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MIDDLE TERTIARY CALCAREOUS NANNOPLANKTON OF THE CIPERO SECTION, TRINIDAD, W. I.

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CONTENTS

I. ABSTRACT

The middle Tertiary calcareous nannoplankton in the Cipero section of Trinidad are described, and their distribution in samples from the foraminiferal zones of Bolli shown. From these data a zonation based on the calcareous nannoplankton is indicated. Some correlations with strata elsewhere, using these zones, are suggested. Of the genera two are new: *Orthorhabdus* and *Orthozygus*. Of the 52 described species 16 are new: *Cyclococcolithus neogammation*, *Helicosphaera ampliaperta*, *Helicosphaera compacta*, *Helicosphaera obliqua*, *Helicosphaera parallela*, *Helicosphaera truncata*, *Staurolithites minutus*, *Discoaster adamanteus*, *Discoaster extensus*, *Discoaster tani ornatus* (n. subsp.), *Orthorhabdus serratus*, *Sphenolithus belemnos*, *Sphenolithus ciperoensis*, *Sphenolithus predistentus*, *Sphenolithus pseudoradians*, and *Triquetrorhabdulus rugosus*.

II. INTRODUCTION

The sequence of Oligocene and Miocene strata in the Cipero section on the west coast of Trinidad has long been one of the important reference sections for middle Tertiary correlations by planktonic foraminifera, particularly since the foraminiferal zonation of it was published by Bolli (1957). Despite structural complications and changing exposures along the coast, the

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type localities of these foraminiferal zones were preferably designated here in the surface exposures or in ones adjacent to this coastal section, rather than in the more continuous succession known from well drillings. These zones are within the Cipero Formation, and only the upper two zones occur in the Lengua Formation, and have type localities at some kilometers to the east (see part IV, samples studied). For convenience in this paper, all this zonal succession is referred to as the Cipero section.

These strata are all of facies which include abundant and well preserved nannoplankton in addition to the planktonic foraminifera, making it possible to relate zonal subdivisions of two important groups of microfossils. An upper part of the Miocene is not present in this section, however, and is thus not considered in this paper. The earliest zone of the Oligocene is likewise missing in this section, but its occurrence elsewhere is discussed and shown in Table 2.

Much data, largely not yet published, have indicated that world-wide biostratigraphic correlations are aided and supported by the combined evidence from the zonal succession of these two quite different groups of planktonic microfossils. Zonal limits would hardly be expected always to correspond in the two groups, and additional subdivision of the strata is thus offered—or serious problems only in case they should cross. Limits on nannoplankton zones proposed here, however, cannot yet be presented, although recognition of the zones in some widely separated regions is indicated.

Most of the described taxa are easily recognized with the light microscope and populations of them are thus known elsewhere. Relatively few appear to be very limited in their time range, and the overlap in ranges must be considered. Particular attention and value is given, however, to the successive forms of a lineage in the genus *Sphenolithus*.

As explained later, this whole group of protists are treated as best classed in the plant kingdom, with the rules of the International Code of Botanical Nomenclature thus applicable.

III. ACKNOWLEDGMENTS

The original samples studied and shown in the table of distribution were very kindly supplied by H. M. Bolli, with the exception of one sample (TR 16) supplied by W. R. Riedel. In addition to the many samples collected elsewhere by Bramlette, many were examined that had been generously sent by H. G. Kugler, C. W. Drooger, E. Martini, M. B. Cita, J. S. Saunders, C. M. Quigley, the JOIDES organization, the Hague Laboratories of the Shell Oil Company, and others. Dean Milo contributed much in an early part of this investigation. Helpful advice from A. R. Loeblich, Jr., Helen Tappan Loeblich, W. R. Riedel, and F. L. Parker was appreciated, as was the preparation of the electron micrographs by Ray MacAdam.

IV. SAMPLES STUDIED

Most of the samples received from Bolli, as representative of his foraminiferal zones, are from the type localities and his original T.T.O.C. numbers are shown on the distribution chart (Table 1). Thus their location and other data are available in his 1957 paper (U.S.N.M. Bull. 215, pp. 100-102). Original type material was not available for some, however, and localities for these samples are listed below.

TTOC 178889 is from a later sampling of the type locality of the *Globorotalia mayeri* Zone indicated for KR 23422.

TTOC 178888 is from that locality indicated as a "co-locality, representing the Radiolaria-rich facies" of the *Globigerinatella insueta* Zone.

TTOC 206262 is from very close to the locality indicated for the type sample (Bo 274) of the *Globorotalia kugleri* Zone.

TTOC 206264 is from the same locality as the type sample (Bo 267 of the *Catapsydrax dissimilis* Zone, but with a correction to 1135 feet rather than the 1050 feet in the published location.

TTOC 193785 is "considered a representative sample of the *Globigerina ampliapertura* Zone" but the precise locality is now unknown.

TR 16 is from the same locality as that published for the type sample of the *Globorotalia fohsi robusta* Zone (TTOC 207274).

The sample from the Red Bluff Formation was received from H. V. Andersen, and

CALCAREOUS NANNOPLANKTON FROM THE OLIGOCENE-MIOCENE OF TRINIDAD, W.I.

TABLE 1

AGE	MIOCENE									OLIGOCENE			
SAMPLE NO.	178890	178889	TR 16	193786	193121	193125	178888	193790	206264	206262	215656	193265	193785
ZONES OF BOLLI SPECIES LEGEND ABUNDANT = ■ COMMON = ● FEW = ○ RARE = /	GLOBOROTALIA MENARDII	GLOBOROTALIA MAYERI	GLOBOROTALIA FOHSI ROBUSTA	GLOBOROTALIA FOHSI LOBATA	GLOBOROTALIA FOHSI FOHSI	GLOBOROTALIA FOHSI BARISANENSIS	GLOBIGERINATELLA INSUETA	CATAPSYDRAX STAINFORTHI	CATAPSYDRAX DISSIMILIS	GLOBOROTALIA KUGLERI	GLOBIGERINA CIPEROENSIS CIPEROENSIS	GLOBOROTALIA OPIMA OPIMA	GLOBIGERINA AMPLIAPERTURA
COCCOLITHACEAE													
Coccolithus bisectus											/	●	○
Coccolithus aff. bisectus										●	●	○	
Coccolithus eopelagicus	/			○	/		/			/	○	●	/
Coccolithus pelagicus s.l.	○	○	●	●	●	○	○	○	●	○	●	●	○
Coccolithus cf. scissurus											/	/	/
Cyclococcolithus leptoporus	●	●	●	●	○	○	/						
Cyclococcolithus neogammation					○	●	■	●	■	■	■	■	●
Coronocyclus nitescens				/	/	/	/	○	●	/	○	○	/
Discolithina cf. anisotrema		/	/	/		/	/			/			/
Discolithina vigintiforata			/	/	○				○	/	/	/	/
Helicosphaera ampliaperta							●	○	/				
Helicosphaera carteri	○	●	■	●	■	■	○	○	○	/			
Helicosphaera compacta												/	●
Helicosphaera intermedia			/	/	○	/	/	○	●	●	■	■	●
Helicosphaera obliqua							/	/	/	/	/		
Helicosphaera parallela							/	○	/	○	○		/
Helicosphaera aff. seminulum											/	○	/
Helicosphaera truncata											○	/	
Rhabdosphaera sp.	/	/	/			/		○					
Scyphosphaera apsteinii		/	/	/		/	/				○	/	/
Scyphosphaera intermedia	/	/	/	/									/
Scyphosphaera lagena			/	/									
Scyphosphaera pulcherrima	/	/	/										
Scyphosphaera recurvata	/		/	/									
Staurolithites minutus													●
Zygrhablithus bijugatus												○	
INCERTAE SEDIS													
Catinaster calyculus	○												
Catinaster coalitus		●											
Discoaster adamanteus									○	/		○	
Discoaster bollii	●	/											
Discoaster brouweri	■	●	○	/	/								
Discoaster challengeri	●	○	●	●	●	○	○	○	○				
Discoaster deflandrei				○	/		●	●	●	●	■	■	○
Discoaster exilis		/	●	○	○	○							
Discoaster extensus								/	●				
Discoaster hamatus	■												
Discoaster kugleri			●	/									
Discoaster pentaradiatus	/												
Discoaster perplexus		/	○	/	○	○	○	/					
Discoaster tani aff. nodifer													/
Discoaster tani ornatus													○
Orthorhabdus serratus							/		■				
Orthozygus aureus													/
Sphenolithus belemnos								●	/	/			
Sphenolithus ciperoensis										/	■	/	
Sphenolithus distentus												●	○
Sphenolithus heteromorphus						●	●						
Sphenolithus moriformis	○	■	■	●	●	●	●	●	●	○	●	■	■
Sphenolithus predistentus												○	●
Sphenolithus pseudoradians													○
Triquetrorhabdulus carinatus									/	●	●		
Triquetrorhabdulus rugosus	/	○	○	○									

was collected from 3.5 feet above the base, in the SW quarter of Sec. 28, T7N, R10W in Mississippi.

The location, depth, and other relations for the core samples from the JOIDES borings are given in a preliminary (officially unpublished) report, "Cruise Report and Preliminary Core Log M/V Caldrill, 1-17, (1965)."

The many (95) samples from Indonesia were from drilled wells, with their location and depths unavailable, but their original stratigraphic assignments are indicated under the discussion of Biostratigraphic Zonation and shown in Table 2.

The twenty examined samples from the Vicksburg Group in Mississippi were collected by C. M. Quigley at localities indicated in the guide book for field trips (Southeastern Section Geological Society of America, 1964 Annual Meeting) prepared by School of Geology, Louisiana State University. As with the many other samples, however, on which were based some suggested stratigraphic correlations indicated in Table 2, details of sample numbers and localities are not given here. Few of these have been adequately examined for a tabulation of all the nannoplankton, but some of the more significant taxa in these samples are recorded with the descriptions of species.

V. METHODS OF STUDY

The preparation of samples and our methods of study with the polarizing light microscope were much the same as described in some detail by Bramlette & Sullivan (1961), and so need not be repeated. The advantages and limitations of study with the electron microscope also remain much the same as previously discussed by Bramlette & Martini (1964), although more use of stereo pairs of pictures and electron scanning techniques is promising. It is necessary to relate taxa described from either of the two methods of microscope study with those from the other method and this is being attempted by some investigators. Features more obvious by one of these methods are commonly not those best seen by the other, however, and misidentifications thus continue to present difficulties.

Many taxa are sufficiently distinctive under light microscope examination, such as the species of *Sphenolithus* between crossed nicols (Pl. 2, fig. 10), that correlation with images from the electron micrograph (Pl. 1, fig. 6) is evident. Less distinctive forms such as *Cyclococcolithus neogammation* (Pl. 4, figs. 3-5) may appear more doubtfully identifiable as the same species of the electron micrographs (Pl. 1, figs. 1-3), particularly if side or oblique views were not presented. In addition to morphologic similarities, however, their identity is assured in this case by the exceptional abundance of *C. neogammation* in a sample examined by both methods.

In certain particular and somewhat restricted investigations, such as that for additional evidence in correlating a Plio-Pleistocene boundary, the refined electron microscope studies of McIntyre (in press) have been most important. Because of the rather limited number of taxa involved and the very small size of many of these, such detailed study seemed feasible and essential to satisfactory results.

For the data on distribution in time and space of the many hundreds of taxa that are needed for extended zonation and correlations, however, thousands of samples need examination. For the present, therefore, the rapid methods with a light miscroscope can provide more adequate information on the distribution of taxa, even though for a lesser number of identifiable taxa, than is possible with electron miscroscope study of a comparatively few samples. Also some distinctive, and stratigraphically significant forms do not occur in sufficient numbers for their probable encounter with the electron microscope examination. For example, the sparse but significant specimens of *Sphenolithus predistentus* in the Boom Clay of the type Rupelian require considerable searching of fields with hundreds of coccoliths and more of clastic particles, even though between crossed nicols the calcite forms stand out like stars in a field of night sky.

The results obtained with this method of study should not require eventual modification from subsequent electron microscope studies, other than an increased refinement from added numbers and subdivisions of taxa involved, and thus, in additional stratigraphic subdivision. Similar considerations on the importance of many observations

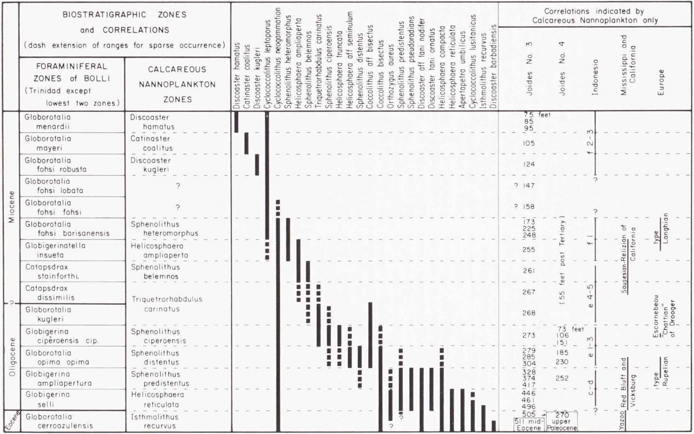
BIOSTRATIGRAPHIC ZONES
and CORRELATIONS
(dash extension of ranges for sparse occurrence)
FORAMINIFERAL ZONES of BOLLI (Trinidad except lowest two zones)
CALCAREOUS NANNOPLANKTON ZONES
Miocene
Oligocene
Eocene
?
Globorotalia menardii
Globorotalia mayeri
Globorotalia fohsi robusta
Globorotalia fohsi lobata
Globorotalia fohsi fohsi
Globorotalia fohsi barisanensis
Globigerinatella insueta
Catapsdrax stainforthi
Catapsdrax dissimilis
Globorotalia kugleri
Globigerina cipèroensis cip.
Globorotalia opima opima
Globigerina ampliapertura
Globigerina selli
Globorotalia cerroazulensis
Discoaster hamatus
Catinaster coalitus
Discoaster kugleri
?
?
Sphenolithus heteromorphus
Helicosphaera ampliaperta
Sphenolithus belemnos
Triquetrorhabdulus carinatus
Sphenolithus ciperoensis
Sphenolithus distentus
Sphenolithus predistentus
Helicosphaera reticulata
Isthmolithus recurvus
Discoaster hamatus
Catinaster coalitus
Discoaster kugleri
Cyclococcolithus leptoporus
Cyclococcolithus neogammation
Sphenolithus heteromorphus
Helicosphaera ampliaperta
Sphenolithus belemnos
Triquetrorhabdulus carinatus
Sphenolithus ciperoensis
Helicosphaera truncata
Helicosphaera aff seminulum
Sphenolithus distentus
Coccolithus aff bisectus
Coccolithus bisectus
Orthozygus aureus
Sphenolithus predistentus
Sphenolithus pseudoradians
Discoaster aff tani nodifer
Discoaster tani ornatus
Helicosphaera compacta
Helicosphaera reticulata
Apertapetra umbilicus
Cyclococcolithus lusitanicus
Isthmolithus recurvus
Discoaster barbadiensis
?
?
Correlations indicated by Calcareous Nannoplankton only
Joides No. 3
Joides No. 4
Indonesia
Mississippi and California
Europe
75 feet
85
95
105
124
? 147
? 158
173
225
248
255
261
267
268
273
279
285
304
328
374
417
446
461
496
505
511 mid-Eocene
(55 feet post Tertiary)
73 feet
106
151
185
230
252
270 upper Paleocene
f 2-3
?
?
f 1
e 4-5
e 1-3
c-d
?
Sausesian-Relizian of California
Yazoo Red Bluff and Vicksburg
type Langhian
Escornebeou "Chattian" of Drooger
type Rupelian

TABLE 2

obviously apply also to the broader taxonomic problems mentioned under Systematic Paleontology.

Preliminary examination of samples to determine whether calcareous nannoplankton are present, or occur in sufficient number or diversity for the purpose of the study, is quickly accomplished between crossed nicols of the microscope where coccoliths, even those 2-3 microns in diameter, are conspicuous though not specifically identifiable with only 500 magnification. Many species also show more of their distinctive character thus than under nonpolarized light. A useful technique employed by D. Milo, especially for preliminary examination, is in having the nicols only partially crossed so that both the birefringence effects and the form with ordinary light are observable. Properly adjusted, such lighting can also approach the appearance of certain surface details seen best by the phase-contrast microscope. Estimation of relative abundance of forms is commonly best made also with the partially crossed nicols as both the birefringent forms and those specimens so oriented as to show no birefringence are observable.

Some approximate indication of the relative abundance of taxa shown in Table 1 has obvious significance for several reasons. Any attempt at precision with percentages seems of questionable value, however, considering both the natural variables and those related to preparation methods. For example, the forms of the genus *Thoracosphaera* are omitted entirely, as their large size precludes even an approximate estimation of abundance without a special treatment of the samples, and available evidence suggests that few recognizable taxa within this genus are of particular stratigraphic significance. The same is true, to a lesser degree, for the species of *Scyphosphaera*, although some of these are considered and shown in the table of distribution.

The terms and symbols for abundance of the species occurrences in the Cipero section are, therefore, only crude approximations, with the following indication of their relative numbers for fields of view under magnification of 500, which commonly includes several hundred specimens.

The symbol (Table 1) for "abundant" implies many specimens observed in such a single field of view; "common" implies several specimens in the field; "few" implies one is apt to be observed in a field; "rare" indicates a specimen is apt to require search of many fields.

VI. BIOSTRATIGRAPHIC ZONATION AND CORRELATIONS

Assignment of strata to a chronostratigraphic unit such as the Oligocene Series or one of its subdivisions, the Rupelian Stage, obviously requires consideration of all independent evidence. This may include zones based on foraminifera, nannoplankton, any other groups of fossils present, and the increasingly important evidence other than paleontology. Local or provincial stages based on all such evidence may be useful, but only zonal names seem appropriate for any stratal subdivisions which are based on any one group of fossils. Rapid progress is being made towards satisfactory assignments to some of the long known stages, such as Maestrichtian, Tortonian, etc. — but their limits in a stratotype locality remain largely undefined. Unfortunately, therefore, there is a tendency to define stages on the range limits of certain fossils rather than by determining the relations of the fossils to a position at the stratotype locality.

Limits for some biostratigraphic zones have been indicated where an approximately continuous sequence of fossiliferous strata is available for subdivision. Such a foraminiferal zonation of the middle Tertiary in Trinidad was presented by Bolli (1957), although it had to be based on the sequence in drilled wells, and the type localities designated in the less complete but observable Cipero section exposed in the coastal cliffs and adjacent areas. Although structural complications, erosion, and recent slumping make this section unsatisfactory, it seems the best available.

A zonation of the calcareous nannoplankton, as indicated by their distribution in the foraminiferal zones of the Cipero section (Table 1) is shown in Table 2. Limits on these nannoplankton zones remain to be determined as an adequate number of samples from each zone of the Cipero section were not available. Therefore, solid lines separating these zones are not indicated in

Table 2. *Dashed* lines indicate, however, the recognizable (though inadequately delimited) extensions of *only* the nannoplankton zones to some widely separated localities elsewhere. These correlations are based on some examination of many samples, although their thorough study, and tabulation of species, is beyond the scope of this paper. Records on the occurrences of the taxa involved in these zonal correlations are, however, included with the systematic description of species.

The distribution of species shown in Table 1, does not indicate many very restricted taxa, and some of those most limited in the vertical succession also seem to be among those most restricted geographically. The peculiar *Orthorhabdus serratus* is an example, although this form or one very closely related does occur in Indonesia. Most of these less widely distributed taxa are thus not included in the plot of ranges (Table 2) which help define the indicated nannoplankton zones. The abundant and widespread taxa of a lineage in *Sphenolithus* seem particularly significant in the zonation, in conjunction with the earliest or latest known occurrence of some long and widely ranging species (e.g. latest occurrence within the Oligocene of some common forms of the late Eocene). Even the less well defined latest occurrence of *Cyclococcolithus neogammation* in its overlap with earliest occurrence of *C. leptoporus* s.l. is of some significance because both are abundant and widespread.

Certain of these nannoplankton zones are little more than biozones, or range zones of a single taxon, particularly as is indicated for the upper three zones. Because recognizable elsewhere in similar succession, however, these biozones of a distinctive species are tentatively shown in the zonation. Until they can be related to the ranges of additional taxa, these are obviously less dependable; nor are these three biozones recognizable in the type Miocene of Europe. No zonal subdivision is indicated by the nannoplankton for strata of the *Globorotalia fohsi lobata* and *Globorotalia fohsi fohsi* Zones, and Bolli differentiated them primarily on these subspecies of a lineage.

Lines delimiting the nannoplankton zones in the Cipero section cannot be indicated without more samples from each, but can be indicated more closely in the cored sequence of samples from the JOIDES drilling off the east coast of Florida. That the limits of these zones might consistently coincide with the limits of foraminiferal zones seems improbable and not expectable in such different groups of fossils. These different and additional zonal boundaries for the two fossil groups should offer additional refinement of stratal subdivision, and give support to each unless they diverge much or cross. Such a discrepancy would offer interesting problems to resolve and doubtless indicate too much reliance on the local range of too few taxa.

The nannoplankton zones recognizable in the lettered subdivisions of the Tertiary in Indonesia were related to those subdivisions from examination of many subsurface samples of deeper water facies than the outcropping shallow water "orbitoidal facies" originally used for the definition of these letter-number subdivisions. The letter assignment of these samples was based, however, on results of field exploration, drilling, and accompanying study by biostratigraphers in areas of Java and Borneo over a period of many years.

The delimitation of these nannoplankton zones in the sequence of cores from JOIDES No. 3 and part of JOIDES No. 4 is indicated by figures of depth below sea-floor of the samples shown in Table 2. No more than three sample depth figures are shown here for any one zone, but intermediate samples were similar in those zones with three indicated. These depth figures obviously cannot be shown to scale and also related to the zones in Table 2, because these zones are represented with equal spacing in this figure. For example, four distinct zones occur within an indicated thickness of about thirty feet (250-279 feet) in JOIDES No. 3, whereas a thickness of more than one hundred feet is indicated for one of the lower zones. The *Sphenolithus ciperoensis* Zone is less than 6 feet in thickness here though represented in approximately 75 feet in JOIDES No. 4. It seems significant that the interval of about 250-270 feet in JOIDES No. 3 was logged as calcarenite, and the samples appear as a "foraminite" with a relatively small percentage of coccoliths, in contrast with those above and below, which are fine coccolith chalk with a small percentage of foraminifera. This interval thus appears to represent reduced accumulation by current winnowing during the very considerable interval of geologic time represented by the four zones, with erosion during and/or subsequent to this time (as well as in Eocene time) at the locality of JOIDES No. 4.

The Red Bluff Formation of Mississippi is indicated here as basal Oligocene, a consensus opinion. The abundant nannoplankton represent the lower part of the *Helicosphaera reticulata* Zone, which zone includes the latest occurrence of this species and several other forms which are common in the upper Eocene, for example *Cyclococcolithus lusitanicus* and *Apertapetra umbilicus* (Levin). *Isthmolithus recurvus*, adopted as the name species for the uppermost Eocene zone by Hay, Mohler, & Wade (1966), occurs in the lower few feet of the Red Bluff, although there is some suggestion from other species of possible reworking here from the underlying Eocene. The basal part of the Vicksburg Group (Marianna-Mint Spring) also contains nannoplankton of this *Helicosphaera reticulata* Zone, and a part of the *Sphenolithus predistentus* Zone. Thus the basal Vicksburg and the Red Bluff Formation appear to represent an early Oligocene that is missing in the Cipero section, but is well represented in JOIDES No. 3 and in Barbados. The upper Vicksburg (Glendon and Byram Marl) includes part of the *Sphenolithus predistentus* Zone and part, at least, of the *S. distentus* Zone—as is indicated also for the type Rupelian Stage.

Although nannoplankton are not abundant in the Boom Clay (type Rupelian) of Belgium, the stratigraphic placement shown in Table 2 is suggested by the presence of the significant *Sphenolithus predistentus* and a limited number of other taxa (see under species descriptions) of this zone, including specimens of *Sphenolithus distentus*, which is more common in the Rupelton of south Germany. On the basis of nannoplankton only, this typical and apparently main part of the Oligocene Series, seems clearly to be later than the *Helicosphaera reticulata* Zone and earlier than *Sphenolithus ciperoensis* Zone.

Nannoplankton zones in the stratotype of the Langhian are indicated with some assurance. Relations to the type Burdigalian, and even more doubtful Aquitanian, cannot be indicated, as no nannoplankton were found in the many samples from their type areas. Very few species occur in the type Chattian, although those strata at Escornebeou and St. Etienne d'Orthe in southwest France which include nannoplankton of the *Sphenolithus ciperoensis* Zone are indicated as "Chattian" of Drooger (Table 2) primarily on the basis of his interpretations (1960) and those of Butt (1966) from the orbitoid and other foraminifera.

Such uncertainties afford little basis for an indicated boundary between the Oligocene and Miocene Series. It is quite arbitrarily shown here between the *Globorotalia kugleri* and *Catapsydrax dissimilis* Zones of Bolli in conformity with his interpretation, and that of Woodring (1960). No basis for such precise placement is apparent from this study of the nannoplankton, and one might even prefer that the boundary occurs below rather than above the *G. kugleri* Zone, merely because the nannoplankton of this zone cannot yet be differentiated from those of the overlying *C. dissimilis* Zone (Tables 1 and 2). Neither this nor the more marked difference of foraminifera, however, affords any proper basis for the boundary until such zones can be related to the Chattian and Aquitanian stratotypes, and until these stages have been sufficiently studied for the International Geological Congress to designate stratal boundaries by fiat. Pending this, strata including the *G. kugleri* Zone, at least, might better be considered merely as Oligo-Miocene.

Despite these problems in relating biostratigraphic zones to the generally recognized chronostratigraphic stages and the series of Lyell, inter-relation of zones based on various groups of fossils affords promise for much clarification of the complex situation. This will not be accomplished, however, by simply redefining stages on the basis of the ranges of any group of fossils.

That some biostratigraphic zones (particularly those based on concurrent range relations) may give a close approach to time relationships seems supported, both by their nearly world-wide occurrence in a regular sequence, and by the agreement between the zonations of different groups of fossils. For example, the placement (Table 2) of the regional Relizian Stage of California in the *Helicosphaera ampliaperta* Zone (primarily on the basis of the overlap in range of that species with the range of equally widespread *Sphenolithus heteromorphus*) has been found to agree with the independent assignment of the planktonic foraminifera by J. Lipps (1967) of part of this stage to the equivalent *Globigerinatella insueta* Zone. Such agreement in the interpretations from these two planktonic groups has few exceptions among the hundreds of deep-sea cores studied. Without additional independent evidence, these few exceptions seem to indicate that we were the culprits, rather than any of the fossils.

VII. SYSTEMATIC PALEONTOLOGY

Revisions in classification of both the living and extinct forms within this group of nannoplankton seem so frequent that none, above the family level, is attempted nor needed here. Although the coccolithophorids proper seem clearly to belong with the unicellular algae, and assignable to such a large category as the *Chrysophyceae*, many others of the extinct fossil calcareous nannoplankton are among "genera incertae sedis", and can merely be classed as Protista.

Problems are inherent in any classification based largely on the skeletal parts, and especially for unicellular organisms not developing special parts of obvious functional value. The problems are increased with the coccolithophorids in that only the disaggregated elements of the skeleton are usually known. For these, both the general "architectural" form and the arrangement of elements in the "ultrastructure", or the lack of such ultrastructure among the ortholithid group, would seem to be obvious characters for differentiation of taxa, but their relative significance remains questionable. Basic form and fine structure are quite different, for example, in the two generations of the living species *Coccolithus pelagicus* according to Parke & Adams (1960). Thus, more knowledge of distribution in time and space of populations and in evolutionary developments, rather than morphology alone, seem essential to the problems of a "natural" classification. Consideraiton of populations seems especially important in the concepts of taxa in such morphologically simple and variable fossils.

Until the protists are separately treated or can be satisfactorily assigned within the plant and animal kingdoms, application of the separate rules of botanical and zoological nomenclature by one or another investigator present some difficulties. Despite some advantages of coverage by the rules of the I.C.Z.N., a consensus seems developing for including all the calcareous nannoplankton with the algae. As this is followed here, the Code of Botanical Nomenclature is applicable.

Family COCCOLITHACEAE Poche, 1913

Genus APERTAPETRA Hay, Mohler & Wade, 1966

APERTAPETRA UMBILICUS (Levin), Levin & Joerger

Pl. 5, figs. 1-2

Coccolithus umbilicus LEVIN, 1965, Jour. Paleontology, v. 39, p. 265, pl. 41, fig. 2.

Apertapetra umbilicus LEVIN & JOERGER, 1967, Micropaleontology, v. 13, p. 166, pl. 1, fig. 9a-c.

Remarks: This large placolith is assigned to the genus of Hay, Mohler & Wade, (1966) which includes those *Coccolithus*-like forms having a distinctively large oval opening of the thin connecting tube between the two shields. This species has some resemblance to the type species *A. samodurovi*, but is clearly the same form as the earlier described *Coccolithus umbilicus*. It is (typically) an unusually large coccolith. with a glassy appearance in transmitted light because of the relatively thin shields and obscurity of the sutures between the many component elements of the shields.

Distribution: A very abundant and widespread species in the upper half of the Eocene and with latest occurrence in the lower Oligocene (*Helicosphaera reticulata* Zone). Not present in the *G. ampliapertura* Zone which is the earliest Oligocene of the Cipero section.

Genus COCCOLITHUS Schwarz, 1894
COCCOLITHUS BISECTUS (Hay, Mohler, & Wade). Bramlette & Wilcoxon, n. comb.
Pl. 4, figs. 11-13

Syracosphaera bisecta HAY, MOHLER, & WADE, 1966, Eclog. Geol. Helvet., v. 59, p. 393, pl. 10, figs. 1-6.

Remarks: Placoliths elliptical with a small elliptical central opening. The larger (distal) shield with numerous very faint striae is thin. Between crossed nicols, the species shows strong birefringence out to the periphery of the shields. The narrow extinction lines in the central area curve clockwise for the distal view, and broaden across the shields. The asymmetric extinction lines of figure 3, plate 10 of Hay, Mohler, & Wade indicates a slightly tilted specimen. Neither their light nor electron miscroscope pictures suggest assignment to *Syracosphaera*. Specimens included in this species seem rather variable in the tube opening, from slit-like in the lower part of its range, to oval in latest occurrences. Average size is distinctly larger than *Cyclococcolithus neogammation*, but tilted specimens of this circular form appear rather similar to *C. bisectus* between crossed nicols.

A rather similar form is illustrated (pl. 4, figs. 9-10), and separately listed in Table 1, as *Coccolithus* aff. *C. bisectus*. This form is normally of smaller size, and the central opening is oval to subround, although these differences seem gradational upward in the section from the typical *C. bisectus*.

Distribution: Common in the two lowest zones of the Oligocene of Trinidad and rare in the *Globigerina ciperoensis ciperoensis* Zone. Common in the late Eocene and Oligocene of many regions, including the type Rupelian.

COCCOLITHUS EOPELAGICUS (Bramlette & Riedel). Bramlette & Sullivan
Pl. 4, figs. 6-8

Tremalithus eopelagicus BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 392, pl. 38, figs. 2a, b.

Coccolithus eopelagicus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, p. 141.

Remarks: This large form resembling *Coccolithus pelagicus* was originally differentiated primarily because large populations of such size and robust character seem ubiquitous from late middle Eocene up to about middle Oligocene. Local populations of the modern *C. pelagicus*, with placoliths of nearly equal size are now known, however, and differentiation as two species becomes difficult and questionable within the late Tertiary, at least.

Distribution: Few in the lower part of the Cipero section and more sparse and questionably identified throughout the upper part.

COCCOLITHUS PELAGICUS (Wallich). Schiller
Pl. 3, figs. 13-15

Coccosphaera pelagica WALLICH, 1877, Ann. Mag. Nat. Hist., ser. 4, v. 19, p. 348, figs. 1, 2, 5, 11, 12.

Coccolithus pelagicus (Wallich). SCHILLER, 1930, *in* RABENHORST, Kryptogamenflora, v. 10, p. 246, figs. 123, 124.

Remarks: Very similar placoliths to those of the abundant species of the modern marine plankton are common throughout most of the Tertiary. Identification of *Maslovella barnesae* (Black and Barnes, 1959), and other such forms of the Mesozoic, as this species is clearly incorrect. *Coccolithus pelagicus* varies in size and in the presence or absence of a bar across the elongate central opening. The modern forms also commonly show delicate rhomboid plates covering the opening, not apparent except in electronmicrographs (Black, 1965, fig. 4). The strongly imbricate radial elements of the distal shield are oriented with the C-axis near enough to vertical, in plan view, to show very little birefringence in the shields (pl. 3, fig. 14) as is likewise indicated for the distal shield of *C. eopelagicus*.

Distribution: Forms very similar to the modern species are included with it (*s.l.*) and occur throughout the Cipero section.

COCCOLITHUS cf. C. SCISSURUS (Hay, Mohler & Wade), Bramlette & Wilcoxon, n. comb.
Pl. 4, figs. 1-2

cf. *Reticulofenestra scissura* HAY, MOHLER, & WADE, 1966, Eclog. Geol. Helvet. v. 59, p. 387, pl. 5, figs. 1-6.

Remarks: Elliptical placoliths with closely appressed shields. Central area large and with a transverse slit. The shields are thin, and the numerous very fine striae are not perceptible with ordinary transmitted light. The peculiar construction in the central area is difficult to interpret with the light microscope, but between crossed nicols shows bright areas in quadrants somewhat like that of *Arkhangelskiella.* This form resembles the light microscope pictures of *Reticulofenestra scissura*, but identification remains questionable, and similarity of the holotype of that species to the type of *Reticulofenestra* is not evident.

Distribution: Rare in the *Globigerina ampliapertura* to *Globigerina ciperoensis ciperoensis* Zones of the Cipero section. Described from the late Eocene of Russia, and common in the late Eocene and early to middle Oligocene elsewhere, up to and including the type Rupelian of Belgium.

Genus CORONOCYCLUS Hay, Mohler & Wade, 1966

CORONOCYCLUS NITESCENS (Kamptner). Bramlette & Wilcoxon, n. comb.

Pl. 1, fig. 4; Pl. 5, figs. 7-8

Umbilicosphaera nitescens KAMPTNER, 1963, Ann. Naturhist. Museum Bd. 66, p. 187-188, pl. 1, fig. 5.

Remarks: The specimens in the Cipero section resemble the photograph by Kamptner, (1963), but not the drawings (figs. 37a, b, c). The various species of this genus, however, need restudy with the electron miscroscope for satisfactory diagnosis. The micrograph (pl. 1, fig. 4) shows the elements curving clockwise (proximal?view) rather than as in the photographs (distal? view) of pl. 5, figs. 7-8.

Distribution: Rare to common throughout most of the Cipero section.

Genus CYCLOCOCCOLITHUS Kamptner, 1954

CYCLOCOCCOLITHUS LEPTOPORUS (Murray & Blackman). Kamptner

Pl. 3, figs.9-12

Coccosphaera leptopora MURRAY & BLACKMAN, 1898, Philos. Trans. Roy. Soc. London, 190B, p. 430-432, 439.

Coccolithophora leptopora (Murray & Blackman). LOHMANN, 1902, Arch. Protistenk. v. 1, p. 138.

Calcidiscus medusoides KAMPTNER, 1954, Arch. Protistenk., v. 100, p. 26, figs. 24, 34.

Tiarolithus medusoides (Kamptner). KAMPTNER, 1958, Arch. Protistenk., v. 103, p. 81.

Cyclococcolithus leptoporus (Murray & Blackman). KAMPTNER, 1954, Arch. Protistenk., v. 100, p. 23, fig. 20.

Remarks: Forms assigned to this species are common, although variable and apparently somewhat different from most in the modern plankton. The number of radial elements of the distal shield varies and is usually greater, at least in the Tertiary, than in the modern form described and figured by Murray & Blackman, 1898. Several investigators (McIntyre, Hay, Bramlette) have concluded that *Tiarolithus medusoides* of Kamptner is the easily separated distal shield of *Cyclococcolithus leptoporus* (pl. 3, figs. 9-10). Such single shields, illustrated in an earlier paper of Martini and Bramlette, (1963) (pl. 102, figs. 1, 2) were then assigned to Kamptner's taxon.

Distribution: Few to common in the upper part of the Cipero section, appearing first in the *Globigerinatella insueta* Zone and continuing to be common in many regions up to the present time. Significance of its earliest occurrence, as related to latest occurrences of *C. neogammation* is mentioned with that species.

CYCLOCOCCOLITHUS LUSITANICUS (Black). Hay, Mohler & Wade

Pl. 3, figs. 16-17

Coccolithus lusitanicus BLACK, 1964, Palaeontology, v. 7, p. 308-309, pl. 50, figs. 1-2.

Cyclococcolithus lusitanicus (Black). HAY, MOHLER & WADE, 1966, Eclog. Geol. Helvet., v. 59, p. 390, pl. 7, figs. 3-6.

Remarks: This circular placolith with circular opening in the heavy connecting tube is a very common and widespread form in the upper Eocene. As with other coccoliths showing strongly imbricate lath-like elements of the distal plate in electron micrographs, these elements are so oriented as to show very little birefringence between crossed nicols of the light microscope (peripheral part obscure in fig. 17). Assignment to this species, originally described from an electron micrograph, seems correct but identification with that of photographs with light microscope by Hay, Mohler & Wade is more certain.

Distribution: Abundant and widespread in the upper Eocene, and up into the lower Oligocene (*Helicosphaera reticulata* Zone), but not in the *G. ampliapertura* Zone which is the earliest Oligocene of the Cipero section.

CYCLOCOCCOLITHUS NEOGAMMATION Bramlette & Wilcoxon, n. sp.

Pl. 1, figs. 1-3; Pl. 4, figs. 3-5

Description: Rather nondescript but very widespread and very abundant circular coccolith, with a circular opening of about 1 micron through the tube connecting the well separated shields. Larger (distal) shield has numerous radial elements discernible with oblique illumination. Specimens (usually forming a large population) are recognizable between crossed nicols by the sharp and distinct extinction lines within the central depression forming about one third of the total diameter (curving counterclockwise on proximal side), with these lines broader, vaguer, and nearly straight radial on the outer shield area. Diameter 6 to 12 μ with mean near 8 μ.

Plate 1, figs. 1-3 are electron micrographs from a sample at 338 feet in JOIDES No. 3 boring where the species is very abundant. The 40-45 radial elements curving counterclockwise on top side of the distal shield are imbricate and show nearly straight radial sutures on the lower (concave) side, as do those of the lower shield. Electron micrographs from Scripps MP 5-1 of early Oligocene age from the central Pacific were prepared and kindly sent in 1961 by John C. Hathaway of the U. S. Geological Survey. These micrographs likewise showed abundant specimens, referred to *C. neogammation* as identified by light microscope, and identical to those of electron micrographs from JOIDES No. 3 (pl. 1, figs. 1-3).

Remarks: Between crossed-nicols it resembles *"Coccolithites" gammation* of Bramlette and Sullivan (1961), a common form in the lower Eocene. However almost no birefringence nor extinction lines are seen in the peripheral area of that coccolith, and *C. neogammation* clearly has two well separated shields that are distinctly concavo-convex.

Distribution: Very common throughout the lower part of the Cipero section up to the *G. fohsi fohsi* Zone. Common also in the Oligocene and early Miocene of Europe, Indonesia, and in Atlantic and Pacific deep-sea cores. The concurrent range of latest *C. neogammation* and earliest *C. leptoporus* (s.l.) may be useful for world wide correlation, because of their abundance and widespread occurrence.

Genus DISCOLITHINA Loeblich & Tappan, 1963

DISCOLITHINA cf. D. ANISOTREMA (Kamptner)

Pl. 5, figs. 5-6

Coccolithites anisotrema KAMPTNER, 1955, Verh. K. Nederl. Akad., Afd. Natuurk, ser. 2, v. 50(2), p. 16, p. 91, fig. 22a-b.

Discolithus anisotrema KAMPTNER, 1956, Anz. Österr. Akad. Wiss., Math.-Naturw. Kl., v. 93, p. 9.

Remarks: This taxon is one of a large number of inadequately described species which have been assigned to various genera. The invalid generic name *Discolithus* has been most commonly used. The form indicated here as cf. *D. anisotrema* resembles Kamptner's drawing of that species, particularly in the outer series of large pores surrounding many finer ones in the oval shield with a low peripheral rim.

Distribution: Specimens occur sparsely throughout the Cipero section.

DISCOLITHINA VIGINTIFORATA (Kamptner ex Deflandre). Loeblich & Tappan

Pl. 5, figs. 3-4

Discolithus vigintiforatus KAMPTNER, 1948, SitzBer. Österr. Akad. Wiss., Math.-Naturw. Kl., Abt. I, v. 157, p. 5, pl. 1, fig. 8; LOEBLICH & TAPPAN, 1963, Proc. Biol. Soc. Wash. v. 76, p. 192.

Discolithus vigintiforatus Kamptner, ex-DEFLANDRE, 1959, Rev. Micropal., v. 2, p. 150; LOEBLICH & TAPPAN, 1966, Phycologia, v. 5, p. 130.

Remarks: This species was designated as type species of *Discolithina* nom. subst. pro *Discolithus*. Specimens in topotype material received from Kamptner are like those of the Cipero section.

Distribution: Few to rare throughout most of the Cipero section, and widespread in the Tertiary.

Genus HELICOSPHAERA Kamptner, 1954

HELICOSPHAERA AMPLIAPERTA
Bramlette & Wilcoxon, n. sp.
Pl. 6, figs. 1-4

Description: This unsual form of the genus is nearly oval in outline, normally showing little of the terminal flare of the larger (distal) shield, and with no bridge in the large oval central opening. There is thus superficial similarity to occasional specimens of other species which have had the central bar broken out. Lack of any central bar is evident in that a population includes none with a bar, nor any irregularity around the peripheral edge of the central opening. Close observation is thus needed to identify many of the smaller specimens. Length 7-12 μ.

Remarks: This distinctive species is not easily recognized as belonging to the genus, except in side view, or by the characteristic extinction lines between crossed nicols in plan view. It is, however, stratigraphically very significant because of its wide geographic and rather restricted time range.

Distribution: Common in the *Globigerinatella insueta* Zone, with distinctly smaller specimens fairly common in the underlying *Catapsydrax stainforthi* and rare in the *Catapsydrax dissimilis* Zones of the Cipero section. Also present in the lower part of the type Langhian and uppermost "Aquitaniano" of Sacco in the Scrivia river section of northern Italy, in Tertiary e 4-5 of Indonesia, and in the Relizian Stage of California.

HELICOSPHAERA CARTERI (Wallich). Kamptner
Pl. 6, figs. 9-10

Coccosphaera carterii WALLICH, 1877, Ann. & Mag. Nat. Hist. ser. 4, v. 19, p. 348, pl. 17, figs. 3, 4, 6, 7, 17.
Helicosphaera carteri (Wallich). KAMPTNER, 1954, Arch. Protistenk. v. 100, p. 21, 73, figs. 17-19.

Remarks: This widespread modern species has been illustrated and described several times, but shows considerable variation. Some specimens included herein are questionable, particularly those of the earlier Miocene. Kamptner's drawings (1954, fig. 17) show correctly the clockwise coiling as observed from the proximal side but the curvature of striae between the radial elements is reversed, and the excellent electromicrographs of Black and Barnes (1961) show mirror images for these features.

Distribution: Common to abundant throughout the Miocene of the Cipero section, and in Miocene to Recent strata of many regions.

HELICOSPHAERA COMPACTA
Bramlette & Wilcoxon, n. sp.
Pl. 6, figs. 5-8

Description: Species having relatively thick shields closely appressed into a compact form of somewhat egg shape, with little peripheral flare of the larger shield. The distal plate shows weak birefringence in contrast to that of the smaller one, and this proximal shield is obliquely truncate. Central area has two openings, and in less calcified specimens also shows several small pits near the outer edge of the truncate side of the smaller plate. Length 10-13 μ.

Remarks: Although not a symmetric oval, this distinctive species does not show well the usual outline of *Helicosphaera* in plan view. Association and gradational features indicate a close relation to the peculiar and more restricted *H. reticulata.*

Distribution: Common in the *Globigerina ampliapertura* Zone and rare in the *Globorotalia opima opima* Zone of the Cipero section. Common in the upper Eocene and Oligocene (Red Bluff and Vicksburg) of Mississippi, and in equivalent strata of Joides core samples, and elsewhere.

HELICOSPHAERA INTERMEDIA Martini
Pl. 6, figs. 11-12

Helicosphaera intermedia MARTINI, 1965, Proc. XVII Symposium Colston Res. Soc., v. 17, p. 404, pl. 35, figs. 1-2.

Remarks: A common form in the middle Tertiary, assigned to this species after study of part of the original sample from a Pacific deep-sea core. Specimens are not common in this core sample, but indicate that the holotype shows somewhat more peripheral flare at end of larger plate than average for the species, although this varies considerably. The holotype was not rotated to the position showing clearly the sigmoid appearance of the bar between crossed-nicols resulting from its compound construction. As with *H. parallela* and *H. seminulum* the bar is not in optical continuity with the shields. This species resembles *H. seminulum seminulum* except for the more distinctly sigmoid appearance of the bar between crossed-nicols and bar more nearly closing the central opening.

Distribution: Common throughout the Oligocene and present in lesser numbers in the lower Miocene of the Cipero section. Widespread and common in strata of comparable age in many regions, and originally described from mid-Tertiary of a Pacific deep-sea core (DWBG 10).

HELICOSPHAERA OBLIQUA
Bramlette & Wilcoxon, n. sp.
Pl. 5, figs. 13-14

Description: Species shows rather small, delicate, and closely appressed elongate shields. Central opening relatively large and spanned by a thin oblique bridge which is in optical continuity with the shield (fig. 14). Length 8-10 μ.

Remarks: A rather small and sparsely occurring species, varying little in character, and perhaps more closely related to *H. carteri* than to any of the other species.

Distribution: Rare in the upper Oligocene and lower Miocene of the Cipero section, and present in the lower Miocene of Italy.

HELICOSPHAERA PARALLELA
Bramlette & Wilcoxon, n. sp.
Pl. 5, figs. 9-10

Description: A typical *Helicosphaera* but not an easily differentiated species. Central area occupied by a parallel-sided bar with little or no central opening apparent even between crossed nicols although not in optical continuity with the shield, and bar nearly parallel to the long axis of specimen. Length 8-13 μ.

Remarks: This form is not easily differentiated from *H. intermedia* although the central bar does not show the sigmoid appearance in any orientation between crossed nicols, and the central area is more completely closed than in *H.* intermedia.

Distribution: Rare to few in the Oliogocene and lower Miocene of the Cipero section.

HELICOSPHAERA RETICULATA
Bramlette & Wilcoxon, n. sp.
Pl. 6, fig. 15

Description: A peculiar, very ornate form of the genus, with the reticulate appearance due to pits in the shields. Two rows of small openings alongside the central bar are normally apparent with a lower focus than that of Fig. 15.

Remarks: Although typical specimens appear quite different from *H. compacta* various intermediate forms and consistent association with the more common and later ranging *H. compacta* indicate their close relationship.

Distribution: Fairly common and typically developed in the Red Bluff Formation (lowest Oligocene) and the upper Eocene of Mississippi, and in equivalent strata of Barbados and the lower Oligocene of the JOIDES borings. Not found in later strata of the Oligocene—such as the *G. ampliapertura* Zone of the Cipero section.

HELICOSPHAERA aff. H. SEMINULUM
Bramlette & Sullivan
Pl. 5, figs. 11-12

Helicosphaera seminulum seminulum BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, p. 144, pl. 4, figs. 1a-c, 2.

Remarks: This form of *Helicosphaera* is similar to *H. seminulum seminulum*, an abundant and widespread form in the lower half of the Eocene. That species, however, does not seem to occur in the upper Eocene of any known region, and the form here recorded from the Oligocene may prove, with more study, to be a distinct taxon.

Distribution: Occurs rather sparsely in the *G. ampliapertura, G. opima opima*, and the *G. ciperoensis ciperoensis* Zones of the Cipero section.

HELICOSPHAERA TRUNCATA
Bramlette & Wilcoxon, n. sp.
Pl. 6, figs. 13-14

Description: Specimens have a somewhat rectangular outline in plan view and the overlapping distal shield is normally sharply truncated rather than rounded off at the end of the flare. Central area with two rather large openings, with the obliquely transverse bridge in optical continuity with the basal shield on one side and laterally extended on other side (fig. 14). Length 10-15 μ.

Remarks: The extended and abruptly truncated end of the flaring shield is less marked in many specimens than that of Pl. 6, figs. 13 & 14, but the unusual appearance between crossed nicols of the bar and adjacent parts of proximal shield is a distinctive character of the species.

Distribution: Rare to few in the *Globorotalia opima opima* and *Globigerina ciperoensis ciperoensis* Zones of the Cipero section, present in Tertiary e 1-3 of Indonesia.

Genus RHABDOSPHAERA Haeckel, 1894

RHABDOSPHAERA sp.

Pl. 3, figs. 7-8

Remarks: This rather nondescript rhabdolith resembles specimens common in the Tertiary elsewhere, but distinctive features are not obvious for a specific assignment without further study, including that with the electron microscope.

Distribution: Few to rare in the Miocene of the Cipero section, and similar forms present in the late Tertiary of Italy and elsewhere.

Genus SCYPHOSPHAERA Lohmann, 1902

SCYPHOSPHAERA APSTEINII Lohmann

Pl. 10, figs. 1, 2, 4

Scyphosphaera apsteinii LOHMANN, 1902, Arch. Protistenk. v. 1, p. 132, pl. 4, figs. 26-30.

Remarks: Lopadoliths assigned to this species of *Scyphosphaera* are the most common ones in the Oligocene and Miocene of Trinidad. Most of the specimens are somewhat larger (14-17 μ) than those reported by Deflandre and by Kamptner, but are otherwise identical.

Distribution: Rare to few throughout the Cipero section. Originally reported from the Recent of Atlantic Ocean and Mediterranean Sea.

SCYPHOSPHAERA INTERMEDIA Deflandre

Pl. 10, fig. 3

Scyphosphaera intermedia DEFLANDRE, 1942, Bull. Soc. Hist. Nat. Toulouse, v. 77, p. 134, figs. 32-36.

Remarks: Some lopadoliths in the upper part of the section are identical to the figures of Deflandre (1942). The size varies considerably but the species is one of the most easily recognized of the genus.

Distribution: Rare in the upper part of the Cipero section. Originally reported from Mio-Pliocene ("Sahelian") of Algeria.

SCYPHOSPHAERA LAGENA Kamptner

Pl. 10, figs. 8-9

Scyphosphaera lagena KAMPTNER, 1955, Verh. K. Nederl. Akad. Wet., Afd. Natuurk., ser. 2, v. 50, p. 25, figs. 124, 127.

Remarks: Lopadoliths assigned to this species correspond very closely in size and shape with those figured by Kamptner (1955) although Trinidad specimens have a slight outward bend at the distal end.

Distribution: Rare in the *Globorotalia fohsi lobata* and *Globorotalia fohsi robusta* Zones of Trinidad. Originally reported from late Tertiary of Indonesia.

SCYPHOSPHAERA PULCHERRIMA Deflandre

Pl. 10, fig. 5

Scyphosphaera pulcherrima DEFLANDRE, 1942, Bull. Soc. Hist. Nat. Toulouse, v. 77, p. 133, figs. 28-31.

Remarks: Deflandre's figure 31 is identical to specimens found in the *Globorotalia fohsi robusta* Zone of Trinidad. Only one specimen like his figures 28-30, with a more constricted neck and widely flaring distal rim, was found in this section.

Distribution: Rare in the upper three zones of the Cipero section. Originally reported from the Mio-Pliocene ("Sahelian") of Algeria.

SCYPHOSPHAERA RECURVATA Deflandre

Pl. 10, figs. 6-7

Scyphosphaera recurvata DEFLANDRE, 1942, Bull. Soc. Hist. Nat. Toulouse, v. 77, p. 132, figs. 17-20.

Remarks: This species is easily distinguished from others of the genus by its broadly inflated outline and slight recurving of the wall at the base (not so evident in the photographs).

Distribution: Rare in the *Globorotalia fohsi lobata*, the *Globorotalia fohsi robusta* Zones, and the *Globorotalia menardii* Zone in the Trinidad section. Originally reported from the Mio-Pliocene ("Sahelian") of Algeria.

Genus STAUROLITHITES Caratini, 1963

As represented by the type (*S. laffittei*), this genus is a zygolith-like form except that the cross-bars bridge the long and short axes of the narrow oval rim. Some unrelated species were also included by Caratini. As here emended the genus should exclude species of circular outline, as this seems one of the more significant distinctions in taxa. Although a few species of elliptical coccoliths approach circularity (subround) in peripheral outline, the central area generally indicates more clearly the elliptical character.

Various such forms have been included under *Zygolithus* and other generic names. *Vekshinella* Loeblich & Tappan (=*Ephippium* Vekshina, 1959) is similar in plan view, but is quite different in showing a very conspicuous spike extending above and below the central junction of the cross-bars.

STAUROLITHITES MINUTUS
Bramlette & Wilcoxon, n. sp.
Pl. 9, figs. 1-13

Description: A very small "zygolith" with an inconspicuous bar across the shorter axis of the elliptical rim, and a bar of complex construction across the longer axis. Between crossed nicols and longer bar thus has a sigmoid appearance (Pl. 9, fig. 13) and its true form is more apparent with a superimposed quartz plate.

Remarks: The very small size of this species makes its study with electron microscope necessary for a more satisfactory description.

Distribution: Although fairly common in the *Globigerina ampliapertura* Zone of Trinidad, it has not yet been recognized elsewhere.

Genus ZYGRHABLITHUS Deflandre, 1959

ZYGRHABLITHUS BIJUGATUS (Deflandre). Deflandre

Zygolithus bijugatus DEFLANDRE *in* DEFLANDRE and FERT, 1954, Ann. Paléont., v. 40, p. 148, pl. 11, figs. 20-21.

Rhabdolithus costatus DEFLANDRE *in* DEFLANDRE & FERT, 1954, Ann. Paléont., v. 40, p. 157, pl. 11, figs. 8-11.

Zygrhablithus bijugatus DEFLANDRE, 1959, Rev. Micropaléont., v. 2, p. 135-136.

Remarks: A very common form in the early Tertiary, this species is unknown higher than the upper Oligocene (type Chattian). The species was found (sparse) only in the *G. opima opima* Zone of Trinidad, and is not illustrated here.

INCERTAE SEDIS

Genus CATINASTER Martini & Bramlette, 1963

CATINASTER CALYCULUS
Martini & Bramlette
Pl. 8, fig. 13

Catinaster calyculus MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 850, pl. 103, figs. 1-6.

Remarks: This distinctive species was originally described from the same Trinidad sample as studied here. It is evidently closely related to the discoasters.

Distribution: Few in the *Globorotalia menardii* Zone of the Cipero section. Few in the middle Miocene of the Mohole drilling, and in the middle Miocene of some Lamont deep-sea cores from the Atlantic Ocean.

CATINASTER COALITUS
Martini & Bramlette
Pl. 8, figs. 9-10

Catinaster coalitus MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 851, pl. 103, figs. 7-10.

Remarks: This small but very distinctive species was originally described from the same Trinidad sample.

Distribution: Common in the *Globorotalia mayeri* Zone of the Cipero section. Rare in the middle Miocene of the Mohole drilling, and common in some Lamont cores in the Atlantic Ocean of equivalent age, and at 95-100 feet in Joides No. 3 boring.

Genus DISCOASTER Tan Sin Hok, 1927

DISCOASTER ADAMANTEUS
Bramlette & Wilcoxon, n. sp.
Pl. 7, fig. 6

Discoaster sp. I MARTINI, 1965, Proc. XVII Symposium Colston Res. Soc., v. 17, p. 405, pl. 36, figs. 11-12.

Remarks: The Trinidad specimens are identical to those figured by Martini from Pacific Deep-Sea cores. Although rather similar to immature specimens of some other species, it seems to be a distinct but uncommon species.

Distribution: Rare to few in the *Globorotalia opima opima* Zone, the *Globorotalia kugleri* Zone, and few in the *Catapsydrax dissimilis* Zone of the Cipero section. Rare in the assemblages A, B, and C of Martini (Oligocene and Miocene in the Pacific deep-sea cores he studied).

DISCOASTER BOLLII Martini & Bramlette
Pl. 8, fig. 11

Discoaster bollii MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 851, pl. 105, figs. 1-4, 7.

Remarks: The holotype was from the same sample of the *Globorotalia menardii* Zone as studied here (TTOC 178890), and the side view showed the distinctive big stem present on both sides of the asterolith. A variant or closely related form, with 5 rather than the more typical 6 rays, is common in a sample considered a "cotype locality" of the *Globorotalia mayeri* Zone (TR-22). This sample, however, is rather different from Bolli's sample (TTOC 178889) of the *Globorotalia mayeri* Zone and the calcareous nannoplankton seem to indicate an intermediate position of TR-22 between our samples of the *Globorotalia menardii* and *Globorotalia mayeri* Zones.

Distribution: Common in the *Globorotalia menardii* Zone and rare in the *Globorotalia mayeri* Zone of the Cipero section, present in the middle Miocene of Haiti and the Experimental Mohole cores.

DISCOASTER BROUWERI Tan Sin Hok
Pl. 8, fig. 12

Discoaster brouweri Tan Sin Hok, sens. emend. BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 402, pl. 39, fig. 12, text-figs. 3a, b.

Remarks: Typical specimens with 6 thin pointed rays are common, as is a somewhat more robust 5 rayed form that is here included but may prove to be a distinct taxon more related to *D. hamatus*. The relatively small central area is about half the length of the individual rays and has a small central knob.

Distribution: This species occurs rarely in the *Globorotalia fohsi fohsi* Zone and is increasingly more common upward into the *Globorotalia menardii* Zone in the Cipero section. It is widespread and abundant in many upper Tertiary samples up to an abrupt extinction near the Plio-Pleistocene boundary. The later occurrences include increasing numbers of 5, 4, and 3 rayed specimens.

DISCOASTER CHALLENGERI
Bramlette & Riedel
Pl. 8, fig. 1

Discoaster challengeri BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 401, pl. 39, fig. 10.

Remarks: Most specimens included here are like the holotype, which was originally described from the same sample (TTOC 178890), of the *Globorotalia menardii* Zone. Atypical forms tentatively included in the species in the lower part of the Miocene of the Cipero section have shorter, thicker, less parallel sided rays, and a somewhat larger central area.

Distribution: This species, along with *D. brouweri*, is among the most common and widespread of the discoasters in the upper Tertiary. In Trinidad, specimens are few to common throughout the Miocene part of the section.

DISCOASTER DEFLANDREI
Bramlette & Riedel
Pl. 7, fig. 4

Discoaster deflandrei BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 399, pl. 39, fig. 6.

Remarks: Holotype was described from a Trinidad sample (Renz no. 90) of the *Globigerina ciperoensis ciperoensis* Zone. Asteroliths vary considerably, with many specimens commonly assigned doubtfully to the species. Terminal bifurcations subrounded to angular. Radius of central disc greater than the length of the rays, and terminal bifurcations expanded so that area between the rays is distinctly rounded. Many specimens have a small inconspicuous stellate knob at the center, with low ridges extending a short distance along each ray.

Distribution: Abundant in the lower (Oligocene) part of the Cipero section, with variants included in the species rather common in the *Globigerinatella insueta* and *Globorotalia fohsi lobata* Zones. This variable species is geographically widespread and ranges from the Eocene to the Miocene;

it is commonly the dominant *Discoaster* in the Oligocene.

DISCOASTER EXILIS Martini & Bramlette

Pl. 7, fig. 3

Discoaster exilis MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 852, pl. 104, figs. 1-3.

Remarks: This species has long slender rays that are slightly tapered and slightly bifurcated or notched at the ends. The original description of the species indicated that the ridges extend along one side of the median line of the rays. However, in most specimens from the Trinidad section this feature is not so evident.

Distribution: Present (few to common) in the four *Globorotalia fohsi* subspecies Zones of the Cipero section. Rare to common in the Middle Miocene of the experimental Mohole cores.

DISCOASTER EXTENSUS

Bramlette & Wilcoxon, n. sp.

Pl. 8, figs. 2-8

Description: Asterolith large and varying greatly in peripheral outline, with six rays that may be bluntly rounded, truncated, or notched at the tips. The central area is broad and nearly flat or complanate. Specimens are distinctly rugose, and commonly show indistinct sutures, extending from the center to the margin between the rays. Diameter 15-22 μ, usually about 18 μ.

Remarks: Despite much variation in outline illustrated by the seven specimens, all gradations occur in this character in the single sample where the species is common, making any subdivision difficult and of questionable value.

Distribution: Common in the *Cataspsydrax dissimilis* Zone and very rare in the *Catapsydrax stainforthi* Zone of the Cipero section.

DISCOASTER HAMATUS Martini & Bramlette

Pl. 7, figs. 9-11

Discoaster hamatus MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 852, pl. 105, figs. 8, 10, 11.

Remarks: A distinctive and widely distributed species originally described and well figured from the same sample (TTOC 178890) of the Cipero section.

Distribution: Common in the *Globorotalia menardii* Zone of the Cipero section. Rare to few in the middle Miocene of the experimental Mohole and Atlantic cores, Joides No. 3, at 75-95 feet and in Tertiary f 2-3 of Indonesia.

DISCOASTER KUGLERI

Martini & Bramlette

Pl. 7, figs. 1-2

Discoaster kugleri MARTINI & BRAMLETTE, 1963, Jour. Paleontology, v. 37, p. 853, pl. 102, figs. 11-13.

Remarks: Specimens typically with short stubby rays, less than half the diameter of the central part. Tips slightly notched and thicker than the central area of the asterolith, as is indicated by brighter, more condensed, lighting near the tips of the rays

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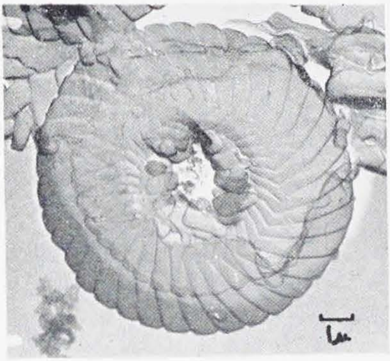
PLATE 1

Electronmicrographs with magnification indicated by the one micron scale on each.

Figures		Page
1–3	*Cyclococcolithus neogammation* Bramlette & Wilcoxon, n. sp. (1) distal view, Joides 3, (338 ft) paratype, U.S.N.M. 650 664, (2) proximal view, same sample, paratype, U.S.N.M. 650 665, (3) side view, same sample, paratype, U.S.N.M. 650 666	104
4	*Coronocyclus nitescens* (Kamptner), n. comb. Proximal(?) view, Joides 3, (338 ft)	103
5	*Sphenolithus distentus* (Martini), n. comb. side view, Joides 3, (338 ft)	122
6	*Sphenolithus predistentus* Bramlette & Wilcoxon, n. sp. side view, Joides 3, (418 ft), paratype, U.S.N.M. 650 668	126



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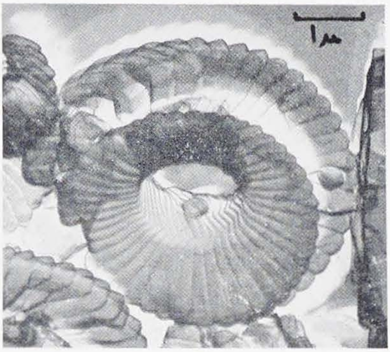

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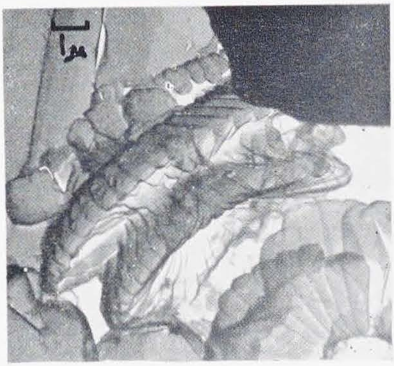

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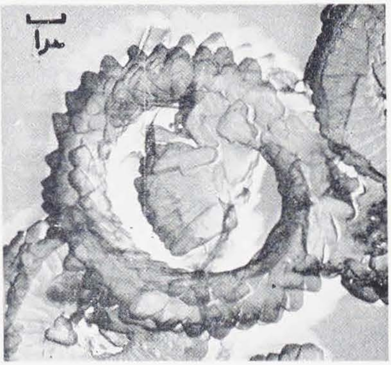

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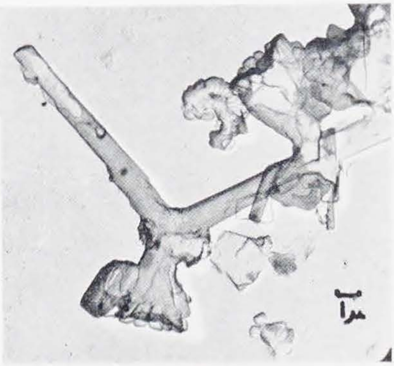

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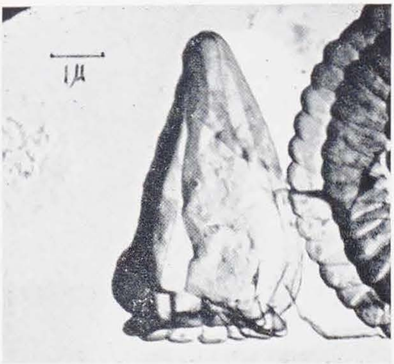

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PLATE 1

(fig. 1). Variants (fig. 2) of these typical specimens have longer rays, thicker centers, and show suture lines extending from the center to the margin between the rays. This variant, or subspecies, is the common and nearly only form in sample TR-16, from approximately the same locality as the type sample. The holotype was from another sample from Bolli of the *Globorotalia fohsi robusta* Zone.

Distribution: Common in the *Globorotalia fohsi robusta* Zone and rare in the *Globorotalia fohsi lobata* Zone of Trinidad.

DISCOASTER PENTARADIATUS Tan Sin Hok

Discoaster pentaradiatus TAN SIN HOK, 1927, Jaarb. Mijnw. Nederl. Indie, v. 55, p. 120, fig. 2; sens. emend. BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 401, pl. 39, fig. 11, text figs. 2a, b.

Remarks: Asteroliths with five or very rarely six slender rays, with long slender bifurcations at the ends. Commonly, one of the bifid spurs appears shorter than the other. *D. pentaradiatus* is separated from some 5 rayed specimens of *D. challengeri* by the extended terminal bifurcations, more delicate rays, and less developed central area.

Distribution: Very rare in the *Globorotalia menardii* Zone of the Cipero section (and therefore not illustrated), but common throughout the later Miocene and Pliocene of many regions.

DISCOASTER PERPLEXUS
Bramlette & Riedel
Pl. 7, fig. 5

Discoaster perplexus BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, p. 400, pl. 39, fig. 9.

Remarks: This small form occurs sparsely in the Miocene of Trinidad, and throughout the late Tertiary of many regions.

Distribution: Rare to few in the Miocene part of the Cipero section.

DISCOASTER TANI ORNATUS
Bramlette & Wilcoxon, n. subsp.
Pl. 7, fig. 8

Description: This subspecies is clearly related to *D. tani nodifer*, and is commonly associated with that subspecies, along with

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PLATE 2

(All specimens x2700)

Figures		Page
1–3	*Spenolithus belemnos* Bramlette & Wilcoxon, n. sp. (1) side view (upper specimen), TTOC 193790, holotype, U.S.N.M. 650 699, (2) long axis 0° to crossed nicols, (3) long axis 45° to crossed nicols	118
4–5	*Sphenolithus distentus* (Martini), n. comb. (4) side view, TTOC 193785, (5) long axis 45° to crossed nicols	122
6–9	*Sphenolithus heteromorphus* Deflandre. (6) slender form, (7) common form, (8) long axis 45° to crossed nicols, (9) long axis 0° to crossed nicols. Both specimens from TTOC 193125	122
10–11	*Sphenolithus predistentus* Bramlette & Wilcoxon, n. sp. (10) long axis 45° to crossed nicols, TTOC 193785, holotype, U.S.N.M. 650 671, (11) long axis 0° to crossed nicols	126
12–14	*Sphenolithus pseudoradians* Bramlette & Wilcoxon, n. sp. (12) side view, TTOC 193785, holotype, U.S.N.M. 650 672, (13) long axis 0° to crossed nicols, (14) long axis 45° to crossed nicols	126
15–20	*Sphenolithus ciperoensis* Bramlette & Wilcoxon, n. sp. (15) side view, TTOC 215 656, holotype, U.S.N.M. 650 673, (16) long axis 0° to crossed nicols, (17) long axis 45° to crossed nicols, (18) basal view in silicone oil, (19) bifurcate form, intermediate to progenitor *S. distentus*, TTOC 215656, paratype, U.S.N.M. 650 674, (20) long axis 45° to crossed nicols	120


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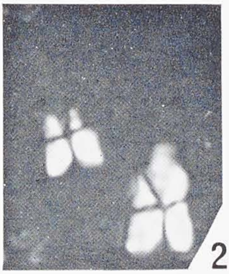
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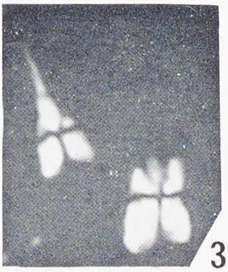
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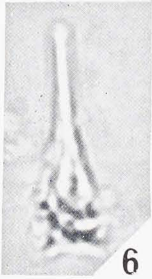
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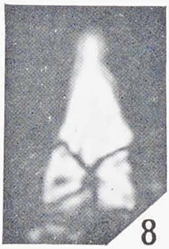
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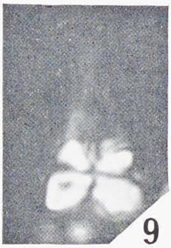
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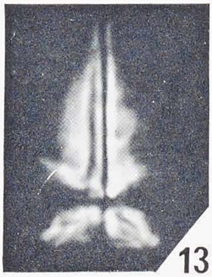
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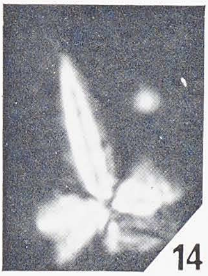
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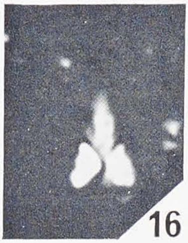
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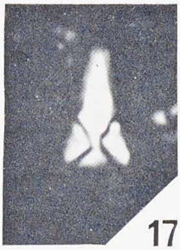
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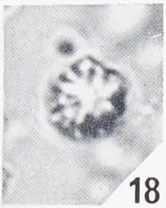
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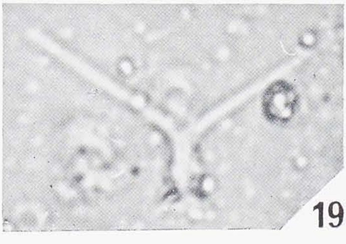
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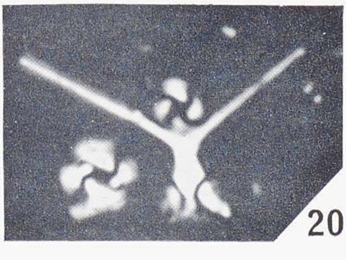
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PLATE 2

intermediate forms. The notch at tip of the five rays is more conspicuous in this new subspecies, and approaches a bifurcation of the tips. The nodes are conspicuous, sharp, and commonly occur as a pair on each side of the rays. The central star is larger, higher, and thus much more conspicuous than that which may or may not occur on *D. tani nodifer*.

Remarks: Fig. 7 of pl. 7 represents an intermediate form between the two subspecies.

Distribution: Common in the Red Bluff Formation (basal Oligocene) along with the name species of the *Helicosphaera reticulata* Zone. Rather widely distributed in equivalent strata, and in part, at least, of the overlying *G. ampliapertura* Zone, which is the lowest Oligocene zone in the Cipero section.

Genus ORTHORHABDUS
Bramlette & Wilcoxon, n. gen.

Elongate rhabdolith-like form either tapering or abruptly decreasing from the enlarged base, formed of calcite acting optically as a unit (ortholithid), and lacking the internal canal of *Rhabdosphaera*. Complete specimens of another but undescribed species of this genus with about 15 radiating "rhabdoliths" have been observed in type Rupelian samples. *Sujkowskiella* (Hay, Mohler, & Wade, 1966) is somewhat similar but has a conspicuous open area in the basal part. *Rhabdosphaera? semiformis* Bramlette & Sullivan, (1961) seems assignable to *Sujkowskiella*.

Type Species: *Orthorhabdus serratus*, new species.

ORTHORHABDUS SERRATUS
Bramlette & Wilcoxon, n. sp.
Pl. 9, figs. 5-10

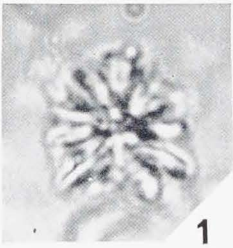
Triquetrorhabdulus sp. MARTINI, 1965, Proc. XVIII, Symposium of Colston Res. Soc., v. 17, p. 408, pl. 36, fig. 6.

Description: An ortholithid species characterized by a three edged rod, larger and normally concave at one end (proximal?) and tapering to a point at the other. The edges are serrate near the large end. Length 10-20 μ.

Remarks: This species differs from *Triquetrorhabdulus carinatus* in having the marked asymmetry of a large base, serrate edges, and in having the C-axis of the calcite normal to the direction of elongation. Martini's Fig. 6 is of a Trinidad specimen of this species, but his Figs. 4 and 5 appear to be prisms of a foraminiferal or other shell and show opposite orientation of the calcite.

PLATE 3
(All specimens x2700)

Figures		Page
1–6	*Sphenolithus moriformis* (Bronnimann & Stradner), n. comb. (1) side view, (2) crossed nicols, (3) basal view, (4) crossed nicols, (5) side view of more conical form, (6) crossed nicols. All 3 specimens from TTOC 206264	124
7–8	*Rhabdosphaera sp.* (1) side view, (8) long axis 45° to crossed nicols, TR 16	107
9–12	*Cyclococcolithus leptoporus* (Murray & Blackman). Kamptner. (9) proximal view of separated distal shield only, (10) crossed nicols, (11) proximal view of complete coccolith, (12) crossed nicols. Both specimens from TR 16	103
13–15	*Coccolithus pelagicus* (Wallich). Schiller. (13) distal view, (14) crossed nicols, (15) phase contrast. TR 16	102
16–17	*Cyclococcolithus lusitanicus* (Black). Hay, Mohler & Wade. (16) distal view, (17) crossed nicols. Red Bluff (SW ¼ sec. 28, T7N, R10W, Mississippi)	103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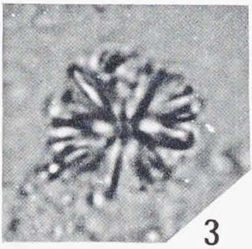
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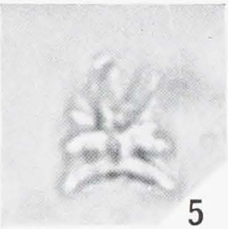
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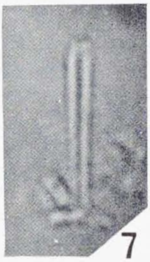
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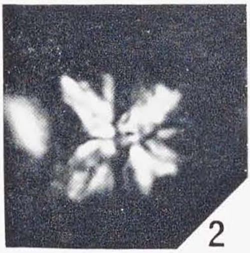
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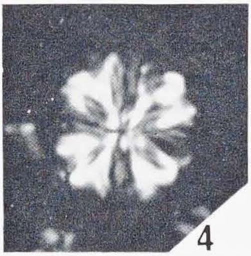
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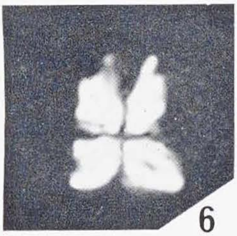
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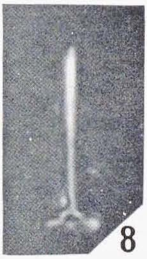
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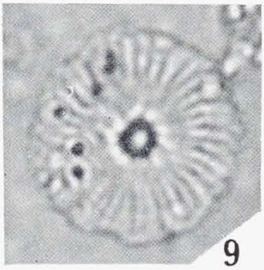
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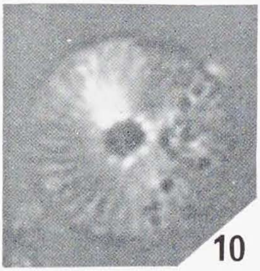
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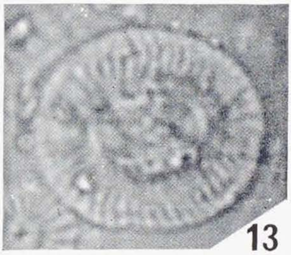
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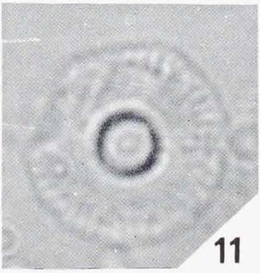
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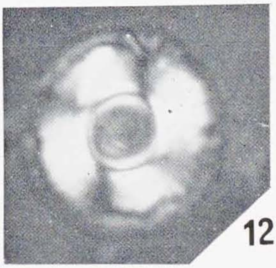
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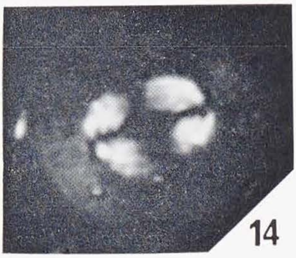
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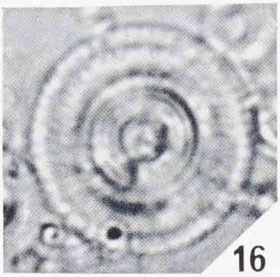
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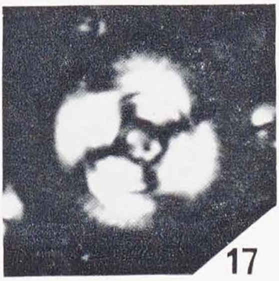
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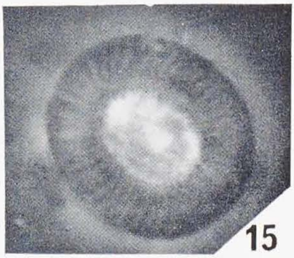
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PLATE 3

Distribution: Common in the *Catapsydrax dissimilis* Zone of the Cipero section and rare in the *Globigerinatella insueta* Zone; small specimens of similar form are sparse in Tertiary e 4-5 of Indonesia.

Genus ORTHOZYGUS
Bramlette & Wilcoxon, n. gen.

This genus is unusual in showing the optical character of the ortholithid group, but in having a zygolith-like form, with the bridging of the elliptical rim across the top, as in *Zygosphaera* of Kamptner (1937). The unvarying high refringence in plan view and the maximum and minimum refringence with rotation in polarized light in side view indicates an ortholithid construction similar to *Discoaster.*

Type Species: *Orthozygus aureus* (Stradner), n. comb.

ORTHOZYGUS AUREUS
(Stradner). Bramlette & Wilcoxon, n. comb.
Pl. 9, figs. 1-4

Zygolithus aureus STRADNER, 1962, Geol. Bundesanst. (Wien), p. 368, pl. 1, figs. 31-36.

Remarks: The distinctive wide bridge across this small elliptical form is evident in plan view, as is the unusual height of this complex bridge in side view (Fig. 3). The original drawn figures of this species were somewhat misleading, but specimens kindly supplied by Stradner confirmed our identification, as did a later photograph by Stradner. Length about 7 μ.

Distribution: Present only in the *Globigerina ampliapertura* Zone of the Cipero section, and in the somewhat earlier Oligocene Red Bluff (*Helicosphaera reticulata* Zone), and the late Eocene of Mississippi. Originally described from the late Eocene of Austria.

Genus SPHENOLITHUS
Deflandre *in* Grassé, 1952

Exceptional attention is here given to species of this genus because of nearly world-wide abundance, and because gradational forms indicate a phylogenetic sequence recognizable also in the stratal succession of Joides borings, Europe, and Indonesia. The sphenoliths of this genus include various modifications of a basic structure of spinose elements radiating from the center of a depressed basal (proximal) area where the spines are lacking. Typically with the apical spine or spines longest, producing the usual wedge shape. The spines, other than the big apical spine characteristic of some species, are rather thin or delicate, or quite robust in samples with all specimens more heavily calcified.

Associated with a persistent stock of the

PLATE 4
(All specimens x2700)

Figures		Page
1–2	*Coccolithus* cf. *C. scissurus* (Hay, Mohler, & Wade), n. comb. (1) distal view, (2) long axis 45° to crossed nicols. TTOC 215656	102
3–5	*Cyclococcolithus neogammation* Bramlette & Wilcoxon, n. sp. (3) proximal view, TTOC 193265, Holotype, U.S.N.M. 650 675, (4) crossed nicols, (5) side view in viscous medium	104
6–8	*Coccolithus eopelagicus* (Bramlette & Riedel). Bramlette & Sullivan. (6) proximal view, (7) long axis 17° to crossed nicols, (8) phase contrast. TR 19. (Riedel recollection from locality of TTOC 193265)	102
9–10	*Coccolithus* aff. *C. bisectus* (Hay, Mohler, & Wade), n. comb. (9) proximal view, (10) long axis 0° to crossed nicols. TR 19. (same locality as above)	102
11–13	*Coccolithus bisectus* (Hay, Mohler, & Wade), n. comb. (11) distal view, low focus, (12) high focus, (13) long axis 45° to crossed nicols. TR 19 (same locality)	102

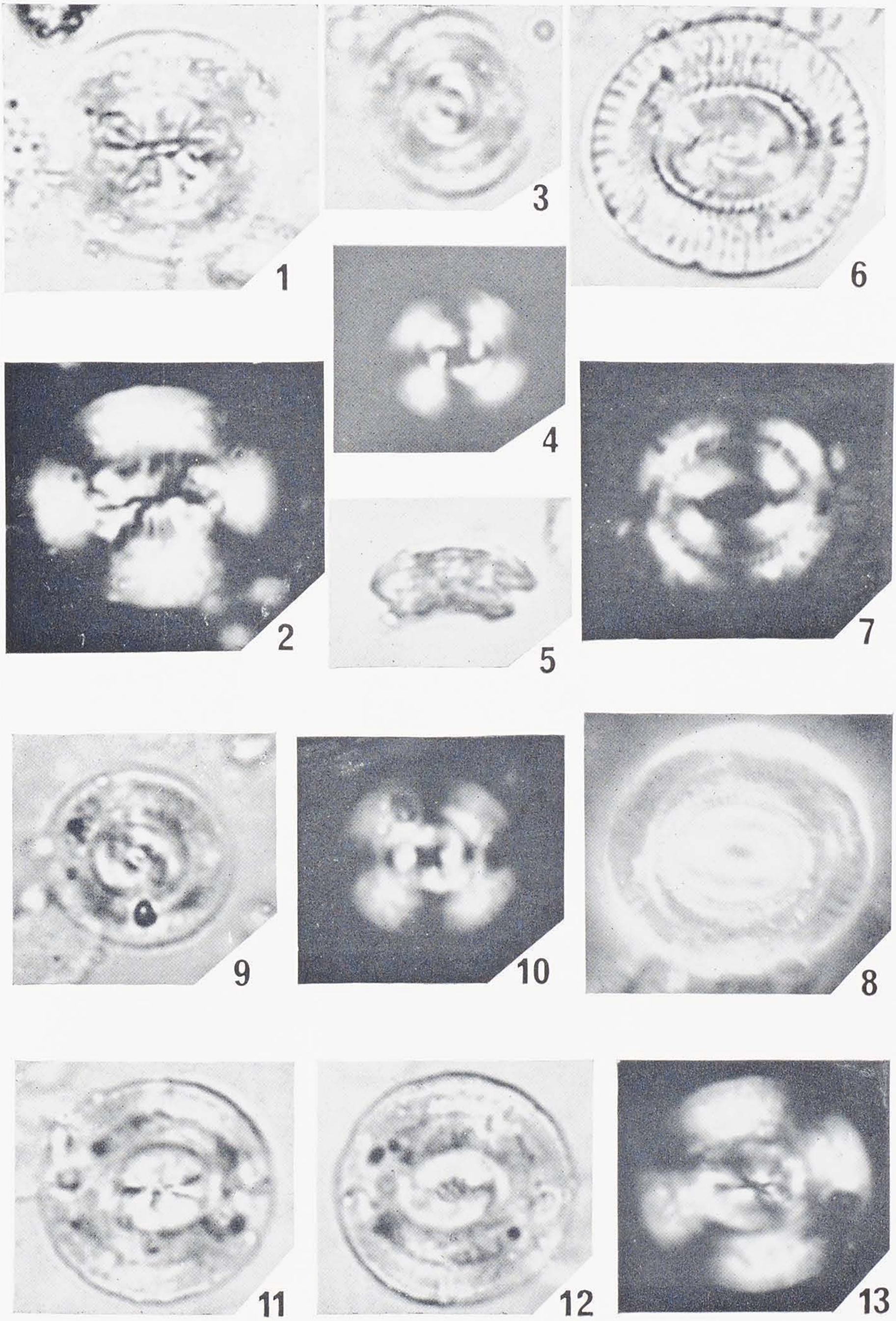

Plate 4

more bulbous sphenoliths included in *S. moriformis*, and the similar *S. abies* of the later Tertiary, are the more distinctive forms with a single apical spine which show the lineage development from *S. predistentus to S. distentus* to *S. ciperoensis*, and less clearly to *S. belemnos*.

Dimorphism in sphenoliths of a species may be indicated because the distinctive forms representing this lineage are consistently associated with more abundant specimens of the *S. moriformis* type which show little obvious differences throughout the succession from the Paleocene.

The radial spines of *Sphenolithus* are not distinct in a Canada balsam mount except between crossed nicols, but their number and arrangement is evident in a low index medium such as silicone, in which specimens were turned for study. Characteristic features of all the species are most obvious, however, from examination between crossed nicols if the specimen is rotated to the two positions of parallel to a nicol, and at 45°. The illustrations show these two positions, both of which are essential for the distinction of the basic construction of a species.

Type Species: *Sphenolithus radians* Deflandre *in* Grassé, 1952.

SPHENOLITHUS BELEMNOS
Bramlette & Wilcoxon, n. sp.
Pl. 2, figs. 1-3

Description: Sphenolith is small, narrow, dart-shaped in side view, with depressed base constructed of about 10-12 spines that constitute about one half to one third of the length. The sphenolith shows a uniform taper up to the pointed apical spine (fig. 3). Much shorter lateral spines, extending upward, are indicated between crossed nicols in the position with the main spine (apical) at extinction.

Remarks: This species is most distinctive and easily recognized between crossed nicols, particularly with the apical spine parallel to either of the nicols and thus at extinction.

Distribution: In the Cipero section, this species is common only in the *Catapsydrax stainforthi* Zone but with some small specimens in the *Catapsydrax dissimilis* and *Globorotalia kugleri* Zones. It is widely distributed in approximately equivalent strata of Italy (upper Pteropod marl near Torino), Joides No. 3 boring at 261 ft., in Div. e 4-5 of Indonesia, some central Pacific cores, and present in Saucesian Stage of California.

PLATE 5
(All specimens x2700)

Figures		Page
1–2	*Apertapetra umbilicus* (Levin). Levin & Joerger. (1) proximal view, (2) long axis 0° to crossed nicols. Red Bluff. (SW ¼, sec. 28. T7N, R10W, Mississippi)	101
3–4	*Discolithina vigintiforata* (Kamptner ex Deflandre). Loeblich & Tappan. (3) distal view, (4) long axis 45° to crossed nicols. TR 20	104
5–6	*Discolithina* cf. *D. anisotrema* (Kamptner), (5) distal view, (6) long axis 45° to crossed nicols. TTOC 178888	104
7–8	*Coronocyclus nitescens* (Kamptner), n. comb. (7) distal(?) view, oblique light, (8) crossed nicols TTOC 206264	103
9–10	*Helicosphaera parallela* Bramlette & Wilcoxon, n. sp. (9) distal view, TR 20, holotype, U.S.N.M. 650 676, (10) long axis 45° to crossed nicols	106
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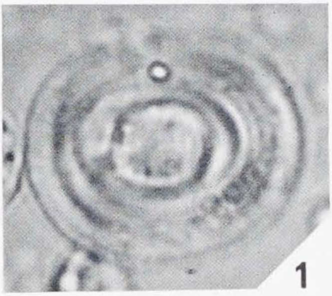
13–14	*Heliscosphaera obliqua* Bramlette & Wilcoxon, n. sp. (13) plan view, TTOC 178888, holotype, U.S.N.M. 650677, (14) long axis 45° to crossed nicols	106



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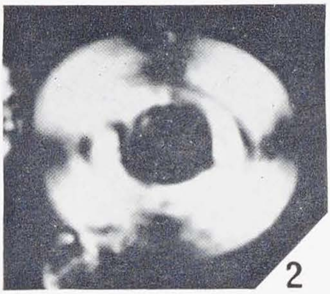

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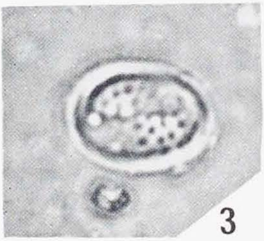

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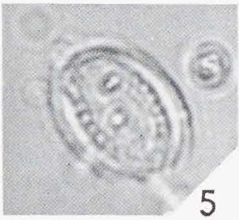

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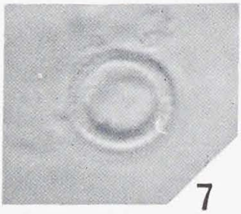

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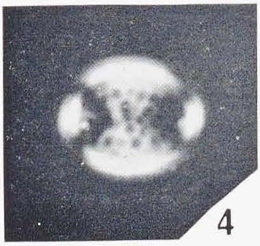

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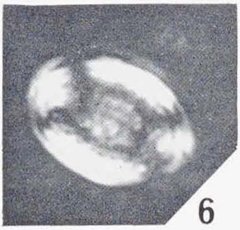

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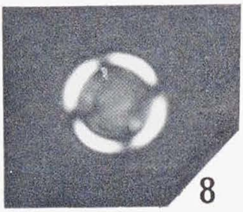

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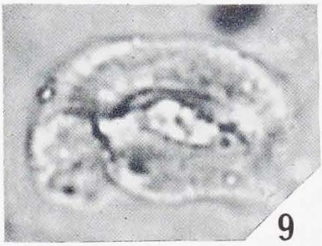

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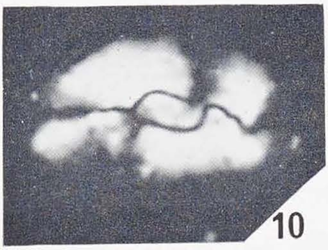

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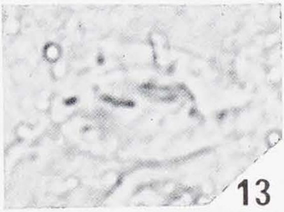

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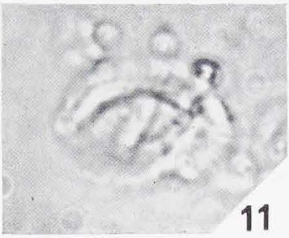

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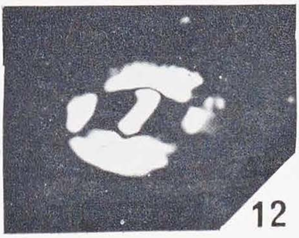

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PLATE 5

SPHENOLITHUS CIPEROENSIS
Bramlette & Wilcoxon, n. sp.
Pl. 2, figs. 15-18, and aff.
in figs. 19, 20

Description: Sphenolith small, with nearly uniform taper from base to tip of apical spine; about 10-12 spines around the distinctly depressed basal area. Apical spine pointed in most specimens but slightly to strongly bifurcate in some otherwise identical forms. The spine consists of coalesced units of calcite of slightly different orinetation (obvious with superimposed quartz plate), hence does not normally show complete extinction between crossed nicols of the apical spine in position parallel to either nicol.

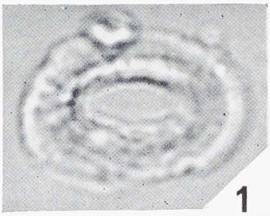
Remarks: Although small, this form is conspicuous between crossed nicols, having a particularly distinctive appearance with length of specimen and apical spine at 45° to either nicol (fig. 17). In this orientation the extinction lines do not cross but appear as two outward curving (chevron-like) lines, with the bright area continuing between them to the base, in contrast to the appearance of *S. distentus* (Pl. 2, fig. 5) in this orientation.

Similar in size and dart-like shape to *S. belemnos,* but the distinction is obvious between crossed nicols. Similarity to *S. distentus* is apparent in the compound apical spine and tendency for bifurcation of this spine. Some overlap in occurrence, including intermediate forms (Pl. 2, figs. 19-20), indicate that this species developed from *S. distentus,* and in turn gave rise to the later *S. belemnos.*

Distribution: Common in the *Globigerina ciperoensis ciperoensis* Zone, and sparse in the *Globorotalia opima opima* Zone of the Cipero section, and in approximately equivalent strata elsewhere; present in a sample from Escornebeou, France received from Drooger, which he correlates with type Chattian on the basis of the species of *Miogypsina* and *Lepidocyclina.* Common in Joides No. 4 boring at 73 ft. to approximately 150 feet, in the subsurface Hackberry Formation of Texas, and in Tertiary e 1-3 of Indonesia.

PLATE 6
(All specimens x2700)

Figures		Page
1–4	*Helicosphaera ampliaperta* Bramlette & Wilcoxon, n. sp. (1) distal view, TTOC 178888, holotype, U.S.N.M. 650 678, (2) long axis 15° clockwise to crossed nicols, (3) long axis 52° clockwise to crossed nicols, (4) proximal view, TTOC 178888 paratype, U.S.N.M. 650 679	105
5–8	*Helicosphaera compacta* Bramlette & Wilcoxon, n. sp. (5) proximal view, TTOC 193785, holotype, U.S.N.M. 650 680, (6) long axis 20° clockwise to crossed nicols, (7) distal view, TTOC 193785, paratype, U.S.N.M. 650 681, (8) long axis 45° to crossed nicols	105
9–10	*Helicosphaera carteri* (Wallich). Kamptner. (9) proximal view, (10) long axis 65° clockwise to crossed nicols. TR 17 (Riedel recollection from locality of TTOC 178888)	105
11–12	*Helicosphaera intermedia* Martini. (11) proximal view, (12) long axis 45° to crossed nicols. TTOC 193265	105
13–14	*Helicosphaera truncata* Bramlette & Wilcoxon, n. sp. (13) proximal view, holotype, U.S.N.M. 650682, (14) long axis 0° to crossed nicols. TR 20 (Riedel recollection from locality of TTOC 215656)	106
15	*Helicosphaera reticulata* Bramlette & Wilcoxon, n. sp. proximal view, Red Bluff (SW ¼, sec. 28, T7N, R10W, Mississippi), holoytpe, U.S.N.M. 650683	106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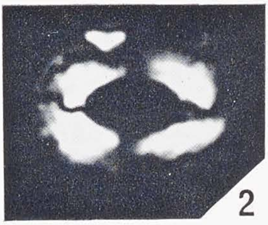
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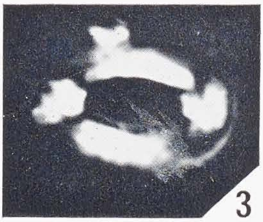
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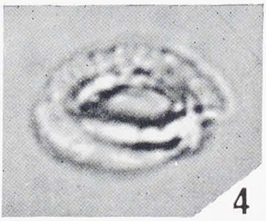
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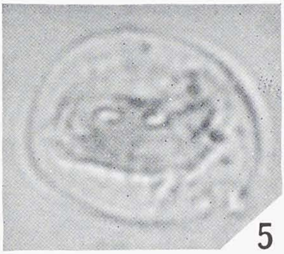
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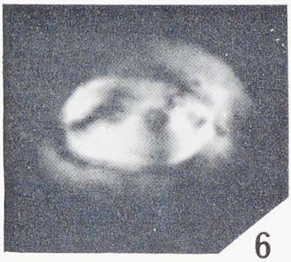
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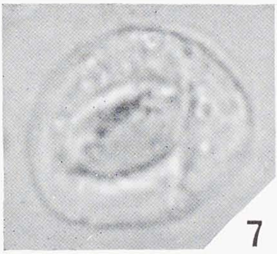
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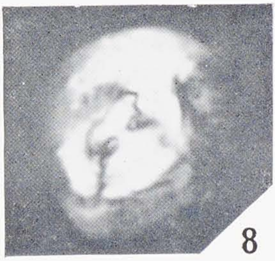
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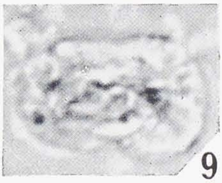
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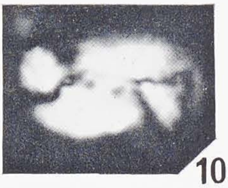
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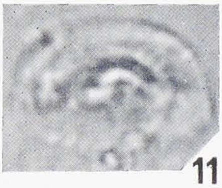
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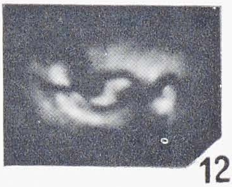
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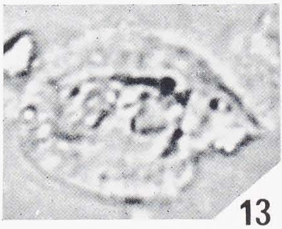
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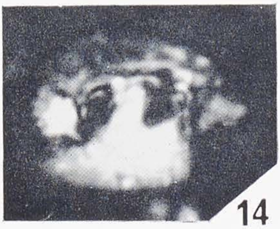
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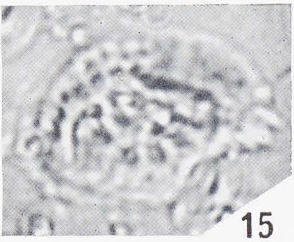
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Plate 6

SPHENOLITHUS DISTENTUS
(Martini). Bramlette & Wilcoxon, n. comb.

Pl. 1, fig. 5; Pl. 2, figs. 4-5

Furcatolithus distentus MARTINI, 1965, Proc. XVIII Symposium Colston Res. Soc., v. 17, p. 407, pl. 35, figs. 7-9.

Remarks: A peculiar form of *Sphenolithus* with the large apical spine largely obscuring the basic spinose architecture of the genus. About 10-12 short basal spines form a depressed base attached to a slightly convex base on the large apical spine. Specimens with strongly bifurcating apical spine are nearly as common as shorter ones with pointed tip that are much less conspicuous. The apical spine consists of coalesced units of calcite of slightly different optical orientation. Despite the marked difference in appearance of specimens with and without the strong bifurcation, their consistent association, gradational forms, and similarity otherwise indicate a single species. Perhaps these represent dimorphous forms on a single living cell, as with some now living coccolithophorids.

The apical spine is easily separated from the short basal spines, particularly in the poorly preserved specimens of some samples. Additional examination of the Scripps deep-sea core MP 40-1 from which Martini described *Furcatolithus distentus* shows that his specimen represented only the large apical spine. Others with the basal spines not separated from the big apical one are present in this core sample, along with more common specimens without the striking bifurcation of the apical spine.

Distribution: Common, although relatively small, in the *Globorotalia opima opima* Zone of Trinidad, with fewer typical forms and intermediate ones occurring with *S. predistentus* in the *Globigerina ampliapertura* Zone a few forms intermediate between typical *S. distentus* and *S. ciperoensis* occur in the *Globigerina ciperoensis ciperoensis* Zone. Especially large, abundant and heavily calcified in Joides No. 3 boring from 278-304 feet, with fewer specimens associated with *S. predistentus* on down to about 500 ft. Present in the Rupelton of Germany, and associated with *S. predistentus* in the type Rupelian of Belgium; also in Tertiary e 1-3 of Indonesia. The sample MP 40-1 was assigned by Martini to the *C. dissimilis* Zone of Bolli, but both the nannoplankton and foraminifera indicate that this sample should be placed in the upper part of the *Globigerina ampliapertura* Zone or lower *Globorotalia opima opima* Zone.

SPHENOLITHUS HETEROMORPHUS
Deflandre

Pl. 2, figs. 6-9

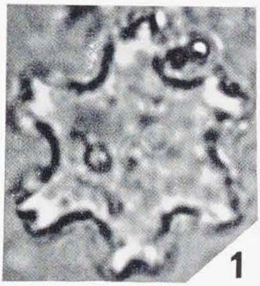
Sphenolithus hetermorphus DEFLANDRE, 1953, C. R. Acad. Sc. [Paris], v. 137, p. 1785, 1786, figs. 1, 2.

Remarks: This sphenolith is well illus-

PLATE 7

(All specimens x2700)

Figures		Page
1-2	*Discoaster kugleri* Martini & Bramlette. (1) Typical form, Barrackpore Oilfield Well 327, (Bolli locality) (2) *D. kugleri var.*, TR 16	110
3	*Discoaster exilis* Martini & Bramlette. Phase contrast, TR 16	110
4	*Discoaster deflandrei* Bramlette & Riedel. From TTOC 215656	109
5	*Discoaster perplexus* Bramlette & Riedel. From TTOC 178889	112
6	*Discoaster adamanteus* Bramlette & Wilcoxon, n. sp. From TTOC 206264, holotype, U.S.N.M. 650 684	108
7-8	*Discoaster tani ornatus* Bramlette & Wilcoxon, n. subsp. (7) form intermediate with *D. tani nodifer*, (8) holotype, U.S.N.M. 650 685. Both specimens from TTOC 193785	112
9-11	*Discoaster hamatus* Martini & Bramlette. (9) plan view, (10) side view, (11) side view, 45° to crossed nicols. Both specimens from TTOC 178890	110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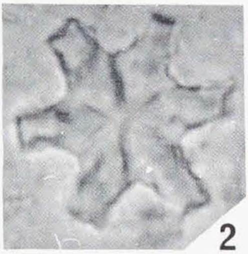
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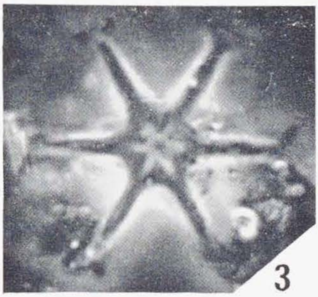
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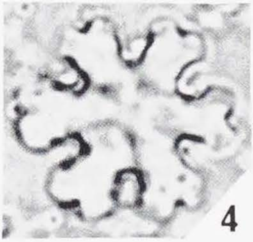
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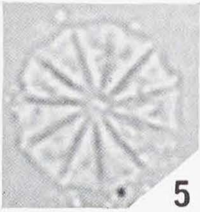
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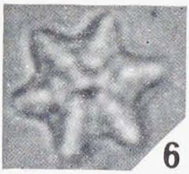
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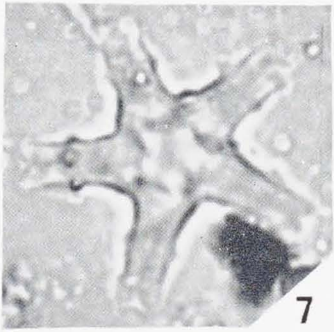
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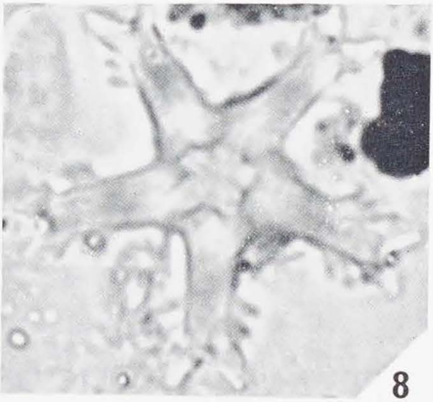
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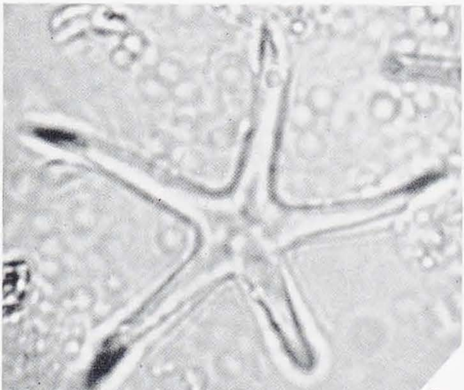
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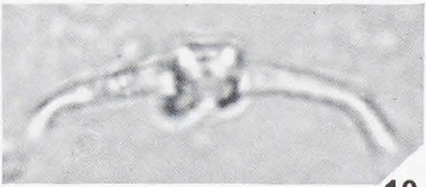
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PLATE 7

trated by Deflandre and Fert (1954) and our forms are identical to those in type material (from Consets Bay) supplied by Deflandre. The appearance between crossed nicols is characteristic, parallel to and at 45° to the nicols, as seen in the figures. Study at various orientations in a viscous medium shows that a series of eight or nine spines surround the depressed basal area lacking spines, with radiating shorter spines above producing the black cross between crossed nicols when the single big apical spine is at extinction position (fig. 9). This apical spine varies markedly in length and robustness (pl. 2, fig. 6, slender form). Differs from *S. radians* Deflandre most obviously in that the big apical spine acts optically as a single unit of calcite.

Distribution: Common in the *Globigerinatella insueta* and *Globorotalia fohsi barisanensis* Zones of the Cipero section, and widespread in approximately equivalent strata including most of the type Langhian of Italy, some Pacific deep-sea cores, Joides No. 3 boring at 180-255 feet, Tertiary f 1 of Indonesia, the Realizian Stage of California, and the originally described occurrence in Barbados.

SPHENOLITHUS MORIFORMIS

(Bronnimann & Stradner). Bramlette & Wilcoxon, n. comb.

Pl. 3, figs. 1-6

Nannoturbella moriformis BRONNIMANN & STRADNER, 1960, Erdoel-Zeitschrift, v. 76, p. 368, figs. 11-16.

Sphenolithus pacificus MARTINI, 1965, Proc. XVII, Symposium of Colston Res. Soc., v. 17, p. 407, pl. 36, figs. 7-10.

Remarks: The numerous radiate spines show a bulbous form in side view, as the apical spines are not much longer than the lateral ones. About ten spines surround the basal depressed area. Size varies greatly in this most abundant species of the genus. The typical form gradually becomes somewhat more conical (fig. 5), and seems to grade by increase in relative length of apical spines through the Miocene, to *S. abies* of the late Miocene and Pliocene. Variations and the gradual change in populations, however, made it impractical to differentiate the two species within the Miocene part of the Cipero section. Bramlette has found that in deep-sea cores the normally smaller form of *S. abies* continues abundant until an abrupt disappearance near the middle of the Plicoene, and believes this offers a significant stratigraphic datum plane.

Variation in the degree of calcification of the spines is very marked in different samples, apparently due in large part, at least, to diagenetic addition of excess calcite, and can result in coalescence into nearly solid forms such as the holotype of *Nannoturbella moriformis*. In such specimens, however, the general outer form and characteristic radial structure centered near the base remain apparent between crossed nicols.

Distribution: Common in the Cipero section, and from the Paleocene to Miocene of

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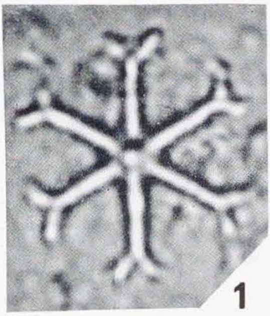
PLATE 8

(All specimens x2700)

Figures		Page
1	*Discoaster challengeri* Bramlette & Riedel. From TTOC 178889	109
7	*Discoaster extensus* Bramlette & Wilcoxon, n. sp. From TTOC 206264, holotype, U.S.N.M. 650 686	110
2, 3, 4, 5, 6, 8	*Discoaster extensus* Bramlette & Wilcoxon, n. sp. From TTOC 206264, paratype, U.S.N.M. 650 687, 650 688, 650 689, 650 690, 650 691, 650 692	110
9–10	*Catinaster coalitus* Martini & Bramlette. (9) side view, (10) plan view. Both specimens from TTOC 178889	108
11	*Discoaster bollii* Martini & Bramlette. From TTOC 178890	109
12	*Discoaster brouweri* Tan Sin Hok. From TTOC 178890	109
13	*Catinaster calyculus* Martini & Bramlette. From TTOC 178890	108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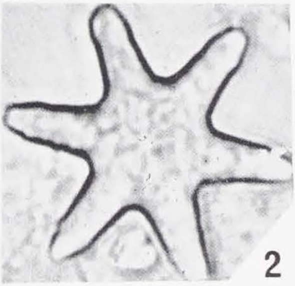
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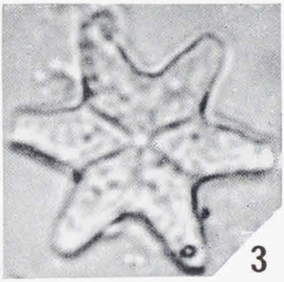
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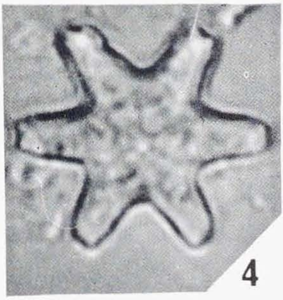
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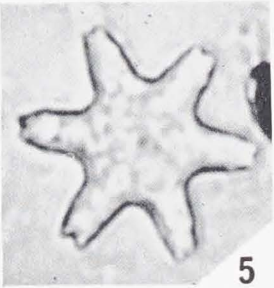
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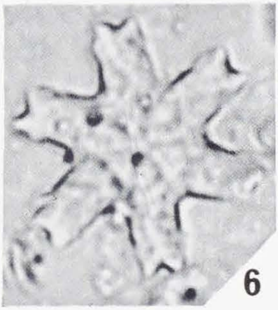
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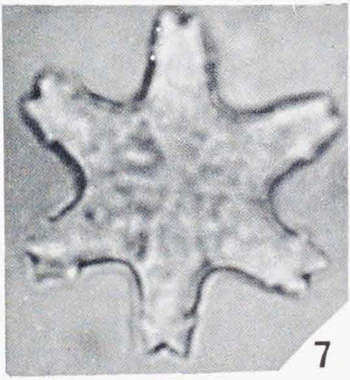
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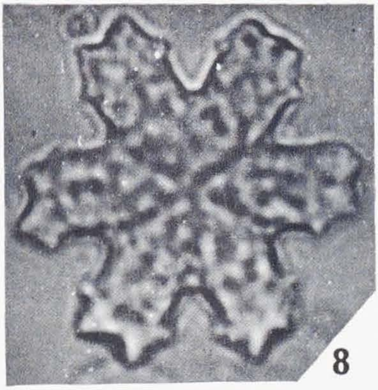
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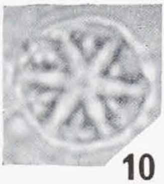
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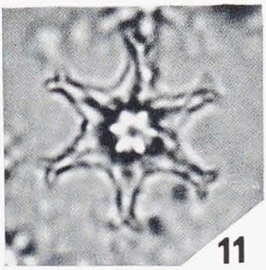
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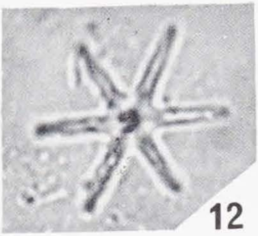
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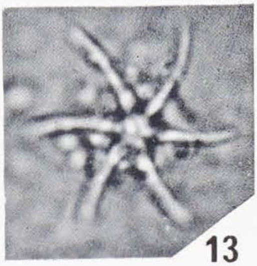
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PLATE 8

many regions. Originally recorded from the Alkazar Formation (L. Eocene) of Cuba.

SPHENOLITHUS PREDISTENTUS
Bramlette & Wilcoxon, n. sp.
Pl. 1, fig. 6 and Pl. 2, figs. 10-11

Description: Sphenolith with a large apical spine, flat or slightly depressed at the base where attached to a single annular ring of 10-12 lateral spines. Apical stem tapers strongly for about half its length and then gradually to a pointed or bifurcating tip. Between crossed nicols the apical spine appears to be formed of coalesced calcite units of slightly different optical orientation.

Remarks: This species is similar to and clearly grades into *S. distentus*. Within the interval of their overlap in range the distinction is difficult except as populations. Otherwise, however, their occurrence in large numbers and many places permit clear differentiation, and the succession of these taxa is of obvious stratigraphic significance. With the apical spine at 45° to the crossed nicols (fig. 10) the small basal spines of *S. predistentus* appear as attached to a nearly flat base of the apical spine, which broad base extends laterally as much or more than the rather inconspicuous basal spines. In similar view, *S. distentus* (fig. 5) shows more conspicuous basal spines and the extinction lines extend upward to overlap some of the base of the apical spine.

Distribution: Common in the *Globigerina ampliapertura* Zone and few in the *Globorotalia opima opima* Zone of Trinidad. Occurs in the Red Bluff and Vicksburg Formations of Mississippi, in Joides No. 3 boring from about 300 feet to 500 feet, associated with *S. distentus* in the type Rupelian of Belgium, in the "Stampiano" of Sacco in northern Italy, in part of the Tertiary d-c of Indonesia, and in some Pacific deep-sea cores.

SPHENOLITHUS PSEUDORADIANS
Bramlette & Wilcoxon, n. sp.
Pl. 2, figs. 12-14

Description: Large sphenolith with big, wide-flaring distal spine and radiate spines in the basal part. Recognized with crossed nicols as a large form with the stem rapidly tapering from near mid-point to a very slightly bifurcating tip. Stem commonly irregularly serrate along the edges. The

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PLATE 9

(All specimens x2700)

Figures		Page
1–4	*Orthozygus aureus* (Stradner), n. comb. (1) plan view, (2) high focus, (3) side view, (4) side view, long axis 45° to crossed nicols. Both specimens from TTOC 193785	116
5–10	*Orthorhabdus serratus* Bramlette & Wilcoxon, n. gen., n. sp. (5) side view, holotype, U.S.N.M. 650 693, (6) long axis 45° to crossed nicols, (7) side view, paratype, U.S.N.M. 650 694, (8) long axis 45° to crossed nicols, (9) plan view, paratype, U.S.N.M. 650 695, (10) end view of tilted specimen, paratype, U.S.N.M. 650 696. All specimens from TTOC 206264	114
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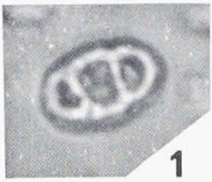
17–18	*Triquetrorhabdulus rugosus* Bramlette & Wilcoxon, n. sp. (17) side view, paratype, U.S.N.M. 650 698, (18) plan view, holotype, U.S N.M. 650 699. Both specimens from TR 16	128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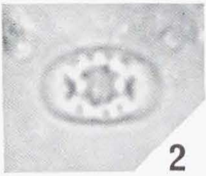
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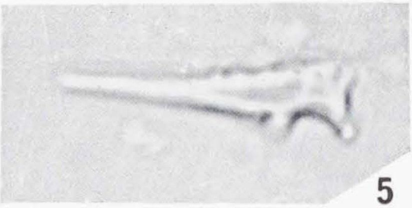
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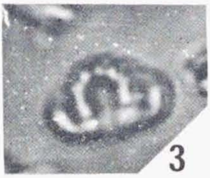
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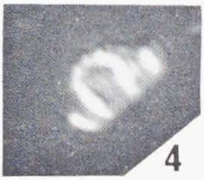
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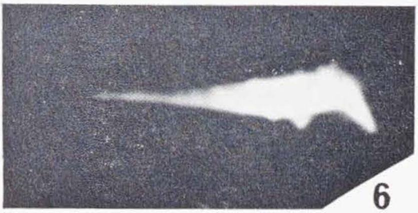
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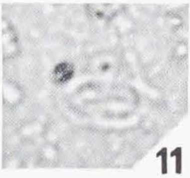
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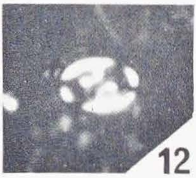
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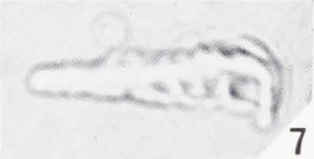
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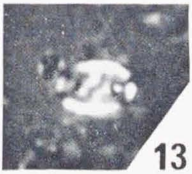
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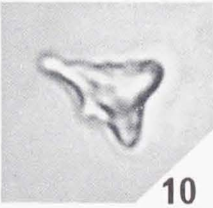
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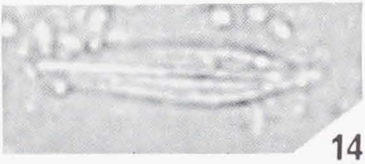
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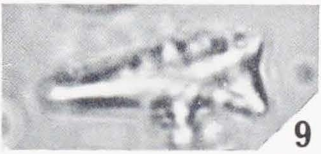
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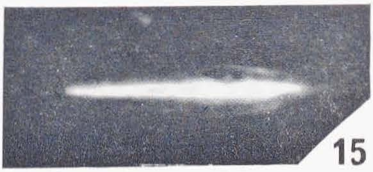
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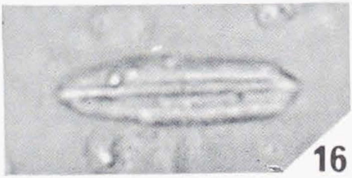
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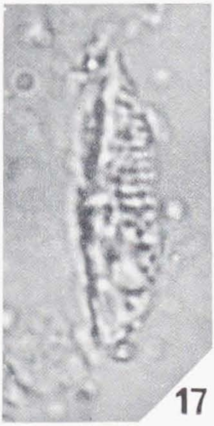
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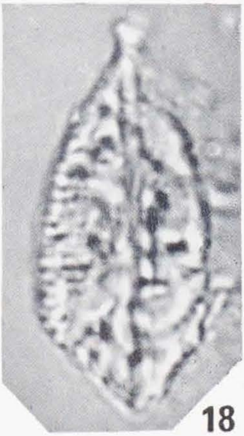
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PLATE 9

broad apical spine is formed of two or more coalesced calcite units of slightly different orientation and shows strong relief along the median line. The slightly depressed base is composed of about eight spines with numerous lateral spines above it.

Remarks: This species differs from *S. radians* Deflandre in having more widely extending spines; in possessing a broader, flaring, commonly serrated stem and slightly bifurcated tip.

Distribution: Rare in the *Globigerina ampliapertura* Zone of the Cipero section. Observed in Guam, Barbados, and several central Pacific and Joides cores of early Oligocene age, and in the upper Eocene Densinyama Formation of Saipan.

Genus TRIQUETRORHABDULUS
Martini, 1965

A three edged rod with the keels about 120° apart, and with pointed or subrounded ends. The original description is emended here to indicate that the ortholithid form has the optic axis of the calcite parallel to the long axis of the rod and not at right angles to the rod as stated by Martini.

Type Species: *Triquetrorhabdulus carinatus.*

TRIQUETRORHABDULUS CARINATUS
Martini
Pl. 9, figs. 14-16

Triquetrorhabdulus carinatus MARTINI, 1965, Proc. XVII, Symposium of Colston Res. Soc., v. 17, p. 408, pl. 36, figs. 1-3.

Remarks: A paratype (fig. 3 of Martini) was from part of our sample TTOC 206262, and specimens like his less tapered holotype are also present in this Trinidad sample. Obvious and easily identified between crossed nicols when oriented at 45° to a polarization plane where it shows maximum birefringence. The optic axis of calcite is parallel to rather than at right angles to the long axis in the type species, requiring our above emendation of the genus.

Distribution: Common in the *Globigerina ciperoensis ciperoensis* and *Globorotalia kugleri* Zones and rare in the *Catapsydrax dissimilis* Zone of the Cipero section, and in approximate age equivalents of some Pacific deep-sea cores (including one of those studied by Martini), in Tertiary e 4-5 of Indonesia, and rare in the Saucesian Stage of California.

TRIQUETRORHABDULUS RUGOSUS
Bramlette & Wilcoxon, n. sp.
Pl. 9, figs. 17-18

Description: Peculiar, elongate, ortholithid form assigned here, although quite different from the type of the genus. The two more extended edges, nearly in the same plane, are rather thick and rugose. The median ridge is low but sharp and not visible in side view (fig. 17) because it apparently lies in a median depression. One end is normally more pointed than the other. Most specimens are about one third as broad as long. Length 15-20 μ.

Remarks: Less calcified specimens show distinct lateral ridges conspicuous in side view (fig. 18). Although the distinctive appearance makes identification easy, the precise form is difficult to determine. The C-axis of the calcite is in a position that

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PLATE 10

(All specimens x2700)

Figures		Page
1–2, 4	*Scyphosphaera apsteinii* Lohmann. (1) side view, (2) crossed nicols, (4) side view, different specimen. Both specimens from TR 16	107
3	*Scyphosphaera intermedia* Deflandre. Side view. From TTOC 193786	107
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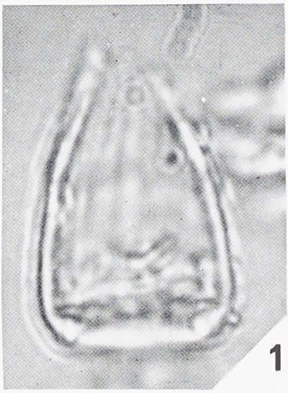
8–9	*Scyphosphaera lagena* Kamptner. (8) side view, (9) crossed nicols. From TTOC 193786	107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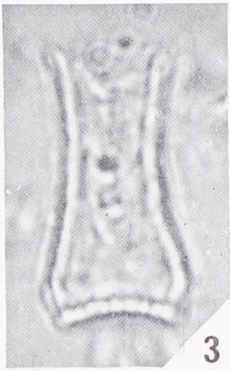
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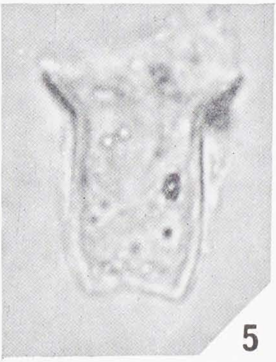
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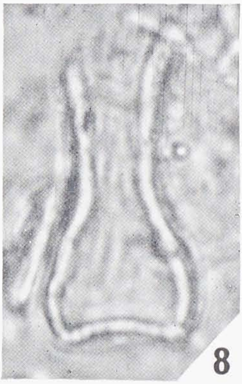
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PLATE 10

results in high relief and low birefringence in most orientations.

Distribution: Few to rare in the *Globorotalia fohsi lobata* up through the *Globorotalia menardii* Zone of the Cipero section, and as yet unknown elsewhere.

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REVIEWS

THE FOSSIL EVIDENCE FOR HUMAN EVOLUTION; GEOLOGY OF THE HIMALAYAS; GEOLOGY OF GRANITE; CARBONATITES

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The Fossil Evidence for Human Evolution, by W. E. LeGros Clark. Second Edition, published by the University of Chicago Press, Chicago and London, 1964, xii + 201 pp., 26 figs., $6.00

In this new edition of the standard work on hominid paleontology and evolution, the author includes all relevant new information which has been discovered since the book first appeared (1955). Of particular interest are the critical commentaries on L. S. B. Leakey's recent discoveries in Olduvai Gorge in Tanganyika. It is shown that not only are generic distinctions such as "*Zinjanthropus*" doubtful, but that most of the australopithecine specimens (if not all) are conspecific with Dart's original species, *Australopithecus africanus*, established in 1925 for the Taung skull.

The book is scholarly, definitive, and among paleoanthropologists the accepted guide for the taxonomy of fossil hominids. Professor Le Gros Clark (professor emeritus, anatomy, Oxford University) reviews the important discoveries of fossil man, evaluates the available evidence, and examines the conclusions that have been drawn from that evidence in demonstrating evolution within the Hominidae. He is clear, concise, and skilled in defining basic concepts as he introduces and employs them. The familiar species, *Pithecanthropus erectus* ("Java Man"), in accord with recent studies is revised and shifted to the genus *Homo*.

This volume is an important, up-to-date contribution to human paleontology and should be a part of the library of any geologist or anthropologist who is concerned with the evolution of Man.

Geology of the Himalayas, by Augusto Gansser. Published by Interscience Publishers (John Wiley & Sons Ltd), London, New York and Sydney, 1964, xvi + 289 pp., 149 figs., 95 photo plates, 4 large folding plates including tectonic and geologic maps and profiles in color, $35.00

This volume is a part of the Interscience *Regional Geology Series*, designed to present surveys of large structural units, independent of national boundaries. The *Geology of the Himalayas* provides a comprehensive view of the greatly scattered literature on this fas-