

ABSTRACT

Three biostratigraphic units are recognized on the basis of the vertical distribution of coccolithophorids and related calcareous nannofossils from the Upper Eocene, Lower Oligocene and Middle Oligocene of exposures at Little Stave Creek and St. Stephens Quarry, Alabama. Of the fifty-four species of nannofossils encountered, seven are described as new.

Calcareous nannoplankton from the Tertiary of Alabama

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INTRODUCTION

The nannofossils which are the basis for the present study were obtained from exposures along Little Stave Creek and at St. Stephens Quarry (text-figure 1). Both of these southeastern Alabama localities have essentially complete exposed sections of Upper Eocene, Lower Oligocene and Middle Oligocene strata (text-figure 2). The vertical distribution of coccolithophorids and related forms in the exposures permits recognition of three biostratigraphic units. These nannofossil units were found to be in agreement with biostratigraphic units previously established on the basis of other fossil invertebrates.

ACKNOWLEDGEMENTS

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STRATIGRAPHY

The Upper Eocene Jackson Group of Alabama contains the Moody's Branch Formation and the overlying Yazoo Formation. The Yazoo Formation has been divided into four members, namely, the North Twistwood Creek Clay, the Cocoa Sand, the Pachuta Marl, and the Shubuta Marl. The sample designations and the positions of the samples in the rock column are indicated in text-figure 2.

The lowest member examined in the present study was the Cocoa Sand. This member is not exposed at St. Stephens Quarry. However, good exposures containing abundant fossils of the echinoid *Periarchus pileusensis* are found in Little Stave Creek. Here, the Cocoa Sand consists of soft, grayish-yellow, glauconitic silts and sands.

The Cocoa Sand and the overlying Pachuta Marl are believed to be equivalent to "Zone A" of Bandy (1949). The Shubuta Marl is the uppermost member of the Yazoo Formation, and, in the area studied, appears to be equivalent to Bandy's "Zone B".

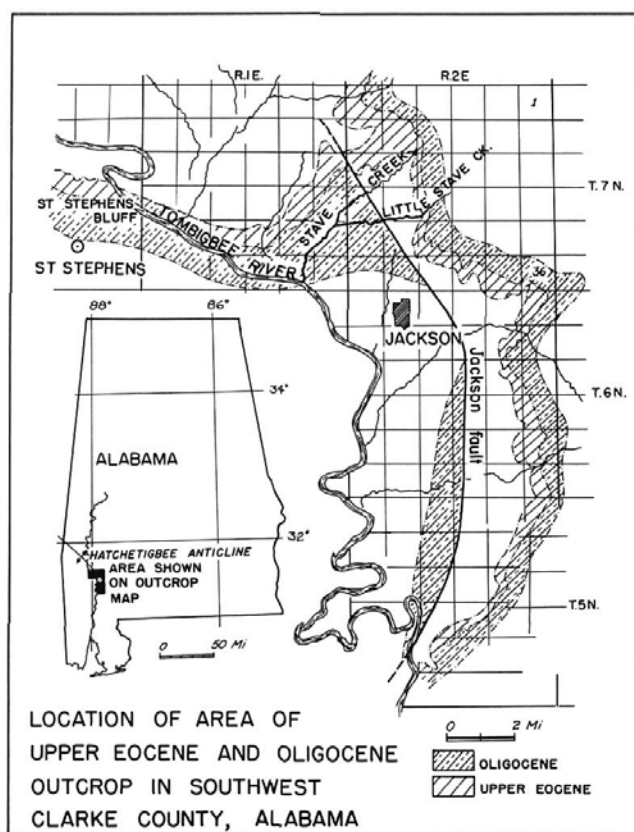
Above the Shubuta Marl lie the grayish-green, glauconitic, often silty beds of the Red Bluff Marl. The pelecypods *Spondylus dumosus* and *Ostrea vicksburgensis* occur abundantly in this formation. Deltaic sediments of the Forest Hill Clay occur above the Red Bluff Marl at St. Stephens Quarry. However, the Forest Hill apparently pinches out east of the quarry and could not be found along the Little Stave Creek outcrop area. The Forest Hill Clay and the Red Bluff Marl represent the Lower Oligocene deposition in the area of study.

In the area investigated, the Marianna Formation of the Vicksburg Group of the Middle Oligocene is divided into two members, namely, the Mint Spring Marl Member and the Marianna Limestone Member. All samples of the Mint Spring Marl were collected along the Little Stave Creek outcrop. The Mint Spring is a pale greenish-gray, glauconitic argillaceous limestone. The characteristic pelecypod occurring in the member is *Pecten poulsoni* s. s. Light gray to white, fossiliferous limestones of the Marianna Limestone Member overlie the Mint Spring Marl. Abundant bryozoans, the orbitoid foraminifer *Lepidocyclina mantelli*, the echinoid *Clypeaster rogersi* and the pelecypod *Pecten poulsoni* s. s. are the fossils that characterize the Marianna Limestone.

BIOSTRATIGRAPHIC ZONES

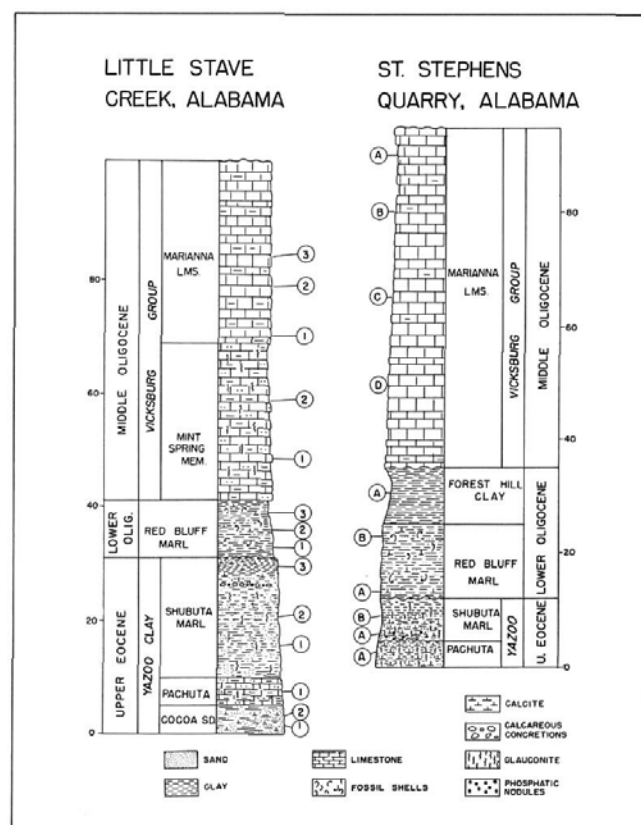
The stratigraphic distribution of species in samples examined for nannoplankton from the Little Stave Creek and St. Stephens Quarry exposures is recorded in Table 1. It is possible to delimit three biostratigraphic units based on the occurrence of the nannofossils.

The lower limit of the first of these units, designated "Unit I", has not as yet been determined. However, the upper boundary is marked by the disappearance of *Discoaster barbadiensis*, *Discoaster saipanensis* and *Pemma papillatum*. Unit I includes at least the three upper members of the Yazoo Formation present in the localities studied. The upper boundary of Unit I coincides with the previously established Upper Eocene-Lower Oligocene boundary.



TEXT-FIGURE 1

Location map



TEXT-FIGURE 2

Stratigraphic sections from which samples were collected.

Biostratigraphic Unit II includes the strata of the Red Bluff Formation. This zone extends upward from Unit I to the horizon at which *Isthmolithus recurvus*, *Rhabdosphaera vitrea*, *Discolithina solida*, *D. pectinata*, *D. macroporus*, *Clathrolithus minutus* and *Micrantholithus basquensis* terminate.

Biostratigraphic Unit III is characterized by the first appearance of *Braarudosphaera rosa*. The upper boundary of Unit III remains undefined until overlying beds can be examined. Unit III includes at least the Mint Spring Marl Member and the Marianna Limestone of Middle Oligocene age.

The abrupt increase in the variety of discoasters in the Upper Eocene Shubuta Member, and also the marked decrease in number and variety of discoliths in the Lower and Middle Oligocene strata, may have local value in correlation.

SYSTEMATIC DESCRIPTIONS

Family COCCOLITHOPHORIDAE Lohmann, 1902

Genus *Coccolithus* Schwarz, 1894

Description: Elliptical coccoliths (placoliths) consisting of two plates joined by a hollow stud or tube. The

plates are concave on their proximal sides. The distal plate is larger than the proximal plate.

Type species: *Coccolithus pelagicus* (Wallich) Schiller, 1930.

Geologic range: Lower Jurassic to Recent.

Coccolithus consuetus Bramlette and Sullivan Plate 1, figure 1a-b

Coccolithus consuetus BRAMLETTE and SULLIVAN, 1961, p. 139, pl. 1, fig. 4a-d.

Remarks: Coccoliths (placoliths) elliptical, plates closely appressed, central opening spanned by an x-shaped structure. The distal plate is identical with that illustrated by Bramlette and Sullivan (1961) and clearly shows the straight radiating striae on both the wide convex outer slope and the narrow inner slope. The central cross is slightly broader in our specimens than in those described by Bramlette and Sullivan. Length 8-12 microns, usually 9 microns.

Hypotypes: Shubuta 3B (12.1-84), WUMC 000050; Shubuta 3B (14.9-72), WUMC 000051.

Distribution: Paleocene, near Gan, France; Paleocene to Lower Eocene of California; Middle Eocene (Weches Formation) of Texas; Upper Eocene (Shubuta Member of Yazoo Formation) of Alabama.

DISTRIBUTION OF TERTIARY COCCOLITHOPHORIDS AND RELATED NANNOPLANKTON OF ALABAMA																												
● ABUNDANT ○ COMMON ○ FREQUENT △ FEW △ RARE	LOCATION	LITTLE STAVE CREEK															ST. STEPHENS QUARRY											
	SERIES	UPPER EOCENE						LOWER OLIGOCENE			MIDDLE OLIGOCENE						UPPER EOCENE			LOWER OLIGOCENE			MIDDLE OLIGOCENE					
	ROCK UNIT	PACHUTA			SHUBUTA			RED BLUFF			MINT SPRINGS			MARIANNA			PACHUTA			RED FOREST			MARIANNA					
		COCOA															SHUBUTA			BLUFF	HILL							
BIOSTRATIGRAPHIC UNIT		I						II			III						I			II			III					
SPECIES		1	2	1	1	2	3	1	2	3	1	2	1	2	3		A	A	B	A	B	A	D	C	B	A		
COCCOLITHOPHORIDAE																												
COCCOLITHUS	CONSUETUS					△	△	△																				
	aff. EOPELAGICUS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	OAMARUENSIS	●	●																									
	c.f. PELAGICUS	○	○	○	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	? PSEUDOGAMMATION	○	○	○	●	●	●	●	●	●	●	●	○	○	○	○	○	●	●	●	●	●	●	○	○	○	○	○
	STAVENSIS	○	○	○	●	●	●	●	●	●							○	○	○	○	○							
	TORTUOSUS	△	△	△	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	○	○			△	△	△	△	△
	APERTAPETRA UMBILICUS	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○			○	○	○	○	○
	CYCLOCOCCOLITHUS ACCLINIS	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○			○	○	○	○	○
	LUMINIS	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	RETICULOFENESTRA CAUCASICA					△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△			△	●	●	●	●
	DISCOLITHINA DISTINCTA	△	△	△	●	○	○	○	△	△	●	●					●	△	△	△	△							
	MACROPORA				●	●	●	●	●	●							●	●	●	●	●							
	OAMARUENSIS			●	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△			△	△	△	△	△
	OVATA	△	△	●	△	●		●	●	●	●	●	●	△	△	△	△	△	●	●	●			△	△	△		
	PECTINATA	●	●	●	△	△	△	△	△	△	△						●	△	△	△	△							
	PLANA	△	△	△	△	△	△	△	△	△	●	●	●				●	△	△	△	△			●	●		●	
	PULCHEROIDES	△	△	△	○	○	○	○	○	○	△	△	●	●	●	●	△	△	○	○	○			●			●	
	RIMOSA				△	△	△	△	△	△	●	●					●	○	●	●	●							
	SOLIDA				●	●	●	●	●	●							●	●	●	●	●							
	c.f. VERSA	●	●	●	△	△	△	△	△	△	△	△	●				●	△	△	△	●			●	●	●	●	●
	HELICOSPHAERA CARTERI	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○			○	○	○	○	○
	RHABDOSPHAERA PERLONGA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	△							
	SCABROSA	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●							
	SEMIFORMIS				●	●	●	●	●	●								●	●	●	●							
	SPINULA	○	○	○	○	○	○	○	○	○	○	○	△	●			○	○	○	○	○	●	△	△	●	●	●	●
	TENUIS	●	●	●	△	○	○	○	○	○	△	●	●	●			●	△	○	○	○			△	△	△	●	
	VITREA	●	●	●	●	●	●	●	●	●							●	●	●	●	●							
	ZYGOLITHUS AUREUS				●	●	●	●	●	●							●	●	●	●	●	●			●	●	●	●
	CRUX	△	△	△	○	○	○	○	○	○	△	△	△	△	△	△	△	○	○	○	○			●	●	●	●	●
	FISCUS																											
	ZYGRHABLITHUS BIJUGATUS		△	△	○	○	○	○	○	○	△	△	△	●	●	●	●	●	△	△	△			●	●	●	●	●
BRAARUDOSPHAERIDAE																												
	BRAARUDOSPHAERA BIGELOWI			●	○	○	○	△	△	△	△	●	●	●	●	●	●	△	○	○	○			△	△	△	△	△
	ROSA																							●	●	●	●	●
	MICRANTHOLITHUS ATTENUATUS	●				●	●	●	●	●	△	△	△	△	△	△		●	●	△	△			△	△	△	△	△
	BASQUENSIS				●	●	●	●	●	●							●	●	●	●	●							
	CRENULATUS	●	●	●	△	△	△	△	△	△	△	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●
	PEMMA PAPILLATUM	●	●	●	●	●											●	●										
LITHOSTROMATIDAE																												
	LITHOSTROMATION PERDURUM		●		●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●			●	●	●	●	●
	TROCHOASTER SIMPLEX				●	●	●				●	●						●	●	●	●			●				
DISCOASTERIDAE																												
	DISCOASTER ASTER	●	△	△	○	○	○	○	○	○	○	○	○	○	○	○	△	△							△	△	△	△
	aff. ASTER				●	●	●	○	○	○	○	○	○	○	○	○	●	△	△	△	△	●	●	●	●	●	●	●
	BARBADIENSIS	●	●	●	△	△	●										●	●	●	●	●							
	BINODOSUS				●	●	●	●	●	●							●	●	●	●	●							
	DEFLANDREI				●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●			●	●	●	●	●
	SAIPANENSIS	●	●	●	●	●	●										●	●	●	●	●							
	TANI				△	△	△	△	△	●	●			●			●	●	●	●	●			●				
	TANI NODIFERA				●	●		●	●	●	●	●					●	●	●	●	●			●			●	
	TRINUS				●	△	△	△	△	△	△	△	△	△	●	●												
INCERTAE SEDIS																												
	CLATHROLITHUS MINUTUS				●	△	△	△	△	●							●	●	●	●								
	ISTHOLITHUS TRIPLUS			●	△	△	△	△	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●			
	RECURVUS	●	●	●	△	△	△	△	●	●	●	●	●	●	●	●	●	●	△	△	△							
	LUCIANORHABDUS DISPAR	●	●	●	△	○	○	●	●	●	△	△	△	△	●	●	●	●	△	△	△			△	△	●		

Genus APERTAPETRA Hay, Mohler and Wade, 1966

Apertapetra umbilicus (Levin)

Plate 1, figure 9a-c

Coccolithus? sp. BOUCHÉ, 1962, pl. 1, fig. 17.

Coccolithus umbilicus LEVIN, 1965, p. 265, pl. 41, fig. 2.

Apertapetra samodurovi HAY, MOHLER and WADE, 1966, p. 388, pl. 6, figs. 1-7.

Remarks: Placoliths with generally circular to slightly elliptical outline, and with a large oval central depression. The peripheral margin is slightly fluted, a feature only occasionally visible in our specimens and not mentioned by Levin (1965) in the original description. Length 15-22 microns, average length 17 microns.

Hypotypes: Marianna 3A (9.0-85.0), WUMC 000063; Red Bluff 2A (5.2-85), WUMC 000064.

Distribution: Eocene and Oligocene of North America and Europe. Upper Eocene of southwestern USSR.

Genus *Cyclococcolithus* Kamptner, 1954

Description: Coccoliths (placoliths) consisting of two circular plates. Distal plate larger than proximal plate. Central depression gives the illusion of a central opening when viewed under the light microscope.

Cyclococcolithus acclinis Levin and Joerger, new species
Plate 1, figure 13a-b

Name: *Acclinis*, adj. (Latin). Inclined.

Description: Thick-rimmed circular placoliths with plates composed of numerous thin, slightly curved crystallites that radiate outward from the central opening to the periphery. Shield slopes sharply toward the inner and outer margins, so that a high central elevated ring exists midway between the two borders. Diameter 6-9 microns, diameter of holotype 8 microns.

Holotype: Shubuta 1B (11.4-80.0), WUMC 000112.

Paratypes: Shubuta 1B (6.9-76.0), WUMC 000113; Shubuta 1B (9.2-74.0), WUMC 000114.

Distribution: Upper Eocene to Middle Oligocene of Alabama.

Cyclococcolithus luminis Sullivan
Plate 1, figure 12a-b; plate 4, figure 17

Cyclococcolithus luminis SULLIVAN, 1965, p. 33, pl. 3, fig. 9a-b.

Remarks: Placoliths circular, plates closely appressed. Central area slightly depressed. Distal side almost flat except near the margin, where the plate curves slightly downward. Fine, straight, radiating striae are visible on the proximal plate and terminate at the finely serrate margin. Diameter of hypotype 5 microns, range of diameter 5-7 microns. The distinctive features of this

form are its circular outline and lack of curvature of rays of the extinction cross.

Hypotype: Mint Spring 2A (13.0-67.0), WUMC 000110.

Distribution: Eocene of California, Eocene and Oligocene of Alabama.

Cyclococcolithus? sp.

Plate 1, figures 10-11

Description: Small placoliths with approximately 35 segments which curve slightly in a clockwise direction, and appear vaguely imbricated toward the right when viewed in ordinary light. Central opening one-fifth of the diameter of the shield. Over-all diameter 7-10 microns.

Remarks: In general appearance this form resembles *Cyclococcolithus leptoporus* (Murray and Blackman) Kamptner, 1954. However, our specimens do not show the characteristic curved extinction cross of *C. leptoporus*. In size, symmetry, and appearance of the radial elements, these forms resemble macrococcoliths of the genus *Umbellosphaera* Paasche (Markali and Paasche, 1954). Definite identification of these forms will not be attempted until electron microscope observations and comparisons are made.

Hypotypes: Shubuta 3B (20.0-84.0), WUMC 000154; Shubuta 2A (17.0-74.9), WUMC 000155; Shubuta 2C (17.5-84.0), WUMC 000156.

Distribution: Upper Eocene of Little Stave Creek and St. Stephens Quarry, Alabama.

Discolithina Loeblich and Tappan, 1963

Description: Elliptical coccoliths with a single proximally concave plate, and with or without development of a rim.

Type species: *Discolithus vigintiforatus* Kamptner, 1948.

Geologic range: Jurassic to Recent.

Discolithina distincta (Bramlette and Sullivan)
Plate 1, figures 14a-b, 15a-b

Discolithus distinctus BRAMLETTE and SULLIVAN, 1961, p. 141, pl. 2, figs. 8a-b, 9a-c. - SULLIVAN, 1964, p. 182, pl. 4, fig. 4a-b. - SULLIVAN, 1965, p. 33, pl. 4, figs. 1-6.

Remarks: The Alabama specimens appear to have a slightly lower and narrower rim than those illustrated by Bramlette and Sullivan (1961). However, they are well within the range of variation for the species shown by Sullivan in his 1964 and 1965 works.

Hypotype: Red Bluff 1B (15.5-84.0), WUMC 000068.

Distribution: Paleocene and Eocene of California, Upper Eocene to Middle Oligocene of southwestern Alabama.

TERTIARY CALCAREOUS NANNOPLANKTON

Discolithina macroporus (Deflandre)

Plate 2, figure 5

Discolithus macroporus DEFLANDRE, 1954, in Deflandre and Fert, p. 24, pl. 11, fig. 5. — STRADNER, 1962, p. 365, pl. 1, figs. 1-13. — COHEN, 1964, p. 236, pl. 3, fig. 5a-b; pl. 4, fig. 6a-b.

Remarks: This small elliptical form is identical with the figured type of Deflandre (1954). The polygonal to subcircular shape of the pores has been clearly shown by Cohen (1964) in his electron micrographs of the species. Stradner's (1962) figures illustrate the wide range of variation of the species. Between crossed nicols, this form does not exhibit birefringence. Length 4-6 microns.

Hypotype: Shubuta 2C (16.8-80.0), WUMC 000067.

Distribution: Upper Eocene of Austria and Oamaru, New Zealand; Upper Eocene to Lower Oligocene of Alabama.

Discolithina oamaruensis (Deflandre)

Plate 2, figure 1a-b

Discolithus oamaruensis DEFLANDRE, 1954, in Deflandre and Fert, p. 139, pl. 12, figs. 1-2.

Remarks: These discoliths have an elevated furrowed rim. The central area is divided by a longitudinal suture. The segments composing the central area are thin and can best be observed with crossed nicols. Segments radiate outward from the central suture.

Hypotype: Mint Spring 1A (7.1-72.0) WUMC 000085; Marianna 1A (4.4-79.0) WUMC 000084.

Distribution: Upper Eocene of Oamaru, New Zealand; Upper Eocene to Middle Oligocene of Alabama.

Discolithina ovata Levin and Joerger, new species

Plate 2, figure 6a-d

Name: *Ovatus*, adj. (Latin). Ovate.

Description: Discoliths fairly thick, lacking rim. Shield composed of 20 to 22 elongate segments which radiate outward from a central longitudinal suture. Fluted periphery. Longitudinal suture modified into two slightly sigmoidal slits. Diameter 8-12 microns, diameter of holotype 9.5 microns.

Holotype: Marianna 3B (19.7-82.0), WUMC 000074.

Paratype: Marianna 2B (76-0.3), WUMC 000075.

Distribution: Upper Eocene and Middle Oligocene of Alabama.

Discolithina pectinata (Bramlette and Sullivan)

Plate 2, figure 4a-b

Discolithus pectinatus BRAMLETTE and SULLIVAN, 1961, p. 142, pl. 3, figs. 4a-b, 5a-b.

Discolithina pectinata (Bramlette and Sullivan). — LEVIN, 1965, p. 266, pl. 41, fig. 8.

Remarks: The Little Stave Creek forms have the thin rim characteristic of the species but with fewer narrow vertical slits than indicated for the holotype. Length 8-11 microns.

Hypotype: Red Bluff 1A (10.3-85.0), WUMC 000078.

Distribution: Lower and Middle Eocene of California, Middle Eocene (Weches Formation) of Texas, Upper and Lower Oligocene of Mississippi and Alabama.

Discolithina plana (Bramlette and Sullivan)

Plate 2, figure 3a-b

Discolithus planus BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, fig. 7a-c.

Discolithina plana (Bramlette and Sullivan). — LEVIN, 1965, p. 266, pl. 41, fig. 9a-c.

Hypotypes: Mint Spring 2A (3.9-79.0), WUMC 000076; Shubuta 1B (21.2-80.0), WUMC 000077.

Distribution: Lower Lutetian of France, Lower and Middle Eocene of California, Upper Eocene to Middle Oligocene of Alabama and Mississippi.

Discolithina pulchroides (Sullivan)

Plate 2, figure 8a-c

Discolithus pulchroides SULLIVAN, 1964, p. 183, pl. 4, fig. 7a-b.

Discolithina pulchra (Deflandre). — LEVIN, 1965, p. 266, pl. 41, fig. 6a-c.

Remarks: The specimens found in the Little Stave Creek area appear to be identical with those described by Sullivan (1964). Sullivan differentiates *D. pulchroides* from *D. pulchra* on the basis of the more oblique transverse central part and vagueness of the slits on *D. pulchroides*. The Alabama forms, and those previously described from the Yazoo Formation of Mississippi (Levin, 1965), do possess the more oblique transverse central structure and are therefore included under *D. pulchroides*. Length 5-11 microns.

Hypotype: Red Bluff 2A (7.2-71.0), WUMC 000079.

Distribution: Paleocene and Eocene of California, Upper Eocene to Middle Oligocene of Alabama and Mississippi.

Discolithina rimosa (Bramlette and Sullivan)

Plate 2, figures 9a-c, 10.

Discolithus rimosus BRAMLETTE and SULLIVAN, 1961, p. 143, pl. 3, figs. 12a-c, 13.

Remarks: Oval discoliths with a large central opening. Distal surface shows vague depressions along the inner marginal border which appear to extend toward the central opening.

Hypotypes: Red Bluff 2B (2.4-84.0), WUMC 000080; Red Bluff 3A (14.6-76.0), WUMC 000081.

Distribution: Paleocene to Middle Eocene of California and France, Upper Eocene to Middle Oligocene of Alabama.

Discolithina solida (Deflandre)

Plate 2, figure 7a-b

Discolithus solidus DEFLANDRE, 1954, in Deflandre and Fert, p. 141, pl. 12, figs. 14-16.

Remarks: This small form with its six pores and high optical relief in Canada balsam agrees closely with illustrations of the holotype. Length 3-5 microns, average length 4 microns.

Distribution: Paleocene and Eocene of California, Middle Eocene of Texas and France, Upper and Lower Oligocene of Alabama.

Discolithina sp. cf. *D. versa* (Bramlette and Sullivan)

Plate 2, figure 11a-b

cf. *Discolithus versus* BRAMLETTE and SULLIVAN, 1961, p. 144, pl. 3, fig. 16a-d.

Remarks: This form differs from *Discolithina plana* by the possession of a distinct rim. Length 8-11 microns, average length 10 microns.

Hypotypes: Red Bluff 1B (6.1-80.0), WUMC 000082; Shubuta 2A (11.1-82.7), WUMC 000083.

Distribution: *D. versa* has been reported from the Lower to Middle Eocene of California, the Middle Eocene (Lower Lutetian) of France, and the Upper Eocene to Middle Oligocene of Alabama.

Genus *RETICULOFENESTRA* Hay, Mohler and

Wade, 1966

Reticulofenestra caucasica Hay, Mohler and Wade

Plate 2, figure 2a-b

Reticulofenestra caucasica HAY, MOHLER and WADE, 1966, pp. 386-387, pl. 2, figs. 5-8; pl. 3, figs. 1-2; pl. 4, figs. 1-2.

Hypotype: Shubuta 1B (17.7-80.0) WUMC 000072.

Distribution: Upper Eocene and Lower and Middle Oligocene of Alabama; Upper Eocene of the southwestern USSR.

Genus *Helicosphaera* Kamptner, 1954

Description: Coccoliths composed of two asymmetrical superimposed plates with segments arranged in the form of a helicoid spiral. A bridge or bar traverses the central opening.

Type species: *Coccosphaera carteri* Wallich, 1877.

Geologic range: Cretaceous to Recent.

Helicosphaera carteri (Wallich)

Plate 2, figure 12a-c

Coccosphaera carteri WALLICH, 1877, p. 348, pl. 17, figs. 3-4. *Coccosphaera pelagica* Wallich, var. *carteri* Wallich. - OSTENFELD, 1899, p. 436.

Coccolithus carteri (Wallich). - KAMPTNER, 1941, pp. 93, 111, pl. 13, fig. 136.

Helicosphaera carteri (Wallich). - KAMPTNER, 1954, p. 21, text-figs. 17-19. - COHEN, 1964, pp. 238, 240, pl. 3, fig. 2a-f; pl. 4, fig. 1a-c.

Remarks: The plates of this helicoid asymmetrical form are joined at the narrow end, with the larger or distal plate overlapping the proximal plate. The species is variable in size (long axis 8-16 microns) and shape. Some forms are broadly oval, while others are narrowly elongate. The ellipsoidal central shield is perforated by elliptical or slitlike depressions. Fine striae are often visible along the margin. Cohen's (1964) electron micrographs illustrate the finer details of the species.

Hypotypes: Shubuta 2C (18.9-84.0), WUMC 000088; Marianna 1B (15.0-85.0), WUMC 000089; Marianna 1A (17.0-79.0), WUMC 000090; Mint Spring 1C (6.3-72.0), WUMC 000091.

Geologic range: Cretaceous to Recent. Common in all samples from the Upper Eocene to the Middle Oligocene of the Little Stave Creek area.

Genus *Rhabdosphaera* Haeckel, 1894

Description: Rhabdolites are trumpet-shaped in outline, with a central canal and a circular (rarely elliptical) basal plate.

Type species: *Rhabdosphaera claviger* Murray and Blackman, 1898.

Geologic range: Jurassic to Recent.

Rhabdosphaera perlonga (Deflandre)

Plate 2, figure 13a-c

Rhabdolithus perlongus DEFLANDRE, 1954, in Deflandre and Fert, p. 158, pl. 12, figs. 34-35; text-fig. 86.

Rhabdosphaera perlonga (Deflandre). - BRAMLETTE and SULLIVAN, 1961, p. 146, pl. 5, fig. 7a-c.

Remarks: The four beadlike elements visible on one side of the base and the non-uniform taper of this species are distinctive. Height 20 to 26 microns, base diameter 4 microns.

Hypotype: Shubuta 2C (20.3-84.0), WUMC 000097.

Distribution: Lower Eocene of California, Middle Eocene of California and Texas (Weches Formation), Lower and Middle Eocene of France, Upper Eocene to Middle Oligocene of Mississippi and Alabama.

Rhabdosphaera scabrosa (Deflandre)

Plate 2, figure 14a-b

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

Rhabdosphaera scabrosa (Deflandre). - BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, fig. 11a-b.

Remarks: The figured specimen displays the rugose appearance characteristic of this species. The central canal is wide and distinct when viewed between crossed nicols. Height 20-25 microns, diameter of base 4-6 microns.

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Hypotype: Shubuta 2A (13.9–75.0), WUMC 000099.

Distribution: Lower to Middle Eocene of California, Middle Eocene (lower Lutetian) of France, Middle Eocene (Weches Formation) of Texas, Upper Eocene to Middle Oligocene of Alabama.

Rhabdosphaera semiformis Bramlette and Sullivan Plate 2, figure 17

Rhabdosphaera? *semiformis* BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, figs. 8–9, 10a–b.

Remarks: This form is restricted to the Red Bluff and Shubuta beds of Little Stave Creek and St. Stephens Quarry. Height varies from 6 to 17 microns; diameter of base 4 microns.

Hypotype: Red Bluff 1B (7.3–76), WUMC 000102.

Distribution: Middle Eocene of California, Upper Eocene (Shubuta) and Lower Oligocene (Red Bluff) of Alabama.

Rhabdosphaera spinula Levin Plate 2, figure 15a–c

Rhabdosphaera spinula LEVIN, 1965, p. 267, pl. 42, fig. 3.

Remarks: Base arched, stem conical for about one-half of the length, then tapering to a point. Diameter of base somewhat variable. The Alabama forms appear to have fine vertical striae on the lower portion of the stem. The canal area occupies approximately three-fifths of the total width of the tube. Height 22–30 microns, diameter of base 5–8 microns.

Hypotype: Red Bluff 3B (4.2–72.0), WUMC 000100.

Distribution: Upper Eocene (Yazoo Formation) of Mississippi, Upper Eocene to Middle Oligocene of Alabama.

Rhabdosphaera tenuis Bramlette and Sullivan Plate 2, figure 16a–b

Rhabdosphaera tenuis BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, fig. 14a–b.

Hypotype: Shubuta 1B (10.7–68.1) WUMC 000098.

Distribution: The species is frequent in the Upper Eocene and Lower Oligocene beds of southwestern Alabama, but rare in the Middle Oligocene. It is common in the Lower and Middle Eocene of California.

Rhabdosphaera vitrea (Deflandre) Plate 2, figure 18

Rhabdolitus vitreus DEFLANDRE, 1954, in Deflandre and Fert, pp. 157–158, pl. 12, figs. 28–29; text-figs. 83–84.

Rhabdosphaera vitrea (Deflandre). – BRAMLETTE and SULLIVAN, 1961, p. 147, pl. 5, figs. 16–17.

Remarks: *Rhabdosphaera vitrea* is characterized by the presence of a collar at the junction of the stem with the base. Height 8–10 microns, diameter of base 5 microns.

Hypotype: Cocoa 1C (10.4–66.0), WUMC 000101.

Distribution: Lower to Middle Eocene of California, Middle Eocene (Lutetian) of France, Middle Eocene of Louisiana (Cane River Formation), and Upper Eocene to Lower Oligocene of Alabama.

Genus *Zycolithus* Matthes, 1956

Description: Coccoliths consisting of an elliptical ring with rim spanned by one or two transverse bars.

Type species: *Zycolithus erectus* Deflandre, 1954; designated by Loeblich and Tappan, 1963.

Geologic range: Upper Jurassic-Pliocene.

Zycolithus aureus Stradner Plate 2, figures 19–21; plate 4, figure 15a–b

Zycolithus aureus STRADNER, 1962, p. 368, pl. 1, figs. 31–36.

Remarks: The variant shown by Stradner (1962) as figure 31, represents the most common form in the Alabama samples. Length 5–7 microns, average length 5 microns.

Hypotypes: Red Bluff B2 (17.6–80.0), WUMC 000092; Red Bluff 1A (4.4–73.0), WUMC 000093; Shubuta 3A (14.2–84.0), WUMC 000094.

Distribution: Upper Eocene of Austria, Upper Eocene to Middle Oligocene of Alabama.

Zycolithus crux (Deflandre and Fert) Plate 2, figure 22a–b

Discolithus crux DEFLANDRE and FERT, 1952, p. 2101, text-fig. 8. *Zycolithus crux* (Deflandre and Fert). – BRAMLETTE and SULLIVAN, 1961, pl. 6, figs. 8–10.

Remarks: These forms are smaller than those figured by Bramlette and Sullivan (1961). However, both the Alabama specimens and the California forms differ from the holotype figure of Deflandre and Fert (1952) in that the central cross divides the central area unequally, being located slightly off the central axis of the ellipse. *Zycolithus crux* differs from *Discolithina bohotnica* (Gorka) in the off-center location of the cross and in the fine striations which occur perpendicular to the border. Length 5–9 microns, average length 6 microns.

Hypotype: Red Bluff 2A (2.4–79.0), WUMC 000096.

Distribution: Lower and Middle Eocene of California, France and Algeria; Upper Eocene to Middle Oligocene of Mississippi and Alabama.

Zygodolichus fiscus Levin and Joerger, new species
Plate 2, figure 23; plate 4, figure 16

Name: *Fiscus*, m. (Latin). Basket.

Description: Zygodolich with a high elliptical rim. Central area transversely spanned by two arching segments or yokes connected by a cross-bar so as to form the letter "H". The arch segment is pierced by three or four small lateral pores near the base of the arch on either side.

Remarks: This small form is rare in the Lower Oligocene. Unlike *Zygodolichus aureus*, it lacks pores in the central area of the arch. The "H" shape of the arch or jugum is the most prominent feature of the species. Holotype dimensions, 3 × 6 microns.

Holotype: Red Bluff 1B (16.5–72.0), WUMC 000095.

Distribution: Lower Oligocene of Alabama.

Genus *Zygrhablithus* Deflandre, 1959

Description: Thick elliptical or subcircular base displaying the optical effect of a cross in the light microscope and surmounted by a rhabdolith-like stem.

Type species: *Zygrhablithus bijugatus* (Deflandre), 1959.

Geologic range: Upper Cretaceous to Middle Oligocene.

Zygrhablithus bijugatus (Deflandre)
Plate 2, figure 24a–b; plate 3, figures 1–4.

Rhabdolithus costatus DEFlandre, 1954, in Deflandre and Fert, p. 157, pl. 11, figs. 8–11; text-figs. 41–42.

Zygodolichus bijugatus DEFlandre, 1954, in Deflandre and Fert, p. 148, pl. 11, fig. 21 only.

Zygrhablithus bijugatus (Deflandre). – DEFlandre, 1959, pp. 135–136.

Hypotypes: Shubuta 1A (12.7–76.0) WUMC 000107; Red Bluff 1A (14.5–73.0), WUMC 000104; Red Bluff 2A (15.6–83.0), WUMC 000106; Red Bluff B2 (20.2–80.0) WUMC 000108.

Distribution: Lower and Middle Eocene of California, Upper Eocene to Middle Oligocene of Mississippi and Alabama, Upper Eocene of Oamaru, New Zealand.

Family *Braarudosphaeridae* Deflandre, 1947

Description: Intact members of the family *Braarudosphaeridae* have the form of a dodecahedron composed of twelve pentaliths. Each of the pentaliths is a plaque composed of five segments.

Genus *Braarudosphaera* Deflandre, 1947

Description: *Braarudosphaeridae* with pentagonal pentaliths consisting of five quadrangular segments, each of which behaves optically as a single crystal of calcite.

Type species: *Pontosphaera bigelowi* Gran and Braarud, 1935.

Geologic range: Jurassic to Recent.

Braarudosphaera bigelowi (Gran and Braarud)
Plate 3, figure 5a–b

Pontosphaera bigelowi GRAN and BRAARUD, 1935, p. 388, text-fig. 67.

Braarudosphaera bigelowi (Gran and Braarud). – DEFlandre, 1947, p. 439, text-figs. 1–5.

Hypotype: Shubuta 2A (18.5–82.7) WUMC 000121.

Distribution: World-wide, Jurassic to Recent.

Braarudosphaera rosa Levin and Joerger, new species
Plate 3, figures 6a–b, 7

Name: *Rosa*, f. (Latin). Rose.

Description: Pentoliths small, with their segments broadly rounded at the periphery so as to present a lobate outline. The species exhibits typical braarudosphaerid extinction characteristics under crossed nicols. Diameter 10 microns.

Remarks: *B. rosa* differs from *B. discula* Bramlette and Riedel, 1954, in the more pronounced peripheral rounding of the segments.

Holotype: Marianna 1B (7.5–69.0), WUMC 000123.

Paratype: Marianna 1A (17.5–75.0), WUMC 000122.

Distribution: At present known only from the Middle Oligocene Mint Spring Marl and Marianna Limestone of Alabama.

Genus *Micrantholithus* Deflandre, 1950

Description: Star-shaped pentaliths composed of five V-shaped crystallographically distinct segments.

Type species: *Micrantholithus flos* Deflandre, 1950.

Geologic range: Paleocene to Middle Oligocene.

Micrantholithus attenuatus Bramlette and Sullivan
Plate 3, figure 9a–b

Micrantholithus attenuatus BRAMLETTE and SULLIVAN, 1961, p. 154, pl. 8, fig. 8.

Hypotypes: Marianna 1A (2.4–75.0), WUMC 000127; Red Bluff 3B (12.3–84.0), WUMC 000167.

Distribution: Lower Eocene and Paleocene of California; Middle Eocene and Upper Eocene of Mississippi and Alabama; Middle Eocene (upper Lutetian) of France.

Micrantholithus basquensis Martini
Plate 3, figure 10a–b

Micrantholithus basquensis MARTINI, 1959, p. 417, pl. 1, figs. 9–12. – BRAMLETTE and SULLIVAN, 1961, p. 154, pl. 8, figs. 14a–c, 15.

Remarks: The Alabama forms bear a closer resemblance to those figured by Bramlette and Sullivan (1961) than to those figured by Martini (1959). Each segment

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has a central depression, corresponding to an indentation of the peripheral margin. Specimens range in diameter from 14 to 17 microns, with the average diameter 15 microns.

Hypotype: Shubuta 3A (8.0–83.0), WUMC 000126.

Distribution: Lower Eocene and Middle Eocene of California; Upper Eocene to Middle Oligocene of Alabama.

Micrantholithus crenulatus Bramlette and Sullivan Plate 3, figure 8a–c

Micrantholithus crenulatus BRAMLETTE and SULLIVAN, 1961, p. 155, pl. 9, figs. 3a–b, 4.

Remarks: *Micrantholithus crenulatus* differs from *Micrantholithus basquensis* in lacking a centrally located depression in each segment. As suggested by the specific name, the periphery is slightly crenulate. Average diameter 11 microns, range in diameter 9–12 microns.

Hypotypes: Mint Spring 1A (2.2–84.0), WUMC 000124; Mint Spring 2A (13.2–83.0), WUMC 000125.

Distribution: Paleocene to Middle Eocene of California, Upper Eocene to Middle Oligocene of Alabama.

Genus *Pemma* Klumpp, 1953

Description: Circular to pentagonal pentoliths composed of five wedge-shaped crystallographically distinct segments.

Type species: *Pemma rotundum* Klumpp, 1953.

Geologic range: Eocene.

Pemma papillatum Martini Plate 3, figure 11a–c

Pemma papillatum MARTINI, 1959, p. 138, text-fig. 1a–b.

Hypotype: Shubuta 2C (17.0–74.0), WUMC 000128.

Distribution: Middle Eocene (Cook Mountain Formation) of Louisiana; Upper Eocene (Yazoo Clay) of Mississippi; Upper Eocene of Cuba, California and Alabama.

Genus *Lithostromation* Deflandre, 1942

Description: Triangular, crudely stellate or hexagonal forms with complex irregularly arranged depressions and ridges.

Type species: *Lithostromation perdurum* Deflandre, 1942.

Geologic range: Eocene and Oligocene.

Lithostromation perdurum Deflandre Plate 3, figures 12–13; plate 4, figure 14

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

Remarks: In *Lithostromation perdurum* the surface is covered with irregular depressions and ridges, which, on many specimens, extend outward from the surface so as to appear as irregularities on the peripheral profile. Average diameter 10 microns.

Hypotypes: Mint Spring 2B (6.4–69.0), WUMC 000129; Red Bluff 1A (11.5–85.0), WUMC 000130; Shubuta 2A (3.7–82.7), WUMC 000131.

Distribution: Upper Eocene to Middle Oligocene of Alabama.

Genus *Trochoaster* Klumpp, 1953

Description: Hexagonal, crudely stellate or irregularly circular forms with labyrinthic branching of surficial ridges.

Type species: *Trochoaster simplex* Klumpp, 1953.

Geologic range: Eocene to Middle Oligocene.

Trochoaster simplex Klumpp Plate 3, figures 20–21

Trochoaster simplex KLUMPP, 1953, p. 385, pl. 16, fig. 9; text-figs. 4/2.

Remarks: The nature of the surface ornamentation on this form is difficult to ascertain under the ordinary microscope. Commonly, a centrally located triradiate pattern is vaguely visible, each ridge of which in turn bifurcates repeatedly toward the periphery in a manner reminiscent of the branching of brachia in crinoids. The over-all appearance is often that of an intricate pattern of pits rimmed by ridges. This appearance is markedly altered by corrosion. The diameter ranges from 11 to 14 microns.

Hypotypes: Shubuta 1B (2.3–84.0), WUMC 000132; Red Bluff 2B (16.2–68.0), WUMC 000133.

Distribution: Lower Eocene of Germany, Lower and Middle Eocene of France, Upper Eocene of Mississippi, Upper Eocene and Middle Oligocene of Alabama, Lower Oligocene of Austria.

Family DISCOASTERIDAE Tan Sin Hok, 1927

Genus *Discoaster* Tan Sin Hok, 1927

Type species: *Discoaster pentaradiatus* Tan Sin Hok, 1927.

Geologic range: Cretaceous to Recent.

Discoaster aster Bramlette and Riedel Plate 3, figures 14–15

Discoaster stella (Ehrenberg). – COLOM and GAMUNDI, 1951, pl. 25, no. 6.

Discoaster aster BRAMLETTE and RIEDEL, 1954, p. 400, pl. 39, fig. 7.

Hypotypes: Shubuta 2A (15.7–79.0), WUMC 000134; Red Bluff 1B (14.9–72.0), WUMC 000135; Shubuta 3B (6.3–84.0), WUMC 000137.

Distribution: World-wide geographic distribution in Tertiary rocks.

Discoaster sp. aff. *D. aster* Bramlette and Riedel
Plate 3, figure 19a-b

Remarks: These small petaloid asteroliths have six bluntly terminated rays. They rarely exceed 6 microns in size. They differ from more typical specimens of *Discoaster aster* in their minute size, more broadly rounded rays, and lesser amount of separation of rays.

Hypotype: Marianna 1B (2.0-73), WUMC 000142.

Discoaster barbadiensis Tan Sin Hok
Plate 3, figure 17a-b

"Kalkerdige Crystalldrusen" EHRENBERG, 1854, p. 155, pl. 24, fig. 67; pl. 25, figs. B13, B15.

"Crystalloids" SORBY, 1861, p. 197. - HILL, 1892, in Jukes-Brown and Harrison, p. 178, text-figs. 4-6.

Discoaster barbadiensis TAN SIN HOK, 1927 (part), p. 119.

Heliodiscoaster barbadiensis (Tan). - DEFLANDRE, 1934, p. 64, text-figs. 22-23, 29-31.

Hemidiscoaster barbadiensis (Tan). - COLOM and GAMUNDI, 1951, pl. 25, no. 1.

Hypotype: Pachuta 1B (12.8-84.0), WUMC 000144.

Distribution: The asteroliths of *Discoaster barbadiensis* are frequent in the Cocoa Sand Member (Yazoo Formation) of the Little Stave Creek section. They are less common in the Pachuta Member and very rare in the Shubuta Member. The species has been reported from the Paleocene, Lower Eocene and Middle Eocene of California; the Lutetian of the Paris and Aquitaine Basins; the Upper Eocene of Alabama and Germany; and the Eocene of Algeria, Barbados, and New Zealand.

Discoaster binodosus Martini
Plate 3, figure 18a-b

Discoaster binodosus MARTINI, 1958, pp. 361-362, pl. 4, figs. 18a-b, 19a-b.

Hypotype: Red Bluff 2C (7.2-80.0), WUMC 000140.

Distribution: Paleocene, Lower Eocene and Middle Eocene of California; Lower Eocene (London Clay) of England; Middle Eocene of Austria; Upper Eocene of northwest Germany; Upper Eocene to Lower Oligocene of Alabama.

Discoaster deflandrei Bramlette and Riedel
Plate 4, figures 1-2

Discoaster deflandrei BRAMLETTE and RIEDEL, 1954, pp. 399-400, pl. 39, fig. 6, text-fig. 1a-c.

Hypotypes: Shubuta 2A (4.1-70.0), WUMC 000141; Red Bluff 2A (3.5-80.0), WUMC 000142.

Distribution: Paleocene, Eocene and Lower Miocene of California; Eocene of Austria, Saipan (Mariana Islands) and Alabama; Oligocene of Alabama, Trinidad, Cuba, Mexico and France.

Discoaster saipanensis Bramlette and Riedel
Plate 3, figure 16

Discoaster saipanensis BRAMLETTE and RIEDEL, 1954, p. 398, pl. 39, fig. 4.

Remarks: *Discoaster saipanensis* differs from *D. barbadiensis* in having fewer rays and in having them separate approximately at the mid-point of each ray. Diameter range 8-12 microns, average diameter 9 microns.

Hypotype: Pachuta 1B (12.0-74.0), WUMC 000149.

Distribution: *D. saipanensis* occurs with greatest frequency in the Cocoa Sand Member (Yazoo Formation) of the Stave Creek area. It diminishes in number above the Cocoa and is rare in the upper Shubuta Member. Elsewhere, the species has been reported from the Upper Eocene of California, Mississippi, Germany and Saipan, and from the Lutetian of Austria.

Discoaster tani Bramlette and Riedel
Plate 4, figure 3a-b

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

Remarks: Only five-rayed forms of *D. tani* have been found in the Alabama samples. Each ray is uniform in width and is terminated by a small V-shaped notch.

Hypotype: Shubuta 1B (4.1-68.0), WUMC 000145.

Distribution: Middle Eocene of Germany; Upper Eocene of Trinidad, New Zealand, France, Saipan, Mississippi, southwestern Alabama, and many other areas; Middle Oligocene of Germany and Alabama.

Discoaster tani nodifera Bramlette and Riedel
Plate 4, figures 4-6

Discoaster tani nodifera BRAMLETTE and RIEDEL, 1954, p. 397, pl. 39, fig. 2.

Hypotypes: Marianna 1A (5.3-80.0), WUMC 000146; Red Bluff 1A (16.6-85.0), WUMC 000148; Shubuta 2A (17.0-75.0), WUMC 000147.

Distribution: Middle Eocene of Austria and Germany; Upper Eocene of Saipan (Mariana Islands), New Zealand, Alabama and Mississippi; Lower to Middle Oligocene of Alabama.

Discoaster trinus Stradner
Plate 4, figures 7, 8a-b

Discoaster molengraaffi Tan. - STRADNER, 1959, p. 1085, text-figs. 15, 24.

Discoaster trinus STRADNER, 1961, p. 85, text-fig. 79.

Remarks: Under the ordinary microscope, *D. trinus* appears to be composed of two triradiate units symmetrically superimposed upon one another. The rays expand toward their terminations and bear a slight terminal notch. Diameter range 10-18 microns, average diameter 14 microns.

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Hypotypes: Shubuta 2A (8.7–84.1), WUMC 000150; Pachuta 1A (10.7–76.0), WUMC 000151; Mint Spring 1C (0.8–76.0), WUMC 000152; Marianna 1A (0.7–69.0), WUMC 000153.

Distribution: Middle Eocene of Austria, Middle Eocene to Middle Oligocene of Alabama.

INCERTAE SEDIS

Genus *Clathrolithus* Deflandre, 1954

Description: Elliptical reticulate bodies composed of a single plate which has the optical characteristics of a unit crystal. In lateral view the plate is slightly arched.

Type species: *Clathrolithus ellipticus* Deflandre, 1954.

Geologic range: Paleocene – Oligocene.

Clathrolithus minutus Bramlette and Sullivan Plate 4, figure 13a–c

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

Remarks: The Little Stave Creek specimens are readily identified as the species described by Bramlette and Sullivan. They possess a fine reticulum of polygonal perforations. The optic C-axis of the plate is perpendicular to the surface of the reticulum. Length 5–6 microns, width 3–4 microns.

Hypotype: Red Bluff B2 (14.0–76.0), WUMC 000165.

Distribution: Lower Eocene of California; Middle Eocene of California, Texas (Weches Formation) and France; Upper Eocene to Lower Oligocene of southwestern Alabama.

Genus *Isthmolithus* Deflandre, 1954

Description: Skeletal elements with parallelogram or rectangular shape divided by one or more transverse barlike structures.

Type species: *Isthmolithus recurvus* Deflandre, 1954.

Geologic range: Eocene – Oligocene.

Isthmolithus recurvus Deflandre Plate 4, figure 11

Isthmolithus recurvus DEFlandre, in Deflandre and Fert, 1954, p. 169, pl. 12, figs. 9–13, text-figs. 119–122.

Remarks: All specimens show the parallelogram form with rounded sides and two transverse bars. Martini (1958) noted that *Isthmolithus recurvus* is suitable as a guide fossil for the Upper Eocene in northwest Germany. In the Alabama sections, however, rare specimens of *I. recurvus* have been found in samples as young as Lower Oligocene. Length 8–10 microns, width 4–5 microns.

Hypotype: Shubuta 2A (9.0–82.7), WUMC 000162.

Distribution: Upper Eocene of Germany, New Zealand (Oamaru), Mississippi and Alabama; Lower Oligocene of Alabama.

Isthmolithus triplus Levin and Joerger, new species Plate 4, figure 12a–b

Name: *Triplus*, adj. (Latin). Triple.

Description: An elongate rectangular form with rounded corners and three openings aligned along the long axis. The openings are separated by two short transverse extensions of the rim portion of the isthmolith. Two joined calcite segments comprise the isthmolith, and each segment behaves optically as a single crystal of calcite. Therefore, the individual segments are easily discerned under crossed nicols when one segment or the other is in the extinction position.

Remarks: This species differs from *Isthmolithus recurvus* Deflandre (1954) in its rectangular rather than parallelogram shape. Also, the sides of the rectangle are very thick, and the central openings are smaller and less rectangular in shape. Length 7–10 microns, width 4–5 microns, holotype 4 × 8 microns.

Holotype: Shubuta 1A (5.0–68.0), WUMC 000163.

Distribution: Upper Eocene to Middle Oligocene of Alabama.

Genus *Lucianorhabdus* Deflandre, 1959

Description: Cylindrical to subcylindrical forms with irregular outline, granular or rugose surface, and clublike terminal expansions. Skeletal elements consist of four calcareous rods joined into a box-like arrangement. Each rod is crystallographically distinct.

Type species: *Lucianorhabdus cayeuxi* Deflandre, 1959.

Geologic range: Cretaceous – Middle Oligocene.

Lucianorhabdus dispar Stradner Plate 4, figures 9a–c, 10a–b

Lucianorhabdus dispar STRADNER, 1961, p. 87, text-figs. 49, 51–52.

Remarks: The specimens from the Alabama sections, though variable in shape and surface roughness, appear to be within the range of variability indicated by Stradner's (1961) illustrations. Length 8–17 microns, width 5–8 microns.

Hypotypes: Shubuta 2C (3.0–68.0), WUMC 000160; Shubuta 1B (0.5–84.3), WUMC 000161.

Distribution: Upper Eocene to Middle Oligocene of Alabama.

PLATE 1

- 1 *Coccolithus consuetus* Bramlette and Sullivan
Hypotype, WUMC 000050, Shubuta 3B (12.1–84.0); a, distal view, drawing; b, long axis 0° to crossed nicols.
- 2 *Coccolithus* sp. aff. *C. eopelagicus* (Bramlette and Riedel)
Hypotype, WUMC 000053, Shubuta 2C (12.7–84.1); a, distal view, drawing; b, distal view, phase contrast.
- 3 *Coccolithus?* *pseudogammation* Bouché
Hypotype, WUMC 000109, Red Bluff 1B (13.7–84.0); a, distal view, phase contrast; b, distal view, drawing; c, distal view, crossed nicols.
- 4 *Coccolithus* sp. cf. *C. pelagicus* (Wallich)
Hypotype, WUMC 000058, Shubuta 1B (21.0–84.0); a, distal view; b, distal view, phase contrast.
- 5 *Coccolithus* sp. cf. *C. pelagicus* (Wallich)
Hypotype, WUMC 000055, Cocoa 1A (7.0–74.0), distal view, phase contrast.
- 6 *Coccolithus oamaruensis?* (Deflandre)
Cocoa 2C (4.1–72.0); a, hypotype, WUMC 000062, corroded specimen, phase contrast; b, drawing of similar specimen.
- 7 *Coccolithus stavensis* Levin and Joerger, n. sp.
Holotype, WUMC 000065, Mint Spring 1A (6.8–72.0); a, distal view, drawing; b, distal view, ordinary light; c, distal view, phase contrast; d, side view, diagrammatic sketch.
- 8 *Coccolithus tortuosus* Levin and Joerger, n. sp.
Holotype, WUMC 000059, Marianna 2B (3.4–76.0); a, side view, drawing; b, distal view, phase contrast; c, distal view, drawing; d, distal view, ordinary light.
- 9 *Apertapetra umbilicus* (Levin)
Hypotype, WUMC 000064, Red Bluff 2A (5.2–85.0); a, proximal view, ordinary light; b, proximal view, phase contrast; c, restored drawing.
- 10 *Cyclococcolithus?* sp.
Shubuta 3B (20.0–84.0), distal view, phase contrast.
- 11 *Cyclococcolithus?* sp.
Shubuta 2A (17.0–74.9), phase contrast, view of three overlapping specimens.
- 12 *Cyclococcolithus luminis* Sullivan
Hypotype, WUMC 000110, Mint Spring 2A (13.0–67.0); a, phase contrast; b, crossed nicols.
- 13 *Cyclococcolithus acclinis* Levin and Joerger, n. sp.
Holotype, WUMC 000112, Shubuta 1B (11.4–80.0); a, distal view, drawing; b, distal view, phase contrast.
- 14 *Discolithina distincta* (Bramlette and Sullivan)
Hypotype, WUMC 000068, Red Bluff 1B (15.5–84.0); a, distal view, phase contrast; b, 20° to crossed nicols.
- 15 *Discolithina distincta* (Bramlette and Sullivan)
Hypotype, WUMC 000069, Red Bluff 1B (7.9–72.0); a, distal view, 20° to crossed nicols; b, distal view, phase contrast.

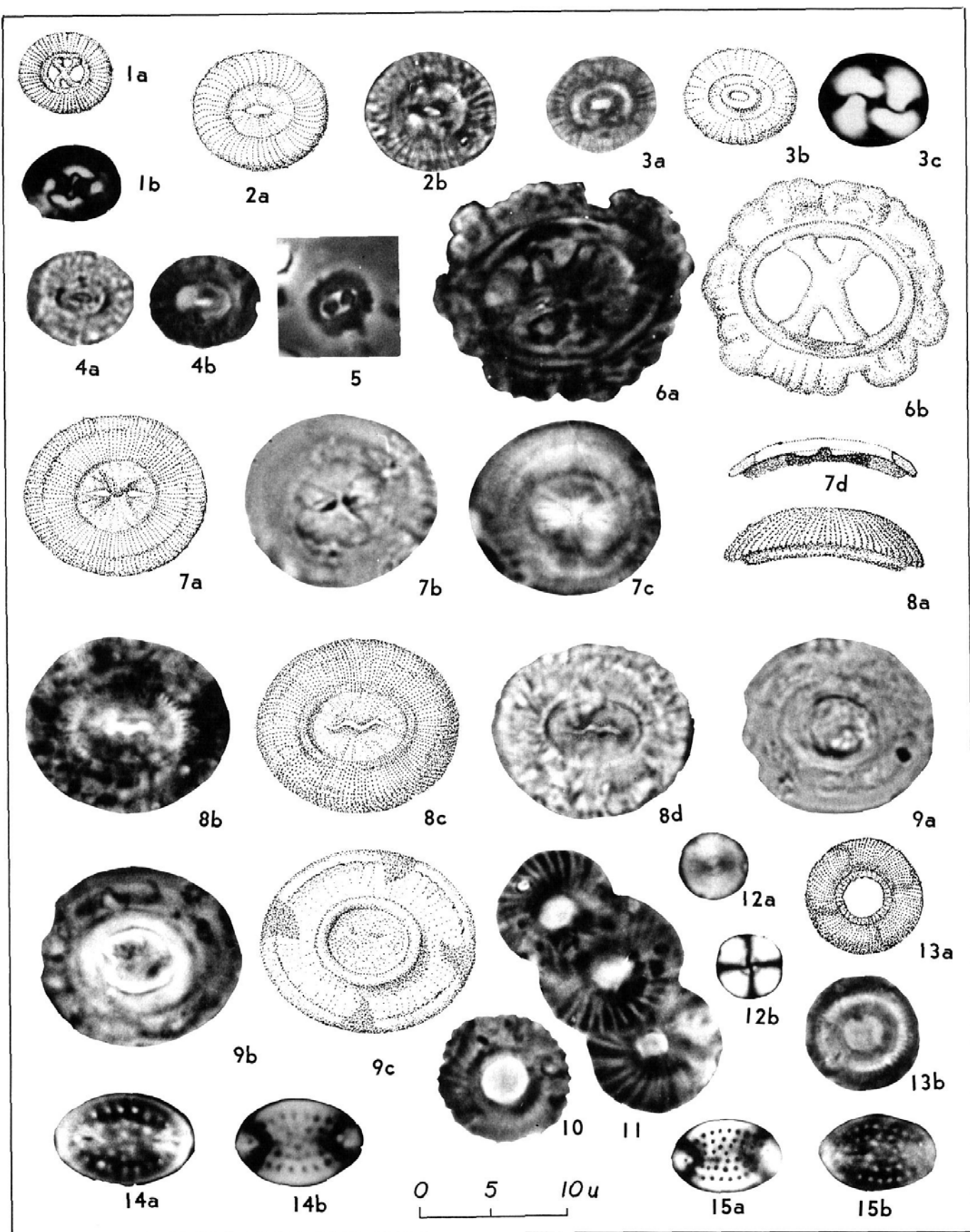


PLATE 2

- 1 *Discolithina oamaruensis* (Deflandre)
Hypotype, WUMC 000085, Marianna 1A (4.4–70.0); a, proximal view; b, drawing.
- 2 *Reticulofenestra caucasica* Hay, Mohler and Wade
WUMC 000071, Shubuta 1B (17.7–80.0); a, proximal view, phase contrast; b, crossed nicols.
- 3 *Discolithina plana* (Bramlette and Sullivan)
Hypotype, WUMC 000076, Mint Spring 2A (3.9–79.0); a, distal view, phase contrast; b, long axis 20° to crossed nicols.
- 4 *Discolithina pectinata* (Bramlette and Sullivan)
Hypotype, WUMC 000078, Red Bluff 1A (10.3–85.0); a, distal view, phase contrast; b, distal view, drawing.
- 5 *Discolithina macroporus* (Deflandre)
Hypotype, WUMC 000067, (16.8–80.0) Shubuta 2C, distal view, phase contrast.
- 6 *Discolithina ovata* Levin and Joerger, n. sp.
Holotype, WUMC 000074, Marianna 3A (19.7–82.0); a, drawing; b, distal view, phase contrast; c, long axis 0° to crossed nicols; d, long axis 70° to crossed nicols.
- 7 *Discolithina? solida* (Deflandre)
Hypotype, WUMC 000086, Shubuta 2C (7.5–84.0); a, distal view, drawing; b, distal view, phase contrast.
- 8 *Discolithina pulcheroides* (Sullivan)
Hypotype, WUMC 000079, Red Bluff 2A (7.2–71.0); a, distal view, drawing; b, distal view, phase contrast; c, 10° to crossed nicols.
- 9 *Discolithina rimosa* (Bramlette and Sullivan)
Hypotype, WUMC 000081, Red Bluff 3A (14.6–76.0); a, distal side, long axis 5° to crossed nicols; b, distal view, phase contrast; c, distal view, drawing.
- 10 *Discolithina rimosa* (Bramlette and Sullivan)
WUMC 000080, Red Bluff 2B (2.4–84.0), long axis 10° to crossed nicols.
- 11 *Discolithina* sp. cf. *D. versa* (Bramlette and Sullivan)
Hypotype, WUMC 000082, Red Bluff 1B (6.1–80.0); a, distal view, phase contrast; b, drawing.
- 12 *Helicosphaera carteri* (Wallich) Kamptner
Hypotype, WUMC 000089, Marianna 1B (15.0–85.0); a, proximal view, phase contrast; b, 45° to crossed nicols; c, proximal view, drawing.
- 13 *Rhabdosphaera perlonga* (Deflandre)
Hypotype, WUMC 000097, Shubuta 2C (20.3–84.0); a, side view, phase contrast; b, ordinary light; c, long axis 45° to crossed nicols.
- 14 *Rhabdosphaera scabrosa* (Deflandre)
Hypotype, WUMC 000099, Shubuta 2A (13.9–75.0); a, crossed nicols; b, side view, drawing.
- 15 *Rhabdosphaera spinula* Levin
Hypotype, WUMC 000100, Red Bluff 3B (4.2–72.0); a, side view, phase contrast; b, ordinary light; c, drawing.
- 16 *Rhabdosphaera tenuis* Bramlette and Sullivan
Hypotype, WUMC 000098, Shubuta 1B (10.7–68.1); a, crossed nicols; b, side view, phase contrast.
- 17 *Rhabdosphaera? semiformis* Bramlette and Sullivan
Hypotype, WUMC 000102, Red Bluff 1B (7.3–76.0), phase contrast.
- 18 *Rhabdosphaera vitrea* (Deflandre)
Hypotype, WUMC 000101, Cocoa 1C (10.4–66.0), drawing.
- 19 *Zygolithus aureus* Stradner
Hypotype, WUMC 000092, Red Bluff B2 (17.6–80.0), ordinary light.
- 20 *Zygolithus aureus* Stradner
Hypotype, WUMC 000093, Red Bluff 1A (4.4–73.0), phase contrast.
- 21 *Zygolithus aureus* Stradner
Hypotype, WUMC 000094, Shubuta 3A (14.2–84.0), phase contrast.
- 22 *Zygolithus crux* Deflandre and Fert
Hypotype, WUMC 000096, Red Bluff 2A (2.4–79.0); a, drawing; b, crossed nicols.
- 23 *Zygolithus fiscus* Levin and Joerger, n. sp.
Holotype, WUMC 000095, Red Bluff 1B (16.5–72.0), phase contrast.
- 24 *Zygrhablithus bijugatus* (Deflandre)
Hypotype, WUMC 000104, Red Bluff 1A (14.5–73.0); a, 45° to crossed nicols; b, phase contrast.

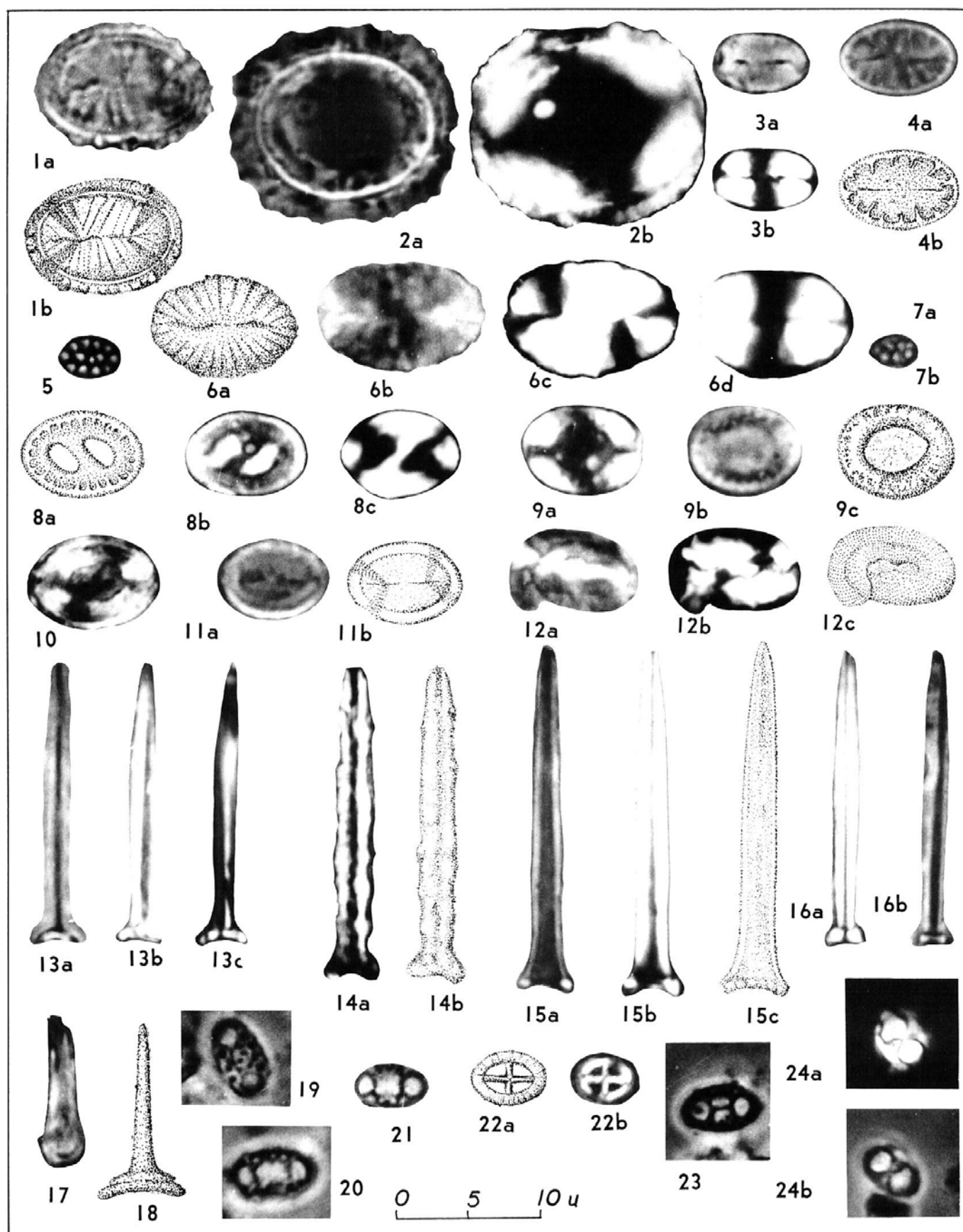
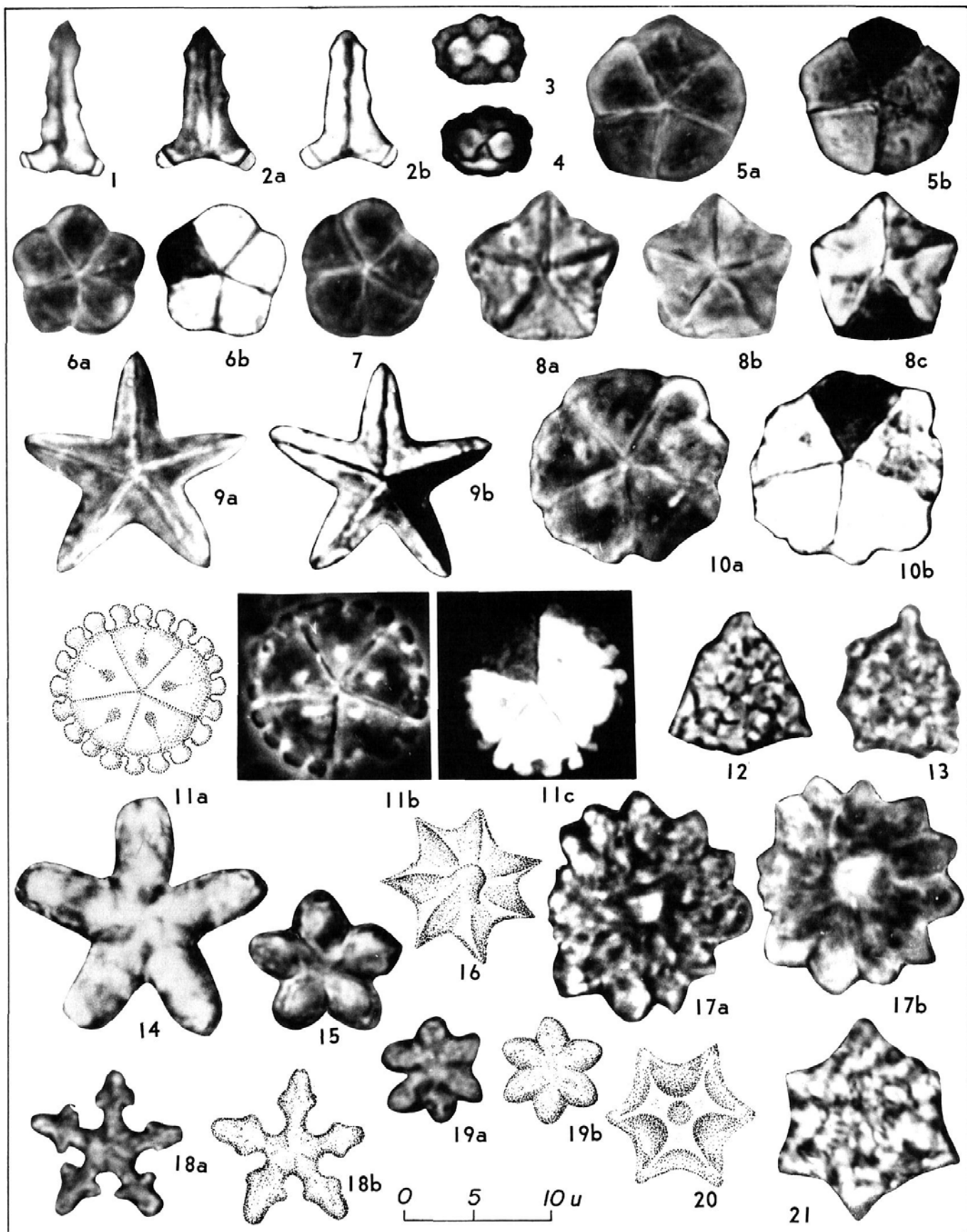


PLATE 3

- 1 *Zygrhablithus bijugatus* (Deflandre)
Hypotype, WUMC 000106, Red Bluff 2A (15.6–83.0), crossed nicols.
- 2 *Zygrhablithus bijugatus* (Deflandre)
Hypotype, WUMC 000105, Red Bluff 2A (6.4–75.1); a, phase contrast; b, crossed nicols.
- 3 *Zygrhablithus bijugatus* (Deflandre)
Hypotype, WUMC 000107, Shubuta 1A (12.7–76.0), basal view, phase contrast.
- 4 *Zygrhablithus bijugatus* (Deflandre)
Hypotype, WUMC 000108, Red Bluff B2 (20.2–80.0), basal view, 45° to crossed nicols.
- 5 *Braarudosphaera bigelowi* (Gran and Braarud)
Hypotype, WUMC 000121, Shubuta 2A (18.5–82.7); a, distal view, phase contrast; b, crossed nicols.
- 6 *Braarudosphaera rosa* Levin and Joerger, n. sp.
Holotype, WUMC 000123, Marianna 1B (7.5–69.0); a, phase contrast; b, crossed nicols.
- 7 *Braarudosphaera rosa* Levin and Joerger, n. sp.
Paratype, WUMC 000122, Marianna 1A (17.5–75.0), crossed nicols.
- 8 *Micrantholithus crenulatus* Bramlette and Sullivan
Hypotype, WUMC 000124, Mint Spring 1A (2.2–85.0); a, ordinary light; b, phase contrast; c, crossed nicols.
- 9 *Micrantholithus attenuatus* Bramlette and Sullivan
Hypotype, WUMC 000127, Marianna 1A (2.4–75.0); a, phase contrast; b, crossed nicols.
- 10 *Micrantholithus basquensis* Martini
Hypotype, WUMC 000126, Shubuta 3A (8.0–83.0); a, phase contrast; b, crossed nicols.
- 11 *Pemma papillatum* Martini
Hypotype, WUMC 000128, Shubuta 2C (17.0–74.0); a, drawing; b, phase contrast; c, crossed nicols.
- 12 *Lithostromation perdurum* Deflandre
Hypotype, WUMC 000129, Mint Spring 2B (6.4–69.0), ordinary light.
- 13 *Lithostromation perdurum* Deflandre
Hypotype, WUMC 000130, Red Bluff 1A (11.5–85.0), corroded specimen.
- 14 *Discoaster aster* Bramlette and Riedel
Hypotype, WUMC 000135, Red Bluff 1B (14.9–72.0), ordinary light.
- 15 *Discoaster aster* Bramlette and Riedel
Hypotype, WUMC 000137, Shubuta 3B (6.3–84.0), ordinary light.
- 16 *Discoaster saipanensis* Bramlette and Riedel
Hypotype, WUMC 000149, Pachuta 1B (12.0–74.0), oblique view, drawing.
- 17 *Discoaster barbadiensis* Tan Sin Hok
Hypotype, WUMC 000144, Pachuta 1B (12.8–84.0); a, ordinary light; b, phase contrast.
- 18 *Discoaster binodosus* Martini
Hypotype, WUMC 000140, Red Bluff 2C (7.2–80.0); a, ordinary light; b, drawing.
- 19 *Discoaster* sp. aff. *D. aster* Bramlette and Riedel
WUMC 000142, Marianna 1B (2.0–73.0); a, ordinary light; b, drawing.
- 20 *Trochoaster simplex* Klumpp
Hypotype, WUMC 000133, Red Bluff 2B (16.2–68.0), drawing.
- 21 *Trochoaster simplex* Klumpp
Hypotype, WUMC 000132, Shubuta 1B (2.3–84.0), ordinary light.

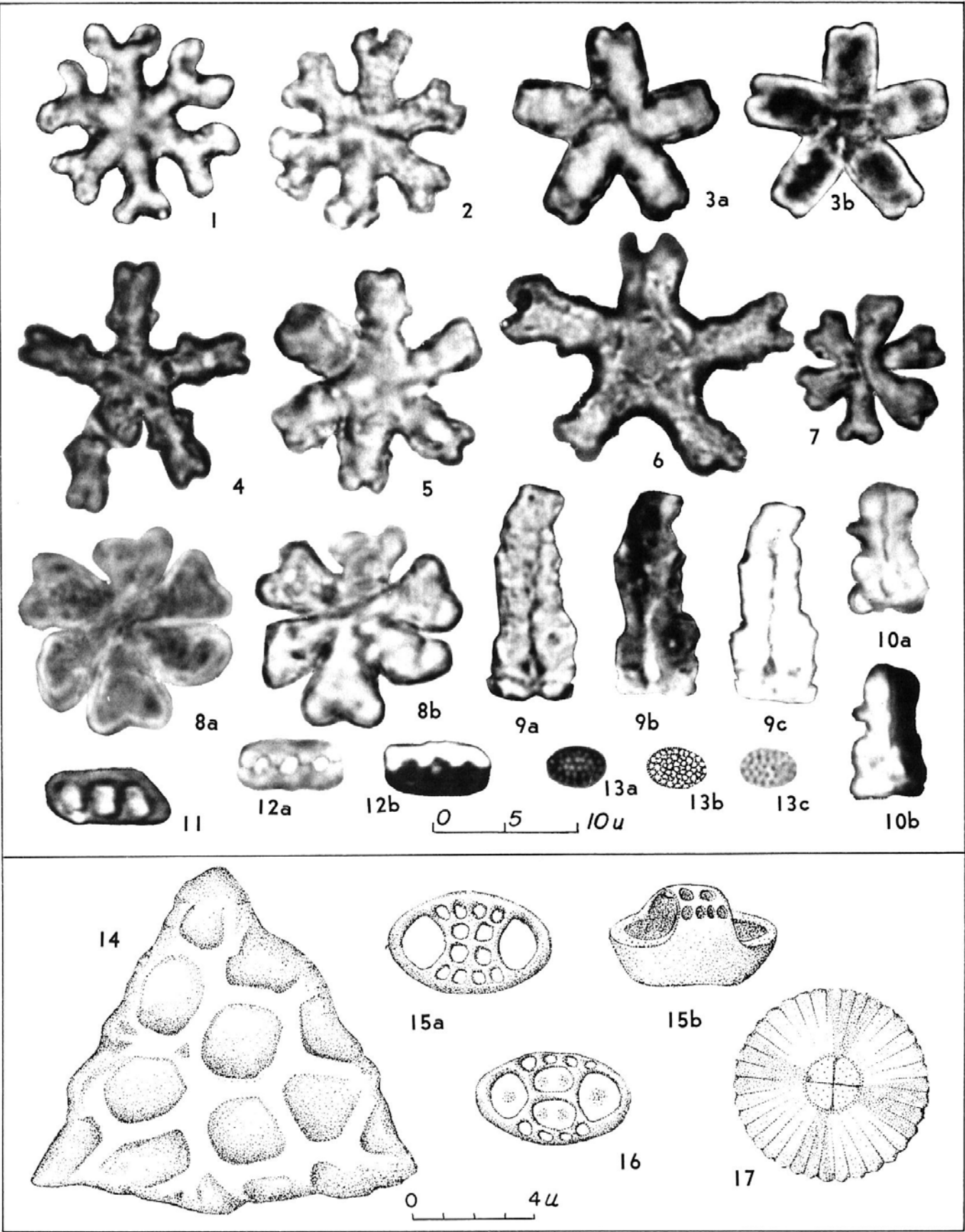


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PLATE 4

- 1 *Discoaster deflandrei* Bramlette and Riedel
Hypotype, WUMC 000141, Shubuta 2A (4.1-70.0), ordinary light.
- 2 *Discoaster deflandrei* Bramlette and Riedel
Hypotype, WUMC 000142, Marianna 1B (3.5-80.0), ordinary light.
- 3 *Discoaster tani* Bramlette and Riedel
Hypotype, WUMC 000145, Shubuta 1B (4.1-68.0); a, ordinary light; b, phase contrast.
- 4 *Discoaster tani nodifera* Bramlette and Riedel
Hypotype, WUMC 000148, Shubuta 2A (17.0-75.0), ordinary light.
- 5 *Discoaster tani nodifera* Bramlette and Riedel
Hypotype, WUMC 000146, Marianna 1A (5.3-80.0), ordinary light.
- 6 *Discoaster tani nodifera* Bramlette and Riedel
Hypotype, WUMC 000147, Red Bluff 1A (16.6-85.0), ordinary light.
- 7 *Discoaster trinus* Stradner
Hypotype, WUMC 000150, Shubuta 2A (8.7-84.1), ordinary light.
- 8 *Discoaster trinus* Stradner
Hypotype, WUMC 000151, Pachuta 1A (10.7-76.0), ordinary light.
- 9 *Lucianorhabdus dispar* Stradner
Hypotype, WUMC 000161, Shubuta 1B (0.5-84.3); a, ordinary light; b, phase contrast; c, 20° to crossed nicols.
- 10 *Lucianorhabdus dispar* Stradner
Hypotype, WUMC 000160, Shubuta 2C (3.0-68.0); a, phase contrast; b, 25° to crossed nicols.
- 11 *Isthmolithus recurvus* Deflandre
Hypotype, WUMC 000162, Shubuta 2A (9.0-82.7), phase contrast.
- 12 *Isthmolithus triplus* Levin and Joerger, n. sp.
Holotype, WUMC 000163, Shubuta 1A (5.0-68.8); a, phase contrast; b, long axis 20° to crossed nicols.
- 13 *Clathrolithus minutus* Bramlette and Sullivan
Hypotype, WUMC 000165, Red Bluff B2 (14.0-76.0); a, phase contrast; b, drawing; c, ordinary light.
- 14 *Lithostromation perdurum* Deflandre
Drawing.
- 15 *Zygolithus aureus* Stradner
a, distal view, drawing; b, side view, drawing.
- 16 *Zygolithus fiscus* Levin and Joerger, n. sp.
Drawing.
- 17 *Cyclococcolithus luminis* Sullivan
Drawing.



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