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Oligocene Calcareous Nannoplankton Biostratigraphy

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ABSTRACT

The calcareous nannoplankton in ten Oligocene sections on both sides of the Atlantic is studied. Seven nannoplankton zones and ten biostratigraphic datum levels are used to correlate the sections. Correlations of nannoplankton zones and planktonic foraminiferal zones of various authors and the biostratigraphic extent of the classical European and U.S. Gulf coast stages are presented. Three new genera (*Cepekiella*, *Discoturbella*, *Holodiscolithus*) and the following 29 new species are described: *Coccolithus crater*, *C. primalis*, *C. tritus*, *Ericsonia bireticulata*, *E. pauciperforata*, *E. quadriperforata*, *Cruciplacolithus flavius*, *Cp. quader*, *Sollasites tardus*, *Reticulofenestra alabamensis*, *R. gabrielae*, *R. inclinata*, *R. minuta*, *R. pectinata*, *Cyclococcolithus arabellus*, *Cc. ciperoensis*, *Cc. lunulus*, *Cc. kingi*, *Ilselithina fusa*, *Blackites incompertus*, *Bramletteius variabilis*, *Ponosphaera alta*, *P. crucifera*, *P. rigida*, *Cepekiella elongata*, *Discoturbella moori*, *Zygosphaera brytika*, *Discoaster rufus*, *Sphenolithus tribulosus*.

ZUSAMMENFASSUNG

Die Korrelation oligozäner Ablagerungen war seit der Einführung dieses Begriffes durch BEYRICH (1854) stark umstritten. Auch die auf planktonische Foraminiferen basierte biostratigraphische Gliederung (z.B. in BOLLI, 1957, 1966 und BLOW, 1969) vermochte keine einheitliche Unterteilung dieses Zeitabschnittes zu bringen, z.T. wegen der Unvollständigkeit der untersuchten Profile. In dieser Arbeit wird gezeigt, dass es mit Hilfe von Nannoplankton möglich ist, das Oligozän zu gliedern und Korrelationen über grosse Distanzen auszuführen. Als Basis für die Zonierung des Unter- und Mitteloligozäns dienten gekernte Proben aus der JOIDES-Bohrung 5 vom Blake Plateau (westlicher Atlantik, vor der Küste von Florida). ROTH & HAY (in HAY & al., 1967) stellten von unten nach oben folgende Zonen auf: *Ericsonia subdisticha*, *Cyclococcolithus margaritae* und *Reticulofenera laevis*. In dem sehr schön aufgeschlossenen Profil der St. Stephens Quarry im Clark County, Alabama, wo der grösste Teil des Oligozäns in günstiger Fazies erhalten ist, konnten diese drei Zonen ebenfalls gefunden werden. In Proben vom Bath Cliff, Barbados, tritt eine Nannoflora auf, die für die beiden untersten oligozänen Nannoplankton-Zonen typisch ist. BRAMLETTE & WILCOXON (1967) publizierten kurz nach ROTH & HAY ebenfalls eine Zonierung des Oligozäns, die nur eine Zone (*Helicosphaera reticulata*) im Unter- und Mitteloligozän enthält, während im oberen Mitteloligozän und im Oberoligozän vier Zonen ausgeschieden wurden (siehe Fig. 1). Beim Studium von Proben aus Trinidad, wo nur das obere Mitteloligozän und das Oberoligozän bekannt sind, wurde festgestellt, dass die von BRAMLETTE & WILCOXON (1967) aufgestellten Oberoligozän-Zonen sehr geeignet sind. Deshalb wurden sie vom Autor formell definiert (siehe BAUMANN & ROTH, 1969). Auch konnten im Profil des Monte Cagnero (Marche) die Nannoplankton-Zonen mit den auf planktonischen Foraminiferen basierten Zonen korreliert werden (siehe Fig. 1). Das Oligozän kann in die folgenden Zonen unterteilt werden (von unten nach oben): *Ericsonia subdisticha*, *Cyclococcolithus margaritae*, *Reticulofenestra laevis*, *Sphenolithus predistentus–Sphenolithus distentus*, *Sphenolithus distentus–Sphenolithus ciperoensis*, *Sphenolithus ciperoensis–Triquetrorhabdulus carinatus* und *Triquetrorhabdulus carinatus–Sphenolithus belemnos*. Diese oberste Zone gehört bereits zum grössten Teil oder sogar ganz zum Miozän.

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Nachdem diese Zonengliederung feststand, wurden die Typusprofile der klassischen europäischen Oligozänstufen auf Nannoplankton untersucht. Dabei zeigte es sich, dass das Latdorfian der *Ericsonia subdisticha* Zone und dem untersten Teil der *Cyclococcolithus margaritae* Zone entspricht. Im deutschen Rupelton konnte die *Cyclococcolithus margaritae* Zone nachgewiesen werden. Die Boom Tone (Type-Rupelian) von Belgien liegen in der *Reticulofenestra laevis* und *Sphenolithus predistentus-Sphenolithus distentus* Zone. Ein Profil von nicht entkalktem Kasseler Meeressand (Profil Glimmerode), aus dem Typusgebiet des Chattian, enthält ebenfalls Nannofloren, die für dieselben zwei Zonen typisch sind. Somit ist zum mindesten ein grosser Teil des Chattian gleich alt wie das Rupelian. Das Vicksburgian der Golfküste (USA) umfasst die *Ericsonia subdisticha*, die *Cyclococcolithus margaritae* und die *Reticulofenestra laevis* Zone.

Zur allgemeineren, weltweiten Korrelation eignen sich charakteristische Datumsflächen. Diese verbinden Ereignisse erster Ordnung (z.B. erstes oder letztes Auftreten einer Art, Umkehr der Polarität des Magnetfeldes der Erde usw.). Im Idealfall sind es isochrone Flächen, doch ist besonders für paläontologische Ereignisse die Zeitgleichheit über weite Teile der Erde nicht immer gewährleistet, da wechselnde ökologische Bedingungen die gleichmässige Ausbreitung einer Art behindern können. Die wichtigsten Nannoplankton-Datumsflächen sind von unten nach oben: Letztes Auftreten von *Discoaster barbadiensis* (fällt mit der Eozän-Oligozän-Grenze zusammen); letztes Auftreten von *Cyclococcolithus formosus* (Grenze Unteroligozän-Mitteloligozän); erstes Auftreten von *Sphenolithus ciperoensis* (Grenze Mitteloligozän-Oberoligozän) und erstes Auftreten von *Sphenolithus belemnos* (nahe an der Oligozän-Miozän-Grenze).

In den Profilen wurden 122 Arten von Nannofossilien festgestellt. Es wurden drei neue Gattungen eingeführt, 29 Arten als neu beschrieben, 25 Arten neuen Gattungen zugeteilt und 22 schon bekannte Arten wurden kritisch diskutiert, da die Auffassungen der verschiedenen Autoren stark divergieren. Die verbleibenden 49 Arten werden lediglich in einer Liste aufgeführt, mit Hinweisen auf die Originalbeschreibung und andere gute Beschreibungen und Illustrationen.

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1. INTRODUCTION

1.1. Purpose of study

The Oligocene nannoplankton has been less studied than that of any other interval of the Tertiary. Much argument has been going on about the planktonic foraminiferal zonations and the position of the boundaries of that interval. It was hoped that a careful study of the calcareous nannoplankton might result in a more satisfactory subdivision of the Oligocene and allow worldwide correlation.

The following program was made before the present study was started:

1. Electron and light microscope study of the calcareous nannofossils from the below listed sequences. Summation of the data accumulated provides a relatively complete record of the Oligocene interval.

A. JOIDES Hole 5 from the Blake Plateau as base.
B. JOIDES Hole 6 and Hole 3.
C. Trinidad, type localities of the zones of BOLLI (1957).
D. Barbados, Lower Oligocene which is absent from Trinidad.
E. Gulf coast; a complete section through the Oligocene as a check for the established zonation.

Type Oligocene area in Europe:

F. Latdorfian of pit Treue IV near Helmstedt.
G. Rupelton of Germany (brick yard Alversdorf, near Helmstedt).
H. Boom clay of Belgium, type locality for the Rupelian, near Boom.
I. Chattian section from Glimmerode near Kassel.
K. Monte Cagnero section as a Mediterranean Oligocene section which is continuous and contains abundant planktonic foraminifera.

2. Correlation of nannofossils and planktonic foraminiferal zones for this interval.

3. Establishing the position of the European and U.S. Gulf Coast stages in the new zonal scheme as far as possible.

1.2. History of European and American stages and limits of the Oligocene

BEYRICH (1854) introduced the term Oligocene for sediments which he thought to be younger than the Eocene and older than the Miocene of LYELL (1833) and which are the result of a great marine transgression in Northern Europe. The following stages were mainly defined in the 19th century in Northern Germany, in Belgium, in the Paris Basin, and in the U.S. Gulf Coast Province.

Tongrian (DUMONT, 1839) for the sables de Grimmertingen, sables de Neereppen and sables de Vieux Joncs (Belgium). Fully marine.

Rupelian (DUMONT, 1849) for the sables de Berg and the argile de Boom (Belgium). Fully marine.

Stampian (D'ORBIGNY, 1852) for the beds from the argile vert de Romainville to the calcaire d'Etampes (Paris Basin). Marine, brackish to limnish.

Sannoisian (MUNIER CHALMAS & DE LAPPARENT, 1893) for the marnes supragypseuses and the calcaire de Sannois (Paris Basin). Brackish to limnish.

Latdorfian (MAYER-EYMAR, 1893) (also sp. Lattorfian) for the beds at Latdorf, Northern Germany. Molluscs described by KOENEN. 1889–94. Fully marine.

Chattian (FUCHS, 1894) for the sands of Kassel at the Gelbe Berg near Niederkaufungen. Fully marine.

Eochattian (HUBACH, 1922, published 1957) for the lower Doberg Schichten, Doberg near Bünde. Based on pectinids. Fully marine.

Neochattian (HUBACH, 1922, published 1957) for the upper Doberg Schichten, Doberg near Bünde. Based on pectinids. Fully marine.

Vichsburgian (MURRAY, 1952) for beds of the age of the type Vicksburg Formation.

Chickasawhayan (MURRAY, 1961) for sediments of the age of the Chickasawhayan Formation as originally defined by the *Shreveport Geological Society* (1934) including the Chickasawhay Limestone and the Paynes Hammock Sands.

The Aquitanian (MAYER-EYMAR, in GRESSLY & MAYER, 1853) was first placed in the Miocene, afterwards transferred to the Oligocene by MAYER-EYMAR (1958) but is now considered to belong to the Miocene by the majority of the invertebrate paleontologists.

Most of the stages mentioned above were conceived as cycles in the sedimentary history, i.e. as the result of transgressions and regressions. Many local basins developed and the sea intermittently inundated various parts of northern Europe. The result was a complex pattern of mostly shallow water deposits. Correlation between the different basins was attempted by means of molluscs and other macrofossils. This difficult task was hampered by great variations in facies, the lack of long sections especially across the boundaries, and by national traditions. There has not been much agreement on the use of the stages; some geologists prefer to use the set Latdorfian, Rupelian, Chattian, others chose Sannoisian and Stampian. In the U.S.A. the Vicksburgian stage (and the Chickasawhayan which is used only rarely) are applied only in the Gulf coast area. In California a set of local stages were established and are still used. The arguments on the position of the stage boundaries and on the correlation of the stages only ceased for a few decades at the beginning of this century.

1.3. Planktonic foraminifera in biostratigraphy

In the middle of this century, the usefulness of planktonic microfossils for biostratigraphy was realized. BRAMLETTE & RIEDEL (1954) and DEFLANDRE & FERT (1954) emphasized the stratigraphic value of calcareous nannofossils. BOLLI (1957) published a subdivision of the Cretaceous to Miocene of Trinidad based on planktonic foraminifera which later proved to be applicable in many parts of the world. BLOW & BANNER (in EAMES & al., 1962) added some zones in the uppermost Eocene and lower Oligocene (see fig. 1) based on samples from Tanzania. EAMES & al. (1962) also lowered the Oligocene-Miocene boundary from the top of the *Globorotalia kugleri* Zone as given by BOLLI (1957) to the base of the *Globigerina ampliatura* Zone (where BOLLI (1957) drew the Eocene-Oligocene boundary). They also indicated that Oligocene deposits were absent from the Caribbean-Gulf Coast area except for some deposits in the Dominican Republic and in Mexico. These statements caused strong reactions and

BOLLI 1957, 1966	BLOW 1969	BAUMANN & ROTH, 1969	ROTH & HAY 1967	BRAMLETTE & WILCOXON 1967	ROTH this paper
Globorotalia kugleri	N.4 Gr. kugleri-Gs. quadrilobatus primordius	Globorotalia kugleri		Triquetrorhabdulus carinatus	Triquetrorhabdulus carinatus Sphenolithus belemnos
Gg. ciperoensis ciperoensis	N.3 Globigerina angulisuturalis	Gg. cipero. ciperoensis		Sphenolithus ciperoensis	Sphenolithus ciperoensis-Triquetrorhabdulus carinatus
Globorotalia opima opima	N.2 Gg. angulisuturalis/ Gr. opima opima	Globorotalia opima opima		Sphenolithus distentus	Sphenolithus distentus-Sphenolithus ciperoensis
Globigerina ampliapertura	P.20/N.1 Gg. sellii/ Pseudohast. barbadoensis	Globigerina euapertura		Sphenolithus predistentus	Sphenolithus predistentus-Sphenolithus distentus
		Globigerina angiporoides angiporoides	Reticulofenestra laevis	Helicosphaera reticulata	Reticulofenestra laevis
Cassigerinella Chipolensis/ Hastigerina micra	P.19 Gg. sellii /Pseudohast. barbadoensis	Gg. sellii	Syracosphaera clathrata		Cyclococcolithus margaritae
	P.18 Gg. tapuraensis	Globigerina gortanii gortanii	Cyclococcolithus margaritae		
	P.17 Gg. gort. gortanii		Ericsonia subdisticha		Ericsonia subdisticha
Globorotalia cerroazulensis	P.16 Cribrohantkenina inflata	Globorotalia cerroazulensis	Isthmolithus recurvus	Isthmolithus recurvus	Isthmolithus recurvus

Fig. 1. Correlation of Upper Eocene-Lower Miocene planktonic foraminiferal and nannoplankton zones.

stimulated further research on this problem and on Oligocene deposits and fossils in many parts of the world. SAITO & BÉ (1964) described planktonic foraminiferal assemblages from the U.S. Gulf Coast which could be compared to the Oligocene faunas from Tanzania and are certainly of Oligocene age. SAUNDERS & CORDEY (presented as paper at the Caribbean Conference, 1965, published 1969) found lower Oligocene planktonic foraminifera in the Bath Cliff section on the island of Barbados, W. I. BOLLI (1966) summarized the state of planktonic foraminiferal zonation and introduced the *Cassigerinella chipolensis- Hastingerina micra* Zone for the interval of BLOW & BANNER'S *Globigerina "oligocaenica"* (= *G. sellii*) Zone. Up to now it has still not been possible to reach full agreement on the zonal scheme to be used for the Eocene to Oligocene nor on the definition of the upper and the lower boundaries of the Oligocene.

1.4. Biology, ecology and biostratigraphic applications of calcareous nannoplankton

Calcareous nannoplankton is a general term for coccoliths and related calcareous elements (discoasters, sphenoliths etc.). Coccoliths are produced by microscopic flagellate algae, generally referred to as coccolithophores, which live mainly in the euphotic zone of the sea. Only one genus with very simple coccoliths occurs in fresh water. The life history of the few well studied species (see PARKE & ADAMS, 1961; BRAARUD, 1963) indicates that skeletal plates of entirely different shapes are produced during the various phases of life history. Isolated elements of the same organism formed at different stages of their life history are sometimes assigned to different species or even genera, e.g. *Crystallolithus hyalineus* GAARDER & MARKALI is the motile phase of the non-motile *Coccolithus pelagicus* (WALLICH) SCHILLER as demonstrated by PARKE & ADAMS (1961). Coccolithosphores reproduce mainly asexually, so that a mutant species might reproduce in great numbers before an exchange of genetic material with non-mutant relatives occurs. This explains the sudden appearance of certain species which do not seem to have evolved gradually from known ancestors. It is also one of the reasons for the rapid rate of evolution in many groups of nannofossils. Sudden changes in the nannofossil assemblages are observed more often than gradual ones. Thus, a great number of distinct markers are available in most parts of the Tertiary to Recent. Calcareous nannoplankton occurs in great numbers in many sediments (10^{10} specimens per cc. in many deep sea oozes). Even sediments from shallow water often contain enough nannofossils for study. The influence of the environment on the nannoplankton is difficult to evaluate for fossil assemblages. More discoasters were found in Oligocene open marine sediments from the tropical, subtropical and Mediterranean region than in Oligocene shallow water deposits of Belgium and Northern Germany, but it is difficult to determine to what extent the influence of temperature or the local environment was decisive for such differences. In general, shallow water deposits are richer in *Braarudosphaeraceae*, coccolithophorids producing pentagonal plates (see MARTINI, 1965). In the oceans of the present time most species have a distinct temperature range, e.g. *Coccolithus pelagicus* is restricted to cooler water, *Umbilicosphaera mirabilis* to subtropical to tropical temperatures (see MCINTYRE & BÉ, 1967). Tertiary relatives of *Coccolithus pelagicus* now referred to as *Ericsonia muiri* (BLACK) seem to be more abundant in sediments from tropical regions than from boreal regions. EDWARDS (1968) derived a Tertiary temperature curve for New Zealand from the abundance of certain nannoplankton genera which are related to modern genera with known temperature ranges.

There are some disadvantages to the study of nannoplankton and its application in stratigraphy. The small size of these fossils makes high quality optical, often electron optical equipment indispensable for their study. Calcareous nannofossils are easily reworked into younger deposits and are usually not damaged during erosion and transportation. Rupelian sediments from Northern Germany, for instance, contain Cretaceous coccoliths in a most beautiful state of preservation; not even in the electron microscope can any damage be detected.

Many species of nannofossils have a worldwide distribution. Only a few show considerable differences in ranges, such as members of the genus *Chiasmolithus* which occur abundantly in the Oligocene of New Zealand (Edwards, personal communication) but are absent to very rare in the American and European Oligocene studied so far. Only in the Oligocene from the central Apennines (see fig. 12) *Chiasmolithus* is relatively more abundant; the absence of other Eocene species excludes reworking as a possible explanation of this fact.

Calcareous nannoplankton is very useful for establishing detailed worldwide zonations and biostratigraphic datum levels. This has already been amply demonstrated by Martini (1958, 1959), Stradner (1958, 1959), Brönnimann & Stradner (1960), Bramlette & Sullivan (1961), Hay (1964) and other authors. In 1967, Hay, Mohler, Roth, Schmidt & Boudreaux summarized the state of nannoplankton zonation, formally defined some zones which had been suggested by others and introduced a number of new ones. Roth & Hay (in Hay & al., 1967) introduced four Oligocene nannoplankton zones which were the result of a careful study of 8 samples from the Oligocene interval of Blake Plateau JOIDES Hole 5 done by the author while at the Institute of Marine Sciences of the University of Miami. Of these four zones (see fig. 1) the *Syracosphaera clathrata* Zone was dropped later because a more extended range of the species was observed in other sections (Roth & al., 1968, Roth 1969a). During the study of upper Oligocene samples from Trinidad it was realized that the three zones (*E. subdisticha*, *Cc. margaritae*, *R. laevis* Zones) only covered the lower and middle Oligocene. It was not attempted by Hay & Roth (in Hay & al. 1967) to define upper Oligocene zones as no sufficiently continuous sections of this interval were known. Bramlette & Wilcoxon (1967) suggested one zone for the lower and middle Oligocene (*Helicosphaera reticulata* Zone) and four zones for the middle and upper Oligocene of Trinidad and some JOIDES Blake plateau cores (Holes 3 and 4). These zones were found to be useful and were redefined and emended by the author in Baumann & Roth (1969). They are mainly based on the evolution of sphenoliths and on some other very easily recognizable species like *Triquetrorhabdulus carinatus* and *Helicopontosphaera ampliaperta*. A total of seven zones could thus be established for the Oligocene and the lowermost Miocene. Only two intervals can be distinguished with the light microscope in the lower and middle Oligocene, a lower one with *Cyclococcolithus formosus* and an upper one without it (see p. 35). The uppermost middle Oligocene (*Sphenolithus predistentus*-*Sphenolithus distentus* Zone) and the upper Oligocene can be subdivided into zones using only light microscopy.

The Oligocene nannoflora includes a great number of species which range from the Eocene into the lower and middle Oligocene where they disappear, e.g. *Cyclococcolithus formosus*, *Isthmolithus recurvus*, *Lanternithus minutus*, *Reticulofenestra umbilica*, and *Discoaster tani nodifer*. The scarcity of discoaters in the lower half of the Oligocene is very characteristic. Only small species of the genera *Cyclococcolithus*, *Coccolithus* and *Reticulfenestra* make their first occurence in the lower to middle Oligocene. The genus *Reticulfenestra* is flourishing and produces many different species in the lower and middle Oligocene; only a few of them range into the upper Oligocene. A rapid evolution of the sphenoliths from *Sphenolithus predistentus* to *Sphenolithus distentus* and to *Sphenolithus ciperoensis* begins in the uppermost middle Oligocene. The basal cycle of elements in *Sphenolithus predistentus* grows and the bifurcating limbs of the stem become stronger and thus result in *Sphenolithus distentus* (see p. 870, pl. XIII, figs. 3, 7).

These two processes continue resulting in *Sphenolithus ciperoensis* with an even larger basal cycle which extends far over the base of the stem and with a very short connection between the base and the bifurcation point in bifurcating specimens. All the above mentioned species of sphenoliths produce non-bifurcating specimens which only show the enlargement of the basal disc in the course of evolution. The origin of *Sphenolithus belemnos* is less clear; it probably arose from *Sphenolithus ciperoensis* by addition of small apical spine elements to the single spine present in the first mentioned species. In the uppermost part of the middle Oligocene the *Discoaster deflandrei* group started to evolve more rapidly, giving rise to *Discoaster saundersi* and *D. lidzi* in the upper Oligocene and to *D. nephados*, *D. trinidadensis*, *D. aulakos* and *D. divaricatus* in the lower Miocene. *Triquetrorhabdulus carinatus* first appears closely below the Oligocene-Miocene boundary and continues into the Miocene where it evolved into other blade shaped species like the lower Miocene *Rhabdothorax serratus* (BRAMLETTE & WILCOXON) n.comb. [= *Orthorhabus serratus* BRAMLETTE & WILCOXON, 1967, pp. 114–115, pl. 9, figs. 5–10, = *Triquetrorhabdulus martinii* GARTNER 1967, p. 6, pl. 10, fig. 1] and the middle Miocene *Triquetrorhabdulus rugosus* BRAMLETTE & WILCOXON [= *Ceratolithus? farnsworthii* GARTNER, 1967, pp. 5–6, pl. 9, figs. 1–4].

1.5. Modern attempts to subdivide and correlate the American and European stages

1.5.1. U.S. Gulf Coast stages

After the sequence of seven nannoplankton zones was established in cores from the Blake Plateau, in Trinidad, and on Barbados, the nannoplankton from the Vicksburgian of Alabama was studied. CHEETHAM (1957, 1963), working on cheilostomate bryozoans from the Upper Eocene-Lower Oligocene of the Gulf Coast area introduced two zones, the *Floridana antiqua* Zone (for the Cocoa Sand Member and the Pachuta Marl Member of the Yazoo Clay, Jackson Group, upper Eocene) and the *Spondylus dumosus* Zone (Shubuta member of the Yazoo Clay and Red Bluff Clay). The latter shows more affinities to the Vicksburgian than to the Jacksonian and was thought to be intermediate between the two. Thus, he drew the Eocene-Oligocene boundary at the base of the Shubuta Clay which has been placed in the Upper Eocene by most authors (see MURRAY, 1961). DEBOO (1965, 1966, 1967) studied the microfauna (benthonic and planktonic foraminifera, ostracods) of many sections in Alabama and Mississippi and subdivided the *Spondylus dumosus* Zone into a lower *Cribrohantkenina inflata* Subzone (Shubuta), and an upper "*Cythereis*" *blanpiedi* Subzone (Red Bluff). He drew the Jacksonian-Vicksburgian boundary at the base of the *Spondylus dumosus* Zone, i.e. at the base of the Shubuta Clay, and the Eocene-Oligocene boundary at the base of the Red Bluff Clay. As mentioned above SAITO & BÉ (1964) compared the planktonic foraminifera from the Vicksburgian with those from the *Globigerina sellii* Zone in Tanzania. LEVIN & JOERGER (1967) distinguished three biostratigraphic units based on nannoplankton in the upper Eocene-Oligocene of Alabama: Unit I (Cocoa through Shubuta) with *Discoaster barbadiensis*, *D. saipanensis* and *Pemma papillatum*, unit II (Red Bluff Clay) with *Isthmolithus recurvus* and *Micrantholithus basquensis*, and Unit III (Mint Springs and Marianna). Their Unit I contains species which are considered to indicate an Upper Eocene age in many parts of the world (e.g. present in the Priabonian, see PROTO-DECIMA, 1969). ROTH (1969a) found three Oligocene

FORMATION	MEMBER	ZONES: Cheetham 1957	Deboo 1965	Blow 1969	Levin & Joerger 1967	Roth this paper
Chickasawhay	Chickasawhay Limestone			N.2-N.3		Sphenolithus distentus-Sphenolithus ciperoensis
Byram	Bucatunna Clay					
						Reticulofenestra laevis
	Glendon Limestone					
Marianna	Marianna Limestone		Lepidocyclina mantelli	P.19	unit III	Cyclococcolithus margaritae
Red Bluff	Red Bluff Clay	Spondylus	"Cythereis blanpiedi"	P.18	unit II	Ericsonia subdisticha
Yazoo	Shubuta	dumosus	Ch. inflata	P.17		Isthmolithus recurvus
	Pachuta	Floridana antiqua		P.16	unit I	
	Coccoa Sd.					

Fig. 2. Rock stratigraphic and biostratigraphic units in the U.S. Gulf coast area.

nannoplankton zones in Alabama (see p. 826). BLOW (1969) places the Red Bluff Clay and the lower Marianna Limestone in his Zone P. 18, the upper part of the Marianna in his Zone P. 19 and the Chickasawhay limestone in his Zone N. 3.

1.5.2. California stages

It has not been possible so far to establish the Oligocene nannoplankton zones here described in California. LIPPS (1967, 1968) indicates the presence of *Cyclococcolithus margaritae* in the Zemorrian stage, together with *Discoaster adamanteus*, *Reticulofenestra* (= *Apertapetra* of LIPPS) which might indicate a Middle Oligocene age. *Triquetrorhabdulus carinatus* and *Sphenolithus belemnos* occur in beds from the Saucesian and indicate a late Oligocene to early Miocene age for that stage. Samples from the Upper Eocene-Lower Oligocene from the Santa Cruz Mountains studied by the author proved to be too poor for detailed zonation.

1.5.3. European stages

Because the seven Oligocene nannoplankton zones could be found in many tropical and subtropical areas in the Caribbean and Gulf Coast Provinces (see ROTH, 1969a) it was attempted to distinguish these zones in the more northern type sections or type areas of the European Oligocene stages. The aim was to express the biostratigraphic extent of these stages in terms of nannofossil zones and to determine the boundaries of the Oligocene. Other fossils have been used to subdivide the Oligocene and to correlate deposits assigned to different stages which are in part age-equivalent.

The foraminiferal genus *Miogypsina* was employed by DROOGER (1960) for the correlation of beds of Chattian, Aquitanian and Vicksburgian age (ACKERS & DROOGER, 1957). *Lepidocyclina*, *Nummulites* and other larger foraminifera served as markers in the Near and Far East (see EAMES & al., 1962, VAN DER VLERK, 1955, and ADAMS, 1967) but they are rare or absent in the European type sections of the Oligocene. The nummulites from the Lower Oligocene of North Germany are small and have few characteristic features. They are assigned to different species by different authors (*Nummulites germanicus*, *N. orbigny*, *N. concinnus*, *N. prestwichianus* u.o.) or considered as ecologically influenced variants (see PAPP, in ANDERSON & al., 1969). Therefore they are not suitable for correlation of small units over long distances. Molluscs have been mainly used to define the stages and correlate the beds belonging to them. They proved to be of limited value for correlation over long distances because they were too dependent on the local environment at the time of deposition (facies fossils). The subdivision of the Chattian based on pectinids established by HUBACH (1927, 1957), GÖRGES (1941, 1951) and ANDERSON (1958, 1961, 1962) could not be followed outside Northern Germany and the lower Rhine valley. Smaller benthonic foraminifera are useful markers in local basins as demonstrated e.g. by SPIEGLER (1965) for the German Rupelton. This zonal scheme of the German Rupelton however cannot even be used with reliability for the Rupelian of Belgium. GROSSHEIDE & TRUNKO (1965) could not subdivide the thick Chattian sections at Doberg and Astrup using benthonic foraminifera where six local biostratigraphic units could be established with pectinids (HUBACH, 1922, 1957). STAESCHE & HILTERMANN (1940) introduced a system of "micropaleontological stages" for the Tertiary of Northern Germany which are based on microfossil assemblages and which are still in use for stratigraphic (surface and subsurface) work. Outside the North German basin it has not been possible to correlate these "micropaleontological stages" with other units (zones, stages). Ostracods are very useful in shallow water Oligocene deposits for correlation within one basin (see MOOS, 1963, 1965, 1966, 1968) or for correlation of brackish deposits (see GRAMANN 1968) but proved to be of little value for long distance correlation. Most of the Oligocene vertebrate remains come from continental sequences that can not yet be correlated in a satisfactory manner with the marine European Oligocene deposits.

After publication of the Oligocene zonation by ROTH & HAY (in HAY & al., 1967) the author studied two samples from well Hantkensbüttel Süd 32 in Northern Germany received from E. Martini. *Ericsonia subdisticha* (Roth & Hay) was found for the first time in Europe in the sample Hantkensbüttel Süd 32, 267–276 m below surface from the Latdorfian clay. Since *Discoaster barbadiensis* and *Discoaster saipanensis* are absent, it was assigned to the *Ericsonia subdisticha* Zone. In a higher sample from the Neuengammer Gassand (Hankensbüttel Süd 32, 258–267 m below surface) a poor assemblage was found with *Cyclococcolithus bollii* which is typical for the uppermost *Ericsonia subdisticha* Zone and the *Cyclococcolithus margaritae* Zone of other regions (see ROTH, 1969b). These results stimulated further research on nannoplankton in Northern Germany. MARTINI & RITZKOWSKI (1968) studied the nannofossils from molluscan fillings from the Koenen Collection. They could prove that molluscs from the type Latdorfian contain nannoplankton belonging to the *Ericsonia subdisticha* Zone and thus corroborating the early Oligocene age of the *Ericsonia subdisticha* Zone assumed by ROTH & HAY based on planktonic foraminifera. The nannoplankton assemblages found in some other molluscs which were thought to be of lower Oligocene age by KOENEN (1889–1894) belong to the middle Eocene *Chiphragmalithus alatus* Zone (= *Chiphragmalithus quadratus* Zone of HAY & al., 1967) and to the upper Eocene *Discoaster tani nodifer* Zone (see MARTINI & RITZKOWSKI, 1968). KOENEN carefully separated the different localities and made it possible to distinguish the lower Oligocene localities from the Eocene localities which originally were all described as lower Oligocene. On the other hand, percentages of Lower Oligocene molluscs surviving from the Eocene or ranging into the Rupelian are only conclusive if the Eocene and Lower Oligocene localities all mentioned in KOENEN as lower Oligocene are separated. KRUTSCH & LOTSCH (1957) postulated that the Latdorfian beds are of Late Eocene age. They reached their conclusion because it is possible to correlate the near-shore Latdorfian beds with deeper water sediments assigned to the uppermost Upper Eocene (or Eocene 5) "micropaleontological stage" of STAESCHE & HILTERMANN (1943) using microfossils and electrologs. These conclusions are refuted because the Latdorf beds are Lower Oligocene by definition. MAYER-EYMAR defined the Latdorfian as lowermost Oligocene stage; BEYRICH (1856) mentioned the "Lager von Engeln" as Lower Oligocene which can be correlated with the type Latdorfian and the Silberberg Formation in pit Treue IV, see p. 818). Good Latdorfian sections occur near Helmstedt and the nannoplankton studied by MARTINI & RITZKOWSKI (1968), ROTH (in BAUMANN & ROTH, 1969) and MARTINI (1969) is identical with nannoflora from the type localities of the *Ericsonia subdisticha* and the lowermost *Cyclococcolithus margaritae* Zones (see fig. 13) from the Blake Plateau, W. Atlantic. The "Obere Schönewalder Schichten" of Brandenburg which contain small nummulites considered to indicate an Eocene age by JARZEVA, LOTSCH & NEMKOV (1968) furnished a nannoplankton assemblage which is indicative for the *Ericsonia subdisticha* Zone (see range charts in LOCKER, 1968, MARTINI, 1969). The Upper Eocene *Isthmolithus recurvus* Zone is missing in Brandenburg. The sands of Grimmertingen, type formation of the lower Tongrian, belong to the *Ericsonia subdisticha* Zone (MARTINI & MOORKENS, 1969) and the Tongrian can thus be correlated at least in part with the Latdorfian.

BRAMLETTE & WILCOXON (1967) place the Rupelian in their *Sphenolithus predistentus* Zone and *Sphenolithus distentus* Zone (see p. 837). The very thick and famous Chattian sections at Doberg and Astrup (see ANDERSON & al., 1969) are devoid of calcareous nannoplankton. It is thus impossible to draw any conclusion on the age of the Neochattian based on nannoplankton. The type Chattian is according to HUBACH (1922) of the same age as the middle part of the Eochattian. The Chattian section from Glimmerode is probably assignable to the Eochattian but further research is in progress (see RITZKOWSKI, 1965). BERGGREN (1969) and BLOW (1969) studied planktonic foraminifera from the Rupelian and Chattian of Northern Germany and Belgium. The species they used for the assignment of the stages to planktonic foraminiferal zones (illustrated by BERGGREN, 1969) are all small and not very distinctive. The same is the case for the planktonic foraminifera illustrated and listed by KIESEL, LOTSCH & TRÜMPER (1969) from the Rupel of the German Democratic Republic. Still, BERGGREN (1969) and BLOW (1969) place the Rupelian in Zone P. 19 based on the concurrence of *Globigerina angiporoides* and *Globigerina ouachitaensis ciperoensis*. The Eochattian of

Astrup belongs to Zone P. 20/N. 1 according to BERGGREN (1969) who relies on transitional forms from *Globigerina opima nana* to *Globorotalia opima opima* and specimens intermediate between *Globigerina angustumbilicata* and *G. angulisuturalis*. According to BERGGREN (1969) it is not possible to assign the Neochattian to standard planktonic foraminiferal zones. BLOW (1969) places the Eochattian into his Zone P. 19 (later part), Zone P. 20/N. 1 and N. 2 (part?) and the Neochattian into his Zone N. 2 and N. 3, without giving any information on the planktonic foraminifera present nor the exact position of the samples studied.

In the framework of the present study zones and datum levels are preferred to stages as means of worldwide correlation because of the following reasons already pointed out by HORNIBROOK (in press):

1. There has not yet been much agreement on the definitions of the Tertiary stages in Europe and the U.S.A. For many stages good type sections are lacking. Some of the type beds have been deposited under ecologic conditions which exclude fossils that can be used for long distance correlation.

2. It has not been possible to find many criteria for adequate correlation of the Oligocene stages outside their type region. Many fossil groups are endemic or very influenced by facies. Planktonic organisms which are the best means of world wide correlation for the Tertiary known so far are practically absent.

3. There is nothing to be gained if European stages are established elsewhere if the fossil composition and facies are entirely different, especially as long as a set of well defined stages in Europe has not been agreed upon. Some of the stages are age-equivalent and for some others the exact age relationships are not yet known.

1.6. Main results of the present study

A total of seven nannoplankton zones are defined and correlated with the existing planktonic foraminiferal zones and stages (see figs. 1, 3).

The European and American stages are expressed in terms of nannoplankton zones as follows:

Latdorfian: *Ericsonia subdisticha* Zone to lowermost part of the *Cyclococcolithus margaritae* Zone.

Lower Tongrian: *Ericsonia subdisticha* Zone.

Rupelian: *Cc. margaritae* Zone to *Sphenolithus predistentus–Sphenolithus distentus* Zone.

Chattian: *Reticolufenestra laevis* Zone to *Sphenolithus predistentus–Sphenolithus distentus* Zone.

Vicksburgian (including Red Bluff): *Ericsonia subdistiacha* to *Reticulofenestra laevis* Zone.

Chickasawhayan: *Sphenolithus distentus–Sphenolithus ciperoensis* Zone.

In addition to the zones ten datum levels are introduced as first order correlation surfaces (not to subdivide zones). Some of these datum levels approximate important boundaries, some of them should be used to define these boundaries. These datum levels can be supplemented by others wherever it factilitates long-distance correlation.

AGE		ZONE	CRITERIA FOR DEFINIG THE ZONAL BOUNDARIES
			base Helicopontosphaera ampliaperta
MIOCENE	Early	Triquetrorhabdulus carinatus-Sphenolithus belemnos	
			base Sphenolithus belemnos
OLIGOCENE	Late	Sphenolithus ciperoensis Triquetrorhabdulus carnatus	
			base Triquetrorhabdulus carinatus
OLIGOCENE	Late	Sphenolithus distentus-Sphenolithus ciperoensis	
			base Sphenolithus ciperoensis
OLIGOCENE	Middle	Sphenolithus predistentus-Sphenolithus distentus	
			base Sphenolithus distentus
OLIGOCENE	Middle	Reticulofenestra laevis	
			base Reticulofenestra laevis
OLIGOCENE	Middle	Cyclococcolithus margaritae	
			base Cyclococcolithus margaritae
OLIGOCENE	Early	Ericsonia subdisticha	
			top Discoaster barbadiensis
EOCENE	Late	Isthmolithus recurvus	

Fig. 3. Age, zones and the criteria for defining the zonal boundaries of the Late Eocene-Early Miocene

The following major datum levels can be found worldwide:

- Highest occurrence of *Discoaster barbadiensis* (Eocene-Oligocene boundary).
- Highest occurrence of *Cyclococcolithus formosus* (Lower-Middle Oligocene boundary).
- First occurence of *Sphenolithus ciperoensis* (Middle-Upper Oligocene boundary).
- First occurrence of *Sphenolithus belemnos* (Oligocene-Miocene boundary).

1.7. Typification

In accordance with the standard practice for carbon replicas, the holotypes, paratypes and the hypotypes of the species described are electron microscope photographic negatives. All the type negatives are deposited at the Basle Natural History Museum and identified by the author's negative numbers and, in square brackets, by the Basle Museum type collection numbers. The Basle Museum is also the depository for the type negatives of the species described by ROTH & HAY (in HAY & al., 1967) and ROTH (1969a). Because the Basle Museum type collection numbers were not listed in those papers, a key with the author's negative numbers and the Basle Museum numbers follows below.

ROTH & HAY in HAY et al. (1967):

IMS-J501-164 = [A780]	IMS-J501-226 = [A790]	IMS-J504-127 = [A800]
IMS-J503-646 = [A781]	IMS-J503-622 = [A791]	IMS-J501-168 = [A801]
IMS-J503-706 = [A782]	IMS-J501-453 = [A792]	IMS-J507-091 = [A802]
IMS-J501-381 = [A783]	IMS-J505-277 = [A793]	IMS-J501-044 = [A803]
IMS-J501-311 = [A784]	IMS-J507-173 = [A794]	
IMS-J501-012 = [A785]	IMS-J503-696 = [A795]	ROTH (1969a):
IMS-J501-451 = [A786]	IMS-J507-184 = [A796]	A600 380 = [A804]
IMS-J501-449 = [A787]	IMS-J507-044 = [A797]	A800 307 = [A805]
IMS-J502-194 = [A788]	IMS-J507-245 = [A798]	A821 207 = [A806]
IMS-J501-320 = [A789]	IMS-J507-048 = [A799]	A827 119 = [A807]

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2. SECTIONS STUDIED

2.1. American sections

2.1.1. JOIDES Blake Plateau cores

In 1965 six cores were taken on the Florida continental shelf, on the Florida-Hatteras Slope, and on the Blake Plateau by the drilling vessel M. V. Caldrill while involved in the JOIDES Deep Earth Sampling Programme (BUNCE & al. 1965). The thickest Oligocene section was encountered in Hole 5 (30° 23' N, 80° 08' W) between 67.1 and 229.2 meters drilled in the Florida-Hatteras slope. It consists of whitish-grey calcilutites with a high content of silicious microfossils. Sediments of Upper Oligocene and Miocene age are missing and the Middle Oligocene beds are covered with Post-Miocene foraminiferal sands. In Hole 3 (28° 30' N, 77° 31 W) and Hole 6 (30° 05' N, 79° 15' W) which were drilled in the Blake Plateau, the Oligocene consists of white Coccolith-Globigerina oozes. Winnowing seems to have left only the larger nannofossils, so that it was not always possible to find the small Lower Oligocene markers. Only a few samples from these two sections were studied. The Upper Oligocene is well represented in Hole 3 but somewhat condensed.

Samples studied:

Hole 5:

Sample	Depth below sea floor	Sample	Depth below sea floor
J510	248′ 9″	J517	500′
J509	260′ 2″	J502	519′ 2″
J508	303′11″	J516	530
J507	337′11″	J501	554′10″
J506	374	J515	589′11″
J505	410′	J514	625′
J519	429′ 9″	J513	657′10″
J504	445′	J512	730′
J518	460′ 5½″	J511	800′
J503	484′		

Hole 6:

Sample	Depth below sea floor
J605	143′ 9″
J604	149′ 7″
J603	162′11″
J602	188′ 4″
J601	199′11″

Hole 3:

Sample	Depth below sea floor
J3-270	271 5″
J3-286	286′
J3-306	306′
J3-323	323′11″
J3-397	397′11″
J3-475	475′11″
J3-494	494′

2.1.2. Alabama

A very complete section through the U.S. Gulf Coast Oligocene was collected with Prof. W. W. Hay in the Lone Star Cement Company Quarry near St. Stephens, Clark County, Alabama, U.S.A. For a geological sketch map and stratigraphical section see LEVIN and JOERGER (1967) and JONES (1967); for more stratigraphical detail see MURRAY (1961). The entire section from the Upper Eocene to the Upper Oligocene is marine and most of it very fossiliferous. The Upper Eocene Yazoo Clay consists of blue-grey sandy and somewhat glauconitic marls. It contains *Cribrohantkenina inflata* (see DEBOO 1965), *Discoaster barbadiensis* and *Discoaster saipanensis* indicating an Upper Eocene age. The Red Bluff Clay is composed of 13.5 feet of interbedded greenish-grey limestones and olive to gray glauconitic marls. Eocene markers are absent except for occasional damaged specimens of Upper Eocene foraminifera. No trace of reworked Eocene nannoplakton could be found in any part of this section. Above the Red Bluff is 9 feet of brown carbonaceous sparingly fossiliferous sandy clays, the Forest Hill Sand. This is overlain by 59 feet of soft cream colored limestones containing *Lepidocyclina mantelli* (MORTON). The Byram Formation begins with 12 feet of Glendon Limestone, a white irregularly indurated skeletal limestone, practically devoid of nannofossils. On top of the Glendon Limestone lies an unnamed Clay Member consisting of 1 foot of olive, glauconic marl with nannofossils. The Bucatunna Clay Member which follows above is composed of 26 feet of grey to black gypsiferous clays, completely barren of nannofossils. The Oligocene part of the section ends with the Chickasawhay Limestone, an alternation of grey marls and marly limestones, 19 feet thick. Information on the Alabama Tertiary can be found in the guidebooks edited by COPELAND (1966) and by JONES (1967).

Samples studied:

Rock unit	Sample number	Stratigraphical distance from base of rock unit
Chickasawhay	A 128	8′
Limestone	A 124	4′
Unnamed Clay Member	A 100	0
Marianna	A 853	53′
Limestone	A 848	48′
	A 843	43′
	A 839	39′
	A 833	33′
	A 827	27′
	A 821	21′
	A 815	15′
	A 809	9′
	A 805	5′
	A 800	0
Red Bluff Clay	A 613	13′
	A 610	10′
	A 608	8′
	A 606	6′
	A 604	4′
	A 600	0

2.1.3. Barbados

A short section through the Oligocene part of the Oceanic Formation at the Bath Cliff was collected by Roth, Saunders and Hay in 1967. The sediments are white foraminiferal marls which sometimes have a chalky appearance. The stratigraphy and the planktonic foraminifera were described by SAUNDERS & CORDEY (1969) and mentioned by BLOW (1969). The bottom part of the Bath Cliff section is rich in radio-

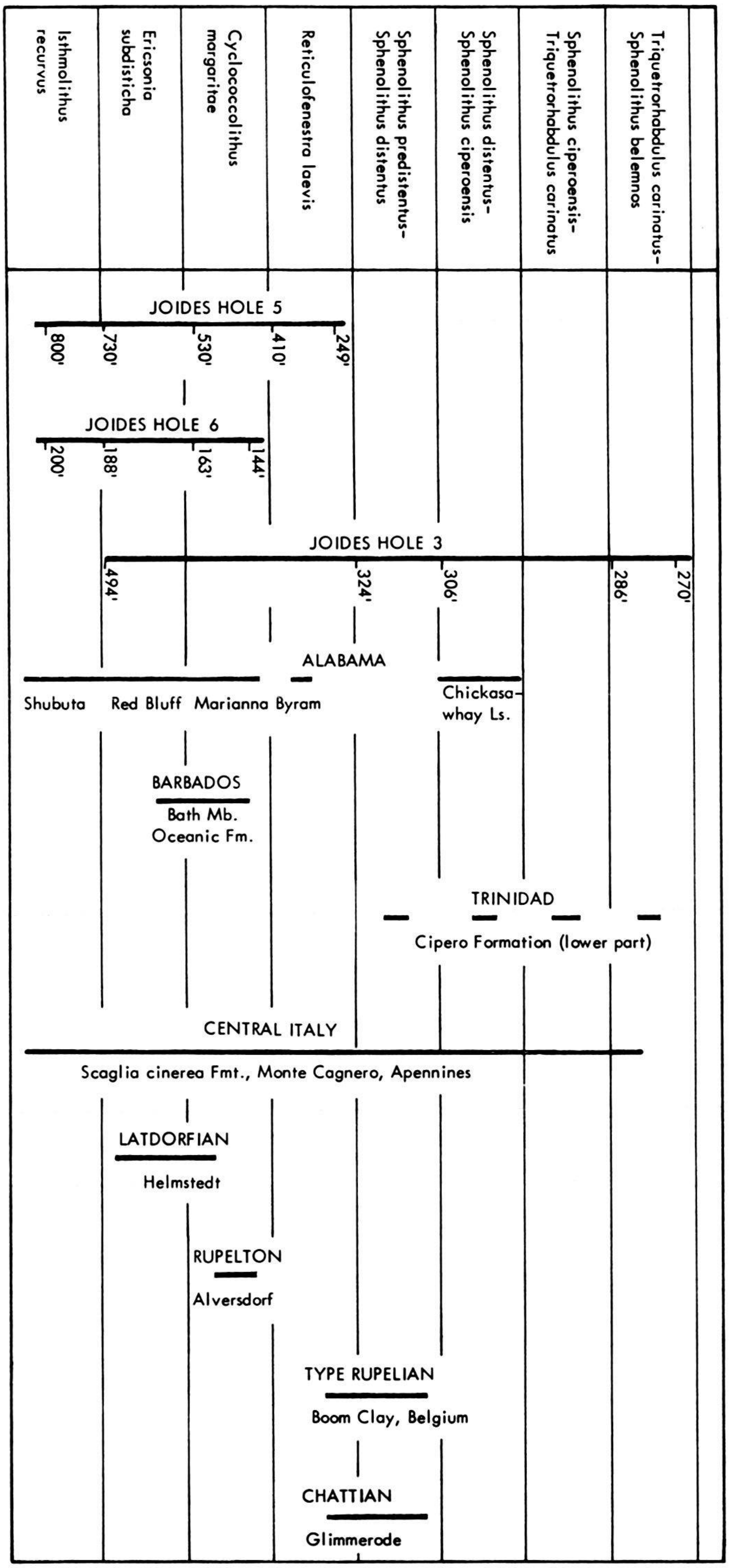


Fig. 4. Biostratigraphic extent of the studied sections.

laria and contains several volcanic ash beds. In the upper half of the lower section at Bath Cliff planktonic foraminifera become more abundant. They are of Uppeı Eocene age and the sediments also contain an Upper Eocene nannoflora (cf. HAY & al., 1967).

The Eocene-Oligocene boundary is not exposed at Bath Cliff but is covered by vegetation (between the lower and middle parts of the section). The middle part of the section (JS 1066–JS 1068), consisting of white foraminiferal marl, belongs to the Oligocene and contains the type locality JS 1066 for Zone P18 (*Globigerina tapuriensis* Zone of BLOW, 1969). Another covered interval separates this from the upper part of the section (JS 1069–JS 1072). The lithology is the same as in the middle part. All the samples collected are listed below. Only five samples (indicated with an asterisk) contain nannofossils which are sufficently well preserved for detailed studies. All the samples which are underlined in the list below are on the map and chart of SAUNDERS & CORDEY (1969). For more details on the stratigraphy of Barbados we refer to SAUNDERS & CORDEY (1969) and to the excursion guide by SAUNDERS (1969).

Bath Cliff section

Part of section	Sample number	Nannofossil content	Stratigraphical distance from top of part
Upper	JS 1072	poor	4′
	JS 1854*	rich	10′
	JS 1855	poor	16′
	JS 1071	poor	20′
	JS 1070	poor	28′
	JS 1856*	rich	33′
	JS 1069	poor	38′
Middle	JS 1857	poor	1′
	JS 1068*	rich	3′
	JS 1067	poor	6′
	JS 1858*	rich	9′
	JS 1066*	rich	15′ (= base of middle part)

2.1.4. Trinidad

Five samples from the Upper Oligocene part of the Cipero Formation of Trinidad were studied in detail with the electron and light microscope. They were collected with Prof. W. W. Hay and J. B. Saunders during a visit to Trinidad in 1967 shortly before most of the Cipero Section was destroyed. The sample from the *Globigerina ampliapertura* Zone is a dark grey marl, the remaining samples consist of brownish to grey foraminiferal marls. Details on the Cipero Formation and the geology of the Cipero Coast can be found in BOLLI (1957), pp. 103–105, BARR & SAUNDERS (1969) and in SAUNDERS & CATER (1969).

Samples studied:

PR 67* from the *Globorotalia kugleri* Zone, San Fernando by-pass, close to JS 267, type locality of the *Catpsydrax dissimilis* Zone of BOLLI (1957) (see SAUNDERS & CARTER, p. 434, fig. 2, stop 5), Bo 291 A′ type locality of the *Globigerina ciperoensis ciperoensis* Zone of BOLLI (1957), Cipero Coast, now destroyed. JS 20, type locality of the *Globorotalia opima opima* Zone of BOLLI (1957), Cipero Coast, now destroyed. JS 1847, *Globigerina ampliapertura* Zone, about 90 m south of locality JS 20, tidal flat, Cipero Coast, now destroyed.

2.2. European sections

2.2.1. Silberbeıg Formation (Latdorfian)

A section of the Silberberg Formation was collected with the help of Dr. F. Gramann and Dr. S. Ritzkowski in the coal pit Treue Baufeld IV, near Helmstedt, Northern Germany (for a map of the locality see fig. 5, for more stratigraphic information see MARTINI & RITZKOWSKI, 1968, and ANDERSON & al., 1969). Above the Middle Eocene coal beds occur the sands, marls and conglomerates of the Annenberg Formation (= lower part of the Helmstedter Gründsand, "Lage mit Pleurotomarien" of MARTINI & RITZKOWSKI). These sediments contain a nannoflora typical for the *Chiphragmalitus alatus* Zone. They grade into the overlying Gehlberg Formation, which consists of glauconitic sands with phosphatic nodules lacking any calcareous fossils. The Gehlberg Formation is overlain by grey, sandy marls of the Silberberg Formation which contain fairly rich nannoplankton and foraminifera assemblages. Another exposure of the Silberberg Formation is at the clay pit on the Silberberg (see MARTINI & RITZKOWSKI, 1968). Unfortunately the section is terminated by Pleistocene glacial drift as in the case of the section in coal pit Treue IV. Middle Oligocene beds do not occur above the Lower Oligocene Silberberg beds at this locality. This factor along with the sterility of the glauconitic sands at the base are the main disadvantages of this section. But it is still one of the best Lower Oligocene sections directly comparable with the type section of the Latdorfian (see MARTINI & RITZKOWSKI, 1968, and MARTINI, 1969). Not far away from the exposures of the Silberberg Formation, the Rupelton which is only slightly younger than the top of the Silberberg Formation in the Silberberg clay pit (both belonging to the *Cyclococcolithus margaritae* Zone), crops out in a clay pit (Brick yard Alversdorf).

Samples studied:

Treue Baufeld IV. coal pit:

Sample number	Distance from base of Silberberg Formation
PR 68/63	18 m
PR 68/62	16 m
PR 68/61	14 m
PR 68/60	12 m
PR 68/59	10 m
PR 68/58	8 m
PR 68/57	5 m
PR 68/56	4 m
PR 68/55	3 m
PR 68/54	2 m

Silberberg clay pit:

PR 68/70	1 m above limestone bed (Clays with *Ostrea queteleti*)
PR 68/69	0.5 m below limestone bed
PR 68/68	2 m below limestone bed

2.2.2. Rupelton of Germany

Only two samples from the German Middle Oligocene were studied (PR 68/64, PR 68/67). They were collected in the clay pit Alversdorf (see fig. 5) Helmstedt and

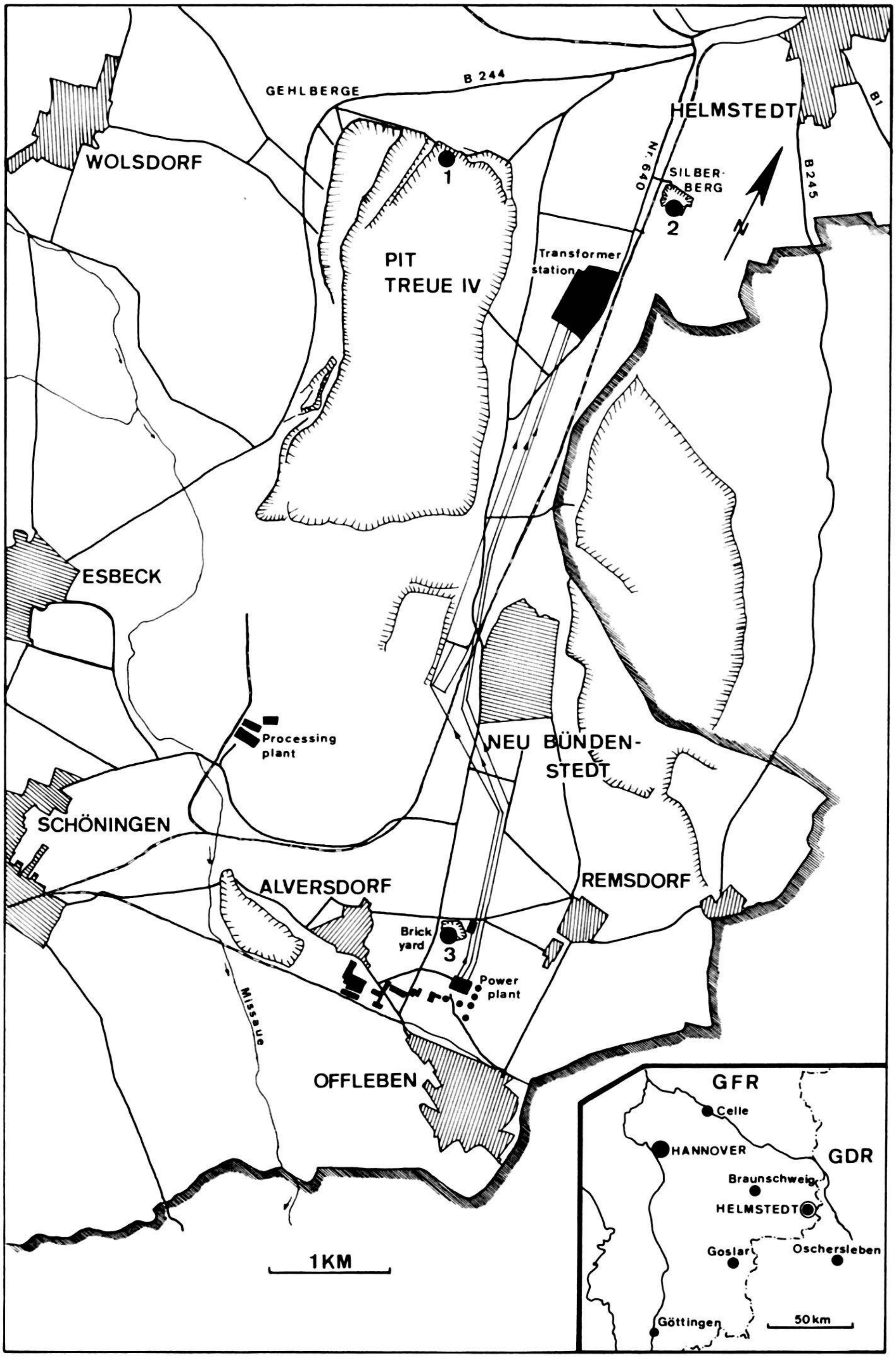


Fig. 5. Sketch map of the Oligocene localities in the Helmstedt area.
1: Latdorfian section at the coal pit Treue IV.
2: Latdorfian section at the clay pit Silberberg.
3: Section of Rupelton at the clay pit Alversdorf.

consist of grey, slightly sandy clay. The exact stratigraphic position of the two samples could not be determined; they were taken from the wall of the shallow pit (ca. 3 m deep) about 10 m apart. Accurate correlation of the Northern German Rupelton with the Boom Clay has not been possible up to the present (see SPIEGLER 1965). These two samples proved to be somewhat older than the Type Rupelian (Boom Clay), and contain many reworked Cretaceous coccoliths.

2.2.3. Boom Clay (Belgium)

Eleven samples from the type Rupelian Boom Clay of Belgium, collected by Prof. H. Schaub (Basel) were studied. For details on the Oligocene stratigraphy of Belgium, see BATJES (1958). The samples from the Brick Yard "Scheerders-Van Kerkhoven (S.V.K.)" near St. Nicolas were so poor in nannoplankton that detailed study was not possible. The samples from the Brick Yard "De Roeck & Verstrepen" proved to be fairly rich in nannoplankton. They consist of grey to bluish-grey clays and silty clays (see BATJES, 1958, fig. 8, section M. W).

Samples studied:

Ru 11: exact location in the pit not known
Ru 9b: 5.1 m above the base of pit
Ru 7: 2.0 m above the base
Ru 6: 1.0 m above the base
Ru 5: base of pit

2.2.4. Höllkopf near Glimmerode (Chattian)

It was difficult to find a suitable Chattian section because most of them lie above the ground water level and have been leached of calcium carbonate. RITZKOWSKI (1967), however, has described a section from the Höllkopf near Glimmerode where the Kasseler Meeressand is not leached. The sediments are sands, sandy marls and silts with four layers of concretions (layers A–D) and three shell beds (see fig. 10 in RITZKOWSKI, 1967). Correlation with the type locality of the Chattian, the Gelbe Berg near Niederkaufung has not yet been attempted. Many reworked Cretaceous coccoliths occur.

The following samples were studied:

PR 68/13: about 5 m above Concretion layer D
PR 68/12: about 0.5 m above Concretion layer D
PR 68/11: about 0.5 m below Concretion layer D
PR 68/18: about 1 m above Concretion layer A

2.2.5. Monte Cagnero, Central Italy

Samples from a section of the Scaglia cinerea collected by P. Baumann were studied. The strata consist of grey to brown-grey calcareous shales. The locality and stratigraphy are described in detail in BAUMANN & ROTH (1969) and in BAUMANN (1970). The nannoflora is only poorly preserved but it was possible to recognize the important zonal markers and correlate the nannofossil zones with BAUMANN'S planktonic foraminiferal Zones (see BAUMANN & ROTH, 1969, fig. 2).

Samples studied:

Sample number	Approximate stratigraphical distance from base of Scaglia cinerea
PB 349	94 m
PB 346	88 m
PB 343	82 m
PB 339	74 m
PB 336	68 m
PB 333	62 m
PB 330	56 m
PB 328	52 m
PB 326	48 m
PB 325	46 m
PB 323	42 m
PB 321	38 m
PB 317	30 m
PB 107	28 m
PB 105	24 m
PB 103	20 m
PB 101	16 m
PB 99	12 m
PB 96	6 m
PB 95	4 m
PB 94	2 m
PB 93	base
PB 92: top of Scaglia variegata	

3. ZONATION OF THE OLIGOCENE

The Eocene-Oligocene boundary can be defined by the last occurrence of *Discoaster barbadiensis* and *Discoaster saipanensis*, the latter usually being more abundant near this boundary. The disappearence of these species coincide with the last occurrence of the genus *Hantkenina*. The Oligocene-Miocene boundary is more difficult to define using nannoplankton. The *Comité du Néogène* (Bologna 1967) recommended the first occurrence of *Globigerinoides* as base of the Miocene. This level lies within the *Globorotalia kugleri* Zone of Bolli (1957) or at the base of Zone N4 (*Globigerinoides quadrilobatus primordius/Globorotalia (Turborotalia) kugleri* Concurrent-range Zone) of Blow (1969). Continuous sections with well preserved nannoplankton for this interval are still unknown, and at the present time it can only be demonstrated that the Oligocene-Miocene boundary falls within or lies at the base of *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone (as defined in this paper). In the following paragraph a short definition of all the Oligocene zones is given and the important species that can be used to recognize each zone are listed. Long-ranging species with little stratigraphic value are not mentioned. There are many more species present and more information can be found in the range charts. The Lower Oligocene can be divided into two intervals if only light microscopy is used: the lower interval is delimited by the last occurrence of *Discoaster barbadiensis* at its base and by the last occurrence of *Cyclococcolithus formosus* at its top. *Lanternithus minutus* and *Isthmolithus recurvus* also disappear at about the same level. This lower interval coincides with the *Ericsonia subdisticha* Zone and the lowermost part of the *Cyclococcolithus*

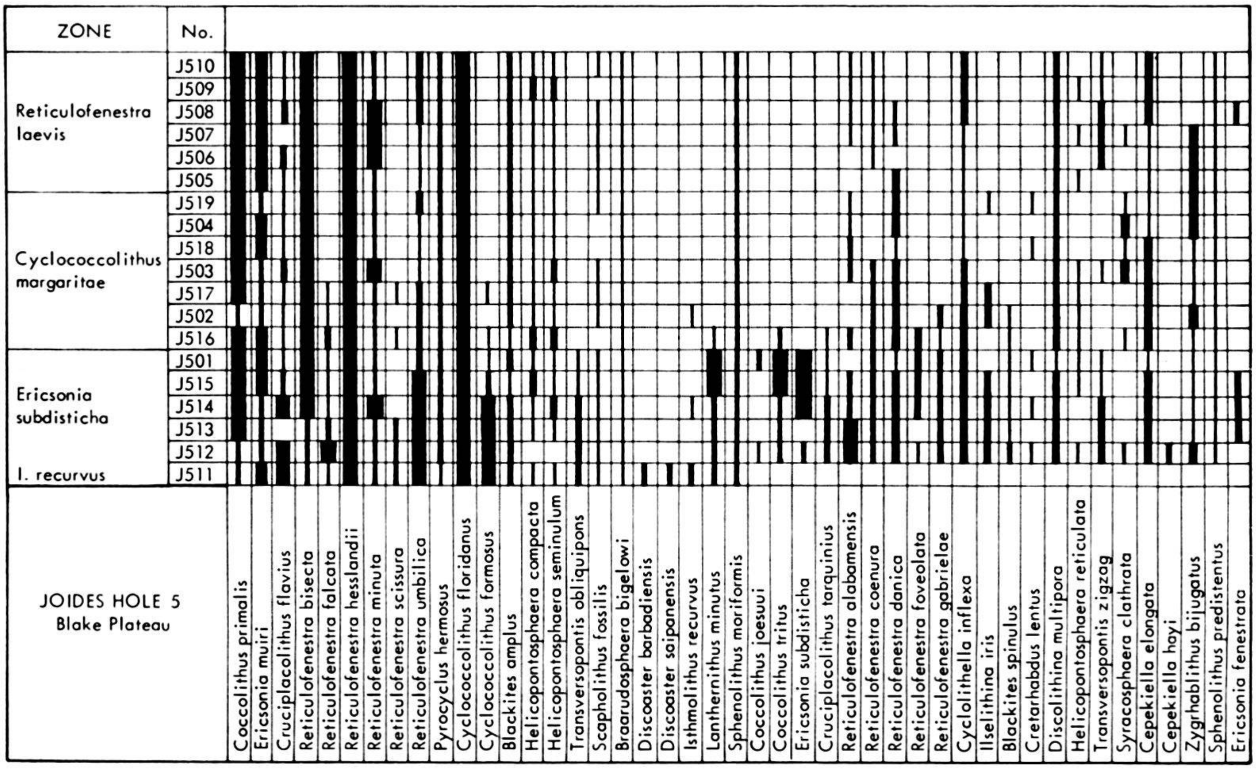


Fig. 6. Distribution of calcareous nannofossils in the Upper Eocene-Oligocene of JOIDES Hole 5, 30° 23′ N, 80° 08′ W, Blake Plateau, Western Atlantic.

margaritae Zone. The upper interval lies above the last occurrence of *Cyclococcolithus formosus* and below the first occurrence of *Sphenolithus distentus* which is very close to the last occurrence of *Reticulofenestra umbilica*. It corresponds to most of the *Cyclococcolithus margaritae* Zone and the *Reticulofenestra laevis* Zone. The Upper Oligocene Zones based on *Sphenolithus* can easily be recognized using only light microscopy. The *Helicosphaera reticulata* Zone of BRAMLETTE & WILCOXON (1967) approximates the *Ericsonia subdisticha* Zone–*Reticulofenestra laevis* Zone interval.

3.1. Lower Oligocene

3.1.1. Ericsonia subdisticha Zone

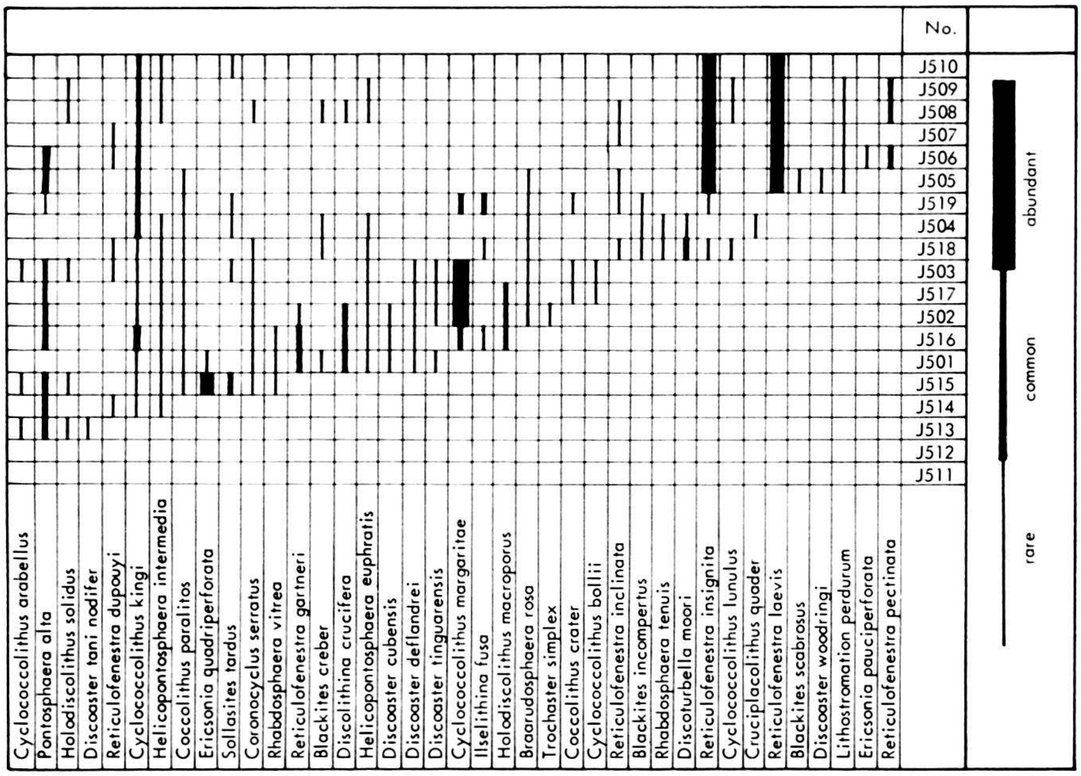
(= *Ellipsolithus subdistichus* Zone ROTH & HAY, in: HAY et al., 1967)

Definition: Interval from the last occurrence of *Discoaster barbadiensis* TAN SIN HOK to the first occurrence of *Cyclococcolithus margaritae* ROTH & HAY.

Authors: ROTH & HAY, 1967.

Type locality: JOIDES Hole 5, Lat. 30° 23′ N, Long. 80° 08′ W, Blake Plateau. (Samples J 512–J 501, most representative sample J 501, see fig. 1)

Important species: *Ericsonia subdisticha* (ROTH & HAY) ROTH, *Cyclococcolithus formosus* KAMPTNER (= synonym: *Coccolithus lusitanicus* BLACK). *Lanternithus minutus* STRADNER, *Isthmolithus recurvus* DEFLANDRE, *Sphenolithus tribulosus* n.sp., *Sphenolithus predistentus* BRAMLETTE & WILCOXON (first occurrence in the upper part



(N.B. All the species listed as *Discolithina* in figs. 6, 7, 9, 11–16 are assigned to the genus *Pontosphaera*, see pp. 860–861)

of the *Isthmolithus recurvus* Zone), *Reticulofenstra gartneri* ROTH & HAY, *Reticulofenstra gabrielae* n. sp., *Coccolithus joensuui* ROTH & HAY.

Remarks: This zone is characterized by the lack of Eocene discoasters such as *Discoaster barbadiensis* and *Discoaster saipanensis.* There are still very many species that range from the Eocene into this Zone, viz. *Isthmolithus recurvus, Lanternithus minutus, Coccolithus formosus* and *Ericsonia subdisticha* which makes its first occurrence in the upper Middle to lower Upper Eocene (personal communication by W. W. Hay and K. Perch-Nielsen, 1969). Thus the presence of *Ericsonia subdisticha* proves an early Oligocene age only if Eocene discoasters are absent and other species typical for the *Ericsonia subdisticha* Zone are present. Samples from JOIDES Hole 5 show very rich and well preserved assemblages belonging to this zone. Even richer and better preserved nannofloras from this zone are found in the Red Bluff Formation and the basal 5 feet of the Marianna Limestone of Alabama. On the island of Barbados, the type level of Zone P. 18 (samples JS 1066) belongs to the uppermost part of the *Ericsonia subdisticha* Zone as well. The Silberberg Formation in the coal pit Treue IV near Helmstedt, Northern Germany, belongs to the *Ericsonia subdisticha* Zone, only the very top of the Silberberg Formation in the Clay Pit on the Silberberg is already in the *Cyclococcolithus margaritae* Zone.

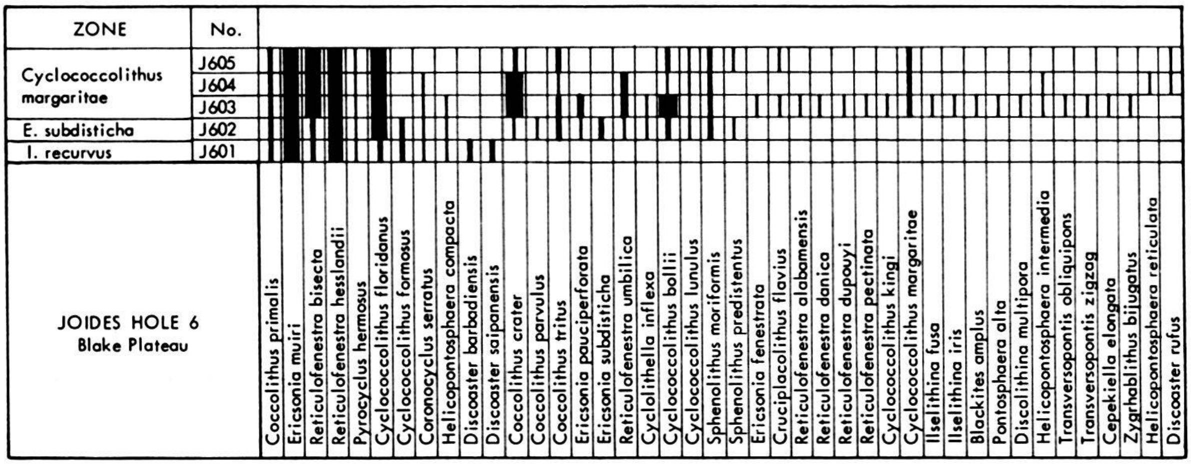


Fig. 7. Distribution of calcareous nannofossils in the Upper Eocene-Oligocene of JOIDES Hole 6, 30° 05′ N, 79° 15′ W, Blake Plateau, Western Atlantic.

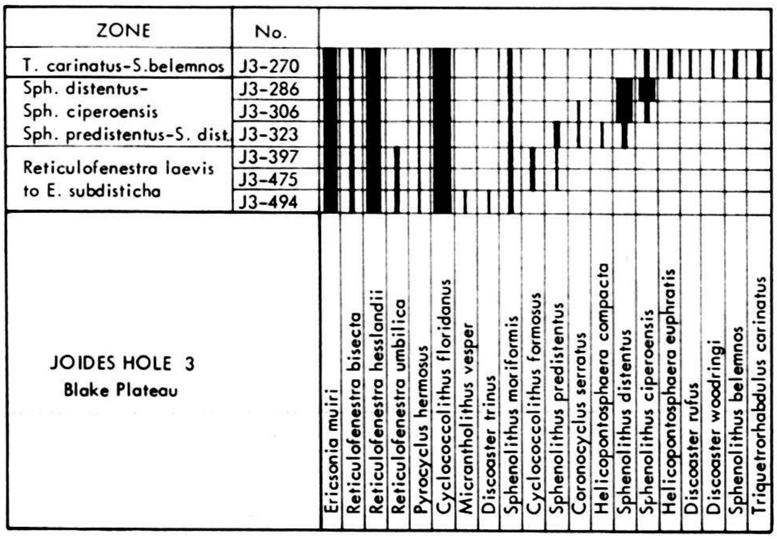


Fig. 8. Distribution of calcareous nannofossils in the Oligocene-Lower Miocene of JOIDES Hole 3, 28° 30′ N, 77° 31′, Blake Plateau, Western Atlantic.

The samples from the Silberberg Formation are not as rich as the Red Bluff samples from Alabama but the assemblage is strikingly similar and all the important markers are present. *Corannulus germanicus* STRADNER, found in the Silberberg Formation, was not found in any other lower Oligocene section.

MARTINI & MOORKENS (1969) showed that the sands of Grimmertingen (Tongrien) belong to the *Ericsonia subdisticha* Zone. The *Ericsonia subdisticha* Zone was also found in the Scaglia cinerea of the Monte Cagnero Section in Central Italy. It is represented by only about 6 meters of sediment. The preservation is poor and therefore an accurate zonation is difficult to establish.

3.2. Middle Oligocene

3.2.1. *Cyclococcolithus margaritae* Zone

Definition: Interval from the first occurrence of *Cyclococcolithus margaritae* ROTH & HAY to the first occurrence of *Reticulofenestra laevis* ROTH & HAY.

Authors: ROTH & HAY, 1967, emend. ROTH, 1969a.

Type locality: JOIDES Hole 5, Lat. 30°23' N, Long. 80°08' W, Blake Plateau (samples J 516–J 519, most representative sample: J 502; see fig. 6).

Important species: Cyclococcolithus margaritae ROTH & HAY, *Cyclococcolithus bollii* ROTH, *Coccolithus crater* n.sp. (the last 2 species first occur in the uppermost part of the underlying zone), *Braarudosphaera rosa* LEVIN & JOERGER (more abundant in shallow water deposits). Disappearing near the base of this zone is *Lanternithus minutus* STRADNER, *Cyclococcolithus formosus* KAMPTNER, and *Isthmolithus recurvus* DEFLANDRE. Near the top of this Zone *Reticulofenestra insignita* ROTH & HAY has its lowest occurrence.

Remarks: The richest and best preserved nannoflora from this zone discovered thus far is found in the type section, in JOIDES Hole 5. In JOIDES Hole 6 the *Cyclococcolithus margaritae* Zone is represented but the smaller coccoliths are missing. The same is the case in JOIDES Hole 3, where the Lower Oligocene nannoplankton zones could not be separated from each other. The Marianna Limestone of Alabama, from 5 feet above the base up to the top, contains a rich assemblage belonging to this zone. The upper part of the Marianna Limestone shows more recrystallization and the coccoliths are less well preserved. The upper part of the Bath Member of the Oceanic Formation contains nannofossil assemblages typical for the *Cyclococcolithus margaritae* Zone. *Cyclococcolithus margaritae* was found in the uppermost part of the Silberberg Formation in the Clay Pit on Silberberg near Helmstedt and in the Rupelton in the nearby Clay Pit Alversdorf. The German Rupelton contains many reworked Cretaceous forms and it is difficult to find the important autochthonous forms. MARTINI (1960) reported mainly reworked nannofossils from the "Rupelton" in the Mainz basin.

In the Monte Cagnero section the *Cyclococcolithus margaritae* Zone is 26 m thick.

3.2.2. *Reticulofenestra laevis* Zone

Definition: Interval from the first occurrence of *Reticulofenestra laevis* ROTH & HAY to the first occurrence of *Sphenolithus distentus* (MARTINI).

Authors: ROTH & HAY, 1967, modified in this paper.

Type locality: JOIDES Hole 5, Lat. 30°23' N, Long. 80°08' W, Blake Plateau (samples J 505–J 510, most representative sample: J 507).

Important species: Reticulofenestra laevis ROTH & HAY, *Reticulofenestra insignita* ROTH & HAY (much more abundant than in the underlaying zone), *Cyclococcolithus bollii* ROTH (rare); the following 5 species do not occur above the *Reticulofenestra laevis* Zone: *Helicopontosphaera reticulata* (BRAMLETTE & WILCOXON), *Reticulofenestra umbilica* (LEVIN), *Reticulofenestra pectinata* n.sp., *Reticulofenestra inclinata* n.sp., and *Lithostromation perdurum* DEFLANDRE.

Remarks: It is impossible to separate the *Cyclococcolithus margaritae* Zone from the *Reticulofenestra laevis* Zone using light microscopy because *Reticulofenestra laevis*

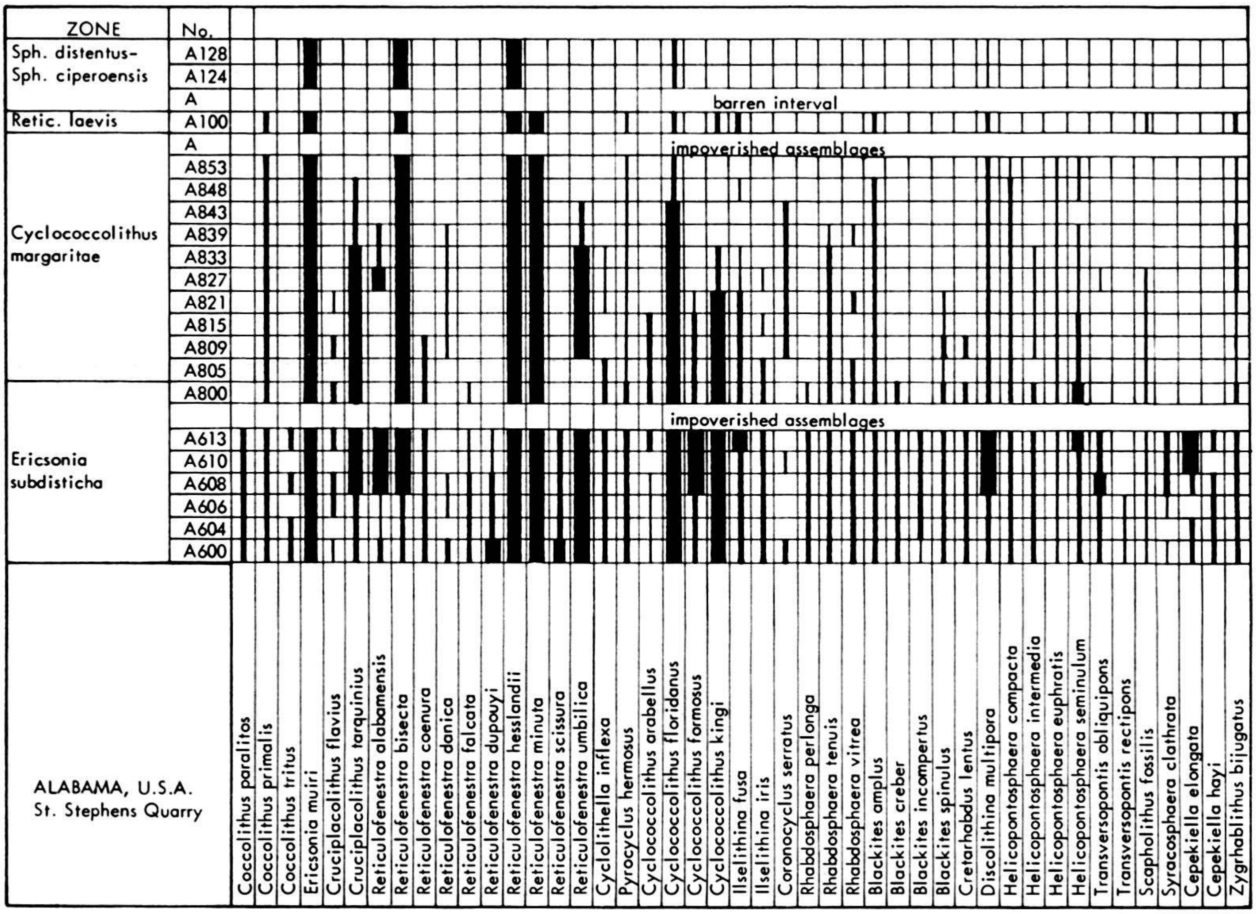
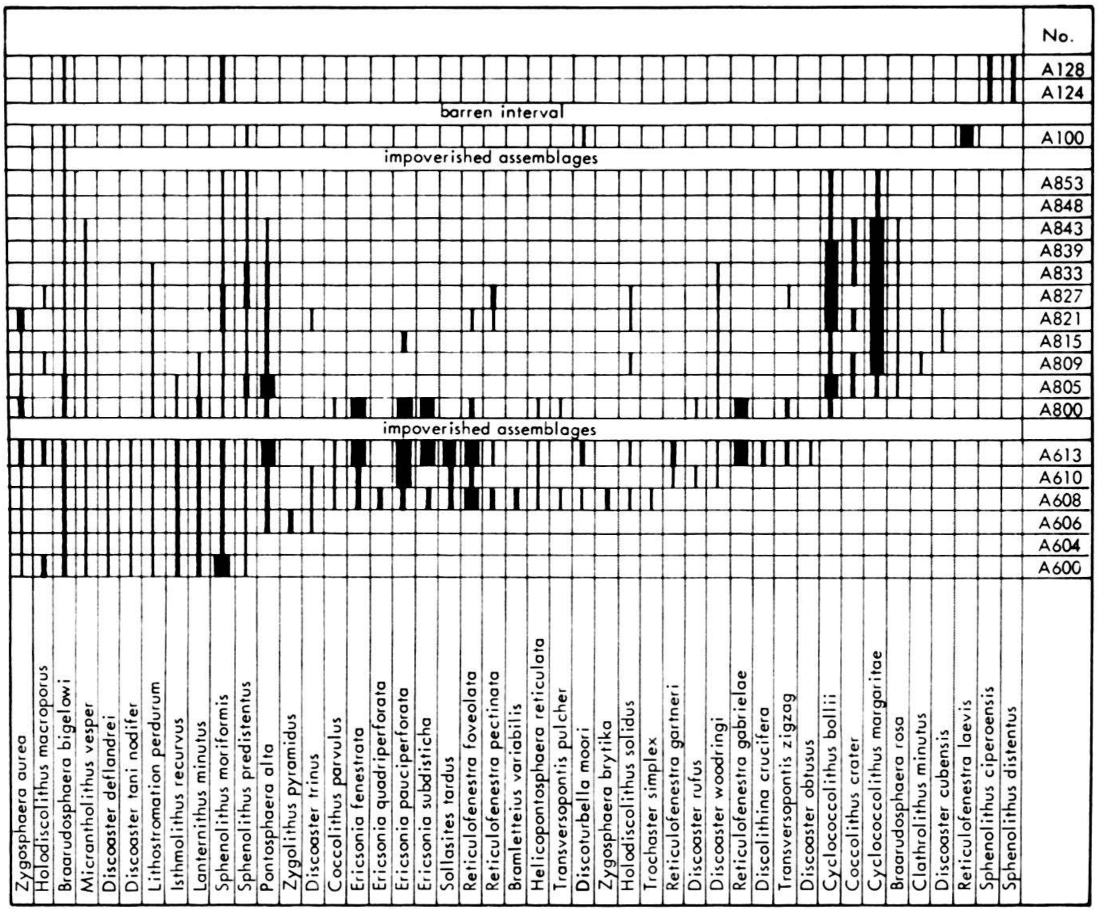


Fig. 9. Distribution of calcareous nannofossils in the Oligocene section at St. Stephens Quarry, Clark County, Alabama, USA.

cannot be identified with that method. The interval covering the two zones is characterized by the absence of *Lanternithus minutus* and *Cyclococcolithus formosus* which only occur in the underlying zone and basal part of the *Cyclococcolithus margaritae* Zone.

Dicoaster saundersi and *Sphenolithus distentus* do not occur below the next higher *Sphenolithus predistentus- Sphenolithus distentus* Zone. The *Reticulofenestra laevis* Zone in JOIDES Hole 5 comprises 50 m of sediment, the lower part containing many siliceous microfossils. The assemblages are fairly rich, but discoasters are rare and limited to long-ranging species of the *D. deflandrei*-group. In Alabama *Reticulofenestra laevis* occurs in the unnamed Clay Member at the base of the Bucutunna Clay. The underlying Glendon Limestone is too poor in nannofossils to be assigned to any Zone and the Bucatunna Clay is completely barren of nannofossils.

In Europe the lower part of the Boom Clay (brick clay pit De Roek & Verstrepen) belongs to the *Reticulofenestra laevis* Zone. The zonal marker *Sphenolithus predistentus* is present, but *Sphenolithus distentus* is still missing, and occurs only in the upper part of the section. The lower part of the Kasseler Meeressande of the now abandonned coal pit on the Höllkopf near Glimmerode belongs to the *Reticulofenestra laevis* Zone.



There are many reworked Cretaceous nannofossils in these deposits, but the marker fossil and *Reticulofenestra umbilica* are present. In the Monte Cagnero section only 4–5 m of the Scaglia cinerea belong to this zone. Perhaps *Reticulfenestra laevis* does not occur below because of the very poor preservation of nannofossils in this part of the section. On the other hand sedimentation might have been very slow during the time of deposition of sediments belonging to the *Reticulofenestra laevis* Zone.

3.2.3. *Sphenolithus predistentus–Sphenolithus distentus* Zone

Definition: Interval with *Sphenolithus predistentus* BRAMLETTE & WILCOXON and *Sphenolithus distentus* (MARTINI) from the first occurrence of *Sphenolithus distentus* (MARTINI) to the first occurrence of *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON.

Authors: BRAMLETTE & WILCOXON, 1967, modified by ROTH, in BAUMANN & ROTH, 1969, modified in this paper.

Type locality: Sample TTOC 193785, near the type locality of the *Globigerina ampiapertura* Zone of BOLLI (1957), Trinidad.

Cotype locality: Samples PB 328–PB 330, most representative sample PB 328, Monte Cagnero, Central Italy.

Important species: Sphenolithus predistentus BRAMLETTE & WILCOXON, *Sphenolithus distentus* (MARTINI), *Discoaster saundersi* HAY, *Ericsonia bireticulata* n.sp.,

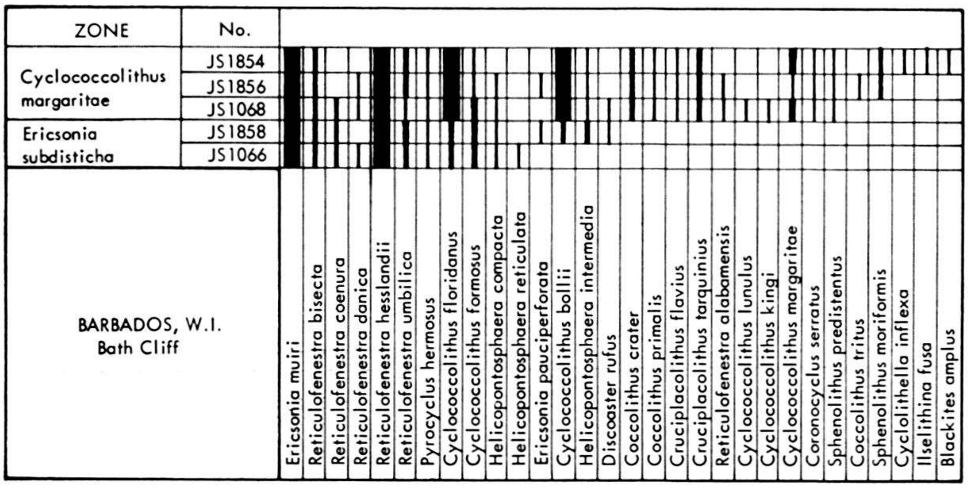


Fig. 10. Distribution of calcareous nannofossils in the Oligocene section at Bath Cliff, Barbados.

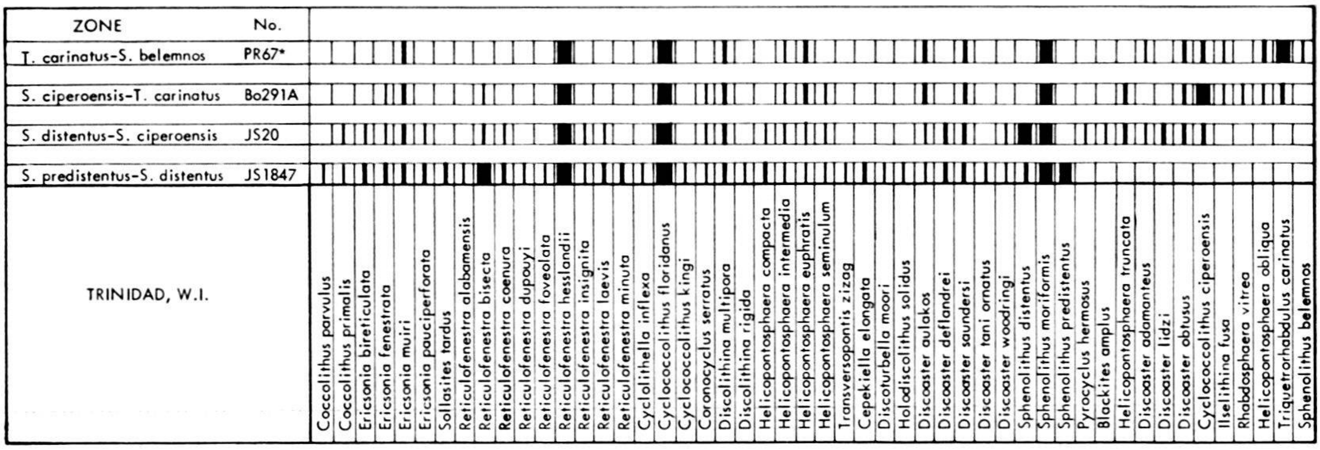


Fig. 11. Distribution of calcareous nannofossils in samples from the type localities or type areas of the planktonic foraminiferal zones of Bolli (1957).

Pontosphaera rigida n. sp. The following species make their last occurrence in this zone: *Cruciplacolithus tarquinius* ROTH & HAY, *Sollasites tardus* n. sp., *Reticulofenestra alabamensis* n. sp., *Reticulofenestra scissura* HAY, MOHLER & WADE, *Reticulofenestra foveolata* (REINHARDT). *Cyclococcolithus kingi* n. sp., *Transversopontis zigzag* ROTH & HAY.

Remarks: The definition of this zone was changed after it was realized that *Sphenolithus distentus* (MARTINI) is more abundant in most sections and can be recognized more easily than *Discoaster saundersi* HAY in poorly preserved samples. A satisfactory section to study this and the following zones in greater detail has not been found. The Cipero Coast section in Trinidad is completely destroyed. Only one sample from the *Sphenolithus predistentus–Sphenolithus distentus* Zone on the Cipero Coast was available (JS 1847); it contains a fairly rich and well preserved assemblage. In Alabama this zone is missing since the unnamed clay member at the base of the

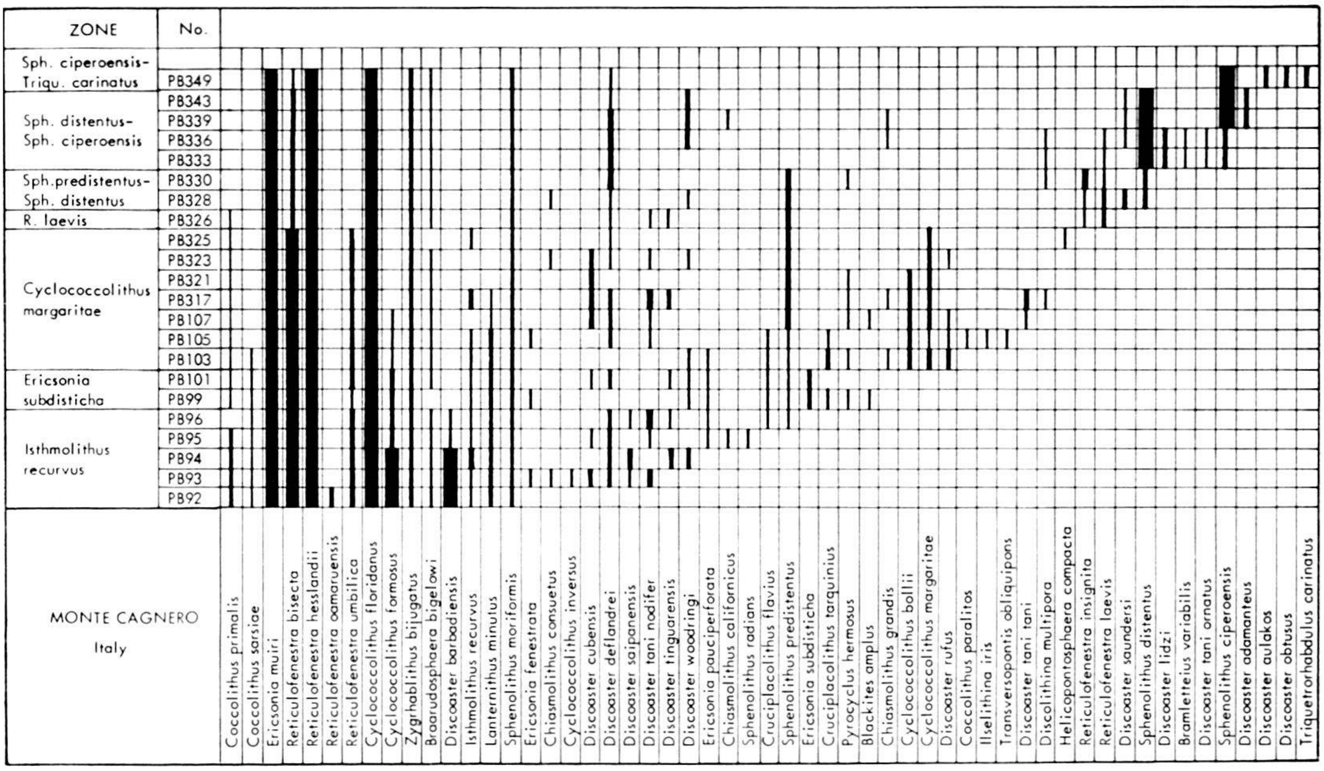


Fig. 12. Distribution of calcareous nannofossils in the Upper Eocene-Oligocene section at the Monte Cagnero, Central Apennines, Italy.

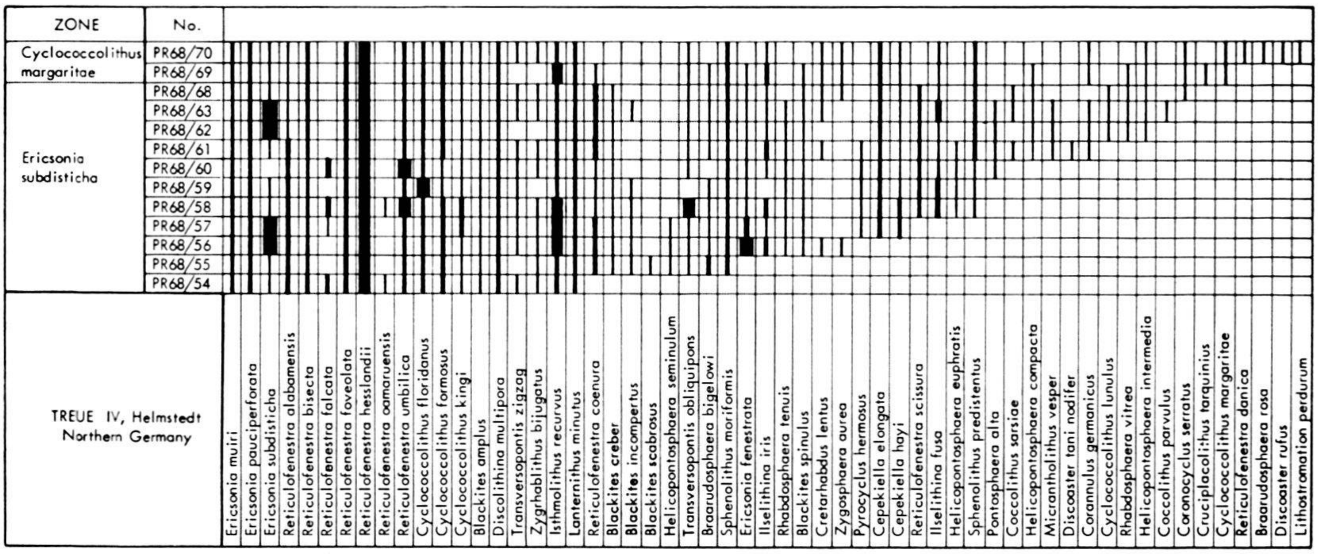


Fig. 13. Distribution of calcareous nannofossils in the Lower Oligocene (Latdorfian) section at the coal pit Treue IV, near Helmstedt, Northern Germany.

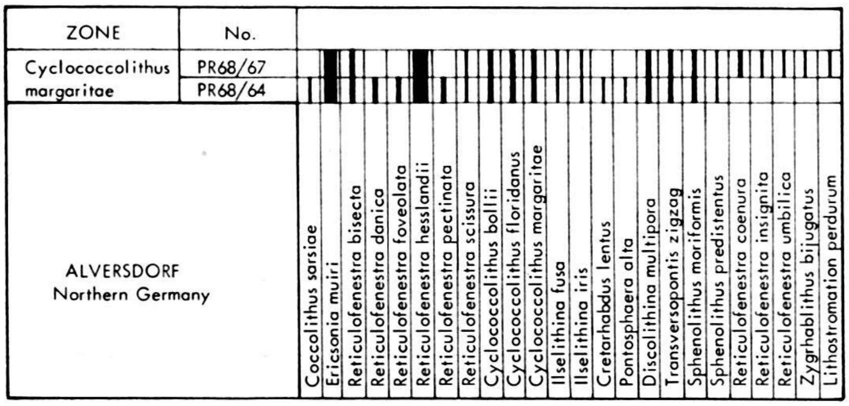


Fig. 14. Distribution of calcareous nannofossils in the Middle Oligocene (Rupelian) section at the clay pit Alversdorf, near Helmstedt, Northern Germany.

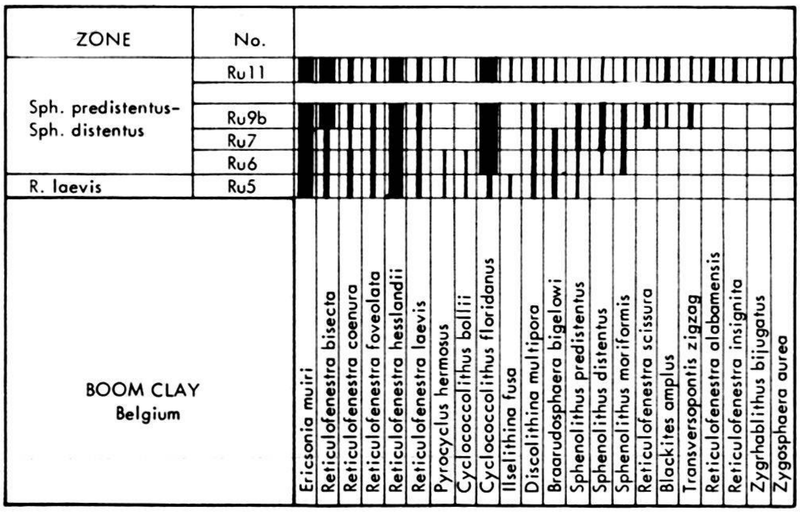


Fig. 15. Distribution of calcareous nannofossils in the type Rupelian section, clay pit "De Roeck & Verstrepen", Boom, Belgium.

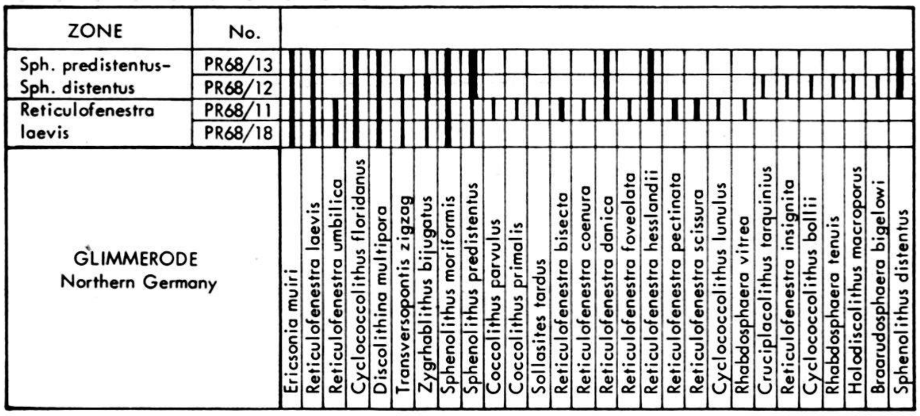


Fig. 16. Distribution of calcareous nannofossils in the Middle Oligocene (Chattian) section at the coal pit Höllkopf, near Glimmerode, Northern Germany.

Bucatunna Clay belongs to the *Reticulofenestra laevis* Zone and the next higher horizon yielding nannofossils, the Chickasawhay Limestone, belongs to the succeeding *Sphenolithus distentus–Sphenolithus ciperoensis* Zone. JOIDES Hole 5 does not contain this zone but post-Miocene deposits rest on top of sediments belonging to the *Reticulofenestra laevis* Zone. In JOIDES Hole 3 the *Sphenolithus predistentus–Sphenolithus distentus* Zone was found at 323' below sea floor; according to BRAMLETTE & WILCOXON, 1967, from 328' to 417' below sea floor. The nannoflora in JOIDES Hole 3 is reduced in number of species because many small forms are missing due to winnowing. Discoasters are very rare in this section, but sphenoliths are abundant and well preserved. Most of the Boom Clay in the Clay Pit De Roek & Verstrepen near Boom (Belgium) belongs to the *Sphenolithus predistentus–Sphenolithus distentus* Zone. BRAMLETTE & WILCOXON have mentioned the fact that it is difficult to find *Sphenolithus distentus* and *Sphenolithus predistentus* in the Boom Clay and an extensive search is required to find a few specimens. Discoasters are practically absent from these deposits; whether this is due to climatic reasons or to some sort of facies control cannot be decided at present. The upper part of the Kasseler Meeressande in the abandoned coal pit on the Höllkopf near Glimmerode also belongs to the *Sphenolithus predistentus- Sphenolithus distentus* Zone. *Sphenolithus distentus* and *Sphenolithus predistentus* are quite rare and not easily found. In the Monte Cagnero Section about 10 m of sediment belong to the *Sphenolithus predistentus–Sphenolithus distentus* Zone.

3.3. Upper Oligocene

3.3.1. *Sphenolithus distentus–Sphenolithus ciperoensis* Zone

Definition: Interval with *Sphenolithus distentus* (MARTINI) and *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON from the first occurrence of *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON to the first occurrence of *Triquetrorhabdulus carinatus* MARTINI.

Authors: BRAMLETTE & WILCOXON, 1967, modified by ROTH, in BAUMANN & ROTH, 1969.

Type locality: Sample TTOC 193265, type locality of the *Globorotalia opima* Zone of BOLLI 1957, Cipero Coast, Trinidad (destroyed).

Cotype locality: Monte Cagnero, Italy, samples PB 333–PB 343, most typical sample PB 333.

Important species: Sphenolithus ciperoensis BRAMLETTE & WILCOXON, *Spheolithus distentus* (MARTINI), *Discoaster lidzi* HAY, *Discoaster adamanteus* BRAMLETTE & WILCOXON, *Cyclococcolithus ciperoensis* n. sp., *Helicopontosphaera truncata* (BRAMLETTE & WILCOXON). The following species appear for the last time in this zone: *Ericsonia bireticulata* n.sp., *Reticulofenestra coenura* (REINHARDT), *Reticulofenestra insignita* ROTH & HAY, *Reticulofenestra laevis* ROTH & HAY, *Blackites amplus* ROTH & HAY, *Helicopontosphaera compacta* (BRAMLETTE & WILCOXON), *Discoaster tani ornatus* BRAMLETTE & WILCOXON.

Remarks: Only one sample from Trinidad was vailable (JS 20). It contains a fairly rich but poorly preserved assemblage. The species of the genus *Reticulofenestra* are less abundant than in the underlying zone. An even poorer nannoflora of this zone was found in JOIDES Hole 3 where only the larger species remain, the small species were carried away by currents. Two samples from the Chickasawhay Limestone from Alabama furnished an assemblage of nannofossils that is assigned to the *Sphenolithus distentus–Sphenolithus ciperoensis* Zone since both markers are present and *Triquetrorhabdulus carinatus* was not found.

In Europe the only section where the *Sphenolithus distentus- Sphenolithus ciperoensis* Zone was encountered so far is in the upper part of the Scaglia cinerea of the Monte Cagnero, Italy, where it measures about 20 m. The preservation is very poor but all the markers were recognized.

3.3.2. *Sphenolithus ciperoensis–Triquetrorhabdulus carinatus* Zone

Definition: Interval with *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON and *Triquetrorhabdulus carinatus* MARTINI from the first occurrence of *Triquetrorhabdulus carinatus* MARTINI to the first occurrence of *Sphenolithus belemnos* BRAMLETTE & WILCOXON.

Authors: BRAMLETTE & WILCOXON, modified by ROTH in BAUMANN & ROTH, 1969.

Type locality: Sample TTOC 215656, type locality of the *Globigerina ciperoensis ciperoensis* Zone of BOLLI 1957, Cipero Coast, Trinidad.

Important species: Sphenolithus ciperoensis BRAMLETTE & WILCOXON, *Triquerorhabdulus carinatus* MARTINI, *Cyclococcolithus ciperoensis* n. sp., *Helicopontosphaera truncata* (BRAMLETTE & WILCOXON). *Helicopontosphaera obliqua* (BRAMLETTE & WILCOXON).

Ericosonia fenestrata (DEFLANDRE) and *Reticulofenestra bisecta* (HAY, MOHLER & WADE) were not found in younger zones.

Remarks: Only one sample from Trinidad, collected at the type locality, was studied. It contains a fairly well preserved nannoflora with a large number of species. BRAMLETTE & WILCOXON found this Zone to be less than 6 feet thick in JOIDES Hole 3.

In the Monte Cagnero section the top sample (PB 349) belongs to this Zone since *Triquetrorhabdulus carinatus* and *Sphenolithus ciperoensis* are present.

3.3.3. *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone

Definition: Interval with *Triquetrorhabdulus carinatus* (MARTINI) and *Sphenolithus belemnos* BRAMLETTE & WILCOXON from the first occurrence of *Sphenolithus belemnos* BRAMLETTE & WILCOXON to the first occurrence of *Helicopontosphaera ampliaperta* (BRAMLETTE & WILCOXON).

Authors: BRAMLETTE & WILCOXON, modified, this paper.

Type locality: Sample TTOC 206262, close to the type locality of the *Globorotalia kugleri* Zone of BOLLI (1957), Trinidad.

Important species: Triquetrorhabdulus carinatus MARTINI, *Sphenolithus belemnos* BRAMLETTE & WILCOXON (small specimen).

Remarks: The *Triquetrorhabdulus carinatus* Zone of BRAMLETTE & WILCOXON (1967) is more extended than the one defined here which covers only the lower part of the original zone below the first occurrence of *Helicopontosphaera ampliaperta* (BRAMLETTE & WILCOXON) n.comb. [= *Helicosphaera ampliaperta* BRAMLETTE & WILCOXON, 1967, p. 105, pl. 6, figs. 1–4] and *Discoaster druggi* BRAMLETTE & WILCOXON. Sample PR 67* from the San Fernando by-pass in Trinidad with a planktonic foraminiferal fauna characteristic for the *Globorotalia kugleri* Zone was found to belong to this zone. It was collected close to the surface and therefore it is slightly weathered and not very rich. A sample from the type locality of the *Globorotalia kugleri* Zone of BOLLI (1957) examined only in the light microscope, is assigned to the *Triquetrorhabdulus carinatus- Sphenolithus belemnos* Zone. This zone is also present in a sample from JOIDES Hole 3 (270′ below sea floor) where small specimens of *Sphenolithus belemnos* were seen in the electron microscope.

The presence of the *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone in Europe has not yet been established.

Until the relation of the Oligocene-Miocene boundary to the *Globorotalia kugleri* Zone is defined, it cannot be decided whether the *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone belongs to the Oligocene or to the Miocene or straddles the boundary.

4. BIOSTRATIGRAPHIC DATUM LEVELS

There is growing recognition of the usefulness of datum levels in addition to zones for correlation. A datum level is defined as the surface connecting all the points marked by a certain event in different sections. Events may be the range limits of fossils, geophysical events (e.g. paleomagnetic reversals), lithologic and other stratigraphic marker horizons (e.g. ash beds) or other well defined changes. Ideally these surfaces connecting points marked by events are parallel isochronous planes. In reality this is not always the case as most events observable in nature will not take place everywhere on this planet nor will they necessarily be contemperaneous everywhere. The origin of a new species happens at a distinct time but its first occurrence at different places is not simultaneous due to the spreading time and to ecological barriers which can hinder or prevent migration into areas other than that of the original appearance. Since datum levels are essentially means of dating and correlation, they should be attached to events which are believed to have occurred in the same manner and at the same time in widely spaced areas, and not to a single observation point. Datum levels can only be applied reliably after careful study of many sections and after the overall fossil composition has been taken into consideration. A certain species can be absent or very rare at a certain level and reappear or become more abundant again higher up in the section. This can either be caused by adverse ecological conditions, solution of delicate forms after or during deposition, winnowing by fluctuating currents, or recrystallisation in the sediment. A certain species can also become so rare at a certain level that it can not be detected in a sample of average size. Zones can often be recognized even if the marker species are absent by using other characteristic species. Datum levels can be combined into informal units as suggested by HORNIBROOK (in press). Datum levels form very flexible means for subdivision of strata and long distance correlation. JENKINS (1966) suggested a great number of datum levels based on planktonic foraminiferal species for the Pacific area. He points out that the ability to locate some datum levels depends on the original geographic distribution of the various species and on the amount of micropaleontological research done in a certain area. BERGGREN (1969, 1970) also advocates the use of datum levels based on planktonic foraminifera for the subdivision of the Tertiary. Datum levels based on nannoplankton have not yet been defined. MARTINI (1969) points out that his "*Cyclococcolithus formosus* boundary" can be found worldwide; it has to be considered a datum level even if it was not formally designated as such. In fig. 17 several nannoplankton and foraminiferal species suitable for defining datum levels are shown with their distribution. Lowest occurrences (if possible lowest evolutionary occurrences) are more reliable datum levels than highest occurrences because nannofossils in particular have a propensity to be reworked into younger sediments and because some species become very rare towards the end of their range and are thus difficult to find. Planktonic foraminiferal datum levels are taken from the literature, mainly from the range charts in BAUMANN & ROTH (1969), BLOW (1969), and BERGGREN (1969).

The following important nannoplankton datum levels are based on species that can be identified in the light microscope:

1. Top *Discoaster barbadiensis* (= Eocene-Oligocene boundary).
3. Top *Cyclococcolithus formosus* (= close to the boundary of Lower and Middle Oligocene).
5. Base *Sphenolithus distentus* (Upper part of Middle Oligocene).
6. Base *Sphenolithus ciperoensis* (Middle-Upper Oligocene boundary).
7. Base *Triquetrorhabdulus carinatus* (upper part of the Upper Oligocene).
8. Base *Sphenolithus belemnos* (approximates the Oligocene-Miocene boundary).
9. Base *Helicopontosphaera ampliaperta* (Lower Miocene not much above the Oligocene-Miocene boundary).
10. Base *Discoaster druggi* (not much above the base of the Miocene).

The datum level close to the Oligocene-Miocene boundary can not be defined more accurately until the exact relation to the *Globigerinoides* datum is known.

The following datum levels are based on species which can only be recognized in the electron microscope. They are based on the lowest occurrence of these species and are thus more reliable than others based on the highest occurrence of a species.

2. Base *Cyclococcolithus margaritae* (closely below the Lower-Middle Oligocene boundary).
4. Base *Reticulofenestra laevis* (upper part of middle Oligocene).

5. CORRELATION OF NANNOPLANKTON ZONES WITH PLANKTONIC FORAMINIFERAL ZONES

A correlation of nannofossil zones with planktonic foraminiferal zones was presented for the Monte Cagnero Section, Italy, by BAUMANN & ROTH (1969) and is summarized here on figures 1 and 17. Correspondence of the *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone with the *Globorotalia kugleri* Zone is only based on Trinidad material.

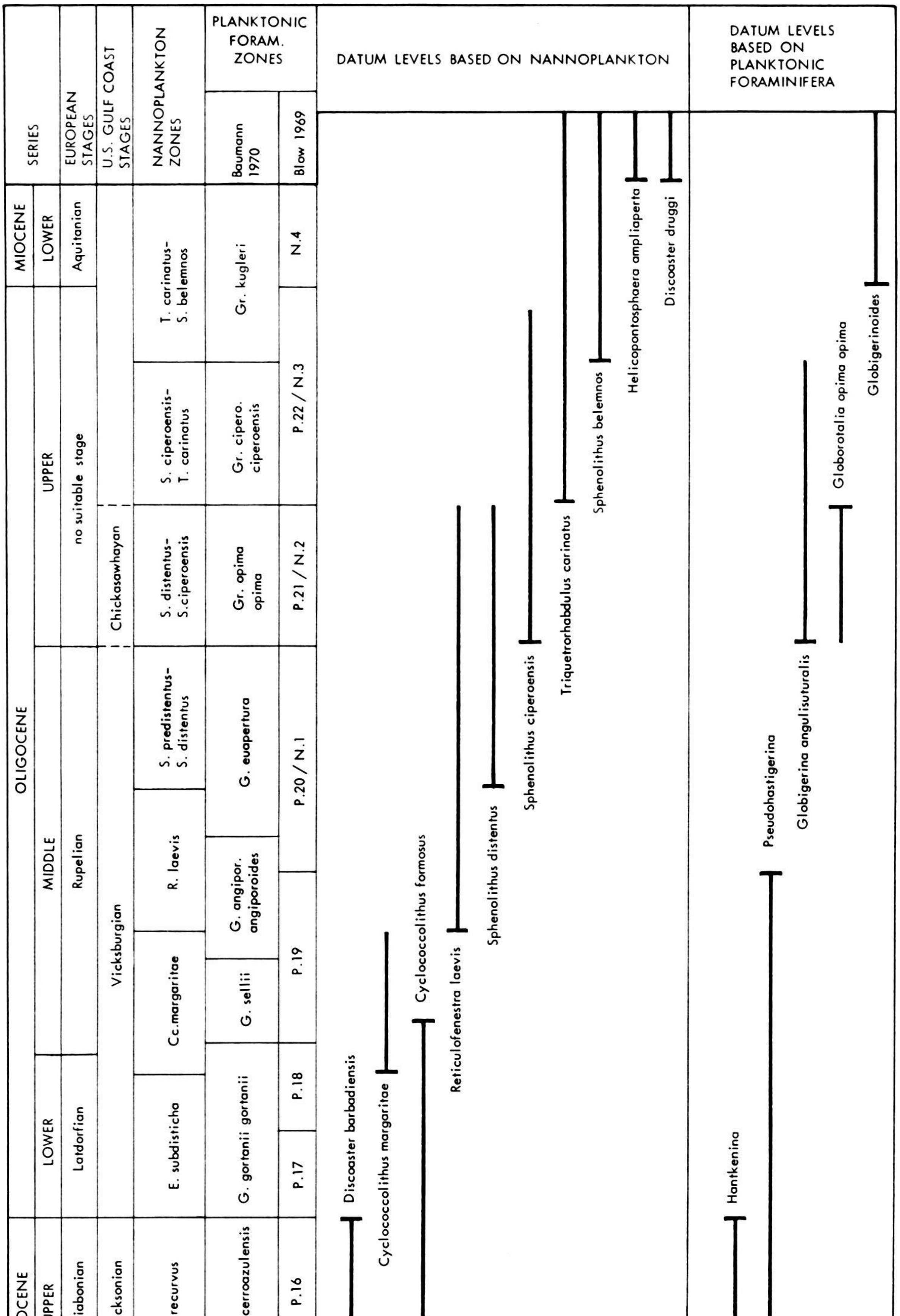


Fig. 17. Upper Eocene-Lower Miocene stages, planktonic formainiferal and nannoplankton zones and datum levels. Tentative relation of planktonic foraminiferal and nannoplankton datum levels is shown.

For some of the sections, samples, or formations studied, information on the planktonic foraminiferal content and zonal assignement of these sediments was taken from the literature. These data are sometimes scanty and imprecise. Thus the correlations that are discussed below are less certain than those with BAUMANN'S zonation of the Monte Cagnero section. DEBOO (1965) found *Cribrohantkenina inflata* in the Yazoo Clay which belongs to the *Isthmolithus recurvus* Zone (see LEVIN & JOERGER, 1967). BLOW (1969) mentioned that the Yazoo Clay of Alabama belongs to his Zone P. 16 (*Cibrohantkenina inflata* Zone). The type sample of BLOW'S Zone P. 18 (*Globigerina tapuriensis* Zone), from the Bath Member of the Oceanic Formation, Bath Cliff, Barbados, lies at a level that belongs to the upper part of the *Ericsonia subdistiacha* Zone. Higher samples from the Bath Cliff section still within Zone P. 18 must be assigned to the *Cyclococcolithus margaritae* Zone. The Red Bluff Formation and the lower part of the Marianna Limestone of Alabama belong to Zone P. 18; the nannoplankton indicates the presence of the *Ericsonia subdisticha* and lower *Cyclococcolithus margaritae* Zone for these beds. The upper part of the Marianna Limestone belongs to Zone P. 19 (*G. sellii* Zone) according to BLOW (1969, fig. 25). It lies within the *Cyclococcolithus margaritae* Zone. BLOW'S Zone P. 19 is present in the Boom Clay of Belgium were the nannofossils indicate the *Reticulofenestra laevis* Zone to *Sphenolithus predistentus* Zone. Thus, BLOW'S Zone P. 19 covers the interval of the upper *Cyclococcolithus margaritae* Zone, the *Reticulofenestra laevis* Zone and, perhaps, the base of the *Sphenolithus predistentus–Sphenolithus distentus* Zone. For the Upper Oligocene zones there is little divergence between planktonic foraminiferal and nannoplankton zonations but the lack of known continuous sections through this interval makes accurate correlations difficult. A sample from the *Globigerina ampliapertura* Zone of Trinidad was found to belong to the *Sphenolithus predistentus–Sphenolithus distentus* Zone; the type sample of the *Globorotalia opima opima* Zone lies within the *Sphenolithus distentus–Sphenolithus ciperoensis* Zone; the type sample of the *Globigerina ciperoensis ciperoensis* Zone contains a nannoflora typical for the *Sphenolithus ciperoensis–Triquetrorhabdulus carinatus* Zone; a sample from the *Globorotalia kugleri* Zone can be assigned to the *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone.

6. CORRELATION OF THE OLIGOCENE STAGES WITH THE NANNOPLANKTON ZONES

A discussion of problems of the European Oligocene stratigraphy is presented on pp. 808–811.

An attempt to determine the extent of the classical European stages in terms of nannofossil zones was made by BAUMANN & ROTH (1969).

6.1. Latdorfian

The Silberberg Formation in the Coal Pit Treue IV, which contains the same nannoflora as mollusc fillings from Latdorf (see MARTINI & RITZKOWSKI, 1968), belongs to the *Ericsonia subdisticha* Zone. The lower part of the Silberberg Formation in the Clay Pit of the Silberberg can also be assigned to the *Ericsonia subdisticha* Zone but the uppermost part of these deposits belong to the *Cyclococcolithus margaritae* Zone. For practical purposes the Latdorfian or Lower Oligocene can be considered identical with the *Ericsonia subdisticha* Zone.

6.2. Tongrian

MARTINI & MOORKENS (1969) showed that the Sands of Grimmertingen, type of the lower Tongrian belong to the *Ericsonia subdisticha* Zone. Latdorfian and Tongrian fall into the same nannoplankton Zone and are thus of approximately the same age.

6.3. Rupelian

Two samples from the Rupelton of the Clay Pit Alversdorf near Helmstedt belong to the *Cyclococcolithus margaritae* Zone. A short section through the Boom Clay in the Clay Pit "De Roeck & Verstrepen" near Boom collected by Prof. H. Schaub in 1961 contains in the lower part a nannoflora typical for the *Reticulofenestra laevis* Zone; in the upper part the occurrence of *Sphenolithus predistentus* together with *Sphenolithus distentus* indicates the presence of the *Sphenolithus predistentus–Sphenolithus distentus* Zone. The Rupelian as a whole covers the interval from the *Cyclococcolithus margaritae* Zone through the *Sphenolithus predistentus–Sphenolithus distentus* Zone. BRAMLETTE & WILCOXON (1967) mentioned the concurrence of the *Sphenolithus predistentus* and *Sphenolithus distentus*, assigning part of the Boom Clay to their *Sphenolithus distentus* Zone. If the emended definitions for the upper Oligocene Zones are used only the presence of *Sphenolithus ciperoensis* would prove a correlation of the upper part of the Boom Clay with the *Sphenolithus distentus–Sphenolithus ciperoensis* Zone.

6.4. Chattian

Selected samples from the Chattian section near Glimmerode (see p. 32) were studied and the lower part proves to be assignable to the *Reticulofenestra laevis* Zone, the upper part of the *Sphenolithus predistentus–Sphenolithus distentus* Zone. The markers are rare, the preservation of the nannoflora is rather poor and the admixture of reworked Cretaceous coccoliths is great. At least part of the Chattian is of the same age as the Rupelian in the type area. The Chattian does not seem very suitable as a stage since planktonic organisms which are most useful for worldwide correlations are very rare and because it is mostly of the same age as the Rupelian.

6.5. Uppermost Oligocene

A suitable stage for the Upper Oligocene (*Sphenolithus distentus–Sphenolithus ciperoensis* Zone to *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone) is still missing. BLOW & SMOUT (1968) suggested resurrecting the Bormidian of PARETO (1856). However, the Bormidian type section contains many reworked fossils and consists mainly of coarsely arenaceous sediments; it is hardly suitable as a standard for international use. The Neochattian is partly of the same age but its type section lies so far in the north that it is difficult to correlate it with tropical and subtropical sediments. Calcareous plankton fossils are rare in the Neochattian and the rich benthonic fauna is not yet usable for worldwide correlation. Thus, the Neochattian, apart from its unacceptable name, is not very useful as an Upper Oligocene stage either.

6.6. Vicksburgian

The Vicksburg deposits of Alabama, which can be correlated with the type Vicksburg of Mississippi (see DEBOO 1965) contain the nannoflora of the *Ericsonia subdisticha*, *Cyclococcolithus margaritae* and *Reticulofenestra laevis* Zones. Preservation of the nannofossils is good and planktonic foraminifera are present along with larger foraminifera, molluscs, echinoids, ostracods. The Vicksburgian seems to be the best Oligocene stage available.

6.7. Chickasawhayan

The *Sphenolithus distentus–Sphenolithus ciperoensis* Zone was found in the Chickasawhay Limestone of Alabama. The Chickasawhay sequence thickens towards the western part of the Gulf Coast and might contain more than one nannoplankton zone.

7. SYSTEMATIC PALEONTOLOGY

Of a total of 122 species encountered in the Oligocene sections studied, 29 species are new, 25 new combinations are made and remarks are presented on 23 species because of differences in species concepts. The remaining 49 species are not described in this paper because they were well covered in previous literature. For those species not described in this paper the author presents a check list (pp. 871–872) where the type reference, other good illustrations, and descriptions are mentioned. Mainly electron micrographs of carbon replicas of the new species are presented here because some species prove to be too small to obtain light micrographs which could be assigned to the same species with certainty. The method described by PERCH-NIELSEN (1967) which allows examination of the same specimen in the light and electron microscope was not used because it was published after the greater part of the electron microscope work for this paper was already finished. For the suprageneric classification the system proposed by PARKE & DIXON (1964) for recent algae is mainly followed here. It differs considerably from the one used by HAY & al. (1967).

Kingdom Plantae
Subkingdom Contophora
Division Chromophyta
Class Haptophyceae, Christensen, 1962
Unicellular flagellates which possess a haptonema.
Order Prymnesiales, Christensen, 1962
Motile phase with an obvious haptonema.

Family Coccolithaceae
Rhabdosphaeraceae
Pontosphaeraceae
Syracosphaeraceae
Zygosphaeraceae
Braarudosphaeraceae
Discoasteraceae
Lithostromationaceae
Triquetrorhabdulaceae
Sphenolithaceae

Family Coccolithaceae KAMPTNER, 1928

Genus *Coccolithus* Schwarz, 1894

Coccolithus crater n. sp.

pl. 1, fig. 2

Definition: A small species of *Coccolithus* with 9–12 elements and a simple central depression.

Description: The distal shield is composed of 9–12 wedge-shaped elements with slight sinistral imbrication. Sutures on the distal shield are straight and radial. In the center of the distal shield is a narrow crater-shaped depression, about a fourth the diameter of the coccolith, with steep smooth walls and triangular cross-section.

Remarks: Coccolithus crater n. sp. differs from *Coccolithus litos* HAY, MOHLER & WADE in its smaller size and in having fewer elements and a smooth depression. *Coccolithus paralitos* ROTH & HAY is about the same size but has about 25 elements and the central depression is surrounded by a cycle of granules.[2])

Holotype: IMS-A 809 004, [A 808].

Length of holotype: 5μ.

Type locality: St. Stephens Quarry, Alabama.

Type level: Marianna Ls., 9 feet above base.

Distribution: JOIDES Hole 5, Alabama and Barbados: *Cc. margaritae* Zone. JOIDES Hole 6: From the *E. subdisticha* through the *Cc. margaritae* Zone.

Coccolithus primalis n. sp.

pl. I, fig. 3

Definition: A very small species of *Coccolithus* consisting of 14–22 elements.

Description: The distal shield is constructed of 14–22 tabular dextrally imbricate elements. The sutures are radial over the greater part of the distal shield and curve strongly counterclockwise near the periphery. The central depression which is about half as long as the whole shield, is a shallow crater filled with tabular elements and coarse angular blocks.

Remarks: Coccolithus primalis n. sp. is distinguished from *Coccolithus sarsiae* BLACK by its smaller size and relatively smaller central area. *Coccolithus paralitos*

[2]) This species resembles *Biscutum castorum* BLACK & BARNES, but the complete lack of other Cretaceous species in the samples where it was found makes roworking highly unlikely.

ROTH & HAY possesses a greater number of elements, and a ring of granules around the central depression which is not present in *Coccolithus primalis* n. sp. *Coccolithus litos* HAY, MOHLER & WADE is larger and has more elements. *Coccolithus crater* n. sp. has fewer elements and a smooth central depression with a sharp angular bottom.

Holotype: IMS-J 506377, [A 809].

Length: 2,7 μ.

Type locality: JOIDES Hole 5, Blake Plateau, Lat. 30° 23′ N, Long. 80° 08′ W.

Type level: 374′ below top. Oligocene.

Occurrence: JOIDES Hole 5, Alabama, Monte Cagnero (Italy), Boom Clay (Belgium), Helmstedt and Glimmerode: throughout the section. Barbados: *Cc. margaritae* Zone. Trinidad: *Sph. predistentus–Sph. distentus* Zone and *Sph. distentus–Sph. ciperoensis* Zone.

Coccolithus tritus n. sp.

pl. I, fig. 1

Definition: A species of *Coccolithus* with a distal shield consisting of two cycles of about 30 elements each.

Description: The distal shield is broadly elliptical and is composed of two cycles of elements. The outer cycle consists of 30–35 tabular dextrally imbricate elements with straight radial sutures. The inner cycle slopes towards the slot at the bottom of the central depression and is built of 28–30 tabular elements which are imbricate dextrally. The sutures of the inner cycle are S-shaped and inclined counterclockwise near the central slot, clockwise in the middle and counterclockwise again near the margin. While the margin of the outer cycle is smooth the margin of the inner cycle is serrate. The inner cycle overlaps the elements of the outer cycle. The length of the central depression is about $^2/_3$ of the whole coccolith.

Remarks: This species is very similar to *Coccolithus cavus* HAY & MOHLER but it has fewer elements and a more regularly built inner cycle of elements. The lining of the central depression of *Ericsonia muiri* BLACK consists of irregular granules and not of curved tabular elements as in *Coccolithus tritus* n. sp.

Holotype: IMS-A 604225, [A 810].

Length: 6.2 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens Alabama.

Type level: Red Bluff Formation, 4 feet above base, Oligocene.

Distribution: JOIDES Hole 5: *E. subdisticha* Zone to lower part of the *R. laevis* Zone. JOIDES Hole 6: *E. subdisticha* Zone through *Cc. margaritae* Zone. Alabama: *E. subdisticha* Zone. Barbados: *Cc. margaritae* Zone.

Genus *Ericsonia* Black, 1964

Ericsonia bireticulata n. sp.

pl. I, figs. 4, 5

Diagnosis: A species of *Ericsonia* with a central opening spanned by two superimposed grilles the upper one being coarse, the lower one fine.

Description: The distal shield is constructed of 32–38 trapezoidal dextrally imbricate elements. The sutures of the distal shield are radial on the distal side. The central depression, about two-thirds the size of the whole coccolith, is covered with a coarse grille with 8–10 round pores arranged in a elongate ellipsoid. Through these pores the finer grille of the proximal side can be seen. The proximal shield consists of three cycles of elements. The outer cycle is built of 32–38 tabular elements, sinistrally imbricate, with sutures inclined slightly counterclockwise as seen from the proximal side. The middle cycle is composed of short, narrow crystals with sutures more strongly inclined counterclockwise. The central area, about half the size of the proximal shield, is covered with a grille with about 20–31 irregularly shaped pores.

Remarks: Ericsonia bireticulata n. sp. differs from *Ericsonia pauciperforata* n. sp. in having two superimposed grilles; this seems to be an unique feature among coccoliths known so far.

Holotype: JS 1847301 [A 811].

Paratype: JS 1847026 [A 812].

Length of holotype: 4.7 μ.

Length of paratype: 5.7 μ.

Type locality: Cipero Coast (sample JS 1847), San Fernando, Trinidad.

Type level: Gg. ampliapertura Zone, Cipero Formation.

Distribuation: Restricted to the *Sph. predistentus–Sph. distentus* Zone Trinidad.

Ericsonia fenestrata (DEFLANDRE & FERT) STRADNER

pl. I, fig. 6

1954 *Discolithus fenestratus* DEFLANDRE & FERT, p. 25, pl. 11, fig. 25, text-fig. 52.

1968 *Ericsonia fenestrata* (DEFLANDRE & FERT) STRADNER in STRADNER & EDWARDS (pro parte), p. 18–19, pl. 10, fig. 4, pl. 11, fig. 1–4 (non pl. 10, fig. 1–3, pl. 11, fig. 5–7).

1968 *Ericsonia fenestrata* (DEFLANDRE & FERT) STRADNER of HAQ (pro parte), p. 22, pl. 1, figs. 11–12 (non pl. 11, fig. 10).

Remarks: In following the original description of DEFLANDRE & FERT (1954) this name is only applied for specimens with many pores (12–20) arranged on lines parallel to the long and the short axis of the ellipse. Specimens with a longitudinal central ridge and few pores either belong to the species *Ericsonia subdisticha* (ROTH & HAY) or to *Ericsonia pauciperforata* n. sp.

Hypotype: IS 1847624 [A 813].

Distribution: JOIDES 5 and Alabama: *E. subdisticha* Zone. JOIDES 6: *Cc. margaritae* Zone. Italy: *I. recurvus* Zone to lower part of *Cc. margaritae* Zone. Trinidad: *Sph. predistentus–Sph. distentus* Zone through *Sph. ciperoensis–Trq. carinatus* Zone (perhaps reworked).

Ericsonia muiri (BLACK) n. comb.

1964 *Coccolithus muiri* BLACK, p. 309, pl. 50, figs. 3–4.

1964 *Ericsonia ovalis* BLACK, p. 312, pl. 52, figs. 5–6.

1967 *Coccolithus* sp. aff. *C. eopelagicus* (BRAMLETTE & RIEDEL) of LEVIN & JOERGER, p. 165, pl. 1, figs. 2a, b.

1967 *Coccolithus* sp. cf. *C. pelagicus* (WALLICH) of LEVIN & JOERGER, p. 165, pl. 1, figs. 4a, b.

1967 *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL) of GARTNER & SMITH, p. 3, pl. 3, figs. 1–5.
1968 *Ericsonia ovalis* BLACK of STRADNER in STRADNER & EDWARDS, p. 17, pl. 8, 9.

Remarks: Coccolithus muiri BLACK has page priority over *Ericsonia ovalis* BLACK which is the proximal view of *Coccolithus muiri.* STRADNER (in STRADNER & EDWARDS, 1968) has given a thorough description of this species. It is not possible to distinguish *Ericsonia muiri* from *Coccolithus eopelagicus* (BRAMLETTE & RIEDEL) in the uppermost Eocene and Oligocene because there is little variation in size and intergrading forms can be found between the two extreme types (see BRAMLETTE & WILCOXON, 1967). *Coccolithus pelagicus* (WALLICH) shows a different construction of the proximal shield with only one cycle of elements and sometimes a cover of plates over the central opening. In *Coccolithus pelagicus* the central crater of the distal plate is covered with smooth small elongate crystals whereas *Ericsonia muiri* has a layer of irregular granules in the crater.

Distribution: From the Upper Eocene through the Oligocene in all the studied sections.

Ericsonia pauciperforata n. sp.

pl. II, fig. 1

1954 *Discolithus* cf. *fenestrata* DEFLANDRE & FERT, Text-fig. 18 (left).
1968 *Ericsonia fenestrata* (DEFLANDRE & FERT) of STRADNER in STRADNER & EDWARDS (pro parte), p. 18, pl. 10, figs. 1–3, pl. 11, figs. 5–7 (non pl. 10, fig. 4, pl. 11, figs. 1–4).
1968 *Ericsonia fenestrata* (DEFLANDRE & FERT) of HAQ (pro parte), p. 22, pl. 1, fig. 10 (non pl. 1, figs. 11–12).

Diagnosis: A species of *Ericsonia* with 5–15 perforations in the central area.

Description: The distal shield contains two cycles of elements, an outer one of 30–35 trapezoidal elements, dextrally imbricate with straight radial suture lines and an inner cycle of the same number of tabular elements, dextrally imbricate, with strongly counterclockwise inclined suture lines. The central area, about half the size of the coccolith, is pierced by 5–15 pores. They are arranged irregularly. In some specimens they surround an area lacking perforations which is never as distinctly elevated as in *Ericsonia subdisticha* (ROTH & HAY).

Remarks: This species differs from *Ericsonia fenestrata* (DEFLANDRE & FERT) as described by DEFLANDRE & FERT 1954 by the irregular arrangement of the perforations. *Ericsonia fenestrata* has pores arranged parallel to the long and short axes of the ellipse. STRADNER's description is too general and he includes specimens that can be referred to the present species in *Ericsonia fenestrata.* In *Ericsonia subdisticha* (ROTH & HAY) two pores are at the end of an distinctly elevated ridge in the long axis of the ellipse and 4 pairs of pores to either side of the central ridge.

Holotype: IMS-A 608157 [A 814].

Length: 5.2 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens Alabama.

Type level: Red Bluff Formation, 8 feet above base.

Occurrence: New Zealand: Upper Eocene, *I. recurvus* Zone. Denmark: Middle to Upper Eocene (personal communication from K. Perch-Nielsen). JOIDES Hole 5: Lower part of the *R. laevis* Zone. JOIDES Hole 6 and Barbados: *Cc. margaritae* Zone. Alabama and Helmstedt, Germany: *E. subdisticha* Zone and *Cc. margaritae* Zone.

Ericsonia quadriperforata n. sp.

pl. II, fig. 2

Diagnosis: A species of *Ericsonia* with four round, large pores in the center.

Description: The distal shield is composed of two cycles of elements; the outer one contains 28–30 trapezoidal dextrally imbricate elements with radial sutures; the inner cycle is built of the same number of tabular elements with broken suture lines, which as a whole are inclined slightly counterclockwise. The center, about $^1/_3$ the size of the distal shield, is occupied by four large round pores.

Remarks: This species differs from *Ericsonia pauciperforata* n. sp. in having only four central pores whereas *Ericsonia pauciperforata* n. sp. has 5–15 smaller pores. *Ericsonia fenestrata* (DEFLANDRE & FERT) and *Ericsonia subdisticha* (ROTH & HAY) have more pores.

Holotype: IMS-J 515234 [A 815].

Length: 5 μ.

Type locality: JOIDES Hole 5, Blake Plateau, Lat. 30°23′ N, Long. 81°08′ W.

Type level: 589′ 11″ below sea floor, Oligocene.

Distribution: JOIDES Hole 5 and Alabama: *E. subdisticha* Zone.

Ericosonia subdisticha (ROTH & HAY) ROTH, 1969

pl. II, figs. 3, 4

1967 *Ellipsolithus subdistichus* ROTH & HAY in HAY et al., pp. 446–447, pl. 6, fig. 7.
1969 *Ericsonia subdisticha* (ROTH & HAY) ROTH in BAUMANN & ROTH, p. 319.
1969 *Ellipsolithus subdistichus* ROTH & HAY, MARTINI, pp. 135–136, pl. 2, figs. 26–27, pl. 4, figs. 38–39.

New diagnosis: A species of *Ericsonia* with four pairs of pores on either side of the long axis, and one hole at each end of the central area.

New description: The coccolith is broadly elliptical. The distal shield is composed of about 31 subtrapezoidal segments which are dextrally imbricate. The sutures have a slight counterclockwise inclination over most of the surface, but curve more strongly in the same direction peripherally. The central area has a longitudinal ridge flanked by four pairs of pores; two additional pores lying in the long axis delimit the ends of the ridge. The proximal shield shows a shallow central depression with 10 pores similarly arranged as on the distal shield, but the central ridge is less pronounced. This central depression is surrounded by a cycle of square crystal blocks which are slightly dextrally imbricate with suture lines inclined slightly couterclockwise. The marginal segments, subtrapezoidal in shape, are dextrally imbricate and the sutures are inclined clockwise. These rings of elements with suture lines of different inclination are typical for genus *Ericsonia*. *Ellipsolithus subdistichus* was therefore transferred to this genus. The general construction of coccolith seems to be of greater taxonomic importance than modification of the central area.

Remarks: This species differs from *Ellipsolithus distichus* (BRAMLETTE & SULLIVAN) in having two shields. *Ericsonia fenestrata* (DEFLANDRE & FERT) has more numerous pores arranged parallel to the axis of the ellipse. In *Ericsonia subdisticha* the pores lie on a narrow ellipse. *Ericsonia pauciperforata* n. sp. shows an irregular distribution of variable numbers of pores without a pronounced central ridge.

Hypotypes: IMS-J 515374 [A 816];
IMS-N1 241 [A 817].

Distribution: *E. subdisticha* Zone in JOIDES Hole 5, Alabama. Monte Cagnero, Italy, Helmstedt (Northern Germany). According to W. W. Hay (personal communication 1969) *Ericsonia subdisticha* also occurs throughout the Upper Eocene.

Genus *Cruciplacolithus* HAY & MOHLER, 1967

Synonym: *Crucilithus* STRADNER, 1968

Cruciplacolithus flavius n. sp.

pl. II, figs. 5, 6

Diagnosis: A small species of *Cruciplacolithus* with a wide central opening and a slim central cross.

Description: The distal shield is narrow elliptical and contains an outer cycle of 25–30 wedge-shaped elements which are dextrally imbricate. The sutures are inclined clockwise near the center and turn sharply counterclockwise peripherally. The inner cycle slopes towards the central depression and is built of about the same number of tabular elements as the outer cycle. The imbrication is dextral and the suture lines are strongly inclined counterclockwise. The cross in the central hole is aligned parallel to the long and short axis of the ellipse. It sometimes shows a central ridge and the arms are always very slim. The proximal shield consists of two cycles as well. The elements of the outer one, 25–30 in number, are wedge-shaped and dextrally imbricate and the suture lines are inclined counterclockwise. The inner cycle has the same number of tabular elements sloping towards the central depression with dextral imbrication. The sutures are inclined strongly counterclockwise. The ridge on the central cross cannot be seen from the proximal side.

Remarks: This species differs from *Cruciplacolithus crux* (DEFLANDRE & FERT) n. comb. [= *Discolithus crux* DEFLANDRE & FERT, 1954, p. 143, pl. 14, fig. 4] in having fewer elements and in being much smaller. *Cruciplacolithus cruciformis* (HAY & TOWE) n. comb. [= *Cyathosphaera cruciformis* HAY & TOWE, 1962, p. 508, pl. 2, fig. 6] is more broadly elliptical; its margin is notched and the cross shows a rather large central knob which is not present in *Cruciplacolithus flavius* n. sp. *Cruciplacolithus tarquinius* ROTH & HAY has a smaller central opening an the inner cycle shows a distinctly serrate margin.

Holotype: IMS-J 504107 [A 818].

Paratype: IMS-J 503229 [A 819].

Length: Holotype: 3.5 μ, Paratype: 2.5 μ.

Type locality: JOIDES Hole 5, Lat. 30° 23′ N, Long. 80° 08′ W, Blake Plateau. *Type level:* 445′ below top, Oligocene.

Distribution: JOIDES Hole 5: From the *I. recurvus* Zone through the *R. laevis* Zone. JOIDED Hole 6 and Barbados: *Cc. margaritae* Zone. Alabama: From the *E. subdisticha* Zone through the *R. laevis* Zone.

Cruciplacolithus quader n. sp.

pl. III, fig. 1

Diagnosis: A species of *Cruciplacolithus* having a central cross with broad arms and a cube in its center.

Description: The distal shield is broadly elliptical and consists of about 22 very strongly dextrally imbricate tabular segments. The sutures are straight and radial. The steep slope of the central area is covered with two cycles of elements. The upper cycle contains 22 sinistrally imbricate tabular elements separated by radial suture lines. The lower cycle which extends somewhat higher than the attachment of the cross bars has the same number of flat plates and radial suture lines. The sutures of the two cycles are offset by less than a quarter of an element. The arms of the central cross which lie in the axis of the ellipse are broad and carry a cube in the center with sides parallel to the arms of the cross. The inter-spaces between the arms of the cross are filled with parallel laths forming a triangular plate leaving only a narrow slit open along the margin of the central depression.

Remarks: This species is distinguished from *Cruciplacolithus cruciformis* (HAY & TOWE) by the relatively smaller central area, the smooth margin of the shield, and by having three cycles in the distal shield. *Cruciplacolithus tarquinius* ROTH & HAY does not have a cube in the center of the cross and the marginal elements are less strongly imbricate.

Holotype: IMS 504101 [A 820].

Length: 3.5 μ.

Type locality: JOIDES Hole 5, Lat. 30°23′N, 80°08′W, Blake Plateau.

Type level: 44′ below top, Oliogocene.

Distribution: Restricted to the *Cc. margaritae* Zone of JOIDES Hole 5.

Genus *Sollasites* BLACK, 1967

Synonym: *Costacentrum* BUKRY, 1969

Sollasites tardus n. sp.

pl. III, figs. 2, 3

Diagnosis: A species of *Sollasites* with 22–26 elements in the proximal and distal shield and an elliptical ring connecting the arms of the central cross.

Description: The distal shield is composed of an outer cycle with 22–26 wedge-shaped elements which are dextrally imbricate; the sutures are inclined clockwise. The inner cycle slopes towards the central depression and is built of 22–26 tabular elements which are dextrally imbricate and with sutures that are inclined counterclockwise. The central depression is spanned by a cross aligned in the long and the short axis of the ellipse. The arms of the cross are connected with each other by an elliptical ring which lies in the middle of the central opening. The proximal shield consists of two cycles of segments, the outer cycle containing 22–26 wedge-shaped dextrally imbricate elements with radial suture lines. The inner cycle is only half as wide as the outer one and slopes towards the central depression. It has the same number of dextrally imbricate elements with sutures inclined counterclockwise.

Remarks: This is the only Tertiary species of the genus *Sollasites* which was thought to be restricted to the Upper Cretaceous. The general construction is so similar to other members of this genus that there is no need to create a new genus. *Sollasites lowei* (BUKRY) n.comb. [= *Costacentrum lowei* BUKRY, 1969, p. 44, pl. 22, figs. 5–6] has more numerous elements (32–36) and in proximal view the inner cycle of elements surrounding the central area is more clearly separated from the outer cycle of elements.

It is impossible that *Sollasites tardus* n.sp. was reworked from older strata because no other Cretaceous nannofossils were present in the samples where it was found.

Holotype: IMS-J 505427 [A 821].

Paratype: IMS-J 510471 [A 822].

Length: Holotype: 3.7 μ. Paratype: 4 μ.

Type locality: JOIDES Hole 5, Lat. 30°23′ N, Long. 81°08′ W, Blake Plateau.

Type level: Oligocene, 410′ below top.

Distribution: JOIDES Hole 5 and Alabama: *E. subdisticha* Zone and *R. laevis* Zone. Trinidad and Glimmerode (Germany): *Sph. predistentus–Sph. distentus* Zone.

Genus *Reticulofenestra* HAY, MOHLER & WADE, 1966

Synonyms: *Dictyococcites* BLACK, 1967

Apertapetra HAY, MOHLER & WADE, 1966

Reticulofenestra alabamensis n. sp.

pl. III, figs. 4, 5

Diagnosis: A small species of *Reticulofenestra* with narrow slits along the outer margin of the central grille.

Description: The distal shield is composed of two cycles of elements. The outer cycle contains 35–40 tabular elements which are strongly dextrally imbricate. The suture lines are radial at the periphery and bend sharply counterclockwise towards the center. The inner cycle is built of sinistrally imbricate tabular elements which are continuous with the bars of the central grille. There are slits between the bars of the grille along the periphery. These bars join in the center and form a slightly elevated area with irregular perforations. The central area is about half as large as the whole coccolith. The proximal shield is only a little smaller than the distal shield and is constructed of 35–40 wedge-shaped segments which are sinistrally imbricate. About every other element extends inwards as one of the grid bars. The intercalated elements end at the margin of the central area and form a slit.

Remarks: This species is distinguished from *Reticulofenestra foveolata* (REINHARDT) by a relatively smaller central grille area and by having an outer cycle of narrow slits and some very small pores in the elevated central portion of the grille. The pores in *Reticulofenestra insignita* ROTH & HAY are more numerous and the grille is more clearly separated from the marginal elements.

Holotype: IMS-A 600360 [A 823].

Paratype: IMS-A 600257 [A 823].

Length: Holotype: 3.2 μ, Paratype: 3.2 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Base of Red Bluff Fm.

Distribution: From the *E. subdisticha* Zone through the *R. laevis* Zone in JOIDES Hole 5. Restricted to the *Cc. margaritae* Zone in JOIDES Hole 6 and on Barbados. From the *E. subdisticha* Zone into the *Cc. margaritae* Zone in Alabama and Helmstedt (Latdorfian). Rare in the *Sph. predistentus–Sph. distentus* Zone of Trinidad.

Reticulofenestra biseceta (HAY, MOHLER & WADE) n. comb.

pl. III, fig. 6

1966 *Syracosphaera bisecta* HAY, MOHLER & WADE, p. 393, pl. 10, figs. 1-6.
1967 *Coccolithus stavenis* LEVIN & JOERGER, p. 165, pl. 1, figs. 7a-d.
1967 *Coccolithus bisectus* (HAY, MOHLER & WADE) BRAMLETTE & WILCOXON, p. 102, pl. 4, figs. 11-13.
1968 *Reticulofenestra dictyoda* (DEFLANDRE & FERT) of STRADNER in STRADNER & EDWARDS, pp. 19–20 (pro parte), pl. 13, figs. 1-2, pl. 14, figs. 2-4 (non pl. 12, figs. 1-3, pl. 14, fig. 1).
1968 *Stradnerius dictyodus* (DEFLANDRE & FERT) HAQ, pp. 31-32 (pro parte), pl. 2, figs. 7-8, pl. 3, figs. 1, 4-6 (non pl. 2, fig. 2, pl. 4, figs. 3-6).
1968 *Cycloplacolithella simplex* HAQ, pp. 25-26 (pro parte), pl. 8, fig. 8 (non pl. 8, figs. 9-10).
1969 *Dictyococcites dictyodus* (DEFLANDRE & FERT) MARTINI, pp. 133-134, pl. 1, fig. 5-6 (non pl. 4, fig. 35).

Remarks: Electron micrographs of the proximal side and etched specimens seen from the distal side prove that this species has a grille in the central hole, which is usually completely hidden below the plates covering the central area on the distal side, but visible in proximal view. The central opening as seen from the proximal side is small, about a third of the length of the whole coccolith. It is covered by a grille consisting of thick bars, each one being continuous with about every third shield element and meeting along the major axis of the ellipse.

Cycloplacolithella simplex HAQ is the isolated distal shield of *Reticulafenestra bisecta* with the plates which usually cover the center broken out. *Reticulafenestra bisecta* is similar to *Reticulofenestra hesslandii* (HAQ) but is distinguished from it by having more elements, regular crystal plates covering the central area, and by the smaller size of the coccolith.

Hypotypes: IMS-J 6-397-12-7 [A 825].

Distribution: From the upper Eocene through the Oligocene.

Reticulofenestra bisecta disappears close to the Oligocene-Miocene boundary and can be used to determine this boundary.

Reticulofenestra coenura (REINHARDT, 1966) n. comb.

1966 *Coccolithus coenurus* REINHARDT, p. 516-517, pl. 1, fig. 7, Text-fig. 6.
1967 *Coccolithus coenurus* REINHARDT, p. 207, pl. 2, figs. 2, 6, pl. 5, fig. 7.
1968 *Reticulofenestra dictyoda* (DEFLANDRE & FERT) of STRADNER in STRADNER & EDWARDS (pro parte), pl. 12, fig. 4 (non pl. 12, figs. 1-3, pl. 13, figs. 1-2, pl. 14, figs. 1-5).

Remarks: It is possible to distinguish the very similar species *Reticulofenestra coenura* (REINHARDT) from *Reticulofenestra umbilica* (LEVIN) which is larger, more broadly elliptical and has more elements in the shields.

Occurrence: Throughout the Oligocene except for the *Sphenolithus ciperoensis–Triquetrorhabdulus carinatus* Zone; more abundant in the lower Oligocene.

Reticulofenestra danica (BLACK) n. comb.

pl. IV, fig. 2

1967 *Dictyococcites danicus* BLACK, p. 141, fig. 2.

Remarks: Distal views of this species show clearly that it can be assigned to the genus *Reticulofenestra*. The central opening is surrounded by a cycle of imbricate wedge-shaped elements that can only be seen from the distal side. This is typical of the genus *Reticulofenestra*. The central area of *Reticulofenestra danica* is relatively larger than in *Reticulofenestra scissura* HAY, MOHLER & WADE and the grille bars are straighter, do not anastomose, and merge along the long axis of the ellipse whereas in *Reticulofenestra scissura* the grille bars are quite irregular, anastomising to produce elongate perforations. *Reticulofenestra bisecta* (HAY, MOHLER & WADE) is considerably larger than *Reticulofenestra danica*.

Hypotype: IMS-J 512389 [A 826].

Occurrence: JOIDES Hole 5: From the *E. subdisticha* Zone into the *R. laevis* Zone. JOIDES Hole 6: *Cc. margaritae* Zone. Alabama: *E. subdisticha* Zone. Glimmerode, N Germany: *R. laevis* through *Sph. predistentus–Sph. distentus* Zone. German Rupel, Clay pit Alversdorf, near Helmstedt: *Cc. margaritae* Zone.

Reticulofenestra falcata (GARTNER & SMITH) n. comb.

1967 *Coccolithus falcatus* GARTNER & SMITH, p. 3, pl. 1, figs. 5, 6.

Remarks: This species is rare from the Upper Eocene into the *Cyclococcolithus margaritae* Zone.

Reticulofenestra foveolata (REINHARDT) n. comb.

1966 *Coccolithus foveolatus* REINHARDT, p. 517, pl. 1, fig. 10.
1967 *Coccolithus foveolatus* REINHARDT, p. 208, pl. 5, figs. 6–9.
1969 *Reticulofenestra insignata* ROTH & HAY of MARTINI, pp. 135–136 (pro parte), pl. 4, fig. 41 (non pl. 2, figs. 15–16).

Remarks: This species differs from *Reticulofenestra insignita* ROTH & HAY in being smaller, in having a narrower rim with fewer elements and fewer and more elongate pores in the relatively larger central grille. *Reticulofenestra foveolata* is common from the upper Eocene into the *Cyclococcolithus margaritae* Zone whereas *Reticulofenestra insignata* first occurs in the uppermost part of the *Cyclococcolithus margaritae* Zone and ranges into the upper Oligocene.

Reticulofenestra gabrielae n. sp.

pl. IV, fig. 1

Diagnosis: A very small species of *Reticulofenestra* with relatively large central grille with about 50 round pores.

Description: The coccosphere seems to consist of about 20 coccoliths. The distal shields is composed of 18–22 wedge-shaped segment which are imbricate dextrally and separated by radial suture lines, which are not always straight but may be jagged. The central area is covered with a grille with about 50 perforations arranged in regular order more or less parallel to the ellipse. Proximal views are not known yet.

Remarks: As in *Reticulofenestra inclinata* n. sp. the wedges around the central grille are absent. It might be possible to create a new genus for these species but too much splitting does not seem advisable at the present time. All the species having a central grille consisting of bars are considered to belong to the genus *Reticulofenestra* whether they have a cycle of wedges surrounding the central hole or not. This species differs from *Reticulofenestra foveolata* (REINHARDT) in being smaller, and in having fewer elements but more small circular perforations.

Holotype: IMS-A 613010 [A 827].

Diameter of Coccosphere: 5 μ.

Length of Coccolith: 1.8 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm., 13′ above base. Oligocene.

Distribution: JOIDES Hole 5: *E. subdisticha* Zone to lower *Cc. margaritae* Zone. Alabama: Upper *E. subdisticha* Zone.

Reticulofenestra hesslandii (HAQ) n. comb.

pl. IV, figs. 3–5

1966 *Ericsonia hesslandii* HAQ, pp. 32–33, pl. 1, fig. 6, pl. 3, fig. 1, pl. 4, fig. 3, pl. 5, figs. 3, 5.

?1969 *Dictyococcites dictyodus* (DEFLANDRE & FERT) MARTINI, pp. 133–134 (pro parte), pl. 4, fig. 7 (non pl. 1, figs. 5–6).

Remarks: This species displays a great variability in shape, size and number of elements. It is distinguished from *Cyclococcolithus floridanus* (ROTH & HAY) by having a coarse central grille, which can be seen in etched specimen and proximal views, and by the less broadly elliptical shape. The proximal shield consists of about 60 elements. The central depression, about one-fifth the size of the whole shield, is covered with a grille consisting of irregular twisted bars.

Hypotypes: IMS-A 815110 [A 828]; IMS-A 600407 [A 829]; IMS-A 600470 [A 830].

Distribution: This species is one of the most abundant coccoliths in all the Oligecene sections studied so far and is found throughout the whole interval.

Reticulofenestra inclinata n. sp.

pl. V, fig. 2

Diagnosis: A species of *Reticulofenestra* consisting of a distal shield with chevron-shaped elements and a central grille with nearly straight bars and long intermediate slits.

Description: The narrowly elliptical shield consists of 34–40 tabular elements which are dextrally imbricate and form a chevron pattern. The suture lines are inclined counterclockwise in the outer half of the shield and turn sharply clockwise in the inner half of the shield. The central area, about two-thirds the size of the coccolith, is covered with a grill with straight bars which are continuous with elements of the shield and meet in the long axis of the ellipse. There are long wide slits between the bars.

Remarks: This species does not have the cycle of wedges around the central opening, which can be found in many other species of *Reticulofenestra*. *Reticulofenestra danica* (BLACK) does not have strongly bent suture lines causing a chevron-pattern.

Holotype: IMS-J 503480 [A 831].

Length: 3.8 μ.

Type locality: JOIDES Hole 5, Lat. 31°23′ N, Long. 80°08′ W, Blake Plateau.

Type level: 484′ below top, Oligocene.

Distribution: JOIDES Hole 5; Upper part of the *Cc. margaritae* Zone and *R. laevis* Zone.

Reticulofenestra laevis ROTH & HAY

pl. V, fig. 5

1969 *Reticulofenestra laevis* ROTH & HAY, HAY et al., p. 449, pl. 7, fig. 11.

Remarks: Only the proximal side was described in HAY & al., 1967. The distal shield consists of an outer cycle of 60–80 dextrally imbricate elements (not 140 elements as stated by ROTH & HAY, which was based on observation of etched and somewhat recrystallized specimens). The margin of the shield is finely serrate and creates the impression that the shield contains more shield elements than it does. The suture lines are inclined counterclockwise. The inner cycle of elements is composed of the same number of sinistrally imbricate plates which form a distinctly raised ring around the central opening.

Hypotype: IMS-A 100280 [A 832].

Distribution: *Reticulofenestra laevis* Zone to the middle of the *Sphenolithus distentus–Sphenolithus ciperoensis* Zone in Oligocene sections on both sides of the Atlantic.

Reticulofenestra minuta n. sp.

pl. V, figs. 3, 4

Diagnosis: A very small species of *Reticulofenestra* with 10–15 pores in the central grille.

Description: The distal shield is constructed of two cycles of elements. The outer one consists of 16–26 wedge-shaped elements which are dextrally imbricate. The sutures are inclined clockwise. The inner cycle contains the same number of dextrally imbricate plates separated by clockwise inclined suture lines. The margin of the inner cycle is serrate. The central depression, about one third the size of the coccolith is covered by a coarse grille with twisted bars. The proximal shield is of nearly the same size as the distal shield. It consists of 16–26 wedge-shaped elements with curved suture lines which are inclined counterclockwise.

Remarks: *Reticulofenestra foveolata* (REINHARDT) has a larger central area and more numerous pores.

Holotype: IMS-A 610130 [A 833].

Paratype: IMS-J 504136 [A 834].

Length: Holotype: 1.5 μ, Paratype: 2.0 μ.

Type locality: The Lone Star Cement Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm., 10′ above base. Oligocene.

Distribution: JOIDES Hole 5 and Alabama: *E. subdisticha* Zone through *R. laevis* Zone. Trinidad: *Sph. predistentus–Sph. distentus* Zone.

Reticulofenestra pectinata n. sp.

pl. V, fig. 1

Diagnosis: A small species of *Reticulofenestra* with a wide central opening, covered with a coarse grille.

Description: The distal shield is constructed of two cycles of elements; the outer one has 50–60 wedge-shaped dextrally imbricate elements. The suture lines are inclined clockwise. The margin of the shield is serrate. An inner cycle of 40–50 wedge-shaped sinistrally imbricate elements forms an elevated ring around the central depression. About every other element is continuous with a grid bar of the central grille. There are long slits between bars. The length of the central opening amounts to about two thirds of the length of the whole coccolith.

Remarks: *Reticulofenestra pectinata* n. sp. is distinguished from *Reticulofenestra alabamensis* n. sp. by a relatively larger central opening and more numerous elements in the shield. *Reticulofenestra insignita* ROTH & HAY is smoother and has a smaller central grille area with smaller, more regularly arranged pores.

Holotype: IMS-A 613664 [A 835].

Length: 3.5 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm., 13′ above base. Oligocene.

Distribution: From the *E. subdisticha* Zone through the *R. laevis* Zone of JOIDES Hole 5, 6, of Alabama, Clay pit. Alversdorf (Rupelton); Glimmerode, both N Germany.

Reticulofenestra scissura HAY, MOHLER & WADE, 1966

1966 *Reticulofenestra scissura* HAY, MOHLER & WADE, p. 387, pl. 5, figs. 1–6.

1968 *Reticulofenestra dictyoda* (DEFLANDRE & FERT) of STRADNER in STRADNER & EDWARDS, pp. 19–20 (pro parte), pl. 12, figs. 1–3, pl. 14, fig. 1 (non pl. 12, fig. 4, pl. 13, figs. 1–2, pl. 14, figs. 2–4).

1969 *Stradnerius dictyodus* (DEFLANDRE & FERT) HAQ, pp. 31–32 (pro parte), pl. 2, figs. 5–6, pl. 3, fig. 2, pl. 4, figs. 3, 6 (non pl. 2, figs. 7–8, pl. 3, figs. 1, 4–6).

?1969 *Reticulofenestra* cf. *insignita* ROTH & HAY of MARTINI, pl. 2, figs. 15–16.

Remarks: The author does not follow the opinions of STRADNER (1968) and HAQ (1968) who lumped many species of *Reticulofenestra* into the species *Reticulofenestra dictyoda* (DEFLANDRE & FERT). *Reticulofenestra scissura* is a distinct species and differs from the lectotype of *Reticulofenestra dictyoda* (DEFLANDRE & FERT) as selected by HAY, MOHLER & WADE, 1966, in having a more narrowly elliptical shape and a relatively larger central grille which is often not as well separated from the marginal elements as in *Reticulofenestra dictyoda* (DEFLANDRE & FERT). *Reticulofenestra dictyoda* (DEFLANDRE & FERT) of STRADNER (1968) and *Stradnerius dictyodus* (DEFLANDRE & FERT) of HAQ (1968) do not correspond with the lectotype of *Reticulofenestra dictyoda* (DEFLANDRE & FERT) (= specimen from Donzacq, DEFLANDRE &

FERT, 1954, Text-fig. 15). Therefore they must be assigned partly to *Reticulofenestra scissura* and partly to *Reticulofenestra bisecta* (HAY, MOHLER & WADE). *Reticulofenestra scissura* is similar to *Reticulofenestra bisecta* (HAY, MOHLER & WADE) but it is distinguished by its wider grille when seen from the proximal side and by its somewhat smaller size. Well preserved specimens of both species show a cover of plates over the central opening but the central area is relatively larger in *Reticulofenestra scissura*. This species is abundant from the Upper Eocene through the Middle Oligocene of many sections on both sides of the Atlantic.

Reticulofenestra umbilica (LEVIN) MARTINI & RITZKOWSKI, 1968

1965 *Coccolithus umbilicus* LEVIN, p. 265, pl. 41, fig. 2.
1966 *Reticulofenestra caucasica* HAY, MOHLER & WADE, pp. 386–387 (pro parte), pl. 2, fig. 5, pl. 3, figs. 1–2, pl. 4, figs. 1–2 (non pl. 2, figs. 6–8).
1966 *Apertapetra samodurovi* HAY, MOHLER & WADE, p. 387 (pro parte), pl. 6, figs. 1–3 (non pl. 6, figs. 4–7).
1967 *Coccolithus pelycomorphus* REINHARDT, p. 515, pl. 1, figs. 2, 6.
1968 *Reticulofenestra placomorpha* (KAMPTNER), STRADNER in STRADNER & EDWARDS, pp. 22–24 (pro parte), pl. 19, figs. 1–2, pl. 20, figs. 1–2, pl. 21, figs. 1–2, pl. 22, figs. 1–4, pl. 23, figs. 1–2, pl. 24, figs. 1–4, pl. 25, figs. 1a, 2 (non pl. 25, fig. 1b).
1968 *Discolithina cuvillieri* LÉZAUD, p. 22, pl. 2, figs. 1–4.
1968 *Reticulofenestra umbilica* (LEVIN) MARTINI & RITZKOWSKI, p. 245, pl. 1, figs. 11–12.
1969 *Reticulofenestra umbilica* (LEVIN) of MARTINI, pp. 137–138.

Remarks: STRADNER in STRADNER & EDWARDS (1968) gives a thorough description of this species but the author does not agree with his synonymy because he included too many species which can easily be distinguished and because it is not possible to prove that *Reticulofenestra umbilica* is identical with *Tremalithus placomorphus* KAMPTNER of which only a schematic drawing exists (see MARTINI, 1969). *Reticulofenestra bisecta* HAY, MOHLER & WADE is somewhat smaller, has a more elliptical grille made of stout bars and on the distal side the central area covered with plates is relatively smaller. Its range is also longer, i.e. into the *Triquetrorhabdulus carinatus–Sphenolithus belemnos* Zone, whereas *Reticulofenestra umbilica* disappears at the top of the *R. laevis* Zone. *Reticulofenestra coenura* (REINHARDT) is smaller and the pores in the central grille are more circular than in the elongate slits in *Reticulofenestra umbilica*. *Reticulofenestra samodurovi* (HAY, MOHLER & WADE) n.comb. [= *Apertapetra samodurovi* HAY, MOHLER & WADE, 1966, p. 387, pl. 6, figs. 4–7 (non pl. 6, figs. 1–3)] differs from *Reticulofenestra umbilica* in being smaller, having a relatively smaller central opening and having two shields of approximately the same size. *Reticulofenestra umbilica* can have a cover of plates over the central opening on the distal side which is typical for many species of the genus *Reticulofenestra*. The disappearance of *Reticulofenestra umbilica* is a good marker horizon to separate the middle from the upper Oligocene. It is abundant from the upper Eocene through the middle Oligocene.

Genus *Cyclococcolithus* KAMPTNER, 1954

pl. VI, figs. 1, 2

Cyclococcolithus arabellus n. sp.

Diagnosis: A small species of *Cyclococcolithus* consisting of 3 cycles of elements in the distal shield.

Description: The circular distal shield is constructed of an outer cycle with 42–46 narrow wedge-shaped elements which are dextrally imbricate and separated by sutures with a clockwise inclination on the inner third of the shield and a radial direction on the outer part of the shield. The middle cycle which surrounds a shallow central depression is built of strongly dextrally imbricate plates which are separated by radial suture lines. The central depression, about a third the size of the whole coccolith, is covered with a cycle of narrow tabular elements, sinistrally imbricate and with clockwise inclined sutures. The center can be pierced by a small hole less than one-tenth the diameter of the whole shield or it can be filled in completely. The proximal shield is of nearly the same size as the distal shield, which can be seen on distal views where the proximal side can be seen through the replica. Proximal views of this species are not known yet.

Remarks: The species differs from *Cyclococcolithus acclinis* LEVIN & JOERGER in being much smaller and in having a relatively smaller central opening. *Cyclococcolithus formosus* KAMPTNER has straight radial sutures, only two cycles in the distal shield, and is much larger.

Holotype: IMS-A 613443 [A 836].

Paratype: IMS-J 507364 [A 837].

Diameter: Holotype 3.6 μ, Paratype: 3.6 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm. 13′ above base.

Distribution: From the *E. subdisticha* Zone into the *Cc. margaritae* in JOIDES Hole 5 and in Alabama.

Cyclococcolithus ciperoensis n. sp.

pl. VI, figs. 3, 6

Diagnosis: A small species of *Cyclococcolithus* with 2 cycles of elements in the distal shield and a coarse central grille.

Description: The distal shield is composed of an outer cycle of 20–30 wedge-shaped elements which are dextrally imbricate, separated by curved suture lines, clockwise inclined near the center and counterclockwise inclined periphally. The inner cycle is built of 20–30 sinistrally imbricate narrow tabular crystals. The sutures are inclined strongly counterclockwise. The central opening as seen from the distal side is about a third the size of the coccolith. The proximal shield consists of 20–30 wedge-shaped segments, sinistrally imbricate, with suture lines inclined counterclockwise. An inner cycle contains about 20 granules which do not overlap each other but are separated by radial to slightly counterclockwise inclined suture lines. The central opening, about half the size of the distal shield if seen from the proximal side, is partly obstructed by bars forming a coarse grille. They are continuous with elements of the inner cycle.

Remarks: This species is distinguished from *Cyclococcolithus margaritae* ROTH & HAY by the greater number of elements, by the curved sutures on the distal shield, the flatter appearance of the whole coccolith, and the central grille. *Cyclococcolithus kingi* n. sp. is much larger and has a relatively larger central opening that can be covered completely by polygonal plates. In the center of *Cyclococcolithus ciperoensis* n. sp. there are only few thick bars separated by wide gaps.

Holotype: ETH - 291A-399 [A 838].

Paratype: ETH - 291A-510 [A 839].

Diameter: Holotype: 2.9 μ, Paratype: 2.75 μ.

Type locality: Cipero coast, Trinidad, Type locality of the *Gg. ciperoensis* Zone of BOLLI, 1957.

Type level: Cipero Fm. *Gg. ciperoensis* Zone.

Distribution: Only found in Trinidad from the *Sph. distentus–Sph. ciperoensis* Zone through the *Triquetrorh. carinatus- Sph. belemnos* Zone.

Cyclococcolithus floridanus (ROTH & HAY) n. comb.

pl. V, fig. 6

1967 *Coccolithus floridanus* ROTH & HAY in HAY et al., 1967, p. 445, pl. 6, figs. 1–4.
1967 *Cyclococcolithus neogammation* BRAMLETTE & WILCOXON, 1967, p. 104, pl. 1, figs. 1–3, pl. 4 figs. 3–5.

Remarks: A well preserved specimen seen from the distal side shows two cycles of elements covering the central depression. The outer cycle consists of strong dextrally imbricate tabular elements, the inner cycle of stout blocks of irregular shape. Typical of *Cycloccolithus floridanus* is the nonobstructed central opening when seen from the proximal side. The type of *Cyclococcolithus neogammation* BRAMLETTE & WILCOXON is a specimen illustrated in a light micrograph and no count of the elements is possible. However, the paratype illustrated in an electron micrograph by BRAMLETTE & WILCOXON (1967) is definitely the same as *Cyclococcolithus floridanus* which has priority as it was published a few weeks before *Cyclococcolithus neogammation*.

Hypotype: IMS J 3-397-12-11 [A 840].

Distribution: Throughout the upper Eocene to Oligocene in all the sections studied.

Cyclococcolithus formosus KAMPTNER

1963 *Cyclococcolithus formosus* KAMPTNER, p. 163, pl. 2, fig. 8.
1964 *Coccolithus lusitanicus* BLACK, p. 308, pl. 50, figs. 1–2.
1966 *Cyclococcolithus lusitanicus* (BLACK), HAY, MOHLER & WADE, p. 390, pl. 7, figs. 3–6.
1967 *Cyclococcolithus orbis* GARTNER & SMITH, p. 4, pl. 4, figs. 1–3.
1968 *Umbilicosphaera formosa* (KAMPTNER) REINHARDT in COHEN & REINHARDT, p. 295.

Remarks: The specimens observed agree well with the published descriptions and illustrations. *Cyclococcolithus formosus* disappears in the lowermost part of the *Cyclococcolithus margaritae* Zone in all the sections studied by the author and not in the upper part of the *Ericsonia subdisticha* Zone as mentioned by MARTINI (1969). The disappearance of the species forms a good marker horizon (datum level) which can be found worldwide. It separates the lower from the middle Oligocene.

Cyclococcolithus lunulus n. sp.

pl. VI, fig. 4

Diagnosis: A large species of *Cyclococcolithus* with a small central opening and 32–25 elements.

Description: The distal shield is very smooth and is composed of 32–25 wedge-shaped elements which are dextrally imbricate. The suture lines are radial near the central hole and turn sharply counterclockwise and maintain the same inclination over the rest of the shield. The shield is flat and slopes from the center towards the periphery. Proximal views are not yet known.

Remarks: This species is distinguished from *Cyclococcolithus inversus* (DEFLANDRE) in having sutures inclined in the opposite direction. *Cyclococcolithus leptoporus* (MURRAY & BLACKMAN) has a convex distal shield with more curved lines.

Holotype: IMS-J 518099 [A 841].

Diameter: 10 μ.

Type locality: JOIDES Hole 5, lat. 30°23 N, Long. 80°08′ W, Blake Plateau.

Type level: 460′ $5^1/_2$″ below top, Oligocene.

Distribution: Cc. margaritae and *R. laevis* Zones of JOIDES Hole 5, *Cc. margaritae* Zone of JOIDES Hole 6 and Barbados.

Cyclococcolithus kingi n. sp.

pl. 6, fig. 5, pl. 7, fig. 1

Diagnosis: A species of *Cyclococcolithus* with a very wide central area.

Description: The distal shield consists of two cycles of elements, an outer with about 50 tabular elements dextrally imbricate and separated by suture lines inclined counterclockwise near the center, spiraling clockwise peripherally. The inner cycle is constructed of 40–50 tabular segments which show a strong dextral imbrication. The sutures are inclined clockwise near the opening, bend sharply counterclockwise in the outer two thirds of the cycle. The central area is about half the size of the whole coccolith. The proximal and distal shields are composed of the same number of wedge-shaped segments. The sutures are inclined counterclockwise near the center and turn radially on the peripheral portion of the proximal shield. The central area is plugged by polygonal shaped plates arranged in a irregular manner; these seem to be delicate because they tend to break out and leave a big central hole that is more commonly observed in this species than the plugged center.

Remarks: This species differs from *Cyclococcolithus inversus* (DEFLANDRE) in having considerably larger central area and more strongly curved sutures.

Holotype: IMS-A 815022 [A 842].

Paratype: IMS-A 606025 [A 843].

Diameter: Holotype: 6 μ, Paratype: 5 μ.

Type locality: The Lone Star Cement Company Quarry St. Stephens, Alabama.

Type level: Marianna Lst., 15′ above base.

Distribution: From the *E. subdisticha* Zone through the *R. laevis* Zone in JOIDES Hole 5 and in Alabama, in the *Cc. margaritae* Zone of JOIDES Hole 6 and in the *Sph. predistentus–Sph. distentus* Zone of Trinidad.

Genus *Ilselithina* STRADNER, 1966

Synonym: *Hayella* ROTH, 1969 (non *Hayella* GARTNER, 1969)

Ilselithina fusa n. sp.

pl. VII, figs. 2, 3

Diagnosis: A species of *Ilselithina* having a distal shield with T-shaped elements and a proximal shield with overlapping tabular elements.

Description: The circular distal shield consists of 6–10 T-shaped elements with short cross pieces. It is delicate and usually damaged. The proximal shield is conical and opens towards the proximal side. It is composed of 10–15 tabular elements which are imbricate dextrally. The overlapping flange is distinctly raised on the distal side of the proximal shield as is the peripheral margin of the segment. The segments are thus interlocked like the tiles on a roof. These ridges merge in the center and form a central core which is pierced by a hole. The sutures on the proximal side of the proximal shield are straight and radial but twisted near the center.

Remarks: This species is distinguished from *Ilselithina iris* STRADNER by the lack of slots in the proximal shield and by the longer and more slender elements in the distal shield. It is also somewhat larger.

Holotype: IMS-A 608372 [A 844].

Paratype: IMS-A 600162 [A 845].

Diameter: Holotype: 2.4 μ, Paratype: 3 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm., 8 above base, Oligocene.

Distribution: From the *E. subdisticha* Zone through the *Cc. margaritae* Zone in JOIDES Hole 5, in the *Cc. margaritae* Zone in JOIDES Hole 6 and on Barbados. From the *E. subdisticha* Zone through the *R. laevis* Zone in Alabama. *E. subdisticha* Zone in the Silberberg beds, Helmstedt. *Cc. margaritae* Zone, Clay pit Alversdorf, near Helmstedt. *R. laevis* Zone into *Sph. predistentus–Sph. distentus* Zone Boom Clay, Belgium. *R. laevis* Zone, Kasseler Meeressande, Glimmerode.

Ilselithina iris STRADNER, 1966

1966 *Ilselithina iris* STRADNER in STRADNER & ADAMIKER, p. 339, Text-fig. 3a–d, pl. 3, fig. 5.
1968 *Ilselithina iris* STRADNER in STRADNER & EDWARDS, pl. 26–28, Text-fig. 3, pl. 28, figs. 1–6, pl. 29, figs. 1–6.
1969 *Hayella elegans* ROTH, p. 464, pl. 1, figs. 1–2.

Remarks: STRADNER (1968) has given a very thorough description of this species. It is common in the Upper Eocene and rare in the Middle Oligocene. It can be easily overlooked in the light microscope because it is small and lacks distinct features.

Genus *Coronocyclus* HAY, MOHLER & WADE, 1966

Coronocyclus serratus HAY, MOHLER & WADE

pl. VII, fig. 4

1966 *Coronocyclus serratus* HAY, MOHLER & WADE, p. 194, pl. 11, figs. 1–5.

Remarks: A well preserved specimen of this species shows that it actually consists of two superimposed cycles of elements. The upper ring is composed of 29 wedge-shaped elements which are imbricate dextrally. The lower cycle is built of about the same number of tabular elements, but these are sinistrally imbricate. As can be seen in the electron micrograph of a proximal side of this species there is an inner cycle of dextrally imbricate elongated crystal cubes. The specimens figured by HAY, MOHLER & WADE are corroded and misleading because the structure could not be determined exactly.

Hypotype: IMS J 3-4 22-20-11 [A 846].

Distribution: Throughout the Oligocene. Rare in most sections.

Family Rhabosphaeraceae LEMMERMANN, 1908

Genus *Rhabdosphaera* HAECKEL, 1894

Rabdosphaera vitrea (DEFLANDRE)

pl. VIII, fig. 6, pl. IX, fig. 1

1954 *Rhabdolithus vitreus* DEFLANDRE in DEFLANDRE & FERT, p. 157–158, pl. 12, figs. 28–29, Text-figs. 83–84.
1961 *Rhabdosphaera vitrea* (DEFLANDRE) BRAMLETTE & SULLIVAN, p. 147, pl. 5, figs. 16–17.
Non 1963 *Rhabdosphaera vitrea* (DEFLANDRE) of HAY & TOWE, p. 952–953, pl. 1, fig. 1.

Remarks: The form figured by HAY & TOWE 1963 is considered to belong to *Blackites creber* (DEFLANDRE) n.comb. [= *Rhabdolithus creber* DEFLANDRE in DEFLANDRE & FERT, p. 157, pl. 12, figs. 31–33, Text-figs. 81, 82]. The basal disc consists of a whirl of laths which are curved in a clockwise direction if seen from the proximal side. The slender stem is supported by four buttresses which are attached to the side of short bases. In the light microscope the thick basal pillar with the struts attached to the side gives the impression of a protruding ring and a short tapering ring above. The structure of this species is quite different from the species of *Blackites*.

Hypotypes: IMS-A 600269 [A 847], IMS-A 608189 [A 848].

Distribution: E. subdisticha Zone and *Cc. margaritae* Zone of JOIDES Hole 5, Alabama; *R. laevis* Zone, Glimmerode, N Germany.

Genus *Blackites* HAY & TOWE, 1962

Blackites amplus ROTH & HAY

pl. VII, fig. 6

1969 *Blackites amplus* ROTH & HAY in HAY et al., p. 445, pl. 7, fig. 10.

Remarks: Only the proximal view was described by ROTH & HAY, 1967. The distal view shows four distinct cycles. The outermost consists of radial trapezoidal elements. The second cycle contains strongly sinistrally imbricate plates showing clockwise inclined sutures that overlap the struts connecting these two outermost cycles forming a serrate margin. The third cycle consists of clockwise imbricate elements that end below the outer margin of the forth cycle. This innermost cycle consists of approximately 20 crystals and forms a collar for the circular opening (base of the spine). *Blackites spinosus* (DEFLANDRE) has a narrower third cycle (counted from the periphery).

Hypotype: IMS-J 503189 [A 849].

Distribution: From the *E. subdisticha* through the *Sph. distentus–Sph. ciperoensis* Zone in nearly all the Oligocene sections studied. *Blackites amplus* is a delicate species readily destroyed by recrystallization.

Blackites incompertus n. sp.

pl. VII, fig. 5, pl. VIII, figs. 1, 2

Diagnosis: A species of *Blackites* with a conical disc which is well separated from the stem.

Description: The basal disc as seen from the proximal side consists of an outer cycle of about 24 trapezoidal elements. The next inner cycle is composed of 50–60 strongly sinistrally imbricate plates separated by sutures which are inclined clockwise in the outer third and turn strongly counterclockwise in the inner part. They are continuous with laths building the stem. A third cycle surrounding the base of the stem and consisting of square crystals can only be seen in side view. The basal plate is clearly separated from the stem and the disc is conical. The stem thickens slightly in the lower third and then tapers regularly to form a sharp point.

Remarks: Blackites incompertus n. sp. differs from *Blackites creber* (DEFLANDRE) in having a flatter basal disc and in lacking a distinct collar at the base of the stem. *Blackites scabrosus* (DEFLANDRE) n. comb. has a smaller disc that protrudes only a little at the base of the fairly thick stem. *Rhabdosphaera perlonga* (DEFLANDRE) has a blunt rounded termination of the stem which is much thicker in the top third than near the base.

Holotype: IMS-A 610358 [A 850].

Paratypes: IMS-A 610105 [A 851]; IMS 610266 [A 852].

Length of the stem of holotype: 13 μ.

Diameter of disc of holotype: 3 μ.

Distribution: E. subdisticha Zone of Alabama. *Cc. margaritae* Zone through *R. laevis* Zone in JOIDES Hole 5. *E. subdisticha* Zone Pit Treue IV, near Helmstedt.

Blackites scabrosus (DEFLANDRE) n. comb.

1954 *Rhabdolithus scabrosus* DEFLANDRE in DEFLANDRE & FERT, p. 158, pl. 12, fig. 30, Text-fig. 85.
1961 *Rhabdosphaera scabrosa* (DEFLANDRE) BRAMLETTE & SULLIVAN, p. 147, pl. 5, figs. 11a–b.
1967 *Rhabdosphaera scabrosa* (DEFLANDRE) REINHARDT, p. 215, pl. 4, fig. 23, pl. 7, fig. 2.

Remarks: The electron micrograph published by REINHARDT (1967) proves that this species must be assigned to the genus *Blackites* since the basal disc contains several cycles of elements.

Distribution: Rare in the Silberberg formation near Helmstedt (Oligocene); found by LEVIN & JOERGER in the Oligocene of Alabama.

Blackites spinulus (LEVIN) n. comb.

pl. VIII, fig. 4

1965 *Rhabdosphaera spinula* LEVIN, p. 267, pl. 42, fig. 3.
1967 *Rhabdosphaera spinula* LEVIN, GARTNER & SMITH, p. 5, pl. 1, figs. 1–2a, b.

Remarks: Most specimens observed agree well with the original description and the electron micrographs given by GARTNER & SMITH (1967). The basal disc consists of three cycles of elements. Thus, this species is assigned to the genus *Blackites*. Some specimens like the one illustrated here have a larger base and a more conical trumpet-shaped stem which is thickest at the base and tapers uniformly.

Hypotype: IMS-A 600271 [A 853].

Distribution: From the *E. subdisticha* Zone into the *Cc. margaritae* Zone in Alabama, in JOIDES Hole 5; Silberberg Fm. near Helmstedt.

Genus *Bramletteius* GARTNER, 1969

Bramletteius variabilis n. sp.

pl. VIII, figs. 3, 5

Diagnosis: A species of *Bramletteius* with a symmetrical square or rounded appendage.

Description: The basal disc consists of two cycles with about 15–20 segments each, separated by a V-shaped groove. The flat appendage attached to the distal side of the disc is narrowest in the lowest part. It is symmetrical and either of rounded, oblong, or rectangular shape.

Remarks: Bramletteius variabilis n. sp. is distinguished from *Bramlettius serraculoides* GARTNER by the symmetrical shape of the flat appendage, which has rounded or angular corners but not beveled or notched corners.

Holotype: IMS-A 608432 [A 854].

Paratype: IMS-A 608420 [A 855].

Length of appendage of the holotype: 2.3 μ.

Length of appendage of the paratype: 2.8 μ.

Type locality: St. Stephens Quarry, Alabama.

Type level: Red Bluff Fm. 8′ above base.

Distribution: Only observed in the *E. subdisticha* Zone of Alabama.

Family Pontosphaeraceae LEMMERMANN, 1908

Genus *Pontosphaera* LOHMANN, 1902

Synonym: *Discolithina* LOEBLICH & TAPPAN, 1963

Pontosphaera alta n. sp.

pl. IX, figs. 2, 3

Diagnosis: A species of *Pontosphaera* with a high straight rim and 60–80 perforations.

Description: The rim consists of about 200 steeply inclined laths. The inclination is clockwise in proximal view. The rim seems to be about one third to half as high as the shield is long. The bottom of the lopadolith is concave when seen from the proximal side, and is composed of about 200 wedge-shaped laths. Only every second lath reaches the center. The 60–80 perforations, about 0.1 μ in diameter are arranged in an ellipse arround the periphery and more or less radially in the center.

Remarks: This species is distinguished from *Pontosphaera multipora* (KAMPTNER) (= *Pontosphaera vadosa* HAY, MOHLER & WADE of authors) by a much higher rim. *Pontosphaera discopora* SCHILLER is very similar but the pores are short conical tubular protrusions on the distal side. In *Pontosphaera alta* n. sp. the pores are not surrounded by craterlike depressions and they are relatively smaller.

Holotype: IMS-A 613138 [A 856].

Paratype: IMS-A 613386 [A 857].

Length: Holotype: 10 μ, Paratype: 12 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm. 13′ above base. Oligocene.

Distribution: *E. subdisticha* Zone through *R. laevis* Zone. JOIDES Hole 6: *Cc. margaritae* Zone Alabama: From the *E. subdisticha* Zone into the *Cc. margaritae* Zone.

Pontosphaera crucifera n. sp.[3]

pl. IX, figs. 4, 5

Diagnosis: A narrowly elliptical small species of *Pontosphaera* with a cross structure in the central opening and short stubs protruding into it.

Description: The rim is rather low and consists of about 44–50 laths which are inclined clockwise as seen from the proximal side. The bottom of the shield is composed of an outer cycle of about 40–50 granules and an inner cycle of about 30–40 wedge-shaped plates about half of which are continuous with short stubs that project into the central slots. The cross in the center displays a broad arm in the long axis of the ellipse and a less pronounced one in the short axis. On the distal side only a narrow cycle of strongly dextrally inclined laths surrounds the central depression with the cross and the indentations.

Remarks: This species differs from *Transversopontis zigzag* ROTH & HAY in having bridges in the axis of the ellipse, and in being smaller. *Transversopontis zigzag* has a more or less diagonal bridge.

Holotype: IMS-A 613652 [A 858].

Paratype: IMS-A 613643 [A 859].

Length: Holotype: 3.5 μ, Paratype: 2.5 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff, Fm. 13′ above base. Oligocene.

Distribution: JOIDES Hole 5: From the *E. subdisticha* Zone into the *R. laevis* Zone. Alabama: *E. subdisticha* Zone.

Pontosphaera multipora (KAMPTNER) n. comb.[4]

1948 *Discolithus multiporus* KAMPTNER, p. 5, pl. 1, fig. 9.
1965 *Discolithina multipora* (KAMPTNER ex DEFLANDRE) MARTINI in WHITTARD & BRADSHAW, p. 400.
1966 *Discolithina confossa* HAY, MOHLER & WADE, p. 392, pl. 9, figs. 1–9.
1966 *Pontosphaera vadosa* HAY, MOHLER & WADE, p. 391, pl. 9, fig. 4 (non pl. 8, figs. 1–3).
1967 *Discolithina distincta* (BRAMLETTE & SULLIVAN) LEVIN & JOERGER, p. 166, pl. 1, figs. 14–15.
1968 *Discolithina multipora* (KAMPTNER) of STRADNER & EDWARDS, pp. 35–37, pl. 32–35, Text-figs. 7a–b.

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[3] On charts listed as *Discolithina crucifera*

[4] On charts listed as *Discolithina multipora*

Remarks: STRADNER in STRADNER & EDWARDS (1968) gives a very thorough description and a complete synonymy. The Oligocene forms agree well with the description.

Distribution: Throughout the Oligocene in all the studied sections.

Pontosphaera rigida n. sp.[5])

pl. IX, fig. 6, pl. X, fig. 1

Diagnosis: A small species of *Pontosphaera* with 50–60 pores and an elevated central ridge on the distal side.

Description: From the distal side the rim is seen to contain very numerous spirally arranged laths. There are 12–14 notches in the peripheral part of the rim. 50–60 pores are arranged in ellipses around the central ridge in the long axis of the shield ellipse. It consists of parallel laths and is about as high as the rim. In proximal view one can see that a layer of about 60 steeply inclined laths with a clockwise inclination covers the rim. The central area is composed of 50–65 wedge-shaped elements with radial sutures. The round pores lie in a central area which is only about half as long as the whole shield.

Remarks: This species differs from *Pontosphaera multipora* (KAMPTNER) in having a central ridge and in the much smaller pores.

Holotype: IMS-JS 1847 445 [A 860].

Paratype: IMS-JS 1847 576 [A 861].

Length: Holotype: 3.0 μ, Paratype: 3.4 μ.

Type locality: Cipero Coast Trinidad, W.I.

Type level: Cipero Fm. *Gg. ampliapertura* Zone.

Distribution: Trinidad: *Sph. predistentus–Sph. distentus* Zone.

Genus *Transversopontis* HAY, MOHLER & WADE, 1966

Transversopontis rectipons (HAQ) n. comb.

1968 *Discolithina rectipons* HAQ, p. 39–40, pl. 7, figs. 7–9, pl. 11, fig. 1.

Remarks: This species agrees well with the original description. In the form observed in the Oligocene the two openings separated by the bridge tend to be somewhat smaller.

Distribution: Lower part of the *E. subdisticha* Zone, Alabama.

Genus *Helicopontosphaera* HAY & MOHLER, 1967

Helicopontosphaera compacta (BRAMLETTE & WILCOXON) n. comb.

pl. X, figs. 2, 4

1967 *Helicosphaera compacta* BRAMLETTE & WILCOXON, p. 105, pl. 6, figs. 5–8.

Remarks: The flange of this broadly elliptical lopadolith contains 120–150 tabular elements which are sinistrally imbricate. It surrounds the floor somewhat more than one and one-half times. On the convex side of the lopadolith the floor is notched along

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5) On charts listed as *Discolithina rigida*

the margin and consists of 70–90 tabular elements separated by radial suture lines; some of those elements pinch out before reaching the center. On the concave side the floor is covered with spirally arranged laths. Two small elliptical holes lie in the center and are separated by a narrow bridge.

Hypotypes: IMS-JS 1847 490 [A 862]; IMS-JS 1847 502 [A 863].

Distribution: From the *I. recurvus* Zone through *Sph. distentus–Sph. ciperoensis* Zone in Alabama, Trinidad, Italy, JOIDES Hole 5, 6; Mt. Cagnero (Italy), Silberberg Fm. (Helmstedt).

Helicopontosphaera euphratis (HAQ) MARTINI

1966 *Helicosphaera euphratis* HAQ, p. 33, pl. 3, figs. 1, 3.
1967 *Helicosphaera parallela* BRAMLETTE & WILCOXON, p. 106, pl. 5, figs. 9–10.
1969 *Helicopontosphaera euphratis* (HAQ) MARTINI, p. 136.

Remarks: Helicopontosphaera euphratis (HAQ) was originally described from core VB 40, level 9.5 cm in a borehole drilled near the village Taba, NW Syria (see HAQ, 1966). The strata at this level were thought to be of late Eocene age. Further studies of the planktonic foraminifera revealed a late Oligocene age for the type level of this species (Zone P. 19 to N. 3 for the whole core according to HAQ, personal communication, 1969). The specimens observed in samples from Trinidad, Alabama, JOIDES Holes 3 and 5, and Northern Germany agree well with the original description and electron micrographs. Electron and light microscopic investigations of the same samples clearly indicate that *Helicosphaera parallela* BRAMLETTE & WILCOXON (of which only light micrographs were published) and *Helicopontosphaera euphratis* (HAQ) MARTINI (which was based only on electron micrographs) are identical and thus synonymous.

Helicopontosphaera euphratis (HAQ) consists of 80–100 tabular elements which are dextrally imbricate. The flange is more flaring and the overall shape is more narrowly elliptical than in *Helicopontosphaera compacta* (BRAMLETTE & WILCOXON). The central depression is commonly completely covered by parallel laths which are not continuous with the flange elements and which are broader than those. In some specimens two small perforations were observed at the ends of the long axis of the central depression.

Distribution: E. subdisticha Zone through *Triq. carinatus–Sph. belemnos* Zone.

Helicopontonsphaera intermedia (MARTINI)

pl. X, fig. 6

1965 *Helicosphaera intermedia* MARTINI, p. 404, pl. 35, figs. 1–2.
1967 *Helicopontosphaera intermedia* (MARTINI) HAY & MOHLER in HAY et al., p. 448.

Remarks: The floor of the lopadolith contains about 80 elements but about every third one pinches out and does not reach the center. The flange contains about 120 elements and is strongly flaring. The two fairly large holes in the center are separated by an oblique bridge. They are not partly obstructed by a grille as in *Helicopontosphaera seminulum* (BRAMLETTE & SULLIVAN) but completely open.

Hypotype: IMS-JS 20 462 [A 864].

Distribution: Throughout the Oligocene in most of the studied sections.

Helicopontosphaera reticulata (BRAMLETTE & WILCOXON) n. comb.

pl. X, fig. 5

Helicosphaera reticulata BRAMLETTE & WILCOXON, p. 106, pl. 6, fig. 15.

Remarks: The floor of this broadly elliptical lopadolith is built of about 60 laths which meet in the middle of the olique bridge. It is pierced by about 12 holes which lie in irregular rows on either side of the bridge. The flange does not flare strongly and extends around the floor only about one and one-third times. It contains about 150 elements. This species is rare and thus difficult to use as a zonal marker.

Hypotype: IMS-JS 1066 047 [A 865].

Distribution: E. subdisticha Zone in Alabama and Barbados, *E. subdisticha* through *R. laevis* Zone in JOIDES Hole 5.

Helicopontosphaera seminulum (BRAMLETTE & SULLIVAN) n. comb.

1961 *Helicosphaera seminulum* BRAMLETTE & SULLIVAN, p. 144, pl. 4, figs. 1–4.
1962 *Helicosphaera seminulum* BRAMLETTE & SULLIVAN; HAY & TOWE, p. 512, pl. 1, figs. 1, 2 (non pl. 1, figs. 3–6).
1967 *Helicosphaera carteri* (WALLICH), LEVIN & JOERGER, p. 168, pl. 2, figs. 12a–c.
1962 *Helicosphaera seminulum* BRAMLETTE & SULLIVAN; GARTNER & SMITH, p. 5, pl. 7, figs. 1–4.
1968 *Helicosphaera seminulum* BRAMLETTE & SULLIVAN; STRADNER & EDWARDS, pp. 38–39, pl. 39, 40.

Remarks: The forms observed agree well with the oiiginal description and the many electron micrographs figured in the literature (esp. GARTNER & SMITH (1967), STRADNER & EDWARDS (1968). Characteristic is the grille that covers the central pores.

Distribution: Paleocene to Upper Oligocene. Abundant species in the Oligocene of all studied sections.

Helicopontosphaera truncata (BRAMLETTE & WILCOXON) n. comb.

pl. X, fig. 3

1967 *Helicosphaera truncata* BRAMLETTE & WILCOXON, pp. 106–107, pl. 6, figs. 13–14.

Remarks: This species has a well separated floor containing about 50 segments separated by radial suture lines. The bridge is quite broad and consists of laths which are parallel to it and continuous with rim elements. The flange is composed of about 100 elements and sharply truncate at the end of the flare. *Helicopontosphaera recta* (HAQ) MARTINI is very similar but has somewhat smaller central openings separated by a narrower bridge.

Hypotype: IMS-JS 20 008 [A 866].

Distribution: Rare in the *Sph. distentus–Sph. ciperoensis* Zone and in the *Sph. ciperoensis–Triq. carinatus* Zone of Trinidad.

Family Syracosphaeraceae LEMMERMANN, 1908

Genus *Cepekiella* n. gen.

Diagnosis: A coccolith consisting of two shields which are connected by short struts. The center is covered with a cupula composed of spirally arranged laths which is attached to the distal shield by struts.

Type species: Cepekiella elongata n. sp.

Discussion: Cepekiella n. gen. differs from the Genus *Naninfula* Perch-Nielsen in having an imperforate and much flatter cupula.

Cepekiella elongata n. sp.

pl. XI, figs. 1, 2

Diagnosis: An elliptical species of *Cepekiella* with about 55–65 elements in the distal shield.

Description: The elliptical distal shield is concave distally and is composed of 55–65 tabular elements which are imbricate sinistrally. Every element is connected by a slim strut with the short central tube. The strongly imbricate spirally arranged plates of the central cupula and the 2–3 struts supporting each of the 30–35 trapezoidal elements of the proximal shield are attached to this central tube. It is built of the fused middle section of the angular struts which seem to be continuous from the proximal to the distal shield.

Remarks: This species differs from *Cepekiella hayi* (STRADNER) in being more narrowly elliptical and in having a wider distal shield.

Holotype: IMS-A 613 574 [A 867].

Paratype: ETH-68-60-806 [A 668].

Length of holotype: 4 μ, of paratype: 4.5 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Fm. 13′ above base.

Distribution: From the *E. subdisticha* Zone through the *R. laevis* Zone in the JOIDES Blake Plateau cores in Alabama; *Sph. predistentus–Sph. distentus* Zone in Trinidad; the *E. subdisticha* Zone in Helmstedt, N Germany.

Cepekiella hayi (STRADNER) n. comb.

pl. XI, fig. 3

1968 *Blackites hayi* STRADNER; STRADNER & EDWARDS, p. 32, figs. 6, 7, Text-figs. 5a, b.

Remarks: The specimens figured by STRADNER & EDWARDS (1968) were badly damaged. On better preserved specimens it can be seen that this species is very broadly elliptical (as is the specimen in STRADNER & EDWARDS, pl. 31, fig. 6) and is composed of a distal shield of 60–71 trapezoidal segments which are imbricate sinistrally and separated by counterclockwise inclined sutures. Short angular struts connect the elements of the distal shield with the 30–35 trapezoidal elements of the proximal shield. In the middle where they bend they are fused to form a short tube. The central cupula is joined to the central tube and consists of elongated crystals from the margin to the centre. *Cepekiella elongata* n. sp. has larger tabular crystals in the peripheral part and narrow laths in the center.

Hypotype: ETH-68-70-855 [A 869].

Distribution: E. subdisticha Zone JOIDES Hole 5, Alabama, *E. subdisticha* and *Cc. margaritae* Zone of Helmstedt, Northern Germany.

Genus *Discoturbella* n. gen.

Diagnosis: A coccolith consisting of one elliptical shield and high central cupula made of a whirl of elongate crystals.

Type species: Discoturbella moori n. sp.

Discussion: Naninfula PERCH-NIELSEN is distinguished from *Discoturbella* n. gen. in having a perforate cupula. *Cepekiella* n. gen. has two shields and a much lower cupula than *Discoturbella* n. gen.

Discoturbella moori n. sp.

pl. XI, fig. 4

Diagnosis: A small species of *Discoturbella* with a high cupula.

Description: The cycle of elements consists of 35–40 trapezoidal segments. Long struts connect it with a central cupula which can be as high as the coccolith is long or much lower. It consists of elongate strongly imbricate plates forming a whirl-pattern.

Remarks: This species differs from *Cepekiella elongata* n. sp. in having only one shield and in having a much higher central cupula. *Calyptrolithus morionium* DEFLANDRE is similar in shape but has a small conical elevation on the cupula. Its ultrastructure is unknown.

Holotype: IMS 608 297 [A 870].

Length of holotype: 2 μ.

Type locality: The Lone Star Cement Company Quarry, St. Stephens, Alabama.

Type level: Red Bluff Formation.

Distribution: JOIDES Hole 5: *Cc. margaritae* Zone. Alabama: *E. subdisticha* Zone and *R. laevis* Zone.

Family Zygosphaeraceae BRAARUD & GAARDER, 1961, emend.

Diagnosis: Holococcoliths formed only of microcrystals of usual crystallographic shape, identical or not. Shape of holococcolith variable, disciform, calyptroform or zygoform.

Type: Zygosphaera KAMPTNER.

The following genera can be assigned to this family:
Calyptrosphaera, *Zygosphaera*, *Zygrhablithus*, *Homozygosphaera*, *Holodiscolithus* n. gen., *Clathrolithus*.

Genus *Zygosphaera* KAMPTNER, 1958

Synonym: *Orthozygus* BRAMLETTE & WILCOXON, 1967.

Zygosphaera aurea (STRADNER) STRADNER

1962 *Zygolithus aureus* STRADNER, pp. 368–369, pl. 1, figs. 31–36.
1967 *Orthozygus aureus* (STRADNER) BRAMLETTE & WILCOXON, p. 116, pl. 9, fig. 1–4.
1968 *Zygosphaera aurea* STRADNER, STRADNER & EDWARDS, p. 46, pl. 44, fig. 6.

Remarks: The forms observed are very similar to the original description and figures and to the figure in STRADNER and EDWARDS (1968). The variability of this species is great. Some specimens have 12 or more perforations in the central bridge, others only six. This species is quite abundant in the Alabama section which shows indications of shallow water, but it is missing in the deep water sediments of JOIDES Hole 5.

Zygosphaera brytika n. sp.

pl. XII, fig. 1

Diagnosis: A species of the genus *Zygosphaera* with a high rim and a narrow X-shaped bridge.

Description: The shape of this species is elongate hexagonal. The rim consists of about 12 rows of crystal cubes arranged quincuncially. The narrow X-shaped bridge is broader at the base but consists of only one row of crystals at the top. It is elevated in the center.

Remarks: This species differs from *Zygosphaera aurea* (STRADNER) in having an X-shaped bridge instead of a perforated wide bridge. *Zygolithus minutus* PERCH-NIELSEN has an H-shaped bridge.

Holotype: A 608 014 [A 871].

Distribution: Restricted to the *E. subdisticha* Zone of Alabama.

Genus *Holodiscolithus* n. gen.

Diagnosis: Elliptical single plate with perforations composed of small crystal cubes in the manner of holococcoliths. Does not exhibit birefringence under crossed nicols.

Type species: Holodiscolithus macroporus (DEFLANDRE).

Remarks: The genus *Discolithina* is a heterogeneous collection. LOEBLICH & TAPPAN designated as type species *Discolithina vigintiforatus* (KAMPTNER) which, according to STRADNER & EDWARDS 1968, falls within the variation of *Discolithina multipora*. The proximal surface of *Discolithina multipora* shows radial sutures, the distal surface spiral sutures. Thus, the central area and the bevelled rim consist of two layers of laths like in members of the genus *Pontosphaera* which has priority.

Holodiscolithus n. gen. does not show any of the characteristic features of the type of *Pontosphaera*. Rim and central area are composed of regular crystal cubes as in *Zygrhablithus* and other holococcoliths. This can be seen only in the electron microscope but the result of this construction is the lack of birefringence under crossed nicols in the light microscope. *Zygrhablithus* possesses a bridge and a stem, but is of similar basic construction.

Holodiscolithus macroporus (DEFLANDRE) n. comb.

pl. XI, fig. 6

1954 *Discolithus macroporus* DEFLANDRE in DEFLANDRE & FERT, v. 40, p. 24, pl. 11, fig. 5.
1962 *Discolithus macroporus* DEFLANDRE; STRADNER, p. 365, pl. 1, figs. 1–13.
1964 *Discolithus macroporus* DEFLANDRE; COHEN, p. 236, pl. 3, figs. 5a–c, pl. 4, figs. 6a–b.
1965 *Discolithus macroporus* DEFLANDRE; COHEN, p. 15, pl. 3, figs. u.
1967 *Discolithina macroporus* (DEFLANDRE), LEVIN & JOERGER p. 167, pl. 2, fig. 5.

Remarks: COHEN 1964 gives a thorough description of this species. He does not discuss the construction of this species, but one can see on the electron micrograph (pl. 4, fig. 6b) that it is built of crystal cubes about 0.1 μ in diameter.

Hypotype: IMS-A 600 088 [A 872].

Distribution: JOIDES Hole 5: *Cc. margaritae* Zone. Alabama: From the *E. subdisticha* Zone into *Cc. margaritae* Zone. Glimmerode, Northern Germany: *Sph. predistentus–Sph. distentus* Zone.

Holodiscolithus solidus (DEFLANDRE) n. comb.

pl. XI, fig. 5

1954 *Discolithus solidus* DEFLANDRE in DEFLANDRE & FERT, p. 141, pl. 12, figs. 14–16.
1961 *Discolithus solidus* DEFLANDRE of BRAMLETTE & SULLIVAN, pp. 143–144, pl. 3, figs. 14a–c, 16.
1965 *Discolithus solidus* DEFLANDRE of SULLIVAN, p. 34, pl. 4, figs. 8a, b.
1967 *Discolithina solida* (DEFLANDRE), LEVIN & JOERGER, p. 168, pl. 2, figs. 12a–c.

Remarks: This elliptical form agrees well with the original description in the general outline and the arrangement of the pores. The elements that make up this species are cubes arranged in layers parallel to the shield.

Hypotype: IMS-A 608 343 [A 873].

Distribution: JOIDES Hole 5: From the *E. subdisticha* Zone through the *R. laevis* Zone. Alabama: From the *E. subdisticha* Zone into the *Cc. margaritae* Zone. Trinidad: *Sph. predistentus–Sph. distentus* Zone.

Genus *Clathrolithus* DEFLANDRE, 1954

Clathrolithus minutus BRAMLETTE & SULLIVAN

pl. XII, fig. 2

1961 *Clathrolithus minutus*, BRAMLETTE & SULLIVAN, p. 157, pl. 10, fig. 18.

Remarks: The observed specimens are similar to the original illustrations of the species. The reticulate body consists of crystal cubes and is thus a holococcolith. It is rare in the *E. subdisticha* Zone and in the very base of the *Cc. margaritae* Zone of Alabama.

Hypotype: IMS-A 809 098, [A 874].

Family Discoasteraceae VEKSHINA, 1959

Genus *Discoaster* TAN SIN HOK, 1927

Discoaster rufus n. sp.

pl. XII, fig. 3

1968 *Discoaster* sp. BLACK, pl. 153, fig. 1.

Diagnosis: A small species of *Discoaster* with five rays showing crystal faces.

Description: The rays are short and have rounded ends, and each one consists of a rhombohedron showing crystal faces. The interray spaces are regular. In the center there is a hexagonal crater-like depression. The sutures between the rays are straight and radial.

Remarks: This species differs from *Discoaster aster* BRAMLETTE & RIEDEL in having rays of a more regular shape and in having radial sutures and a central crater.

Holotype: IMS-J 3-397-7-6 [A 875].

Type locality: JOIDES Hole 3, Blake Plateau, Long. 28°30′N Lat. 77°31′W.

Type level: 397′ below sea floor, Oligocene.

Distribution: Cc. margaritae Zone through *Sph. predistentus–Sph. distentus* Zone.

Discoaster tani nodifer BRAMLETTE & RIEDEL

pl. XII, fig. 4

1954 *Discoaster tani nodifer* BRAMLETTE & RIEDEL, pp. 397–398, pl. 39, fig. 2.

Remarks: The specimens encountered in the samples studied are identical with the type species. The central star can be seen clearly. The arms show indications of a ridge. The species is rare in the lower Oligocene.

Hypotype: IMS-A 800 046 [A 876].

Discoaster trinus STRADNER

pl. XII, fig. 5

1959 *Discoaster molengraffi* TAN of STRADNER, pl. 1085, Text-figs. 15, 24.
1961 *Discoaster trinus* STRADNER, p. 85, text-fig. 85.

Remarks: The electron microscope reveals many crystal faces on the rays. It can be seen that it is built like a hemidiscoaster. The species occurs rarely in the lower Oligocene.

Hypotype: IMS-J 3-75-9-1 [A 877].

Discoaster woodringi BRAMLETTE & RIEDEL

pl. XII, fig. 6

1956 *Discoaster woodringi* BRAMLETTE & RIEDEL 1956, p. 400, pl. 39, figs. 8a–b.

Remarks: The forms observed compare well with the original illustration. Some specimens show a less raised center and others deeper groves between the rays than shown on the original illustrations. The species is found from the *Cc. margaritae* Zone through the *Sph. distentus–Sph. ciperoensis* Zone in the JOIDES Holes 3, 5 in Trinidad, in Alabama and in Italy.

Holotype: JMS-J 30 005 [A 878].

Family Lithostromationaceae HAQ, 1967

Genus *Lithostromation* DEFLANDRE, 1942

Lithostromation perdurum DEFLANDRE

pl. XIII, figs. 1, 2

1942 *Lithostromation perdurum* DEFLANDRE, pp. 917–919, Text-figs. 1–9.

Remarks: The variability of this species is great. From 5 to more than 15 depressions were counted. No crystal elements could be observed and it seems that this form consists of one crystal.

Hypotypes: IMS-J 509 209 [A 879]; IMS-A 800 072 [A 880].

Distribution: Rare specimens from the *E. subdisticha* Zone to the *R. laevis* Zone in Alabama and JOIDES Hole 5.

Family Triquetrorhabdulaceae LIPPS, 1969

Genus *Triquetrorhabdulus* MARTINI, 1965

Triquetrorhabdulus carinatus MARTINI

pl. XIV, fig. 6

1965 *Triquetrorhabdulus carinatus* MARTINI, p. 408, pl. 26, figs. 1–3.
1969 *Triquetrorhabdulus carinatus* MARTINI; LIPPS, p. 1030, pl. 126, figs. 1–4.

Remarks: The specimens observed agree well with the original description and with the very thorough description by LIPPS (1969).

Hypotype: IMS-Bo 291 A 458 [A 881].

Distribution: Sph. ciperoensis–Triq. carinatus Zone to *Triq. carinatus–Sph. belemnos* Zone.

Family Sphenolithaceae VEKSHINA, 1959

Genus *Sphenolithus* DEFLANDRE, 1954

Sphenolithus belemnos BRAMLETTE & WILCOXON

pl. XIII, figs. 5, 6

1967 *Sphenolithus belemnos* BRAMLETTE & WILCOXON, p. 118, pl. 2, figs. 1–3.

Remarks: Only small specimens were observed in the samples studied. The dart-shaped sphenolith has a basal cycle of about 12 elements. The apical spine begins with another cycle of irregular segments and the upper half of the spine is built of about four wedge-shaped elements which taper to form a fairly sharp point.

Hypotypes: IMS-J 3-270-18-8 [A 882]; IMS-JS 267* 083 [A 883].

Distribution: Triq. carinatus–Sph. belemnos Zone and younger (not studied in this paper).

Sphenolithus ciperoensis BRAMLETTE & WILCOXON

pl. XIII, fig. 4, pl. XIV, figs. 1, 2

1967 *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON, p. 120, pl. 2, figs. 15–18, and aff. in figs. 19–20.

Remarks: BRAMLETTE & WILCOXON gave only light micrographs of this species. While studying samples from JOIDES Blake Plateau Hole 3, well preserved specimens of this species were observed in the electron microscope. The basal cycle of elements consists of 10–15 wedge-shaped crystals. The apical spine is built of four elongated segments which taper to form a sharp point; two of the segments may continue into the extended bifurcations. The part below the bifurcation is much shorter than in the bifurcated specimens of *Sphenolithus distentus* (MARTINI).

Hypotypes: IMS-J3-306-16-7, [A 884]; IMS-J3-270-18-2 [A 885]; IMS-JS 267* 070 [A 886].

Distribution: From the *Sph. distentus–Sph. ciperoensis* Zone into the *Triq. carinatus–Sph. belemnos* Zone in Trinidad and JOIDES Hole 3.

Sphenolithus distentus (Martini) Bramlette & Wilcoxon

pl. XIII, figs. 3, 7

1965 *Furcatolithus distentus* Martini, p. 407, p. 135, figs. 7–9.
1967 *Sphenolithus distentus* (Martini) Bramlette & Wilcoxon, p. 112, pl. 1, fig. 5, pl. 2, figs. 4, 5.

Remarks: Well preserved specimens of this species were found in JOIDES Hole 3 samples and compare well with specimens from the Cipero Coast samples. The basal cycle consists of about 12 wedges, the apical spine seems to be composed of only four wedge-shaped elements, two of which are continuous with the bifurcations. The shaft from the basal cycle to the bifurcation is longer than in *Sphenolithus ciperoensis* Bramlette & Wilcoxon and the basal disc is not much broader than the base of the apical spine whereas in *Sphenolithus ciperoensis* it is distinctly wider.

Hypotypes: IMS-J3-397-13-5 [A 887]; IMS-J3-422-10-10 [A 888].

Distribution: From the *Sph. predistentus–Sph. distentus* Zone through the *Sph. distentus–Sph. ciperoensis* Zone in Trinidad, Alabama, Italy (Monte Cagnero), Belgium (Boom Clay), Nothern Germany (Glimmerode, Kasseler Meeressande).

Sphenolithus moriformis (Brönnimann & Stradner) Bramlette & Wilcoxon

pl. XIV, figs. 3, 4

1960 *Nannoturbella moriformis* Brönnimann & Stradner, p. 386, figs. 11–16.
1965 *Sphenolithus pacificus* Martini, p. 407, pl. 36, figs. 7–10.
1967 *Sphenolithus moriformis* (Brönnimann & Stradner) Bramlette & Wilcoxon, pp. 124–125, pl. 3, figs. 1–6.

Remarks: Two different but intergrading forms could be observed in the electron microscope. The two extreme types are illustrated here. One has a basal cycle of 8–10 long slender spines, projecting downward, a middle section of about 20 spines sticking out radially, and 3–4 slender spines on top (Fig. 4). The other has about the same number of spines but they are shorter, blunter and more wedge-shaped. The whole body is shorter and more round, almost hemispherical (Fig. 3).

Hypotypes: IMS-J3-475-11-1 [A 889]; IMS-J3-381-20-5 [A 890].

Distribution: Throughout the Upper Eocene and Oligocene.

Sphenolithus tribulosus n. sp.

pl. XIV, figs. 5, 7, 8

Diagnosis: A species of *Sphenolithus* with a small base and a large apical spine covered with about six serrate longitudinal ridges.

Descriptions: The base is depressed and consists of 10–12 slender elements. The apical spine expands in the lower third and protrudes more than the basal elements. In the upper two thirds it tapers regularly to form a pointed or bifurcated tip which consists of two crystalls separated by a depressed suture line. The apical spine carries six serrate ridges consisting of subparallel laths which point in the direction of the tip of the apical spine and form a 20–45° angle with the axis of the spine. The serrate margin of the apical spine can be discerned in the light microscope.

Remarks: This species differs from *Sphenolithus predistentus* BRAMLETTE & WILCOXON in having serrate ridges on the apical spine and in showing nearly complete extinction between crossed nicols when the apical spine is parallel to either nicol. The surface sculpture of *Sphenolithus predistentus* is smooth, and in polarized light the apical spine is brightly illuminated even when parallel to either nicol.

Holotype: IMS-A 608 504 [A 891].

Paratype: A 613-L 001 A + B [A 892, A 893].

Length of Holotype: 6,5 μ.

Occurrence: Sphenolithus tribulosus n. sp. occurs with *Sphenolithus predistentus* in the *E. subdistichus* Zone and in the *Cc. margaritae* Zone of Alabama, but is rare in the *Sph. predistentus–Sph. distentus* Zone of Trinidad. (NOTE: *Sphenolithus tribulosus* n. sp. is not listed on the range charts.)

Check list of species

Unless stated otherwise only the type reference is given. If another reference is mentioned, the reason is indicated by the following abbreviations:

EM: good electron micrograph
LM: good light micrograph
D: detailed description

Coccolithus joensuui ROTH & HAY in HAY et al., 1967, pp. 445–446, pl. 6, fig. 5.

Coccolithus paralitos ROTH & HAY in HAY et al., p. 446, pl. 6, fig. 6.

Coccolithus parvulus (DEFLANDRE & FERT) STRADNER [= *Tremalithus parvulus* DEFLANDRE & FERT, 1954, p. 154, pl. 14, fig. 6]. EM: STRADNER & EDWARDS, 1968, p. 16, pl. 7, figs. 1–2.

Coccolithus sarsiae BLACK, 1962, p. 125, pl. 8, fig. 2, pl. 9, figs. 2–6.

Cruciplacolithus tarquinius ROTH & HAY in HAY et al., 1967, p. 446, pl. 6, fig. 8.

Chiasmolithus californicus (SULLIVAN) HAY & MOHLER [= *Coccolithus californicus* SULLIVAN, 1964, p. 180, pl. 1, figs. 7a–d]. EM: HAY & MOHLER, 1967, p. 1527, pl. 196, figs. 18–20, pl. 198, fig. 5.

Chiasmolithus consuetus (BRAMLETTE & SULLIVAN) HAY & MOHLER [= *Coccolithus consuetus* BRAMLETTE & SULLIVAN, 1961, p. 139, pl. 1, figs. 2a–c]. EM: HAY & MOHLER, 1967, p. 1526, pl. 196, figs. 23–25, pl. 198, fig. 16.

Chiasmolithus grandis (BRAMLETTE & RIEDEL) n. comb. [= *Coccolithus grandis* BRAMLETTE & RIEDEL, 1954, p. 391, pl. 38, figs. 1a–b]. LM, D: BRAMLETTE & SULLIVAN, p. 140, pl. 2, figs. 1a–b, 2a–c, 3.

Reticulofenestra dupouyi (DEFLANDRE & FERT) HAY, MOHLER & WADE [= *Discolithus dupouyi* DEFLANDRE & FERT, 1952, p. 2101, Text-fig. 1. DEFLANDRE & FERT, 1954, p. 142, pl. 14, figs. 1, 9, 10, 12]. EM: STRADNER & EDWARDS, 1968, p. 20, pl. 15.

Reticulofenestra gartneri ROTH & HAY in HAY et al., 1967, p. 449, pl. 7, fig. 1.

Reticulofenestra insignita ROTH & HAY in HAY et al., 1967, p. 449, pl. 7, figs. 2–3.

Reticulofenestra oamaruensis (DEFLANDRE) STRADNER [= *Discolithus oamaruensis* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 139, pl. 12, figs. 1–2]. EM: STRADNER & EDWARDS, 1968, pp. 21–22, pl. 16–18, Text-fig. 2B.

Cyclolithella inflexa (KAMPTNER ex DEFLANDRE) LOEBLICH & TAPPAN [= *Cyclolithus inflexus* KAMPTNER ex DEFLANDRE in PIVETAU, 1952, p. 110, fig. 50]. EM: STRADNER & EDWARDS, 1968, p. 25, pl. 7, fig. 4.

Pyrocyclus hermosus ROTH & HAY in HAY et al., 1967, p. 448, pl. 6, figs. 10–12.

Cyclococcolithus bolii ROTH, 1969, p. 465, pl. 1, figs. 3–4.

Cyclococcolithus inversus (DEFLANDRE) HAY, MOHLER & WADE [= *Cyclococcolithus leptoporus* var. *inversus* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 150 (pro parte), pl. 9, figs. 4–5]. EM: STRADNER & EDWARDS, 1968, pp. 25–26, pl. 26–27.

Cyclococcolithus margaritae ROTH & HAY in HAY et al., 1967, p. 446, pl. 6, fig. 9.

Rhabdosphaera perlonga (DEFLANDRE) BRAMLETTE & SULLIVAN [= *Rhabdolithus perlongus* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 150, pl. 12, figs. 34–35, Text-fig. 86]. LM: BRAMLETTE & SULLIVAN, 1961, p. 146, pl. 5, figs. 1–3.

Rhabdosphaera tenuis BRAMLETTE & SULLIVAN, 1961, p. 147, pl. 5, figs. 14a–b.

Cretarhabdus lentus STRADNER in STRADNER & EDWARDS, 1968, pp. 33–34, pl. 44, fig. 7, ext-fig. 6.

Transversopontis obliquipons (DEFLANDRE) HAY, MOHLER & WADE [= *Discolithus obliquipons* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 139, pl. 11, figs. 1–2]. EM: PERCH-NIELSEN, 1967, p. 27, pl. 3, figs. 6–8.

Transversopontis pulcher (DEFLANDRE) HAY, MOHLER & WADE [= *Discolithus pulcher* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 142, pl. 12, figs. 17–18]. EM: PERCH-NIELSEN, pp. 27–28, pl. 3, figs. 9–11.

Transversopontis zigzag ROTH & HAY in HAY et al., p. 450, pl. 7, figs. 4–6.

Zygolithus pyramidus PERCH-NIELSEN, 1967, p. 29, pl. 5, figs. 1–5.

Scapholithus fossilis DEFLANDRE in DEFLANDRE & FERT, 1954, p. 165, pl. 8, figs. 12, 16, 17.

Syracosphaera clathrata ROTH & HAY in HAY et al., 1967, pp. 449–450, pl. 7, fig. 9.

Zygrhablithus bijugatus (DEFLANDRE) [= *Zygolithus bijugatus* DEFLANDRE in DEFLANDRE & FERT, 1954, p. 148, pl. 11, figs. 20–21, Text-fig. 59]. EM: GARTNER & SMITH, 1967, p. 5, pl. 8, figs. 1–6.

Braarudosphaera bigelowi (GRAN & BRAARUD) DEFLANDRE [= *Pontosphaera bigelowi* GRAN & BRAARUD, 1935, p. 388, fig. 67]. EM: HAY & TOWE, 1962a, pp. 426–428, fig. 1.

Braarudosphaera rosa LEVIN & JOERGER, 1967, p. 170, pl. 3, figs. 6a–b, 7.

Micrantholithus vesper DEFLANDRE, 1950, p. 1157, Text-figs. 5–7. EM: HAY, MOHLER & WADE, 1966, p. 395, pl. 12, fig. 4.

Discoaster adamanteus BRAMLETTE & WILCOXON, 1967, p. 108, pl. 7, fig. 6.

Discoaster aulakos GARTNER, 1967, p. 2, pl. 4, figs. 4–5.

Discoaster barbadiensis TAN SIN HOK, 1927, p. 415. D: BRAMLETTE & RIEDEL, 1954, p. 398, pl. 39, figs. 5a–b. LM: HAY et al., 1967, pl. 1, figs. 9–11. EM: HAQ, 1969, pp. 6–7, pl. 3, figs. 4–7.

Discoaster cubensis FURRAZOLA-BERMUDEZ & ITURRALDE-VINENT, 1967, p. 10, pl. 2, figs. 6–7.

Discoaster deflandrei BRAMLETTE & RIEDEL, 1954, p. 399, pl. 39, fig. 6, Text-figs. 1a–c. LM: HAY et al., 1967, pl. 2, figs. 6–9.

Discoaster lidzi HAY in HAY et al., 1967, p. 452, pl. 2, figs. 1–3.

Discoaster obtusus GARTNER, 1967, p. 2, pl. 3, figs. 1–6.

Discoaster saipanesis BRAMLETTE & RIEDEL, 1954, pp. 398, pl. 39, fig. 4. EM: HAY, MOHLER & WADE, 1966, p. 396, pl. 11, figs. 8–9, pl. 13, fig. 1. LM: HAY et al., 1967, pl. 1, figs. 4–6.

Discoaster saundersi HAY in HAY et al., 1967, p. 453, pl. 3, figs. 2–6.

Discoaster tani tani BRAMLETTE & RIEDEL, 1954, p. 397, pl. 39, fig. 1.

Discoaster tani ornatus BRAMLETTE & WILCOXON, 1967, pp. 112, 114, pl. 7, fig. 8.

Discoaster tinguarensis FURRAZOLA-BERMUDEZ & ITTURRALDE-VINENT, 1967, p. 9, pl. 2, figs. 3–4.

Trochaster simplex KLUMPP, 1953, p. 385, pl. 16, fig. 7, Text-fig. 4/2. D, LM: MARTINI, 1958, p. 368, pl. 5, figs. 25a–b.

Sphenolithus predistentus BRAMLETTE & WILCOXON, 1967, p. 92, pl. 1, fig. 6, pl. 2, figs. 10–11.

Sphenolithus radians DEFLANDRE in GRASSÉ, 1952, p. 446, figs. 343 J–K, 363 A–G. LM: DEFLANDRE & FERT, 1954, p. 49, pl. XII, figs. 36–38, Text-figs. 109–112.

Isthmolithus recurvus DEFLANDRE in DEFLANDRE & FERT, 1954, p. 196, pl. 12, figs. 9–13, Text-figs. 119–122. EM: HAY, MOHLER & WADE, 1966, pp. 396–397, pl. 12, figs. 1–3, pl. 13, fig. 3.

Lanternithus minutus STRADNER, 1962, p. 375, pl. 2, figs. 12–15. D, LM: LOCKER, 1967, pp. 361–362, pl. 365, figs. 1–8. EM: GARTNER & BUKRY, 1969, pp. 1217–1218, pl. 139.

Corannulus germanicus STRADNER, 1962, p. 366, pl. 1, figs. 21–30.

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Index

[Rejected names enclosed within square brackets]

Plate I

Fig. 1 *Coccolithus tritus* n. sp. Holotype A 604 225 [A 810], 15000 ×, distal view, Red Bluff Fm., 4′ above base, Alabama.

Fig. 2 *Coccolithus crater* n. sp. Holotype A 809 004 [A 808], 15000 ×, distal view, Marianna Ls., 9′ above base, Alabama.

Fig. 3 *Coccolithus primalis* n. sp. Holotype J 506 377 [A 809], 15000 ×, distal view, JOIDES Hole 5, 374′ below top, Blake Plateau, W Atlantic.

Fig. 4 *Ericsonia bireticulata* n. sp. Paratype JS 1847 026 [A 812], 15000 ×, proximal view, Cipero Fm., Trinidad.

Fig. 5 *Ericsonia bireticulata* n. sp. Holotype JS 147 301 [A 811], 15000 ×, distal view, Cipero Fm., Trinidad.

Fig. 6 *Ericsonia fenestrata* (Deflandre & Fert) Stradner. Hypotype JS 1847 624 [A 813], 15000 ×, distal view, Cipero Fm., Trinidad.

PLATE I

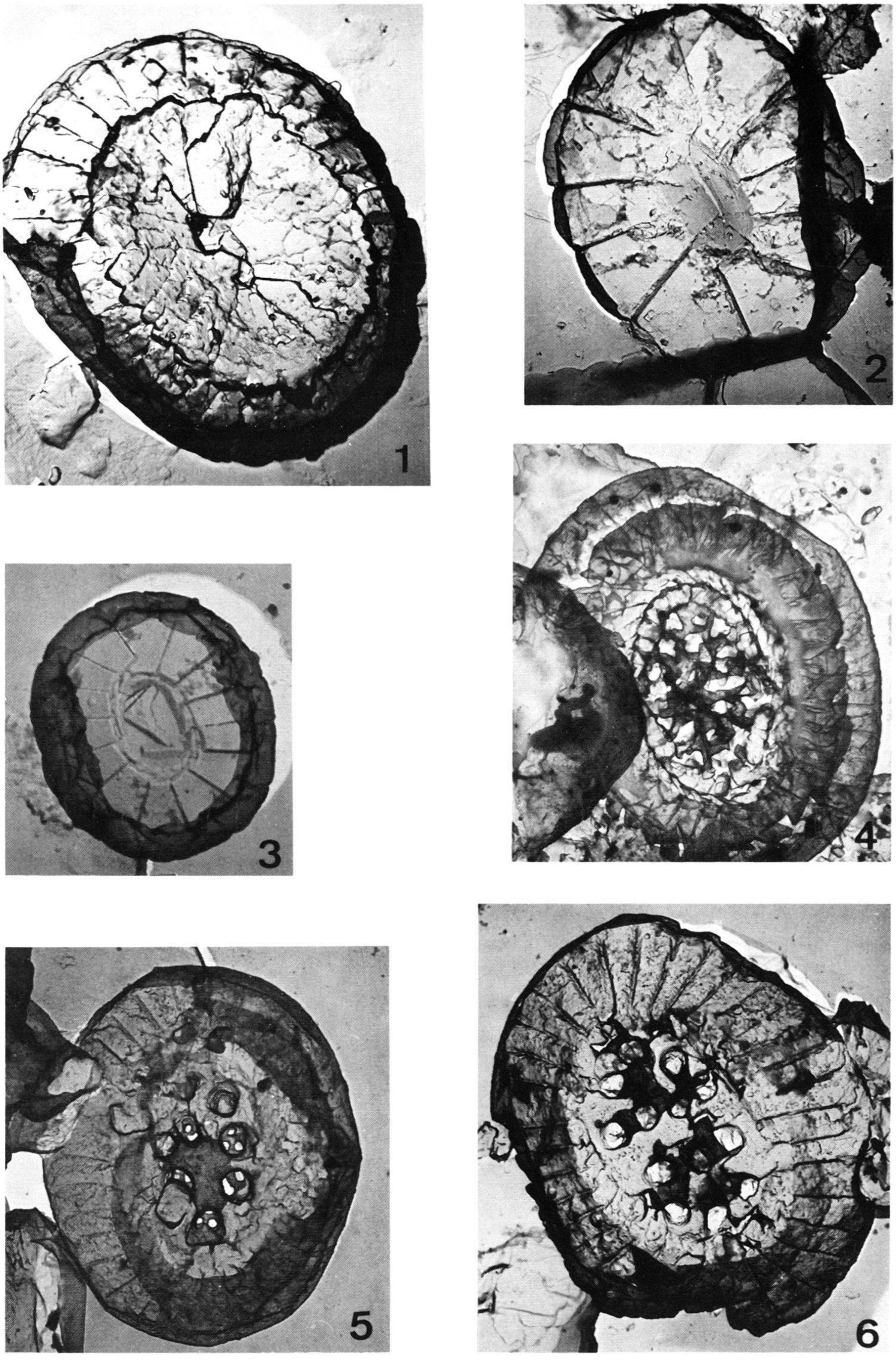

Plate II

Fig. 1 *Ericsonia pauciperforata* n. sp. Holotype A 608 157 [A 814], 15000×, distal view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 2 *Ericsonia quadriperforata* n. sp. Holotype J 515 234 [A 815], 15000×, distal view, JOIDES Hole 5, 589′11″ below top, Blake Plateau, W Atlantic.

Fig. 3 *Ericsonia subdisticha* (Roth & Hay) Roth. Hypotype J 515 374 [A 816], 15000×, distal view, JOIDES Hole 5, 589′11″ below top, Blake Plateau, W Atlantic.

Fig. 4 *Ericsonia subdisticha* (Roth & Hay) Roth. Hypotype N1 247 [A 817], 15000×, proximal view, Latdorf Clay, Well Hankensbüttel Süd 32, 267–276 m, Northern Germany.

Fig. 5 *Cruciplacolithus flavius* n. sp. Paratype J 503 229 [A 819], 15000×, proximal view, JOIDES Hole 5, 484′ below top, Blake Plateau, W Atlantic.

Fig. 6 *Cruciplacolithus flavius* n. sp. Holotype J 504 107 [A 818], 15000×, distal view, JOIDES Hole 5, 445′ below top, Blake Plateau, W Atlantic.

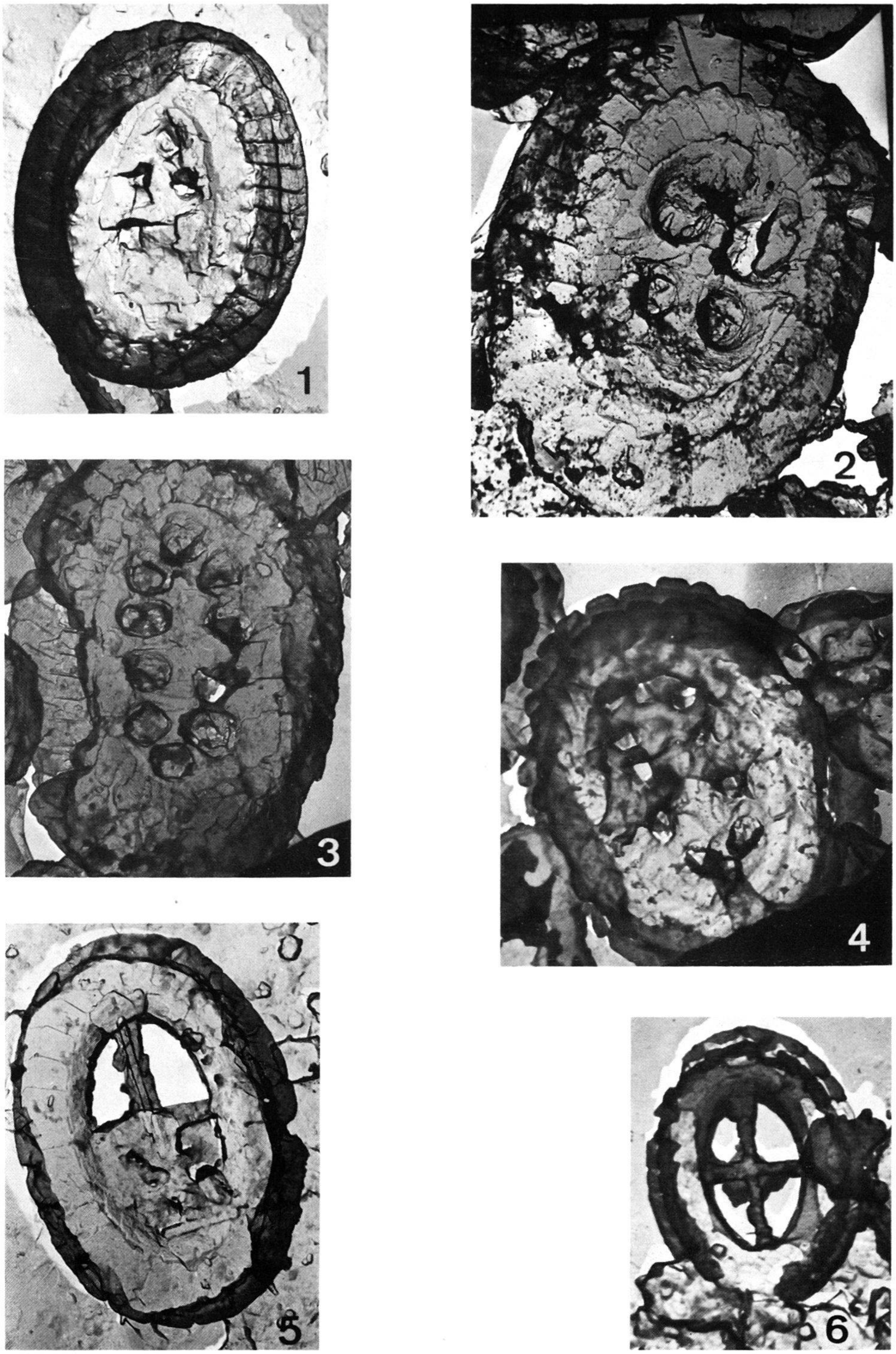
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Plate III

Fig. 1 *Cruciplacolithus quader* n. sp. Holotype J 504 101 [A 820], 15000×, distal view, JOIDES Hole 5, 445′ below top, Blake Plateau, W Atlantic.

Fig. 2 *Sollasites tardus* n. sp. Paratype J 510 471 [A 822], 15000×, proximal view, JOIDES Hole 5, 248′ below top, Blake Plateau, W Atlantic.

Fig. 3 *Sollasites tardus* n. sp. Holotype J 505 427 [A 821], 15000×, distal view, JOIDES Hole 5, 410′ below top, Blake Plateau, W Atlantic.

Fig. 4 *Reticulofenestra alabamensis* n. sp. Holotype A 600 360 [A 823], 15000× distal view, Red Bluff Fm., base, Alabama.

Fig. 5 *Reticulofenestra alabamensis* n. sp. Paratype A 600 257 [A 824], 15000×, proximal view, Red Bluff Fm., base, Alabama.

Fig. 6 *Reticulofenestra bisecta* (HAY, MOHLER & WADE) n. comb. Hypotype J6-397-12-7 [A 825], 5200×, proximal view. (In the upper and lower left *Sphenolithus predistentus* BRAMLETTE & WILCOXON.) JOIDES Hole 6, 397′ below top, Blake Plateau, W Atlantic.

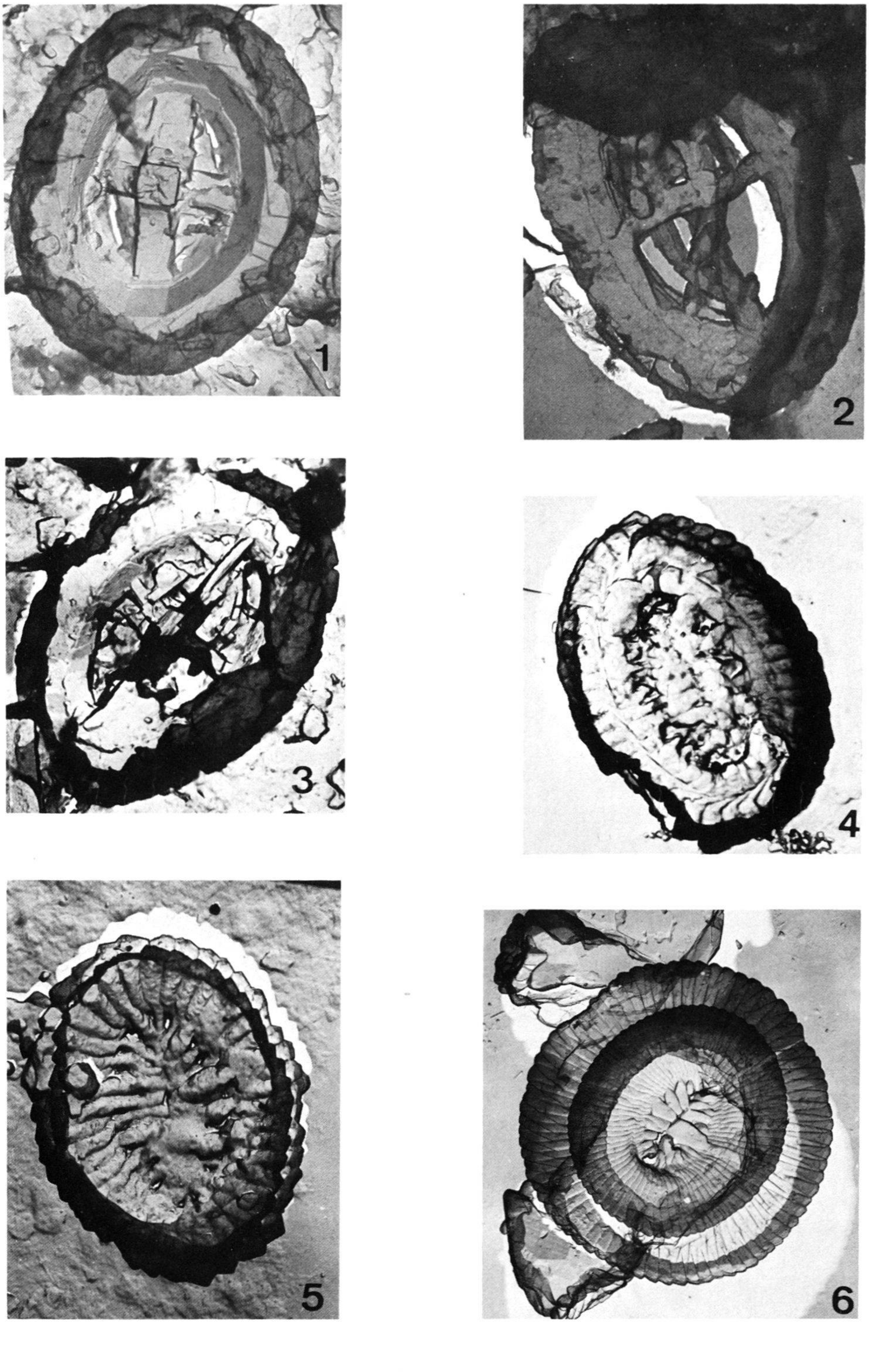
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Plate IV

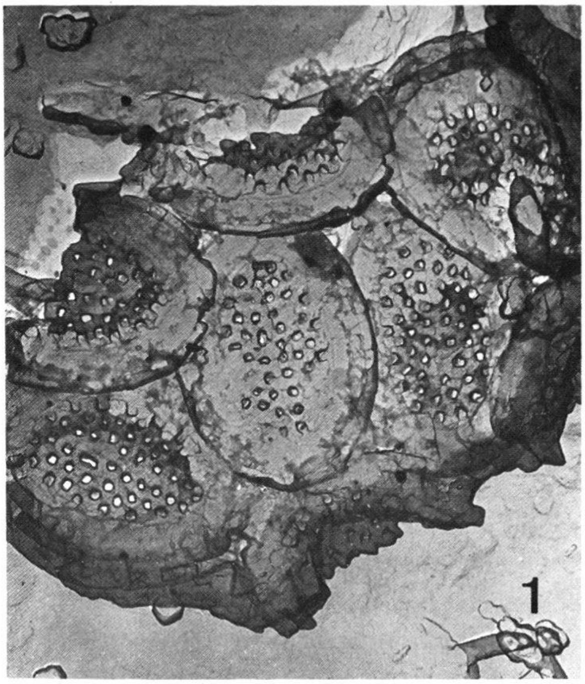
Fig. 1 *Reticulofenestra gabrielae* n. sp. Holotype A 613 110 [A 827], 15000×, broken coccosphere, Red Bluff Fm., 13′ above base, Alabama.

Fig. 2 *Reticulofenestra danica* (Black) n. comb. Hypotype J 512 389 [A 826], 10000×, distal view JOIDES Hole 5, 730′ below top, Blake Plateau, W Atlantic.

Fig. 3 *Reticulofenestra hesslandii* (Haq) n. comb. Hypotype A 600 470 [A 830], 15000×, proximal view, Red Bluff Fm., base, Alabama.

Fig. 4 *Reticulofenestra hesslandii* (Haq) n. comb. Hypotype A 815 110 [A 823], 10000×, coccosphere, Marianna Ls., 15′ above base, Alabama.

Fig. 5 *Reticulofenestra hesslandii* (Haq) n. comb. Hypotype A 600 406 [A 829], 10000×, (A) specimen in the lower left, distal view, (B) specimen in the upper right, proximal view, Red Bluff Fm., basa, Alabama.



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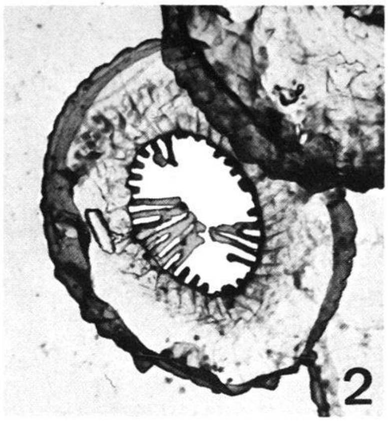

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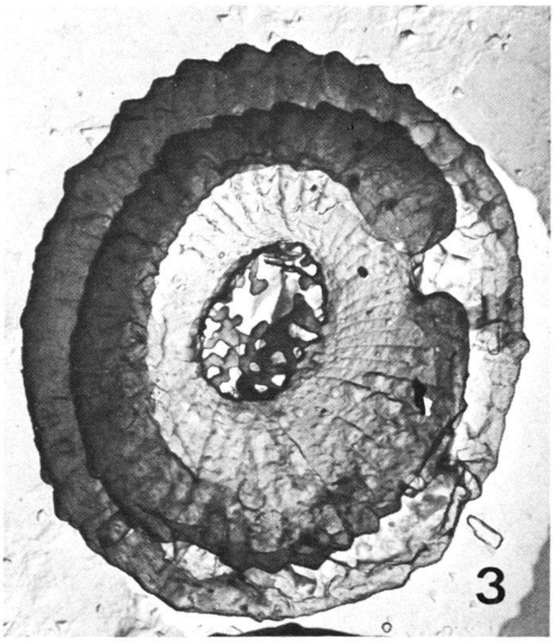

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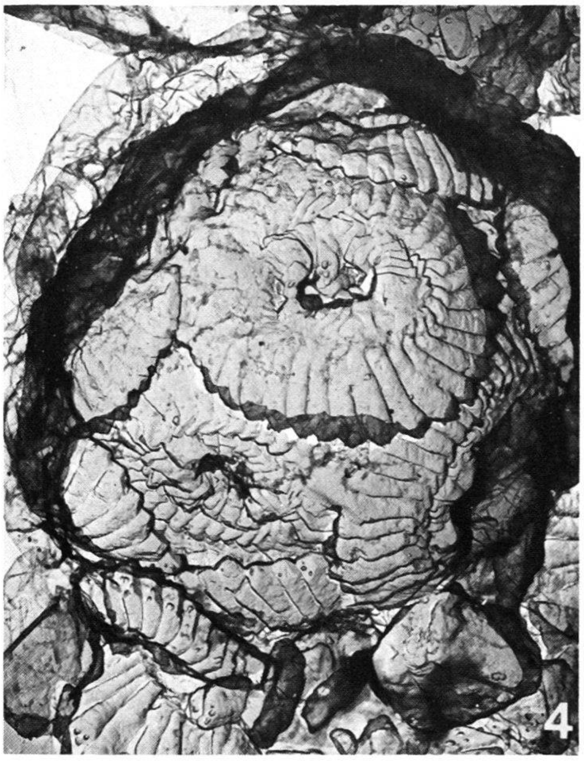

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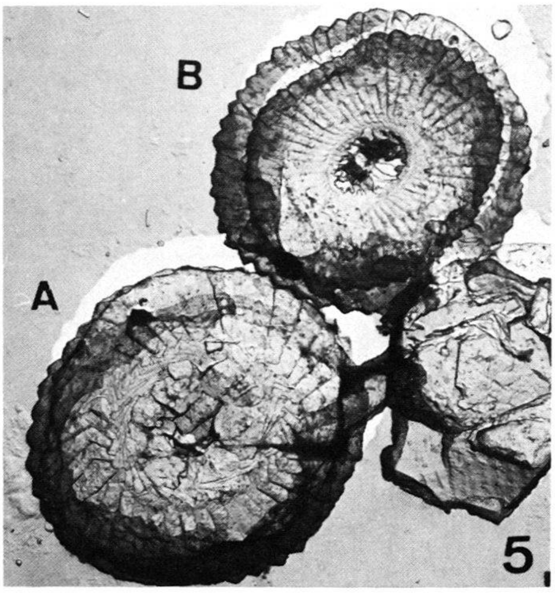

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Plate V

Fig. 1 *Reticulofenestra pectinata* n. sp. Holotype A 613 664 [A 835], 15000 ×, distal view, Red Bluff Fm., 13′ above base, Alabama.

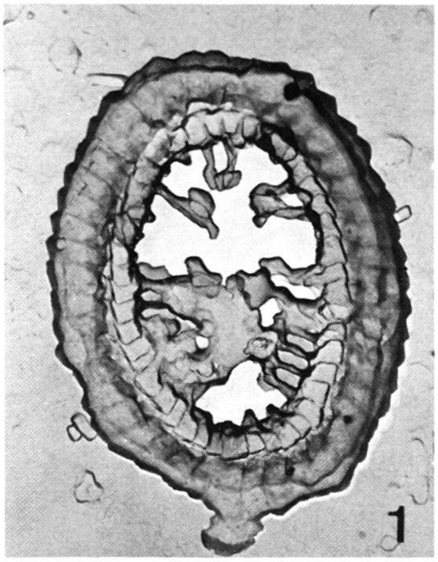
Fig. 2 *Reticulofenestra inclinata* n. sp. Holotype J 503 480 [A 831], 15000 ×, JOIDES Hole 5, 484′ below top, Blake Plateau, W Atlantic.

Fig. 3 *Reticulofenestra minuta* n. sp. Holotype A 610 130 [A 833], 15000 ×, distal view, Red Bluff Fm., 10′ from base, Alabama.

Fig. 4 *Reticulofenestra minuta* n. sp. Paratype J 504 136 [A 834], 15000 ×, proximal view JOIDES Hole 5, 445′ below top, Blake Plateau, W Atlantic.

Fig. 5 *Reticulofenestra laevis* ROTH & HAY. Hypotype A 100 280 [A 832], 15000 ×, distal view, Byram Fm., unnamed Clay Mb., Alabama.

Fig. 6 *Cyclococcolithus floridanus* (ROTH & HAY) n. comb. Hypotype J3-397-12-11 [A 840], 10000 ×, distal view, JOIDES Hole 3, 397′ below top, Blake Plateau, W Atlantic.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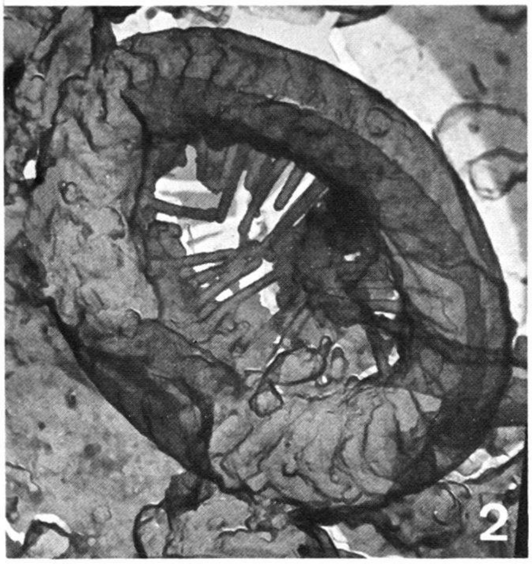
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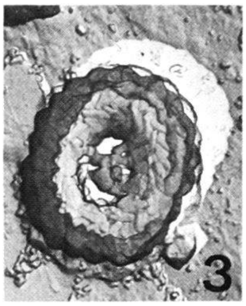
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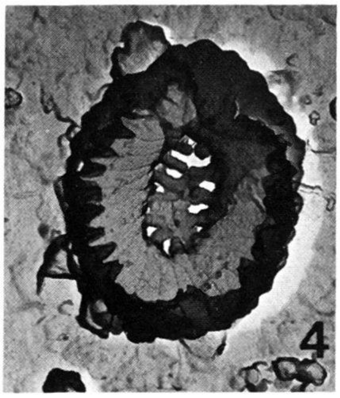
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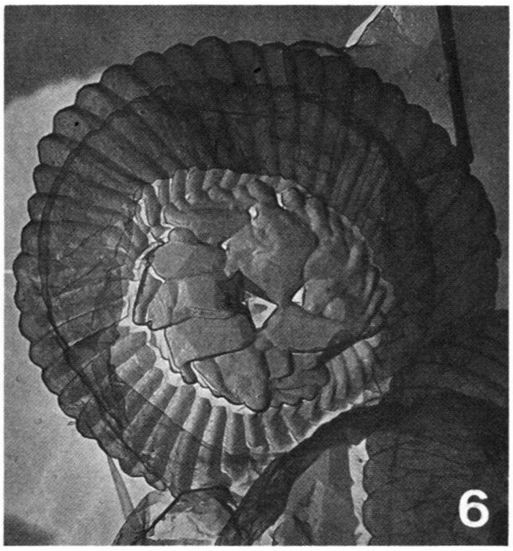
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Plate VI

Fig. 1 *Cyclococcolithus arabellus* n. sp. Holotype A 613 443 [A 836], 15000 ×, distal view, Red Bluff Fm., 13′ above base, Alabama.

Fig. 2 *Cyclococcolithus arabellus* n. sp. Paratype J 507 264 [A 837], 15000 ×, distal view, JOIDES Hole 5, 337′11″ below top, Blake Plateau, W Atlantic.

Fig. 3 *Cyclococcolithus ciperoensis* n. sp. Holotype ETH 291 A-399 [A 838], 10000 ×, proximal view, Cipero Fm., Trinidad.

Fig. 4 *Cyclococcolithus lunulus* n. sp. Holotype J 518 099 [A 841], 6000 ×, distal view, JOIDES Hole 5, 460′5$^1/_2$″ below top, Blake Plateau, W Atlantic.

Fig. 5 *Cyclococcolithus kingi* n. sp. Paratype A 606 025 [A 43], 10000 ×, proximal view, Red Bluff Fm., 6′ above base, Alabama.

Fig. 6 *Cyclococcolithus ciperoensis* n. sp. Paratype ETH 291 A-510 [A 839], 12000 ×, distal view, Cipero Fm., Trinidad.

 Plate VI

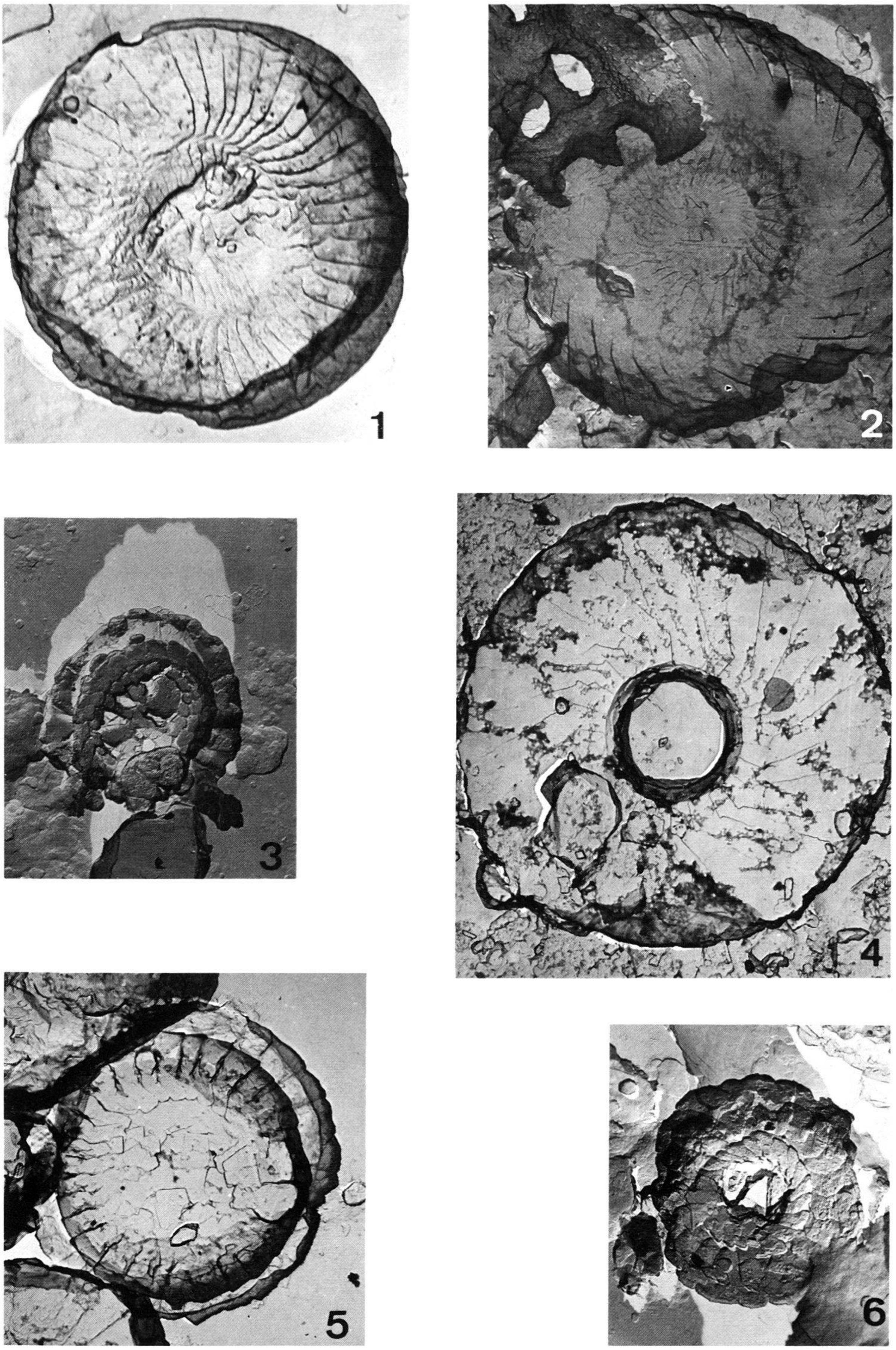

Plate VII

Fig. 1 *Cyclococcolithus kingi* n. sp. Holotype A 815 022 [A 842], 10000 ×, distal view, Marianna Ls., 15′ from base, Alabama.

Fig. 2 *Ilselithina fusa* n. sp. Paratype A 600 162 [A 845], 15000 ×, proximal view, Red Bluff Fm., base, Alabama.

Fig. 3 *Ilselithina fusa* n. sp. Holotype A 608 372 [A 844], 15000 ×, distal view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 4 *Coronocyclus serratus* HAY, MOHLER & WADE. Hypotype J3-4222-20-11 [A 846], 10000 ×, distal view, JOIDES Hole 3, 422′ below top, Blake Plateau, W Atlantic.

Fig. 5 *Blackites incompertus* n. sp. Holotype A 610 358 [A 850], 5000 ×, side view, Red Bluff Fm., 10′ above base, Alabama.

Fig. 6 *Blackites amplus* ROTH & HAY. Hypotype J 503 189 [A 849], 6000 ×, distal view, JOIDES Hole 5, 484′ below top, Blake Plateau, W Atlantic.

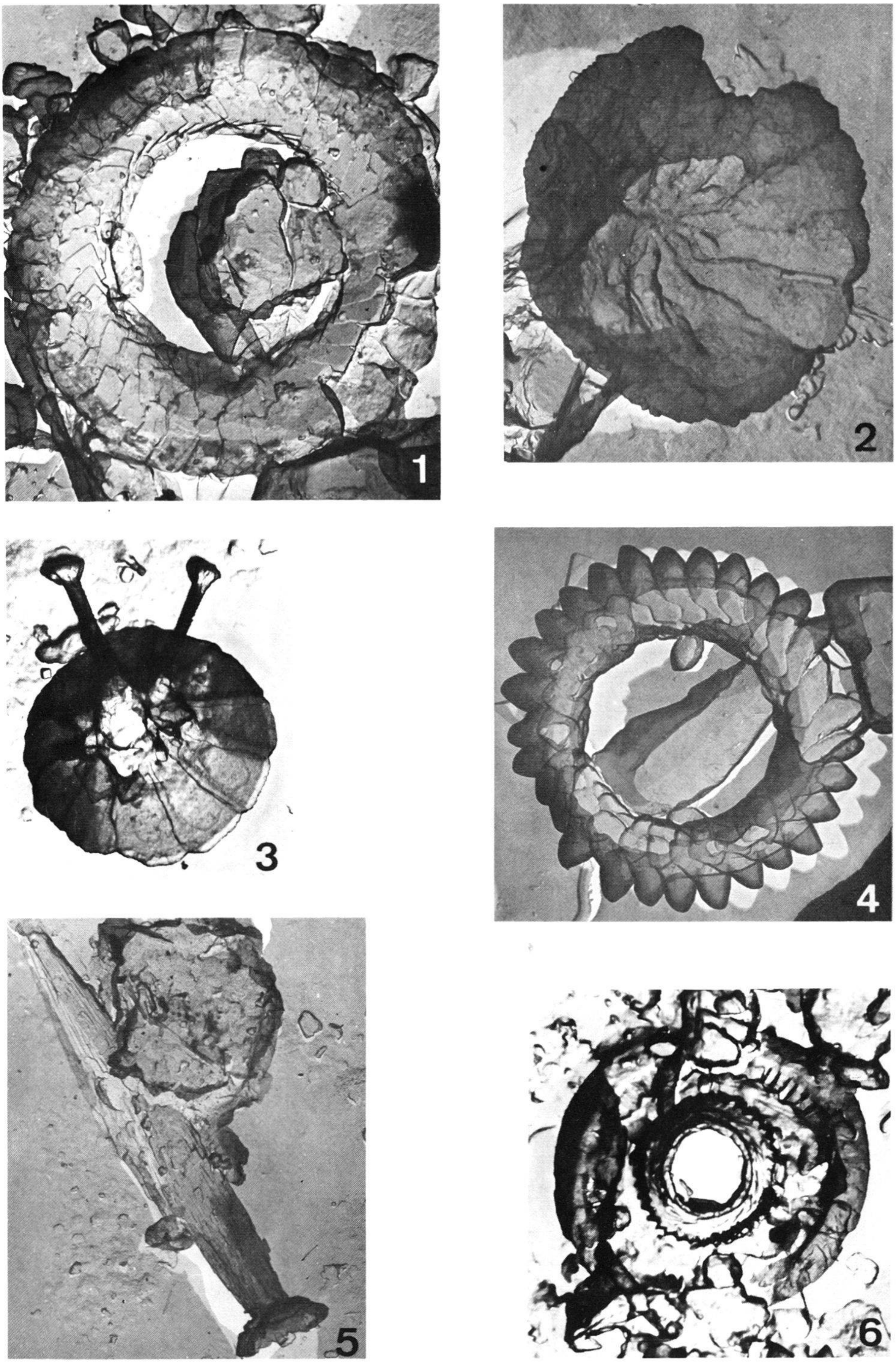
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Plate VIII

Fig. 1 *Blackites incompertus* n. sp. Paratype A 610 266 [A 852], 5000×, side view, Red Bluff Fm., 10′ above base, Alabama.

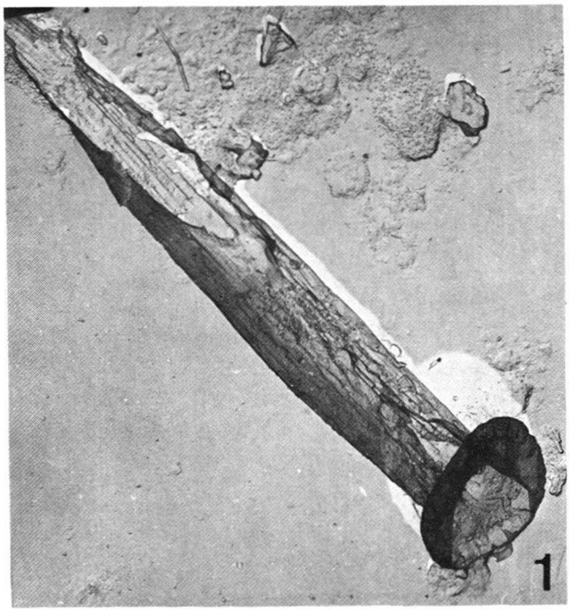
Fig. 2 *Blackites incompertus* n. sp. Paratype A 610 105 [A 851], 10000×, side view, Red Bluff Fm., 10′ above base, Alabama.

Fig. 3 *Bramletteius variabilis* n. sp. Holotype A 608 432 [A 854], 15000×, side view Red Bluff Fm., 8′ above base, Alabama.

Fig. 4 *Blackites spinulus* (LEVIN) n. comb. Hypotype A 600 271 [A 853], 5000×, side view, Red Bluff Fm., base, Alabama.

Fig. 5 *Bramletteius variabilis* n. sp. Paratype A 608 420 [A 855], 15000×, side view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 6 *Rhabdosphaera vitrea* (DEFLANDRE) BRAMLETTE & SULLIVAN. Hypotype A 608 189 [A 848], 10000×, side view, Red Bluff Fm., 8′ above base.



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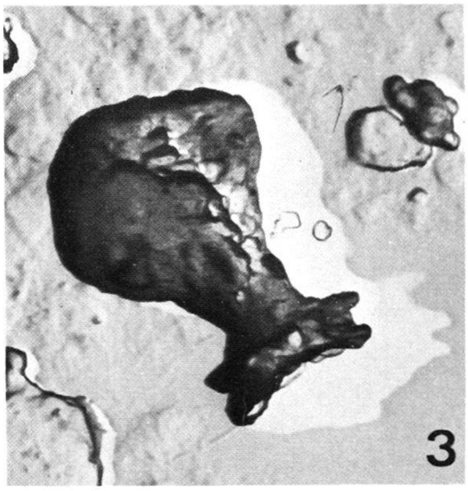

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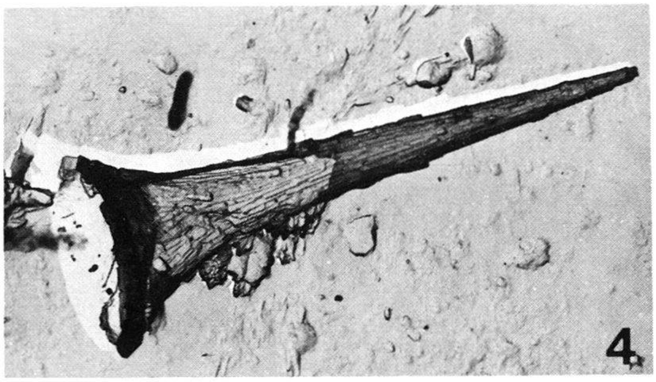

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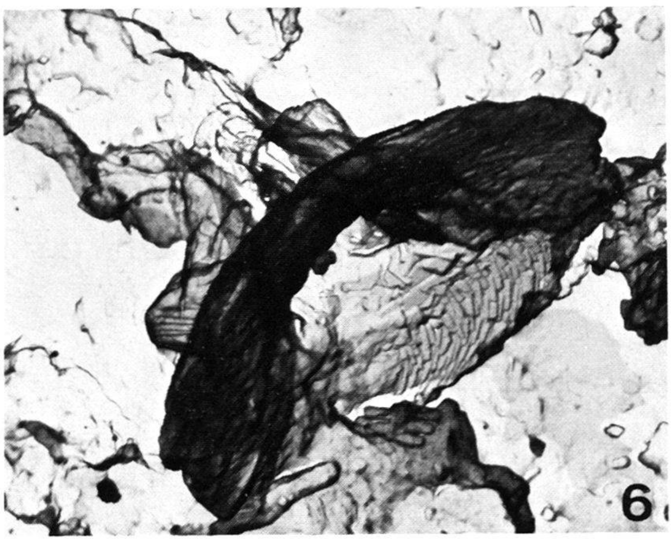

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Plate IX

Fig. 1 *Rhabdosphaera vitrea* (DEFLANDRE) BRAMLETTE & SULLIVAN. Hypotype A 6000 296 [A 847], 10000 ×, side view, Red Bluff Fm., base, Alabama.

Fig. 2 *Pontosphaera alta* n. sp. Paratype A 613 386 [A 857], 5000 ×, proximal view, Red Bluff Fm., 13′ above base, Alabama.

Fig. 3 *Pontosphaera alta* n. sp. Holotype A 613 138 [A 856], 5000 ×, proximal view, Red Bluff Fm., 13′ above base, Alabama.

Fig. 4 *Pontosphaera crucifera* n. sp. Holotype A 613 652 [A 858], 15000 ×, proximal view, Red Bluff Fm., 13′ above base, Alabama.

Fig. 5 *Pontosphaera crucifera* n. sp. Paratype A 613 643 [A 859], 15000 ×, distal view, Red Bluff Fm., 13′ above base, Alabama.

Fig. 6 *Pantosphaera rigida* n. sp. Holotype JS 1847 445 [A 860], 15000 ×, distal view, Cipero Fm., Trinidad.

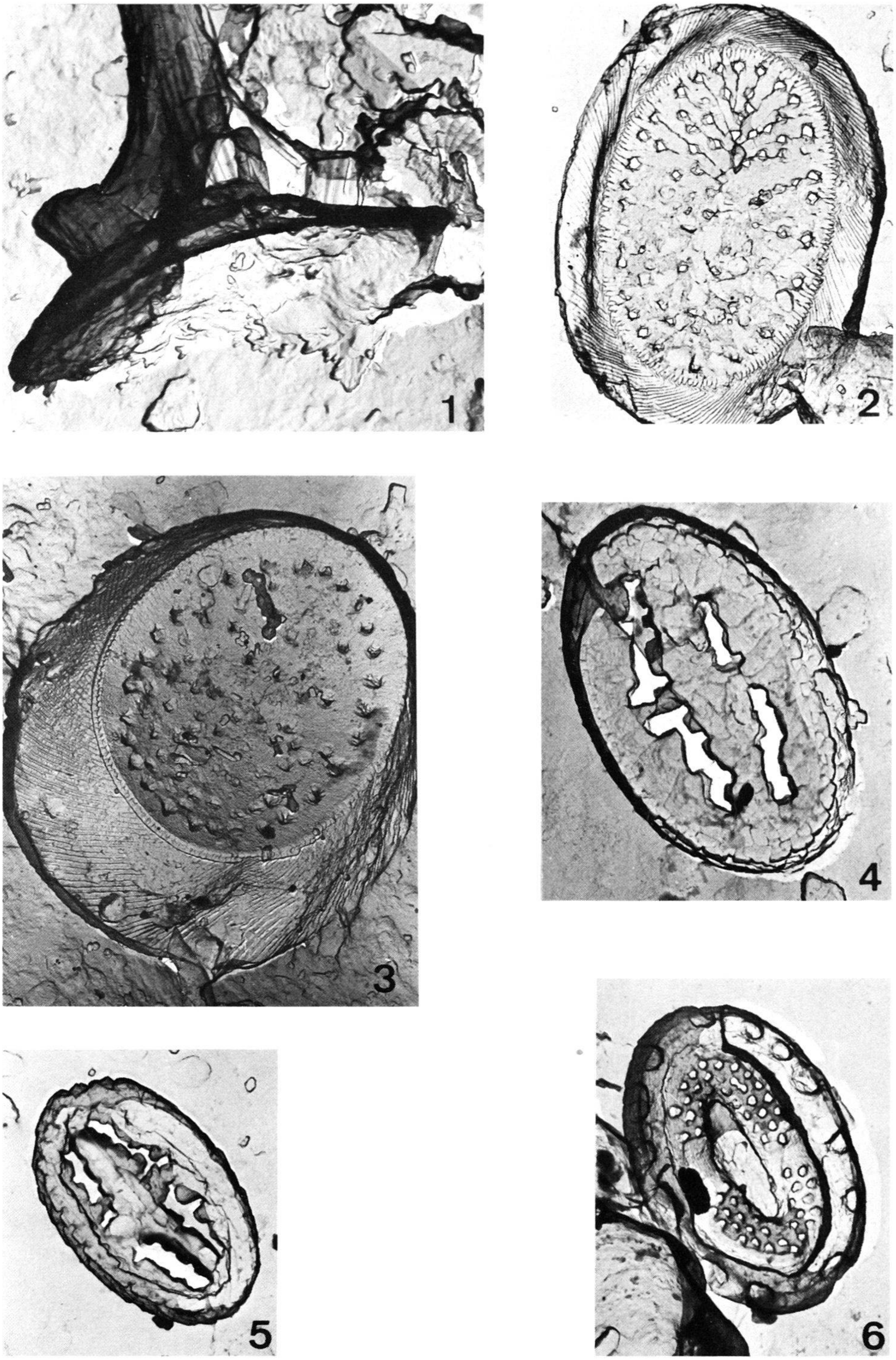
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Plate X

Fig. 1 — *Pontosphaera rigida* n. sp. Paratype JS 1847 576 [A 861], 15000×, proximal view, Cipero Fm., Trinidad.

Fig. 2 — *Helicopontosphaera compacta* (Bramlette & Wilcoxon) n. comb. Hypotype JS 1847 490 [A 862], 10000×, proximal view, Cipero Fm., Trinidad.

Fig. 3 — *Helicopontosphaera truncata* (Bramlette & Wilcoxon) n. comb. Hypotype JS 20 008 [A 866], 10000×, convex side, Cipero Fm., Trinidad.

Fig. 4 — *Helicopontosphaera compacta* (Bramlette & Wilcoxon) n. comb. Hypotype JS 1847 502 [A 863], 10000×, concave side, Cipero Fm., Trinidad.

Fig. 5 — *Helicopontosphaera reticulata* (Bramlette & Wilcoxon) n. comb. Hypotype JS 1066 047 [A 865], 10000×, convex side, Oceanic Fm., Barbados.

Fig. 6 — *Helicopontosphaera intermedia* (Martini) Hay & Mohler. Hypotype JS 20 462 [A 864], 10000×, convex side, Cipero Fm., Trinidad.

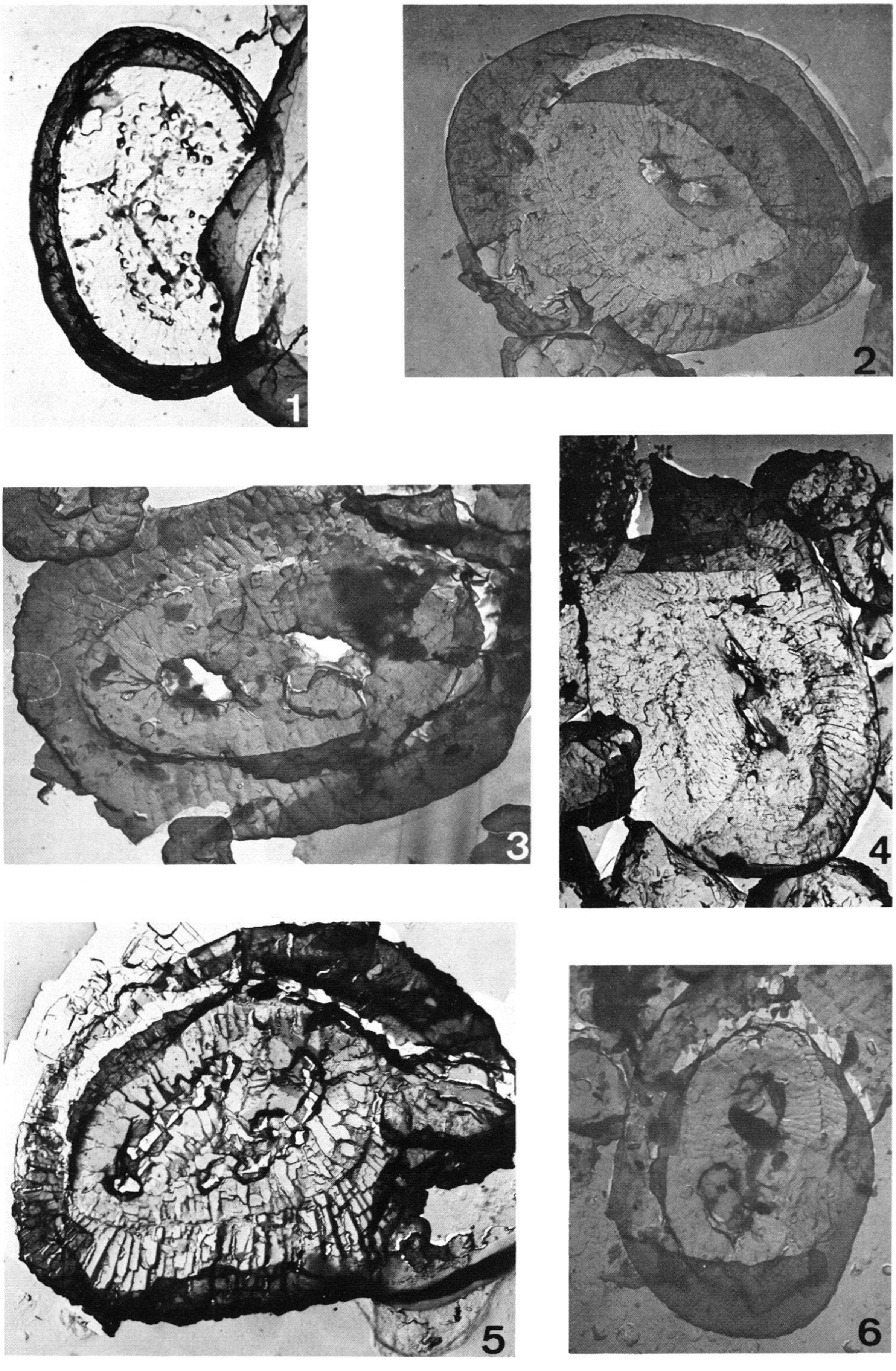
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Plate XI

Fig. 1 *Cepekiella elongata* n. sp. Holotype A 613 574 [A 867], 15000×, distal view, Red Bluff Fm., 13′ above base, Alabama.

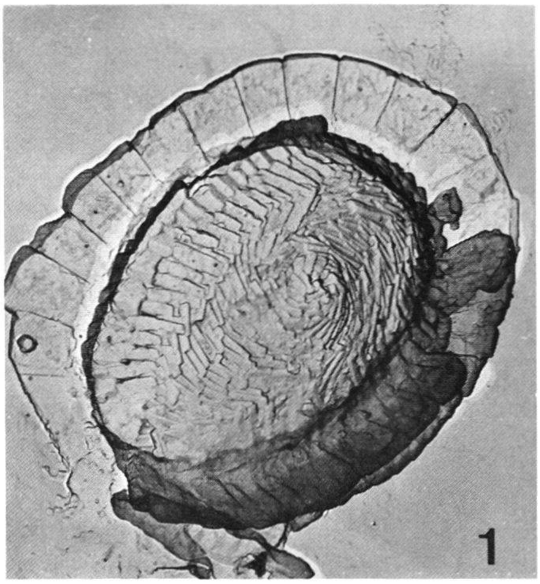
Fig. 2 *Cepekiella elongata* n. sp. Paratype ETH 68-30-806 [A 868], 15000×, proximal view, Silberberg Fm., near Helmstedt, Northern Germany.

Fig. 3 *Cepekiella hayi* (Stradner) n. comb. Hypotype ETH 68-70-855 [A 869], distal view, Silberberg Fm., Silberberg, Northern Germany.

Fig. 4 *Discoturbella moori* n. sp. Holotype A 608 297 [A 870], 10000×, side view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 5 *Holodiscolithus solidus* (Deflandre) n. comb. Hypotype A 608 343 [A 873], 15000×, distal view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 6 *Holodiscolithus macroporus* (Deflandre) n. comb. Hypotype A 600 088 [A 872], 15000×, distal view, Red Bluff Fm., base, Alabama.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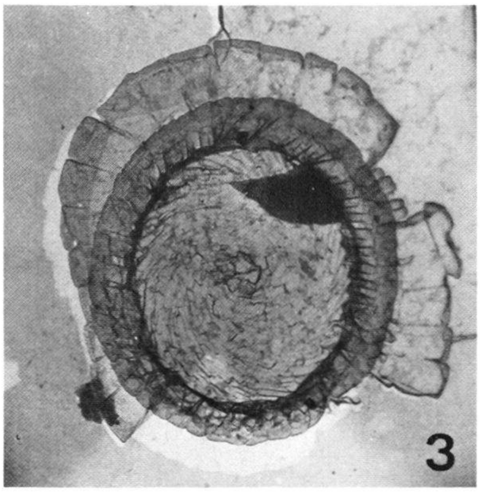
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Plate XII

Fig. 1 *Zygosphaera brytika* n. sp. Holotype A 608 088 [A 871], 15000×, distal view, Red Bluff Fm., 8′ above base, Alabama.

Fig. 2 *Clathrolithus minutus* DEFLANDRE. Hypotype A 809 098 [A 874], 10000×, distal view, Marianna Ls., 9′ above base, Alabama.

Fig. 3 *Discoaster rufus* n. sp. Holotype J3-397-7-6 [A 875], 8600×, JOIDES Hole 3, 397′ below top, Blake Plateau, W Atlantic.

Fig. 4 *Discoaster tani nodifer* BRAMLETTE & RIEDEL. Hypotype A 800046 [A 876], 5000×, base of Marianna Ls., Alabama.

Fig. 5 *Discoaster trinus* STRADNER. Hypotype J3-475-9-1 [A 877], 4800×, JOIDES Hole 3, 475′ below top, Blake Plateau, W Atlantic.

Fig. 6 *Discoaster woodringi* BRAMLETTE & RIEDEL. Hypotype J 301 003 [A 878], 5000×, JOIDES Hole 3, 270′ below top, Blake Plateau, W Atlantic.

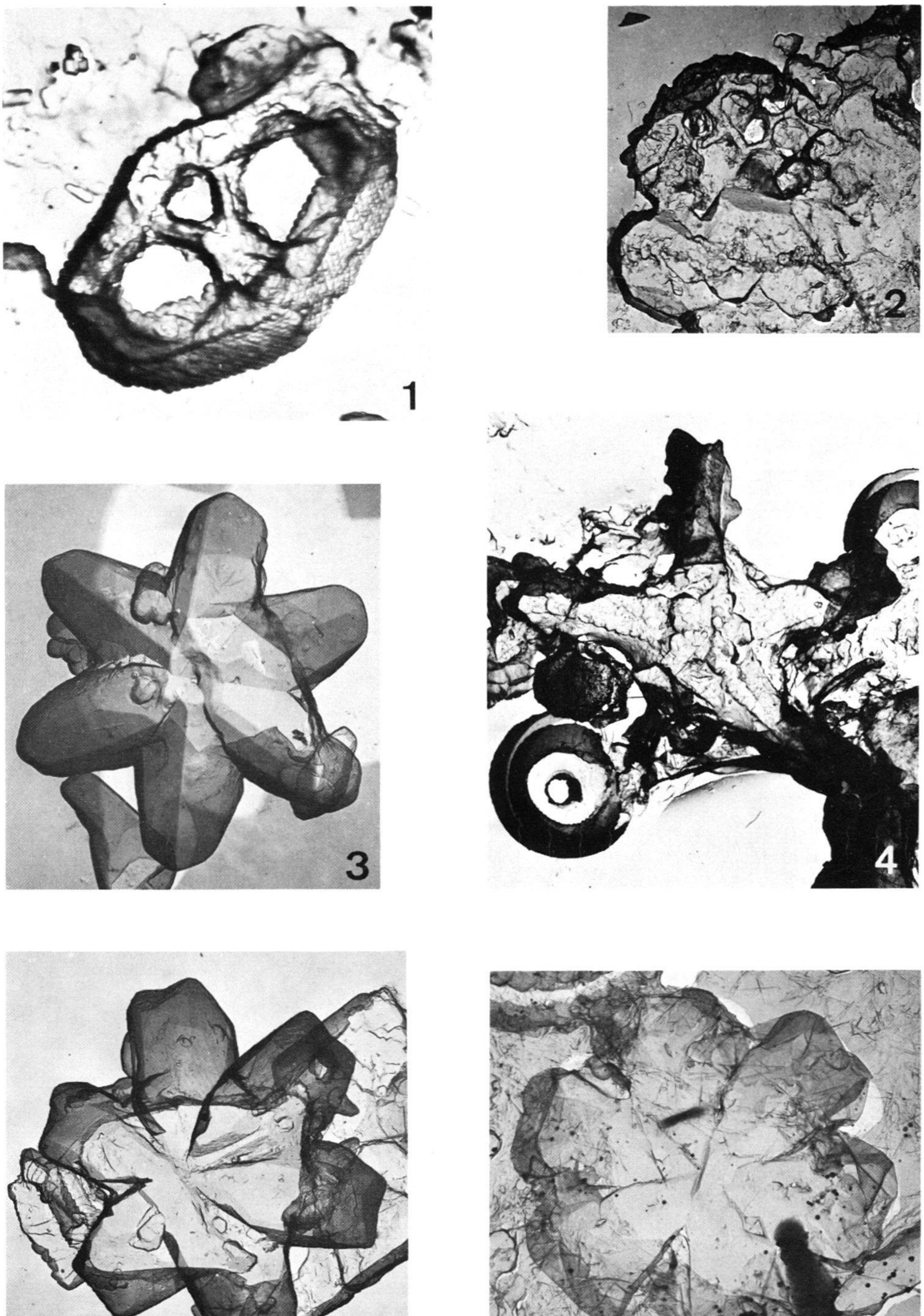
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Plate XIII

Fig. 1 *Lithostromation perdurum* DEFLANDRE. Hypotype J 509 209 [A 879], 5000×, JOIDES Hole 5, 260′2″ below top, Blake Plateau, W Atlantic.

Fig. 2 *Lithostromation perdurum* DEFLANDRE. Hypotype A 800 072 [A 880], 5000×, base of Marianna Ls., Alabama.

Fig. 3 *Sphenolithus distentus* (MARTINI) BRAMLETTE & WILCOXON. Hypotype J3-422-20-10 [A 888], 3850×, JOIDES Hole 3, 422′ below top, Blake Plateau, W Atlantic.

Fig. 4 *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON. Hypotype J3-270-18-2 [A 885], 10300×, JOIDES Hole 3, 270′ below top, Blake Plateau, W Atlantic.

Fig. 5 *Sphenolithus belemnos* BRAMLETTE & WILCOXON. Hypotype JS 267* 083 [A 883], 6000×, Cipero Fm., Trinidad.

Fig. 6 *Sphenolithus belemnos* BRAMLETTE & WILCOXON. Hypotype J3-270-18-8 [A 882], 6800×, JOIDES Hole 3, 270′ below top, Blake Plateau, W Atlantic.

Fig. 7 *Sphenolithus distentus* (MARTINI) BRAMLETTE & WILCOXON. Hypotype J3-397-13-5 [A 887], 6800×, JOIDES Hole 3, 397′ below top, Blake Plateau, W Atlantic.

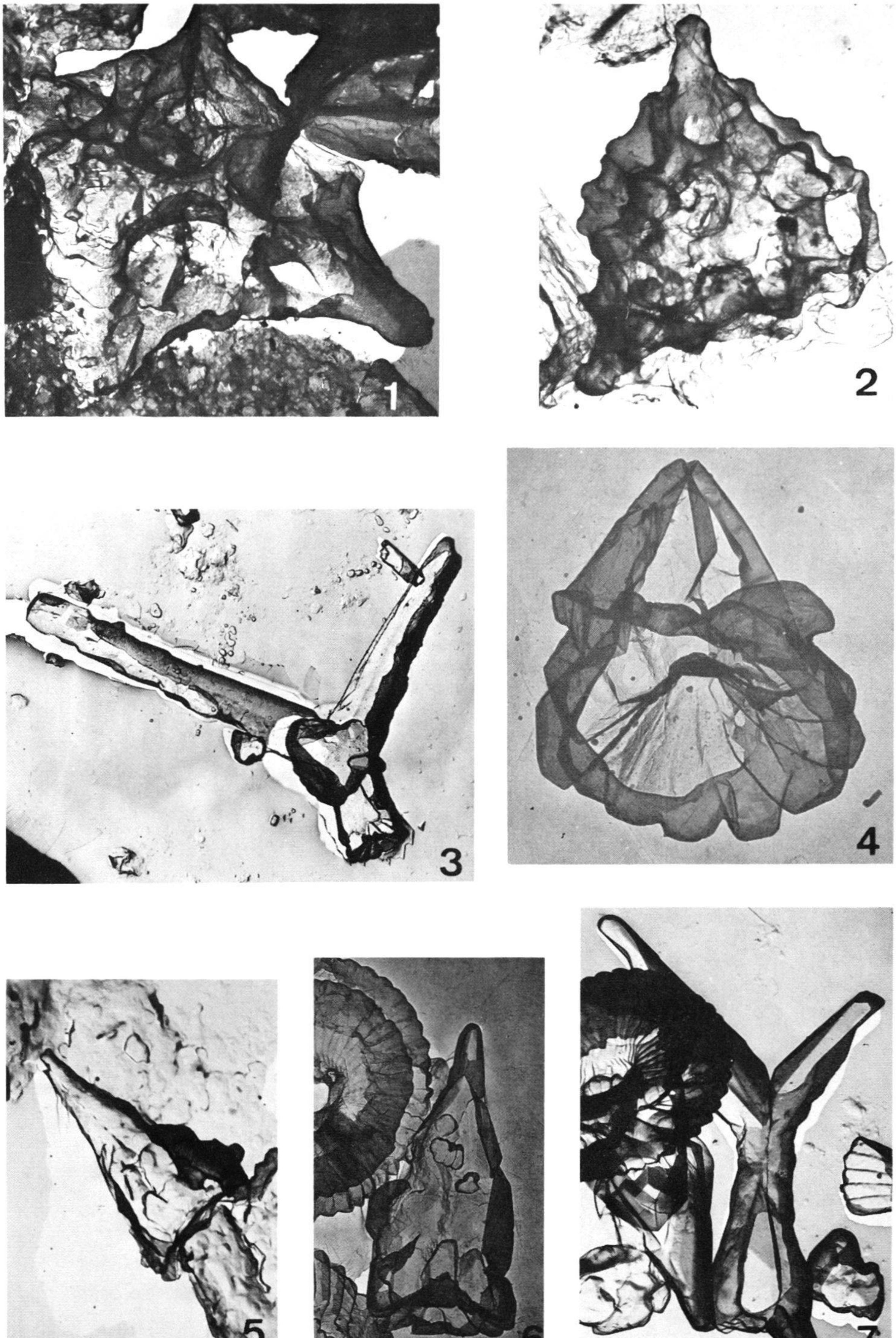
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Plate XIV

Fig. 1 — *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON. Hypotype JS 267* 070 [A 886], 5000 ×, Cipero Fm., Trinidad.

Fig. 2 — *Sphenolithus ciperoensis* BRAMLETTE & WILCOXON. Hypotype J3-306-16-7 [A 884], 10000 ×, JOIDES Hole 3, 306′ below top, B lake Plateau, W Atlantic.

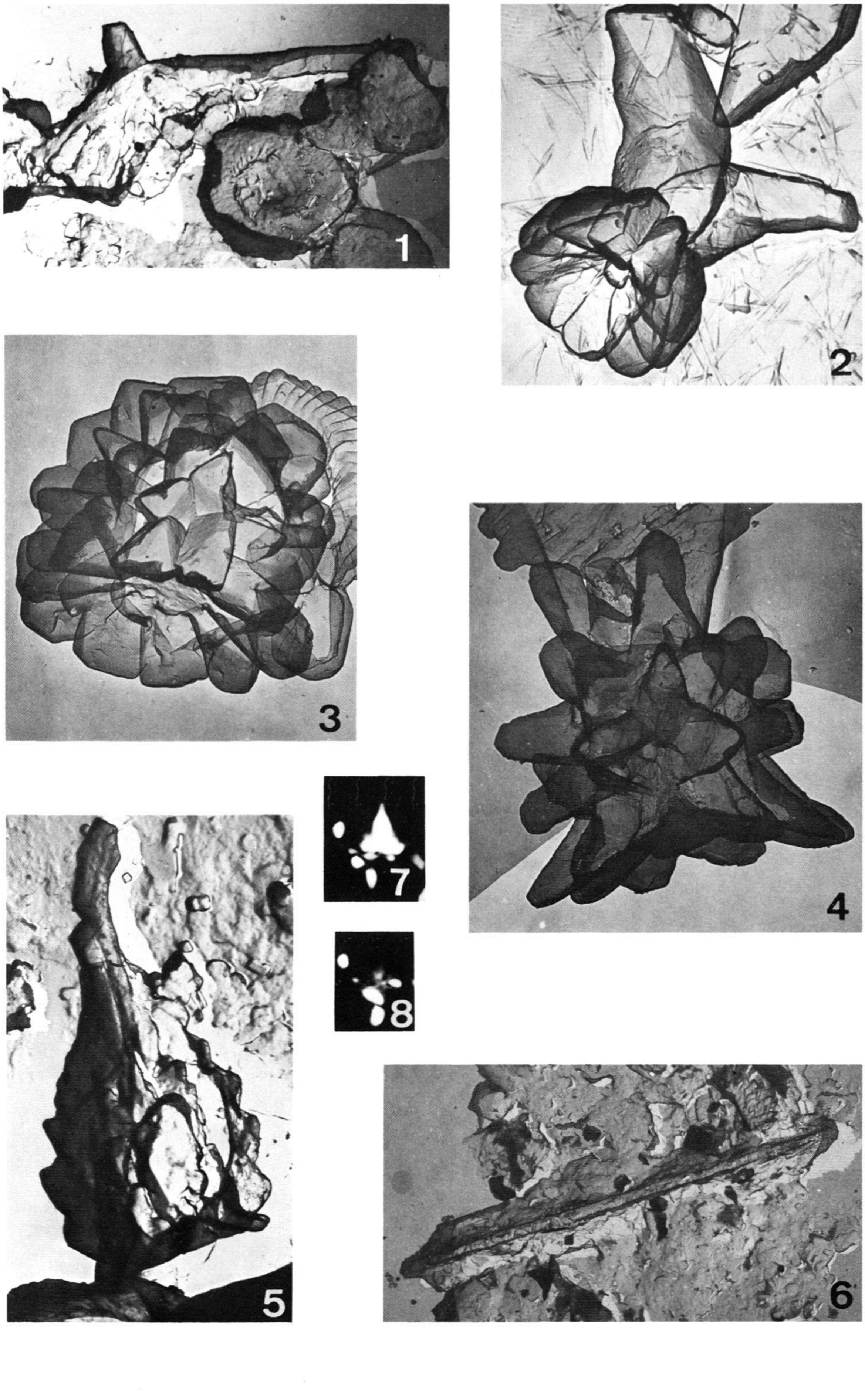
Fig. 3 — *Sphenolithus moriformis* (BRÖNNIMANN & STRADNER) BRAMLETTE & WILCOXON, Hypotype J3-475-11-1 [A 889], 9000 ×, JOIDES Hole 3, 475′ below top, B lake Plateau, W Atlantic.

Fig. 4 — *Sphenolithus moriformis* (BRÖNNIMANN & STRADNER) BRAMLETTE & WILCOXON. Hypotype J3-381-20-5 [A 890], 9500 ×, JOIDES Hole 3, 381′ below top, Blake Plateau, W Atlantic.

Fig. 5 — *Sphenolithus tribulosus* n. sp. Holotype A 608 504 [A 891], 10000 ×, Red Bluff Fm., 8′ above base, Alabama.

Fig. 6 — *Triquetrorhabdulus carinatus* MARTINI. Hypotype Bo291 A 458 [A 881], 10000 ×, Cipero Fm., Trinidad.

Fig. 7, 8 — *Sphenolithus tribulosus* n. sp. Paratype A 613-Lool A + B, 1750 ×, (7)A, long axis 45° to crossed nicols, [A 892], (8) B, long axis 0° to crossed nicols [A 893]; Red Bluff Fm., 13′ above base, Alabama.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