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CALCAREOUS NANNOFOSSIL SYSTEMATICS, PALEOECOLOGY, AND BIOSTRATIGRAPHY OF THE MIDDLE EOCENE WECHES FORMATION OF TEXAS

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ILLUSTRATIONS

I. ABSTRACT

Eighty previously described species of calcareous nannofossils representing 25 genera are figured with scanning-electron micrographs and photomicrographs. Improved criteria for identifying and distinguishing species and genera are presented based upon their appearance in the scanning-electron microscope. Nine new combinations are formed.

Based upon the stratigraphic range of key species, the *Discoaster lodoensis* Zone, *Discoaster sublodoensis* Zone, *Discoaster tani* s.l.-*Sphenolithus radians* Zone, *Reticulofenestra umbilica*-*Sphenolithus furcatolithoides* Zone, *Pemma papillatum* Zone, *Reticulofenestra* Datum and *Discoaster saipanensis* Datum of Gartner's 1971 Paleogene Nannofossil Zonation are recognized. The positions of two missing zones, *Bramletteius serraculoides* Zone and *Chiphragmalithus quadratus* Zone, have been inferred.

Variations in the occurrence and abundance of species between outcrop and subsurface samples were found to exist. These variations may be the result of differential preservation or the result of living species being restricted to particular areas of the neritic environment. The following species were found only in the subsurface portion of the Weches and are considered indicators of the outer neritic environment:

Chiasmolithus titus
Pontosphaera plana
Pontosphaera versa
Micrantholithus procerus
Sphenolithus furcatolithoides
Sphenolithus obtusus
Trochoaster radiatus
Discoaster aster
Discoaster diastypus
Discoaster triangularis
Discoaster woodringi

The following species were found to occur in several subsurface samples but appeared in only one or two outcrop samples. These species probably could live throughout the neritic environment but preferred deeper portions or were better preserved in deeper water deposits.

Chiasmolithus grandis
Pontosphaera pectinata
Braarudosphaera discula
Micrantholithus flos
Micrantholithus ornatus
Helicopontosphaera lophota
Rhabdolithes rudis
Discoaster stella
Discoaster barbadiensis
Discoaster saipanensis
Discoaster tani nodifer

Lophodolithus rotundus and *Marthasterites furcatus* occurred exclusively in outcrop samples. *Chiasmolithus bidens*, *Blackites amplus* and *Trochoaster simplex* occurred several times in outcrop samples but each is found only once in the subsurface. These five species are considered indicative of the middle to inner neritic environment. *Cyclococcolithina formosa*, *Cruciplacolithus staurion*, and *Zygrhablithus bijugatus* occurred in both subsurface and surface samples but were generally present in greater abundance in subsurface samples. *Ericsonia muiri*, *Reticulofenestra coenura*, *Koczyia wechesensis*, *Traversopontis pulchriporus*, *Blackites tenuis*, and *Discoaster elegans* were present in greater abundance in outcrop samples.

II. INTRODUCTION

Calcareous nannofossils are small fossilized carbonate bodies (1-50 microns) produced by two distinct groups of organisms. These are the ascidians, which are marine protochordates, and the coccolithophores, unicellular golden-brown algae of the Division Chrysophyta. The fossil record of the ascidians is sparse, and shows little evolutionary change, but fossilized coccolithophores are abundant in marine sediments and show many evolutionary changes (Haq, 1971d).

The coccolithophores are a group of largely marine, planktonic algae. Diversely shaped calcareous bodies, known as coccoliths, are produced during some phase of their life cycle. Coccoliths may be constructed of uniform calcite crystals, in which case they are known as holococcoliths (Braarud, *et al.*, 1955). However, heterococcoliths (Braarud *et al.*, 1955), constructed of variously shaped calcite elements, are more common. Holococcoliths have been observed to be formed outside the cytoplasmic membrane but inside an outer membrane of the algal cell (Manton and Leedale, 1963). Heterococcoliths, however, are produced on a preformed organic template within the protoplasm of the cell and subsequently migrate to the cell surface (Wilbur and Watabe, 1963). Here they are extruded and form an external covering. The resulting test, composed of interlocking coccoliths, is known as a coccosphere.

An organic membrane coats the surface of each coccolith and probably serves to retard dissolution (Cita, 1971). Upon the death of the algal cell the coccosphere disaggregates and settles to the ocean floor. Coccoliths and rare coccospheres have been found in marine sediments from the early Jurassic to the Holocene with single unconfirmed reports of coccoliths being found in the Permian (Pirini Radrizzani, 1971) and Pennsylvanian (Noël, 1965).

Star-shaped carbonate bodies known as discoasters first appeared in the Paleocene in association with coccolith species. Discoasters persisted throughout most of the Cenozoic, becoming extinct during the Pliocene and only rare and questionable occurrences are known from the Pleistocene. During this time they too underwent many evolutionary changes (Haq, 1971d; Prins, 1971). By reason of their common occurrence with coccolithophores, discoasters are assumed to have also been produced by pelagic algae. The term nannofossil(s) has come to be used in a general sense when referring to calcareous fossils believed related to the coccolithophores and will be so used in this paper.

The planktonic habit of the calcareous nannofossils made it possible for the many new species to spread quickly throughout the oceans of the world. This along with the large number of specimens recoverable from small samples makes them ideal for transoceanic correlations and for subdividing marine strata into biostratigraphic zones (Bramlette and Wilcoxon, 1967; Hay *et al.*, 1967; Gartner, 1969, 1971; Roth, 1970; Martini, 1971c; Edwards, 1971; Hornibrook and Edwards, 1971).

At present the ecology and paleoecology of calcareous nannofossils is poorly understood. Fossil assemblages have been found in sediments deposited under marine to slightly brackish conditions. Open-ocean and shelf assemblages have been identified, although the reasons for such provincialism in planktonic organisms are not yet known. It is currently believed that dissolution of certain species is an important factor in the production of fossil assemblages indicative of environments of deposition. The middle Eocene Weches Formation of Texas was selected for study in an effort to gain a better understanding of the paleoecology of the nannofossils of the neritic environment.

The Weches is a relatively thin transgressive marine formation deposited conformably upon the regressive Queen City Formation of Texas. The formation consists of fossiliferous glauconitic clays, marls and limestones deposited within the neritic environment. The Weches Formation was selected for examination because a great deal was known about its paleoecology; foraminifera, ostracoda and larger marine invertebrates having been studied in detail (Stenzel, 1945; Stephenson, 1946; Feray, 1948; Curtis, 1955; Shafiq, 1969; Guevara and Garcia, 1972). It was also known that a well-developed flora of nannofossils existed although they had not been studied systematically (Bramlette and Sullivan, 1961).

III. ACKNOWLEDGMENTS AND DEPOSITORY OF TYPES

I wish to thank Dorothy J. Echols and Harold L. Levin of the Department of Earth Sciences, Washington University, St. Louis, Missouri, for their assistance and encouragement during this research. Thanks are also due Marie Greider and Edward Finke of the Department of Pathology, Washington University Medical School, for their generous cooperation and assistance in making the scanning-electron microscope available and to A. D. Ellis, Jr., David Bukry, and Stefan Gartner, Jr., for constructive review of the manuscript.

The writer is also grateful to William R. Walton, Geological Research Director, Amoco Production Company, Tulsa, Oklahoma, for making samples available and to Melvin L. Shourd for assistance in the field.

This work was supported by a Grant-in-Aid of Research from the Society of the Sigma Xi and the Washington University Graduate School Faculty Research Fund. The scanning-electron microscope was made available through Health Science Advancement Award F-304-FR 06115 to Washington University.

Light-microscope slides and SEM negatives prepared for this study have been deposited in the Washington University Micropaleontological Collection (W.U.M.C), Department of Earth Sciences, Washington University, St. Louis, Missouri, 63130.

Hypotype data for figured specimens is given in the following format with photomicrographs listed first, followed by SEM micrographs. The name of the outcrop from which the sample was collected appears, followed by the letter designation of the sample (Figure 2). County name, well number and depth in feet are reported for subsurface samples. Following the sample and location data for photomicrographs, slide coordinates in parentheses, the W.U.M.C. number and the size of the specimen are given. If the specimen in the SEM micrograph is from a different locality or sample the appropriate data is given, followed by the number of the SEM negative designated as hypotype and the specimen size. Several specimens from a sample collected along the Sabine River appear as figured specimens. The stratigraphic position of this sample within the Weches Formation is not known. This sample is referred to as Sabine River E in the hypotype data.

IV. STRATIGRAPHY AND PALEOECOLOGY

The Weches Formation in Texas has been assigned to the middle Eocene Claiborne Group in Texas. It is correlative with the Cane River Formation in Louisiana, the Winona Formation in Mississippi, the lower Lisbon Formation in Alabama and the upper Lake City Limestone in Florida. The name Weches was proposed by Wendlandt and Knebel (1929, p. 1356) to designate the clayey glauconitic beds below the Sparta Sands and above the Queen City Sands. However, no type locality was designated. Stenzel (1944) subsequently designated as type localities, outcrops of the Weches in three roadcut sections on Texas State Highway 21 west of Weches, Texas. Regrettably these type sections are leached and oxidized, making them unsuitable for paleontological study.

In 1938 Stenzel divided the Weches Formation into three members: the Tyus, Viesca, and Therrill, but in 1952 he elevated the Therrill Member to the rank of formation. The Tyus Member is a slightly glauconitic calcareous marl containing the oyster *Ostrea lisbonensis* Harris, many irregular lime nodules, a limestone bench or bedded limestone concretions and few fossils. According to Stenzel, limestone or lime nodules are the outstanding component of the Tyus Member. The Viesca Member is a poorly bedded, fossiliferous, argillaceous, calcareous glauconitic unit. Glauconite is the outstanding feature of this member.

The marine character of the Weches persists throughout eastern and south central Texas, changing to a gypsiferous, carbonaceous, sandy clay near the margin of the Rio Grande Embayment. The formation becomes generally nonmarine and indistinguishable from the Queen City where the two formations merge into the El Pico Clay (Eargle, 1968).

Feray (1948) examined the environmental significance of foraminifera as related to the sedimentary characteristics of the Weches Formation. He concluded that the Tyus facies represented:

> "Sediments deposited in warm, shallow, agitated marine water that was relatively clear. The presence of glauconite, an abundance of shell fragments, and an absence of bedding indicates slow sedimentation and thorough reworking of sediments by burrowing and mud-eating benthonic

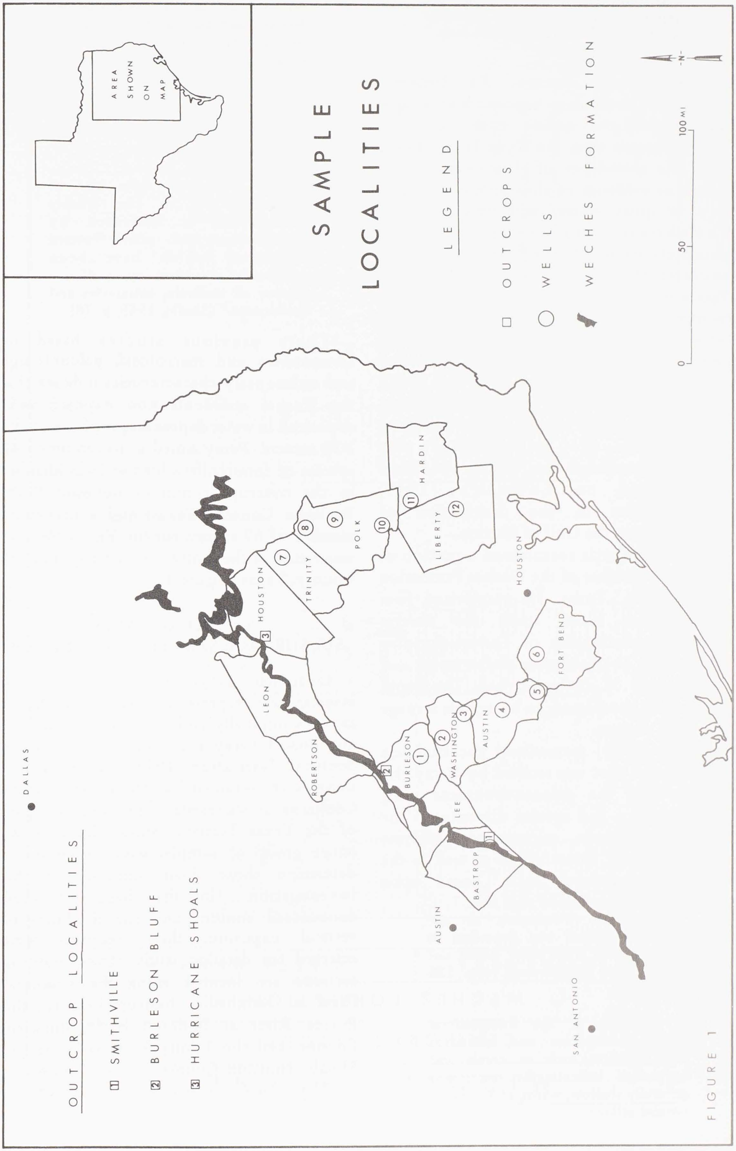
AREA SHOWN ON MAP
SAMPLE LOCALITIES
LEGEND
OUTCROPS
WELLS
WECHES FORMATION
0
50
100 MI
N
OUTCROP LOCALITIES
1 SMITHVILLE
2 BURLESON BLUFF
3 HURRICANE SHOALS
DALLAS
AUSTIN
SAN ANTONIO
HOUSTON
LEON
HOUSTON
TRINITY
POLK
HARDIN
LIBERTY
ROBERTSON
BURLESON
WASHINGTON
AUSTIN
FORT BEND
LEE
BASTROP

FIGURE 1

> organisms. The Tyus sediments were deposited in water which probably was not over five to six fathoms deep." (Feray, 1948, p. 189)

The Viesca facies, he believed, represented sediments deposited at a slow rate, within the neritic zone, in water slightly deeper than the Tyus facies. Feray cited the abundance of glauconitized fecal pellets as evidence of slow accumulation of clay in quiet water, with reworking by benthonic organisms allowing glauconitization of the fecal pellets. He estimated the depth of water in which the Viesca was deposited to be 6 to 15 fathoms. However, in a concluding paragraph Feray remarked that the uniform occurrence of the foraminifera genera *Quinqueloculina* and *Triloculina* throughout the Tyus and Viesca suggests a greater depth of water, possibly to 30 fathoms. Feray's paleoecological interpretations are in agreement with Stenzel's macrofossil data (1938; 1945) and were based on Lowman's (1949) investigations of the distribution of foraminifera in the Gulf of Mexico.

In 1955, Curtis reexamined a portion of the Viesca Member of the Weches Formation at Smithville, Texas. He recognized four depth zones based upon the inverse frequency relationship of *Quinqueloculina claiborniana* to *Siphonina claibornensis* and the presence of an oyster bed. The depth zones were considered to be within a range of 1–100 meters.

Shafiq (1969) reexamined the Burleson Bluff section that was studied by Feray. He reconstructed the paleoenvironment using the abundance and species diversity of the calcareous-perforate, calcareous-imperforate and arenaceous foraminifera as well as the foraminifera/ostracoda ratio. Based upon these data, he concluded that the:

> "(7) Weches Formation at the localities studied was deposited in environments with water depth not deeper than middle shelf (app. 328 feet).
>
> (8) Presence of the foraminiferal genus *Asterigerina* and abundant filter feeders such as corals and bryozoans indicate the water was generally shallow, warm, clear, and of normal salinity.
>
> (9) Presence of clay and fine silt deposits and associated filter feeders indicate the currents were generally weak during the deposition of the Weches sediments. Well worn foraminiferal shells are the result of post-depositional chemical conditions and not physical abrasion of wave action.
>
> (10) A moderately slow rate of sedimentation in the Weches Formation is indicated by homogeneous and poorly sorted sediments which have been completely reworked by a diverse infauna of molluscs, ostracodes and crustaceans." (Shafiq, 1969, p. 78)

These previous studies based on foraminifera and macrofossil paleontology and sedimentary characteristics indicate that the Weches sediments now exposed were deposited in water depths ranging from one to 100 meters. Feray noted a maximum of 48 species of foraminifera for the Tyus Member in the outcrop section at Burleson Bluff, Burleson County, Texas; and a maximum number of 67 species for the Viesca Member was found at the Smithville outcrop, Bastrop County, Texas (Figure 1).

V. OUTCROP AND SUBSURFACE SAMPLE DESCRIPTIONS

Outcrop samples utilized in this investigation represent portions of larger samples originally collected by H. B. Stenzel and Daniel Feray and used by Feray in his doctoral dissertation (1948). These outcrop samples are retained by Amoco Production Company as standards of reference for part of the Texas Tertiary. Smear slides of the entire group of samples were examined to determine those most suitable for this investigation. On the basis of their nannofossil content and the thickness of vertical exposure, three sections were selected for detailed study. These outcrop sections are located along the Colorado River at Smithville, Bastrop County; the Brazos River at Burleson Bluff, Burleson County; and the Trinity River at Hurricane Shoals, Houston County, Texas (Figures 1, 2). These localities bear the following Texas Bureau of Economic Geology locality

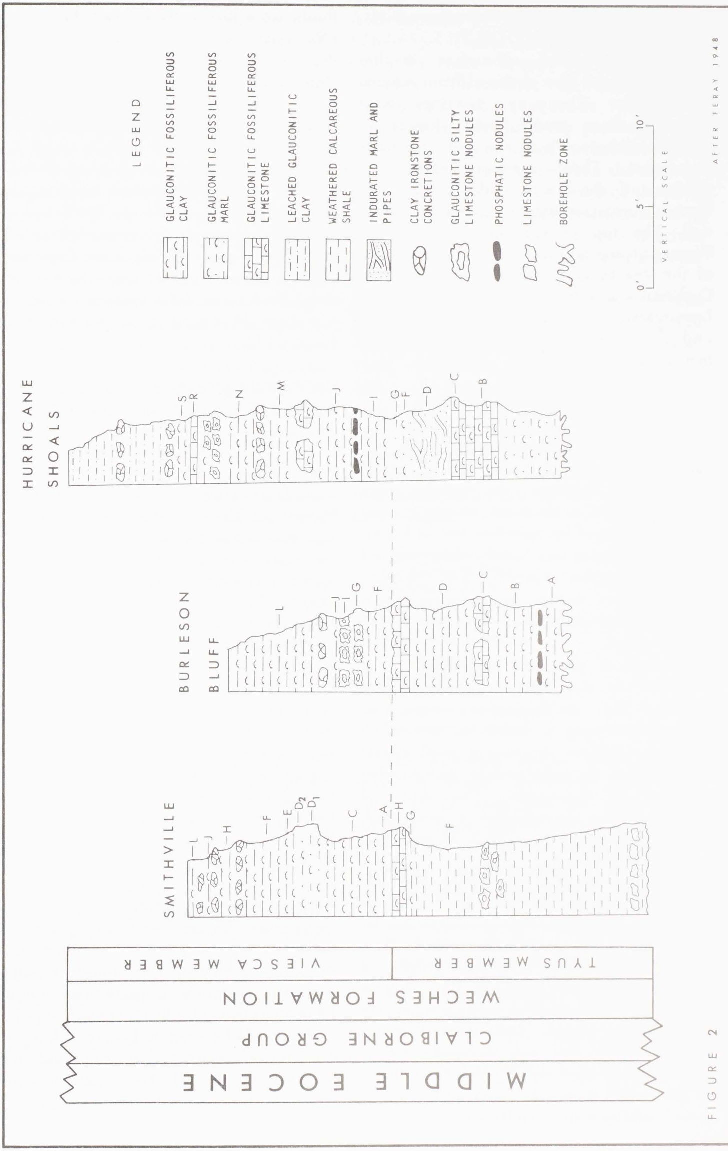
STRATIGRAPHIC SECTION
SMITHVILLE
BURLESON BLUFF
HURRICANE SHOALS
LEGEND
GLAUCONITIC FOSSILIFEROUS CLAY
GLAUCONITIC FOSSILIFEROUS MARL
GLAUCONITIC FOSSILIFEROUS LIMESTONE
LEACHED GLAUCONITIC CLAY
WEATHERED CALCAREOUS SHALE
INDURATED MARL AND PIPES
CLAY IRONSTONE CONCRETIONS
GLAUCONITIC SILTY LIMESTONE NODULES
PHOSPHATIC NODULES
LIMESTONE NODULES
BOREHOLE ZONE
0' 5' 10'
VERTICAL SCALE
AFTER FERAY 1948
MIDDLE EOCENE
CLAIBORNE GROUP
WECHES FORMATION
VIESCA MEMBER
TYUS MEMBER

FIGURE 2

numbers: Smithville, 11-T-2; Burleson Bluff, 26-T-6; Hurricane Shoals, 113-T-15.

Samples of the subsurface Weches Formation were also obtained from Amoco Production Company. Cuttings were examined from twelve wells (Figure 1) located to the south of the belt of Weches exposures. Three samples representing portions of the lower, middle and upper Weches Formation were obtained from each well. The top of the subsurface Weches Formation was recognized by the occurrence of the foraminifera *Textularia smithvillensis* Cushman and Ellisor in Cushman, 1933, or *Lamarckina claibornensis* Cushman, 1929, and a down-dip equivalent, *Bifarina turriformis* Hussey, 1943.

VI. SAMPLE PREPARATION

A five gram portion of each sample was placed in 50 ml of distilled water. After standing for an hour, the samples were disaggregated in an ultrasonic cleaner for one minute, followed by agitation for 24 hours. Outcrop material was loosely disaggregated in less than five minutes. Well cuttings, however, were mainly well-indurated shale chips requiring much more time for disaggregation.

Portions of the final suspension to be examined in the light microscope were obtained by shaking the sample jar vigorously, letting it stand for ten to 15 seconds, and then touching a small plastic soda straw to the water surface, withdrawing a drop of suspension. The drop of suspension was spread over a cover slip, dried and cemented to a 25 X 75 mm glass microscope slide.

Specimens to be examined in the SEM were prepared as follows: A droplet of suspension was withdrawn from the 50 ml sample jar in the same manner as if a glass slide were being prepared. This droplet of suspension was then placed in a watch glass and diluted with distilled water until it was only slightly turbid. A 12 mm diameter circular cover slip was covered with a cushion of distilled water. One to two drops of the turbid suspension were added to the water cushion with a capillary tube. The two fluids were mixed by blowing through the tube onto the liquid-covered surface. The dried cover slips were placed on standard aluminum SEM specimen studs, circled with Elmer's glue, dried, coated with chromium in a vacuum evaporator, and viewed in the SEM.

A technique for transferring specimens observed and photographed with the light microscope to the SEM was perfected near the conclusion of this investigation. The technique involves circling located specimens on the circular cover slip which is then transferred to an SEM specimen stud. This technique is described in Sherwood and Levin, 1973.

VII. BIOSTRATIGRAPHIC RESULTS AND PALEOECOLOGICAL INTERPRETATIONS

Eighty previously described species representing 25 genera of calcareous nannofossils were identified from the Weches Formation. The relative abundance of species was determined by counting 200 specimens per slide and the results of the counts recorded as a percentage on the distribution chart (Table 1). Outcrop samples are indicated by the letter designations used on the stratigraphic sections, and well samples are indicated by their depth in feet below sea level.

A prominent limestone bed at both Burleson Bluff and Smithville was used to accurately combine outcrop sections containing the best flora into a composite stratigraphic section. Gartner's (1971) *Discoaster tani* s.l.–*Sphenolithus radians* Zone, *Reticulofenestra umbilica*–*Sphenolithus furcatolithoides* Zone, *Pemma papillatum* Zone, *Reticulofenestra* Datum and *Discoaster saipanensis* Datum were recognized and delineated within the composite stratigraphic section. The composite outcrop section is assignable to nannofossil zones NP 13 (upper) through NP 16 of Martini (1971).

As would be expected in an onlap-offlap depositional system, younger and older portions of the Weches Formation were found in downdip subsurface samples. The older portion of the formation is assignable to Gartner's *Discoaster lodoensis* Zone and *Discoaster sublodoensis* Zone. The younger portion, indicated by the occurrence of *Chiasmolithus oamaruensis,* would have to be at least as young as the lower portion of Gartner's *Hayella situliformis* Zone. The older subsurface sediments can be assigned to the upper portion of NP 12 and NP 13 (lower). The younger subsurface sediments are assignable to Martini's NP 18.

Martini (1971) and Gartner (1971) assign somewhat different total ranges to particular Eocene guide nannofossils. As a result, age assignment of parts of the Weches differ, depending upon which scheme of zonation is utilized. The age assignment of samples in the composite stratigraphic section is based upon the first occurrences of age diagnostic species within each sample (Figure 3). The ranges of diagnostic species used in determining the age of samples are those of Gartner (1971).

Two zones indicated by Gartner as indicative of the middle Eocene (*Bramletteius serraculoides* and *Chiphragmalithus quadratus* Zones) were not found in either the surface or subsurface sections of the Weches Formation. The *Bramletteius serraculoides* Zone should have occurred between the *Pemma papillatum* Zone and *Discoaster saipanensis* Datum. The *Chiphragmalithus quadratus* Zone should have occurred between the *Discoaster tani* s.1.–*Sphenolithus radians* Zone and the *Discoaster sublodoensis* Zone.

The absence of *Bramletteius serraculoides* may be due to the preference of this species for an open-ocean paleoenvironment. Gartner (1971, p. 104) has reported the occurrence of *Bramletteius serraculoides* in pelagic oozes, and noted that it is only rarely encountered in hemipelagic sediments. The absence of the *Chiphragmalithus quadratus* Zone may be attributed either to this species preference for an open-ocean paleoenvironment, or its lack of preservation in the Weches. Erosion or nondeposition of Weches sediments representing these intervals of time may also account for the absence of these species.

The assemblage of nannofossils observed in the subsurface samples contained 13 of the 20 species suggested as indicators of shelf deposits by Bukry *et al.* (1971, pp. 1264-65). Twelve of these 20 shelf indicators were found in the outcrop samples. Therefore, all samples are considered to represent the shelf environment. The down-dip position of the subsurface samples indicates that they were deposited in deeper water than the outcrop sections whereas the occurrence of the shelf assemblage of nannofossils restricts them to the neritic environment. Thus the subsurface samples are considered to represent a deeper (outer neritic) paleoenvironment.

Variations in the occurrence and abundance of species between outcrop and subsurface samples were found to exist. These variations may be the result of differential preservation or the result of living species being restricted to particular areas of the neritic environment. The following species were found only in the subsurface portion of the Weches and are considered indicators of the outer neritic environment.

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Braarudosphaera discula
Micrantholithus flos
Micrantholithus ornatus
Helicopontosphaera lophota
Rhabdolithes rudis
Discoaster stella
Discoaster barbadiensis
Discoaster saipanensis
Discoaster tani nodifer

Lophodolithus rotundus and *Marthasterites furcatus* occurred exclusively in outcrop samples. *Chiasmolithus bidens, Blackites amplus* and *Trochoaster simplex* occurred several times in outcrop samples but each is found only once in the subsurface. These five species are considered indicative of the middle to inner neritic environment. *Cyclococcolithina formosa, Cruciplacolithus staurion,* and *Zygrhablithus bijugatus* occurred in both subsurface and surface samples but were generally present in greater abundance in subsurface samples. *Ericsonia muiri, Reticulofenestra coenura, Koczyia wechesensis, Transversopontis pulchriporus, Blackites tenuis,* and *Discoaster elegans* were present in greater abundance in outcrop samples.

The abundant occurrence of the holococcolith *Zygrhablithus bijugatus* in the slowly deposited, reworked (bioturbated) sediments of the Weches Formation suggests that the occurrence of this species in shelf environments is not necessarily a preservation artifact as suggested by Gartner and Bukry (1969). The occurrence of *Zygrhablithus bijugatus* as well as the observed lateral variations within the coccolith population may reflect a preference for nutrients provided by ocean currents, upwelling or other currently unrecognized causative factors. However, the absence of the holococcoliths *Lanternithus minutus* (*Reticulofenestra umbilica Sphenolithus furcatolithoides* Zone) and *Daktylethra punctulata* (*Pemma papillatum* Zone), reported in the Eocene Lisbon Formation of Alabama (Gartner and Bukry, 1969) may mean that *Zygrhablithus bijugatus* is just more resistant to destruction than *Lanternithus minutus* and *Daktylethra punctulata.*

The presence of several species within the Weches Formation requires the extension of their first occurrence backward in time. *Blackites amplus* was previously known from the upper Eocene and lower Oligocene, and *Cruciplacolithus tenuiforatus* was known only from the Oligocene and Miocene of North Africa and Europe prior to their discovery in the early middle Eocene portion of the Weches Formation. The presence of *Trochoaster radiatus,* previously known from Germany, marks the first occurrence of this species in North America and expands its range to include the middle and upper Eocene. The range of *Discoaster tumescens* is expanded to include the late middle Eocene to Miocene.

The ranges of *Chiasmolithus consuetus, C. solitus, C. gigas, C. expansus, C. bidens, Cruciplacolithus eminens,* and *Chiphragmalithus calathus* extended beyond their previously indicated extinction points. The upward extension of so many ranges strongly suggests reworking of these species throughout the Weches Formation probably by burrowing organisms.

The first occurrence of *Blackites amplus* near the base of the *Discoaster tani* s.l.—*Sphenolithus radians* Zone may provide an additional marker for the base of this zone. The first occurrence of *Micrantholithus ornatus* and *Discoaster tumescens* probably provide correlative horizons which are younger than but which closely approximate the *Discoaster saipanensis* Datum.

In summary, the present study supports the finer biostratigraphic divisions proposed by Gartner (1971). The stratigraphic distribution of the 80 species of nannofossils in the Weches Formation permits the recognition of five of Gartner's (1971) middle Eocene nannofossil zones and two correlative datums. In addition, the positions of two missing Eocene zones have been inferred. It is also demonstrated that variations in the distribution of calcareous nannofossils exist within the shelf environment. It is hoped that this work will encourage others to make examinations of shelf deposits for nannoplankton biofacies, and that in time assemblages indicative of discreet divisions of the shelf will be recognized and the factors controlling assemblage distribution better understood.

VIII. SYSTEMATIC PLACEMENT

Initially most paleontologists considered coccolithophorids to be animals (Protozoans) and applied rules of Zoological Nomenclature to their description and

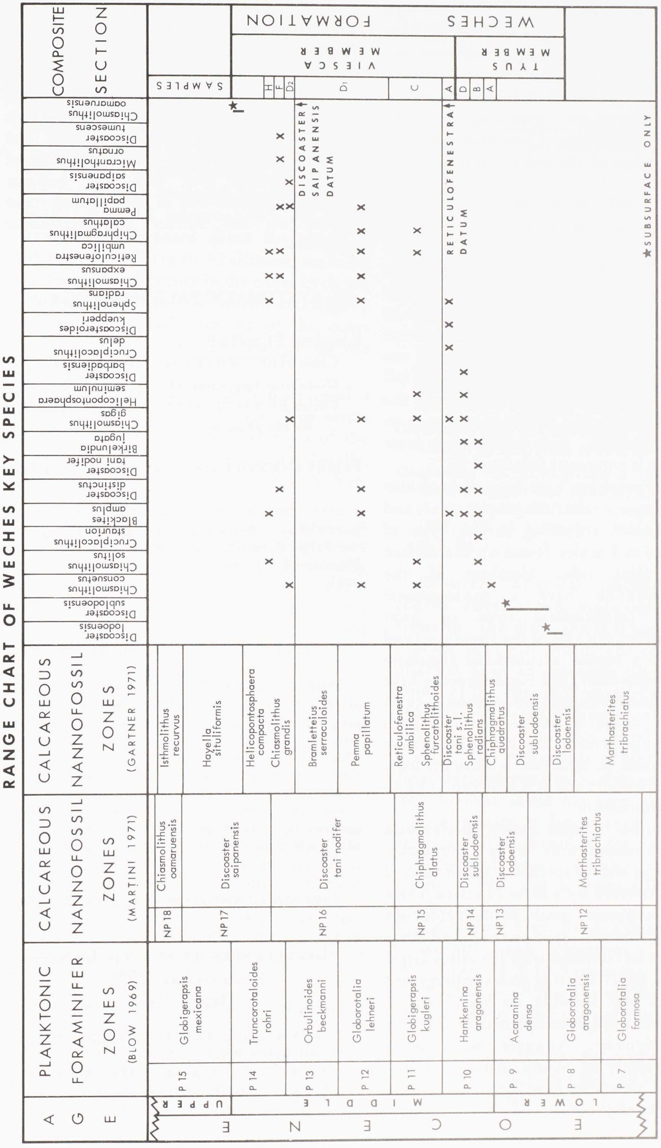
RANGE CHART OF WECHES KEY SPECIES
AGE
PLANKTONIC FORAMINIFER ZONES (BLOW 1969)
CALCAREOUS NANNOFOSSIL ZONES (MARTINI 1971)
CALCAREOUS NANNOFOSSIL ZONES (GARTNER 1971)
COMPOSITE SECTION
SAMPLES
WECHES FORMATION
VIESCA MEMBER
TYUS MEMBER
UPPER
MIDDLE
LOWER
EOCENE
P 15 Globigerapsis mexicana
P 14 Truncorotaloides rohri
P 13 Orbulinoides beckmanni
P 12 Globorotalia lehneri
P 11 Globigerapsis kugleri
P 10 Hantkenina aragonensis
P 9 Acarinina densa
P 8 Globorotalia aragonensis
P 7 Globorotalia formosa
NP 18 Chiasmolithus oamaruensis
NP 17 Discoaster saipanensis
NP 16 Discoaster tani nodifer
NP 15 Chiphragmalithus alatus
NP 14 Discoaster sublodoensis
NP 13 Discoaster lodoensis
NP 12 Marthasterites tribrachiatus
Isthmolithus recurvus
Hayella situliformis
Helicopontosphaera compacta
Chiasmolithus grandis
Bramletteius serraculoides
Pemma papillatum
Reticulofenestra umbilica
Sphenolithus furcatolithoides
Discoaster tani s.l.
Sphenolithus radians
Chiphragmalithus quadratus
Discoaster sublodoensis
Discoaster lodoensis
Marthasterites tribrachiatus
Chiasmolithus oamaruensis
Discoaster tumescens
Micrantholithus ornatus
Discoaster saipanensis
Pemma papillatum
Chiphragmalithus calathus
Reticulofenestra umbilica
Chiasmolithus expansus
Sphenolithus radians
Discoasteroides kuepperi
Cruciplacolithus delus
Discoaster barbadiensis
Helicopontosphaera seminulum
Chiasmolithus gigas
Birkelundia jugata
Discoaster tani nodifer
Discoaster distinctus
Blackites amplus
Cruciplacolithus staurion
Chiasmolithus solitus
Chiasmolithus consuetus
Discoaster sublodoensis
Discoaster lodoensis
H F D2 D1 C A D B A
DISCOASTER SAIPANENSIS DATUM
RETICULOFENESTRA DATUM
★SUBSURFACE ONLY

FIGURE 3

classification. However, within the last several years many paleontologists have accepted the fact that coccoliths are algal skeletons and applied rules of Botanical Nomenclature to their descriptions and classifications. Coccolithophores are herein assigned to the Division Chrysophyta, Class Haptophyceae and the rules of Botanical Nomenclature applied.

Species of algae assigned to the Chrysophyta are distinguished from other algae by four main features. These features are: (1) The nature of the photosynthetic pigments (Chlorophyll "a" and carotenoids); (2) variability of flagellation (uniflagelate or biflagelate); (3) the type of reserve products in the cell (oil and chrysolaminarin are present; starch is never present); (4) and cell structure (a cellulose wall is absent, the outer cell membrane shows a tendency to become silicified, and endogenous cyst production is common) (Morris, 1967).

The Chrysophyta have been divided into two classes, the Haptophyceae and Chrysophyceae, according to the type of flagellation and scales found on the surface of the algal cells. Members of the Chrysophyceae have a pantonematic flagellum (longitudinal rows of hairs arranged along the axis of the flagellum) and some have a second acronematic flagellum (smooth, whip-like). The Haptophyceae have two acronematic flagella. In addition, a third appendage called a haptonema has been observed to be present in some species of the Haptophyceae. Its structure is different from that of a flagellum and it is believed to be an organ of attachment.

Both classes of algae possess species with the cell bounded only by a cytoplasmic membrane as well as species in which the cell surface is covered by a layer of scales. These scales are extremely small, being visible only with the electron microscope, and they should not be confused with the much larger coccoliths. Species having scales impregnated with silica and showing no basic type of construction have been assigned to the class Chrysophyceae. Species with scales consisting solely of organic matter and with a uniform structure have been assigned to the class Haptophyceae.

Parke (1961) summarized the evidence indicating that coccoliths belong in the class Haptophyceae. She reported that the coccolithophorids *Cricosphaera carterae, Cricosphaera sp., Pleurochrysis scherffelii* and *Coccolithus pelagicus* possess two acronematic flagella and a haptonema. She also reported that scales consisting solely of organic matter and with the uniform structure characteristic of the Haptophyceae existed on the surface of *Coccolithus pelagicus.*

IX. SYSTEMATIC PALEONTOLOGY

Kingdom PLANTAE

Class HAPTOPHYCEAE, Christensen, 1962

Unicellular flagellates which possess a haptonema.

Order PRYMNESIALES, Christensen, 1962

Motile phase with an obvious haptonema.

Family COCCOLITHACEAE Kamptner, 1928

Description: Coccolithophores bearing placoliths, proximal shield producing an interference figure, distal shield dark or faintly illuminated in two quadrants in cross-polarized light.

Genus BIRKELUNDIA Perch-Nielsen, 1971

Description: Elliptical coccoliths with a distal shield of slightly overlapping elements with a simple basal shield. The central field can be filled, empty, or bridged. This genus is distinguished from *Chiasmolithus, Cruciplacolithus, Coccolithus,* and *Ericsonia* by having a proximal shield made of a single cycle of elements which lie next to each other. The other of the above mentioned genera contain two cycles of elements in the proximal shield which are oriented in opposite directions.

Type Species: Birkelundia arenosa Perch-Nielsen

BIRKELUNDIA JUGATA (Perch-Nielsen)
Perch-Nielsen, 1971
Plate 2, fig. 1

Tremalithus jugatus PERCH-NIELSEN, 1967, p. 28, pl. 4, figs. 6,7.

Birkelundia jugata (Perch-Nielsen). PERCH-NIELSEN, 1971a, p. 947, fig. 5; PERCH-NIELSEN, 1971b, p. 10, pl. 1, figs. 6-8;

Remarks: Elliptical placoliths showing in distal view an outer cycle of elements steeply inclined with respect to a raised ring which surrounds an open elliptical central area. The central area is spanned by a crossbar aligned parallel to the short axis of the ellipse. Below the level of the crossbar a shelf extends around the open central area. The rectangular elements of the ring are about 1.0 X 0.2 microns, with the longer axes radially disposed about the center of the coccolith. Forty to 50 elements make up the ring. The elements in the outer cycle are a little longer than one micron and slightly wedge-shaped. Each element of the outer cycle corresponds to an element of the raised ring.

Perch-Nielsen has designated as basal a view showing a convex surface. This seems unlikely because all other members of the Family Coccolithaceae are convex distally. The convex surface of this species is here considered as distal.

In distal view *Birkelundia jugata* is distinguished from *Coccolithus pelagicus* by the presence of the raised ring surrounding the central area. The cycle of elements surrounding the raised ring is more steeply inclined than the elements of the distal shield of *C. pelagicus*.

Hypotype: Smithville A, SEM Negative 5665; Size: 9 microns long.

Occurrence: Reported from the Eocene of Denmark.

Genus COCCOLITHUS Schwarz, 1894

Description: Elliptical placoliths, with the distal shield larger than the proximal shield. The elements of the distal shield have the crystallographic C-axes perpendicular to the plane of the shield. The observed interference figure is produced by the proximal shield and the collar. The distal shield is joined to the proximal shield by a hollow tube, and both shields are concave on their proximal sides.

Type Species: Coccolithus oceanicus Schwarz.

COCCOLITHUS EOPELAGICUS
(Bramlette and Riedel)
Bramlette and Sullivan, 1961
Plate 1, figs. 1, 2

"Coccolithus" JUKES-BROWN and HARRISON, 1892, p. 178, fig. 8.

Tremalithus eopelagicus BRAMLETTE and RIEDEL, 1954, p. 392, pl. 38, fig. 2;

Coccolithus eopelagicus (Bramlette and Riedel). BRAMLETTE and SULLIVAN, 1961, p. 141; STRADNER, 1962, p. 178; STRADNER, 1964, p. 134, text-figs. 1-2; HAY, MOHLER and WADE, 1966, p. 385, pl. 1, fig. 1; EDWARDS, 1966, p. 485, figs. 8, 11; HAQ, 1966, p. 29, pl. 1, fig. 4; pl. 1, fig. 4; pl. 5, fig. 6; BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 6–8; REINHARDT, 1967, p. 204, pl. 1, figs. 1, 2, 5, 6 *non* fig. 19; pl. 4, figs. 3, 6, 10; *non* pl. 5, figs. 1–4; *non* pl. 6, fig. 7; *non* text-figs. 3, 4; STRADNER and EDWARDS, 1968, p. 15, pl. 6, figs. 1–4; RADOMSKI, 1968, p. 564, pl. 45, figs. 5, 6; BILGÜTAY, JAFAR, STRADNER, and SZÖTS, 1969, p. 174, pl. 2, figs. 1, 2; MARTINI, 1969b, p. 131; GARTNER, 1971, figs. 4, 5.

Coccolithus aff. *C. eopelagicus* (Bramlette and Riedel). LEVIN, 1965, p. 266, pl. 41, fig. 4.

Coccolithus cf. C. *eopelagicus* (Bramlette and Riedel). LEVIN and JOERGER, 1967, p. 165, pl. 1, fig. 2; ACHUTHAN and STRADNER, 1969, p. 4, pl. 1, figs. 5–7; HAQ, 1971d, p. 19, pl. 2, fig. 7.

Remarks: Elliptical placolith with a convex distal shield made up of 50–60 elements. The distal shield is larger than the concave proximal shield. The center of this placolith bears an enlongate slit which often produces the optical illusion of two holes or depressions located at the ends of the slit.

The sutures on the distal shield are straight. The outer cycle of elements in the distal shield shows low birefringence whereas the proximal shield has high birefringence.

This species is larger than *Coccolithus pelagicus*. The central slot is generally broader and more circular than in *C. pelagicus*. The slot is more elliptical than that in *C. sarsiae*.

Hypotype: Fort Bend County 6, 9490, Photomicrograph Negatives 23-20 and 23-21; Size: 14 X 12.5 microns.

Occurrence: Known from the Paleocene to Holocene in many parts of the world.

COCCOLITHUS PELAGICUS
(Wallich) Schiller, 1930
Plate 1, figs. 3, 4
Plate 2, fig. 2

Coccosphaera pelagica WALLICH, 1877, p. 348, figs. 1, 2, 5, 11, 12.

Coccolithus pelagicus (Wallich). SCHILLER, 1930, p. 246, figs. 123, 124; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 151, pl. 8, figs. 8–11; KAMPTNER, 1954, p. 20, figs. 14, 15; MANIVIT, 1961, p. 347, pl. 2, figs. 1–3; NARASIMHAN, 1961, p. 119, pl. 4, fig. 17; pl. 8, fig. 12; MARTINI and BRAMLETTE, 1963, p. 849; BLACK, 1963, p. 44, pl. 1, fig. 7; COHEN, 1965a, p. 12, pl. 1, figs. a–c; MARTINI, 1965, p. 402, pl. 34, figs. 1–3; HAQ, 1966, p. 31, pl. 1, fig. 5; BRAMLETTE and WILCOXON, 1967, p. 102, pl. 3, figs. 3–5; LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 4a,b; 5; MCINTYRE and BÉ, 1967, p. 569, pl. 8, figs. A–C; MCINTYRE, BÉ, and PREIKSTAS, 1967, p. 11, pl. 4, fig. A–B; REINHARDT, 1967, p. 204, pl. 1, fig. 19; pl. 4, figs. 5, 6, 10; pl. 5, figs. 1, 3; text-figs. 3, 4; RADOMSKI, 1968, p. 566, pl. 43, figs. 3, 4; BOUDREAUX and HAY, 1969, p. 256, pl. 1, figs. 1–9; CLOCCHIATTI, 1969, p. 79, pl. 3, figs. 6a, b; MARTINI, 1969a, p. 286, pl. 26, figs. 1, 2; MARTINI, 1969b, p. 131; BUKRY, 1971a, p. 965, pl. 1, figs. 1, 2. CLOCCHIATTI, 1971, p. 26, pl. 1, figs. 1–5; pl. 2, figs. 1–5; text-figs. 3, 4; PERCH-NIELSEN, 1971a, p. 947, fig. 5.

Coccolithus cf. *C. pelagicus* BOUCHÉ, 1962, p. 83, pl. 1, figs. 12, 13, 24.

Remarks: Elliptical placoliths with a convex distal shield connected to a smaller concave proximal shield. The distal shield consists of 35–45 elements redially disposed about the central area. The central area is smooth showing no striae. It contains an elliptical opening spanned by a crossbar on the proximal shield which is aligned with the short axis of the ellipse. The crossbar is not always present. The C-axis of the elements in the distal shield is oriented nearly perpendicular to the plane of the shield. This results in low birefringence seen in the distal shields. Sutures may be seen to curve counterclockwise near the periphery of the distal shield.

The central area makes up a smaller portion of the distal shield in this species than in *Coccolithus eopelagicus*. *C. eopelagicus* is more circular than *C. pelagicus*. Both species show low birefringence in the outer cycle of elements and high birefringence in the central area.

Hypotypes: Hurricane Shoals M (26.3; 68.0); W.U.M.C. 000204; Size: 15 X 12.5 microns. Smithville A , SEM Negative 4871; Size: 7 X 5 microns.

Occurrence : World-wide throughout the Cenozoic with greatest abundance in the upper Cenozoic.

COCCOLITHUS SARSIAE Black, 1962
Plate 1, figs. 5, 6, 7
Plate 2, fig. 3

Coccolithus sarsiae BLACK, 1962, p. 125, pl. 8, fig. 2; pl. 9, figs. 2–6; HAY, MOHLER and WADE, 1966, pl. 1, figs. 2–5; CLOCCHIATTI, 1971, p. 31, pl. 3, fig. 2.

Coccolithus sp. cf. *C. sarsiae* BLACK, pl. 451, fig. 6.

Coccolithus pelagicus REINHARDT, 1967, p. 204, pl. 5, figs. 2, 4; pl. 6, fig. 7.

Remarks: Elliptical placoliths with 36–45 radially arranged elements in the outer cycle of the distal shield. The central area is composed of granular elements and occupies less than one-half the width of the distal shield. An elliptical opening perforates the central area. The convex distal shield is larger than the concave proximal shield. The distal shield shows low birefringence in cross-polarized light.

The central area of this species is more prominent in phase-contrast illumination than the central areas of *C. pelagicus* or *C. eopelagicus*. The ends of the elliptical central perforation are rounded, giving it a slit-like appearance. The figured specimens of *C. pelagicus* from Reinhardt (1967), have been referred to this taxon on the basis of a similar number of elements in the distal shield.

Hypotypes: Smithville A (10.7; 76.7), W.U.M.C. 000205; Size: 10X 7.5 microns. SEM Negative 5693; Size: 8.2 x 7.8 microns.

Occurrence: This species has been reported from the upper Eocene of Nal'chik Southwestern U.S.S.R.; a Tertiary outcrop on the continental slope off Brittany; and the Oligocene of Odder, Denmark.

COCCOLITHUS sp.

Remarks: Placoliths in the size range of 5–8 microns which could not be assigned to other taxa of this genus have been placed here. These specimens may be round, subcircular, or elliptical and differ from the identified species of this genus in the size and shape of their central area, the width of the outer cycle of elements in the distal shield or in the nature of their interference pattern. This entry is made to provide a quantitative evaluation of forms not assignable to described species of this genus.

Genus CHIASMOLITHUS
Hay, Mohler, and Wade, 1966

Description: Placoliths with a prominent central opening spanned by an X-shaped structure. Distal rim wider than proximal rim.

Type Species: Chiasmolithus oamaruensis (Deflandre) Hay, Mohler and Wade.

CHIASMOLITHUS BIDENS
(Bramlette and Sullivan)
Hay and Mohler, 1967
Plate 1, figs. 8, 9, 10
Plate 2, figs. 4, 5

Coccolithus bidens BRAMLETTE AND SULLIVAN, 1961, p. 139, pl. 1, fig. 1; SULLIVAN, 1964, p. 180, pl. 1, fig. 10; SULLIVAN, 1965, p. 131; EDWARDS, 1966, figs. 2, 5.

Chiasmolithus bidens (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1526, pl. 196, figs. 23–25; *non* figs. 14, 15, 16; pl. 197, figs. 4, 9, 14; RADOMSKI, 1968, p. 558, pl. 44, figs. 5, 6; GARTNER, 1970, p. 941, fig. 7; GARTNER, 1971, figs. 3–5; HAQ, 1971a, p. 15, pl. 3, fig. 3; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Remarks: Elliptical placoliths with a steeply slanting, narrow outer cycle of approximately 60 elements and a wider smooth inner cycle of elements on the distal shield. The distal shield is larger than the proximal shield and has a large central opening spanned by a modified X-shaped crossbar. The crossbar shows an axial line in transmitted light and in cross-polarized light. The distal surface of the crossbar is made up of calcite laths with their long axes aligned parallel to the axis of the crossbar segments. The crossbar consists of one nearly straight segment abutted by two shorter segments.

SEM micrographs show the proximal disc to be smoothly textured. However, the surface of the tube which joins the proximal and distal discs is lined with a reticulate network of calcite elements. This network of calcite elements extends upward onto the underside of the distal disc covering the proximal surface of the crossbar and the open interareas. Stefan Gartner, Jr., suggested, in his review of the manuscript, that the figured specimen is *C. solitus*.

Hypotypes: Sabine River E (23.1; 68.4), W.U.M.C. 000206; Size: 10 X 8 microns. SEM Negative 5121; Size: 10 microns longs. SEM Negative 5135; Size: 13 microns long.

Occurrence: Reported from the middle Paleocene into the lower Eocene. In the Weches Formation it was found to exist near the middle Eocene-upper Eocene boundary with *C. oamaruensis*.

CHIASMOLITHUS CONSUETUS
(Bramlette and Sullivan)
Hay and Mohler, 1967
Plate 1, figs. 11, 12
Plate 2, fig. 6

Coccolithus consuetus BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 2; BOUCHÉ, 1962, p. 83, pl. 1, fig. 18; SULLIVAN, 1964, p. 180, pl. 3, fig. 1; SULLIVAN, 1965, p. 31; REINHARDT, 1967, p. 206, pl. 2, figs. 14, 18; *non* pl. 1, figs. 12, 15, 16, 20; *non* pl. 2, figs. 13, 15, 17, 19; HAY, MOHLER and WADE, 1966, p. 388; GARTNER, 1971, figs. 1, 3–5.

Chiasmolithus consuetus (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1526, pl. 198, fig. 16; *non* pl. 196, figs. 23, 24, 25; RADOMSKI, 1968, pl. 45, figs. 11, 12; BILGÜTAY *et al.* 1969, p. 174, pl. 2, fig. 5; HAQ, 1971, p. 15, pl. 3, figs. 6, 7; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus bidens (Bramlette and Sullivan). HAY and MOHLER, 1967, pl. 196, figs. 14, 15, 17.

Chiasmolithus danicus (Brotzen). HAY and MOHLER, 1967, pl. 198, figs. 12, 13; PERCH-NIELSEN, 1971, p. 951, fig. 6.

PLATE 1

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X

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1, 2	*Coccolithus eopelagicus*(Bramlette and Riedel) Kamptner .... Distal view, from Fort Bend County 6, 9490. 1. Phase-contrast, Photomicrograph negative 23–20. 2. Between crossed-polarizers, Photomicrograph negative 23–21.	13
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11, 12	*Chiasmolithus consuetus* (Bramlette and Sullivan) Hay and Mohler .... Distal view, from Hurricane Shoals J (10.4; 71.2), W.U.M.C. 000207. 11. Phase-contrast 12. Between crossed-polarizers	15
13, 14	*Chiasmolithus expansus* (Bramlette and Sullivan) Gartner .... Distal view, from Hurricane Shoals M (24.3; 74.2), W.U.M.C. 000208. 13. Phase-contrast 14. Between crossed-polarizers	18
15, 16	*Chiasmolithus solitus* (Bramlette and Sullivan) Locker .... Distal view, from Smithville C (16.8; 75.5), W.U.M.C. 000211. 15. Phase-contrast, parallel to analyzer 16. Between crossed-polarizers	20

(continued next page)

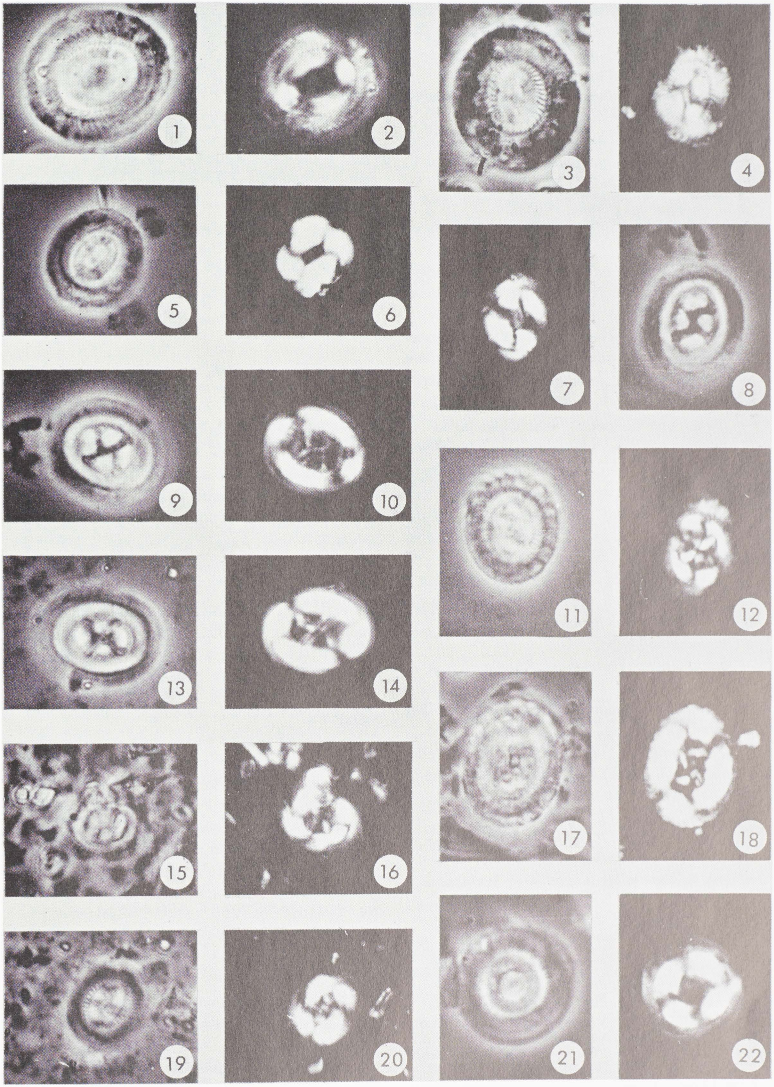

PLATE 1

17, 18 *Chiasmolithus gigas* (Bramlette and Sullivan) Gartner 19
Distal view, from Smithville D_2 (07.4; 75.3), W.U.M.C. 000209.

17. Phase-contrast
18. Between crossed-polarizers

19, 20 *Chiasmolithus titus* Gartner 20
Distal view, from Hardin County 11, 8148 (28.6; 75.0), W.U.M.C. 000212.

19. Phase-contrast
20. Between crossed-polarizers

21, 22 *Cyclococcolithina formosa* (Kamptner) Wilcoxon 24
Distal view, from Fort Bend County 6, 10180 (07.7; 73.8), W.U.M.C. 000216.

21. Phase-contrast
22. Between crossed-polarizers

Remarks: Elliptical placoliths with an X-shaped crossbar spanning and largely filling a small open central area. The distal shield has a wide, steeply sloping outer cycle of 38–42 tabular elements. The sutures between elements are directed radially from the center of the placolith. The inner cycle of elements around the central opening is quite narrow. The crossbar shows no axial lines in transmitted light or in cross-polarized light.

Hypotypes: Hurricane Shoals J (10.4; 71.2), W.U.M.C. 000207; Size: 10 X 9 microns. Fort Bend County 6,9490, SEM negative 5795; Size: 9 X 7.5 microns.

Occurrence: Reported from the Paleocene (Danian) to the middle Eocene of various parts of the world.

CHIASMOLITHUS EXPANSUS
(Bramlette and Sullivan)
Gartner, 1970
Plate 1, figs. 13, 14

Coccolithus expansus BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 5; SULLIVAN, 1965, p. 32, pl. 2, fig. 5; HAY, MOHLER and WADE, 1966, p. 388.

Chiasmolithus expansus (Bramlette and Sullivan). GARTNER, 1970, p. 943, fig. 11–1, 2; GARTNER, 1971, figs. 4, 5; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 17, pl. 10, figs. 1–3; pl. 11, fig. 5; pl. 60, figs. 9, 10.

?Chiasmolithus aff. *C. expansus* (Bramlette and Sullivan). HAQ, 1971c, p. 109, pl. 11, figs. 10, 11.

Remarks: Elliptical placoliths with a large central opening spanned by an H-shaped crossbar. The outer and inner cycle of elements of the distal shield are relatively narrow with the outer cycle being the widest. The distal shield is larger than the proximal shield. The crossbar is arched slightly above the plane of the distal shield. In transmitted light and in cross-polarized light, an axial line is present along the crossbars.

Forms of this species encountered in the Weches Formation are somewhat smaller than those generally reported in the literature. The outer cycle of elements of the distal shield is also wider than most figured specimens. However, the shape of the crossbar and the appearance of the axial line are definitely that of *C. expansus* as figured by Gartner (1970). Stefan Gartner, Jr., suggested that the figured specimen is *C. solitus* in his review of the manuscript.

Hypotype: Hurricane Shoals M (24.3; 74.2) W.U.M.C. 000208; Size: 12 X 10 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS GIGAS
(Bramlette and Sullivan) Radomski, 1968
Plate 1, figs. 17, 18
Plate 2, fig. 7

Coccolithus gigas BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 1, fig. 6; SULLIVAN, 1965, p. 32, pl. 2, fig. 6; HAY, MOHLER, and WADE, 1966, p. 388; BYSTRICKÁ, 1969b, pl. 16, figs. 7–10.

Chiasmolithus gigas (Bramlette and Sullivan). RADOMSKI, 1968, p. 559, pl. 44, figs. 1, 2; GARTNER, 1970, p. 943, figs. 12, 13a, b, c; GARTNER, 1971, figs. 1, 4, 5; PERCH-NIELSEN, 1971a, p. 947, fig. 6; ROTH, BAUMANN, and BERTOLINO, 1971, figs. 5, 7.

Chiasmolithus cf. *C. gigas* (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, p. 17, pl. 14, fig. 7.

Remarks: Large elliptical placoliths with a modified H-shaped crossbar spanning a small open central area. The distal shield has a wide nearly flat outer cycle of 36–40 wedge-shaped elements surrounding a narrow inner cycle of 32–36 rectangular elements. The distal shield is larger than the proximal shield. The crossbar does not show an axial suture or axial line in transmitted light or in cross-polarized light, contrary to Gartner's 1970 report. SEM micrographs show the crossbar to be made of robust laths with their axes aligned parallel to the axes of the crossbar segments. Stefan Gartner, Jr., questioned the identification of this species in his review of the manuscript.

Hypotypes: Smithville D_2 (07.4; 75.3), W.U.M.C. 000209; Size: 12.5 X 10 microns. SEM negative 1; Size: 9.5 X 7.5 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

CHIASMOLITHUS GRANDIS
(Bramlette and Riedel) Radomski, 1968
Plate 3, figs. 1, 2

Coccolithus cretaceus, Arkhangelsky. DEFLANDRE *in* GRASSÉ, 1952, p. 463, text-fig. 360d.

Coccolithus grandis BRAMLETTE and RIEDEL, 1954, p. 391, pl. 38, figs. 1a–b; DEFLANDRE and FERT, 1954, p. 152, text-fig. 48; BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 2, figs. 1a–b, 2a–c, 3; NARASIMHAN, 1961, pl. 4, fig. 13; pl. 8, fig. 10; HAY, MOHLER and WADE, 1966, p. 388.

Chiasmolithus grandis (Bramlette and Riedel). RADOMSKI, 1968, p. 560, pl. 44, figs. 3, 4; BILGÜTAY *et al.*, 1969, p. 173, pl. 2, figs. 3, 4; GARTNER, 1970, p. 944, figs. 11–3, 14; GARTNER, 1971, figs. 1, 2, 4, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 18, pl. 9, figs. 1, 3; pl. 10, fig. 4; pl. 60, figs. 1, 2; ROTH, BAUMANN, BERTOLINO,1971, figs. 5, 7.

Remarks: Large elliptical placoliths with a modified H-shaped crossbar spanning a large open central area. The distal shield has a steep, slightly convex outer slope, a narrow smooth inner slope and is larger than the proximal shield. The crossbar bears an axial suture in transmitted light and has one to several closely spaced dark parallel axial lines in cross-polarized light. Tooth-like projections extend into the interareas between crossbars from the smooth inner slope of the distal shield on all specimens.

Hypotype: Smithville A (07.2; 70.1), W.U.M.C. 000210; Size: 20 X 15 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS OAMARUENSIS
(Deflandre) Hay, Mohler, and Wade, 1966
Plate 2, fig. 8

Tremalithus oamaruensis DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 154, pl. 11, fig. 22; text-figs. 72–74.

Coccolithus oamaruensis (Deflandre). LEVIN, 1965, p. 265, pl. 41, fig. 3; LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 6a–b.

Chiasmolithus oamaruensis (Deflandre). HAY, MOHLER and WADE, 1966, p. 388, pl 7, fig. 1; STRADNER and EDWARDS, 1968, p. 13, pl. 1–5; RADOMSKI, 1968, p. 560; GARTNER, 1971, figs. 4, 5; HAQ, 1971c, p. 108, pl. 11, fig. 9; pl. 12, figs. 6–9; pl. 15, fig. 6; PERCH-NIELSEN, 1971a, p. 947, fig. 6; PERCH-NIELSEN, 1971b, p. 20, pl. 14, fig. 6; pl. 60, figs. 11, 12; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5–9.

Remarks: Elliptical placoliths with a narrow, steeply sloping outer cycle of 65–75 elements. The sutures between elements are inclined slightly clockwise. The inner cycle of elements is wider and composed of indistinct crystallites which appear to be narrower than those in the outer cycle. The moderately large open central area is spanned by a nearly perfect X-shaped crossbar. The crossbar is only slightly arched and shows an axial line in transmitted light and cross-polarized light. The distal shield is larger than the proximal shield. Stefan Gartner, Jr., questioned the identification of this species in his review of the manuscript.

Hypotype: Liberty County 12, 10210, SEM negative 6482; Size: 9 X 7 microns.

Occurrence: Reported from the upper Eocene into the lower Oligocene in various parts of the world.

CHIASMOLITHUS SOLITUS
(Bramlette and Sullivan)
Locker, 1968
Plate 1, figs. 15, 16

Coccolithus solitus BRAMLETTE and SULLIVAN, 1961, p. 140, pl. 2, fig. 4; SULLIVAN, 1964, p. 181, pl. 1, fig. 13; SULLIVAN, 1965, p. 32; HAY, MOHLER and WADE, 1966, p. 388; RADOMSKI, 1968, p. 560, pl. 45, figs. 13, 14; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus solitus (Bramlette and Sullivan). LOCKER, 1968, pp. 221, 222, 227, pl. 1, figs. 5, 6; PERCH-NIELSEN, 1971b, pl. 11, fig. 1; pl. 12, figs. 1-5; pl. 13, fig. 5; pl. 14, fig. 11; pl. 60, figs. 19, 20.

Remarks: Elliptical placoliths with the outer and inner cycle of elements in the distal shield nearly equal in width. The large open central area is spanned by a delicate X-shaped crossbar. The crossbar does not always bear an axial line in transmitted light or in cross-polarized light.

This species is variable in its appearance. In some forms the outer cycle of elements is wider than the inner cycle and vice versa. The crossbar generally formed a nearly perfect "X" but sometimes two shorter segments are offset along one long straight segment. The forms encountered in the Weches Formation ranged between those figured by Bramlette and Sullivan (1961) and Gartner (1970).

Hypotype: Smithville C (16.8; 75.5), W.U.M.C. 000211; Size: 14 X 9.5 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

CHIASMOLITHUS TITUS
Gartner, 1970
Plate 1, figs. 19, 20

Coccolithus consuetus Bramlette and Sullivan. LEVIN and JOERGER, 1967, p. 164, pl. 1, figs. 1a–b; *non* BRAMLETTE and SULLIVAN, 1961; PERCH-NIELSEN, 1971a, p. 947, fig. 6.

Chiasmolithus titus GARTNER, 1970, p. 945, fig. 17; GARTNER, 1971, figs. 1, 4, 5.

Remarks: Elliptical placoliths with the outer cycle of elements of the distal shield wider than the inner cycle. A small central opening is present in the distal shield and is spanned by an X-shaped crossbar. One segment of the crossbar is straight; the other S-shaped. The ends of the "S" are parallel to the short axis of the ellipse whereas the middle is parallel to the long axis. The crossbar does not bear an axial line in transmitted light or in cross-polarized light.

The S-shaped crossbar is distinctive and is the sole consistent distinguishing feature of this species.

Hypotype: Hardin County 11, 8148 (28.6; 75.0), W.U.M.C. 000212; Size: 9 X 7 microns.

Occurrence: Reported from the middle and upper Eocene of the Gulf Coast area of the United States, where it is particularly well developed in the Shubuta Member of the Yazoo Clay in Mississippi and the Lisbon Formation at Little Stave Creek, Alabama.

Genus CRUCIPLACOLITHUS
Hay and Mohler, 1967
Synonym: Crucilithus
Stradner, 1968.

Description: Concave elliptical placoliths with a central cross, having arms oriented in the major and minor axes of the open elliptical central area.

Type Species: Cruciplacolithus tenuis (Stradner) Hay and Mohler.

CRUCIPLACOLITHUS DELUS (Bramlette and Sullivan) Perch-Nielsen, 1971
Plate 3, figs. 7–10
Plate 2, figs. 9, 10

Coccolithites delus BRAMLETTE and SULLIVAN, 1961, p. 151, pl. 7, figs. 1,2; SULLIVAN, 1964, p. 180, pl. 1, figs. 8, 9; SULLIVAN, 1965, p. 31.

Cyathosphaera crux (Deflandre). HAY and TOWE, 1962, p. 507, pl. 2, fig. 1.

Coccolithus delus (Bramlette and Sullivan). PERCH-NIELSEN, 1967, p. 22, pl. 1, figs. 1–3.

Campylosphaera dela (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1531, pl. 198, fig. 14; BUKRY and KENNEDY, 1969, fig. 3, no. 1; GARTNER, 1971, figs. 3–5.

Cruciplacolithus delus (Bramlette and Sullivan). PERCH-NIELSEN, 1971a, p. 947, fig. 7; PERCH-NIELSEN, 1971b, p. 22, pl. 13, figs. 7, 8.

Remarks: Strongly arched elliptical placolith with a large open central area spanned by a crossbar. The arms of the crossbar are aligned parallel to the major and minor axes of the ellipse. The distal shield is strongly convex and only slightly larger than the proximal shield. The distal shield is composed of an outer cycle of approximately 60 dextrally imbricate tabular elements which are steeply inclined relative to the innermost cycle of elements. The nature of this inner cycle of elements could not be determined from the SEM micrographs available.

The proximal shield is strongly arched and composed of two or possibly three cycles of crystal elements. The crossbar is 0.8 microns across and is attached to the proximal shield. When viewed in transmitted light or in phase-contrast illumination the specimen appears rectangular in distal view and sub-elliptical in proximal view.

C. delus cannot be placed in the genus *Campylosphaera* because Kamptner (1963, p. 151) states in the description of this genus that "Eine proximale (basale) Randscheibe ist nicht verhanden." (A proximal basal rim disc is not present.) SEM micrographs show that a proximal shield is definitely present in this species.

The rectangular appearance, the large open central area, and the rather narrow distal shield serve to distinguish this species from other members of the genus encountered in the Weches Formation.

Hypotypes: Sabine River E (24.1; 79.4), W.U.M.C. 000213, Size: 8X 6 microns. SEM negative 6470; Size: 8.5 microns long. Austin County 5, 8968, SEM negative 5557; Size: 9.5 microns long.

Occurrence: Reported from the Paleocene to middle Eocene of California, the middle Eocene of Donzacq, France, and the lower Eocene of Pakistan.

CRUCIPLACOLITHUS EMINENS (Bramlette and Sullivan) Hay and Mohler, 1967
Plate 2, fig. 11

Coccolithus eminens BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 3; SULLIVAN, 1964, p. 181, pl. 1, figs. 11, 12; SULLIVAN, 1965, p. 31.

Cruciplacolithus eminens (Bramlette and Sullivan). HAY and MOHLER, 1967, p. 1527, pl. 196, figs. 26–28; pl. 198, figs. 9, 10.

?*Cruciplacolithus* aff. *C. eminens* (Bramlette and Sullivan). HAQ, 1971c, p. 109, pl. 20, fig. 5.

Remarks: Subcircular to elliptical placoliths, concave on the proximal side and convex on the distal side. The elements on the distal shield are strongly sloping. The central opening is large relative to the overall size of the distal shield. The proximal shield is only slightly smaller than the distal shield. The crossbar is attached to the proximal shield and is aligned with an arm parallel to each axis of the ellipse.

C. eminens is distinguished from *C. staurion* by its smaller size, from *C. tenuiforatus* by its larger central opening and from *C. delus* by being more elliptical and less strongly arched. It has been suggested that this specimen belongs in the genus *Toweius*. However, there is no evidence of a reticulate grill in the central area as is characteristic of *Toweius*.

Hypotype: Smithville D_2, SEM negative 5815; Size : 7 X 6 microns.

Occurrence: Reported from the Paleocene of California, Alabama, and France.

CRUCIPLACOLITHUS STAURION
(Bramlette and Sullivan)
Gartner, 1971
Plate 3, figs. 5, 6

Coccolithus staurion BRAMLETTE and SULLIVAN, 1961, p. 141, pl. 2, figs. 5, 6; SULLIVAN, 1964, p. 181, pl. 3, figs. 2, 3; SULLIVAN, 1965, p. 32, pl. 3, fig. 7.

Cruciplacolithus staurion PERCH-NIELSEN, 1971a, p. 947, fig. 7 (transfer invalid).

Cruciplacolithus staurion (Bramlette and Sullivan). GARTNER, 1971, p. 109, fig. 4.

Birkelundia staurion (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, p. 11, pl. 15, figs. 1, 3–6; pl. 61, figs. 16, 17.

Remarks: Large subcircular placolith with a large central opening spanned by a central cross. Approximately 60 elements, separated by straight sutures, are visible in the distal shield under phase-contrast illumination. The placolith is not strongly arched. The distal shield is larger than the proximal shield. The outer cycle of elements of the distal shield is much wider than the inner cycle.

PLATE 2

Magnification 4500 X

Figures		Page
1	*Birkelundia jugata* (Perch-Nielsen) Perch-Nielsen .... Distal view, from Smithville A, SEM negative 5665.	12
2	*Coccolithus pelagicus* (Wallich) Schiller .... Proximal view, from Smithville A, SEM negative 4871.	13
3	*Coccolithus sarsiae* Black .... Distal view, from Smithville A, SEM negative 5693.	14
4, 5	*Chiasmolithus bidens* (Bramlette and Sullivan) Hay and Mohler .... From Sabine River E. 4. Proximal view, SEM negative 5121. 5. Distal view, SEM negative 5135.	15
6	*Chiasmolithus consuetus* (Bramlette and Sullivan) Hay and Mohler .... Distal view, from Fort Bend County 6, 9490, SEM negative 5795.	15
7	*Chiasmolithus gigas* (Bramlette and Sullivan) Gartner .... Distal view, from Smithville D_2, SEM negative 1.	19
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9, 10	*Cruciplacolithus delus* (Bramlette and Sullivan) Perch-Nielsen .... 9. Proximal view, from Austin County 5, 8968, SEM negative 5557. 10. Distal view, from Sabine River E, SEM negative 6470.	21
11	*Cruciplacolithus eminens* (Bramlette and Sullivan) Hay and Mohler .... Proximal view, from Smithville D_2, SEM negative 5815.	21

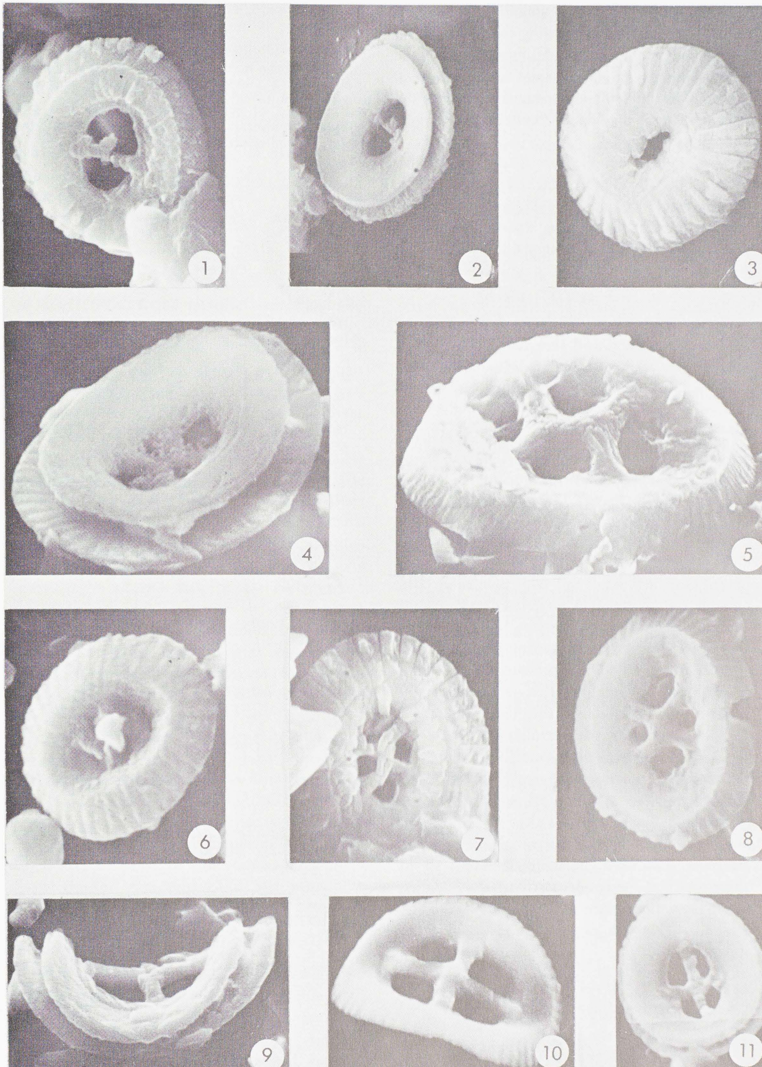

PLATE 2

This species is distinguished by its large size and large central opening from the other members of this genus. However, many of the individuals of this species range down to 10 microns. These are distinguished from *C. tenuiforatus*by a wider crossbar and larger central opening.

Hypotype: Hurricane Shoals 205 M (17.9; 76.8), W.U.M.C. 000214; Size: 18.5 X 15 microns.

Occurrence: Reported from the lower and middle Eocene of California.

CRUCIPLACOLITHUS TENUIFORATUS
Clocchiatti and Jerkovic, 1970
Plate 3, figs. 17, 18
Plate 4, fig. 1

Cruciplacolithus tenuiforatus CLOCCHIATTI and JERKOVIĆ, 1970, p. 2, pl. 1, figs. 1–3; pl. 2, figs. 1–6; CLOCCHIATTI, 1971, p. 31, pl. 7, figs. 2–4; HAQ, 1971b, p. 80, pl. 10; fig. 11; HAQ, 1971c, p. 109, pl. 15, figs. 1, ?2, 5; PERCH-NIELSEN, 1971 a, p. 947, fig. 5.

Remarks: Subcircular to elliptical placoliths, concave on the proximal and convex on the distal side with a small central opening similar in size to that of *Coccolithus pelagicus.* The central opening is spanned by a cross attached to the proximal end of the central tube. The placolith is not strongly arched but elements of the distal shield are steeply inclined to the periphery.

This species is distinguished from *C. staurion* by its smaller overall size (9 X 10 microns versus 14 X 18 microns). The general size is the same as that of *C. eminens* but the central opening is much larger in *C. eminens.* The width of the crossbars is about the same in *C. eminens* and *C. tenuiforatus,* being less than 0.5 micron. In *C. staurion* and *C. delus* the crossbar is closer to 0.8 micron wide.

Hypotypes: Hurricane Shoals 205 M (21.95; 74.35), W.U.M.C. 000215; Size: 9 X 10 microns. Smithville D_2, SEM negative 5818; Size: 9 X 10 microns.

Occurrence: Reported from the upper Miocene in Yogoslavia and Algeria and the Oligocene of Syria and Western Germany

Genus CYCLOCOCCOLITHINA
(Kamptner)
Wilcoxon, 1970

Description: Circular placoliths having a circular central perforation.

Type Species: Cyclococcolithina leptopora (Murray and Blackman) Wilcoxon.

CYCLOCOCCOLITHINA FORMOSA
(Kamptner)
Wilcoxon, 1970
Plate 1, figs. 21, 22
Plate 4, fig. 2

Cyclococcolithus formosus KAMPTNER, 1963, p. 163, pl. 2, fig. 8, text-fig. 20; REINHARDT, 1966, p. 22, pl. 21, fig. 8; REINHARDT, 1967, p. 209, pl. 1, figs. 3, 4, 7, 8; pl. 6, figs. 3, 6; text-fig. 11; RADOMSKI, 1968, p. 568, pl. 44, figs. 7, 8; MARTINI, 1969b, p. 132, pl. 1, figs. 1, 2; ROTH, 1970, p. 854; MARTINI, 1971c, p. 743, pl. 3, figs. 1, 2; ROTH, BAUMANN, BERTOLINO, 1971, figs. 6–9.

Cyclococcolithus cf. *formosus* Kamptner. COHEN, 1965, p. 26, pl. 2, figs. a–g; *non* pl. 19, figs. c–e.

Coccolithus aff. *C. eopelagicus* (Bramlette and Riedel). LEVIN, 1965, p. 266, pl. 41, fig. 5; *non* fig. 4.

Coccolithus lusitanicus BLACK, 1964, p. 308, pl. 50, figs. 1, 2.

Cyclococcolithus lusitanicus (Black). HAY, MOHLER and WADE, 1966, p. 390, pl. 7, figs. 3–6; BRAMLETTE and WILCOXON, 1967, p. 103, pl. 3, figs. 16, 17; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 5.

Cyclococcolithus orbis GARTNER and SMITH, 1967, p. 4, pl. 4, figs. 1–3.

Umbilicosphaera formosa (Kamptner). REINHARDT *in* COHEN and REINHARDT, 1968, p. 295.

Cyclococcolithina formosa (Kamptner). WILCOXON, 1970, p. 82; GARTNER, 1971, p. 109, figs. 1, 4, 5.

Remarks: Circular placoliths with the distal shield larger than the proximal shield. Thirty-nine to 45 sinistrally imbricate elements make up the distal shield. Each element has a flat surface and terminates peripherally in a gently rounded surface. Clockwise inclined sutures are prominent near the periphery but fade closer to the central collar. The central collar consists of 20 gently tapered, radially disposed elements which widen distally. Between each of these elements are more strongly wedge-shaped elements which are from five to nine-tenths the length of the adjacent elements. The total number of elements in the central collar is usually equal to the number of elements in the distal shield. The line of contact between the central collar and the surrounding cycle of elements of the distal shield is serrated.

The diameter of the central collar is equal to about 60 percent of the diameter of the distal shield. In cross-polarized light a very distinct swastika-like interference figure is observed. The central collar appears to make up less than 50 percent of the diameter of the placolith when observed under phase contrast illumination.

Forms of this species found in the Weches Formation appear similar to Black's (1964) electronmicrographs and the light and electronmicrographs of Gartner and Smith (1967) and Hay, Mohler and Wade (1966). However, upon closer examination the imbrication of the outer cycle elements in the distal shield are seen to be sinistral, not dextral as suggested by Gartner and Smith. Nonetheless, this sinistral imbrication is in agreement with Black (1964, pl. 50, fig. 2). The sutures in the distal shield of the Weches forms are inclined clockwise as in the transmission electronmicrograph and line drawing (1967, text-fig. 11) by Reinhardt and the electronmicrographs of Hay, Mohler and Wade, whereas Black and Gartner and Smith show counterclockwise inclinations.

Despite the above differences the Weches forms are assigned to this species because of their similar size, and their appearance in phase-contrast illumination and in cross-polarized light.

Hypotypes: Fort Bend County 6, 10180 (07.7; 73.8), W.U.M.C. 000216; Size: 12 microns. Smithville A SEM negative 5612; Size: 8.2 microns.

Occurrence: Reported from the early lower Eocene to near the lower Oligocene-middle Oligocene boundary in various parts of the world.

Genus ERICSONIA
Black, 1964

Description: Elliptical to circular placoliths with a well-defined elliptical central opening. The proximal shield consists of three concentric rings of crystals that are oriented in different directions.

Type Species: Ericsonia occidentalis Black.

ERICSONIA MUIRI
(Black)
Roth, 1970
Plate 3, figs. 21, 22
Plate 4, figs. 3, 7

Coccolithus muiri BLACK, 1964, p. 309, pl. 50, figs. 3, 4; HAQ, 1966, p. 29, pl. 1, fig. 3; pl. 4, figs. 4, 5.

Coccolithus eopelagicus (Bramlette and Riedel). GARTNER and SMITH, 1967, p. 3, pl. 3, figs. 1–5.

Ericsonia ovalis BLACK, 1964, p. 312, pl. 52, figs. 5, 6; STRADNER *in* STRADNER and EDWARDS, 1968, p. 17, pls. 8, 9; HAQ, 1968a, p. 21, pl. 1, figs. 4–9; pl. 2, figs. 1–4; pl. 4, figs. 1, 2; HAQ, 1971b, p. 70, pl. 10, fig. 10; HAQ, 1971c, p. 107, pl. 13, figs. 1, 2, 11; PERCH-NIELSEN, 1971a, p. 947, fig. 5; PERCH-NIELSEN, 1971b, p. 14, pl. 1, figs. 2, 4, 5; pl. 7, fig. 7; pl. 61, figs. 22,23; RAMSAY, 1971, p. 190, pl. 3, figs. 4, 5.

Ericsonia muiri (Black). ROTH, 1970, p. 841.

Remarks: Elliptical placoliths with the distal shield larger than the proximal shield. An elliptical central opening about one-third the width of the central area is present. Thirty-five elements are present in the outer cycle of the distal shield. The proximal disc consists of three cycles of crystal elements around the large central opening.

Hypotypes: Smithville F (20.2, 75.5), W.U.M.C. 000217; Size: 8.5 X 7 microns. Smithville A SEM negative 4876; Size: 7 microns long. SEM negative 5124; Size: 8.5 microns long.

Occurrence: Reported from the middle Eocene through the Oligocene in various parts of the world.

PLATE 3

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X

(continued next page)

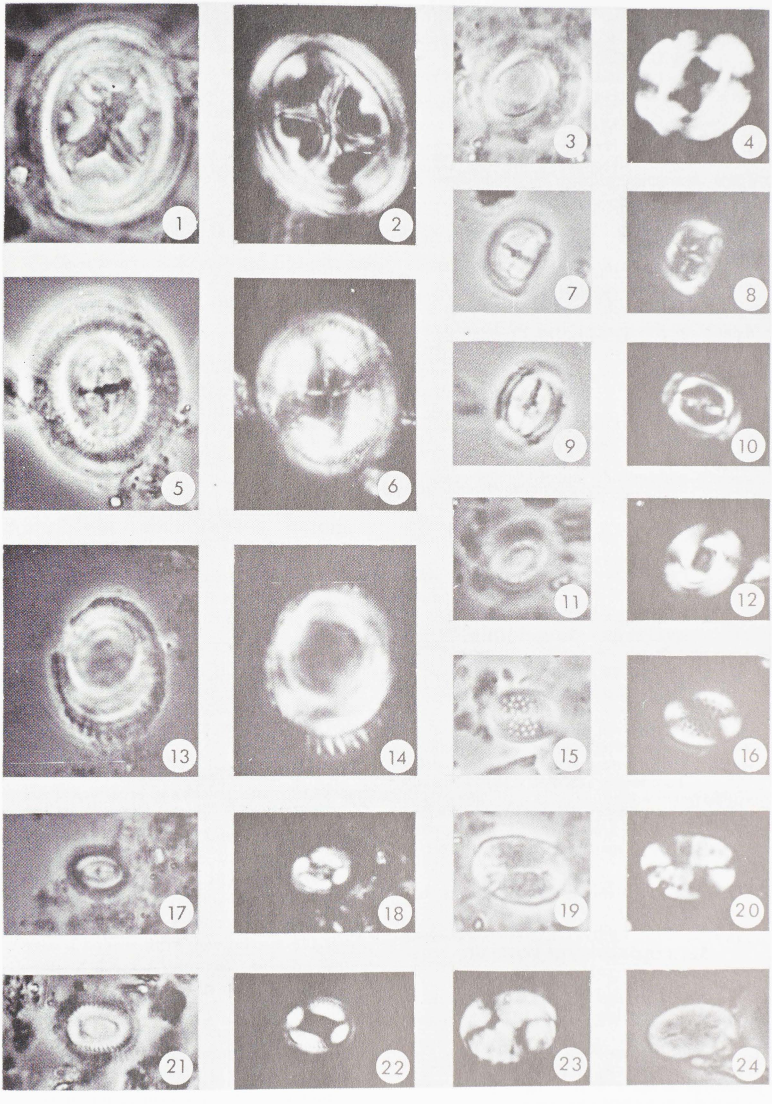

PLATE 3

15, 16 *Pontosphaera multipora* (Kamptner) Roth 30
19, 20 Parallel to analyzer. Hypotype from Fort Bend County 6, 10180 (12.0; 75.4), W.U.M.C. 000221.

15. Distal view, phase-contrast
16. Distal view, between crossed-polarizers
19. Hypotype, proximal view, phase-contrast
20. Hypotype, proximal view, between crossed-polarizers

17, 18 *Cruciplacolithus tenuiforatus* Clocchiatti and Jerković 24
Distal view, from Hurricane Shoals M (21.95; 74.35), W.U.M.C. 000215.

17. Phase-contrast
18. Between crossed-polarizers

21, 22 *Ericsonia muiri* (Black) Roth 25
Proximal view, parallel to analyzer, from Smithville F (20.2; 75.5), W.U.M.C. 000217.

21. Phase-contrast
22. Between crossed-polarizers

23 *Pontosphaera pectinata* (Bramlette and Sullivan) n. comb 30
Distal view, parallel to analyzer, between crossed-polarizers, from Polk County 10, 6880 (29.3; 75.1), W.U.M.C. 000222.

24 *Pontosphaera plana* (Bramlette and Sullivan) Haq 31
Distal view?, between crossed-polarizers, from Sabine River E (06.9; 70.8), W.U.M.C. 000223.

Genus RETICULOFENESTRA
Hay, Mohler and Wade, 1966

Synonyms: Dictyococcites
Black, 1967;
Apertapetra
Hay, Mohler and Wade, 1966.

Description: Large sub-circular to elliptical placoliths bearing a large central opening. The central opening is spanned by a reticulate net of calcite elements.

Type Species: Reticulofenestra caucasica Hay, Mohler, and Wade.

RETICULOFENESTRA COENURA
(Reinhardt)
Roth, 1970
Plate 3, figs. 11, 12

Coccolithus coenurus REINHARDT, 1966, p. 516, pl. 1, fig. 7; text-fig. 6; REINHARDT, 1967, p. 207, pl. 2, figs. 2, 6; pl. 5, fig. 5; pl. 20, fig. 3; text-fig. 7; RADOMSKI, 1968, p. 561, pl. 45, figs. 3, 4.

Reticulofenestra coenura (Reinhardt). ROTH, 1970, p. 847; HAQ, 1971b, p. 72, pl. 1, figs. 10, 11; PERCH-NIELSEN, 1971a, p. 960, fig. 15; ROTH, BAUMANN, BERTOLINO, 1971, fig. 5.

Remarks: Subcircular placoliths with a concave proximal shield and a convex distal shield. Specimens range between 7–10 microns in length and 5–7 microns in width. The outer cycle of elements of the distal shield are so small as to not be resolvable at 1000 X with the oil immersion objective. The central area consists of a very narrow (about 0.5 micron wide) rim around a large central opening. The rim is much brighter than the outer cycle of elements of the distal shield. The central opening is approximately 4 microns long and 2 microns wide. In phase-contrast illumination no structures are seen to be present in the central opening. In cross-polarized light the central rim is very bright; narrow extinction zones which widen towards the periphery of the distal shield originate here. The length and width of the distal shield and the central opening are rather variable.

Reticulofenestra coenura is smaller than *R. umbilica*. *R. pseudoumbilica* is similar to this species but is distinguished from it by having a shorter distance across the distal shield between the central opening and the periphery.

Hypotype: Smithville C (13.3; 74.7), W.U.M.C. 000218; Size: 8 X 7 microns.

Occurrence: Reported from the Eocene of Germany and the western Polish Carpathians, and the Oligocene in western Germany.

RETICULOFENESTRA UMBILICA
(Levin)
Martini and Ritzkowski, 1968
Plate 3, figs. 3, 4

Coccolithus sp. BOUCHÉ, 1962, p. 84, pl. 1, figs. 17, 21, 22.

Coccolithus pelycomorphus REINHARDT, 1967, p. 206, pl. 1, figs. 10, 11, 14; pl. 5, fig. 10; pl. 7, fig. 4.

Coccolithus umbilicus LEVIN, 1965, p. 265, pl. 41, fig. 2; MARTINI, 1967, p. 604; GARTNER and SMITH, 1967, p. 3, pl. 1, figs. 3, 4; pl. 2, figs. 1–3.

Apertapetra umbilica (Levin). LEVIN and JOERGER, 1967, p. 166, pl. 1, fig. 9; BRAMLETTE and WILCOXON, 1967, p. 101, pl. 5, figs. 1, 2.

Apertapetra samodurovi HAY, MOHLER and WADE, 1966, p. 387, pl. 6, figs. 1–5.

Reticulofenestra caucasica HAY, MOHLER and WADE, 1966, p. 386, pls. 3, 4; PERCH-NIELSEN, 1967, p. 26, pl. 1, figs. 9–11.

Reticulofenestra placomorpha STRADNER *in* STRADNER and EDWARDS, 1968, p. 22, pls. 19–21; pl. 22, fig. 1; pl. 23; pl. 24; pl. 25, figs. 1, 2; HAQ, 1968, p. 29, pl. 3, fig. 3; pl. 5, figs. 1–3.

Reticulofenestra umbilica (Levin). MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, figs. 11, 12; MARTINI, 1969, p. 137; ROTH, 1970, p. 852; GARTNER, 1971, figs. 1, 2, 4, 5; HAQ, 1971b, p. 77, pl. 7, figs. 5, 6; pl. 10, figs. 12, 13; MARTINI, 1971, p. 741, pl. 2, figs. 18, 19; PERCH-NIELSEN, 1971a, p. 960, fig. 15; PERCH-NIELSEN, 1971b, p. 30, pl. 21, fig. 7; pl. 23, figs. 1, 2; pl. 24, figs. 1–3; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5–9.

?*Reticulofenestra* cf. *R. umbilica* (Levin) Martini and Ritzkowski. HAQ, 1971c, p. 112, pl. 13, figs. 13, 14.

Remarks: Large subcircular placolith with a large central opening spanned by a reticulate network of calcite elements. The proximal shield is smaller than the distal shield. The inner cycle of elements of the distal shield is brighter than the outer cycle in phase-contrast illumination and especially in cross-polarized light. The elements of the distal shield are barely resolvable at 1000 X with the oil immersion objective. Approximately 80 elements are present in the distal shield.

Hypotype: Fort Bend County 6, 10180 (13.7; 75.5), W.U.M.C. 000219; Size: 15 X 13 microns.

Occurrence: From the middle Eocene through the middle Oligocene in various parts of the world.

Family PONTOSPHAERACEAE
Lemmermann, 1908

Description: Coccolithophores bearing shallow lopadoliths which may or many not possess central spines.

Genus LOPHODOLITHUS
Deflandre, 1954

Description: Asymmetrical ellipsoidal rim that enlarges and thickens at one end and may or may not be crossed by a bridge.

Type Species: Lophodolithus mochlophorus Deflandre.

LOPHODOLITHUS ROTUNDUS
Bukry and Percival, 1971
Plate 3, figs. 13, 14

Lophodolithus rotundus BUKRY and PERCIVAL, 1971, p. 134, pl. 5, figs. 6, 7.

Remarks: Large asymmetrical ellipsoidal lophodolith with a nearly circular central opening located near the end of the plate where the rim, or outer cycle of elements, is narrowest. The diameter of the central opening is equal to one-third to one-half the length of the long axis of the ellipse. The rim gradually widens from its narrowest point until it is two-and one-half to three times wider at the opposite end of the long axis of the ellipse. The rim consists of many fine radially disposed elements. The elements become longer and wider as the widest end of the rim is approached.

Hypotype: Hurricane Shoals J (10.3; 70.5), W.U.M.C. 000220; Size: 16 X 12 microns.

Occurrence: Reported from the middle Eocene of a South Pacific deep-sea core.

Genus PONTOSPHAERA
Lohmann, 1902

Description: Simple shallow lopadoliths (lopodolith) with a continuous elliptical wall composed of many thin imbricate laths. The height of the wall does not exceed the longest diameter of the base plate.

Type Species: Pontosphaera syracusana Lohmann.

PONTOSPHAERA MULTIPORA
(Kamptner)
Roth, 1970
Plate 3, figs. 15, 16, 19, 20
Plate 4, figs. 8, 9

Discolithus multiporus KAMPTNER, 1948, p. 5, pl. 1, fig. 9; STRADNER, 1964, p. 134, text-figs. 4–8; CLOCCHIATTI, 1971, p. 48, pl. 12, figs. 1–8, text-fig. 6.

Discolithus confossus (Hay, Mohler and Wade). CLOCCHIATTI, 1971, p. 46, pl. 11, figs. 1, 2, 4.

Discolithus crassus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 30, pl. 15, figs. 12, 13; text-fig. 49.

Discolithus distinctus BRAMLETTE and SULLIVAN, 1961, p. 141, pl. 2, figs. 8, 9; SULLIVAN, 1964, p. 182, pl. 4, fig. 4; SULLIVAN, 1965, p. 33, pl. 4, figs. 1–6; REINHARDT, 1967, p. 212, pl. 3, fig. 4.

Discolithus cf. *distinctus* COHEN, 1965a, p. 15, pl. 3, figs. r––t.

Discolithus distinctoides REINHARDT, 1967, p. 212, pl. 3, figs. 2, 3, 6.

Discolithina multipora (Kamptner). MARTINI, 1965, p. 400; HAQ, 1968, p. 36, pl. 6, figs. 4–9; STRADNER and EDWARDS, 1968, p. 35, pls. 32–35; text-fig. 7; STRADNER, 1969, p. 665, pl. 2, figs. 1, 2; pls. 3, 4; ACHUTHAN and STRADNER, 1969, p. 6; PERCH-NIELSEN, 1971b, p. 34, pl. 26, figs. 1–5.

Discolithina confossa HAY, MOHLER and WADE, 1966, p. 392, pl. 9, figs. 1–9; LOCKER, 1968, pl. 1, fig. 18.

Discolithina distincta (Bramlette and Sullivan). LEVIN and JOERGER, 1967, p. 166, pl. 1, figs. 14, 15; MARTINI, 1969b, p. 134, pl. 1, figs. 7, 8; MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, figs. 7, 8.

Discolithina sp. aff. *D. distincta* (Bramlette and Sullivan). GARTNER and SMITH, 1967, p. 5, pl. 6, figs. 4–6.

Discolithina sp. BUKRY and BRAMLETTE, 1969, pl. 6, fig. D.

Pontosphaera vadosa HAY, MOHLER and WADE, 1966, p. 391, pl. 8, fig. 4; *non* pl. 8, figs. 1–3; PERCH-NIELSEN, 1967, p. 26, pl. 2, figs. 6–9; HODSON and WEST, 1970, p. 175, pl. 4, fig. 2.

Pontosphaera multipora (Kamptner). ROTH, 1970, p. 860; HAQ, 1971a, p. 21; HAQ, 1971b, pl. 4, figs. 4–6, 8, 9; pl. 7, figs. 3, 4; pl. 14, figs. 4, 5.

Remarks: Elliptical discolith with 40–45 perforations arranged in three concentric ellipses in the base plate. An imperforate peripheral rim is attached to the edge of the base plate. The peripheral rim is two to three times higher than the thickness of the base plate. The base plate is concave proximally and convex distally. Under phase-contrast illumination the proximal surface shows the presence of rectangular laths oriented with their long axis perpendicular to the long axis of the ellipse. The distal view shows only the perforations. A longitudinal suture parallels the long axis of the ellipse and is visible from both sides of the base plate.

Hypotypes: Fort Bend County 6, 10180 (12.0; 75.4), W.U.M.C. 000221; Size: 12 X 8 microns. Fort Bend County 6,9490, SEM negative 5915; Size: 11 X 7 microns. Hurricane Shoals J, SEM negative 6437; Size: 11 X 7 microns.

Occurrence: Reported from the middle and upper Eocene to the Miocene in various parts of the world.

PONTOSPHAERA PECTINATA
(Bramlette and Sullivan)
n. comb
Plate 3, fig. 23
Plate 4, fig. 4

Discolithus pectinatus BRAMLETTE and SULLIVAN, 1961, p. 142, pl. 3, figs. 4, 5; SULLIVAN, 1964, p. 183, pl. 4, fig. 8; SULLIVAN, 1965, p. 34.

Discolithina pectinata (Bramlette and Sullivan). LEVIN, 1965, p. 266, pl. 41, fig. 8; LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 4; PERCH-NIELSEN, 1967, p. 25, pl. 2, figs. 10–12; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 6; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971b, p. 35, pl. 26, fig. 6.

Remarks: Discolith with a moderately wide rim containing 20–25 vertical ribs. The discolith is concave proximally and convex distally. The base plate has two subcircular perforations. The crossbar which separates the perforations bears a longitudinal slit. In cross-polarized light the interference isogyres look very much like a biaxial interference figure. The apices of the isogyres are located at the sites of the perforations.

The SEM micrograph shows a specimen that has some overgrowths along the rim. The overgrowths have made the vertical ribs appear shorter than those in the specimens figured by Bramlette and Sullivan (1961, pl. 3, figs. 4, 5). This species is distinguished from *P. pulchra* by having circular rather than semicircular openings in the base plate, by a longitudinal line which bisects the base plate, and by having more of the base plate visible. *Discolithina panarium* is larger and has perforations along the rim, whereas *P. pectinata* has no perforations along the rim.

Hypotypes: Polk County 10, 6880 (29.3; 75.1), W.U.M.C. 000222; Size: 9 X 7.5 microns. Sabine River E, SEM negative 6395; Size: 10.5 X 8 microns.

Occurrence: Reported from the upper Paleocene through the lower Oligocene.

PONTOSPHAERA PLANA
(Bramlette and Sullivan)
Haq, 1971
Plate 3, fig. 24
Plate 5, figs. 3, 4

Discolithus planus BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, fig. 7; SULLIVAN, 1964, p. 183, pl. 4, fig. 6; SULLIVAN, 1965, p. 34; *non* COHEN, 1965a, p. 14, pl. 2, figs. p–s; REINHARDT, 1967, p. 214, pl. 3, figs. 12, 16; text-fig. 16.

Discolithina plana (Bramlette and Sullivan). LEVIN, 1965, p. 266, pl. 41, fig. 9; LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 3; HAQ, 1967, p. 59, pl. 6, figs. 1–3; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 10; BILGÜTAY *et al.*, 1969, pl. 4, figs. 8, 9; PERCH-NIELSEN, 1971b, p. 35, pl. 29, fig. 4.

Pontosphaera plana (Bramlette and Sullivan). HAQ, 1971a, p. 22, pl. 10, fig. 1; pl. 12, fig. 6; HAQ, 1971b, p. 82; HAQ, 1971c, p. 113, pl. 11, figs. ?5-8; pl. 21, fig. 1; RAMSAY, 1971, p. 206.

Remarks: Discoliths with thick elongate elliptical base plates. The surface of the plate is smooth, bearing two slightly sigmoid slits near the ends of the long axis of the ellipse. The plate is concave proximally, convex distally and is not bordered by a rim. In cross-polarized light a biaxial interference figure is produced when the long axis of the ellipse is rotated a few degrees counterclockwise from the direction of the polarizer. When the long axis parallels the polarizer a black band cuts diagonally across the plate.

The assignment of this species to the genus *Pontosphaera* seems questionable. *Pontosphaera* contains forms with a continuous wall, a feature not present in *P. plana.* In well samples 6880 and 8365 specimens of *P. plana* were observed with a small perforation at the inner end of the sigmoid slits. However, *P. plana* does not conveniently fit into the genus *Transversopontis* because it lacks two large openings. It appears that *P. plana* should have been retained in *Discolithina.*

Hypotype: Sabine River E (06.9; 70.8), W.U.M.C. 000223; Size: 10 X 6 microns.

Occurrence: Reported from the Paleocene through the middle Oligocene in various parts of the world.

PONTOSPHAERA VERSA
(Bramlette and Sullivan)
n. comb.
Plate 5, figs. 1, 2
Plate 4, fig. 10

Discolithus versus BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 3, fig. 16; SULLIVAN, 1964, p. 183, pl. 4, fig. 11; SULLIVAN, 1965, p. 35, pl. 5, figs. 8, 9.

Discolithina sp. cf. *D. versa* (Bramlette and Sullivan). LEVIN and JOERGER, 1967, p. 168, pl. 2, fig. 11.

Remarks: Elliptical discoliths with a low, moderately wide rim enclosing the base plate. Under phase-contrast illumination the long axis of the ellipse is outlined by a narrow line, the ends of which thicken and appear as sigmoid slits. The discolith is concave proximally and convex distally. In cross-polarized light a black band cuts diagonally across the plate. SEM micrographs show that the rim is only a little thicker than the base plate. As seen from the distal side the rim and base plate appear to be constructed of rectangular crystal laths. The axes of the laths are annularly disposed. The annular arrangement of laths appears quite similar to that shown for *Pontosphaera multipora* by Stradner *in* Stradner and Edwards (1968, p. 36, fig. 7a).

The SEM and light micrographs are of the same specimen. A close systematic relationship with *Pontosphaera multipora* is suggested on the basis of the similarity of arrangement and form of the rectangular laths seen in distal view.

Hypotype: Sabine River E, SEM negative 6338; Size: 13 X 11 microns.

PLATE 4

Magnification 4500 X

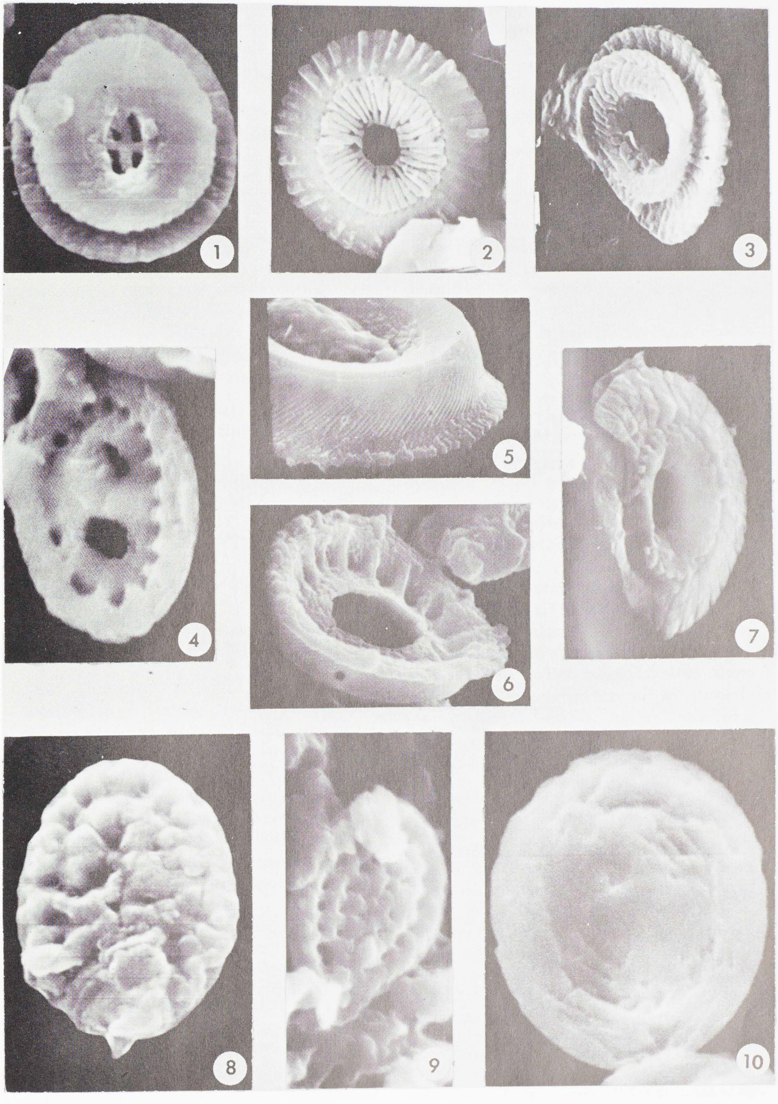

PLATE 4

Occurrence: Reported from the upper Paleocene through the lower and middle Oligocene in North America.

Genus KOCZYIA
Boudreaux and Hay, 1969

Description: Lopadoliths (lopodoliths) having a distal margin which flares outward abruptly.

Type Species: Koczyia lepida Boudreaux and Hay.

KOCZYIA WECHESENSIS
(Bukry and Percival)
n. comb.
Plate 4, figs. 5, 6
Plate 5, figs. 5, 6

?Syracosphaera wechesensis BUKRY and PERCIVAL, 1971 p. 142, pl. 7, figs. 7–10.

Discolithina amphitheatralis LEVIN and SHERWOOD, 1971, p. 731. text-fig. 1.

Koczyia excelsa PERCH-NIELSEN, 1971b, p. 37, pl. 28, figs. 1–5; pl. 60, fig. 16.

Remarks: Crown-shaped discoliths with a large central opening and a broad rim. The rim is ornamented by 19–23 elliptical depressions, each separated by a steeply inclined buttress. The outer rim is composed of approximately 150 inclined crystal laths which are covered on the proximal side by a circle of rectangular crystal elements. The elements of the rim terminate distally in an irregular flange which overhangs the periphery of the rim. In cross-polarized light a biaxial interference pattern is observed. The discolith is only slightly concave proximally and convex distally.

The photomicrographs are of topotype material for *?Syracosphaera wechesensis*, provided by David Bukry. Study of this material produced only specimens assignable to *Discolithina amphitheatralis*. The species name *wechesensis* has priority because it appeared in print three months before *D. amphitheatralis*. Transfer is made to the genus *Koczyia* because of the continuous rim of thin imbricate laths which terminate distally in a flange overhanging the rim.

Hypotype: Roberts School, San Augustine County, Texas 1 (28.9; 76.7), W.U.M.C. 000224; Size: 10 X 8 microns. Smithville A , SEM negatives 2 and 4877.

Occurrence: Reported from the lower Eocene in Denmark and the middle Eocene in Texas, Alabama and the Caucasus Mountains of the U.S.S.R.

Genus TRANSVERSOPONTIS
Hay, Mohler and Wade, 1966

Description: Shallow elliptical lopodoliths with two large openings in the ends of the ellipse separated by a central bridge.

Type Species: Transversopontis obliquipons (Deflandre) Hay, Mohler, and Wade.

TRANSVERSOPONTIS OCELLATUS
(Bramlette and Sullivan)
n. comb.
Plate 5, figs. 7, 8
Plate 6, figs. 3, 4

Discolithus ocellatus BRAMLETTE and SULLIVAN, 1961, p. 142, pl. 3, fig. 2; HAY and TOWE, 1962, p. 501, pl. 8; SULLIVAN, 1964, p. 183, pl. 4, figs. 1, 2; SULLIVAN, 1965, p. 34; REINHARDT, 1967, p. 213, pl. 3, figs. 9, 13, 17; text-fig. 15.

Discolithina ocellata (Bramlette and Sullivan). PERCH-NIELSEN, 1971b, pl. 29, fig. 6.

Crepidolithus ocellatus (Bramlette and Sullivan). RAMSAY, 1971, p. 206.

Pontosphaera ocellata (Bramlette and Sullivan). RAMSAY, 1971, p. 206.

Remarks: Elliptical discoliths with moderately thick plates and without encircling rims. SEM micrographs show the discolith to be made up of a proximal plate and a slightly larger distal plate. These two plates are welded to each other. The proximal surface is smooth and concave. The distal surface bears long thin laths which are annularly arranged. The plate is penetrated by two perforations located along the long axis of the ellipse. The perforations are separated by a moderately wide crossbar, which is interrupted near its center by a longitudinal slit. In cross-polarized light a wide extinction band cuts diagonally across the plate when the long axis is oriented parallel to the direction of the analyzer of polarizer.

It is assumed that the electron micrograph figured by Hay and Towe (1962) is a view of the proximal surface of a specimen that is better preserved than those found within the Weches Formation. Specimens did not show the high birefringence reported by Bramlette and Sullivan.

Hypotypes: Smithville A (19.4; 74.9), W.U.M.C. 000225; Size: 10 X 7.5 microns. Smithville D_1, SEM negative 5817; Size: 10 X 8 microns. Smithville A, SEM negative 5685; Size: 10 X 7.5 microns.

Occurrence: Reported from the Paleocene and Eocene in North America and the Eocene in Germany and France.

TRANSVERSOPONTIS PULCHRA
(Deflandre)
Haq, 1971
Plate 5, figs. 11, 12
Plate 6, figs. 1, 2

Discolithus pulcher DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 142, pl. 12, figs. 17, 18; BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, fig. 8; MANIVIT, 1961, p. 344, pl. 1, fig. 8; NARASIMHAN, 1961, p. 149, pl. 7, fig. 12; BOUCHÉ, 1962, p. 82, pl. 7, figs. 7, 8; text-fig. 2; SULLIVAN, 1964, p. 183, pl. 4, fig. 7; SULLIVAN, 1965, p. 34, pl. 5, REINHARDT, 1967, p. 214, pl. 3, figs. 10, 14; text-fig. 17.

Discolithina pulchra (Deflandre). LEVIN, 1965, *non* p. 266, pl. 41, fig. 6; BUKRY and KENNEDY, 1969, p. 42, fig. 3, no. 11; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 4.

Transversopontis pulcher (Deflandre). HAY, MOHLER and WADE, 1966, p. 391, (transfer invalid); PERCH-NIELSEN, 1967, p. 27, pl. 3, figs. 9–11; PERCH-NIELSEN, 1971a, p. 956, fig. 13; PERCH-NIELSEN, 1971b, p. 39, pl. 28, fig. 6; pl. 31, figs. 2, 3; pl. 32, figs. 5, 6; HAQ, 1971b, p. 85, pl. 5, figs. 10, 11; pl. 17, fig. 3.

Transversopontis pulcher (Deflandre). HAQ, 1971, p. 23.

Pontosphaera pulcher (Deflandre). RAMSAY, 1971, *non* p. 206, pl. 4, fig. 1 (transfer invalid).

Remarks: Shallow elliptical lopodoliths which are only slightly concave proximally and slightly convex distally. Proximal view of this species reveals a thin base plate surmounted by a thick layer of 150-200 imbricate laths. The rim formed by the laths flares distally and is only a little thicker than the central area. The central area of the lopodolith is perforated by two large semicircular openings separated by a transverse bar. The crossbar is inclined only slightly to the minor axis of the ellipse and is interrupted by a slit at its half-length. When viewed under phase-contrast the specimens show about 20 slots or ridges perpendicular to the periphery of the lopodolith. SEM micrographs of corroded specimens reveal the presence of tunnels beneath the base plate. These tunnels are normally covered by the imbricate rim elements. It is believed that these tunnels produce the slots or ribs observed in the light microscope.

The crossbar in this species more closely parallels the short axis of the ellipse than the crossbar in *T. pulcheroides*.

Hypotypes: Smithville D_2 (21.7; 75.4), W.U.M.C. 000226; Size: 9 X 7 microns. Smithville A, SEM negative 5658; Size: 7 X 5 microns. SEM negative 5823; Size: 8 X 6 microns.

Occurrence: Reported from the Paleocene through the Eocene in various parts of the world.

TRANSVERSOPONTIS PULCHEROIDES
(Sullivan)
Perch-Nielsen, 1971
Plate 5, figs. 15, 16

Discolithus pulcheroides SULLIVAN, 1964, p. 183, pl. 4, fig. 7; SULLIVAN, 1965, p. 34; REINHARDT, 1967, p. 214, pl. 3, fig. 18; pl. 4, fig. 5; text-fig. 18.

Discolithus aff. *D. pulcher* BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, figs. 9, 10.

Discolithina pulchra (Deflandre). LEVIN, 1965, p. 266, pl. 41, fig. 6.

Discolithina pulcheroides (Sullivan). LEVIN and JOERGER, 1967, p. 167, pl. 2, fig. 8; STRADNER and EDWARDS, 1968, p. 38, pl. 38, figs. 6–10; HAQ, 1968, p. 38, pl. 7, figs. 1–3; MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, fig. 4; RADOMSKI, 1968, p. 570; MARTINI, 1969b, p. 135, pl. 1, figs. 9–10; ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, fig. 5.

Discolithina sp. cf. *D. pulcheroides* (Sullivan). GARTNER and SMITH, 1967, p. 4, pl. 6, figs. 1–3.

PLATE 5

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X

Figures | Page

1, 2 *Pontosphaera versa* (Bramlette and Sullivan) n. comb. 31
Distal view, from Sabine River E.

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Pontosphaera plana* (Bramlette and Sullivan) Haq 31
Distal view, from Sabine River E, (06.9; 70.8), W. U. M.C. 000223.

3. 23 degrees counterclockwise from polarizer, between crossed-polarizers
4. Parallel to polarizer, between crossed-polarizers

5, 6 *Koczyia wechesensis* (Bukry and Percival) n. comb. 34
Topotype, distal view, from Roberts School, San Augustine County 1 (28.9; 76.7), W.U.M.C. 000224.

5. Phase-contrast
6. Between crossed-polarizers

7, 8 *Transversopontis ocellatus* (Bramlette and Sullivan) n. comb 34
Distal view, from Smithville A (19.4; 74.9), W.U.M.C. 000225.

7. Phase-contrast
8. Between crossed-polarizers

9, 10 *Helicopontosphaera seminulum* (Bramlette and Sullivan) Roth 39
Proximal view, from Sabine River E, Photomicrograph negatives 16–5, 16–6.

9. Phase-contrast
10. Between crossed-polarizers

11, 12 *Transversopontis pulchra* (Deflandre) Haq 35
Parallel to analyzer, from Smithville D_2 (21.7; 75.4), W.U.M.C. 000226.

11. Phase-contrast
12. Between crossed-polarizers

13, 14 *Helicopontosphaera lophota* (Bramlette and Sullivan) Perch-Nielsen 40
Distal view?, from Sabine River E, Photomicrograph negatives 18–9, 18–10.

13. Phase-contrast
14. Between crossed-polarizers

(continued next page)

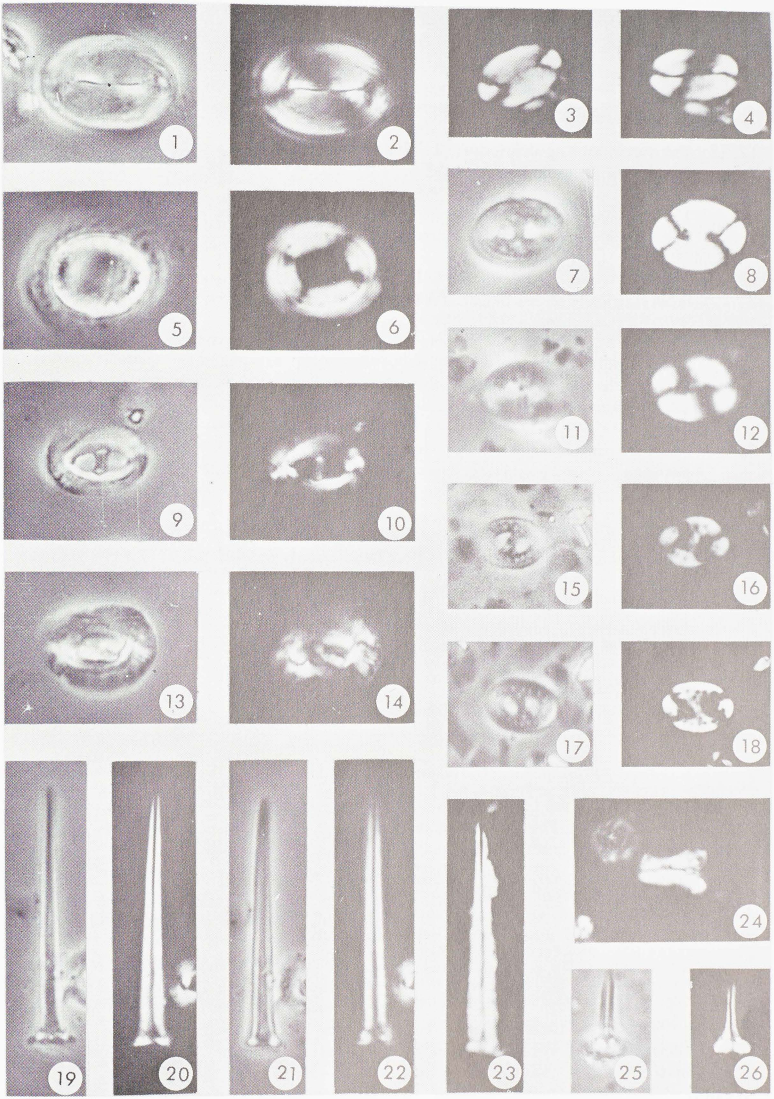

PLATE 5

15, 16 *Transversopontis pulcheroides* (Sullivan) Perch-Nielsen 35
Distal view, parallel to analyzer, from Smithville A (13.2; 75.8), W.U.M.C. 000227.

15. Phase-contrast
16. Between crossed-polarizers

17, 18 *Transversopontis pulchriporus* (Reinhardt) n. comb. 39
Distal view, from Smithville A (15.5; 74.0), W.U.M.C. 000228.

17. Phase-contrast, 20 degrees counterclockwise from polarizer
18. Between crossed-polarizers, parallel to analyzer

19–22 *Blackites tenuis* (Bramlette and Sullivan) n. comb. 42
From Hurricane Shoals M (20.3; 79.8), W.U.M.C. 000232.

19. Phase-contrast
20. Between crossed-polarizers
21. Phase-contrast, parallel to analyzer
22. Between crossed-polarizers, parallel to analyzer

23 *Blackites scabrosus* (Deflandre) Roth 41
Between crossed-polarizers, from Hurricane Shoals J (28.3; 73.7), W.U.M.C. 000237.

24 *Rhabdolithes rudis* (Bramlette and Sullivan) n. comb. 45
Between crossed-polarizers, from Fort Bend County 6, 9490 (08.2; 77.1), W.U.M.C. 000233.

25, 26 *Blackites creber* (Deflandre) n. comb. 41
Distal view, from Hurricane Shoals M. (26.2; 74.2), W.U.M.C. 000230.

25. Phase-contrast
26. Between crossed-polarizers

Transversopontis obliquipons (Deflandre). PERCH-NIELSEN, 1967, p. 27, pl. 3, figs. 6–8; HODSON and WEST, 1971, p. 174, pl. 2, fig. 4; *non* pl. 1, fig. 4; HAQ, 1971b, p. 84, pl. 7, figs. 5, 6; pl. 8, figs. 1–9; pl. 17, figs. 2, 3.

Transversopontis pulcheroides (Sullivan). PERCH-NIELSEN, 1971a, p. 360, fig. 13 (transfer invalid).

Transversopontis pulcheroides (Sullivan). PERCH-NIELSEN, 1971b, p. 40, pl. 33, figs. 3, 7.

Remarks: Elliptical discoliths with two large semicircular perforations separated by a moderately wide obliquely disposed crossbar. The imperforate crossbar is interrupted at its half-length by a slit parallel to the long axis of the ellipse. On the distal side the periphery of the discolith is made up of a band of rectangular crystal laths annularly arranged. Inside this band of crystal laths a ring of 11–15 depressions are found. No true wall surrounds the discolith, and no true perforations are observed. The discolith is concave proximally and convex distally.

The transverse central bar is more oblique than the crossbar in *T. pulchra.* In the light microscope *T. pulchra* appears to bear slots whereas *T. pulcheroides* bears circular depressions. The distance from the depressions to the periphery in *T. pulcheroides* is greater than the distance in *T. pulchriporus.*

Hypotype: Smithville A (13.2; 75.8), W.U.M.C. 000227; Size: 7 X 5 microns.

Occurrence: Reported from the Paleocene through the lower and middle Oligocene in various parts of the world.

TRANSVERSOPONTIS PULCHRIPORUS
(Reinhardt)
n. comb.
Plate 5, figs. 17, 18
Plate 6, fig. 6

Discolithus pulchriporus REINHARDT, 1967, p. 214, pl. 3, figs. 21–23; pl. 7, fig. 3.

Remarks: Elliptical discoliths gently convex distally and concave proximally. Two large semicircular perforations are located along the long axis of the ellipse. These perforations are separated by a moderately wide obliquely disposed crossbar which thins toward the center and is interrupted at its half-length by a slit. In distal view the plate is seen to be bordered by a low moderately wide rim. Between the peripheral rim and the semicircular perforations a single row of 14–18 elliptical depressions surround the discolith. At each end of the crossbar inside the row of depressions, one and sometimes two additional depressions are present. In phase-contrast and in cross-polarized light all depressions appear as perforations. The depressions are most easily seen in cross-polarized light, especially those at the end of the crossbar.

When observed in the light microscope this species is distinguished from *T. pulchra* by the presence of an oblique rather than straight bridge and by round, pore-like perforations rather than ridges or slots near the periphery of the discolith. *T. pulcheroides* does not have perforations at the ends of the crossbar as *T. pulchriporus* does. The depressions are located closer to the periphery of the discolith in *T. pulchriporus* than in *T. pulcheroides*.

Hypotypes: Smithville A (15.5; 74.0), W.U.M.C. 000228; Size: 7 X 4.5 microns. Smithville A, SEM negative 5621; Size: 6 microns long.

Occurrence: Reported from the Eocene in Germany.

Genus HELICOPONTOSPHAERA
Hay and Mohler, 1967

Description: Complex shallow lopodoliths with a spiral wall.

Type Species: Helicopontosphaera kamptneri Hay and Mohler.

HELICOPONTOSPHAERA SEMINULUM
(Bramlette and Sullivan)
Roth, 1970
Plate 5, figs. 9, 10
Plate 6, fig. 8

Helicosphaera seminulum seminulum BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 4, figs. 1, 2; HAY and TOWE, 1962, p. 512, pl. 1, figs. 1–3; 5; SULLIVAN, 1964, p. 184, pl. 5, fig. 1; SULLIVAN, 1965, p. 35; PERCH-NIELSEN, 1967, pl. 3, figs. 4, 5; CLOCCHIATTI, 1971, p. 40, pl. 17; figs. 2–4; GARTNER, 1971, figs. 1, 4, 5.

Helicosphaera aff. *H. seminulum* Bramlette and Sullivan. BRAMLETTE and WILCOXON, 1967, p. 106, pl. 5, figs. 11, 12.

Helicosphaera seminulum Bramlette and Sullivan. ACHUTHAN and STRADNER, 1969, p. 6, pl. 2, figs. 7, 8.

Helicopontosphaera seminulum seminulum (Bramlette and Sullivan). BUKRY and KENNEDY, 1969, p. 42 (transfer invalid).

Helicopontosphaera seminulum (Bramlette and Sullivan). ROTH, 1970, p. 863; HAQ, 1971b, p. 87; PERCH-NIELSEN, 1971a, p. 956, fig. 14; PERCH-NIELSEN, 1971b, p. 44, pl. 34, fig. 4; pl. 35, figs. 1, 2, 5, 6; pl. 36, figs. 4, 7, 8; pl. 37, fig. 6. RAMSAY, 1971, p. 206, pl. 3, fig. 7.

Remarks: Elliptical helicoid coccolith with two curved plates. When viewed from the proximal side a smaller proximal plate is observed. The distal plate and the proximal plate are one and the same for the full length of one side of the plate at which point two separate plates are formed. The distal plate is now distinct from the proximal plate and continues to spiral outward along the remaining side of the proximal plate. As the distal plate spirals around the coccolith it gradually widens until at the end opposite the initial separation of the two plates it is wider than the previous cycle, and wider than the other end of the placolith. The termination of the spiraling distal plate is usually more abrupt than that observed in the electronmicrographs. When viewed with phase-contrast the portion of the coccolith where the two plates fuse is quite distinct as is the remainder of the proximal shield. A distinctive crossbar, aligned with the short axis of the elliptical plate, divides the central opening into two sub-rectangular openings. The crossbar is located in the proximal shield.

The phase-contrast and SEM micrographs are of the same specimen. The blurred top side of Figure 9, Plate 5, represents that portion of the coccolith where the proximal and distal shield are fused. The sharper bottom half represents that portion where the plates have become separated.

Hypotype: Sabine River E, Photomicrograph negatives 16–5, 16–6. SEM negative 6471; Size: 11 X 8 microns.

Occurrence: Reported from the Paleocene through the middle Oligocene.

HELICOPONTOSPHAERA LOPHOTA
(Bramlette and Sullivan)
Haq, 1971
Plate 5, figs. 13, 14

Helicosphaera seminulum lophota BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 4, figs. 3, 4; SULLIVAN, 1964, p. 184, pl. 5, fig. 1; SULLIVAN, 1965, p. 35, pl. 6, fig. 5; PERCH-NIELSEN, 1967, p. 25, pl. 3, figs. 1–3; GARTNER, 1971, figs. 1, 4, 5.

Helicosphaera seminulum Bramlette and Sullivan. GARTNER and SMITH, 1967, p. 5, pl. 7, figs. 1–4; STRADNER and EDWARDS, 1968, p. 38, pls. 39, 40.

Helicopontosphaera seminulum lophota (Bramlette and Sullivan). BUKRY and KENNEDY, 1969, p. 42, fig. 4, nos. 2, 3 (transfer invalid).

Helicopontosphaera lophota (Bramlette and Sullivan). PERCH-NIELSEN, 1971a, p. 956, fig. 14 (transfer invalid).

Helicopontosphaera lophota (Bramlette and Sullivan). HAQ, 1971b, p. 87, pl. 3, fig. 12; HAQ, 1971c, p. 116, pl. 10, figs. 8, 9. PERCH-NIELSEN, 1971b, p. 43, pl. 34, figs. 1, 2; pl. 36, figs. 1, 2.

Helicopontosphaera seminulum lophota (Bramlette and Sullivan). GARTNER, 1971, p. 116.

Remarks: Elliptical to subcircular placoliths with a wide single cycle of elements in the distal shield when viewed from the distal side. Two small subcircular openings are present along the long axis of the ellipse. The two perforations are separated by a narrow bridge which is inclined at an angle of a few degrees to the long axis of the ellipse. One end of the plate is wider than the other. In cross-polarized light a black sigmoid isogyre runs the length of the plate paralleling the long axis.

This species is wider than *H. seminulum* throughout its length and at the enlarged end. The openings in the central area are much smaller than those in *H. seminulum*.

Hypotype: Sabine River E, Photomicrograph negatives 18–9, 18–10; Size: 11.5 X 10 microns.

Occurrence: Reported from the upper Paleocene into the upper Eocene in North America and Europe.

Family RHABDOSPHAERACEAE
Lemmermann, 1908

Description: Coccolithophores bearing rhabdoliths that may be club or nail-shaped.

Genus BLACKITES
(Hay and Towe)
Stradner, 1968

Description: Rhabdoliths with distally tapering shafts attached to the distal side of a circular basal plate composed of at least three cycles of radially or tangentially arranged crystal elements.

Type species: Blackites rectus (Deflandre) Stradner.

BLACKITES AMPLUS
Roth and Hay, 1967
Plate 6, figs. 9, 10
Plate 7, figs. 3, 4

Blackites amplus ROTH and HAY, 1967, p. 445, pl. 7, fig. 10; ROTH, 1970, p. 857, pl. 7, fig. 6; PERCH-NIELSEN, 1971a, p. 963, fig. 16.

Blackites spinosus (Deflandre and Fert) Hay and Towe. BLACK, 1965, p. 134, fig. 17; HODSON and WEST, 1970, p. 186, pl. 2, fig. 5; text-fig. 3.

Remarks: Circular plates approximately 6–7 microns across. With phase-contrast the plates are seen to bear a central circular perforation nearly 2 microns in diameter. A smooth ring surrounds the central perforation and is in turn surrounded by a narrow (0.2 micron) depression and a cycle of trapezohedral elements. Between 26 and 34 of these elements are present. Their long axes are radially disposed with respect to the center of the plate. The sutures between trapezohedral elements are inclined clockwise in proximal view. In cross-polarized light the central ring and the outer cycle of rectangular elements are bright. Four crenulate isogyres located 90 degrees from each other cut across the bright central ring when viewed from the distal side. SEM micrographs show three cycles of elements about a central perforation. An outer cycle of trapezohedral elements is connected by 80–85 rod-like elements to an inner cycle of sinistrally imbricate elements. With phase-contrast illumination the sinistrally imbricate elements are seen as the smooth ring and the rod-like elements are invisible. The sutures on the inner cycle of elements are inclined counterclockwise near the central perforation and clockwise near their periphery.

This species is distinguished from *B. spinosus* by the simpler construction of the rod elements, and the lack of secondary slits in the trapezohedral elements where they join the rods.

Hypotypes: Smithville D_1, (06.3;75.5), W.U.M.C. 000229; Size: 6 microns. Smithville A, SEM negative 5668; Size: 6 microns. SEM negative 5816; Size: 5 microns.

Occurrence: Previously reported from the lower Oligocene with questionable occurrence in the upper Eocene.

BLACKITES CREBER
(Deflandre)
n. comb.
Plate 5, figs. 25, 26

Rhabdolithus creber DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 157, pl. 12, figs. 31–33; text-figs. 81, 82; MANIVIT, 1961, p. 353, pl. 3, fig. 7; BOUCHÉ, 1962, p. 84, pl. 1, fig. 6.

Rhabdosphaera crebra (Deflandre). BRAMLETTE and SULLIVAN, 1961, p. 146, pl. 5, figs. 1–3; HAY and TOWE, 1963, p. 953, pl. 1, figs. 2–5; pl. 2, figs. 1–5; SULLIVAN, 1964, p. 185, pl. 7, fig. 3; SULLIVAN, 1965, p. 36, pl. 7, figs. 4, 5.

Rhabdolithes creber (Deflandre). HAY, MOHLER and WADE, 1966, p. 390; HODSON and WEST, 1970, p. 182, pl. 2, figs. 2, 3; pl. 3, fig. 3; text-fig. 3.

Blackites creber (Deflandre). STRADNER and EDWARDS, 1968, p. 29 (transfer invalid); PERCH-NIELSEN, 1971 a, p. 963, fig. 16 (transfer invalid).

Remarks: Rhabdoliths with a short spike surmounting a circular base plate. In the light microscope the base plate appears flat on the proximal side and gently rounded on the distal side. The spike has a collar structure at its base and gently tapers from that collar throughout most of its length, then abruptly comes to a point. In cross-polarized light with the long axis of the rhabdolith parallel to the polarizer, the base plate and spike are brightly illuminated with the collar only barely discernable.

Hypotype: Hurricane Shoals M (26.2; 74.2), W.U.M.C. 000230; Size: 7.5 X 3 microns.

Occurrence: Reported from the Paleocene and Eocene in North America and the Eocene in Europe and the Northwest Caucasus Mountains of the U.S.S.R.

BLACKITES SCABROSUS
(Deflandre)
Roth, 1970
Plate 5, fig. 23

Rhabdolithus scabrosus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 158, pl. 12, fig. 30; text-fig. 85.

Rhabdosphaera scabrosa (Deflandre). BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, fig. 11; SULLIVAN, 1965, p. 37; pl. 7, fig. 6; REINHARDT, 1967, p. 215, pl. 4, fig. 23; pl. 7, fig. 2.

Blackites scabrosus (Deflandre). ROTH, 1970, p. 858.

Remarks: This species is very similar to *B. tenuis* in its appearance under phase-contrast and in cross-polarized light but is distinguished from *B. tenuis* by its rugose surface.

Hypotype: Hurricane Shoals J (28.3; 73.7), W.U.M.C. 000231; Size: 23 X 5 microns.

Occurrence: Reported from the lower Eocene through the Oligocene in North America and Europe.

BLACKITES TENUIS
(Bramlette and Sullivan)
n. comb.

Plate 5, figs. 19–22
Plate 6, figs. 5, 7

Rhabdosphaera tenuis BRAMLETTE and SULLIVAN, 1961, p. 147; pl. 5, fig. 14; BENEŠOVÁ and HANZLÍKOVÁ, 1962, pl. 4, fig. 2; SULLIVAN, 1964, p. 186, pl. 7, fig. 4; SULLIVAN, 1965, p. 37, pl. 7, fig. 10; LEVIN and JOERGER, 1967, p. 169, pl. 2, fig. 16; RADOMSKI, 1968, p. 573, pl. 46, fig. 13; MARTINI, 1969b, p. 138, pl. 3, figs. 30, 31; HAQ, 1971b, p. 89, pl. 5, fig. 14; ?pl. 11, fig. 3.

PLATE 6

Magnification 4500 X

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1, 2	*Transversopontis pulchra* (Deflandre) Haq .... Proximal view, from Smithville A. 1. SEM negative 5823 2. SEM negative 5658	35
3, 4	*Transversopontis ocellatus* (Bramlette and Sullivan) n. comb. .... 3. Distal view, from Smithville A, SEM negative 5817. 4. Proximal view, from Smithville D_1, SEM negative 5817.	34
5, 7	*Blackites tenuis* (Bramlette and Sullivan) n. comb. .... From Smithville A. 5. Distal view, SEM negative 5674 7. Proximal view, SEM negative 5689	42
6	*Transversopontis pulchriporus* (Reinhardt) n. comb. .... Distal view, from Smithville A, SEM negative 5621.	39
8	*Helicopontosphaera seminulum* (Bramlette and Sullivan) Roth .... Proximal view, from Sabine River E, SEM negative 6471.	39
9, 10	*Blackites amplus* Roth and Hay .... From Smithville A 9. Proximal view?, SEM negative 5668 10. Distal view, SEM negative 5816	40
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12	*Braarudosphaera discula* Bramlette and Riedel .... From Smithville A, TEM negative 1.	48

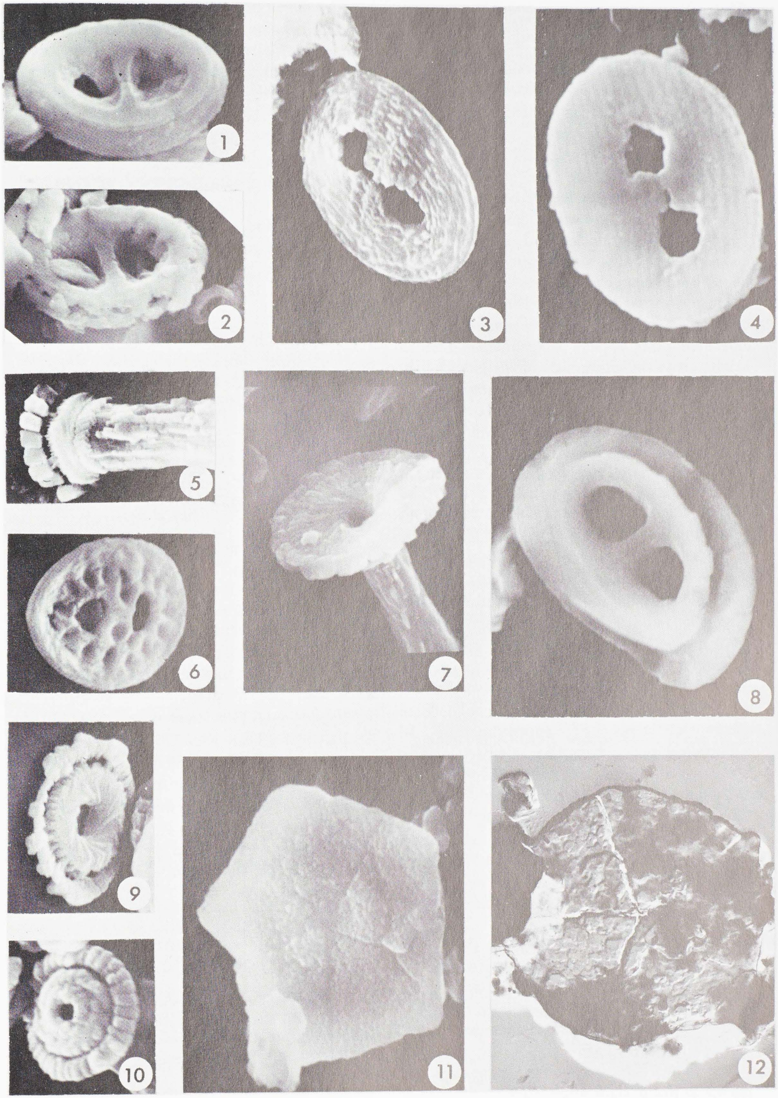

PLATE 6

Rhabdolithes tenuis HODSON and WEST, 1970, p. 184, pl. 3, fig. 1.

Remarks: Rhabdoliths with a relatively small circular base plate which bears a long uniformly tapering stem. The stem terminates distally in a sharp point. Depending upon the orientation of the long axis with respect to the polarizer, two distinct morphologies can be observed. When parallel to the polarizer, the base plate appears to bear nodes and is joined to a collar which surrounds a uniformly tapering needle-like stem. No central canal is visible in this orientation. When the long axis is oriented parallel to the analyzer the collar and base plate appear fused and are seen as bright areas on either side of the rhabdolith. The stem gently flares and joins with these bright areas. The stem tapers gently to a sharp point at the distal end. In this position the stem appears twice as thick as when viewed parallel to the polarizer. In addition, the central canal is now clearly visible. The canal extends the length of the stem becoming narrower near the distal tip.

SEM micrographs of this species reveal the presence of three or possibly four cycles of morphologically different crystal elements making up the base plate. Based upon this information this species is transferred to the genus *Blackites*.

On the proximal side (Plate 6, figure 7), the outermost cycle of elements in the base plate consists of approximately 30 non-imbricate rectangular elements. The long axis of each element is radially arranged with respect to the center of the plate. The outer cycle of elements does not lie in the same plane as the remaining element, but is inclined to them at a small angle. This small inclination is responsible for the slightly concave appearance of the base plate in cross section.

Each rectangular element in the outer cycle is joined to three or sometimes four rods or plates that make up the second cycle of elements. The plates are radially arranged, extending inward and becoming more rod-like as they join the third cycle of elements. At the center of the plate each rod makes a sharp right-angle turn and extends up inside the stem.

The distal side of the base plate (Plate 6, figure 5) shows two outer cycles of elements that appear essentially the same in size and shape as those of the proximal side. However, the third cycle of elements consists of plates that are strongly sinistrally imbricate. The sutures between the plates are inclined clockwise. The inner portion of these plates appears to extend upward and forms a shallow ring around the base of the stem. This ring comes into contact with a cycle of sinistrally imbricate plates which make up the remainder of the collar. The upper plates of the collar are roughly twice as long as wide, and their long axis is parallel to the long axis of the stem.

It appears likely that only the two outermost cycles of elements are visible from both the proximal and the distal sides of the base plate. The rods of the third cycle of the proximal side run under the third cycle elements of the distal side. The shallow ring on the distal side may be formed by the rods extending through from the proximal side.

The stem consists of many long, thin and wide crystal laths. The long axis of the lath is aligned parallel to the long axis of the stem. The intermediate axis is radially arranged with respect to the center of the stem. The lath is approximately three times wider than thick and six times longer than wide.

Hypotypes: Hurricane Shoals M (20.3; 79.8), W.U.M.C. 000232; Size: 23 X 5 microns. Smithville A, SEM negative 5689; Size: 6 microns across base plate. SEM negative 5674; Size: 4.5 microns across base plate.

Occurrence: Reported from the Eocene and Oligocene in North America and the Eocene in Europe.

Genus RHABDOLITHES
Schmidt, 1870

Description: Centrally perforated subcircular to circular basal shields surmounted by a radial stem which is hollow. A collar may be present next to the shield.

Type Species: Rhabdosphaera claviger Murray and Blackman.

RHABDOLITHES GLADIUS (Locker) n. comb.

Rhabdosphaera gladius LOCKER, 1967, p. 766, pl. 1, fig. 8; pl. 2, fig. 12; MARTINI, 1969b, pl. 2, figs. 17, 18; MARTINI, 1971c, p. 741, pl. 2, figs. 8, 9.

Remarks: Rhabdoliths with a thick rounded base surmounted by a broad short spine. A collar is present where the spine joins the circular base. The spine is hollow, thins a little just above the collar and then thickens again before coming to a broadly rounded point. In cross-polarized light the spine and base are brightly illuminated. This species may belong in *Blackites,* however, it was not possible to examine the base plate with the electronmicroscope to determine the nature of its construction.

Occurrence: Reported from the middle Eocene in Germany.

RHABDOLITHES RUDIS (Bramlette and Sullivan) n. comb. Plate 5, fig. 24

Rhabdosphaera rudis BRAMLETTE and SULLIVAN, 1961, p. 146, pl. 5, fig. 6; SULLIVAN, 1964, p. 185, pl. 7, figs. 5, 6; SULLIVAN, 1965, p. 37, pl. 7, fig. 2.

Remarks: Trapezohedral-shaped rhabdoliths with a thick circular base plate surmounted by a short but very wide stem. The stem is almost as wide as the base and is bisected by a narrow black line when viewed in cross-polarized light. The walls of the stem are very thick leaving only a narrow hollow canal. The surface of the stem is rugose. Stefan Gartner, Jr., suggested that this is *Zygrhablithus bijugatus* in his review of the manuscript.

Hypotype: Fort Bend County 6, 9490 (08.2; 77.1), W.U.M.C. 000233; Size: 6.5 X 4.5 microns.

Occurrence: Reported from the Paleocene and lower Eocene in California.

Family BRAARUDOSPHAERACEAE Deflandre, 1947

Description: Coccolithophores bearing pentaliths. The coccosphere is composed of twelve pentaliths and has the form of a dodecahedron. Each pentalith consists of five distinct crystallites constructed of laminae of rhombohedral crystals stacked parallel to the base of the pentalith. The sutures between elements make angles of 72 degrees with each other. Living examples of *Braarudosphaera bigelowi* contain large chromatophores but do not possess a nucleus of flagellae.

Genus BRAARUDOSPHAERA Deflandre, 1947

Description: Pentaliths with straight or curving outer margins. No perforations or depressions are present on the elements of the pentalith. Forms with straight margins have trapezohedral elements making up the pentalith.

Type Species: Braarudosphaera bigelowi (Gran and Braarud) Deflandre.

BRAARUDOSPHAERA BIGELOWI (Gran and Braarud) Deflandre, 1947 Plate 6, fig. 11 Plate 7, figs. 1, 2

Pontosphaera bigelowi GRAN and BRAARUD, 1935, p. 398, text-fig. 67.

Braarudosphaera bigelowi (Gran and Braarud). DEFLANDRE, 1947, p. 439, figs. 1–5; DEFLANDRE, 1950, p. 1156, text-figs. 1–4; KLUMPP, 1953, p. 380, fig. 2, nos. 1, 2; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 165, pl. 10, figs. 8–13; pl. 13, figs. 7–9; BRAMLETTE and RIEDEL, 1954, p. 393, pl. 38, fig. 6a, b; MARTINI, 1958, p. 355, pl. 2, fig. 6; STRADNER, 1959, p. 482; text-figs. 63, 68; MARTINI, 1960, p. 73, pl. 8, fig. 1; MANIVIT, 1961, p. 354, pl. 4, fig. 1; *non* fig. 2; STRADNER *in* STRADNER and PAPP, 1961, p. 116, pl. 37, figs. 1–3; text-fig. 12–1; BRAMLETTE and SULLIVAN, 1961, p. 153, pl. 8, figs. 1a, b, 2–5; NARASIMHAN, 1961, p. 56, pl. 8, fig. 15; pl. 1, figs. 1, 2; BOUCHÉ, 1962, p. 85, pl. 4, figs. 1, 5; HAY and TOWE, 1962, p. 427; text-fig. 1; STRADNER, 1963, pl. 6, fig. 9; SULLIVAN, 1964, p. 188, pl. 8, figs. 1a, b; BYSTRICKÁ, 1964, p. 211, pl. 7, fig. 7; BÓNA, 1964, p. 127, pl. 14, fig. 1; COHEN, 1965, p. 31, pl. 6, figs. a–d; LEVIN, 1965, p. 268, pl. 42, figs. 4, 5; BLACK, 1965, p. 135, fig. 23; SULLIVAN, 1965, p. 39; HAY, MOHLER and WADE, 1966, p. 394; HAY and MOHLER, p. 1535, pl. 202, figs. 12, 16, 20; LEVIN and JOERGER, 1967, p. 170, pl. 3, figs. 5a–b; GARTNER and SMITH, 1967, p. 6, pl. 9, figs. 1–3; HAQ, 1968, p. 41, pl. 11, figs. 3, 4; RADOMSKI, 1968, p. 576, pl. 48, fig. 4; BOUDREAUX and HAY, 1969, p. 281, pl. 8, figs. 21–23; BYSTRICKÁ, 1969, p. 230, pl. 43, fig. 14; MARTINI, 1969a, p. 290, pl. 27, figs. 9,

PLATE 7

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X
unless otherwise specified.

Figures Page

1, 2 *Braarudosphaera bigelowi* (Gran and Braarud) Deflandre 45
From Smithville A (01.4; 77.0), W.U.M.C. 000234.

1. Phase-contrast
2. Between crossed-polarizers

3, 4 *Blackites amplus* Roth and Hay 40
Distal view, from Smithville D_1 (06.3; 75.5), W.U.M.C. 000229.

3. Phase-contrast
4. Between crossed-polarizers

5, 6 *Micrantholithus ornatus* Sullivan 49
From Fort Bend County 6, 10180 (16.2; 75.4), W.U.M.C. 000237.

5. Phase-contrast
6. Between crossed-polarizers

7, 8 *Micrantholithus flos* Deflandre 49
From Smithville A (03.15; 76.9), W.U.M.C. 000236.

7. Phase-contrast
8. Between crossed polarizers

9, 10 *Pemma angulatum* Martini 50
From Smithville A.

9. Phase-contrast
10. Between crossed-polarizers

11, 12 *Micrantholithus procerus* Bukry and Bramlette 49
15, 16 Hypotype from Polk County 9, 5333 (22.5; 74.1), W.U.M.C. 000238.

11. Hypotype, phase-contrast
12. Hypotype, between crossed-polarizers
15. Side view, phase-contrast, 900 X
16. Side view, between crossed-polarizers, 900 X

13, 14 *Pemma basquense crassum* (Bouché) Bybell and Gartner 50
From Smithville A

13. Phase-contrast
14. Between crossed-polarizers

(continued next page)

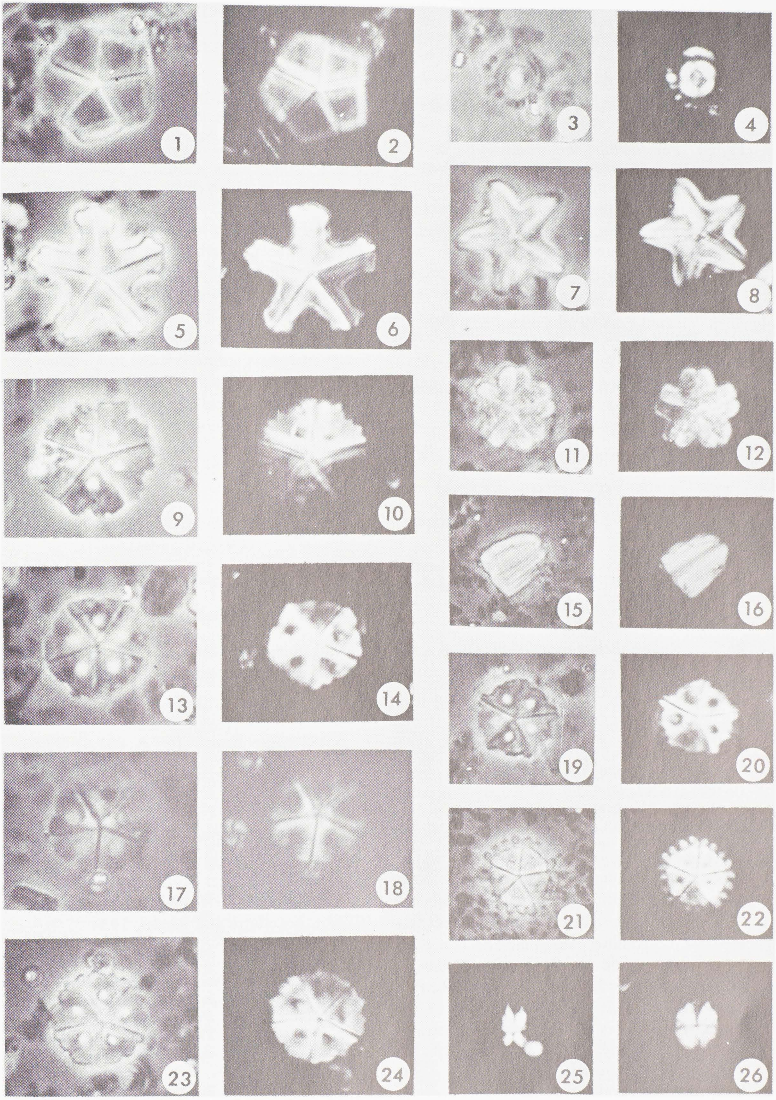

PLATE 7

17, 18 *Pemma bulbosus* (Bouché) n. comb. 51
From Smithville A

17. Phase-contrast
18. Between crossed-polarizers

19, 20 *Pemma basquense basquense* (Martini) Bybell and Gartner 50
From Hurricane Shoals J (15.8; 74.7), W.U.M.C. 000239.

19. Phase-contrast
20. Between crossed-polarizers

21, 22 *Pemma papillatum* Martini 51
Magnification 900 X
From Fort Bend County 6, 9490

21. Phase-contrast
22. Between crossed-polarizers

23, 24 *Pemma major* (Bouché) n. comb. 51
From Smithville A (20.2; 79.8), W.U.M.C. 000240.

23. Phase-contrast
24. Between crossed-polarizers

25 *Sphenolithus furcatolithoides* Locker 54
Side view, between crossed-polarizers, from Polk County 9, 5457 (24.8; 75.0), W.U.M.C.000241.

26 *Sphenolithus moriformis* (Bronnemann and Stradner) Bramlette and Wilcoxon . 54
Basal view, between crossed-polarizers, from Liberty County 12, 10960 (18.85; 75.1), W.U.M.C. 000242.

10; HODSON and WEST, 1970, p. 170; BARTOLINI, 1970, p. 152, pl. 1, fig. 1; PERCH-NIELSEN, 1971a, p. 942, fig. 1; HAQ, 1971a, p. 47, pl. 6, fig. 3; HAQ, 1971 b, p. 92, pl. 5, fig. 13; pl. 11, fig. 6; HAQ, 1971c, p. 121; PERCH-NIELSEN, 1971b, p. 59; RAMSAY, 1971, p. 206, pl. 4, fig. 2; BYBELL and GARTNER, 1972 [1973], p. 323, pl. 1, figs. 1, 2.

Remarks: Pentaliths made up of five separate crystalline elements. The complete pentalith has five flat sides which meet at angles of 120 degrees. Each element is trapezohedral in outline, having each of the three longer sides at least twice as long as the shortest side. Each flat side of the pentalith is composed of one short and one long trapezohedral leg which are part of two adjacent pentalith elements.

Hypotypes: Smithville A (01.4; 77.0), W.U.M.C. 000234; Size: 12.5 microns. Fort Bend County 6, 9490, SEM negative 6485; Size: 11 microns.

Occurrence: Reported from various parts of the world throughout the Cenozoic.

BRAARUDOSPHAERA DISCULA
Bramlette and Riedel, 1954
Plate 6, fig. 12

Braarudosphaera discula BRAMLETTE and RIEDEL, 1954, p. 394, pl. 38, fig. 7; BRAMLETTE and SULLIVAN, 1961, p. 153, pl. 8, figs. 6, 7; STRADNER *in* STRADNER and Papp, 1961, p. 117, text-fig. 12–3; SULLIVAN, 1964, p. 188, pl. 8, fig. 2; SULLIVAN, 1965, p. 39, pl. 8, figs. 1, 3; HAY and MOHLER, 1967, p. 1535, pl. 202, figs. 13–15; BYSTRICKÁ, 1969, p. 231, pl. 43, fig.

13; PERCH-NIELSEN, 1969, p. 57, pl. 7, figs. 1, 2; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 323.

Braarudosphaera aff. *discula* (Bramlette and Riedel). RADOMSKI, 1968, p. 576, pl. 47, fig. 3; HAQ, 1971c, p. 121, pl. 17, fig. 3.

Braarudosphaera cf. *discula* Bramlette and Riedel. BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 6.

Remarks: Discoidal pentaliths without perforations on the pentalith elements. The peripheral surface of each segment is curved. The sutures between elements form angles of 72 degrees. Transmission electronmicrographs show the pentaliths to be made up of small rhombic elements.

Hypotype: Smithville A, Transmission electronmicrograph 1; Size: 10 microns.

Occurrence: Reported from the Paleocene through the lower and middle Eocene in various parts of the world.

Genus MICRANTHOLITHUS Deflandre, 1950

Description: Pentaliths with V-shaped segments.

Type Species: Micrantholithus flos Deflandre.

MICRANTHOLITHUS FLOS Deflandre, 1950
Plate 7, figs. 7, 8

Micrantholithus flos DEFLANDRE, 1950, p. 1158, text-fig. 8–11; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 166, pl. 13, figs. 10, 11; text-figs. 113, 114; MARTINI, 1958, p. 356, pl. 1, fig. 2; STRADNER, 1959, p. 482; text-fig. 60; MARTINI, 1960, p. 74, pl. 8, fig. 4; BRAMLETTE and SULLIVAN, 1961, p. 155, pl. 9, fig. 8; MANIVIT, 1961, p. 355, pl. 4, fig. 3; MARTINI, 1961, p. 6, pl. 1, fig. 11; STRADNER *in* STRADNER and PAPP, 1961, p. 121, pl. 39, figs. 3, 4; text-fig. 12/9; BOUCHÉ, 1962, p. 87, pl. 2, figs. 1, 2; text-figs. 13, 14; HAY and TOWE, 1962, p. 427, fig. 6; SULLIVAN, 1964, p. 189, pl. 9, fig. 5; SULLIVAN, 1965, p. 40, pl. 9, figs. 1–3; BUKRY and KENNEDY, 1969, p. 42, fig. 4, no. 1; HAQ, 1971b, p. 91; HAQ, 1971c, p. 121, pl. 6, fig. 3; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Micrantholithus sp.. HAY and MOHLER, 1967, p. 1535, pl. 202, figs. 17–19.

Remarks: Pentaliths constructed of V-shaped segments. Lateral thickenings occur along both sides of the sutures. A narrow zone along the periphery of the segments is not thickened, producing a thin shelf.

Specimens of this species in the Weches Formation have only a narrow zone along the periphery of the segments that is not thickened. Most specimens of this species figured in the literature show a triangular area that is not thickened. The Weches specimens have been assigned to this species, even though they lack the thinned triangular area, because they do not have the thin tenuous rays characteristic of *M. vesper*.

Hypotype: Smithville A (03.15; 76.9), W.U.M.C. 000236; Size: 10 microns.

Occurrence: Reported from the Paleocene and Eocene in various parts of the world.

MICRANTHOLITHUS ORNATUS Sullivan, 1965
Plate 7, figs. 5, 6

Micrantholithus ornatus SULLIVAN, 1965, p. 40, pl. 8, fig. 7; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 325, pl. 1, figs. 15, 16.

Remarks: Pentalith with V-shaped segments. Near the ends of the arms of the "V" lateral nodes occur, which extend into the inter-arm area. Beyond the nodes the arms thin and terminate in a small rounded node.

Hypotype: Fort Bend County 6, 10180 (16.2; 75.4), W.U.M.C. 000237; Size: 12 microns.

Occurrence: Reported from the early middle Eocene in Alabama and California, and the upper Eocene in Hungary.

MICRANTHOLITHUS PROCERUS Bukry and Bramlette, 1969
Plate 7, figs. 11, 12, 15, 16

Micrantholithus procerus BUKRY and BRAMLETTE, 1969, p. 136, pl. 2, figs. 12–15; GARTNER, 1971, figs. 1, 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 325, pl. 3, figs. 1–6.

Remarks: Pentaliths with V-shaped segments. The indentation that gives the V-shape to the segments is not very pronounced. In plan view the outline of this species appears much like that of *Pemma angulatum.* The peripheral terminations of the segments are broadly rounded. No depressions are present on the segments of the pentalith. In side view this species is from one to nearly two times longer than it is wide. The body of the pentalith tapers from a flat base to a broadly rounded termination.

Hypotype: Polk County 9, 5333 (22.5; 74.1), W.U.M.C. 000238; Size: 8 microns.

Occurrence: Reported from the early middle Eocene in various parts of the world.

Genus PEMMA
Klumpp, 1953

Description: Pentaliths with a circular or pentagonal outline having a depression or perforation in each of the five segments.

Type Species: Pemma rotundum Klumpp.

PEMMA ANGULATUM
Martini, 1959
Plate 7, figs. 9, 10
Plate 8, fig. 4

Pemma angulatum MARTINI, 1959b, p. 416, pl. 1, figs. 1–4; GARTNER and SMITH, 1967, p. 6, pl. 11, fig. 1; LOCKER, 1968, pl. 2, fig. 13; ACHUTHAN and STRADNER, 1969, p. 8, pl. 5, fig. 9; GARTNER, 1971, figs. 4, 5; HAQ, 1971a, p. 45, pl. 7, figs. 5–7; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Remarks: Pentaliths with a peripheral notch located midway between the sutures of each segment. That portion of the pentalith segment between the notch and the suture terminates peripherally in a nearly flat surface. The flat terminations give this species the appearance of having five flat sides. Each flat side is made up of portions of two segments. Between the peripheral notch and the apex of each pentalith segment a nearly circular depression is seen with phase-contrast illumination.

The flat sides of this species distinguish it from other members of the genus.

Hypotype: Smithville A, SEM negative 5619; Size: 12 microns.

Occurrence: Reported from the Eocene in North America and Europe.

PEMMA BASQUENSE BASQUENSE
(Martini)
Bybell and Gartner, 1972 [1973]
Plate 7, figs. 19, 20

Micrantholithus basquensis MARTINI, 1959b, p. 417, pl. 1, figs. 9–12; SULLIVAN, 1965, p. 39, pl. 8, figs. 4, 5; BILGÜTAY *et al.*, 1969, p. 174, pl. 5, figs. 1–4; GARTNER, 1971, fig. 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 59, pl. 56, fig. 1.

Micrantholithus basquensis basquensis Martini. BOUCHÉ, 1962, p. 85, pl. 2, fig. 11.

Micrantholithus cf. *basquensis* Martini. ACHUTHAN and STRADNER, 1969, p. 7, pl. 5, figs. 7, 8.

Pemma basquense basquense (Martini). BYBELL and GARTNER, 1972 [1973], p. 325, pl. 3, *non* figs. 7–14.

Pemma stradneri (Chang). BYBELL and GARTNER, 1972 [1973], p. 330, pl. 5, figs. 1–4.

Remarks: Circular pentaliths bearing a diamond-shaped depression on each segment. The outline of the specimen is regularly undulatory. The undulations are produced by thickenings along the sutures which extend beyond the periphery of the pentalith body, and one or two protrusions located along the periphery of the pentalith between the sutures of each segment.

The length of the marginal protrusions distinguishes this species. All protrusions are the same length. In *P. stradneri* the protrusions between the sutures are longer than those along the sutures.

Hypotype: Hurricane Shoals J (15.8; 74.7), W.U.M.C. 000239; Size: 7 microns.

Occurrence: Reported from the middle Eocene in North America and the middle and upper Eocene in Europe.

PEMMA BASQUENSE CRASSUM
(Bouché)
Bybell and Gartner, 1972 [1973]
Plate 7, figs. 13, 14
Plate 8, figs. 2, 3

Micrantholithus basquensis Martini. BRAMLETTE and SULLIVAN, 1961, pl. 8, figs. 14, 15;

LEVIN and JOERGER, 1967, p. 170, pl. 3, fig. 10; GARTNER, 1971, fig. 4; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 59, pl. 56, fig. 1.

Micrantholithus basquensis crassus BOUCHÉ, 1962, p. 85, pl. 2, figs. 3, 9, 10.

Pemma basquense crassum (Bouché). BYBELL and GARTNER, 1972 [1973], p. 326, pl. 4, figs. 1–6.

Remarks: Circular pentaliths bearing a large diamond-shaped depression on each segment. An indentation is present midway between sutures. This gives each segment of the pentalith a bilobate periphery. The indentation is joined to the central depression by a narrow valley produced by a reduction in the thickness of the pentalith in this area. The pentalith is made up of laminae stacked parallel to each other and perpendicular to the sutures.

Pemma basquense crassum is distinguished from *P. b. basquense* by the lack of protrusions at, and midway between, the sutures. The periphery of *P. b. crassum* is bilobate between sutures with a narrow valley connecting the peripheral indentation to the diamond-shaped central depression. In *P. bulbosus* this valley is much wider and the peripheral indentation deeper. The side walls of the valley in *P. bulbosus* extend to the sutures, giving the area along the sutures a rounded appearance.

Hypotype: Smithville A, SEM negatives 5673 and 5677; Size: 9 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

PEMMA BULBOSUS
(Bouché)
n. comb.
Plate 7, figs. 17, 18
Plate 8, fig. 8

Micrantholithus bulbosus BOUCHÉ, 1962, p. 87, pl. 2, figs. 4–7, text-fig. 12; PERCH-NIELSEN, 1971a, p. 942, fig. 1.

Remarks: Circular pentalith bearing a large depression on each segment. The depressions open to a peripheral indentation by way of a rather wide valley. The segments are bilobate between the sutures, but the lobes are smaller and the valley wider than in *Pemma basquense crassum*. The apex of the depression is located further from the apex of the pentalith segments than in *P. b. crassum* or *P. b. basquense*.

Pemma bulbosus is distinguished from *P. b. basquense* and *P. b. crassum* by its subcircular rather than diamond-shaped depressions and the greater distance from the apex of pentalith segments to the depressions. *P. b. crassum* does not have as wide a valley joining the central depression to the periphery as does *P. bulbosus* but it does have larger lobes between sutures.

Hypotype: Smithville A, SEM negative 5672; Size: 7 microns.

Occurrence: Reported from the middle Eocene in France.

PEMMA MAJOR
(Bouché)
n. comb.
Plate 7, figs. 23, 24

Micrantholithus parasiensis major BOUCHÉ, 1962, p. 86, pl. 2, figs. 17, 19, 20, 21, 25; text-fig. 11.

Remarks: Circular pentaliths bearing a diamond-shaped depression on each segment. The outline of the specimen is gently undulatory. The undulations are produced by thickenings along the sutures which extend a short distance beyond the periphery of the pentalith body. Two short, broadly rounded scallops appear between the sutures. Each segment thus bears two broad scallops and a less rounded, narrower protrusion along each suture. Specimens are 9 microns across or larger.

The nearly equal length of the protrusions and scallops distinguish this species from *Pemma stradneri* where the protrusions between sutures are longer than those at the sutures. In *P. b. basquense* the protrusions are narrower and more angular than those of *P. major*.

Hypotype: Smithville A (20.2; 79.8), W.U.M.C. 000240; Size: 9 microns.

Occurrence: Reported from the middle Eocene of the Paris Basin, France.

PEMMA PAPILLATUM
Martini, 1959
Plate 7, figs. 21, 22
Plate 8, fig. 5

Pemma papillatum MARTINI, 1959, p. 139, fig. 1; STRADNER, 1959a, p. 487, figs. 67, 68; STRADNER *in* STRADNER and PAPP, 1961, p. 120, pl. 38, figs. 4–6; *non* figs. 2, 3; *non* text-fig. 12–7; LEVIN, 1965, p. 269, pl. 42, figs. 7, 8. LEVIN and JOERGER, 1967, p. 171, pl. 3, fig. 11; GARTNER and SMITH, 1967, p. 6, pl. 10, figs. 1–3a, b; STRADNER, 1969, p. 666, pl. 6, figs. 6, 7; GARTNER, 1971, figs. 1, 2, 4, 5; HAQ, 1971a, p. 45, pl. 6, figs. 5–7; pl. 7, figs. 3, 4; pl. 8, figs. 2, 4, 5; PERCH-NIELSEN, 1971a, p. 942, fig. 1; BYBELL and GARTNER, 1972 [1973], p. 328, pl. 1, figs. 17–20.

Remarks: Circular pentalith with a subcircular depression on each segment. The periphery bears 20 nodes, four to each segment. The nodes distinguish this species from other members of the genus.

Hypotype: Fort Bend County 6, 9490, SEM negative 5907; Size: 14 microns.

Occurrence: Reported from the middle and upper Eocene in various parts of the world and the lower and middle Eocene in Mexico.

PEMMA ROTUNDUM
Klumpp, 1953
Plate 8, fig. 1
Plate 9, figs. 1, 2

Pemma rotundum KLUMPP, 1953, p. 381, pl. 16, fig. 3; text-fig. 2, 3; MARTINI, 1958, p. 355, pl. 2, fig. 7; MARTINI, 1959b, pl. 1, figs. 5a, 6–8; STRADNER, 1959, p. 487, text-fig. 66; MARTINI, 1960, p. 74, pl. 8, fig. 6; MARTINI, 1961, p. 7; STRADNER *in* STRADNER and

PLATE 8

Magnification 4500 X

Figures Page

1 *Pemma rotundum* Klumpp 52
Basal view, from Smithville A, SEM negative 5681.

2, 3 *Pemma basquense crassum* (Bouché) Bybell and Gartner 50
From Smithville A

2. Top view, SEM negative 5673
3. Top view, SEM negative 5677

4 *Pemma angulatum* Martini 50
Basal view, from Smithville A, SEM negative 5619.

5 *Pemma papillatum* Martini 51
Basal view, from Fort Bend County 6, 9490, SEM negative 5907.

6, 7 *Neococcolithes dubius* (Deflandre) Black 70
Distal view, from Smithville D_1.

6. SEM negative 5819
7. SEM negative 5883

8 *Pemma bulbosus* (Bouché) n. comb. 51
Top view, from Smithville A, SEM negative 5672.

9, 10 *Trochoaster simplex* Klumpp 55
From Smithville A.

9. Frontal view, SEM negative 5824.
10. Rear view, SEM negative 5880

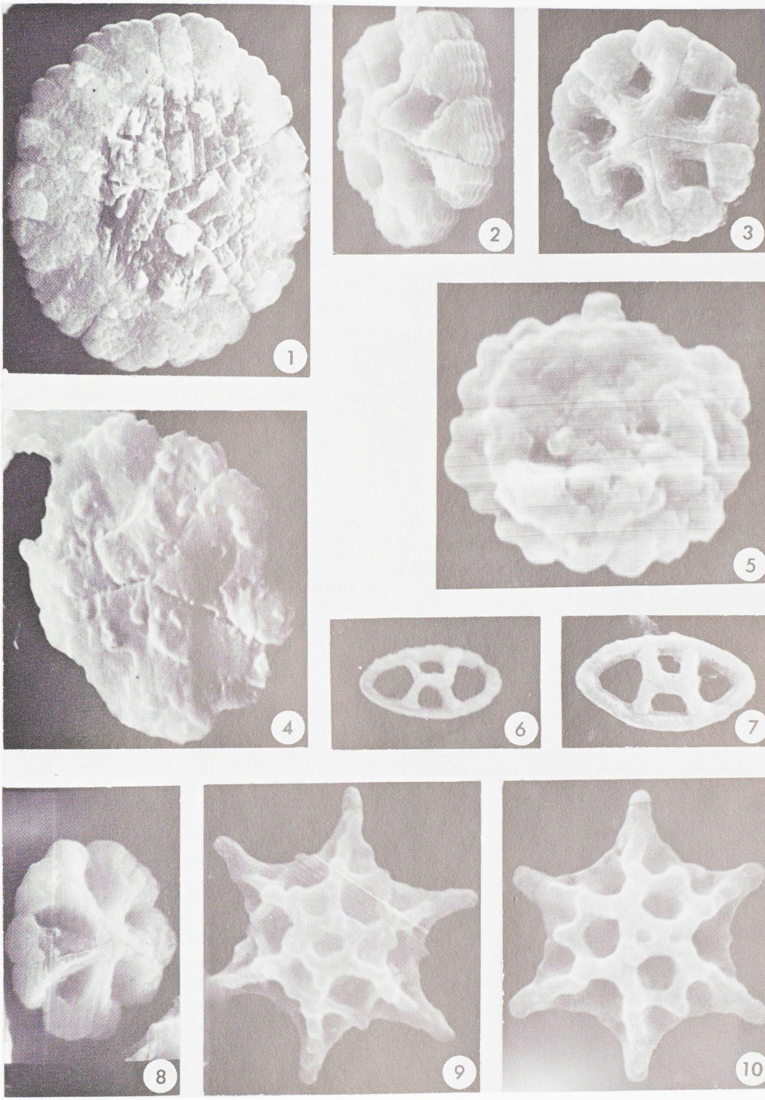

PLATE 8

PAPP, 1961, p. 119, pl. 38, fig. 1a, b; text-fig. 12–6; HAY and TOWE, 1962, p. 427; text-figs. 4, 5; COHEN, 1965a, p. 31; pl. 6, fig. e; HODSON and WEST, 1970, p. 172, pl. 1, fig. 3; HAQ, 1971, p. 46, pl. 7, fig. 10; PERCH-NIELSEN, 1971a, p. 942, fig. 1; PERCH-NIELSEN, 1971b, p. 60; pl. 56, fig. 5, 6. BYBELL and GARTNER, 1972 [1973], p. 330.

Remarks: Circular pentaliths with only slight irregularities in the periphery of the segments. A circular depression is located near the apex of each segment.

The nearly circular outline of the species distinguishes it from other members of the genus.

Hypotype: Smithville A, SEM negative 5681; Size: 10 microns.

Occurrence: Reported from the middle Eocene in various parts of the world and the middle and upper Eocene in Germany and Hungary.

Family SPHENOLITHACEAE
Deflandre, 1952

Description: Beehive or wedge-shaped calcium carbonate objects composed of spines set on a base composed of multiple elements.

Genus SPHENOLITHUS
Deflandre, 1954

Description: Beehive or wedge-shaped calcium carbonate objects consisting of a distal, single or bifurcating spine constructed of rod- or blade-like elements set on the convex side of a concave proximal shield. The proximal shield is constructed of rod-like to tabular elements radiating from a point, and is more or less circular.

Type Species: Sphenolithus radians Deflandre.

SPHENOLITHUS FURCATOLITHOIDES
Locker, 1967
Plate 7, fig. 25

Sphenolithus furcatolithoides LOCKER, 1967, p. 363, pls. 14–16; text-figs. 7, 8; GARTNER, 1971, figs. 1, 2, 4, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 49, figs. 1–4; RAMSAY, 1971, p. 201, pl. 2, figs. 6, 7; ROTH, BAUMANN, and BARTOLINO, 1971, fig. 5.

Remarks: Sphenoliths with two prominent apical spines, each of which consists of four blade-like elements. The apical spines taper towards the distal end. Cycles of lateral elements are present between the apical spines and the proximal shield. The concave proximal shield consists of a single cycle of eight to ten tabular-shaped elements.

Sphenolithus furcatolithoides is referable to "morphotype one" of this genus (Roth, Franz, and Wise, Jr., 1971), which also contains *S. radians, S. pseudoradians,* and *S. heteromorphus.*

Hypotype: Polk County 9, 5457 (24.8; 75.0), W.U.M.C. 000241; Size: 6 X 2.5 microns.

Occurrence: Reported from the middle and early upper Eocene in various parts of the world.

SPHENOLITHUS MORIFORMIS
(Bronnimann and Stradner)
Bramlette and Wilcoxon, 1967
Plate 7, fig. 26

Nannoturbella moriformis BRONNIMANN and STRADNER, 1960, p. 368, figs. 11–16; (Erdoel-Zeitschrift, v. 76).

Sphenolithus pacificus MARTINI, 1965, p. 407, pl. 36, figs. 7–10.

Sphenolithus moriformis (Bronnimann and Stradner). BRAMLETTE and WILCOXON, 1967, p. 124, pl. 3, figs. 1–6; RADOMSKI, 1968, p. 558, pl. 43, figs. 19, 20; ROTH, 1970, p. 870, pl. 14, figs. 3, 4; GARTNER, 1971, figs. 4, 5; HAQ, 1971a, p. 33; HAQ, 1971b, p. 92, pl. 13, figs. 9, 10; HAQ, 1971c, p. 123, pl. 1, figs. ?7, 14, 25, 26; pl. 2, figs. 9, 10; pl. 3, figs. 5–9, PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 49, figs. 5–10; ROTH, BAUMANN, BERTOLINO, 1971, figs. 5, 7, 8; ROTH, FRANZ, WISE, JR., 1971, p. 1105, pl. 5, figs. 4–6.

Remarks: Sphenoliths with many spines radiating from a concave proximal area. Under phase-contrast illumination the distal side reveals many elements radially disposed about the median axis of the sphenolith. In cross-polarized light four brightly illuminated trianguloid areas separated by extinction isogyres are observed.

Specimens of this species appear very much like those figured by Bramlette and Wilcoxon (1967).

Hypotype: Liberty County 12, 10960 (18.85; 75.1), W.U.M.C. 000242; Size: 5 microns.

Occurrence: Reported from the Paleocene to the Miocene in many regions of the world.

SPHENOLITHUS OBTUSUS
Bukry, 1971

Sphenolithus obtusus BUKRY, 1971, p. 321, pl. 6, figs. 1–9.

Remarks: The specimens encountered in the Weches Formation are very similar to those figured by Bukry (1971). *Sphenolithus obtusus* appears to belong to "morphotype one" or "three" of this genus (Roth, Franz, and Wise, Jr., 1971). Exact assignment cannot be made because electron micrographs are not available for study.

Occurrence: Reported from late middle Eocene sediments of Horizon Ridge, northwestern Pacific Ocean.

SPHENOLITHUS RADIANS
Deflandre, 1952
Plate 9, figs. 3, 4.

Sphenolithus radians DEFLANDRE, 1952, p. 466, fig. 363; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 163, pl. 12, figs. 36–38; text-figs. 109–112; BRAMLETTE and SULLIVAN, 1961, p. 166, pl. 14, figs. 6–8; MANIVIT, 1961, p. 354, pl. 3, figs. 9, 10; SULLIVAN, 1964, p. 194, pl. 9, fig. 10; COHEN, 1965a, p. 35, pl. 5, figs. n–p; SULLIVAN, 1965, p. 45, pl. 11, fig. 3; RADOMSKI, 1968, p. 588, pl. 46, fig. 14; CLOCCHIATTI, 1971, p. 65, pl. 23, fig. 5; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 34, pl. 10, fig. 8; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 963, fig. 17; PERCH-NIELSEN, 1971b, p. 53, pl. 47, figs. 1–9; pl. 48, figs. 1–7; ROTH, BAUMANN, and BERTOLINO, 1971, fig. 8; ROTH, FRANZ, and WISE, JR., 1971, p. 1102, pl. 1, figs. 1, 2.

Remarks: Sphenoliths with a prominent rectangular base surmounted by a tapering apical spine. Electronmicrographs have shown the base to consist of a labyrinth composed of radially disposed wedge-shaped elements surmounted by four to seven blade-like segments that make up the apical spine.

Hypotype: Fort Bend County 6, 10180 (14.8; 75.4), W.U.M.C. 000243; Size: 5 X 3.5 microns.

Occurrence: Reported from the Paleocene through the Oligocene in various parts of the world.

Family LITHOSTROMATIONACEAE
Deflandre, 1959

Description: Forms related to *Lithostromation* that have similar faces on both sides.

Genus TROCHOASTER
Klumpp, 1953

Description: Biconvex stellate body of ortholithid microstructure bearing six or twelve rays. The equatorial shape is hexagonal or circular which distinguishes the genus from *Lithostromation,* which has a three-sided equatorial shape.

Type Species: Trochoaster simplex Klumpp.

TROCHOASTER SIMPLEX
Klumpp, 1953
Plate 8, figs. 9, 10
Plate 9, fig. 8

Trochoaster simplex KLUMPP, 1953, p. 385, pl. 16, fig. 7; MARTINI, 1958, p. 368, pl. 5, fig. 25; MARTINI and STRADNER, 1960, p. 269, fig. 19; STRADNER and PAPP, 1961, p. 4, fig. 14–3; pl. 42, fig. 4; BOUCHÉ, 1962, p. 91–92, pl. 4, fig. 6; LEVIN, 1965, p. 271, pl. 43; figs. 7–9; LEVIN and JOERGER, 1967, p. 171, pl. 3, figs. 20–21; HODSON and WEST, 1970, p. 170; PERCH-NIELSEN, 1971a, p. 956, fig. 12; PERCH-NIELSEN, 1971b, p. 58, pl. 57, fig. 8.

Trochoaster duplex KLUMPP, 1953, p. 385, pl. 16, fig. 10.

Polycladolithus stellaris STRADNER, 1959, p. 487, figs. 74, 75, 77 e–h.

Remarks: Forms encountered in the Weches Formation have six rays extending beyond the central biconvex body. In frontal view the equatorial outline between rays is hexagonal. The surface of the biconvex body consists of a small central window. Six ridges radiate outward from the walls of the windows. The rays are connected by a crudely annular cycle of ridges spanning the inter-ray areas, producing six additional windows. Three windows are equal in size to the central window and alternate with larger windows.

PLATE 9

The long axis of each specimen is parallel to
the polarizer unless otherwise specified.

Magnification 1800 X

(continued next page)

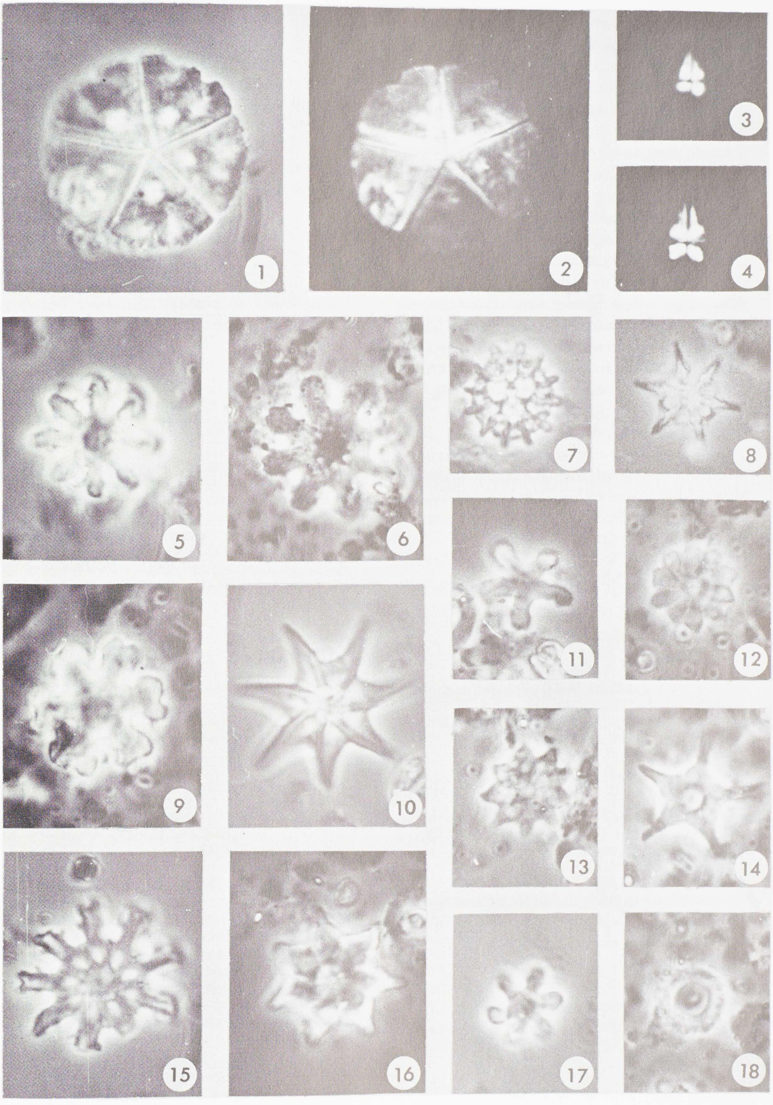

PLATE 9

15 *Discoaster mirus* Deflandre 64
Phase-contrast, from Sabine River E.

16 *Discoaster saipanensis* Bramlette and Riedel 65
Phase-contrast, from Hardin County 11, 8271 (02.7; 74.4), W.U.M.C. 000254.

17 *Discoaster tumescens* Noël 68
Phase-contrast, from Smithville A.

18 *Discoaster lenticularis* Bramlette and Sullivan 64
Phase-contrast, from Fort Bend County 6, 10180 (12.6; 75.4), W.U.M.C. 000253.

The ridges which border the larger windows are directed outward toward the periphery forming a V, the apex of which is located at the center of the inter-ray area.

The opposite side shows a small central window surrounded by six radial rays. Three large windows and three small depressions alternate in inter-ray areas. Specimens were free of overgrowths of calcite; only a few showed broken rays.

Hypotype: Smithville A, SEM negatives 5824 and 5880; Size: 11.5 microns.

Occurrence: Reported from the Eocene through the middle Miocene in various parts of the world.

TROCHASTER RADIATUS
Locker, 1965
Plate 9, fig. 7

Trochoaster radiatus LOCKER, 1965, p. 1258, pl. 2, fig. 1; text-fig. 1; PERCH-NIELSEN, 1971a, p. 956, fig. 12.

Remarks: Biconvex body of labyrinthic construction. Three circular openings approximately 1.5 microns across are disposed at 120 degrees to each other about the center of the top side. The openings are separated by a three-armed ridge at the center and bordered by annular ridges which give rise to twelve radially disposed rays. The radial rays extend beyond the equator of the body, protruding approximately 1 micron. The opposite side of the body has the arms of the central bridge rotated 60 degrees relative to those of the top side.

Hypotype: Hurricane Shoals J (14.7; 80.8), W.U.M.C. 000244; Size: 10 microns.

Occurrence: Reported from the upper Eocene in north central Germany.

Family DISCOASTERACEAE
Tan, 1927

Description: Rosette or star-shaped calcareous discs (asteroliths) of radiating construction with ortholithid optical features in cross-polarized light. The discs may be ornamented with stars, knobs, ridges, sutures or pores. Some forms may bear stems on one or both sides of the disc.

Genus DISCOASTER
Tan, 1927

Description: Rosette or star-shaped asteroliths with or without simple stems on one or both sides. In cross-polarized light the specimen is extinct in all positions in plan view.

Type Species: *Discoaster pentaradiatus* Tan.

DISCOASTER ASTER
Bramlette and Riedel, 1954
Plate 9, fig. 11

Discoaster aster BRAMLETTE and RIEDEL, 1954, p. 400, pl. 39, fig. 7; BRAMLETTE, 1957, p. 249, pl. 61, fig. 4; STRADNER, 1959, p. 1088, fig. 29; NARASIMHAN, 1961, p. 70, pl. 2, fig. 2; STRADNER and PAPP, 1961, p. 63, pl. 1, fig. 1–7; text-fig. 8–1; LEVIN, 1965, p. 270, pl. 43, fig. 3; LEVIN and JOERGER, 1967, p. 171, pl. 3, figs. 14, 15; RADOMSKI, 1968, p. 578; BYSTRICKÁ, 1969b, pl. 17, fig. 14; BARTOLINI and PARINI, 1969, p. 86, pl. 8, fig. 4; CLOCCHIATTI, 1971, p. 71, pl. 24, figs. 3, 4; pl. 25, fig. 1; pl. 26, fig. 1; text-fig. 12. PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Planar stellate asterolith usually of five or six rays. The free length of the rays is one to two times greater than the radius of the central disc. The rays are broad with rounded, blunt ends. The sides of the ray are often rugose giving a saw-tooth appearance to some rays. The rays may be straight throughout their length or slightly curved. The width of separation between rays is highly variable. The inter-ray area is subangular to rounded. No button or star has been observed on the central disc.

Hypotype: Fort Bend County 6, 9490 (09.1; 77.2), W.U.M.C. 000245; Size: 7 microns.

Occurrence: Reported from the Tertiary and possibly Quaternary of various parts of the world.

DISCOASTER BARBADIENSIS
Tan, 1927
Plate 9, fig. 12
Plate 10, fig. 1

Discoaster barbadiensis TAN, 1927, p. 119; BERSIER, 1939, p. 238, figs. 22–29; BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, fig. 5a, b; BRAMLETTE, 1957, pl. 61, fig. 10; MARTINI, 1958, p. 366, pl. 5, fig. 24a–c; STRADNER, 1959, p. 1082, fig. 2; STRADNER, 1959, p. 484, fig. 28; MARTINI, 1960, p. 76, pl. 8, fig. 10; STRADNER and PAPP, 1961, p. 95, pl. 28, figs. 1, 2; text-figs. 9–7, 18–6, 24–3; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 2; MANIVIT, 1961, p. 369, pl. 10, figs. 1–5; NARASIMHAN, 1961, p. 73, pl. 8, fig. 16; *non* HAY and TOWE, 1962, p. 515, pl. 10, figs. 3, 5; BOUCHÉ, 1962, p. 89, pl. 3, figs. 1–4; text-figs. 16, 17 and c; STRADNER, 1962, p. 181, pl. 2, figs. 6, 7; SULLIVAN, 1964, p. 189, pl. 10, figs. 5, 6; COHEN, 1965a, p. 32, pl. 7, figs. a–d; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 17; HAQ, 1967, p. 63, figs. 1, 2; HAY *et al.*, 1967, pl. 1, figs. 9–11: LOCKER, 1968, p. 224, pl. 1, fig. 13; RADOMSKI, 1968, pl. 47, fig. 11; ACHUTHAN and STRADNER, 1969, p. 5, pl. 4, figs. 1, 2; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 4; BYSTRICKÁ, 1969a, p. 207, pl. 40, figs. 2–4; BYSTRICKÁ, 1969b, p. 81, pl. 11, figs. 1–11; pl. 17, figs. 1–13; HAQ, 1969, p. 6, pl. 3, figs. 4–7; text-fig. 1A; HONJO and MINOURA, 1969, p. 166, figs. 3, 4; MARTINI, 1969a, pl. 29, fig. 9; HOFFMANN, 1970, p. 11, pl. 1, figs. 1–4; HODSON and WEST, 1970, p. 168, pl. 1, figs. 2, 5; CLOCCHIATTI, 1971, p. 72, pl. 30, figs. 1–4; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 35, pl. 8, figs. 6, 7; pl. 10, figs. 11, 12; HAQ, 1971b, p. 89, MARTINI, 1971c, p. 743, PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 61, pl. 51, fig. 5; RAMSAY, 1971, p. 206, pl. 1, fig. 5; ROTH, BAUMANN and BERTOLINO, 1971, figs. 5–9.

Remarks: Concavo-convex discoaster with 9–14 petal-like rays. The rays are joined throughout most of their length. At the periphery the terminations of the rays are rounded, blunt or slightly pointed. The convex side of the asterolith bears a small central knob, the concave side a short stem.

The knob on the convex side of *Discoaster barbadiensis* is smaller and less prominent than the knob found on the convex side of *D. elegans.* The periphery of *D. elegans* is more deeply serrate giving the rays long, tapering terminations. Annular rings or ridges are concentrically arranged about the center of *D. elegans;* no such ridges are present in *D. barbadiensis. D. barbadiensis* shows less relief in Canada balsam than *D. elegans.*

Hypotypes: Polk County 9, 5333 (21.0; 73.5), W.U.M.C. 000246; Size: 8 microns. Fort Bend County 6, 9490, SEM negative 5792; Size: 15 microns.

Occurrence: Reported from the Eocene in various parts of the world.

DISCOASTER BINODOSUS BINODOSUS
Martini, 1958
Plate 9, fig. 5
Plate 10, fig. 6

Discoaster binodosus binodosus MARTINI, 1958, p. 362, pl. 4, fig. 18; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 61, pl. 52, fig. 6.

Discoaster binodosus MARTINI, 1959, p. 138; STRADNER, 1959a, p. 1084, fig. 18; STRADNER, 1959b, p. 479, fig. 42; MARTINI, 1960, p. 79, pl. 9, fig. 20; NOËL, 1960, p. 212, pl. 1, fig. 15; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 1; MARTINI, 1961, p. 12, pl. 3, fig. 25; NARASIMHAN, 1961, p. 92, pl. 9, fig. 5; STRADNER *in* STRADNER and PAPP, 1961, p. 66, pl. 4, figs. 1–7; pl. 5, figs. 1–6; text-fig. 8–4; BOUCHÉ, 1962, p. 9, pl. 3, fig. 9; *non* text-fig. 27; STRADNER, 1962, p. 181, pl. 1, figs. 1–6; SULLIVAN, 1964, p. 189, pl. 11, fig. 5; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 18; PERCH-NIELSEN, 1967, p. 30, pl. 7, figs. 5–9; LOCKER, 1968, p. 223, pl. 1, fig. 14; RADOMSKI, 1968, p. 579; BYSTRICKÁ, 1969, p. 208, pl. 63, figs. 6–8; HOFFMANN, 1970, p. 13, pl. 2, figs. 4–7; GARTNER, 1971, fig. 3; HAQ, 1971a, p. 36, pl. 14, fig. 4; HAQ, 1971b, p. 90, pl. 12, fig. 9; MARTINI, 1971, p. 743, pl. 2, fig. 4.

Remarks: Discoaster with six to nine rays around a large central disc. The central disc bears a flat button. The rays are equal to or longer than the radius of the central disc. Each ray bears a pair of rounded nodes at its half length. The rays are of uniform width to the paired nodes. Beyond the nodes the rays narrow and become rounded at their tips.

Hypotypes: Fort Bend County 6, 9490 (04.1; 76.4), W.U.M.C. 000247; Size: 11 microns. Sabine River E, SEM negative 6483; Size: 13 microns.

Occurrence: Reported from the Paleocene through the Miocene in various parts of the world.

DISCOASTER BINODOSUS HIRUNDINUS
Martini, 1958
Plate 9, fig. 6
Plate 10, fig. 7

Discoaster binodosus hirundinus MARTINI, 1958, p. 362, pl. 4, fig. 19; MARTINI, 1960, p. 79, pl. 9, fig. 21; HAY, MOHLER and WADE, 1966, p. 395, pl. 13, fig. 2; PERCH-NIELSEN, 1967, p. 30, pl. 7, figs. 1–4; HOFFMANN, 1970, p. 15, pl. 2, figs. 2, 3; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 62, pl. 52, fig. 7.

Discoaster binodosus Martini. BOUCHÉ, 1962, p. 90; text-fig. 27; BYSTRICKÁ, 1964, p. 213, pl. 5, fig. 5; MARTINI, 1971c, p. 743.

Discoaster tani nodifer Bramlette and Riedel. LEVIN, 1965, p. 270, pl. 43, fig. 5; CLOCCHIATTI, 1971, p. 90, pl. 38, fig. 2.

Remarks: Discoasters with six to nine rays about a large central disc. The central disc bears a star-shaped central button. The rays extend beyond the central disc a distance equal to or greater than the radius of the central disc. Each ray bears a pair of nodes at its half length. Beyond the nodes the rays narrow and terminate peripherally with blunt ends which are notched.

The peripheral notch in each ray distinguishes this sub-species from *Discoaster binodosus binodosus.* The specimen illustrated in the light micrograph has thicker rays than is typical of the Weches specimens of this species.

Hypotypes: Polk County 9, 5333 (27.8; 80.2), W.U.M.C. 000248; Size: 15 microns. Sabine River E, SEM negative 6473; Size: 13 microns.

Occurrence: Reported from the upper Eocene and lower Oligocene in Europe.

DISCOASTER DEFLANDREI
Bramlette and Riedel, 1954
Plate 9, fig. 9

Discoaster deflandrei BRAMLETTE and RIEDEL, 1954, p. 399, pl. 39, fig. 6; text-fig. 1a–c; BRAMLETTE, 1957, p. 249, pl. 6, fig. 6; MARTINI, 1958, p. 363, pl. 5, fig. 23; STRADNER, 1959, p. 1087, fig. 25; NOËL, 1960, p. 219, pl. 3, figs. 7–9; BRAMLETTE and SULLIVAN, 1961, p. 158, pl. 11, fig. 4; MANIVIT, 1961, p. 367, pl. 9, fig. 4; MARTINI, 1961, p. 13, pl. 3, fig. 27; STRADNER *in* STRADNER and PAPP, 1961, p. 71, pl. 10, figs. 1–6; text-fig. 8–7; STRADNER, 1962, p. 181, pl. 39, fig. 6; SULLIVAN, 1964, p. 190, pl. 11, fig. 8; COHEN, 1965a, p. 23, pl. 7, fig. h; BRAMLETTE and WILCOXON, 1967, p. 109, pl. 7, fig. 4; HAY *et al.,* 1967, p. 460, pl. 2, figs. 6–9; LEVIN and JOERGER, 1967, p. 172, pl. 4, figs. 1, 2; BYSTRICKÁ, 1969a, p. 210, pl. 63, figs. 1–3; RADOMSKI, 1968, p. 579, pl. 47, fig. 6; BYSTRICKÁ, 1969b, p. 83, pl. 13, figs. 1–4; CLOCCHIATTI, 1971, p. 80, pl. 33, fig. 3; pl. 34, fig. 1, 2; GARTNER, 1971, fig. 5., HAQ, 1971b, p. 90, pl. 12, fig. 10; HAQ, 1971c, p. 119. PERCH-NIELSEN, 1971a, p. 951, fig. 10; ROTH, BAUMANN, and BERTOLINO, 1971, fig. 5.

Remarks: Stellate asterolith usually having six rays around a central disc. The rays may be longer or shorter than the radius of the central disc. The more delicate forms in the Weches usually have arms longer than the radius of the central disc while the more robust forms have arms shorter than the central disc. The distal one-half to one-third of the rays thicken and bifurcate, producing a gently tapering wide open V-shaped terminal notch. The terminal notch may be rounded but is usually angular. The outline of the thickened area is angular or rounded. The area between rays is subcircular. The central disc sometimes bears a distinct knob.

Hypotype: Fort Bend County 6, 10180 (15.8; 75.4), W.U.M.C. 000249; Size: 12.5 microns.

Occurrence: Reported from the Paleocene to the lower Miocene in various parts of the world.

DISCOASTER DIASTYPUS
Bramlette and Sullivan, 1961
Plate 9, fig. 13

Discoaster diastypus BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, figs. 6–8; SULLIVAN, 1964, p. 190, pl. 10, figs. 3, 4;

SULLIVAN, 1965, p. 41; GARTNER, 1971, figs. 1, 3, 5; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 62, pl. 51, fig. 8–10.

Discoaster aff. *D. diastypus* BRAMLETTE and SULLIVAN, 1961, pl. 11, figs. 9, 10.

Remarks: Asteroliths with nine or ten broad, sharply pointed rays joined through most of their length. The nearly straight rays surround a central button on the convex side and a stem on the concave side.

Hypotype: Austin County 5, 9625(29.7; 75.5), W.U.M.C. 000250; Size: 10 microns.

Occurrence: Reported from the lower Eocene in the United States and Europe.

DISCOASTER DISTINCTUS
Martini, 1958
Plate 11, figs. 6–8
Plate 12, figs. 3, 5

Discoaster distinctus MARTINI, 1958, p. 363, pl. 4, fig. 17; MARTINI, 1959, p. 138; STRADNER, 1959, p. 1086, *non* fig. 20; STRADNER, 1959 p. 484, *non* figs. 33–39; MARTINI, 1960, p. 77, pl. 9, fig. 15; BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, figs. 11–13; MARTINI, 1961, p. 14, pl. 3, fig. 28; NARASIMHAN, 1961, p. 83, pl. 9, fig. 14; pl. 1, fig. 6; STRADNER *in* STRADNER and PAPP, 1961, p. 72, pl. 2, fig. 1; BOUCHÉ, 1962, p. 91, pl. 3, fig. 14; text-fig. 30; STRADNER, 1962, p. 181, pl. 2, fig. 1; SULLIVAN, 1964, p. 190, pl. 11, fig. 7; SULLIVAN, 1965, p. 41, pl. 10, fig. 4; HAY, MOHLER and WADE, 1966, p. 395, pl. 13, *non* fig. 2; BUKRY and KENNEDY, 1969, fig. 3, no. 6; BYSTRICKÁ, 1969, p. 210, pl. 63, figs. 10, 11; HODSON and WEST, 1970, p. 167, pl. 1, fig. 1; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 10; PERCH-NIELSEN, 1971b, p. 63, pl. 52, fig. 5; pl. 53, fig. 1.

Remarks: Discoasters with five or six rays. The rays are appreciably longer than the radius of the central disc. The central disc bears a distinct star-shaped button. The sides of the rays are sub-parallel, thinning as they leave the central disc. At one-half to three-fourths the length of the ray a strong bifurcation and rapid lateral thickening occurs, producing a deep rectangular shaped terminal notch in each ray. Close to or at the point of bifurcation a pair of lateral nodes often occurs on the sides of the rays.

TEM micrographs by Hodson and West (1970) have revealed that the deep terminal notches are partly filled by calcite and thus appear less pronounced in electron micrographs. SEM micrographs of specimens from the Weches Formation also show the notch to be filled.

Hypotypes: Hurricane Shoals M (19.6; 76.1), W.U.M.C. 000251; Size: 11 microns. Smithville A, SEM negative 5882; Size: 10.5 microns. Fort Bend County 6, 9490, SEM negative 5794.

Occurrence: Reported from the middle and upper Eocene in various parts of the world and the lower Eocene of France.

DISCOASTER ELEGANS
Bramlette and Sullivan, 1961
Plate 10, figs. 2, 4
Plate 11, figs. 1, 2

Discoaster elegans BRAMLETTE and SULLIVAN, 1961, p. 159, pl. 11, fig. 16; STRADNER *in* STRADNER and PAPP, 1961, p. 97, pl. 28, figs. 4a, b; BOUCHÉ, 1962, p. 89, pl. 3, figs. 5–7; text-figs. 18–20 and c; SULLIVAN, 1964, p. 190, pl. 10, figs. 1, 2; RADOMSKI, 1968, p. 580; BYSTRICKÁ, 1969a, p. 211, pl. 40, figs. 7–10; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 63, pl. 51, figs. 2, 3.

Discoaster stradneri NOËL, 1960, p. 215, pl. 2, *non* fig. 7; MARTINI, 1961, p. 10, pl. 2, fig. 22; pl. 5, fig. 52.

Discoaster barbadiensis Tan. NARASIMHAN, 1961, p. 73, pl. 9, fig. 18; HAY and TOWE, 1962, p. 515, pl. 10, figs. 3, 5; CLOCCHIATTI, 1971, p. 72, pl. 30, figs. 1–4; RAMSAY, 1971, p. 206, pl. 1, fig. 4.

Discoaster boulangeri LEZAUD, 1968, p. 23, pl. 1, figs. 9–12; pl. 2, fig. 14; PERCH-NIELSEN, 1971b, p. 62, pl. 52, fig. 1.

Discoaster saipanensis Bramlette and Riedel. CLOCCHIATTI, 1971, p. 87, pl. 31, figs. 1–3; pl. 32, fig. 3; text-fig. 18; PERCH-NIELSEN, 1971b, p. 65, pl. 52, fig. 4.

Remarks: Concavo-convex asterolith with 11–15 rays. The rays are arched along their midline and terminate in pointed or blunt tips. SEM micrographs show that the edges of the rays are slightly thickened with a ridge on the concave side of the asterolith. The ridges extend up into a conical stem on the concave side. A small round button is located at the center of the convex side. In the light microscope concentric rings or ridges are observed on both the concave and convex sides of this species. SEM micrographs show these ridges only on the concave side.

The degree of taper to the terminations of the rays is variable. Forms with blunt tips have rays with cross sections that are not gently

Discoaster spp. BRAMLETTE and SULLIVAN, 1961, p. 163, pl. 13, figs. 1–5.

Remarks: Planar asterolith of eight to ten rays. The ray length is less than the radius of the large central disc. The width of the rays is quite variable; some forms have spaces between rays large enough to accommodate an additional ray whereas others have spaces equal to less than half the ray width. The wider the ray the shorter its length relative to the central disc. The sides of the rays are parallel for any given specimen. Slight thickening occurs at the distal end of the rays just before they bifurcate. The terminal notch produced by the bifurcation may be V or U-shaped. At about half the length of the ray, lateral rectangular to rounded projections occur. In the more robust forms the distance between the lateral projections and the terminal thickenings is less.

The central disc bears a star of six to eight points. Teardrop-shaped ridges radiate from just beyond the edge of the star.The large end of the teardrops project slightly beyond the periphery of the central disc into the interray area. The surface of the central disc and the rays are covered with pustules.

The photomicrograph and SEM micrograph (Plate 12, figure 1) are of the same specimen. The photomicrograph shows the teardrop ridges to be prominent and located on the surface of the specimen. The SEM picture shows that no ridges exist on the top surface; it appears that they are located on the underside.

Hypotype: Sabine River E, SEM negative 6469, Size: 18 microns.

Occurrence: Reported from the Eocene in various parts of the world.

PLATE 10

Magnification 4500 X
unless otherwise specified.

Figures		Page
1	*Discoaster barbadiensis* Tan From Fort Bend County 6, 9490, SEM negative 5792.	59
2, 4	*Discoaster elegans* Bramlette and Sullivan From Smithville A 2. Concave side, SEM negative 4879 4. Convex side, SEM negative 5801	61
3	*Discoaster tumescens* Noël From Smithville A, SEM negative 5875.	68
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7	*Discoaster binodosus hirundinus* Martini From Sabine River E, SEM negative 6473.	60

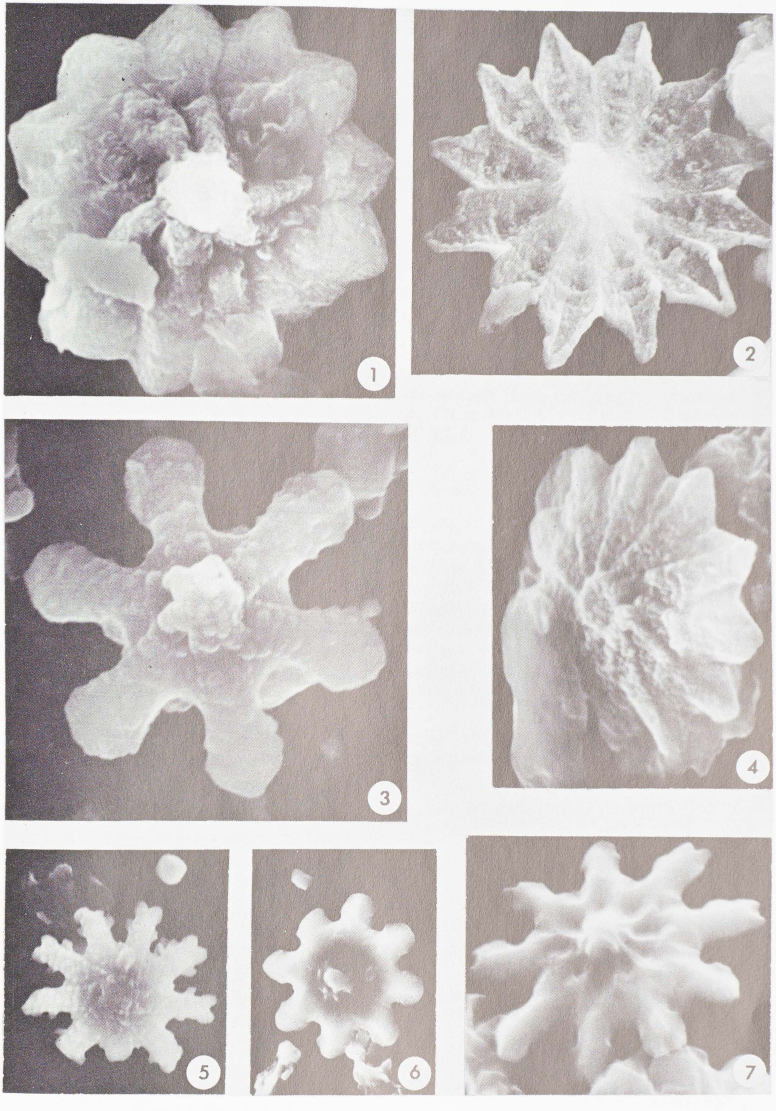

PLATE 10

rounded but have a wide flat surface on the convex side of the ray. *D. elegans* is distinguished from *D. barbadiensis* by being more strongly convex, having more gently tapered terminations to the rays, showing more relief in Canada balsam, and having a longer stem.

Hypotypes: Smithville A (23.0; 71.2), W.U.M.C. 000252; Size: 15 microns. SEM negative 4879; Size: 14 microns.

Occurrence: Reported from the Paleocene and Eocene in various parts of the world.

DISCOASTER LENTICULARIS
Bramlette and Sullivan, 1961
Plate 9, fig. 18

Discoaster lenticularis BRAMLETTE and SULLIVAN, 1961, p. 160, pl. 12, figs. 1, 2; BOUCHÉ, 1962, p. 90, pl. 3, figs. 11–13; text-figs. 22, 23; SULLIVAN, 1964, p. 191, pl. 11, fig. 1; SULLIVAN, 1965, p. 42, pl. 10, fig. 10; HAY and MOHLER, 1967, p. 1539; RADOMSKI, 1968, p. 582, pl. 48, fig. 1; HAQ, 1971a, p. 39, pl. 14, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Discoidal asterolith with 20–26 narrow rays joined throughout most of their length and terminating bluntly. A smooth central button occupies nearly half the diameter of the asterolith. A shallow depression is located at the center of the button.

Hypotype: Fort Bend County 6, 10180 (12.6; 75.4), W.U.M.C. 000253; Size: 7 microns.

Occurrence: Reported from the upper Paleocene through the lower Eocene in various parts of the world.

DISCOASTER LODOENSIS
Bramlette and Riedel, 1954
Plate 9, fig. 10
Plate 12, figs. 1, 2

Discoaster lodoensis BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, figs. 3a, b; MARTINI, 1958, p. 366, pl. 6, figs. 28a–d; STRADNER, 1959a, p. 478, figs. 14–16, 19, 20; STRADNER, 1959b, p. 1083, fig. 5; MARTINI, 1960, p. 76, pl. 8, fig. 11; BRAMLETTE and SULLIVAN, 1961, p. 161, pl. 12, figs. 4, 5; MANIVIT, 1961, p. 361, pl. 6, figs. 4, 5; NARASIMHAN, 1961, p. 75, pl. 1, fig. 15, pl. 3, figs. 13, 14; pl. 8, figs. 14, 17; STRADNER, 1961, p. 86, figs. 84, 85; STRADNER *in* STRADNER and PAPP, 1961, p. 92, pls. 25, 26; text-figs. 9–3, 24–9; HAY and TOWE, 1962, p. 514, pl. 10, figs. 2, 4, 6; SULLIVAN, 1964, p. 191, pl. 11, fig. 14; BLACK, 1965, fig. 20; COHEN, 1965a, p. 33, pl. 25, fig. 3; SULLIVAN, 1965, p. 42, pl. 10, fig. 14; HAQ, 1967, p. 63, pl. 7, figs. 3, 6, 7; BYSTRICKÁ, 1969a, p. 214, pl. 61, figs. 1–5; RADOMSKI, 1968, p. 582, pl. 47, figs. 10, 12; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 3; HAQ, 1969, p. 10, pl. 2, figs. 1–4; text-figs. 4E–G; HAQ, 1971a, p. 39; GARTNER, 1971, figs 1, 2, 4, 5; MARTINI, 1971c, p. 741, pl. 2, fig. 2; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, pl. 52, fig. 2; RAMSAY, 1971, p. 206; pl. 1, figs. 8, 9.

Remarks: Stellate asterolith of five to seven curved rays which taper to a sharp point. The rays are joined for about one-half their length. The gently convex side of the asterolith bears a prominent stem. A ridge runs along one side of each ray and extends into the center where it becomes part of the stem. The ridges run up the side of the stem and terminate as raised nodes around the edge of the stem. In plan view the rays are seen to spiral counterclockwise on the stem-bearing side. This side of the asterolith has been named the "facies laevagyra" by Stradner.

Light and SEM micrograph 6466 are of the same specimen.

Hypotypes: Sabine River E, SEM negative 6369; Size: 13 microns. SEM negative 6466; Size: 18 microns.

Occurrence: Reported from the lower and middle Eocene in various parts of the world.

DISCOASTER MIRUS
Deflandre, 1952
Plate 9, fig. 15
Plate 10, fig. 5

Discoaster mirus DEFLANDRE *in* GRASSÉ, 1952, p. 465, fig. 362Z, invalid no description; DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 168; text-fig. 118; STRADNER, 1959a, p. 479, fig. 41; NOËL, 1960, p. 217, pl. 2, fig. 10; MARTINI, 1961, p. 12, pl. 3, fig. 24; NARASIMHAN, 1961, *non* p. 89, pl. 1, fig. 17; pl. 9, fig. 7; STRADNER, 1961, p. 1086, fig. 23; STRADNER *in* STRADNER and PAPP, 1961, p. 68, pl. 6, figs. 5, 6; pl. 7, figs. 1–5; text-figs. 8–5, 24–7; BYSTRICKÁ, 1969a, p. 215, pl. 63, figs. 4, 5; BYSTRICKÁ, 1969b, p. 83, pl. 13, figs. 9–11; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 10; ROTH, BAUMANN, and BARTOLINO, 1971, figs. 5, 7, 9.

DISCOASTER SAIPANENSIS
Bramlette and Riedel, 1954
Plate 9, fig. 16
Plate 12, fig. 4

Discoaster saipanensis BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, fig. 4; BRAMLETTE, 1957, p. 249, pl. 61, fig. 7; MARTINI, 1958, p. 367, pl. 6, fig. 29; STRADNER, 1959, p. 1083, fig. 3; MARTINI, 1960, p. 76, pl. 8, fig. 12; NOËL, 1960, p. 210, pl. 1, fig. 13; MANIVIT, 1961, p. 359, pl. 6, figs. 1–3; NARASIMHAN, 1961, p. 77, pl. 1, fig. 13; pl. 2, fig. 3; STRADNER *in* STRADNER and PAPP, 1961, p. 90, pl. 22, figs. 6, 7, 9; text-fig. 9–5; HAY, MOHLER and WADE, 1966, p. 396, pl. 11, figs. 8, 9; pl. 13, fig. 1; GARTNER and SMITH, 1967, p. 6, pl. 12, figs. 4, 5; HAQ, 1967, p. 64, pl. 8, figs. 4, 6, 7; HAY *et al.*, 1967, pl. 1, figs. 4–6; LEVIN and JOERGER, 1967, p. 172, pl. 3, fig. 16; RADOMSKI, 1968, p. 584, pl. 48, fig. 2; BILGÜTAY *et al.*, 1969, p. 173, pl. 3, fig. 5; STRADNER, 1969, p. 665, pl. 6, fig. 5; BYSTRICKÁ, 1969a, p. 220, pl. 59, figs. 11–13; BYSTRICKÁ, 1969b, p. 80, pl. 11, figs. 12–17; pl. 12, figs. 1–13; pl. 16, figs. 1, 2; pl. 18, figs. 1, 12; HAQ, 1969a, *non* p. 12, pl. 4, figs. 1–3; text-fig. 2d; CLOCCHIATTI, 1971, p. 87, pl. 31, figs. 1–3; pl. 32, fig. 3; text-fig. 18; GARTNER, 1971, figs. 1, 4, 5; HAQ, 1971a, p. 42; MARTINI, 1971c, p. 741, pl. 2, fig. 20; PERCH-NIELSEN, 1971a, p. 951, fig. 8; PERCH-NIELSEN, 1971b, p. 65, pl. 51, fig. 4; *non* pl. 52, fig. 4; ROTH, BAUMANN, BARTOLINO, 1971, figs. 5–9.

Remarks: Stellate asterolith with six or seven generally straight rays joined through slightly more than one-half their length. Straight to slightly curved ridges radiate from a central knob covering the joined portion of the rays. The free portion of the ray tapers gently, then steeply and terminates in rounded points.

This species is distinguished from *D. barbadiensis* by fewer but more pointed rays and by ridges running along the joined portions of the rays.

Hypotypes: Hardin County 11, 8271 (02.7; 75.4), W.U.M.C. 000254; Size: 13 microns. Fort Bend County 6, 9490, SEM negative 5796; Size: 8 microns.

Occurrence: Reported from the Eocene and lower Oligocene in various parts of the world.

DISCOASTER STELLA
(Ehrenberg)
Gardet, 1955
Plate 11, figs. 3, 4

Discoaster stella (Ehrenberg). GARDET, 1955, p. 529, pl. 8, figs. 81a–e, pl. 11, figs. 98-99; NOËL, 1960, p. 208, pl. 1, figs. 2–11.

Remarks: Stellate asteroliths with six rays. The length of the rays is equal to the radius of the central area. The rays are broad at the margin of the central area but taper to sharp points. The inter-ray area is V-shaped. The rays appear to be inclined at a shallow angle to the surface of the thick central area.

Hypotype: Fort Bend County 6, 10180 (07.4; 71.9), W.U.M.C. 000255; Size: 12 microns.

Occurrence: Reported from the Eocene through the Pliocene in various parts of the world.

DISCOASTER SUBLODOENSIS
Bramlette and Sullivan, 1961
Plate 9, fig. 14

Discoaster sublodoensis BRAMLETTE and SULLIVAN, 1961, p. 162; pl. 12, fig. 6; BOUCHÉ, 1962, p. 90, pl. 3, figs. 18, 19; text-figs. 25, 26; SULLIVAN, 1965, p. 43, pl. 10, fig. 11; GARTNER, 1971, figs. 2, 4; MARTINI, 1971c, p. 741, pl. 2, fig. 3; PERCH-NIELSEN, 1971a, p. 951, fig. 8; RAMSAY, 1971, pl. 1, figs. 8, 9.

Remarks: Stellate asterolith of five or six straight rays. The rays are sharply pointed, widening at first gently and then rapidly as they fuse with the central disc. The length of the rays is greater than the radius of the central disc. A flat circular button is present at the center of the disc.

Hypotype: Fort Bend County 6, 10180 (15.2; 74.9), W.U.M.C. 000256; Size: 13 microns.

Occurrence: Reported from the middle Eocene in various parts of the world.

DISCOASTER TANI NODIFER
Bramlette and Riedel, 1954
Plate 11, fig. 5

Discoaster tani nodifer BRAMLETTE and RIEDEL, 1954, p. 397, pl. 39, fig. 2; MARTINI, 1959, p. 138; MARTINI, 1960, p. 78, pl. 9, fig. 19; NOËL, 1960, p. 218, pl. 2, fig. 13; MANIVIT, 1961, p. 367, pl. 9, fig. 1; NARASIMHAN, 1961, p. 80, pl. 8, fig. 5; LEVIN, 1965, p. 270, pl. 43, fig. 5; HAY *et al.*, 1967, pl. 1, fig. 2; LEVIN and JOERGER, 1967, p. 172, pl. 4, figs. 4–6; HAQ, 1968, p. 46, pl. 10, fig. 7; MARTINI, 1968, p. 240, pl. 1, fig. 5; MARTINI and RITZKOWSKI, 1968, pl. 1, fig. 5; BYSTRICKÁ, 1969, p. 223, pl. 62, fig. 2;

PLATE 11

The long axis of each specimen is parallel to the polarizer unless otherwise specified.

Magnification 1800 X

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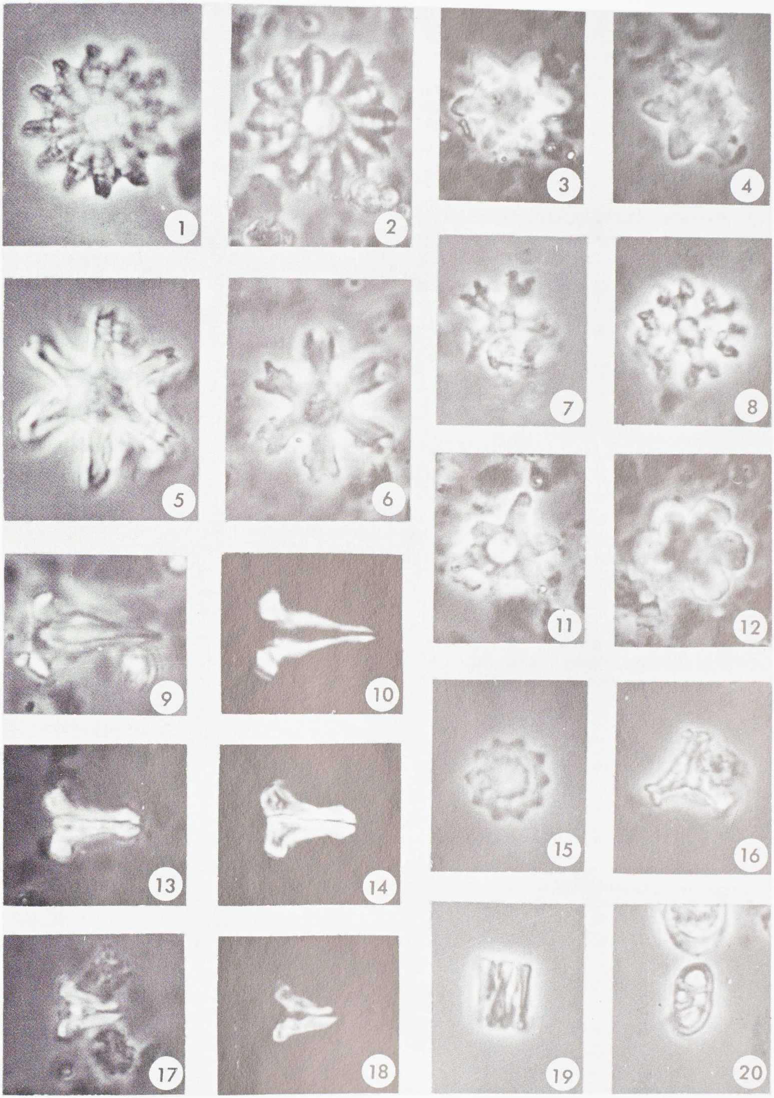

PLATE 11

STRADNER, 1969, p. 665, pl. 6, fig. 4; ROTH, 1970, p. 868, pl. 12, fig. 4; CLOCCHIATTI, 1971, p. 90, pl. 38, fig. 2; GARTNER, 1971, fig. 1, 4, 5; HAQ, 1971a, p. 42, pl. 10, fig. 13; HAQ, 1971b, p. 91, pl. 12, fig. 4; MARTINI, 1971, p. 743, PERCH-NIELSEN, 1971a, p. 951, fig. 8; ROTH, BAUMANN, and BARTOLINO, 1971, figs. 5, 7, 8.

Discoaster tani Bramlette and Riedel. RADOMSKI, 1968, p. 585.

Remarks: Asterolith of five to seven rays. The rays are robust, of uniform width and bear paired barb-like projections at their half-lengths. This subspecies is distinguished from *D. tani tani* by a terminal notch in each ray. There is a slight widening of the rays adjacent to the terminal notch. The free length of the rays is roughly equal to the radius of the central disc. A star-shaped button is sometimes present at the center of the disc.

Discoaster binodosus hirundinus is distinguished from *D. tani nodifer* by its larger central disc and the central button which is sometimes surrounded by an annular ring. The paired projections along the rays are rounder in *D. b. hirundinus.* The rays narrow from the paired projection to their distal end and bear a more conspicuous terminal notch than *D. t. nodifer.*

Hypotype: Sabine River E (08.6; 79.2), W.U.M.C. 000257; Size: 16 microns.

Occurrence: Reported from the middle and upper Eocene in various parts of the world.

DISCOASTER TRIANGULARIS
Bystricka', 1966
Plate 11, fig. 11
Plate 12, fig. 6

Discoaster triangularis BYSTRICKA', 1966, p. 239, figs. 8, 9; BYSTRICKA', 1969, p. 223, pl. 64, fig. 11; PERCH-NIELSEN, 1971a, p. 951, fig. 8

Remarks: Triangular-shaped discoaster with six rays. Three long rays alternate with three short rays producing the triangular outline of this species. A large circular button is located at the center of the specimen. The rays are broad, tapering only slightly before terminating in rounded points.

The termination of the rays may be pointed in some specimens. Where the terminations are pointed, the rays are more strongly tapered and shorter in length.

Hypotypes: Fort Bend County 6,10180 (06.6; 71.5), W.U.M.C. 000258; Size: 9 microns across base. SEM negative 6478; Size: 9 microns across base.

Occurrence: Reported from the upper Eocene in the Western Carpathians.

DISCOASTER TUMESCENS
Noël, 1960
Plate 9, fig. 17
Plate 10, fig. 3

Discoaster tumescens NOËL, 1960, p. 207, 218; pl. 3, figs. 1–3; PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Stellate aterolith usually with six rays. The free length of the rays is equal to or a little longer than the radius of the central disc. The rays thicken towards the distal end and terminate in subcircular lobes. SEM micrographs reveal the presence of a star-shaped central button with its rays pointing toward the inter-ray areas. The surface of the asterolith is covered with pustules. The inter-ray areas are variable in shape; most are subcircular but some are triangular.

Hypotype: Smithville A, SEM negative 5875; Size: 14 microns.

Occurrence: Reported from the Oligocene to the Miocene in various parts of the world.

DISCOASTER WOODRINGI
Bramlette and Riedel, 1954
Plate 11, fig. 12

Discoaster woodringi BRAMLETTE and RIEDEL, 1954, p. 400, pl. 39, fig. 8; BRAMLETTE, 1957, p. 249, pl. 61, fig. 5; FURRAZOLA-BERMUDEZ and ITURRALDE-VINENT, 1967, p. 9, pl. 1, figs. 4, 5; ROTH, 1970, p. 868, pl. 12, fig. 6; CLOCCHIATTI, 1971, p. 94, pl. 28, fig. 1; GARTNER, 1971, fig. 5; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Rotund asteroliths with six thick rays. The free length of the rays is a little greater than the radius of the central disc. The rays are wide and broadly rounded at their distal end. The inter-ray area is V-shaped or gently rounded.

Hypotype: Fort Bend County 6, 10180 (14.1; 72.1), W.U.M.C. 000259; Size: 11 microns.

Occurrence: Reported from the upper Eocene into the upper Oligocene in various parts of the world.

Genus DISCOASTEROIDES
Bramlette and Sullivan, 1961

Description: Asteroliths having a large, terminally concave stem flaring out as radiate elements at the end. The stem shows an interference pattern in cross-polarized light.

Type Species: *Discoasteroides kuepperi* (Stradner) Bramlette and Sullivan.

DISCOASTEROIDES KUEPPERI
(Stradner)
Bramlette and Sullivan, 1961
Plate 11, fig. 15
Plate 12, figs. 8, 9

Discoaster kuepperi STRADNER, 1959, p. 478, figs. 17, 21; MARTINI, 1961, p. 14, pl. 3, fig. 29; STRADNER *in* STRADNER and PAPP, 1961, p. 93, pl. 27, figs. 1–6; text-figs. 9–6, 16; PERCH-NIELSEN, 1971b, p. 64, pl. 51, figs. 6, 7, 9, 11, 12.

Discoasteroides kuepperi (Stradner). BRAMLETTE and SULLIVAN, 1961, p. 163, pl.13, figs. 16–19; HAY and TOWE, 1962, p. 515, pl. 10, *non* fig. 1; SULLIVAN, 1964, p. 192, pl. 12, figs. 1, 2; SULLIVAN, 1965, p. 44, HAQ, 1967, p. 62, pl. 4, figs. 1–6; BYSTRICKÁ, 1968, p. 224, pl. 60, figs. 9, 10; HAQ, 1968, p. 47, pl. 10, fig. 6; RADOMSKI, 1968, p. 586, pl. 48, figs. 5, 7–9; BYSTRICKÁ, 1969, p. 85, pl. 16, figs. 2, 3; HAQ, 1969, p. 15, pl. 3, figs. 1–3; HAQ, 1971a, p. 43; MARTINI, 1971c, p. 743; PERCH-NIELSEN, 1971a, p. 951, fig. 8.

Remarks: Stellate asterolith of seven to ten rays bearing a large, flared, terminally concave heliolithid stem on its concave side. The diameter of the flared end of the stem is equal to one-half that of the asterolith. The rays of the asterolith are joined throughout most of their length and terminate in sharp points. Ridges run between each ray and join the stem. The ridges extend up the sides of the stem and terminate as flared elements of the stem. The stem bears a large concave depression. The flared elements of the stem are located between the rays of the asterolith. Concentric ridges cross each ray on the stem-bearing side. The rays thus look very much like the rays on the concave side of *D. elegans*.

Hypotypes: Sabine River E (11.6; 73.6), W.U.M.C. 000260; Size: 6 microns, and SEM negatives 6334 and 6468; Size: 8 microns.

Occurrence: Reported from the Eocene in various parts of the world, with questionable occurrrence in the Paleocene.

Genus MARTHASTERITES
Deflandre, 1959

Description: Three-armed asteroliths with curved or straight arms radiating from an undifferentiated center. The arms may be of variable length and terminate simply or fork and bear variously disposed prongs.

Type species: *Marthasterites furcatus* Deflandre.

MARTHASTERITES FURCATUS
(Deflandre)
Deflandre, 1959
Plate 11, fig. 16
Plate 12, fig. 7

Discoaster furcatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 168, pl. 13, fig. 14; STRADNER, 1959, p. 1084, fig. 7; STRADNER, 1959, p. 477, fig. 1; MARTINI, 1960, p. 81, pl. 10, fig. 33.

Marthasterites furcatus (Deflandre). DEFLANDRE, 1959, pp. 133, 138, pl. 2, figs. 3–12, 16; *non* pl. 3, figs. 1–5; DEFLANDRE, 1961, pl. 3, fig. 31; NARASIMHAN, 1961, p. 66, pl. 5, figs. 9, 10, 16; pl. 9, figs. 16, 17; STRADNER, 1961, p. 83, figs. 62, 63; STRADNER *in* STRADNER and PAPP, 1961, p. 108, pl. 34, figs. 1, 2, 5; text-figs. 11–1, 11–3; STRADNER, 1963, pl. 2, fig. 11; STRADNER, 1964, fig. 46.

Trochoasterites hohnensis (Martini). BOUCHÉ, 1962, p. 91, pl. 4, figs. 13, 14.

Marthasterites hohnensis (Martini). PERCH-NIELSEN, 1971a, p. 951, fig. 9.

Remarks: Tri-radiate asterolith with rays all in the same plane. Each ray appears to be made up of three rectangular elements. The elements are fastened together in such a way as to give a nine-sided cross-section to each ray. The elements are widest at the center of the asterolith but taper gently toward the distal ends of the rays. Here each element curves away from the axis of the ray producing three nodes. Each node may itself bifurcate. Stefan Gartner, Jr., questioned the identification of this specimen in his review of the manuscript.

Hypotypes: Hurricane Shoals J (10.0; 69.9) W.U.M.C. 000261; Size: length of one ray, 4-5 microns. SEM negative 6443; Size: length of one ray, 4-5 microns.

Occurrence: Reported from the Middle Cretaceous to the middle Miocene.

Family ZYGODISCACEAE
Hay and Mohler, 1967

Description: Coccoliths consisting of an open elliptical ring made up of imbricate tabular laths spanned by an I, X, or H-shaped structure which is symmetrical about the short axis of the ellipse. Rim dextrogyre in distal view between crossed polarizers.

Genus CHIPHRAGMALITHUS
Bramlette and Sullivan, 1961

Description: Basket-shaped coccoliths divided into quadrants by cross-septa. The septa may be higher than the side walls.

Type Species: *Chiphragmalithus calathus* Bramlette and Sullivan.

CHIPHRAGMALITHUS CALATHUS
Bramlette and Sullivan, 1961
Plate 11, fig. 19

Chiphragmalithus calathus BRAMLETTE and SULLIVAN, 1961, p. 156, pl. 10, figs. 7, 8–10; SULLIVAN, 1964, p. 179, pl. 1, figs. 3–6; SULLIVAN, 1965, p. 30, pl. 1, figs. 9–18; REINHARDT, 1967, p. 218, pl. 4, fig. 18; PERCH-NIELSEN, 1971a, p. 967, fig. 21; PERCH-NIELSEN, 1971b, p. 47, pl. 39, fig. 4.

Remarks: In side view this species has a rectangular outline, being higher than it is wide. Three irregular ridges are seen to extend the length of the specimen in this view. One end is a little wider than the other. These ridges really are the side walls and one cross septum of the specimen. In plan view the specimens are nearly square with a thin rim surrounding an open central area which is spanned by an X-shaped central structure. The entire specimen is bright in side view between crossed-polarizers.

Hypotype: Sabine River E (77.7; 73.6), W.U.M.C. 000262; Size: 5 x 6 microns.

Occurrence: Reported from the Paleocene and lower Eocene in California and Denmark.

Genus NEOCOCCOLITHES
Sujkowski, 1931

Description: Thin delicate elliptical rim spanned by an H-shaped structure. The rim widens distally; in cross-polarized light the rim appears nearly isotropic.

Type Species: *Neococcolithes lososnensis* Sujkowski.

NEOCOCCOLITHES DUBIUS
(Deflandre)
Black, 1967
Plate 8, figs. 6, 7
Plate 11, fig. 20

Zygolithus dubius DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 149, text-fig. 43, 44, 68; GORKA, 1957, p. 267, pl. 1, fig. 6; MARTINI, 1958, p. 369, pl. 1, figs. 1a–c, *non* 1b; MARTINI, 1960, p. 83, pl. 11, fig. 39; BRAMLETTE and SULLIVAN, 1961, p. 343, pl. 1, fi. 4; *non* fig. 3; BOUCHÉ, 1962, p. 82, pl. 1, fig. 5; COHEN, 1965a, p. 26, pl. 4, fig. 5; PERCH-NIELSEN, 1967a, p. 130, pl. 1, fig. 3; PERCH-NIELSEN, 1967b, p. 28, pl. 5, figs. 13, 14; REINHARDT, 1967, p. 218, pl. 4, figs. 14–16; 19, 20; LOCKER, 1968, p. 222, pl. 2, fig. 19; PERCH-NIELSEN, 1968, p. 22, pl. 1, figs. 1–4; BILGÜTAY *et al.*, 1969, p. 174, pl. 2, figs. 4, 5; MARTINI, 1971c, p. 743.

Chiphragmalithus dubius (Deflandre). SULLIVAN, 1964, p. 179, pl. 1, fig. 2; SULLIVAN, 1965, p. 30, pl. 1, figs. 1, 2.

Neococcolithes dubius (Deflandre). BLACK, 1967, p. 143; RADOMSKI, 1968, p. 572, pl. 48, fig. 17; HODSON and WEST, 1970, p. 173, pl. 2, fig. 1; PERCH-NIELSEN, 1971a, p. 967, fig. 21; PERCH-NIELSEN, 1971b, figs. 1, 3–5; RAMSAY, 1971, p. 206, pl. 3, fig. 9.

Zygolithus minutus PERCH-NIELSEN, 1967, p. 28, pl. 5, figs. 6, 7; PERCH-NIELSEN, 1971b, p. 47, pl. 42, figs. 1–4.

Remarks: Coccoliths with a thin elliptical rim enclosing an open central area spanned by an H-shaped structure. The elements of the spanning structure extend above the elliptical rim. The crossbar of the H is aligned parallel to the long axis of the ellipse. The thickness of the crossbar elements is about the same as that of the rim. Elements of the rim and crossbar produce a vague interference pattern.

Neococcolithes dubius is distinguished from *N. protenus* by the presence of an H-shaped structure in the central area which extends up to the rim, and a more elongate elliptical form to the rim.

Hypotype: Smithville D_1, SEM negatives 5819 and 5883; Size: 5–8 microns long.

Occurrence: Reported from the Eocene of various places in the world and the Jurassic in North Africa; the Upper Cretaceous in Poland and the Miocene in Hungary.

Family ZYGOSPHAERACEAE Braarud and Gaarder, 1961

Description: Holococcoliths formed of microcrystals; the shape of the holococcoliths is variable.

Genus ZYGRHABLITHUS Deflandre, 1959

Description: Holococcoliths with a subcircular to elliptical basal ring bearing a diagonal cross which extends upward above the ring in the form of four tapering shafts.

Type Species: *Zygrhablithus bijugatus* (Deflandre) Deflandre.

ZYGRHABLITHUS BIJUGATUS (Deflandre) Deflandre, 1959 Plate 11, figs. 9, 10, 13, 14, 17, 18 Plate 12, figs. 10–12

Zygolithus bijugatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 148, pl. 11, figs. 20, 21.

Rhabdolithus costatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, p. 159, pl. 11, figs. 8–11; text-figs. 41, 42, 77–79.

Rhabdosphaera semiformis BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, figs. 8–10.

Zygrhablithus bijugatus (Deflandre). DEFLANDRE, 1959, p. 135; BRAMLETTE and SULLIVAN, 1961, p. 151, pl. 6, figs. 16–18; BOUCHÉ, 1962, p. 84, pl. 1, figs. 9–11; HAY and TOWE, 1962, p. 502, pl. 2, fig. 2; SULLIVAN, 1964, p. 187, pl. 7, figs. 9, 10; COHEN, 1965a, p. 27, pl. 4, figs. n, m; LEVIN, 1965, p. 267, pl. 42, fig. 1; SULLIVAN, 1965, p. 38; GARTNER and SMITH, 1967, p. 5, pl. 8, figs. 1–6; HAQ, 1967, p. 61; LEVIN and JOERGER, 1967, p. 170, pl. 2, fig. 24; pl. 3, figs. 1–4; HAQ, 1968, p. 40; pl. 7, fig. 10; pl. 9, figs. 10, 11; RADOMSKI, 1968, p. 575, pl. 43, figs. 11–13; STRADNER and EDWARDS, 1968, p. 44, pl. 42, 43; GARTNER and BUKRY, 1969, p. 1218, pl. 140, figs. 3–6; pl. 142, figs. 1, 2; HODSON and WEST, 1970, p. 174, pl. 3, fig. 2; HAQ, 1971a, p. 30, pl. 10, fig. 7; HAQ, 1971b, p. 89, pl. 12, fig. 5; pl. 13, figs 11–14; pl. 17, fig. 8; HAQ, 1971c, p. 118, pl. 17, fig. 5; PERCH-NIELSEN, 1971a, p. 945, fig. 3; PERCH-NIELSEN, 1971b, p. 58, pl. 58, fig. 7–9; pl. 59, fig. 10.

Remarks: Zygoliths with an open elliptical basal ring which widens toward the distal side. The ring is crossed by an X-shaped bridge which extends high above its distal surface as four blades. The blades bifurcate, forming four short prongs at the terminal periphery of the blades. The other branch of each bifurcate blade continues on a short distance and terminates in a rounded node (Plate 12, figure 10).

The rounded terminal node and prong on each blade is not always present. In small forms of this species the blades taper from the distal surface of the basal ring to a sharp distal point (Plate 12, figure 11). In some large specimens the blades have an undulating periphery (Plate 12, figure 12).

The various sizes and morphologies of this species suggest the existence of dimorphic holococcoliths on the coccospheres of *Zygrhablithus bijugatus*..

Hypotypes: Smithville A (02.6; 71.6), W.U.M.C. 000263; Size: 9 x 12.5 microns. SEM negative 5618; Size: 5 x 5 microns. SEM negative 5670; Size: 10 x 8 microns. SEM negative 6397; Size: 7 x 9 microns. Fort Bend County 6, 10180 (20.9; 72.3), W.U.M.C. 000264; Size: 6 x 10 microns.

Occurrence: Reported from the Eocene and Oligocene in various parts of the world.

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PLATE 12

Magnification 4500 X
unless otherwise specified.

Figures		Page

1, 2 *Discoaster lodoensis* Bramlette and Riedel 64
From Sabine River E.

1. The same specimen as in Plate 9, Figure 10, 1800 X, SEM negative 6466
2. 1620 X, SEM negative 6339

3, 5 *Discoaster distinctus* Martini 61

3. From Smithville A, SEM negative 5882.
5. From Fort Bend County 6, 9490, SEM negative 5794.

4 *Discoaster saipanensis* Bramlette and Riedel 65
From Fort Bend County 6, 9490, SEM negative 5796.

6 *Discoaster triangularis* Bystricka′ 68
From Fort Bend County 6, 10180, SEM negative 6478.

7 *Marthasterites furcatus* (Deflandre) Deflandre 69
From Hurricane Shoals J, SEM negative 6443.

8, 9 *Discoasteroides kuepperi* (Stradner) Bramlette and Sullivan 69
From Sabine River E.

8. Concave side, SEM negative 6468
9. Concave side, SEM negative 6334

10–12 *Zygrhablithus bijugatus* (Deflandre) Deflandre 71
From Smithville A.

10. SEM negative 5670
11. SEM negative 5618
12. SEM negative 6397

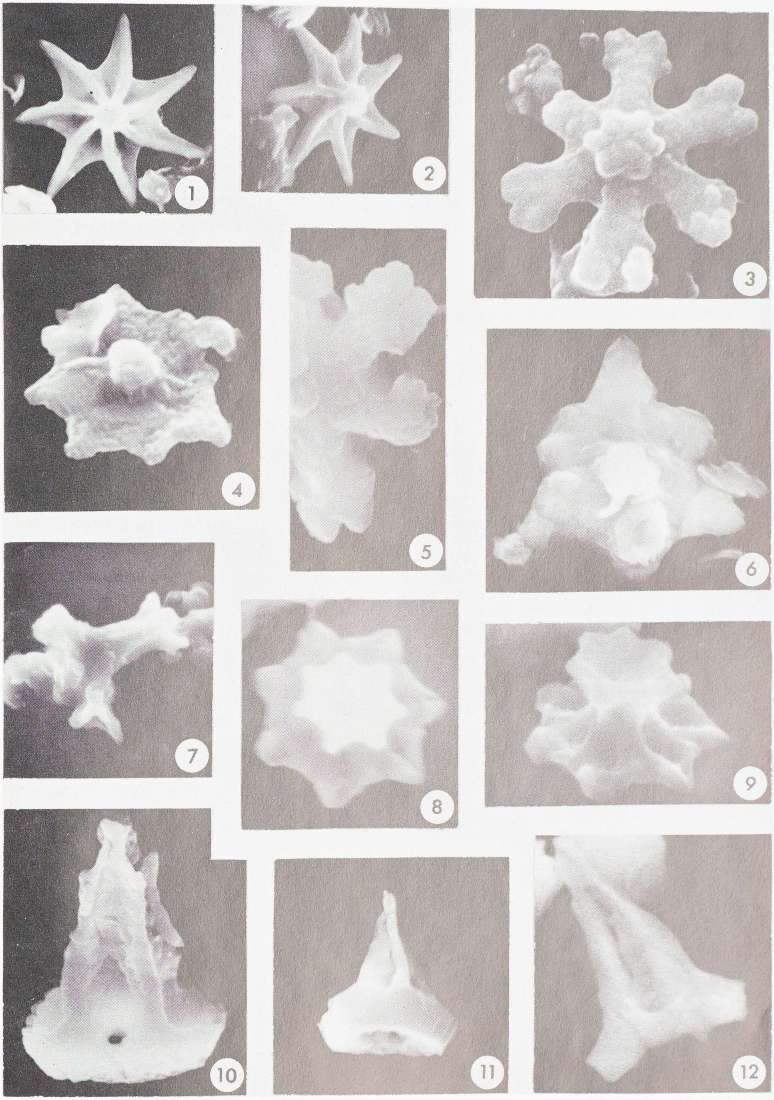

PLATE 12

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