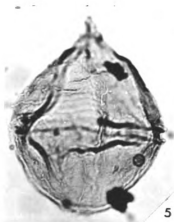
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3



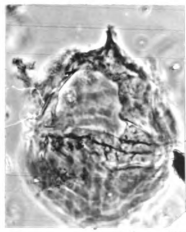
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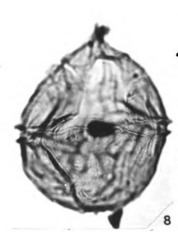
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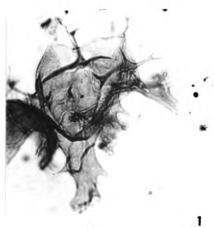
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7a



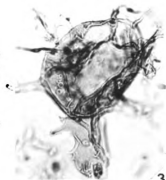
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1



2



3



4



5



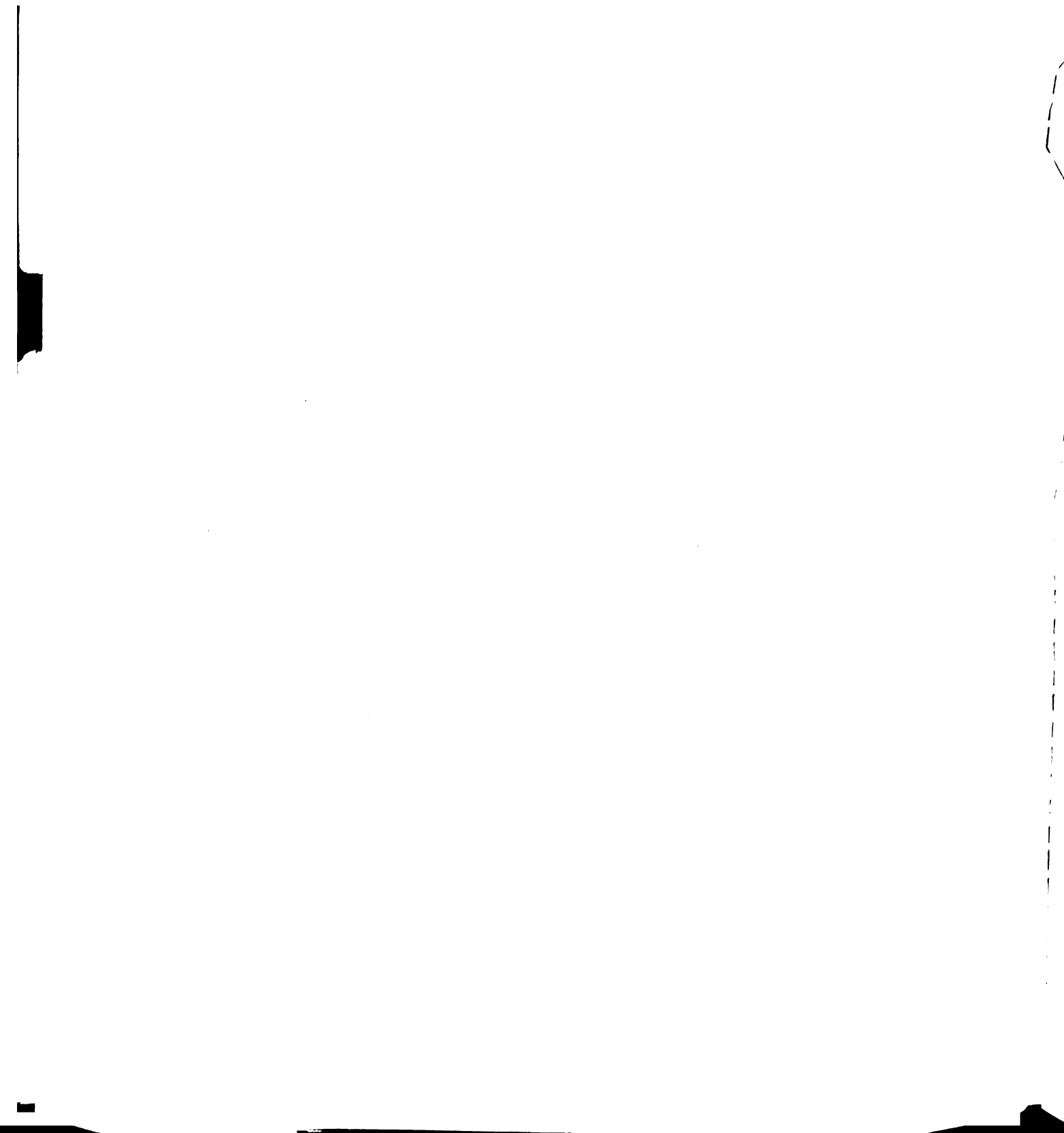
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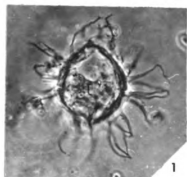


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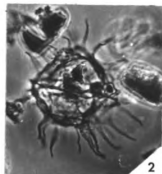


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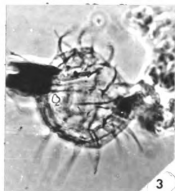




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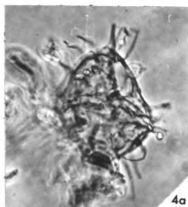
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3



4



4a



5



6



7



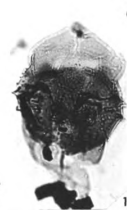
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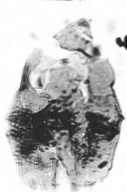
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10



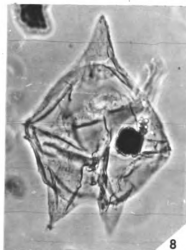
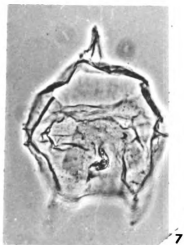
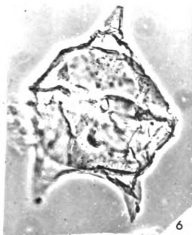
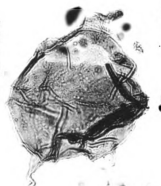
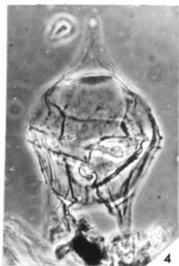
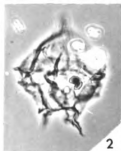
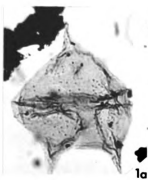
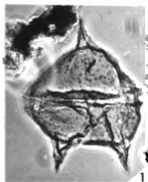
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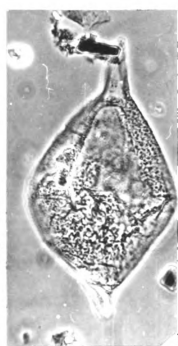
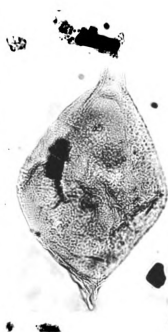
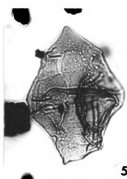
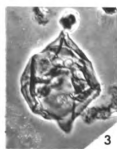
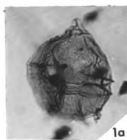
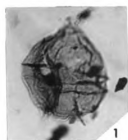


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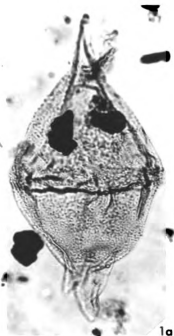
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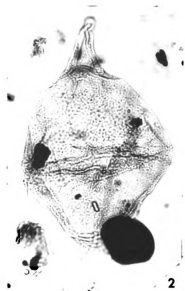




1



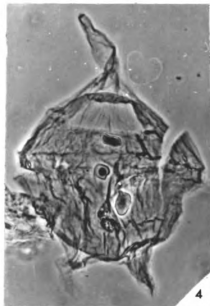
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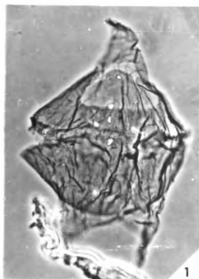
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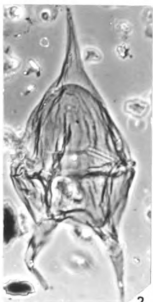
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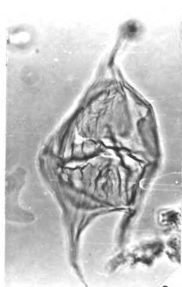
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1



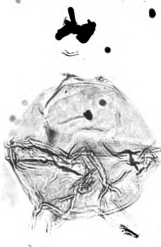
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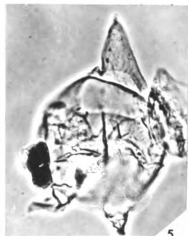
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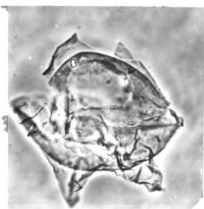
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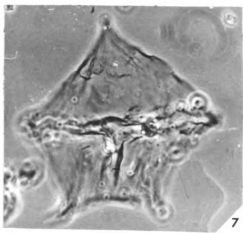
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5



6



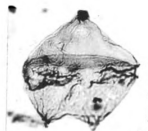
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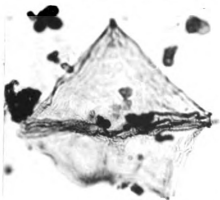
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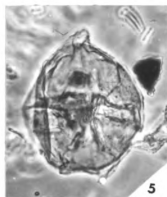
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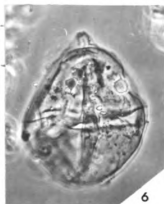
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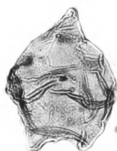
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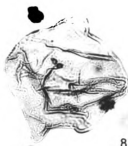
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7



7a



8



8a



9



9a

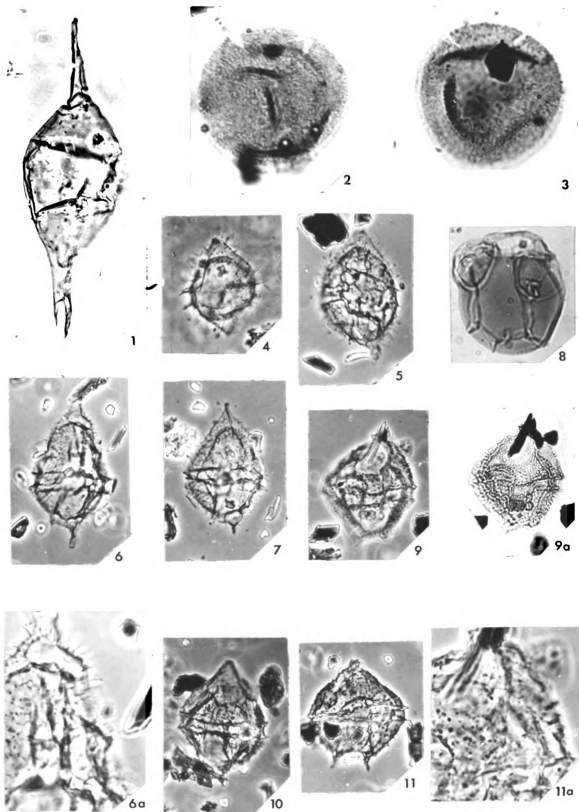


PLATE 31

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