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JOURNAL OF PALEONTOLOGY, v. 41, no. 6, p. 1505–1541, PLS. 196–206, 5 TEXT-FIGS., NOVEMBER 1967

CALCAREOUS NANNOPLANKTON FROM EARLY TERTIARY ROCKS AT PONT LABAU, FRANCE, AND PALEOCENE—EARLY EOCENE CORRELATIONS

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ABSTRACT—Well-preserved assemblages of calcareous nannofossils are found in Paleocene-early Eocene pelagic sediments on the north flank of the Pyrenees south of Pau, Basses Pyrenees, France. Nearly continuous exposures through the Paleocene strata at Pont Labau provide a reference section for correlation with other localities in Europe and the Americas.

Forty-four species belonging to 21 genera are described in detail, using ordinary transmitted light and phase contrast illumination for general investigation, and observation of the forms between crossed polarizers and electron microscopy of carbon replicas for determination of structure. The following new families are proposed: Prinsiaceae, Heliolithaceae, Zygodiscaceae, and Fasciculithaceae. The family Coccolithaceae Kamptner, 1928, is emended. A new subfamily, Cyclococcolithoideae, is proposed, and the subfamily Coccolithoideae Kamptner, 1928, is emended. The following new genera are recognized: *Conococcolithus Prinsius*, and *Toweius*, and the following eight new species are described: *Coccolithus cavus*, *C. apomenmoneumus*, *Conococcolithus minutus*, *Toweius craticulus*, *Ericsonia subpertusa*, *Scapholithus apertus*, *S. rhombiformis*, and *Fasciculithus schaubi*.

INTRODUCTION

CALCAREOUS nannofossils exhibit a number of peculiarities which are essentially unique to this group. Calcareous nannofossils are produced by two widely separated groups of organisms: 1, the ascidians, marine protochordates which develop minute spherical bodies that are covered with short pyramidal protuberances and 2, the

EXPLANATION OF PLATE 196

Illustrations are of light micrographs, ×2250.

FIGS. *1–3*—*Coccolithus cavus* n. sp. Paratype, UI-H-2728, GAN 837, distal views: *1*, phase contrast; *2*, ordinary transmitted light; *3*, between crossed nicols.
4–6—*Conococcolithus minutus* n. gen., n. sp. Paratype, UI-H-2729, GAN 837, distal views: *4*, phase contrast; *5*, ordinary transmitted light; *6*, between crossed nicols.
7–9—*Toweius craticulus* n. sp. Paratype, UI-H-2730, GAN 807, proximal views: 7, phase contrast; *8*, ordinary transmitted light; *9*, between crossed nicols.
10–13—*Coccolithus bisulcus* Stradner. *10*, Hypotype, UI-H-2733, GAN 809, distal view, ordinary transmitted light. *11*, Hypotype, U1-H-2734, GAN 809, distal view, ordinary transmitted light, *12*, Hypotype, UI-H-2735, GAN 809, distal view phase contrast, *13*, Hypotype, UI-H-2736, GAN 809, distal view between crossed nicols.
14,15,17—*Chiasmolithus bidens* (Bramlette & Sullivan). Hypotype, UI-H-2731, GAN 807, distal views: *14*, phase contrast; *15*, ordinary transmitted light, *17*, between crossed nicols.
16,21,22—*Chiasmolithus danicus* (Brotzen). Hypotype, UI-H-2738, GAN 795, distal views: *16*, phase contrast; *21*, ordinary transmitted light; *22*, between crossed nicols.
18–20—*Chiasmolithus californicus* (Sullivan). Hypotype, UI-H-2739, GAN 834, distal views; *18*, phase contrast; *19*, ordinary transmitted light; *20*, between crossed nicols.
23–25—*Chiasmolithus consuetus* (Bramlette & Sullivan), Hypotype, UI-H-2737, GAN 834, distal views: *23*, phase contrast; *24*, ordinary transmitted light; *25*, between crossed nicols.
26–28—*Cruciplacolithus eminens* (Bramlette & Sullivan). Hypotype, UI-H-2741, GAN 834, distal views: *26*, phase contrast; *27*, ordinary transmitted light; *28*, between crossed nicols.
29–31—*Cruciplacolithus tenuis* (Stradner). Hypotype, UI-H-2740, GAN 807, distal views: *29* phase contrast; *30*, ordinary transmitted light; *31*, between crossed nicols.
32–35—*Markalius astroporus* (Stradner). Hypotype, UI-H-2742, GAN 807, proximal views: *32*, phase contrast high focus; *33*, phase contrast low focus; *34*, ordinary transmitted light; *35*, between crossed nicols.

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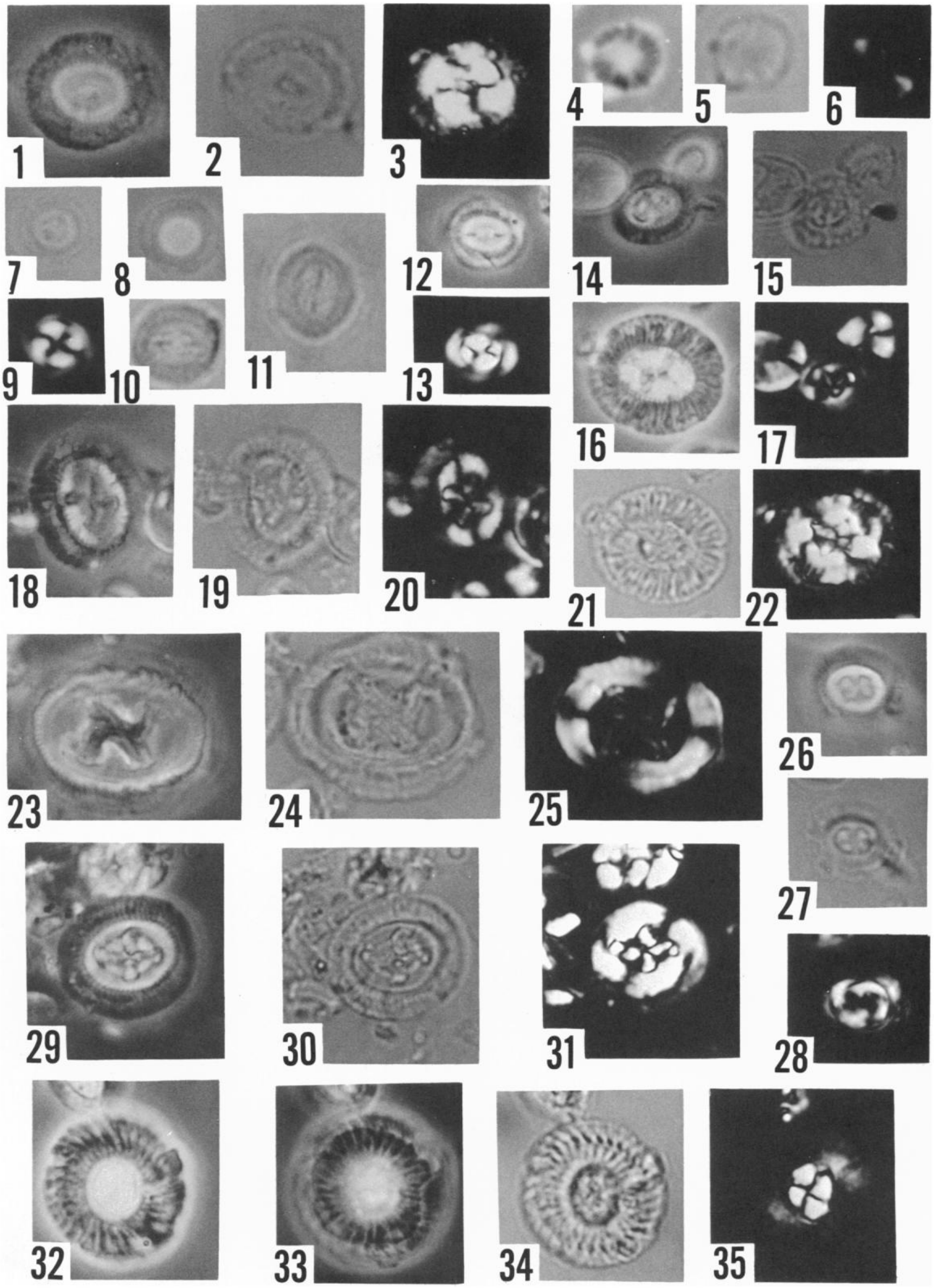

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coccolithophores, a group of pelagic algae which are almost exclusively marine. The skeletal remains of the ascidians are relatively rare and show little evolutionary change. Skeletal remains of the coccolithophores, however, are abundant constituents of marine sediments and exhibit a great variety of forms. In addition to the calcareous nannofossils that are obviously related to modern ascidians and coccolithophores, a wide variety of distinctive extinct forms is encountered in Jurassic, Cretaceous, and Tertiary rocks. Because many of these forms are associated with coccoliths, they are commonly considered to have also been produced by planktonic marine algae, although such an origin cannot be demonstrated by objective evidence. Coccoliths and associated calcareous nannofossils are commonly referred to as fossil nannoplankton, and the sediments in which they are found abundantly are termed "pelagic sediments".

Calcareous nannofossils have the following four fundamental peculiarities: 1, the ubiquity of their occurrence, 2, their occurrence in massive numbers, 3, their distinctive shapes, and 4, their propensity to reappear in younger strata through reworking.

Calcareous nannofossils have a worldwide distribution in Jurassic, Cretaceous, Tertiary, Quaternary, and Recent marine strata. Although some Recent coccolithophores exhibit a distribution that is controlled by climate, most species are found throughout tropical and temperate waters of the world.

The numbers of calcareous nannofossils are commonly astronomical. A cubic centimeter of marine shale may contain as many as 10^9 specimens, and a slide prepared for light microscopy will commonly have more than 10^5 specimens. The ready abundance of specimens for study will permit the application of drastically new techniques for accurate correlation.

The third important factor is the distinctive nature of many important species. Although evolutionary lineages can be traced in many species groups, other distinctive species appear very suddenly and apparently without any obvious ancestor. Although studies of life cycles of coccolithophores have only recently begun, it is evident that one of the most common forms of reproduction is asexual simple cell division. Mutants which vary highly from their ancestors are thus not only possible but are likely to be encountered. Most mutations, of course, can be expected to be unsuccessful, but a small percentage will be better adapted than their predecessors and thus will likely survive. Many of the most useful guide fossils probably represent such mutant forms; they appear suddenly, apparently without any distinct ancestor, flourish briefly, and become extinct.

The three above-mentioned peculiarities of nannofossils are all helpful to the paleontologist who is interested in correlating strata between localities. The fourth peculiarity is the chief disadvantage of the calcareous nannofossils, namely, their tendency to survive reworking so that they appear in younger strata long after the organism which produced them became extinct. The small size of the calcareous nannofossils makes them essentially immune to mechanical abrasion so that until they pass into an unfavorable chemical environment, they will persist as clastic particles. Some workers have suggested that sufficiently prolonged searching in a sample will produce every species which is found in older strata. Although this is an overstatement, reworking certainly is a major problem in studying calcareous nannofossils. Recognition of all the reworked specimens in a given sample is manifestly impossible until knowledge of all the species and their stratigraphic distribution in "clean sections" has been worked out. Obviously, many years must elapse before this is accomplished, if ever. The production of calcareous nannofossils proceeds at such a rapid rate, however, that reworked forms constitute only a small percentage of the total assemblage in most deposits. "Clean" samples, without any reworked forms, are rare.

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Mr. Charles Copeland of the Alabama State Geological Survey provided much valuable information on localities in Alabama, and Mr. Charles Canning of the U. S. Army Corps of Engineers arranged and assisted collection of

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samples from the power house excavation at Miller's Ferry Dam site. Dr. F. Stearns McNiel offered suggestions on the best sections in the Gulf Coast area for observing the Cretaceous—Tertiary boundary in uninterrupted sequences of strata, and Professor Lyman Toulmin of Florida State University offered valuable discussion and information on sampling sites; Messrs. Peter Roth and Pavel Čepek aided in collecting the samples.

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STRATIGRAPHIC SECTION AT GAN-PONT LABAU

South of Pau, in the foothills of the Pyrenees, Cretaceous and Paleogene strata are exposed. Although most of the area is well covered with vegetation, extensive stratigraphic sections may be studied at several places. Paleocene strata are best exposed along the highway Pau-Gan-Rebenacq-Laruns (Route Nationale 134bis). Gubler & Pomeyrol (1946) published a geological sketch map of the area and presented an excellent review of the literature concerning the geology of the region. Their stratigraphic terminology is reproduced in Text-figure 1.

LASSEUBE	GAN (CHEMIN DE FER)	ROUTE DE LARUNS (PONT LABAU)
	Conglomerat de Jurancon	
	Lumachelle à *Assilina leymeriei*	Lacune de visibilité
Marnes eqivalentes	Marnes de la Tuilerie de Gan	
	Sables de Boulou	
Sables et marnes à Nummulites, Assilines, Alveolines		Sables et Marnes
Sables graveleux		Graviers de base
	Marne à Globigerines	Lacune de visibilité
	Calcaires à *Discocyclina seunesi, Opeculina heberti* et marnes blanches	
Sables et marnes à Globigerines de base		
Calcaires crayeux à *Jeronya pyrenaica, Echinocorys*, etc...		

TEXT-FIG. 1—Stratigraphic terminology of Paleocene—early Eocene strata in the the region around Gan, Basses Pyrenees [after Gubler & Pomeyrol (1946)].

The section starts in Gan, at the clay pit of the brick factory (Tuilerie de Gan). This large exposure has been a rich source of fossils and has been an important reference locality in discussions of the correlation of the Yprésian Stage into the Aquitaine. Martini (1961) studied the nannoplankton of three samples from the brick factory clay pit and recorded the following species: **Tetralithus gothicus* Deflandre, 1959; **Hexalithus hexalithus* = *Hexalithus noelae* Loeblich & Tappan, 1966; *Braarudosphaera bigelowi* (Gran & Braarud), 1935; *Micrantholithus vesper* Deflandre, 1954; *M. flos* Deflandre, 1954; *M. inaequalis* Martini, 1961; **Discoaster multiradiatus* Bramlette & Riedel, 1954; *D. stradneri* Martini, 1961; *D. lodoensis* Bramlette & Riedel, 1954; *D. mirus* Deflandre, 1954; *D. distinctus* Martini, 1958; *D. cruciformis*, Martini, 1958; *Marthasterites tribrachiatus* (Bramlette & Riedel), 1954; **M. furcatus* (Deflandre), 1954; **Nannotetraster staurophorous* (Gardet), 1955; and **Microrhabdulus decoratus* Deflandre, 1959.

Species in the foregoing list that are marked by an asterisk (*) have subsequently been found to be restricted to Cretaceous or earlier Tertiary strata and appear in the beds that are exposed in the clay pit because of reworking. The Tuilerie de Gan beds have been assigned to the "Ypréso-Lutetien" by Gubler & Pomeyrol (1946), to the "hoheres Ypresien" by Martini (1961), and to the boundary of the *Marthasterites tribrachiatus* and *Discoaster lodoensis* Zones by Hay (1964). The boundary of the *Marthasterites tribrachiatus* and *Discoaster lodoensis* Zones, by correlation with the Schlierenflysch section in Switzerland, lies in the lower part of the Cuisian (Schaub, 1965; Hay & Mohler, 1965).

South of the clay pit in Gan, exposures are small and discontinuous. In 1960, accompanied by Professor Hans Schaub of Basel, Hay collected the following well-known localities south of Gan: 1, "Ferme Berdoulou" on Route Nationale 134 (ditch on the east side of the railroad track 50 meters north of the viaduct just west of the farm), which was considered Thanetian by Douvillé (1919) and 2, "Ancot" (also called "Encot") on Route Nationale 134bis, the "marnes grises à Globigerines" of Gubler & Pomeyrol (1946). Both of the foregoing localities yielded very poorly preserved nannofossils, which cannot be fitted into a scheme of zonation.

Martini (1961) described the nannoplankton from an exposure at Km. 2.950 on the Gan—

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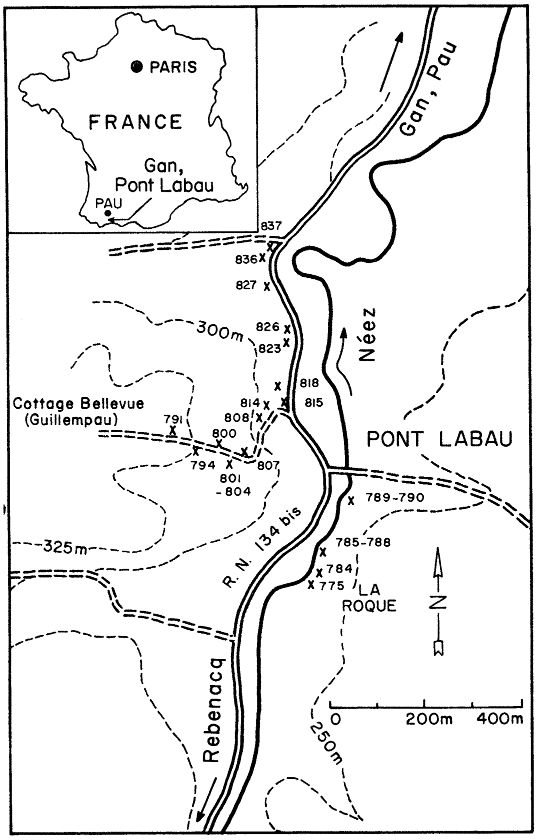

TEXT-FIG. 2—Map showing location of samples in the section at Pont Labau.

Rebenacq road (Route Nationale 134bis), near Pont Labau and found the following species: *Tetralithus obscurus* Deflandre, 1959; *Discoaster multriradiatus* (Bramlette & Riedel), 1954; *D. nobilis* Martini, 1961; *Zygolithus concinnus* Martini, 1961; and *Lucianorhabdus cayeuxi* Deflandre, 1959. The sample yielding these species came from the portion of the section which can now be assigned to the *Discoaster multiradiatus* Zone.

In 1961, Hay, accompanied by D. S. Marszalek, collected several additional isolated localities along the road from Gan to Lasseube, but unfortunately those which lie stratigraphically below the Tuilerie de Gan beds again proved to contain only poorly preserved nannofossils. Along the Route Nationale 134bis at Pont Labau, Hay and Marszalek collected a suite of five samples that contained well-preserved nannofossils in large numbers. The results of this preliminary investigation were presented at the "Premier Colloque Internationale sur la Paleogène" in Bordeaux in 1962 (Hay, 1964). Exposures along the highway were assigned to three nannofossil zones, in descending order, the *Discoaster multiradiatus* Zone, the *Discoaster gemmeus* Zone, and a tentatively proposed *Discoaster delicatus* Zone.

Mohler, in 1963, collected the section at Pont Labau in detail; Text-figure 2 shows the location of some of the 65 samples collected. The rest of the samples were spaced as evenly as outcrop conditions would permit between those whose locations are shown on the map. Of these samples, 51 contained good nannofossil assemblages.

A description of the Pont Labau section was presented in Guidebook 3 of the Premier Colloque Internationale du Paleogène, "Voyages d'Étude dans le Béarn, la Chalosse et le Pays Basque," (Anonymous, 1962). The following is a free translation from the guidebook:

"Danien"

The section begins on the right side of the river Néez in some abandoned limestone quarries where vertically or subvertically folded, chalky, algal and brecciated limestones with some marly intercalations can be observed. These intercalations contain
Globigerina daubjergensis Brönnimann, 1953
Globorotalia compressa (Plummer, 1932).
According to Gubler & Pomeyrol (1946, p. 416) the following macrofossils were determined by Seunes (1890) from these strata
Nautilus danicus Schlotheim
Jeronia pyrenaica Seunes
Coraster beneharnicus Seunes
Coraster sphaericus Seunes
Coraster marsoi Seunes
Echinocorys pyrenaicus Seunes
Echinocorys douvillei Seunes
Echinocorys vulgaris Breyn.
The Danian limestones grade into the less steeply inclined Paleocene strata.

"Paleocène inférieur"

80 m marly limestones with planktonic Foraminifera, bioclastic limestones with Rotalids and Miscellaneids and microbrecciated limestones including rare marly intercalations with
Globorotalia angulata (White, 1928)
Globorotalia pseudobulloides (Plummer, 1926).
On the left side of the river Néez the
"Paleocène supérieur transgressif" with *Globorotalia angulata* (White, 1928) and *Globorotalia velascoensis* (Cushman, 1925) can be observed. It is subdivided into the "Sables inférieurs" and the "Sables supérieurs"
The "Sables inférieurs" (80m) grade into algal limestones which contain
Discocyclina seunesi Douvillé, 1922
Operculina heberti Munier-Chalmas, 1884
Alveolina primaeva Reichel, 1936 (at top).
The "Sables supérieurs" (70m) exposed along the route from Gan to Rebenacq, form the top of the section. They consist cf a continuous alternation of sands and marls.

Exposures on the east side of the Néez, above Pont Labau (samples 775–779), correspond to the "Danien" and "Paleocene inférieur" of the

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guidebook. The two units are gradational, and a sharp distinction cannot be made between them on the basis of lithology. The contact with Cretaceous rocks is not exposed. Formal rock-stratigraphic names have not been proposed for these strata and, to fill this need for an objective name, the term "Calcaire de La Roque" is here proposed. La Roque is the local name for the quarries just above the bridge, which form the type locality for this unit.

The "Paleocene supérieur transgressif" is exposed on the west side of the Route Nationale 134bis and along the road leading to Cottage Bellevue (Guillempau). The rock-stratigraphic name "Couches de Pont Labau" is proposed here for this unit.

Strata in exposures along the drive to Cottage Bellevue (samples 791–814) correspond to the "Sables inférieurs". Outcrops are not extensive, as they are essentially limited to the very shallow ditch that borders the road; the vertical extent of the exposures is commonly only a few centimeters and rarely as much as a half meter. Strike and dip of the beds is difficult to determine as bedding is commonly indistinct. The section does not contain any useful marker beds.

The "Sables supérieurs" beds (samples 815–837) are exposed along the Route Nationale in intermittent outcrops. Some road cuts have a vertical extent of 2 meters. Again marker beds are absent, and the general homogeneity of the strata makes accurate determination of the strike difficult; the dip approximates 50°N.

Because of the poor exposures, the difficulty of determining strike and dip with precision, and the lack of marker beds, a stratigraphic section has not been drawn. Although the approximate thicknesses of the units are known, precise determination of the stratigraphic level of particular samples is difficult; however, the stratigraphic sequence of the samples has been established.

The terms "Danien", "Paleocène inférieur," and "Paleocène supérieur" have been inaccurately applied to these units, and their use should be discontinued in favor of more objective field terminology.

The word "transgressif", applied to the Couches de Pont Labau, is unfortunate. The strata that are exposed on the east and west sides of the Néez differ in lithology, but the contact between the Calcaire de La Roque and the Couches de Pont Labau is not well exposed and hence its nature is speculative.

The distribution of calcareous nannofossils at Pont Labau is presented in Text-figures 3 and 4; the latter figure also indicates correlation of European sections and localities as deduced by occurrences of calcareous nannofossils.

SECTION AT PADERNO D'ADDA, ITALY

Cretaceous and Tertiary rocks are extensively exposed on the south flank of the Alps. The section along the Adda River, near the village of Paderno south of Lecco, provides a continuous exposure of steeply dipping reddish calcareous shales ("scaglia"). The section has been described in detail by Bolli & Cita (1960), and the sequence of planktonic foraminiferal zones that have been found in Trinidad by Bolli (1957) are noted in continuous exposures at Paderno d'Adda. Mohler, assisted by Professor Hans Bolli, Professor Maria Cita, Dr. Isabella Premoli Silva, and Dr. Hanspeter Luterbacher, collected this section in 1963. Although the nannofossils are not as well preserved as at Gan-Pont Labau, they are readily identifiable (see Text-fig. 4). The section has the advantage of being continuously exposed and extends stratigraphically above and below the section of Gan-Pont Labau. Sample numbers that are used to refer to collections from Paderno d'Adda correspond to those of Bolli & Cita (1960).

VELASCO SHALE, TAMPICO EMBAYMENT, MEXICO

The Velasco Shale of Paleocene age has played a role in discussions of nannoplankton correlation; Bramlette & Sullivan (1961) stated that the *Heliolithus riedeli* and *Discoaster multiradiatus* Zones could be found in the Velasco. Hay (1960) indicated that *Discoaster multiradiatus* ranged through the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones in the Velasco Shale.

The Velasco Shale is exposed in isolated outcrops that are scattered over the densely vegetated plain of the Tampico Embayment. Continuous sections are not exposed on the surface, and only rotary drilled samples are available from wells that penetrate the Velasco. Rotary drill samples are unsuitable for establishing nannofossil zonation because the fossils are recirculated with the drilling mud. Along the highway from Tampico to Ciudad Valles only three road cuts expose Velasco Shale, but samples from these contain planktonic foraminifers and calcareous nannofossils in an excellent state of preservation. The following samples were obtained by Hay and were located with respect to kilometer posts along the road:

V-13: km. 85.8, Ciudad Valles—Tampico Highway; cut exposing 3 meters of soft reddish Velasco Shale belonging to *Globorotalia uncinata* Zone.

V-14: km. 83.5, Ciudad Valles—Tampico Highway; cut exposing 5 meters of soft reddish Velasco Shale belonging to *Globorotalia pusilla pusilla* Zone. [This locality was considered by

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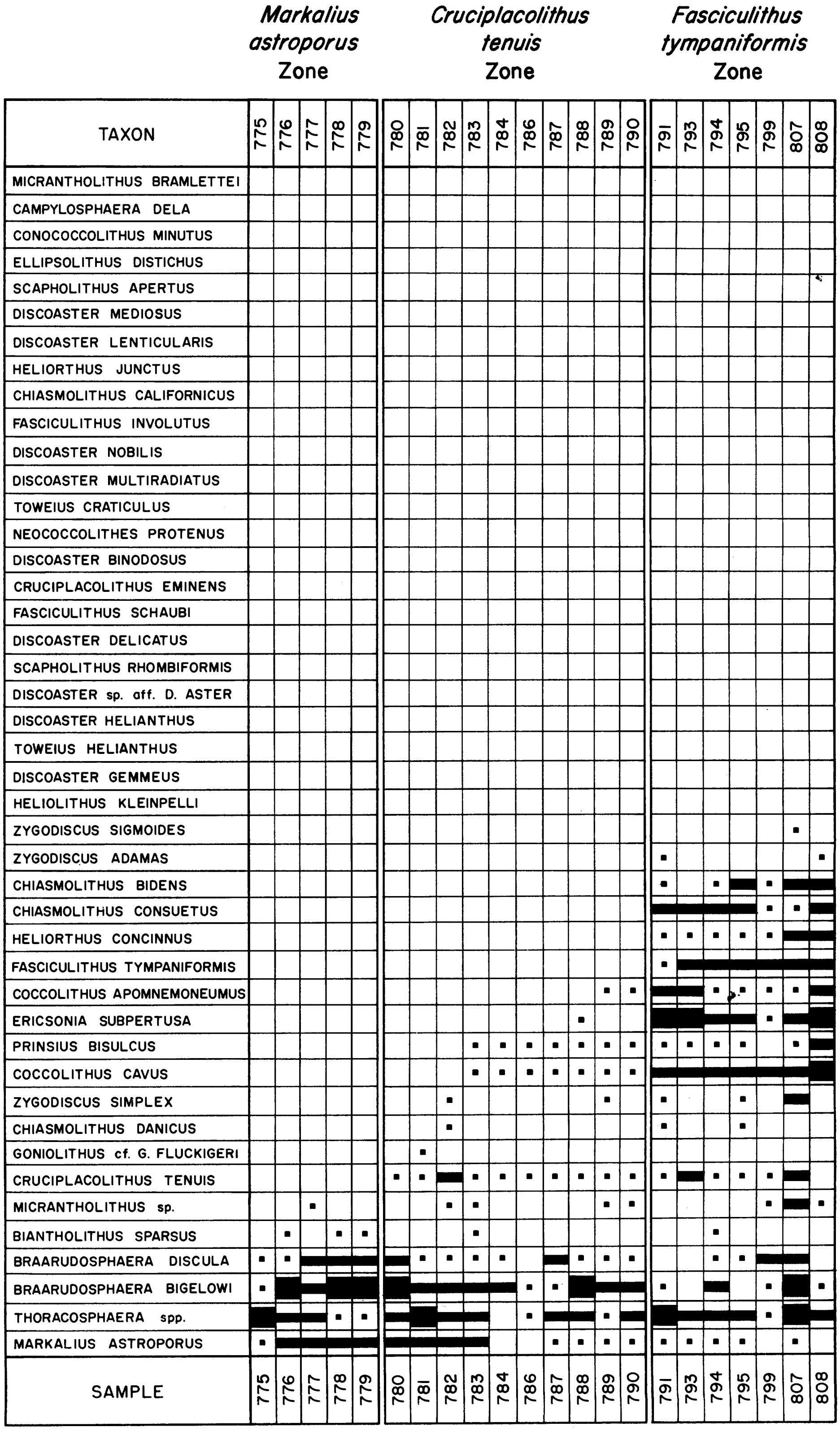

TEXT-FIG. 3—Distribution of calcareous

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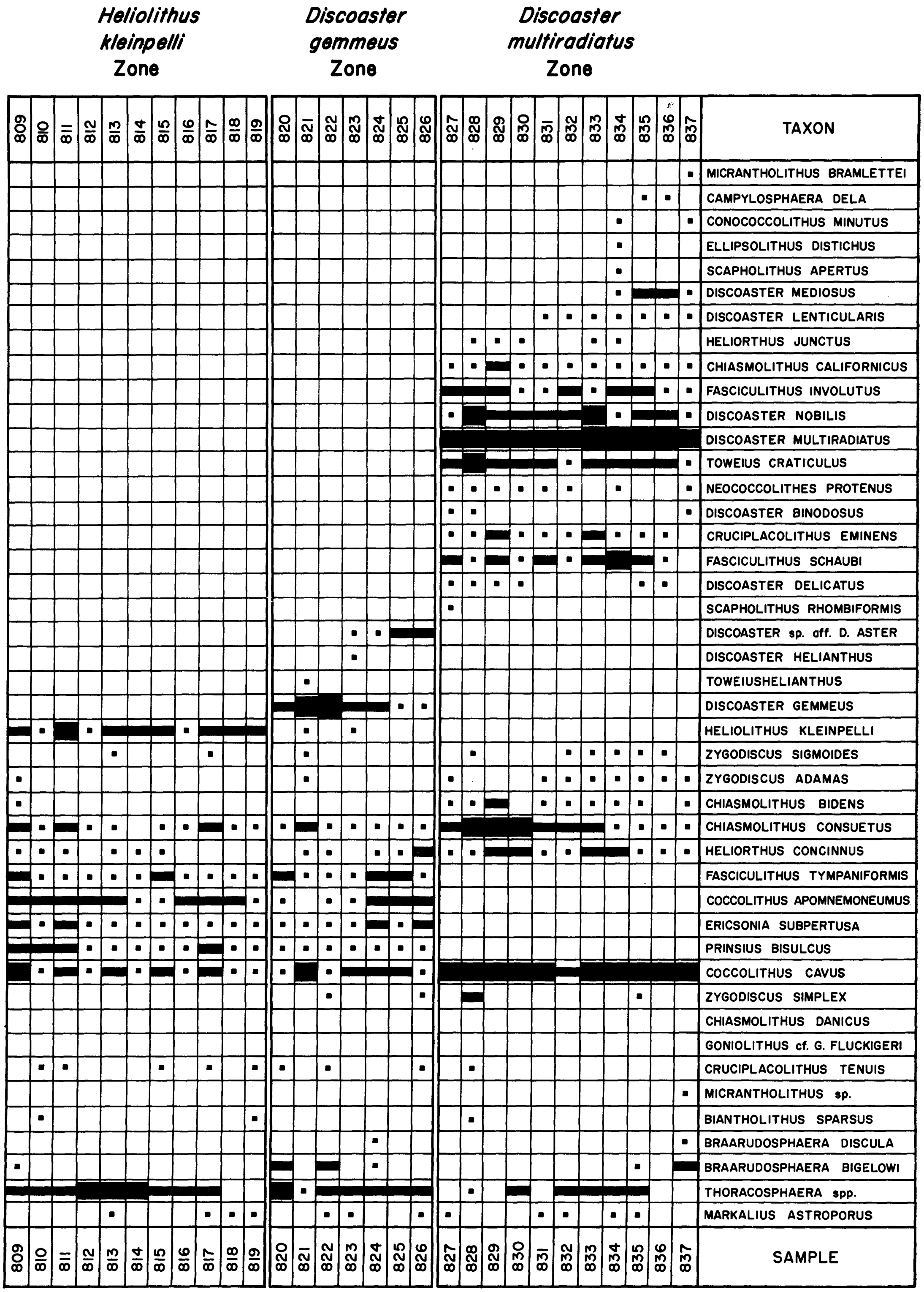

nannofossils in the section at Pont Labau.

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ZONE	AQUITAINE GAN-PONT LABAU		PADERNO D'ADDA NUMBERS OF BOLLI & CITA, 1960	AUSTRIA SALZBURG STRADNER, 1963	SWITZERLAND OBWALDEN (HAY & MOHLER, 1965)		NORTHERN EUROPE	NORTHERN GERMANY (MARTINI 1959, 1964)	USSR CRIMEA-CAUCASUS WADE, MOHLER & HAY, 1963
DISCOASTER LODOENSIS ZONE	TUILERIE DE DONZACQ		40 39		SCHLIERENFLYSCH	S-b734 S-b620	YPERN CLAY	UNTERES OBER-EOZAN	SIMFEROPOLIAN
MARTHASTERITES TRIBRACHIATUS ZONE	TUILERIE DE GAN		37 36		SCHLIERENFLYSCH	S-b605 S-b500x	YPERN CLAY	UNTER-EOZAN 3	BAKHCHISARAIAN
DISCOASTER BINODOSUS ZONE			35 32	ROTERZSCHICHTEN	SCHLIERENFLYSCH	S-b475 II S-a454			BAKHCHISARAIAN
MARTHASTERITES CONTORTUS ZONE					SCHLIERENFLYSCH	S-450 II S-446			
DISCOASTER MULTIRADIATUS ZONE	COUCHES DE PONT LABAU	GAN 837 GAN 827	28 25		SCHLIERENFLYSCH	S-423 S-408			
HELIOLITHUS RIEDELI ZONE	COUCHES DE PONT LABAU	? COVERED ?	24	GRYPHEENBANK (E) CRANIENSANDSTEIN			THANET SAND		
DISCOASTER GEMMEUS ZONE	COUCHES DE PONT LABAU	GAN 826 GAN 820	23	? EITELGRABEN 181 ?					
HELIOLITHUS KLEINPELLI ZONE	COUCHES DE PONT LABAU	GAN 819 GAN 809	22						KACHINSKIAN
FSCICULITHUS TYMPANIFORMIS ZONE	COUCHES DE PONT LABAU	GAN 808 GAN 791	21 16	OICHINGER SCHICHTEN D			LELLINGE GREENSAND		
CRUCIPLACOLITHUS TENUIS ZONE	CALCAIRE DE LA ROQUE	GAN 790 GAN 780	15 12	OICHINGER SCHICHTEN C B A			TYPE DANIAN (FAXE) TYPE DANIAN (STEVNS KLINT)	KATHARI-NENHOF	
ERICSONIA ASTROPORA ZONE	CALCAIRE DE LA ROQUE	GAN 779 GAN 775	11 9				TYPE DANIAN (STEVNS KLINT) FISKELER		

TEXT-FIG. 4—Correlation of sections and localities in Europe as based on calcareous nannofossils. [For "*Fsciculithus tympaniformis* Zone" read "*Fasciculithus tympaniformis* Zone"; for "*Ericsonia astropora* Zone" read "*Markalius astroporus* Zone".]

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ZONE	TRINIDAD LIZARD SPRINGS FM.	MEXICO VELASCO FM.	CUBA LA HABANA (BRONNIMANN & RIGASSI, 1963)	UNITED STATES GULF COAST	
DISCOASTER LODOENSIS ZONE			UNIVERSIDAD FM. PRINCIPE MEMBER		
MARTHASTERITES TRIBRACHIATUS ZONE	*GLOBOROTALIA ARAGONENSIS* ZONE		UNIVERSIDAD FM. TOLEDO MEMBER CAPDEVILA FM.		
DISCOASTER BINODOSUS ZONE					
MARTHASTERITES CONTORTUS ZONE	*GLOBOROTALIA REX* ZONE		ALKÁZAR FM.		
DISCOASTER MULTIRADIATUS ZONE	*GLOBOROTALIA VELASCOENSIS* ZONE	*GLOBOROTALIA VELASCOENSIS* ZONE *GLOBOROTALIA PSEUDOMENARDII* ZONE	ALKÁZAR FM.	BASHI	
HELIOLITHUS RIEDELI ZONE	*GLOBOROTALIA PSEUDOMENARDII* ZONE			NANAFALIA	
DISCOASTER GEMMEUS ZONE					
HELIOLITHUS KLEINPELLI ZONE		*GLOBOROTALIA PUSILLA PUSILLA* ZONE			
FASCICULITHUS TYMPANIFORMIS ZONE	*GLOBOROTALIA PUSILLA PUSILLA* ZONE			CLAYTON	McBRYDE
CRUCIPLACOLITHUS TENUIS ZONE	*GLOBOROTALIA UNCINATA* ZONE	*GLOBOROTALIA UNCINATA* ZONE			PINE BARREN
MARKALIUS ASTROPORUS ZONE					PINE BARREN

TEXT-FIG. 5—Correlation of sections and localities in the Carribean and Gulf of Mexico regions as based on calcareous nannofossils.

Hay (1960) to belong to the *Globoborotalia uncinata* Zone but can be assigned to the *G. pusilla pusilla* Zone.]

V-15: km. 75.5, Ciudad Valles—Tampico Highway; cut as highway ascends hill just west of Ebano, exposing about 7 meters of reddish Velasco Shale and pure planktonic foraminiferal sand; the lower part of the section belongs to the *Globorotalia pseudomenardii* Zone, and the upper part to the *Globorotalia velascoensis* Zone.

The nannofossil zones to which the planktonic foraminiferal zones correspond are given in Text-figure 5.

LIZARD SPRINGS FORMATION, TRINIDAD

A suite of seven samples of the Lizard Springs Formation [Paleocene—early Eocene; *Globorotalia trinidadensis* Zone through *Globorotalia velascoensis* Zone considered Paleocene and *Globorotalia rex* Zone through *Globorotalia aragonensis* Zone considered early Eocene by Bolli (1957); we believe all strata represented by these zones are Paleocene in age] was supplied by Drs. Hans Kugler and John Saunders of Texaco Trinidad, Inc. Data concerning these samples follow: 1, *Globorotalia trinidadensis* Zone (type locality), Moruga Well 3, core from 10259-10261-foot level; 2, *Globorotalia uncinata* Zone (type locality), sample K.R. 23375, Pointe-à-Pierre; 3, *Globorotalia pusilla pusilla* Zone (type locality), Guayaguayare Well 159, core from 4524-4536-foot level; 4, *Globorotalia pseudomenardii* Zone (type locality), sample K. 10832, Pointe-à-Pierre; 5, *Globorotalia velascoensis* Zone (cotype locality), sample K. 9415, Pointe-à-Pierre; 6, *Globorotalia rex* Zone (type locality), sample Hk. 1831, tributary of Cascas River; and 7, *Globorotalia aragonensis* Zone (type locality), sample Rz. 413, Vistabella.

The nannofossil zones to which these samples belong are shown in Text-figure 5.

SALZBURG, AUSTRIA

North of Salzburg, Paleocene strata are exposed in small outcrops along streams. Gohrbandt (1963a,b) has described these localities in detail and gave an account of their planktonic foraminiferal assemblages. Stradner *in* Gohrbandt (1963a) has described the calcareous nannofossils. Hay collected samples for comparative purposes during the field trip of the Eighth European Micropaleontological Colloquium in 1963.

CUBA

The determinations of Brönnimann & Stradner *in* Brönnimann & Rigassi (1963) have been used to assign strata to the zones that are used here (see Text-fig. 5).

TEXAS

Samples of the Midway Group, which we regard as Paleocene in age, were collected by Hay at the following three localities:

1. Exposure of the Mesozoic—Cenozoic contact and the base of the Kincaid Formation on

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Walker Creek, about 5 miles northwest of Cameron, Milam County [Stop 14 of 1962 GSA Field Excursion No. 2, described by Smith (1962)]; sample designations and their stratigraphic positions are:

GSA-62-14B, Littig Member, Kincaid Formation, 6 inches above the Mesozoic—Cenozoic contact; and

GSA-62-14C, Pisgah Member, Kincaid Formation, 3 feet above the Mesozoic—Cenozoic contact.

The Wills Point Formation was sampled at two sites:

2. WP-1, gully in a field, 150 yards east of Texas Route 14, 2 miles north of the center of Mexia, Limestone County; and

3. WP-2, road cut near top of hill on the Corsicana—Navarro road, just south of the junction with the road to Mildred, Navarro County.

ALABAMA

Paleocene strata in Alabama are especially well exposed in Wilcox and adjoining counties. Descriptions of many exposures have been presented by LaMoreaux & Toulmin (1959).

A section across the Mesozoic—Cenozoic boundary along Dallas County Road 59, just north of Wilcox County, was collected by Hay and P. Čepek in March 1967; sample designations and their stratigraphic positions are:

1. DC-59-3, about 1 foot above base of glauconitic sandy clay regarded as marking the Mesozoic—Cenozoic contact, exposed in upper part of road cut where Dallas County Road 59 turns north, about 1/2 mile from Wilcox County line;

2. DC-59-4, base of outcrop along Dallas County Road 59, about 150 feet southeast of collecting site of sample DC-59-3, about 5 feet stratigraphically above DC-59-3;

3. DC-59-5, top of above outcrop, about 3 feet stratigraphically above collecting site of sample DC-59-4; and

4. DC-59-6, outcrop about 50 yards north of Wilcox County line on Dallas County Road 59.

The excavation for the hydroelectric power plant at Millers Ferry Dam on the Alabama River in Wilcox County, south of Alabama Route 10 and located just opposite Midway Landing, was sampled by Hay and P. Roth, with the aid and guidance of C. Canning. The basal 10 feet of the Pine Barren Member of the Clayton Formation (Early Paleocene) was sampled every 4 inches, and the remainder of the 72 feet of Pine Barren strata that are exposed in the excavation was sampled every 4 feet.

The contact of the Pine Barren Member and the McBryde Limestone Member of the Clayton Formation is exposed in the road cut along the north side of Alabama Route 28, 0.8 mile west of the Alabama River bridge, Wilcox County. The following samples were collected at this site by Hay and P. Čepek:

1. ALA-28-1, dark-grey shale of Pine Barren Member exposed at base of cut;

2. ALA-28-2, white to tan sandy limestone, base of McBryde Limestone Member, exposed in upper part of cut, 6 feet stratigraphically above collecting site of sample ALA-28-1; and

3. ALA-28-3, soft white marl exposed in roadside ditch about 50 yards northwest of main road cut, at top of hill, probably about 20 feet stratigraphically above collecting site of sample ALA-28-2.

The McBryde Limestone Member is well exposed in the bed of Rock Creek, where Alabama Route 10 crosses the creek, about 0.8 mile south of the junction of Alabama Route 10 and Alabama Route 28. The sample designated ALA-10-1 was collected at this locality by Hay and P. Roth.

Hay and P. Čepek attempted to collect the McBryde Limestone locality at Livingston in Sumter County, as many of the specimens illustrated by Bramlette & Martini (1964) were from this locality. The Livingston exposure is now overgrown, and good material for comparative purposes could not be collected.

A sample from the Nanafalia Formation, in the *Ostrea thirsae* Beds, was collected by Hay and P. Roth at the road cut along Alabama Route 5, 1.2 miles south of Kimbrough, Wilcox County. The Nanafalia has long been considered as early Eocene in age and was so regarded by Loeblich & Tappan (1957); we consider this formation to be of late Paleocene age, as did Gartner & Hay (1962).

The Bashi Marl Member of the Hatchetigbee Formation, which we consider to be of late Paleocene age, was sampled by Hay along Alabama Highway 69, in a road cut [described by Copeland (1966)] just south of Bashi Creek, Clarke County, and the sample was designated ALA-69-4.

Professor Ernest E. Russell provided a sample of the Bashi Marl from the type locality at Woods Bluff on the Tombigbee River at the mouth of Bashi Creek, Clarke County.

The Tallahatta Formation was sampled by Hay at the exposure [described in Copeland (1966)] on the Conecuh River just below Point "A" Dam, Covington County, Alabama.

MISSISSIPPI

Guided by E. E. Russell, Hay and P. Čepek

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collected a section across the Mesozoic—Cenozoic boundary and through the Clayton Formation along a farm road just south of Johnson Creek in the S½ sec. 4, T. 20 N., R. 13 E., Clay County, Mississippi: sample designations and their stratigraphic positions are:

1. I-5, 6 inches above the Mesozoic—Cenozoic contact picked on the basis of a color change from grey clayey marl (Prairie Bluff of very Late Cretaceous age) to yellowish clayey marl (glauconitic?);
2. I-6, about 4 feet stratigraphically above collecting site of sample I-5; specimens of *Ostrea pulaskensis* Harris are common; and
3. I-7, about 4 feet stratigraphically above collecting site of sample I-6.

Professor Russell provided a sample of the Bashi Marl Member of the Hatchetigbee Formation from a locality 100 yards south of the "Red Hot Truck Stop" on U. S. Highway 80 in Meridian, Mississippi.

BIOSTRATIGRAPHIC ZONATION AND CORRELATION

A brief account of the development of biostratigraphic zonation of Cenozoic strata, utilizing calcareous nannoplankton fossils, and names for previously undescribed zones of the Paleocene have been presented by Hay & Mohler *in* Hay and others (1967). The purpose of the present work is to give a detailed account of the distribution of calcareous nannofossils in the reference section at Pont Labau and to indicate and discuss correlations in the Paleocene—middle Eocene interval.

As has been discussed by Hay & Mohler *in* Hay and others (1967), the zones described here are not assemblage zones as defined by the American commission of Stratigraphic Nomenclature (1961) but are concurrent range zones that are based on a number of selected species. The limits of the zones are defined by the appearance or disappearance of a particular species in the reference section. The same criteria are used elsewhere whenever possible, but in the absence of the defining species in a particular area, the boundary is drawn on the basis of other species which have bases or tops of ranges that approximate those of the defining species. The middle of a zone is, of course, much easier to recognize than the limits of the zone, as the assemblage that is characteristic of the middle part of the zone under consideration differs more from the assemblage of the middle portion of the next higher or lower zone than from the assemblages that are immediately adjacent to the boundary of the zone under consideration.

A discussion of the zones based on calcareous nannoplankton fossils follows.

Markalius astroporus Zone

Definition.—Interval from the first occurrence of *Markalius astroporus* (Stradner) to the first occurrence of *Cruciplacolithus helis* (Stradner).

Authors.—Mohler & Hay *in* Hay and others (1967).

Type locality.—Pont Labau, Carrières de La Roque; lower part of the Calcaire de La Roque (samples, GAN 775–779; most representative sample, GAN 778).

Remarks.—This is the lowest nannofossil zone which can be recognized in Tertiary strata and is characterized by an assemblage that is remarkable for its lack of diversity. *Markalius astroporus* and *Cruciplacolithus helis*, the species which define the limits of the zone in the type section, are among the most ubiquitous of nannofossil species and, as a result, this zone should be found almost everywhere unless it is missing because of a hiatus. In the type section at Pont Labau, *Biantholithus sparsus* Bramlette & Martini is found in a few samples, but *Braarudosphaera bigelowi* (Gran & Braarud) and *Braarudosphaera discula* Bramlette & Riedel, two very long-ranging species, are abundant. A flood of *Thoracosphaera* species is noted at the very base of the zone, as can be observed in Alabama. In the Holtug section at Stevns Klint on the Island of Seeland, Denmark, one of the cotype localities of the Danian Stage (here considered to be of early Paleocene age) the Fiskeler (fish-clay) and the chalk immediately overlying it belong to this zone. The chalk that is immediately below the Fiskeler, assigned by Danish geologists to the Maastrichtian, is filled with representatives of *Arkhangelskiella*, *Cribrosphaera*, and other typically Cretaceous genera. One of the samples described by Bramlette & Martini (1964), Kjolby Gaard 8 (basal Danian), contains the assemblage that is characteristic of the *Markalius astroporus* Zone.

The lowest planktonic foraminiferal zone in Tertiary strata is the *Globigerina eugubina* Zone that was described by Luterbacher & Premoli-Silva (1964) from the Scaglia at Gubbio, Italy. Although the validity of this zone has been questioned by Berggren (1965), it has been accepted by Bolli (1966). The *Globigerina eugubina* Zone has not been reported from the type Danian, but Hofker (1960) noted that the basal meter of the Danian beds at Stevens Klint contains forms that he regarded as primitive forerunners of *Globigerina daubjergensis* and *G. pseudobulloides*. At Paderno d'Adda, niveaux 9-11 of Bolli & Cita (1960) belong to the *Markalius astroporus* Zone, and it can be established that the upper limit of the *M. astroporus* Zone

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lies within the *Globorotalia trinidadensis-Globigerina daubjergensis* Zone.

In Alabama, the *Markalius astroporus* Zone is thickest (probably of the order of 15 feet) along Dallas County Route 59. Sample DC-59-3 contains no calcareous material, but samples DC-59-4 and DC-59-5 contain abundant nannofossils. Most of the nannoflora consists of specimens of *Arkhangelskiella* that were probably reworked from the immediately underlying Prairie Bluff Chalk. A few specimens of *Markalius astroporus* are in sample DC-59-4, and many more specimens are found in sample DC-59-5.

In the exposure at the power plant excavation at Millers Ferry Dam, the lower 4 feet of the Pine Barren can be assigned to the *Markalius astroporus* Zone. The basal 18 inches contain obviously reworked and corroded coccoliths of Cretaceous age, but these become relatively rare in higher strata.

Traced to the west into Mississippi, a hiatus develops between the top of the Cretaceous and the base of the Paleocene, and at Johnson Creek, no samples can be assigned to the *Markalius astroporus* Zone. Thus, observations on nannofossils confirm the relations suggested by LaMoureaux & Toulmin (1959, Pl. 3) that the most complete stratigraphic record is found in Wilcox County.

The excavation at Miller's Ferry Dam provided a unique opportunity for observing the nature of the Cretaceous—Tertiary contact. The floor of the excavation was the top of the Prairie Bluff Chalk; this horizon was cleaned off with great care to preserve as much of the chalk as possible. According to C. Canning, Geologist for the U.S. Army Corps of Engineers, the contact is gently irregular and exhibits about 3 feet of relief in the excavation. The depressions in the chalk do not drain from one to another and obviously do not represent karst phenomena as the chalk beneath them shows no sign of solution. The depressions were filled with pebbles of glauconite, and in a few places driftwood that was bored by specimens of *Teredo* Linnaeus was found. One driftwood log had been mostly destroyed by bulldozers before it was finally noticed but it originally must have been several tens of feet long. Fish teeth were found at the base of the Pine Barren strata and, while Hay and Roth were collecting samples, a specimen of *Hercoglossa* Conrad was removed from the wall of the excavation about 8 feet above the base of the Pine Barren. The lower 10 feet of the Pine Barren beds are unconsolidated glauconitic sand; higher beds are more indurated, and sandy limestone bands form prominent ledges. The lithology of the basal 10 feet of the Pine Barren strata is strikingly similar to the Littig Member of the Kincaid Formation in Texas. The Cretaceous–Tertiary contact is much more subtle along Dallas County Road 59. There, the contact must be picked in the field by the disappearance of *Exogyra* Say and an increase in the amount of glauconite, which causes the surface of the outcrop to weather yellow.

Bramlette (1965) discussed the nature of the mass extinction of calcareous nannoplankton at the end of the Cretaceous and replacement of the Mesozoic nannoflora by new genera and species

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EXPLANATION OF PLATE 197

Illustrations are of electron micrographs of carbon replicas, ×4500.

FIGS. *1,11,13*—*Conococcolithus minutus* n. gen., n. sp. 1, Holotype, UI-H-2613, GAN 834, distal view. *11*, Paratype, UI-H-2612, GAN 837, side view. *13*, Paratype, UI-H-2610, GAN 837, oblique distal view.

2,3—*Toweius craticulus* n. gen., n. sp. *2*, Holotype, UI-H-2617, GAN 834, proximal view. *3*, Paratype, UI-H-2618, GAN 834, distal view.

4,9,14—*Chiasmolithus bidens* (Bramlette & Sullivan). *4*, Hypotype, UI-H-2632, GAN 834, proximal view. *9*, Hypotype, UI-H-2630, [sample 6+1 of Bramlette & Sullivan (1961) from Lodo Formation], proximal view. *14*, Hypotype, UI-H-2631, [sample 6+1 of Bramlette & Sullivan (1961) from Lodo Formation], proximal view.

5,7,10,12—*Coccolithus cavus* n. sp. *5*, Paratype, UI-H-2602, GAN 826, oblique side view. *7*, Paratype, UI-H-2608, GAN 826, proximal view. *10*, Paratype, UI-H-2609, GAN 826, distal view. *12*, Holotype, UI-N-2585, GAN 795, distal view.

6—*Prinsius bisulcus* (Stradner). Hypotype, UI-H-2732, GAN 826, distal view.

8—*Toweius helianthus* (Hay & Towe). Hypotype, UI-H-2615, GAN 811, proximal view.

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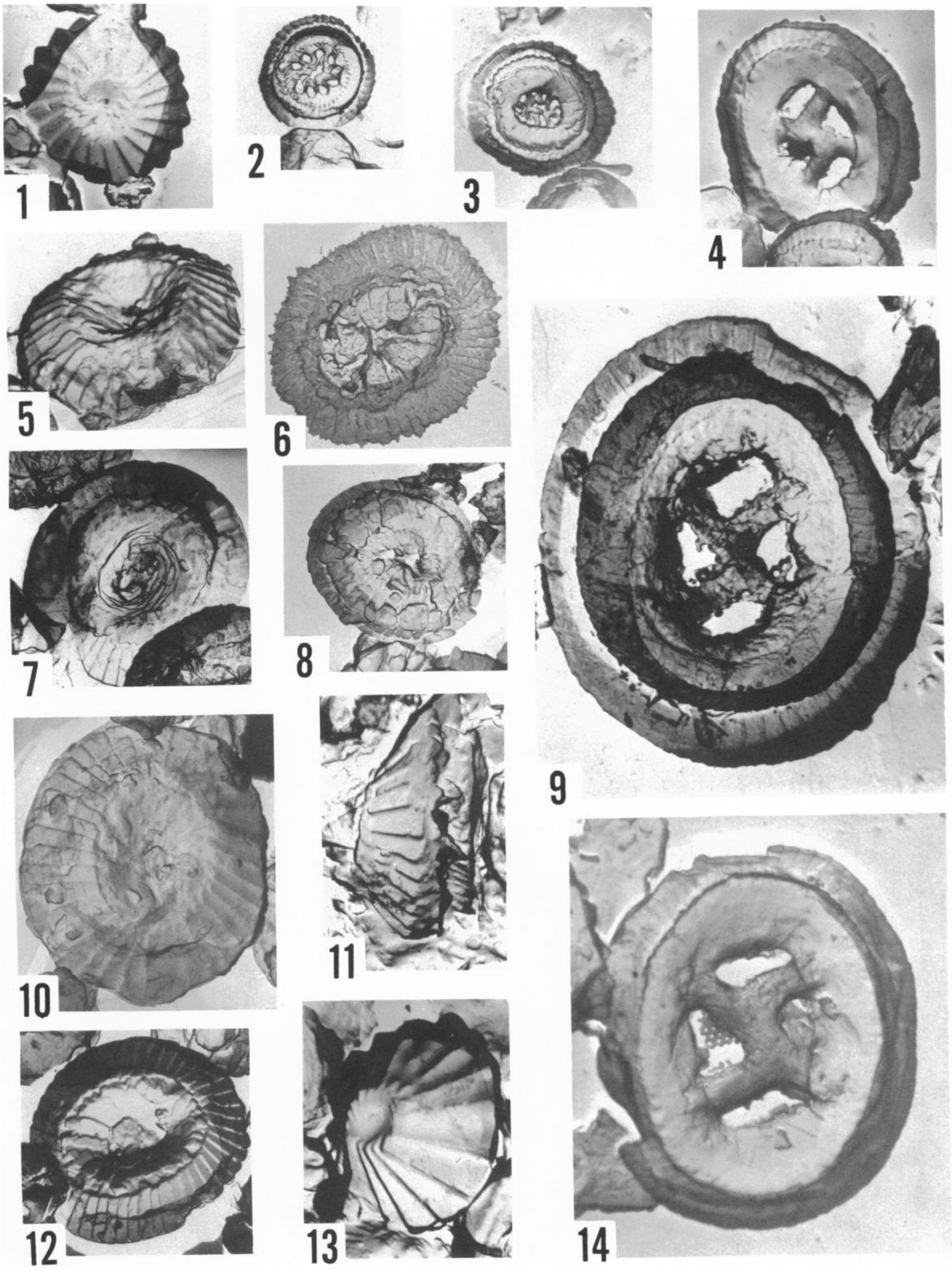

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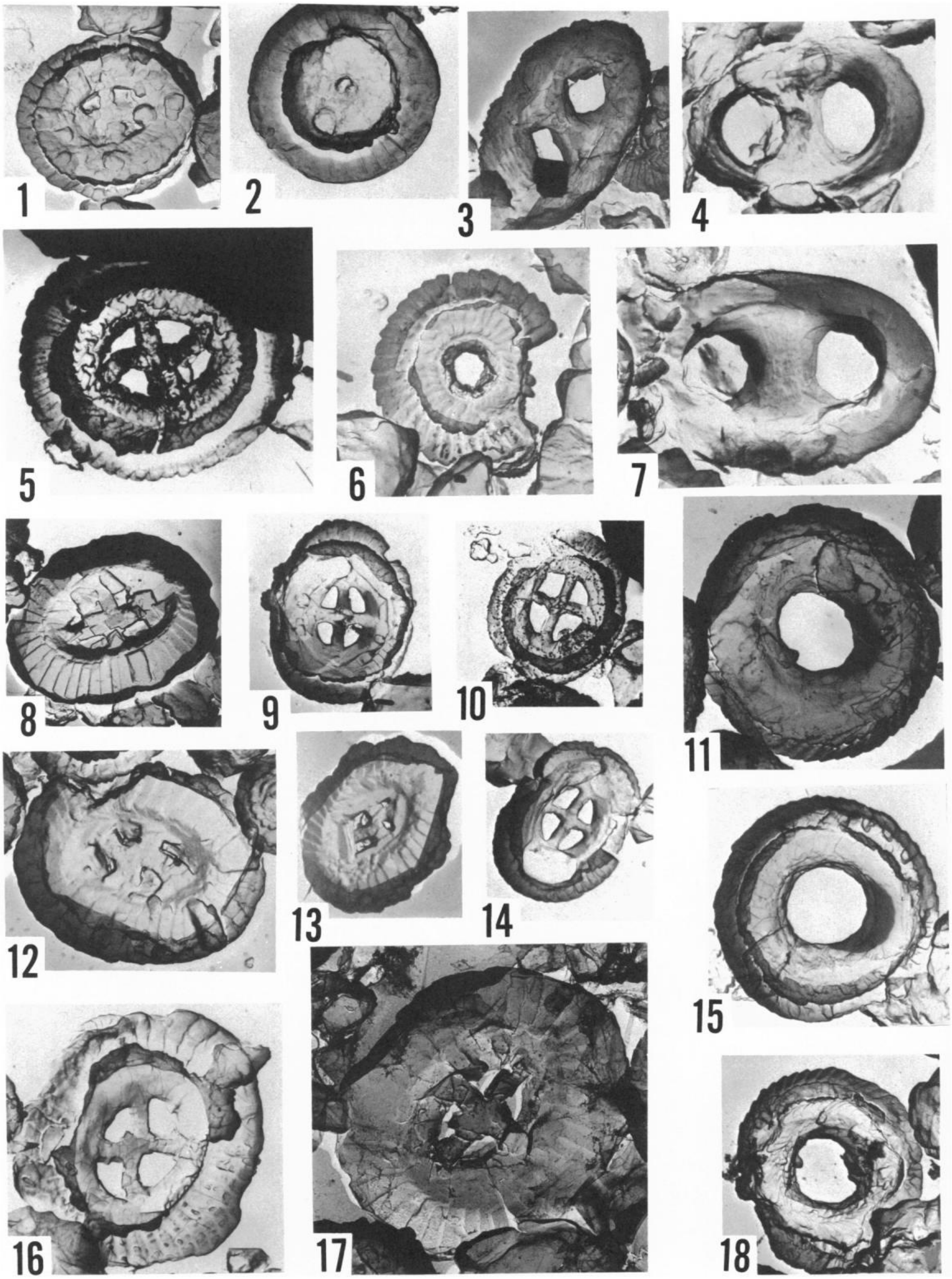

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The samples which were available to him for study (with the exception of Kjolby Gaard 8) represented the *Cruciplacolithus helis* or *Fasciculithus tympaniformis* Zones and did not give as accurate a picture of the event as is now possible. The physical event which ended the Mesozoic apparently had the following effects:

1. Cretaceous planktonic foraminifera and calcareous nannofossils were largely annihilated, leaving only a relatively small number of survivors which evolved quickly into new species. This conclusion is the inevitable result of study of the most complete records of the event, such as the Scalia section that was described by Luterbacher & Premoli-Silva (1964) the Danian exposures that were discussed by Hofker (1960) and the Wilcox County sections.

2. Submarine erosion took place over very extensive areas. The Walker Creek exposure in Texas and the Millers Ferry site offer good evidence of this process.

3. Conditions suddenly became well suited to the formation of glauconite. Bramlette (1965) has commented on the many reports of abundant glauconite at the base of the Paleocene, and the similarity of the glauconitic Fiskeler strata in Denmark, the basal Pine Barren beds in Wilcox County, Alabama, and the Littig Member of the Kincaid Formation in Texas is striking.

4. After the event, the number of species of calcareous plankton increased slowly, so that a considerable time elapsed before the assemblages achieved a diversity approximating that immediately prior to the end of Cretaceous time.

Many hypotheses have been advanced to explain the sudden extinction of so many animal and plant species at the end Mesozoic time. Bramlette (1965) suggested the possibility of a massive phytoplankton bloom that was triggered by a sudden influx of nutrients. Tappan (1966) suggested that an increase in carbon dioxide content of the atmosphere and oceans as a result of a decline of phytoplankton populations would result in an increase of temperature, decrease of pH, and collapse of the marine food pyramid. Hay (1960) postulated that the extinction of Cretaceous species might have been caused by sudden cooling of the oceans. At present it is not possible to decide which of the foregoing hypotheses best explains the observations. Samples from Millers Ferry are currently being analyzed isotopically to determine whether the Pine Barren calcareous plankton lived in water warmer or cooler than that inhabited by Prairie Bluff plankton.

Cruciplacolithus tenuis Zone

Definition.—Interval from the first appearance of *Cruciplacolithus tenuis* (Stradner) to the first appearance of *Fasciculithus tympaniformis*, Hay & Mohler.

Authors.—Mohler & Hay, *in* Hay and others (1967).

Type locality.—Pont Labau, right side of the

EXPLANATION OF PLATE 198

Illustrations are of electron micrographs of carbon replicas, ×4500.

FIGS. *1,17*—*Cruciplacolithus tenuis* (Stradner). 1, Hypotype, UI-H-2638, GAN 782, proximal view. *17*, Hypotype, UI-H-2637, GAN 811, distal view.

2,6—*Markalius astroporus* (Stradner). *2*. Hypotype, UI-H-2643, GAN 827, proximal view. *6*, Hypotype, UI-H-2642, GAN 834, proximal view.

3,4,7—*Zygodiscus adamas* Bramlette & Sullivan. *3*, Hypotype, UI-H-2663, GAN 834, proximal view. *4*, Hypotype, UI-H-2662, GAN 834, distal view. *7*, Hypotype, UI-H-2661, GAN 834, proximal view.

5—*Chiasmolithus californicus* (Sullivan). Hypotype, UI-H-2636, [sample 6+1 of Bramlette & Sullivan (1961) from Lodo Formation], proximal view.

8,12,13—*Chiasmolithus danicus* (Brotzen). *8*, Hypotype, UI-H-2660, GAN 795, distal view. *12*, Hypotype, UI-H-2635, GAN 782, distal view. *13*, Hypotype, UI-H-2634, GAN 795, distal view.

9,10—*Cruciplacolithus eminens* (Bramlette & Sullivan). *9*, Hypotype, UI-H-2641, GAN 834, proximal view. *10*, Hypotype, UI-H-2640, GAN 834, proximal view.

11,15,18—*Ericsonia subpertusa* n. sp. *11*, Paratype, UI-H-2659, GAN 795, distal view. *15*, Paratype, UI-H-2658, GAN 795, proximal view. *18*, Holotype, UI-H-2657, GAN 822, distal view.

14—*Campylosphaera dela* (Bramlette & Sullivan). Hypotype, UI-H-2639, GAN 834, distal view.

16—*Chiasmolithus consuetus* (Bramlette & Sullivan). Hypotype, UI-H-2633, GAN 834, proximal view.

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Néez; upper part of the Calcaire de La Roque (samples, GAN 780–790; most representative sample, GAN 782).

Remarks.—Several new species appear in the interval spanned by this zone. The assemblages are much more diverse than those of the *Markalius astroporus* Zone. In the section at Pont Labau, *Prinsius bisulcus* (Stradner) and *Coccolithus cavus* n. sp. have their first occurrence in the lower part of the *Cruciplacolithus tenuis* Zone, and *Ericsonia subpertusa* n. sp. and *Coccolithus apomnemoneumus* n. sp. appear near the top of the zone. *Chiasmolithus danicus* (Brotzen) is rare at Pont Labau but first appears in the *Cruciplacolithus tenuis* Zone; it is abundant in samples from Denmark and Sweden that are assigned to this zone. The limestone at Faxe, cotype locality of the Danian Stage, and the upper part of the exposure at Stevns Klint belong to this zone.

At Paderno d'Adda, the upper limit of the *Cruciplacolithus tenuis* Zone lies in the upper part of the *Globorotalia uncinata* Zone. In Austria, the *Cruciplacolithus tenuis* Zone corresponds to Zones A (=*Globorotalia trinidadensis* Zone), B (=*Globorotalia uncinata* Zone), and C (=*Globorotalia angulata* Zone) of Gohrbandt (1963a). Samples from locality V-13 in the Tampico Embayment, Mexico (*Globorotalia uncinata* Zone) contain an assemblage that is typical for the lower or middle part of the *Cruciplacolithus tenuis* Zone. In Trinidad, the *Globorotalia uncinata* Zone has a poorly preserved nannoflora but can be assigned to the *Cruciplacolithus tenuis* Zone.

In Dallas County, Alabama, sample DC-59-6 has an assemblage that is characteristic for the lower part of the *Cruciplacolithus tenuis* Zone. In the Millers Ferry excavation, this zone extends from 4 feet above the Prairie Bluff Chalk to the top of the excavation. The Pine Barren is almost sterile at the collecting site of sample ALA-28-1, just west of the J. Lee Long Bridge over the Alabama River, but the McBryde Limestone is fossiliferous and must be assigned to the next higher zone. At Johnsons Creek, Mississippi, samples I-5 through I-7 belong to the *Cruciplacolithus tenuis* Zone.

In Texas, samples from the Littig and Pisgah Members of the Kincaid Formation represent the *Cruciplacolithus tenuis* Zone. At Walker Creek, the Littig Member is only 18 inches thick; the *Markalius astroporus* Zone possibly may not be recognized here because of mixing of the nannofossils by burrowing organisms.

All of the samples that were referred to the Danian by Bramlette & Martini (1964), except Kjolby Gaard 8 and Alabama 2A, belong to the *Cruciplacolithus tenuis* Zone.

Fasciculithus tympaniformis Zone

Definition.—Interval from the first occurrence of *Fasciculithus tympaniformis* Hay & Mohler to the first occurrence of *Heliolithus kleinpelli* Sullivan.

Authors.—Mohler & Hay *in* Hay and others (1967).

Type locality.—Pont Labau, exposures along road to Cottage Bellevue (Guillempau), lower part of the Couches de Pont Labau (samples, GAN 791–808; most representative sample, GAN 795).

Remarks.—The appearance in the basal sample of this zone of *Heliorthus concinnus* (Martini), *Chiasmolithus consuetus* (Bramlette & Sullivan), *C. bidens* (Bramlette & Sullivan), and *Zygodiscus adamas* Bramlette & Sullivan, in addition to *Fasciculithus tympaniformis* Hay & Mohler, suggests that a covered interval exists between the exposures on the right bank of the Néez and those along the road to Cottage Bellevue. At the present tine, the order of appearance of these species is unknown, and all may be regarded as markers for the base of the zone.

The Lellinge Greensand (Paleocene), the unit overlying the Danian chalks in Denmark, contains *Chiasmolithus bidens* and rare specimens of *Fasciculithus tympaniformis* and may be assigned to the *F. tympaniformis* Zone.

At Paderno d'Adda, this zone is found in niveaux 16-21 of Bolli & Cita (1960). Thus, it corresponds to the upper part of the *Globorotalia uncinata* Zone, the *Globorotalia pusilla pusilla* Zone, and the lower part of the *Globorotalia pseudomenardii* Zone. In the Oichinger Schichten (Paleocene) in Austria, the *Fasciculithus tympaniformis* Zone may be represented by Zone D (probably=*Globorotalia angulata* Zone) from which we have no sample for comparison. At the time that Stradner compiled his list of species, however, *Fasciculithus* was a monotypic genus, so a possibility exists that the specimens that were described as *Fasciculithus involutus* Bramlette & Sullivan upon re-examination may prove to be *Fasciculithus tympaniformis*. The same may also hold for assemblages A-7083 [Ynezian (Paleocene) part of the lower portion of the Lodo Formation, Kern County, California] of Sullivan (1964) and A-7612 ["Martinez" (Paleocene), Simi Valley, California] of Sullivan (1965).

The *Fasciculithus tympaniformis* Zone has not been found in the Velasco Shale, possibly because of lack of exposures. The sample from the *Globorotalia pusilla pusilla* Zone of Trinidad contains rare specimens of *Fasciculithus tympaniformis* and can be assigned to this zone.

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The McBryde Limestone Member of the Clayton Formation in Alabama (samples ALA-28-3 and ALA-10-1) contains all species characteristic of the *Fasciculithus tympaniformis* Zone, except for the zonal species itself and can be referred to the *F. tympaniformis* Zone, although the possibility cannot be excluded that the McBryde Limestone might correlate with the interval between samples GAN 790 and GAN 791. A good section through the McBryde Limestone and upper part of the Pine Barren Member has not yet been observed. The Wills Point Formation of the Midway Group in Texas contains only sparse assemblages of nannoplankton fossils but *Chiasmolithus bidens*, *Heliorthus concinnus*, and *Cruciplacolithus helis* are present; thus, the Wills Point may be correlated with the McBryde Limestone and placed in the *Fasciculithus tympaniformis* Zone.

Heliolithus kleinpelli Zone

Definition.—Interval from the first appearance of *Heliolithus kleinpelli* Sullivan to the first appearance of *Discoaster gemmeus* Stradner.

Authors.—Mohler & Hay *in* Hay and others (1967).

Type locality.—Pont Labau, exposures along the lower part of the road to Cottage Bellevue (Guillempau) and Route Nationale 134bis, middle part of the Couches de Pont Labau (samples, GAN 809–819; most representative sample, GAN 811).

Remarks.—At Pont Labau, this zone corresponds to the range zone of the name species. It is found in two samples above GAN 819 but is probably reworked. *Markalius astroporus* and *Cruciplacolithus tenuis* are very rare in the *Heliolithus kleinpelli* Zone and may have become extinct before deposition of the *Fasciculithus tympaniformis* Zone was complete.

At Paderno d'Adda, the *Heliolithus kleinpelli* Zone is found close to niveau 22 of Bolli & Cita (1960) and falls into the middle part of the *Globorotalia pseudomenardii* Zone. The *Heliolithus kleinpelli* Zone has not yet been found in Austria nor is it encountered in any of the samples from Trinidad. In Mexico, it is represented at locality V-14 (*Globorotalia pusilla pusilla* Zone).

Sullivan (1964) noted that in California *Heliolithus kleinpelli* is found in the "Martinez" of the Simi Valley and in the basal "Bolado Park Formation" (Paleocene) near Tres Pinos; this suggests that the species is restricted to Ynezian strata. The assemblages from these localities are presented in tabular form in Sullivan (1965) and are apparently typical for the *Heliolithus kleinpelli* Zone, except for the presence of *Fasciculithus involutus*. Inasmuch as *Fasciculithus involutus* was the only described species of the genus at the time of Sullivan's publications, re-examination of the samples may show the species to be *Fasciculithus tympaniformis*.

A sample from the Bakchisaray section in the Crimea, that has been referred to the Kachinskian Stage (Palocene), was placed in the *Heliolithus riedeli* Zone by Wade, Mohler & Hay (1965). Re-examination of the sample reveals that such assignment was incorrect, and it belongs to the *Heliclithus kleinpelli* Zone.

Discoaster gemmeus Zone

Definition.—Interval from the first occurrence of *Discoaster gemmeus* Stradner to the first occurrence of *Heliolithus riedeli* Bramlette & Sullivan.

Author.—Hay (1964).

Type locality.—Pont Labau, along Route Nationale 134 bis; middle part of the Couches de Pont Labau (samples, GAN 820–826; most representative sample, GAN 822).

Remarks.—The upper limit of this zone is not exposed at Pont Labau. The assemblage is characterized by a flood of specimens of *Discoaster gemmeus;* these are accompanied by *Discoaster helianthus* Bramlette & Sullivan and at other localities by *Discoaster delicatus* Bramlette & Sullivan. *Discoaster aster* Bramlette & Riedel appears near the top of the zone.

At Paderno d'Adda, the *Discoaster gemmeus* Zone has been found close to niveau 23 of Bolli & Cita (1960). The *Discoaster gemmeus* Zone has not been encountered in the samples from Salzburg, although Stradner's [*in* Stradner & Papp (1961)] "Eitelgraben 181" sample may belong here.

Heliolithus riedeli Zone

Definition.—Interval from the first occurrence of *Heliolithus riedeli* Bramlette & Sullivan to the first occurrence of *Discoaster multiradiatus* Bramlette & Riedel.

Authors.—Bramlette & Sullivan (1961).

Type locality.—Lodo Gulch, side gully, lower part of Lodo Formation, Fresno County, California. [Lodo samples 6+1 and 7 of Bramlette & Sullivan (1961); most representative sample, Lodo 6+1].

Remarks.—At the type locality, strata below the *Heliolithus riedeli* Zone are unfossiliferous, and a barren interval intervenes between the highest sample of the *Heliolithus riedeli* Zone and the lowest sample of the *Discoaster multiradiatus* Zone. Forms that were listed by Bramlette & Sullivan (1961) as not found above the *Heliolithus riedeli* Zone are *Discoaster helianthus* Bramlette & Sullivan and *Heliorthus junctus* (Bramlette & Sullivan) (=*Zygolithus*

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junctus Bramlette & Sullivan), in addition to the zonal species.

The *Heliolithus riedeli* Zone is not exposed at Pont Labau; a covered interval about 100 meters long separates samples GAN 826 and GAN 827.

The *Heliolithus riedeli* Zone is present at Paderno d'Adda, overlying the *Discoaster gemmeus* Zone, between niveaux 23 and 24 of Bolli & Cita (1960). In Salzburg, the *Heliolithus riedeli* Zone assemblage is found in the Craniensandstein and Grypheenbank [lower part of Zone E of Gohrbandt (1963a) = *Globorotalia pseudomenardii* Zone].

The sample of the *Globorotalia pseudomenardii* Zone type locality in Trinidad belongs to the *Heliolithus riedeli* Zone, as has already been noted by Bramlette & Sullivan (1961).

Although the planktonic foraminifera that were described from the Thanet Sand of England by Haynes (1955) have been found to be reworked from Cretaceous beds (Haynes & El-Naggar, 1964), Cretaceous coccoliths are rare in the Thanet Beds, and the nannofossil assemblage appears to be largely indigenous. We were able to confirm the presence of *Heliolithus riedeli* which had previously been noted by Bramlette & Sullivan (1961).

Bramlette & Sullivan also mentioned that the Nanafalia Formation contains *H. riedeli* and other species of Unit 1 of the Lodo Formation. The sample from the *Ostrea thirsae* Beds south of Kimbrough, Wilcox County, which is the locality for the Nanafalia planktonic foraminifers that were illustrated by Loeblich & Tappan (1957), contains a sparse assemblage that can be assigned to the *Heliolithus riedeli* Zone. Although Loeblich & Tappan referred the Nanafalia assemblage to the *Globorotalia rex* Zone, Gartner & Hay (1962) have observed that the assemblage is actually characteristic of the *Globorotalia pseudomenardii* Zone.

The *Fasciculithus* Faunule (Paleocene), South Gully Zonule (Paleocene), and Vine Hill Faunule (Paleocene) of Sullivan (1964) and the Lower Santa Susana Zonule (Paleocene) of Sullivan (1965) are typical *Heliolithus riedeli* Zone assemblages.

Discoaster multiradiatus Zone

Definition.—Interval from the first occurrence of *Discoaster multiradiatus* Bramlette & Riedel to the first occurrence of *Marthasterites bramletti* Brönnimann & Stradner.

Authors.—Bramlette & Sullivan (1961).

Type locality.—Lodo Gulch and side gully, lower part of Lodo Formation (Unit 2), Fresno County, California [samples 19–22 and 30–32 of Bramlette & Sullivan (1961)].

Remarks.—The lower limit of this zone at the type locality is not easily determined because of the barren interval intervening between Lodo samples 7 and 19 (Bramlette & Sullivan, 1961). The upper limit is so marked and abrupt that Bramlette & Sullivan suggested that a discontinuity might exist and observed that glauconite

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EXPLANATION OF PLATE 199

Illustrations are of light micrographs, ×2250.

FIGS. *1–3*—*Ericsonia subpertusa* n. sp. Paratype, UI-H-2743, GAN 807, distal views: *1*, phase contrast; *2*, ordinary transmitted light; *3*, between crossed nicols.

4–7—*Heliolithus kleinpelli* Sullivan. Hypotype, UI-H-2744, GAN 811, plan views: *4*, phase contrast, contrast, high focus; *5*, phase contrast, low focus; *6*, ordinary transmitted light; *7*, between crossed nicols.

8–10—*Zygodiscus adamas* Bramlette & Sullivan. Hypotype, UI-H-2745, GAN 809, proximal views: *8*, phase contrast; *9*, ordinary transmitted light; *10*, between crossed nicols.

11,15,22—*Zygodiscus simplex* (Bramlette & Sullivan). Hypotype, UI-H-2747, GAN 834, distal views: *11*, phase contrast; *15*, ordinary transmitted light, *22*, between crossed nicols.

12–14—*Zygodiscus sigmoides* Bramlette & Sullivan. Hypotype, UI-H-2746, GAN 807, distal views: *12*, phase contrast; *13*, ordinary transmitted light; *14*, between crossed nicols.

16–18—*Heliorthus concinnus* (Martini). Hypotype, UI-H-2748, GAN 837, distal views: *16*, phase contrast; *17*, ordinary transmitted light; *18*, between crossed nicols.

19–21—*Neococcolithes protenus* (Bramlette & Sullivan). Hypotype, UI-H-2749, GAN 834, proximal views: *19*, phase contrast; *20*, between crossed nicols; *21*, ordinary transmitted light.

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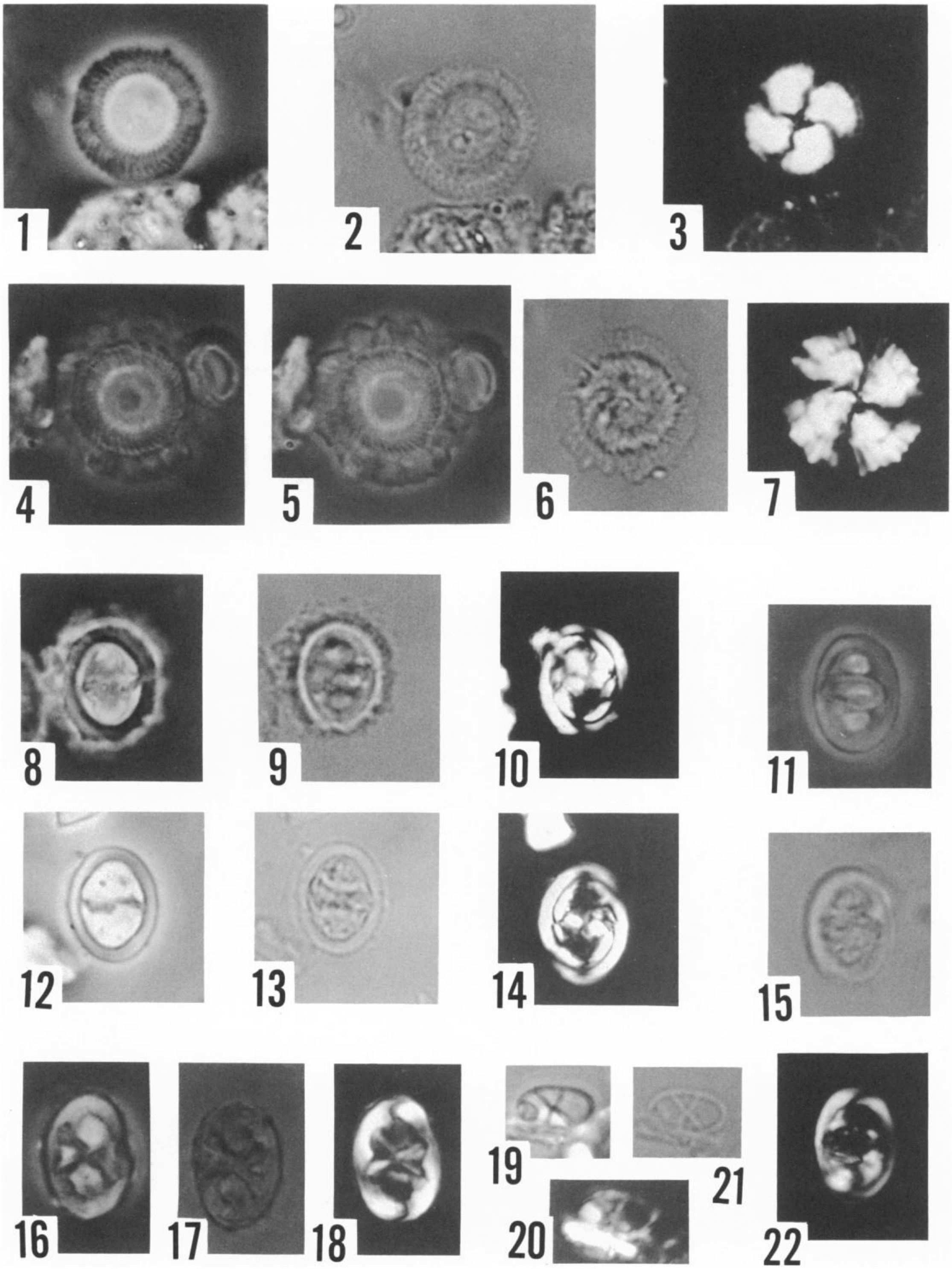

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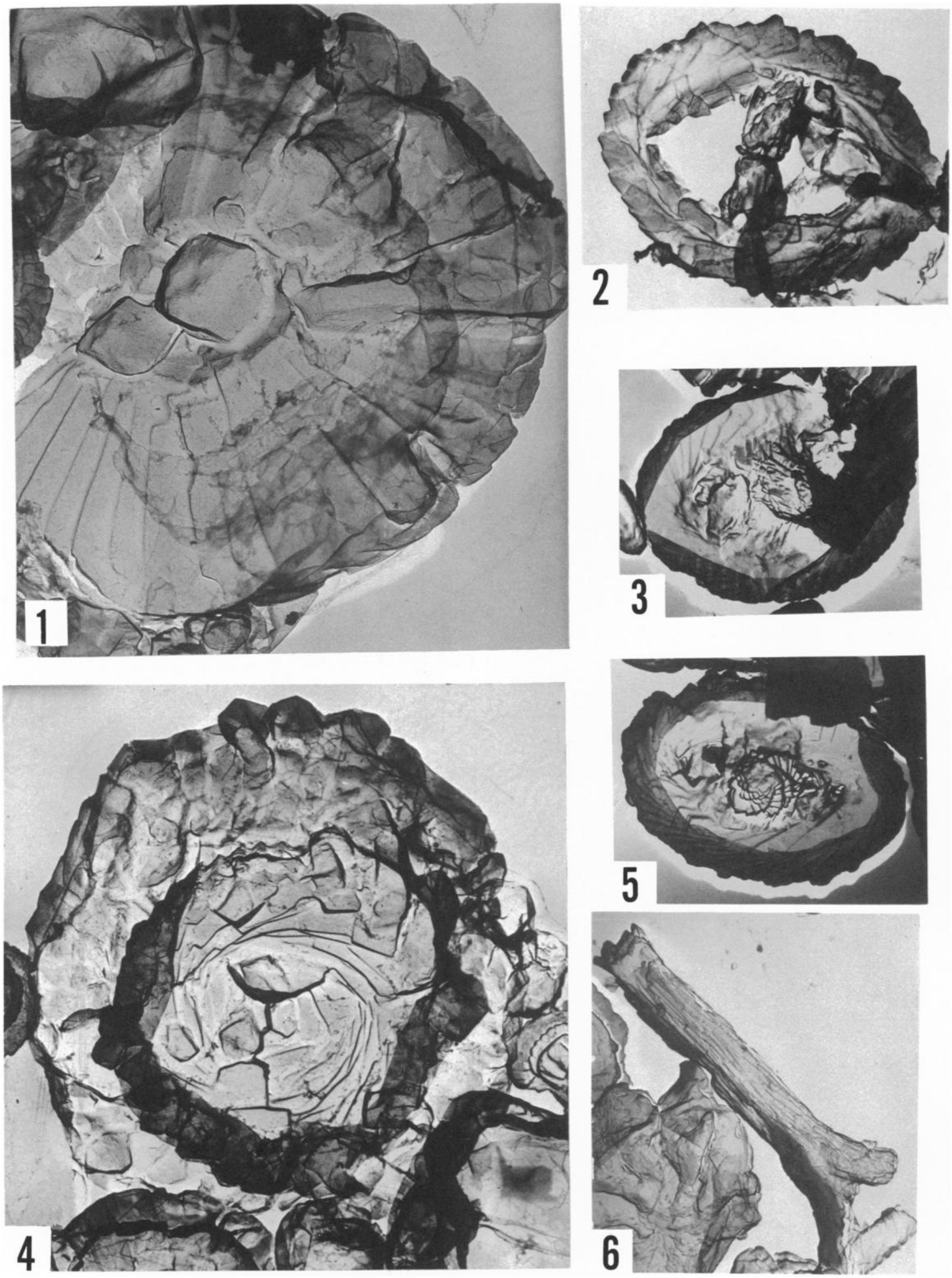

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is concentrated at the boundary between the *Discoaster multiradiatus* Zone and the *Discoaster tribrachiatus* Zone.

At Pont Labau, the limits of the *Discoaster multiradiatus* Zone are not exposed. Characteristic species at Pont Labau include *Toweius craticulus* n. gen., n. sp., *Discoaster nobilis* Martini, *D. binodosus* Martini, *Fasciculithus schaubi* n. sp., *F. involutus* Bramlette & Sullivan, *Cruciplacolithus eminens* (Bramlette & Sullivan), *Chiasmolithus californicus* (Sullivan), and *Ellipsolithus distichus* (Bramlette & Sullivan). *Discoaster mediosus* Bramlette & Sullivan and *D. lenticularis* Bramlette & Sullivan appear in the upper part of the exposure.

At Paderno d'Adda, the *Discoaster multiradiatus* Zone extends from niveau 25 to about niveau 28 (Bolli & Cita, 1960) and lies entirely within the *Globorotalia velascoensis* Zone. In the Schlierenflysch (Cretaceous—early Eocene) it occupies the lowermost part of the *Nummulites*-bearing beds (Paleocene) [S-408 to S-423, Hay & Mohler (1965)] and in agreement with this observation, it coincides with the upper part of Zone E of Gohrbandt (1963). In the Velasco Shale of Mexico, the upper part of the *Globorotalia pseudomenardii* Zone and at least the lower part of the *Globorotalia velascoensis* Zone carry a *Discoaster multiradiatus* Zone assemblage. Bramlette & Sullivan (1961) noted that a sample from the *Globorotalia velascoensis* Zone in Trinidad belongs to the *Discoaster multiradiatus* Zone. Mohler (1966) found that the *Discoaster multiradiatus* Zone straddles the *Globorotalia pseudomenardii* Zone—*Globorotalia velascoensis* Zone boundary in Switzerland.

The upper part of the Watershed Faunule (Paleocene) and the Sierra Blanca Faunule (Paleocene) of Sullivan (1964) and the Lower "Boaldo Park" Faunule (Paleocene) and Middle Santa Susana Zonule (Paleocene) of Sullivan (1965) contain typical *Discoaster multiradiatus* Zone species.

Samples of the Bashi Marl Member of the Hatchetigbee Formation from Alabama and Mississippi contain a *Discoaster multiradiatus* Zone assemblage. *Discoaster multiradiatus* is common at the type locality of the Bashi but is very rare in the Mississippi sample. The Mississippi sample contains abundant representatives of *Zygodiscus plectopons* Bramlette & Sullivan, which in California is restricted to the *Discoaster multiradiatus* Zone.

Marthasterites contortus Zone

Definition.—From the first appearance of *Marthasterites bramlettei* Brönniman & Stradner to the last occurrence of *M. contortus* (Stradner).

Author.—Hay (1964).

Type locality.—Gorge of the Grosse Schliere, Obwalden, Switzerland; Schlierenflysch [samples S 446b to S 450II of Hay & Mohler (1965); most representative sample, S 446d].

Remarks.—Both the upper and lower limits of this zone are exposed in the Schlierenflysch. *Marthasterites bramlettei* rapidly evolved into *M. contortus* at the base of this zone. *Discoaster multiradiatus* is present at the base of the *Marthasterites contortus* Zone, and *D. binodosus* ranges through this zone.

The *Marthasterites contortus* Zone cannot be recognized at Paderno d'Adda because of poor exposures and inadequate preservation of the nannofloras. The type locality of the Spilecciano [considered late Paleocene by Cita & Bolli (1961); regarded as early Eocene by Brönnimann, Stradner & Szöts (1965); and here considered as late Paleocene] in northern Italy, however, does belong to the *Marthasterites contortus* Zone. The Spilecciano was examined for calcareous plankton by Cita & Bolli (1961). They considered the planktonic foraminiferal as

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Explanation of Plate 200

Illustrations are of electron micrographs of carbon replicas and are ×4500, except figure 2 (×9000).

Figs. *1–4*—*Heliolithus kleinpelli* Sullivan. *1*, Hypotype, UI-H-2664, GAN 811, bottom view, *4*, Hypctype, UI-H-2665, GAN 811, top view.

2,3,5,6—*Zygodiscus simplex* (Bramlette & Sullivan). *2*, Hypotype, UI-H-2667, GAN 811, proximal view. *3*, Hypotype, UI-H-2669, GAN 795, distal view, *5*, Hypotype, UI-H-2668, GAN 795, distal view. *6*, Hypotype, UI-H-2666, GAN 822, side view.

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semblage to be typical of the *Globorotalia velascoensis* Zone. They (Cita & Bolli, 1961) quoted Hay as stating in a personal communication that the nannoflora is representative of the *Discoaster multiradiatus* Zone. Brönnimann, Stradner & Szöts (1965) presented the results of a restudy of the type Spilecciano. They found relatively few specimens of *Globorotalia velascoensis* and abundant specimens of *G. rex* Martin and suggested that the assemblage might belong to the *Globorotalia rex* Zone. They (Brönnimann, Stradner & Szöts, 1965) also noted the presence of *Marthasterites bramlettei* and *M. contortus*; thus, the Spilecciano can now be correlated with the lower part of the *Marthasterites contortus* Zone.

In Trinidad, the type locality of the *Globorotalia rex* Zone belongs to the upper part of the *Marthasterites contortus* Zone. Some of the samples of the Alkázar Formation [considered early Eocene by Brönnimann & Stradner (1960) but here regarded as late Paleocene] of Cuba that were described by Brönnimann & Rigassi (1963) indicate the presence of the lower part of the *Marthasterites contortus* Zone, but other Alkázar samples carry a *Discoaster multiradiatus* Zone assemblage.

Discoaster binodosus Zone

Definition.—Interval from the last occurrence of *Marthasterites contortus* (Stradner) to the first occurrence of *Discoaster lodoensis* Bramlette & Riedel.

Authors.—Mohler & Hay *in* Hay and others (1967).

Type locality.—Gorge of the Grosse Schliere, Obwalden, Switzerland; Schlierenflysch [samples S a454 to S b475II of Hay & Mohler (1965); most representative sample, S 458II].

Remarks.—*Marthasterites tribrachiatus* Bramlette & Riedel evolved from *M. contortus* at the base of this zone. *Discoaster binodosus*, *D, diastypus* Bramlette & Sullivan, and *D. mediosus* are generally common in assemblages from this zone.

At Paderno d'Adda, the *Discoaster binodosus* Zone coincides with niveaux 32 to 35 of Bolli & Cita (1960) and falls into the upper part of the *Globorotalia rex* and the lower portion of the *Globorotalia formosa formosa*—*Globorotalia aragonensis* Zones. In the Salzkammergut, the *Discoaster binodosus* Zone is represented in the Roterzschichten (previously referred to early Eocene but here considered as late Paleocene) [Zone F of Gohrbandt (1963a) = *Globorotalia rex* Zone].

In Belgium, the Clay of Flanders [variously considered as early Eocene (equivalent of the Cuisian) or late Paleocene and here regarded as late Paleocene] at Kortemark, in the type area for the Yprésian, includes this zone in its lower part. Wade, Mohler & Hay (1965) observed that a sample from the *Operculina semiinvoluta* Zone of the Bakhchisaraian Stage (generally regarded as early Eocene but here considered to be Paleocene) at the type section in the Crimea contains an assemblage that represents the *Discoaster binodosus* Zone.

In California, the *Discoaster binodosus* Zone is represented by samples 23, 33, and 34 of Bramlette & Sullivan (1961), by the *Chiphragmalithus* Zonule (Paleocene) of Sullivan (1964), and by the lower part of the Upper "Bolado Park" Zonule (Paleocene) and the lowest sample of the Lower North Gully Zonule (Paleocene) of Sullivan (1965).

Marthasterites tribrachiatus Zone

Definition.—Interval from the first occurrence of *Discoaster lodoensis* Bramlette & Riedel to the last occurrence of *Marthasterites tribrachiatus* (Bramlette & Riedel).

Authors.—Brönnimann & Stradner (1960); nannoflora listed in Brönnimann & Rigassi (1963).

Type locality.—Reparto Capri, on west side of the Calzada de Bejucal between Arroyo Apolo and Arroyo Naranjo, La Habana, Cuba; Capdevila Formation [termed early Eocene by Brönnimann & Stradner (1966) but here regarded as late Paleocene] [samples BR 820 to BR 811 of Brönnimann & Rigassi (1963); most representative sample, BR 811].

Remarks.—This zone, as originally proposed, was based on the nannoflora of the Capdevila Formation of the Habana area, Cuba, and is characterized by the joint occurrence of *Marthasterites tribrachiatus* and *Discoaster lodoensis.* Other common species include *Discoaster distinctus* Martini, *D. binodosus*, and *D. barbadiensis* Tan Sin Hok.

In the section exposed south of Pau, the beds that can be observed in the Tuilerie de Gan belong to the top of the *Marthasterites tribrachiatus* Zone. The upper part of the Clay of Flanders at Kortemark in the type area of the Yprésian contains *Marthasterites tribrachiatus* and rare specimens of *Discoaster lodoensis* and represents the lower part of this zone. The "unter Eozän 3" of Martini (1959) also belongs to the *Marthasterites tribrachiatus* Zone. Samples from the *Nummulites crimensis* Zone and the lower part of the *Assilina placentula* Zone in the type section of the Bakhchisaraian Stage have an assemblage that is typical of the *Marthasterites tribrachiatus* Zone.

At Paderno d'Adda, the *Marthasterites tribrachiatus* Zone extends from niveau 36 to 37 of Bolli & Cita (1960), that is, the upper part of the *Globorotalia formosa formosa*—*Globorotalia ar-*

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agonensis Zone and the lower part of the *Hantkenina aragonensis* Zone of Bolli & Cita (1960). A sample from the *Globorotalia aragonensis* Zone of Trinidad represents the lower part of the *Marthasterites tribrachiatus* Zone, where specimens of *Discoaster lodoensis* are rare and small.

In California, the portion of Unit 3 of the Lodo Formation from sample 25 of Bramlette & Sullivan (1961) to the top of the unit belongs to the *Marthasterites tribrachiatus* Zone. The Las Juntas Faunule [considered early Eocene by Sullivan (1964); here considered transitional Paleocene—Eocene], the Sierra Blanca Faunule [regarded as early Eocene by Sullivan (1964); here considered transitional Paleocene—Eocene], the North Gully Faunule [considered early Eocene by Sullivan (1964; here referred to the Paleocene—Eocene transitional interval], the *Braarudosphaera* Zonule [considered to be Bulitian (Paleocene) and Penutian (Eocene) by Sullivan (1964); here referred to the Paleocene—Eocene tansition], the Las Juntas Zonule [considered early Eocene by Sullivan (1964); here believed to be transitional Paleocene—Eocene], the middle portion of the Upper "Bolado Park" Zonule [early Eocene of Sullivan (1965); here regarded as transitional Paleocene—Eocene], the lower Lucia Faunule [early Eocene of Sullivan (1965); here referred to the Paleocene—Eocene transition], the Cantua-Arroyo Hondo Zonule [early Eocene of Sullivan (1965); here regarded as transitional Paleocene—Eocene], the upper portion of the Lower North Gully Zonule [early Eocene of Sullivan (1965); here referred to the Paleocene—Eocene transitional interval], the Las Cruces—Poppin Shale Faunules [early Eocene of Sullivan (1965); here considered transitional Paleocene—Eocene], and probably the lower part of the Upper Lodo Zonule [early Eocene of Sullivan (1965); here assigned to the Paleocene—Eocene transitional interval] belong to the *Marthasterites tribrachiatus* Zone.

Specialists in different areas of paleontology place the Paleocene—Eocene boundary at a variety of levels. We prefer the solution of the problem that was proposed by Hottinger & Schaub (1960), that is, to draw the boundary at the base of the Cuisian, the earliest generally accepted Eocene stage in the Paris Basin which is type area for both the Paleocene and the Eocene. Samples from the type locality of the Cuisian Stage lack calcareous nannofossils but do contain large foraminifers so that the base of the Cuisian is defined as the base of the *Nummulites planulatus* Zone by Hottinger & Schaub (1960). The intercalation of *Nummulites*-bearing beds and pelagic sediments in the Schlierenflysch permits correlation of nummulitid and calcareous nannofossil zonations (Hay & Schaub, 1960). There the base of the *Nummulites planulatus* Zone lies about the middle of the *Marthasterites tribrachiatus* Zone (Schaub, 1965; Hay & Mohler, 1965).

In the Gulf Coast, the Bashi Member of the Hatchetigbee Formation has a *Discoaster multiradiatus* Zone assemblage and thus belongs well below the Paleocene-Eocene boundary as here defined. According to Bramlette & Sullivan (1961), samples from the Tallahatta Formation have a meager nannofossil assemblage that is similar to their Unit 4, which would be indicative of the *Discoaster lodoensis* Zone or higher. Thus, according to existing knowledge, the Paleocene—Eocene boundary, as recognized by Hottinger & Schaub (1960), approximates the boundary between the Sabine and Claiborne Stages of the Gulf Coast.

In California, current usage places the Paleocene—Eocene boundary between the Bulitian and Penutian Stages. Data presented by Sullivan (1964, 1965) demonstrate that the *Marthasterites tribrachiatus* Zone is found at the base of the Penutian Stage. The Paleocene—Eocene boundary, as defined by Hottinger & Schaub (1960), would be slightly above the base of the Penutian, at a level which cannot now be determined precisely.

Discoaster lodoensis Zone

Definition.—Interval from the last occurrence of *Marthasterites tribrachiatus* Bramlette & Riedel to the first occurrence of *Discoaster sublodensis* Bramlette & Sullivan.

Authors.—Brönnimann & Stradner (1960); nannoflora listed in Brönnimann & Rigassi (1963).

Type locality.—Tejar Andrade, east of La Lisa, about 500 m. southwest of Autodromo de Matianao, La Habana, Cuba; Principe Member, Universidad Formation [middle Eocene according to Brönnimann & Stradner (1960) but here regarded as early Eocene] [sample BR 858, a locality described in detail by Brönnimann & Rigassi (1963) and mentioned by Brönnimann & Stradner (1960)].

Remarks.—At Paderno d'Adda, the *Discoaster lodoensis* Zone is found in niveaux 39 and 40 of Bolli & Cita (1960) and corresponds to the middle part of the *Hantkenina aragonensis* Zone. The "unteres Ober Eozän" of Martini (1959) contains a typical *Discoaster lodoensis* Zone assemblage. Exposures of clay at Donzacq, which were referred to the Lutetian by Burger, Cuvillier & Schoeffler (1945) but more recently demonstrated to be Cuisian by Hottinger & Schaub (1960), contain a rich *Discoaster lodoensis* Zone assemblage, which is contaminated by reworked nannofossils from older Tertiary and Cretaceous

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strata. At Cherkessk, in the Caucasus, samples from the *Acarinina crassaeformis* Zone of the Simferopolian Stage (generally regarded as middle Eocene but here considered as early Eocene) belong to the *Discoaster lodoensis* Zone.

In California, the Upper "Vacaville" Zonule (Eocene), the Muir Zonule (Eocene), the Alhambra Zonule (Eocene), the Upper Lucia Faunule (Eocene), and the middle part of the Upper Lodo Zonule (Eocene) [samples A-7053 and A-7054 of Sullivan (1965)] belong to this zone.

SYSTEMATIC PALEONTOLOGY

Terminology.—The technical terms that are used in the following descriptions are defined in Hay, Mohler & Wade (1966). In addition, two new terms are here introduced to describe the swastikalike interference figures that are observed between crossed polarizers. When the limbs of the interference figure curve to the left as they are traced outward from the center, in distal view, the figure is termed laevogyre; when they curve to the right, the figure is termed dextrogyre. These terms have been adapted from the descriptions of members of the subgenus *Gyrodiscoaster* Stradner *in* Stradner & Papp (1961).

Typification.—All new species are based on electron micrographs. Because the original specimen is destroyed in the preparation of the carbon replica and because the replica itself is subject to contamination by the electron beam and is easily destroyed, one of the micrographs of each species has been designated as holotype, and others have been designated as paratypes. All material is deposited in the collections of the Department of Geology, University of Illinois (UI), Urbana, Illinois.

PLANT KINGDOM

Division PHAEOPHYTA Wettstein (1901) emend. Rothmaler, 1949

Class COCCOLITHOPHYCEAE Rothmaler, 1951

Order HELIOLITHAE Deflandre, 1952

Family COCCOLITHACEAE Kamptner, 1928 emend.

Diagnosis.—Coccolithophores bearing placoliths; proximal shield producing interference figure, distal shield dark or faintly illuminated in two quadrants between crossed polarizers.

Subfamily COCCOLITHOIDEAE Kamptner, 1928 emend.

Diagnosis.—Placoliths elliptical, interference figure of proximal shield laevogyre in distal view.

Genus COCCOLITHUS Schwarz, 1894

COCCOLITHUS CAVUS n. sp.

Pl. 196, figs. 1–3; Pl. 197, figs. 5,7,10,12

Diagnosis.—A species of *Coccolithus* having an unusually large central area and 40 to 64 segments in the distal shield.

Description.—The distal shield is subcircular to elliptical and composed of 40 to 64, generally 48 to 52, wedge-shaped dextrally imbricate segments that are separated by straight sutures showing a slight clockwise inclination in dista

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EXPLANATION OF PLATE 201

Illustrations are of electron micrographs of carbon replicas, ×4500

FIGS. *1,2,4,5*—*Ellipsolithus distichus* (Bramlette & Sullivan). *1*, Hypotype UI-H-2683, GAN 834, distal view. *2*, Hypotype, UI-H-2682, GAN 834, distal view. *4*, Hypotype. UI-H-2685, GAN 834, distal view. *5*, Hypotype. UI-H-2684, GAN 834, distal view.

3—*Zygodiscus simplex* (Bramlette & Sullivan). Hypotype, UI-H-2670, GAN 834, side view.

6,7,10—*Heliorthus concinnus* (Martini). *6*, Hypotype, UI-H-2672, GAN 834, oblique distal view. *7*, Hypotype, UI-H-2671, GAN 834, proximal view. *10*, Hypotype, UI-H-2673, GAN 795, distal view.

8,15—*Coccolithus apomnemoneumus* n. sp. *8*, Holotype, UI-H-2686, GAN 826, proximal view. *15*, Paratype, UI-H-2687, GAN 826, distal view.

9—*Neococcolithes protenus* (Bramlette & Sullivan). Hypotype, UI-H-2674, GAN 834, distal view.

11,12,14—*Scapholithus apertus* n. sp. *11*, Paratype, UI-H-2676, GAN 834, plan view. *12*, Holotype, UI-H-2675, GAN 834, plan view. *14*, Paratype, UI-H-2677, GAN 834, plan view.

13,16–18—*Scapholithus rhombiformis* n. sp. *13*, Paratype, UI-H-2678, GAN 827, oblique view. *16*, Paratype, UI-H-2681, GAN 827; oblique view. *17*, Holotype, UI-H-2680, GAN 827, oblique view. *18*, Paratype, UI-H-2679, GAN 827, oblique view.

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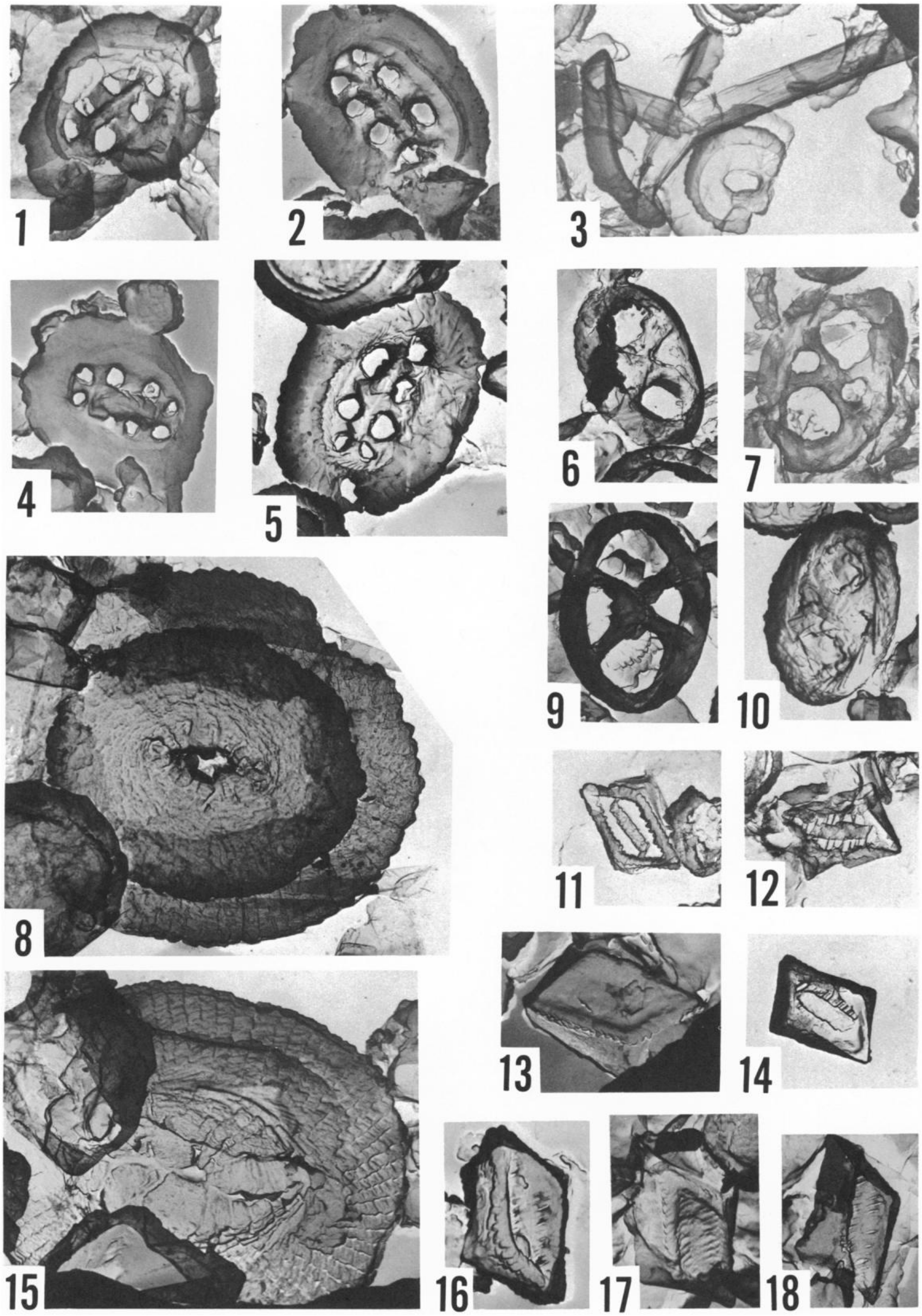

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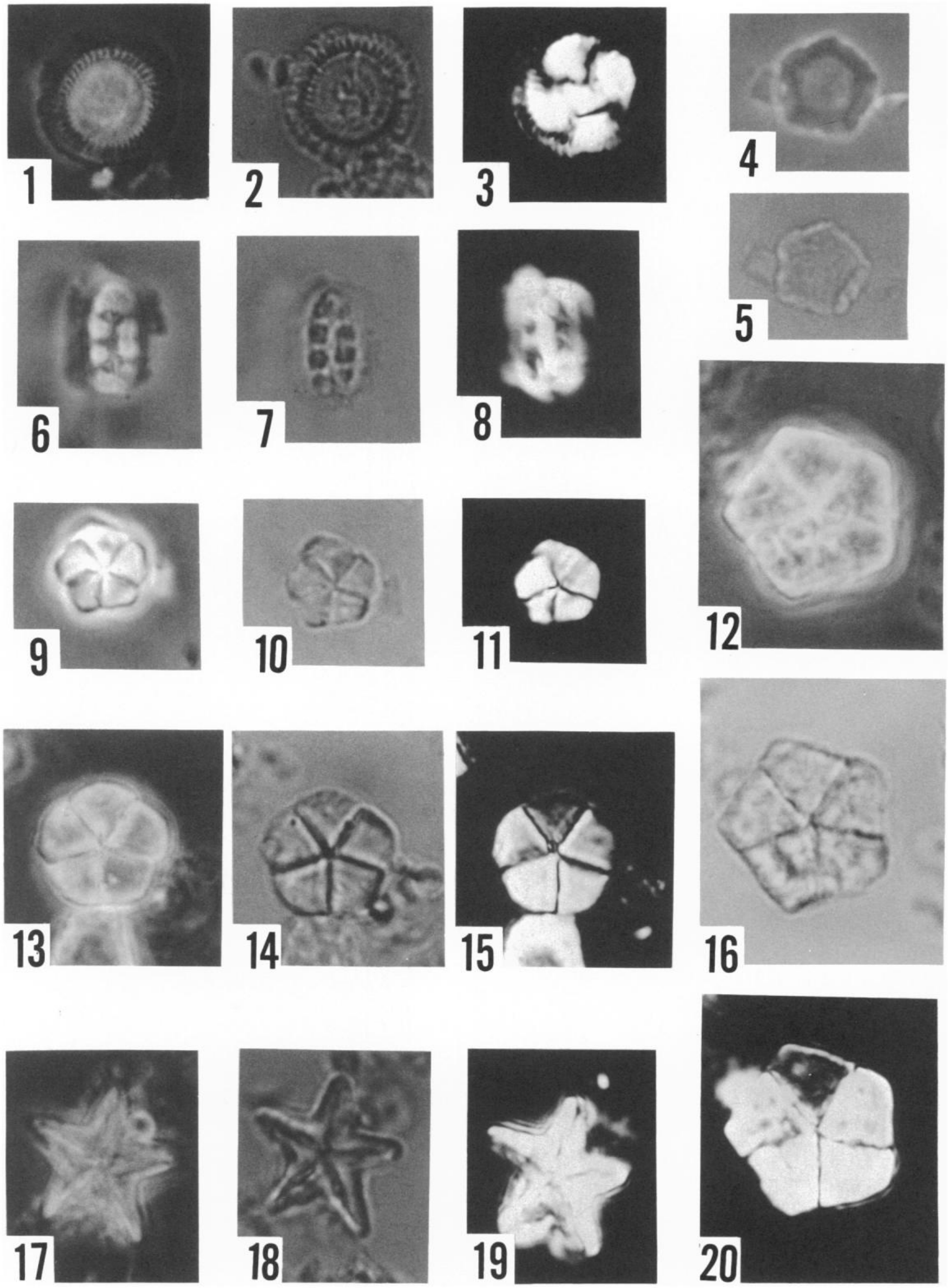

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view. The central area of the distal shield forms a large craterlike depression that is more or less filled by cycles of imbricate segments; the most peripheral of these cycles is composed of wedge-shaped segments that are equal in number to those in the distal shield and form a distinctive corona; the inner cycles are more irregular; the proximal shield is composed of segments equal in number to those of the distal shield and has a serrate margin. In proximal view, the sutures of the proximal shield are inclined clockwise out to the middle of the shield and thence turn sharply to be inclined counterclockwise peripherally. The sutures on the proximal side of the distal shield are inclined counterclockwise in the same degree as those of the periphery of the proximal shield.

Remarks. The segments in the shields of this new species are intermediate in number between those of *Coccolithus sarsiae* Black (about 40) and C. *eopelagicus* Bramlette & Riedel (about 60), and *C. apomnemoneumus* n. sp. (about 56 to 72). The number of segments in *C. cavus* is about the same as in *C. pelagicus* Wallich (48), a Recent species, but the former has a much larger central depression.

The trivial name, meaning hollow, refers to the deep open central area.

Maximum diameter.—7.5 to 11μ.

Minimum diameter.—6.5 to 9.5μ.

Holotype.—UI-H-2585 (Pl. 197, fig. 12).

Paratypes.—UI-H-2599-2609, 2715, 2728.

Locus typicus.—Gan, Pont Labau.

Stratum typicum.—GAN 795 (*Fasciculithus tympaniformis* Zone).

Occurrence.—*Coccolithus cavus* n. sp. extends from the upper part of the *Cruciplacolithus tenuis* Zone throughout the section at Pont Labau and becomes especially abundant in the *Discoaster multiradiatus* Zone.

COCCOLITHUS APOMNEMONEUMUS n. sp.
Pl. 201, figs. 8, 15; Pl. 202, figs. 1–3

Diagnosis.—A species of *Coccolithus* possessing a broad distal rim having 56 to 72 segments, narrow proximal rim displaying a similar number of segments, and a central area closed by several layers of tabular elements.

Description.—The distal rim of this species is composed of 56 to 72 dextrally imbricate wedges. The sutures are inclined strongly clockwise as they ascend the inner margin of the wedges, thence angle sharply at the upper edge to turn slightly counterclockwise on the upper surface. The proximal rim is similarly constructed but is much narrower, and the inner portions are covered by the numerous small laths forming the plug of the central area. In distal view the central area is filled by many layers of imbricate tabulae. In proximal view numerous small laths that are arranged in ellipses can be observed.

Remarks.—This species has a wider proximal shield than encountered in other species of *Coccolithus*. In the light microscope, *C. apom-*

EXPLANATION OF PLATE 202

Illustrations are of light micrographs, ×2250.

FIGS. *1–3*—*Coccolithus apomnemoneumus* n. sp. Paratype, UI-H-2750, GAN 834, distal views: *1*, phase con trast; *2*, ordinary transmitted light; *3*, between crossed nicols.

4,5—*Goniolithus* cf. *G. fluckigeri* Deflandre. Hypotype, UI-H-2751, GAN 781, plan views: *4*, phase contrast; *5*, ordinary transmitted light.

6–8—*Ellipsolithus distichus* (Bramlette & Sullivan). Hypotype, UI-H-2752, GAN 834, distal views: *6*, phase contrast; *7*, ordinary transmitted light; *8*, between crossed nicols.

9–11—*Braarudosphaera imbricata* Manivit. Hypotype, UI-H-2753. GAN 834, plan views: *9*, phase contrast; *10*, ordinary transmitted light: *11*, between crossed nicols.

12,16,20—*Braarudosphaera bigelowi* (Gran & Braarud). Hypotype, UI-H-2754, GAN 807, plan views: *12*, phase contrast; *16*, ordinary transmitted light; *20*, between crossed nicols.

13–15—*Braarudosphaera discula* Bramlette & Sullivan. Hypotype, UI-H-2755, GAN 807, plan views: *13*, phase contrast; *14*, ordinary transmitted light; *15*, between crossed nicols.

17–19—*Micrantholithus* sp. Hypotype, UI-H-2756, GAN 807, plan views: *17*, phase contrast; *18*, ordinary transmitted light; *19*, between crossed nicols.

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nemoneumus may be confused with *C. cavus* n. sp. but is distinguished by having more segments and a larger central area under polarized light, forming a variably complex portion of the interference cross.

The trivial name, meaning easily forgotten, was selected because we nearly omitted to include this species in the original range determinations.

Maximum diameter.—15μ.

Minimum diameter.—13μ.

Holotype.—UI-H-2686 (Pl. 201, fig. 8).

Paratypes.—UI-H2687, 2688, 2750.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 826 (*Discoaster gemmeus* Zone).

Occurrence.—*C. apomenmoneumus* ranges from the upper part of the *Cruciplacolithus tenuis* Zone throught the *Fasciculithus tympaniformis*, *Heliolithus kleinpelli*, and *Discoaster gemmeus* Zones and is found locally and randomly (reworked?) in the top of the *Discoaster multiradiatus* Zone.

Genus CHIASMOLITHUS Hay, Mohler & Wade, 1966

CHIASMOLITHUS BIDENS (Bramlette & Sullivan)

Pl. 196, figs. 14,15,17; Pl. 197, figs. 4,9,14

Coccolithus bidens BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 139, Pl. 1, fig. 1; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 72, Pl. 8, figs. 1,2; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 180, Pl. 1, fig. 10a,b;——, 1965, *ibid*., v. 53, p. 31.

Remarks.—This species is characterized by the small central area having a correspondingly small X-shaped structure. The most unique feature, as viewed by the electron microscope, is a minute reticule spanning the openings between the limbs of the X. The distal shield is composed of about 60 to 75 segments that are slightly imbricate dextrally and that have sutures showing a slight clockwise inclination in distal view. The proximal shield has an equal number of segments, but the sutures of the proximal shield, as seen in proximal view, are centrally slightly, peripherally strongly, inclined clockwise.

Maximum diameter.—6μ to 10μ.

Minimum diameter.—5μ to 8μ.

Hypotypes.—UI-H-2630–2632, 2731.

Occurrence.—Two of the electron micrographs are of specimens from the Lodo Formation of California [sample 6+1 of Bramlette & Sullivan (1961)]. Specimens from Pont Labau are not as well preserved and show only traces of the edges of the reticulate net. In California this species was found only in the *Heliolithus riedeli* Zone. At Pont Labau it was observed in the *Fasciculithus tympaniformis* Zone and sporadically in the *Discoaster multiradiatus* Zone (reworked?).

CHIASMOLITHUS CONSUETUS (Bramlette & Sullivan)

Pl. 196, figs. 23–25; Pl. 198, fig. 16

Coccolithus consuetus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 139, Pl. 1, fig. 2a-c; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 74, Pl. 8, figs. 10–12; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 180, Pl. 3, fig. 1a,b;——, 1965, *ibid*., v. 53, p. 31.

Remarks.—In distal view, the distal shield of this species is composed of about 40 wedge-shaped dextrally imbricate segments. The sutures between the septa are straight and oriented almost precisely radially in distal view. In proximal view the segments of the distal shield appear to thicken peripherally and again are separated by straight radial sutures. The X-shaped central structure is apparently made of rhombs of calcite, each limb being constructed by a single row of four or five rhombs.

Maximum diameter.—10μ.

Minimum diameter.—9μ.

Hypotypes.—UI-H-2633, 2737.

Occurrence.—This species was originally described from the Lodo Formation of California where it has been determined to range through the *Heliolithus riedeli*, *Discoaster multiradiatus*, and *Discoaster tribrachiatus* Zones of Bramlette & Sullivan (1961). Study of the Pont Labau section permits the lower limit of its range to be extended to include the *Discoaster gemmeus*, *Heliolithus kleinpelli*, and *Fasciculithus tympaniformis* Zones.

CHIASMOLITHUS DANICUS (Brotzen)

Pl. 196, figs. 16,21,22; Pl. 198, figs. 8,12,13

Cribrosphaerella danica BROTZEN, 1959, Sver. geol. Unders., ser. C. no. 571, p. 25, Text-fig. 9 (nos. 3–6).
Coccolithus danicus (Brotzen). BRAMLETTE & MARTINI, 1964, Micropaleontology, v. 10, no. 3, p. 298, Pl. 1, figs. 15,16.

Remarks.—The distal shield is composed of 40 to 50 dextrally imbricate wedge-shaped segments. These border a deep, broad central depression. The X-shaped structure in the central area is robust and constructed of large fused calcite rhombs, leaving only small openings.

Maximum diameter.—8–9μ.

Miminum diameter.—6.5–7.5μ.

Hypotypes.—UI-H-2634, 2635, 2660, 2738.

Occurrence.—This species was originally described from Danian strata in Sweden. Bramlette & Martini (1964) have found this species in Danian beds of Denmark, France, Tunisia, and Alabama. The range of *Chiasmolithus danicus* at

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Pont Labau is not easy to determine with certainty because of its rarity but it is found in the *Cruciplacolithus tenuis* and *Fasciculithus tympaniformis* Zones.

CHIASMOLITHUS CALIFORNICUS (Sullivan)
Pl. 196, figs. 18–20; Pl. 198, fig. 5

Coccolithus aff. *C. gigas* BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 140, Pl. 1, fig. 7a-d.
Coccolithus californicus SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 180, Pl. 2, figs. 3a,b; 4a,b; ——, 1965, *ibid.*, v. 53, p. 31.

Remarks.—This species differs from *Chiasmolithus consuetus* in having a more delicate distal shield that displays sutures. Specimens of *C. californicus* from Pont Labau, where the species is rare, have been observed under the light microscope, but electron micrographs have not been obtained of forms from this locality. Electron micrographs have been obtained of it, however, in material from the Lodo Formation [sample 6+1 of Bramlette & Sullivan (1961)]. These show the distal shield to be composed of about 60 segments. The sutures of the proximal and distal sides of the distal shield are offset, and because of the extreme thinness of the shield produce a finely striate effect in the light microscope. The sutures of both sides have a slight counterclockwise inclination in proximal view. The proximal shield is composed of about 60 segments that are separated by complex sutures. The sutures arise from the juncture with the thick central tube, having first a strong counterclockwise inclination; they bend sharply clockwise on the surface of the proximal shield but become almost radial at the periphery of the shield. The X-shaped central structure is similar to that of *Chiasmolithus consuetus.*

Maximum diameter.—16μ.

Minimum diameter.—13μ.

Hypotypes.—UI-H-2636, 2739.

Occurrence.—Originally described as *Coccolithus* aff. *C. gigas* from the Lodo Formation of California, this form was found to be restricted to the *Heliolithus riedeli* Zone. Sullivan (1964, 1965) recognized it as a distinct species and has found it in several other localities exposing the *Heliolithus riedeli* Zone. At Pont Labau *Chiasmolithus californicus* is noted in the *Discoaster multiradiatus* Zone.

Genus CRUCIPLACOLITHUS Hay & Mohler, 1967

CRUCIPLACOLITHUS EMINENS (Bramlette & Sullivan)
Pl. 196, figs. 26–28; Pl. 198, figs. 9, 10

Coccolithus eminens BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 139, Pl. 1, fig. 3a-d; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 181, Pl. 1, figs. 11a-b, 12a,b; ——, 1965, *ibid.*, v. 53, p. 31.

Remarks.—This species is distinguished from other members of the genus by its relatively small central area. It differs from *Campylosphaera dela* in being evenly and broadly concave.

Maximum diameter.—5.5–6.5μ.

Minimum diameter.—5–5.5μ.

Hypotypes.—UI-H-2640, 2641, 2741.

Occurrence.—Originally described from the *Heliolithus riedeli* Zone of the Lodo Formation in California, this species is found at Pont Labau throughout the *Discoaster multiradiatus* Zone

CRUCIPLACOLITHUS TENUIS (Stradner)
Pl. 196, figs. 29–31; Pl. 198, figs. 1,17

Heliorthus tenuis STRADNER, 1961, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 77, p. 84, Text-figs. 64,65.
Coccolithus helis STRADNER, [*nom. subst. pro Coccolithus* (*Heliorthus*) *tenuis* Stradner, *non Coccolithus tenuis* Kamptner], *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, p. 74, Pl. 8, fig. 16, Pl. 9, figs. 1,2; BRAMLETTE & MARTINI, 1964, Micropaleontology, v. 10, no. 3, p. 298–299, Pl. 1, figs. 10-12, Pl. 7, figs. 5a,b?,6?; EDWARDS, 1966, New Zealand Jour. Geology and Geophysics, v. 9, no. 4, Text-figs. 9,12.
Cruciplacolithus tenuis (Stradner) HAY & MOHLER, *in* HAY AND OTHERS, in press, Gulf Coast Assoc. Geol. Soc., Trans.

Remarks.—The broad distal shield of this species is composed of about 40 dextrally imbricate wedge-shaped segments. The sutures are straight and have a nearly radial orientation. The central depression has a broad sloping margin. The proximal shield is narrower than the distal shield but is composed of the same number of segments. The sutures on the proximal side of the proximal shield are inclined counterclockwise as they ascend the margin of the central area and thence bend sharply to become subradial. The X-shaped structure in the central area is robust and is composed of fused calcite rhombs; four or five arms form each arm.

Some question exists concerning whether the electron micrographs of Bramlette & Martini (1964) represent this species; they may illustrate a reworked Cretaceous form.

Maximum diameter.—7–12μ.

Minimum diameter.—6–9μ.

Hypotypes.—UI-H-2637, 2638, 2740.

Occurrence.—Originally described from the Danian of Austria (Stradner, 1961), this species has been reported by Bramlette & Martini (1964) in samples from the type Danian, where it is said to be most common in middle Danian beds. Bramlette & Martini have also recorded it in samples from Tunisia and Alabama, and Edwards (1966) has found it in New Zealand. At Pont Labau, this species ranges through the

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Cruciplacolithis tenuis and *Fasciculithus tympaniformis* Zones; is rare in the *Heliolithus kleinpelli* and *Discoaster gemmeus* Zones; and is found randomly in the *Discoaster multiradiatus* Zone.

Subfamily CYCLOCOCCOLITHOIDEAE n. subfam.

Diagnosis.—Placoliths circular, interference figure of proximal shield radial to subradial.

Genus MARKALIUS Bramlette & Martini, 1964

Remarks.—Bramlette & Martini (1964) designated *Markalius inversus* (Deflandre) [= *Cyclococcolithus leptoporus* (Murray & Blackman) var. *inversus* Deflandre], originally described from the Oamaru Diatomite (late Eocene) of New Zealand, as type species. Hay, Mohler & Wade (1966) noted that the late Eocene type species resembles *Cyclococcolithus leptoporus* (Murray & Blackman) in all respects, except that the sutures have precisely the opposite orientation. The number of segments in the distal shield of both species is generally 28. From this observation, Hay, Mohler & Wade suggested that *Markalius* might be considered a synonym of *Cyclococcolithus*. It now appears, however, that the clockwise inclination of the sutures on the distal shield is characteristic of several Paleogene species and serves to differentiate them readily from younger species having counterclockwise inclination of the sutures.

MARKALIUS ASTROPORUS (Stradner)
Pl. 196, figs. 32–35; Pl. 198, figs. 2,6

Cyclococcolithus astroporus STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 75, Pl. 9, figs. 5–7, Text-fig. 3/2a,b.

Markalius inversus (Deflandre). BRAMLETTE & MARTINI, 1964, (part), Micropaleontology, v. 10, no. 3, 302, Pl. 2, figs. 4–9, Pl. 7, fig. 2a,b.

Remarks.—The electron micrographs of forms that were referred to *Markalius inversus* (Deflandre) by Bramlette & Martini (1964) probably represent the new species *Ericsonia subpertusa* that is described below. Of the light micrographs of Bramlette & Martini, figures 4, 5, and 6 on Plate 2 most closely resemble Stradner's figure (1963) of *Cyclococcolithus astroporus*. The other light micrographs of Bramlette & Martini might represent another species, possibly *Ericsonia subpertusa*.

Diameter.—8-10μ.

Hypotypes.—UI-H-2642, 2643, 2742.

Occurrence.—*Markalius astroporus* was originally described by Stradner (1963) from the Oichinger Schichten of Salzburg, where it was found in zones A, B, and C. Bramlette & Martini (1964) have recorded it from the type Danian of Denmark and from France, Tunisia, Alabama, and have noted rare specimens from the Maastrichtian of Denmark and Alabama. At Pont Labau this form is used to define the lowermost zone of the section. It ranges through this and through the lower part of the *Cruciplacolithus tenuis* Zone and is observed randomly (?reworked) through the whole section. We have not observed it in any Cretaceous samples.

Genus CONOCOCCOLITHUS n. gen.

Diagnosis.—Circular placoliths having the form of a truncate cone.

Type species.—*Conococcolithus minutus* n. sp.

Remarks.—As in *Cyclococcolithus*, the c-axes of the elements in the distal shield are oriented at

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EXPLANATION OF PLATE 203

Illustrations are of electron micrographs of carbon replicas and are ×4500, except figures 8(×2250) and 9(×9000).

FIGS. *1,3,6,9*—*Fasciculithus involutus* Bramlette & Sullivan. *1,* Hypotype, UI-H-2695, GAN 827, top view. *3,* Hypotype, UI-H-2696, GAN 827, top view. *6.* Hypotype, UI-H-2697, GAN 827, side view. *9,* Hypotype, UI-H-2694, GAN 827, side view.

2,4,7,10—*Fasciculithus schaubi* n. sp. *2,* Paratype, UI-H-2691, GAN 834, side view. *4,* Paratype, UI-H-2692, GAN 834, top view. *7,* Paratype, UI-H-2693, GAN 827, oblique bottom view. *10,* Holotype, UI-H-2690, GAN 834, side view.

5—*Thoracosphaera saxea* Stradner. Hypotype, UI-H-2688, GAN 795, fragmentary specimen.

8—*Thoracosphaera deflandrei* Kamptner. Hypotype, UI-H-2689 GAN 837, side view.

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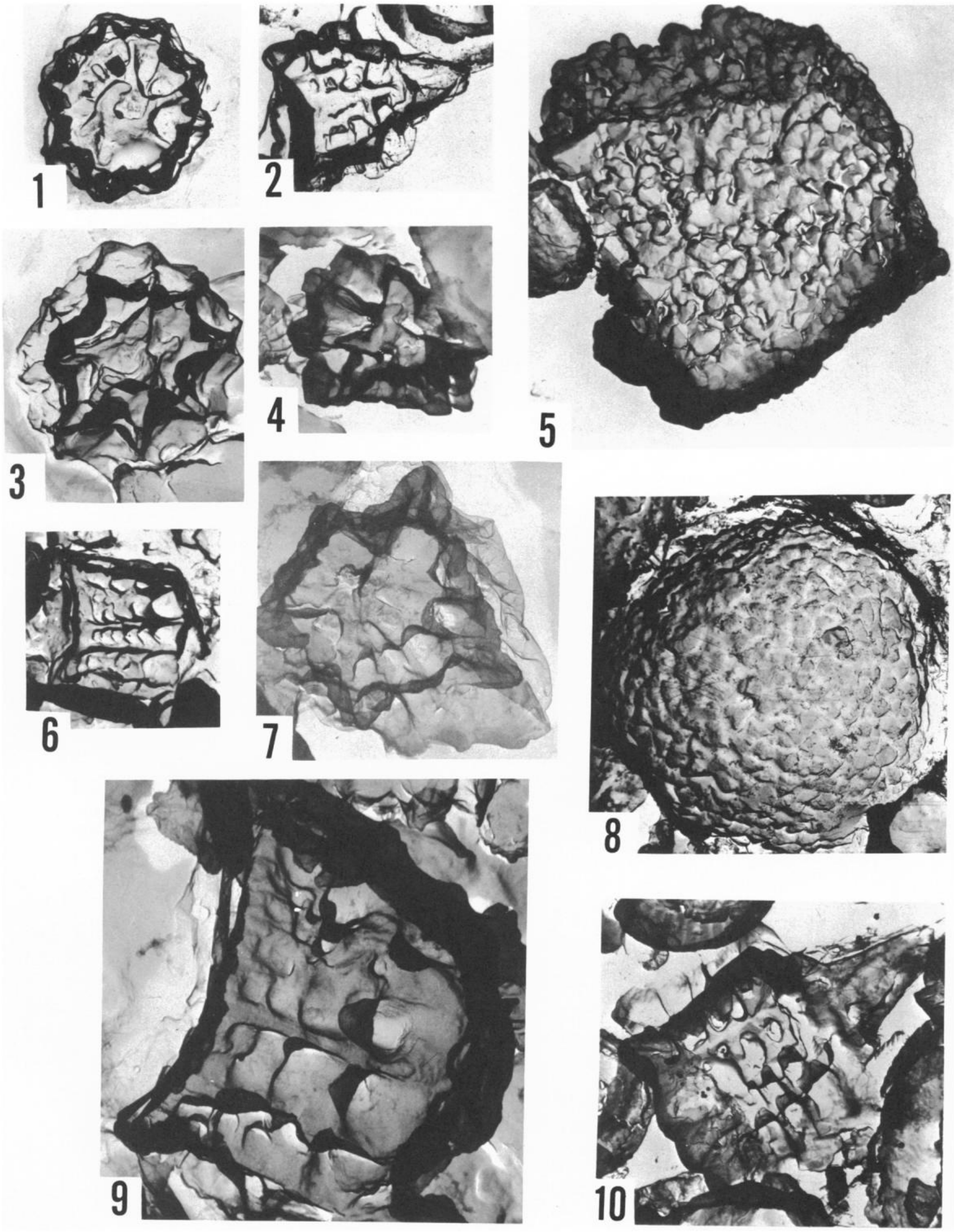

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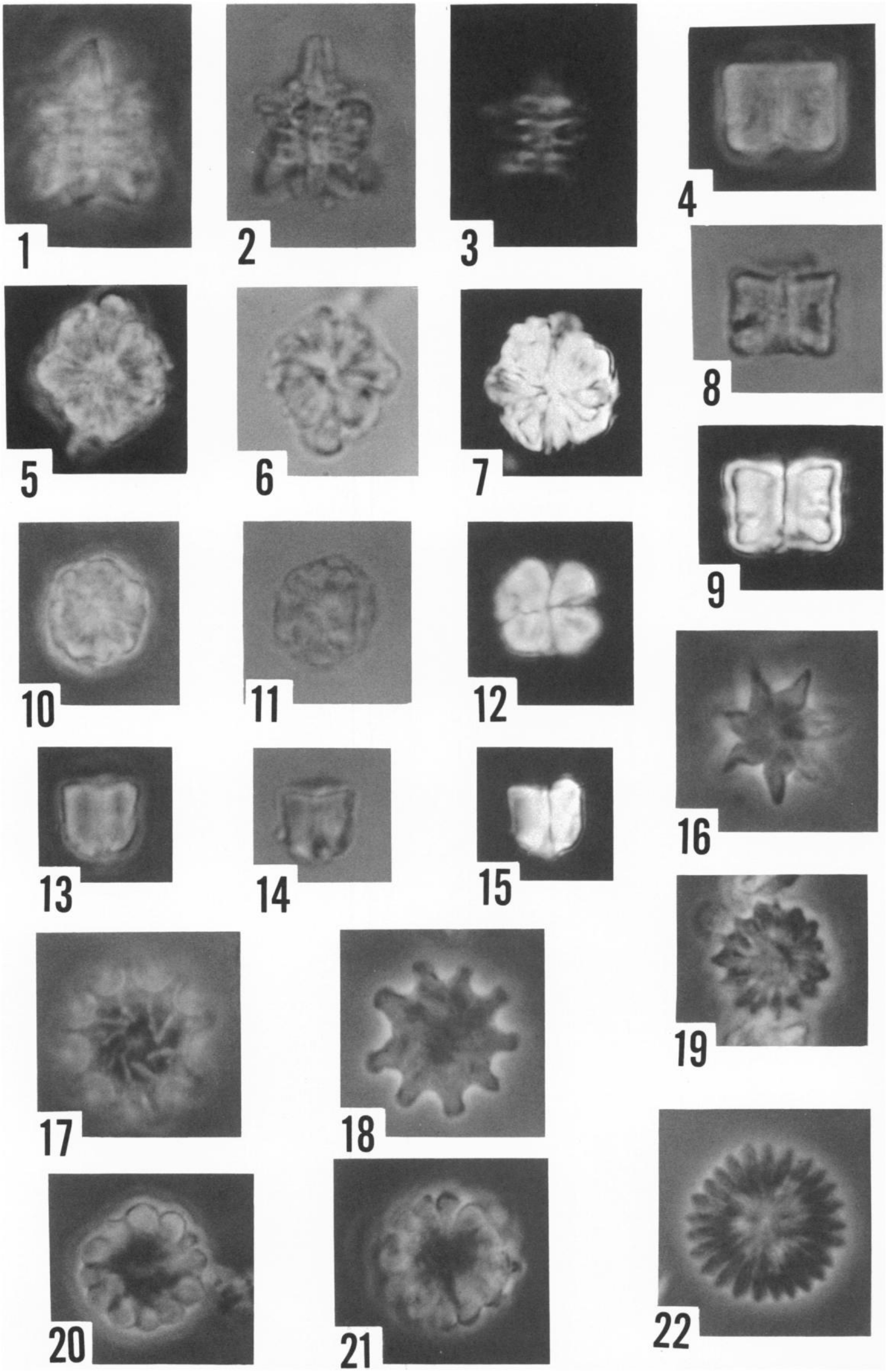

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right angles to the base of the cone, but those in the proximal shield form a very faint interference figure between crossed nicols.

The new generic name directs attention to the conical shape of members of this genus and their resemblance to *Coccolithus* in optical behaviour.

CONOCOCCOLITHUS MINUTUS n. sp.
Pl. 196, figs. 4–6; Pl. 197, figs. 1,11,13

Diagnosis.—A species of *Conococcolithus* having a subcircular outline, truncate conical cross section, a very small central depression, and 18 to 21 segments in each shield.

Description.—This species has a subcircular distal shield composed of 18 to 21 large wedge-shaped dextrally imbricate segments. The shield is strongly convex, producing a conical cross section. The very small, shallow central depression has no visible plates within it. Distally, the wedges of the distal shield may flare peripherally to form a rim about the central depression. The proximal shield projects slightly proximally from the distal shield in side view but has a slightly lesser diameter.

Remarks.—This new species is easily distinguished by its conical form and by the very small central depression. It evidently represents a highly specialized member of the subfamily Cyclococcolithoideae and probably has a shorter range than do most species in this subfamily.

The trivial name was selected to suggest the small size of the species.

Maximum diameter.—8μ.

Thickness.—5μ.

Holotype.—UI-H-2613 (Pl. 197, fig. 1).

Paratypes.—UI-H-2610–2612, 2729.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 837 (*Discoaster multiradiatus* Zone).

Occurrence.—*Conococcolithus minutus* is rare in the upper part of the *Discoaster multiradiatus* Zone.

Family PRINSIACEAE n. fam.

Diagnosis.—Oval, subcircular or circular placoliths; interference figure between crossed polarizers is dextrogyre in distal view.

Genus PRINSIUS n. gen.

Diagnosis.—Elliptical placoliths, with simple, solidly constructed distal shield; interference figure between crossed polarizers dextrogyre; proximal shield bright, distal shield somewhat fainter.

Type species.—*Coccolithus bisulcus* Stradner.

Remarks.—The new generic name honors B. Prins, Royal Dutch Shell Company, Netherlands.

PRINSIUS BISULCUS (Stradner)
Pl. 196, figs. 10–13; Pl. 197, fig. 6

Coccolithus bisulcus STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 72, Pl. 8, figs. 3–6, Text-fig. 3a,b.

Remarks.—This species is characterized by thin elliptical placoliths having two apparent

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EXPLANATION OF PLATE 204

Illustrations are of light micrographs, ×2250.

FIGS. *1–3,5–7*—*Fasciculithus schaubi* n. sp. *1–3*, Paratype, UI-H-2757, GAN 834, side views: *1*, phase contrast; *2*, ordinary transmitted light; *3*, between crossed nicols. *5–7*, Paratype, UI-H-2758, GAN 834, top views: *5*, phase contrast; *6*, ordinary transmitted light; *7*, between crossed nicols.

4,8,9—*Fasciculithus involutus* Bramlette & Sullivan. Hypotype, UI-H-2759, GAN 834, side views: *4*, phase contrast; *8*, ordinary transmitted light; *9*, between crossed nicols.

10–15—*Fasciculithus tympaniformis* Hay & Mohler. *10–12*, Hypotype, UI-H-2760, GAN 823, top views: *10*, phase contrast; *11*, ordinary transmitted light; *12*, between crossed nicols. *13–15*, Hypotype, UI-H-2761, GAN 823, side views: *13*, phase contrast; *14*, ordinary transmitted light; *15*, between crossed nicols.

16—*Discoaster nobilis* Martini. Hypotype, UI-H-2762, GAN 834, plan view, phase contrast.

17,18—*Discoaster mediosus* Bramlette & Sullivan. Hypotype, UI-H-2763, GAN 834, plan views: *17*, phase contrast, high focus; *18*, phase contrast, low focus.

19–21—*Discoaster gemmeus* Stradner. *19*, Hypotype, UI-H-2764, GAN 837, plan view, phase contrast. *20*, Hypotype, UI-H-2765, GAN 837, plan view, phase contrast. *21*, Hypotype, UI-H-2766, GAN 837, plan view, phase contrast.

22—*Discoaster multiradiatus* Bramlette & Riedel. Hypotype, UI-H-2767, GAN 834, plan view, phase contrast.

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furcae at the ends of the long axis of the ellipse in the central area. The central area appears to be minutely perforate in the light microscope.

Maximum diameter.—5–6μ.

Minimum diameter.—4.5–5μ.

Hypotypes.—UI-H-2732-2736.

Occurrence.—Originally described from zones A to E of the Oichinger Schichten, this species begins at Pont Labau in the middle part of the *Cruciplacolithus tenuis* Zone and ranges through the *Fasiculithus tympaniformis*, *Heliolithus kleinpelli*, and *Discoaster gemmeus* Zones and is found randomly and locally in the *Discoaster multiradiatus* Zone.

Genus ELLIPSOLITHUS Sullivan, 1964

ELLIPSOLITHUS DISTICHUS (Bramlette & Sullivan)

Pl. 201, figs. 1,2,4,5; Pl. 202, figs. 6–8

Coccolithites distichus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 152, Pl. 7, fig. 8a-c; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 76, Pl. 9, figs. 3,4.

Ellipsolithus distichus (Bramlette & Sullivan). SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 184, Pl. 5, figs. 4a,b, 5a-c, 6a,b;——, 1965, *ibid.*, v. 53, p. 35.

Remarks.—Electron microscopic investigation reveals that this species has a rim that is composed of 50 to 60 wedge-shaped segments imbricate dextrally in distal view. The central area is unique as it bears two rows having four perforations, each symmetrical about the long axis of the ellipse and about $\frac{1}{2}\mu$ in diameter. Dividing the two rows of pores in the longitudinal axis of the ellipse is a carina that rises to near the level of the upper surface of the rim.

Maximum diameter.—7–9μ.

Minimum diameter.—6–7μ.

Hypotypes.—UI-H-2682-2685, 2752.

Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from the Lodo Formation in California where it was recorded from the *Heliolithus riedeli*, *Discoaster multiradiatus*, and *Discoaster tribrachiatus* Zones. Stradner (1963) found this species in the Oichinger Schichten in Salzburg in Zone D. At Pont Labau, *Ellipsolithus distichus* has been encountered in the *Discoaster multiradiatus* Zone.

Genus TOWEIUS n. gen.

Diagnosis.—Circular to subcircular placoliths, having shields composed of nonimbricate to slightly imbricate petaloid or tapezoidal segments; central area displaying a reticulate grille; proximal shield bright, distal shield faintly illuminated between crossed polarizers.

Type species.—*Toweius craticulus* n. sp.

Remarks.—The new generic name honors K. M. Towe, U. S. National Museum, Washington, D. C.

TOWEIUS HELIANTHUS (Hay & Towe)

Pl. 197, fig. 8

Heliolithus helianthus HAY & TOWE, 1963 (1962), Eclogae Geol. Helvetiae, v. 55, no. 2, p. 506, Pl. 5, figs. 1–3.

Remarks.—*Toweius helianthus*, first described (Hay & Towe, 1963) as belonging to the genus *Heliolithus*, has on further examination been found to be a placolith. The characteristic feature is the ring of crescentic openings around the margin of the central area. Specimens that were found at Pont Labau resemble the types but are poorly preserved.

Diameter.—7–9μ.

Hypotype.—UI-H-2615.

Occurrence.—Originally described (Hay & Towe, 1963) from the Cuisian clays at Donzacq, rare specimens of this species have been found in the *Discoaster gemmeus* Zone at Pont Labau.

TOWEIUS CRATICULUS n. sp.

Pl. 196, figs. 7–9; Pl. 197, figs. 2,3

Diagnosis.—A species of *Toweius* having 8 to 20 large subcircular perforations in the central grille.

Description.—The distal shield is composed of 40 to 60 tabular segments which overlap slightly dextrally; the sutures between the segments have a slight clockwise inclination if seen in distal view; and the margin of the shield is distinctly serrate. The central area is complex and is surrounded distally by two cycles of dextrally imbricate wedge-shaped segments. The sutures of these cycles have a slight clockwise inclination out to the edge of the segments but turn sharply counterclockwise to descend. The grille spanning the central area has 8 to 20 perforations depending on the size of the coccolith. The proximal shield is composed of about the same number of segments as the distal shield but bears a series of intersegmental notches along the inner margin. Sutures of the proximal shield are inclined slightly clockwise in distal view, and the margin is smooth.

Remarks.—This species is highly distinctive and is readily differentiated from *T. helianthus* (Hay & Towe) by having relatively few perforations in the central area. This species is apparently a forerunner of the much larger and more complex species of *Reticulofenestra* Hay, Mohler & Wade of Eocene age.

The trivial name, meaning grille, refers to the perforate central area.

Maximum diameter.—3.5–8μ.

Minimum diameter.—3–7μ.

Holotype.—UI-H, 2617 (Pl. 197, fig. 2).

Paratypes.—UI-H-2618-2629, 2730.

Locus typicus.—Pont Labau.

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Stratum typicum.—GAN 834. (*Discoaster multiradiatus* Zone).

Occurrence.—This species ranges through the *Discoaster multiradiatus* Zone. It is also abundant in the lowermost sample [6+1 of Bramlette & Sullivan (1961)] from the Lodo Formation of California that is assigned to the *Heliolithus riedeli* Zone.

Genus ERICSONIA Black, 1964
ERICSONIA SUBPERTUSA n. sp.
Pl. 198, figs. 11,15,18; Pl. 199, figs. 1–3

Markalius inversus (Deflandre). BRAMLETTE & MARTINI, 1964, (part), Micropaleontology, v. 10, no. 3, p. 302, Pl. 7, fig. 2a,b.

Diagnosis.—Circular to subcircular species of *Ericsonia* having a large central opening and four cycles of 50 to 60 segments, each visible in distal view.

Description.—The complex distal shield is composed of four cycles of 50 to 60 segments in each cycle. The innermost pair of cycles produces the herringbone pattern that is characteristic of the genus; the third cycle has sutures which are almost radial; the outer cycle has sutures which are steeply inclined clockwise in distal view. The proximal shield is slightly more than half as wide as the distal shield, and sutures are inclined gently clockwise in proximal view. The central opening is about one third the diameter of the coccolith.

Remarks.—*Ericsonia subpertusa* resembles *E. alternans* Black in having four cycles of segments visible in distal view but has a markedly larger central opening than the latter species. *E. occidentalis* Black, the type species of the genus, has only three cycles visible in distal view. The stereoscopic pair of electron micrographs that were published by Bramlette & Martini (1964) shows more of the details of the proximal view of the new species. In order to see the pair as a proximal view with maximum relief, it is necessary to reproduce the illustrations, cut them apart, and reorient them as follows: 2a should be on the right, 2b on the left, and the pictures should be rotated 45° counterclockwise. a form illustrated by figures 7 and 8 on Plate 2 in Bramlette & Martini (1964) may also belong to *E. subpertusa*.

The trivial name suggests that the central opening in some specimens may appear plugged when viewed by the light microscope.

Diameter.—4–8μ.

Holotype.—UI-H-2657 (Pl. 198, fig. 18).

Paratypes.—UI-H-2658, 2659, 2743.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 834 (*Discoaster multiradiatus* Zone).

Occurrence.—At Pont Labau *Ericsonia subpertusa* ranges from the upper part of the *Cruciplacolithus tenuis* through the *Fasciculithus tympaniformis*, *Heliolithus kleinpelli*, and *Discoaster multiradiatus* Zones.

Genus CAMPYLOSPHAERA Kamptner, 1963
CAMPYLOSPHAERA DELA (Bramlette & Sullivan)
Pl. 198, fig. 14

Coccolithites delus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, nc. 2, p. 151–152, Pl. 7, figs. 1a-c,2a,b; SULLIVAN, 1964, California Univ. Pubs. Gecl. Sci., v. 44, no. 3, p. 180, Pl. 1, figs. 8,9; ——, 1965, *ibid.*, v. 53, p. 31.

Remarks.—This species is distinguished by a cross in the central area and by the strongly inward curved ends of the subquadrate placolith.

Maximum diameter.—6μ.

Minimum diameter.—5μ.

Hypotype.—UI-H-2639.

Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from the Lodo Formation in California, where it appears in the *Discoaster multiradiatus* Zone and ranges through the whole section. *Campylosphaera dela* is encountered rarely in the upper part of the *Discoaster miltiradiatus* Zone at Pont Labau.

Family HELIOLITHACEAE n. fam.

Diagnosis.—Coccoliths composed of two abbuting shields lacking a connecting tube; one shield having subradial sutures, producing a strong interference pattern between crossed polarizers; the other shield somewhat smaller, showing steeply inclined sutures and strongly imbricate segments.

Genus HELIOLITHUS Bramlette & Sullivan, 1961
HELIOLITHUS KLEINPELLI Sullivan
Pl. 199, figs. 4–7; Pl. 200, figs. 1–4

Heliolithus kleinpelli SULLIVAN, 1964, California Univ., Pubs. Geol. Sci., v. 44, no. 3, p. 193, Pl. 12, fig. 5a,b.

Remarks.—This species possesses two closely appressed shields; the larger is probably distal, although the specimens are nearly discoidal in side view. The larger shield consists of about 50 segments which are sinistrally imbricate if viewed from the side bearing the smaller shield. The smaller shield consists of many wedges which are strongly imbricate dextrally and produce a characteristic pattern of rotation of the sutures as the lens of the light microscope is raised or lowered. The same effect can be observed in specimens of *Heliolithus riedeli* Bramlette & Sullivan, but the rotation is not so pronounced. *H. kleinpelli* is nearly discoidal and very thin in side view, and in viscous mounts cannot be confused with the double cone of *Heliolithus riedeli*. In plan view, the two species are not so

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easily distinguished, but *H. kleinpelli* is larger, has more rays, and its fringes have a higher order interference color if viewed in polarized light, so that a good first order yellow is reached in large specimens.

Diameter.—9 to 16μ

Hypotypes.—UI-H-2664, 2665, 2744.

Occurrence.—*Heliolithus kleinpelli* was originally described (Sullivan, 1964) from California, but its range could not be accurately determined there because of its limited occurrence in a few isolated outcrops in which good stratigraphic control was lacking. In the section at Pont Labau, this species is restricted to a zone immediately below the appearance of the first discoasters.

Family ZYGODISCACEAE n. fam.

Diagnosis.—Coccoliths consisting of an elliptical ring composed of strongly imbricate laths or tabulae and an open central area spanned by an I-, X-, or H-shaped structure symmetrical about the short axis of the ellipse. Rim dextrogyre in distal view between crossed polarizers.

Genus ZYGODISCUS Bramlette & Sullivan, 1961

ZYGODISCUS ADAMAS Bramlette & Sullivan

Pl. 198, figs. 3,4,7; Pl. 199, figs. 8–10

Zygodiscus adamas BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 148, Pl. 4, figs. 9a-c,10a-c; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 76–77, Pl. 9, figs. 13,14; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 186, Pl. 6, figs. 4a,b,5a,b,6a,b; ——, 1965, *ibid.*, v. 53, p. 37.

Remarks.—Electron microscopic study reveals that the rim of this species is constructed in the manner typical for syracosphaerids. It is composed of 150 to 200 small imbricate laths that are inclined at an angle in excess of 60° to a radius of the ellipse. The bar spanning the central opening in the minor axis of the ellipse is also constructed of long thin laths. Appearance in the light microscope suggests that these are arranged into four groups that have different optical orientation, dividing the bar into four quadrants.

Maximum diameter.—6μ–11μ.

Minimum diameter.—4.5μ–7.5μ.

Hypotypes.—UI-H-2661–2663, 2745.

Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from California, where it was found in the *Discoaster multiradiatus* Zone and in the base of the *Discoaster tribrachiatus* Zone in the Lodo Formation. Sullivan (1964) has extended its range in California down into the *Heliolithus riedeli* Zone. Stradner (1963) has recorded this species from the entire sequence of the Oichinger Schichten of Salzburg (Zones A-D) and from the *Discoaster multiradiatus* Zone. At Pont Labau *Z. adamas* is found in the *Fasciculithus tympaniformis*, *Discoaster gemmeus*, and *Discoaster multiradiatus* Zones.

ZYGODISCUS SIGMOIDES Bramlette & Sullivan

Pl. 199, figs. 12–14

Zygodiscus sigmoides BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 149, Pl. 4, fig. 11a-e; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 187, Pl. 5, fig. 7a–c; BRAMLETTE & MARTINI, 1964, Micropaleontology, v. 10, no. 3, p. 303, Pl. 4, figs. 4,5; SULLIVAN, 1965, California Univ. Pubs. Geol. Sci., v. 53, p. 38, Pl. 6, figs. 8a,b, 9a,b.

Remarks.—No electron micrographs are available of this species, which is rare at Pont Labau. Light micrographs agree closely with the figure of the holotype. Bramlette & Martini (1964) placed *Z. simplex* in synonymy with this species and suggested that the two forms may be dimorphic coccoliths of a single species. This relation is somewhat speculative as the two forms do not consistently occur together. The two species are considered distinct here.

Maximum diameter.—7μ.

Minimum diameter.—6μ.

Hypotype.—UI-H-2746.

Occurrence.—*Z. sigmoides* was originally described (Bramlette & Sullivan, 1961) from the *Heliolithus riedeli* and *Discoaster multiradiatus* Zones of the Lodo Formation of California. It has been reported by Bramlette & Martini (1964) from the type section of the Danian and from Danian strata in France, Tunisia, and Alabama, as well as from higher Paleocene rocks. At Pont Labau, this species is extremely rare but is found in the *Fasciculithus tympaniformis*, *Heliolithus kleinpelli*, *Discoaster gemmeus*, and *Discoaster multiradiatus* Zones.

ZYGODISCUS SIMPLEX (Bramlette & Sullivan)

Pl. 199, figs. 11,15,22; Pl. 200, figs. 2,3,5,6; Pl. 201, fig. 3

Zygrhablithus simplex BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 151, Pl. 6, figs. 19,29a,b,21,22; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 187, Pl. 7, fig. 11; ——, 1965, *ibid.*, v. 53, p. 39.

Zygodiscus sigmoides Bramlette & Sullivan (part). BRAMLETTE & MARTINI, 1964, Micropaleontology, v. 10, no. 3, p. 303, Pl. 4, fig. 3.

Remarks.—As noted above, Bramlette & Martini (1964) considered this form to represent a dimorphic coccolith of *Z. sigmoides*. In order to be as objective as possible, however, we consider it a distinct species. The only way in which the hypothesis of Bramlette & Martini can be proved is to find a fossil coccosphere having both kinds of coccoliths together, which has not yet been done.

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The elements composing the rim of this species are much broader than those of *Z. adamas*. In proximal view the rim consists of about 40 segments having a strong dextral imbrication. The sutures are strongly inclined clockwise as they ascend the edge of the central opening and thence angle sharply onto the surface of the rim; on the surface they are straight and inclined moderately counterclockwise. In distal view, the rim is edged with a cycle of 60 to 68 elongate laths which are sinistrally imbricate and strongly inclined clockwise. The stem arises as a V-shaped structure, with each limb attached to the rim in the minor axis of the ellipse. The angle between the two limbs is about 90°. They fuse 1 to 2μ above the disc to form a single straight stem that is perpendicular to the plane of the disc. Each limb and the stem proper is composed of elongate narrow laths. In distal view these can be seen to have a spiral arrangement.

Maximum diameter.—8–12μ.

Minimum diameter.—6–9μ.

Height.—15μ.

Hypotypes.—UI-H-2666-2670, 2747.

Occurrence.—Originally described (Bramlette & Sullivan, 1961) from the *Heliolithus riedeli* and *Discoaster multiradiatus* Zones of the Lodo Formation in California. Bramlette & Martini (1964) have figured a specimen from the Clayton Formation of Alabama. At Pont Labau, this species is found randomly and locally through the *Cruciplacolithus tenuis*, *Fasciculithus tympaniformis*, *Heliolithus kleinpelli*, *Discoaster gemmeus*, and *Discoaster multiradiatus* Zones.

Genus HELIORTHUS Brönnimann & Stradner, 1960

Diagnosis.—An elliptical ring having an X-shaped structure spanning the central opening.

Type Species.—*Heliorthus fallax* Brönnimann & Stradner, 1960.

Remarks.—The taxon *Zygolithus* Matthes has generally been used for calcareous nannofossils that conform to the description of this genus. Maslov (1963), however, designated *Zygolithus dubius* Deflandre as type species of *Zygolithus*. *Zygolithus dubius* Deflandre, 1954, is a junior synonym of *Neococcolithes lososnensis* Sujkowski, 1931, and the central structure in *Neococcolithes lososnensis* (=*Zygolithus dubius*) is not X-shaped, but the two sides of the X are separated by a bar in the long axis of the ellipse.

HELIORTHUS CONCINNUS (Martini)
Pl. 199, figs. 16–18; Pl. 201, figs. 6–7,10

Zygolithus concinnus MARTINI, 1961, Senckenbergiana Lethaea, v. 42, no. 1–2, p. 18, Pl. 3, fig. 35, Pl. 5, fig. 54; BRAMLETTE & MARTINI, 1964, Micropaleontology, v. 10, no. 3, p. 304, Pl. 4, figs. 13,14, Pl. 7, fig. 3a,b; SULLIVAN, 1965, California Univ. Pubs. Geol. Sci., v. 53, p. 38.

Zygolithus chiastus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 149, Pl. 6, figs. 1a-d,2a,b,3a,b; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, Pl. 10, figs. 1–3; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 187, Pl. 7, fig. 12.

Remarks.—Electron microscopic investigation reveals that the rim of this species is constructed of strongly imbricate triangular segments. These are arranged in such a way that the flat side of the triangle is visible on the proximal surface of the rim, but the ridgelike distal surface is made of the imbricate tips of the triangular segments. The details of the X-shaped central structure are obscure, but it is apparently composed of laths.

Maximum diameter.—6–7μ.

Minimum diameter.—4.5–5μ.

Hypotypes.—UI-H-2671-2673, 2748.

Occurrence.—Originally described (Martini, 1961) from the late Paleocene of southwestern France, this species has also been found in California, where it ranges through the *Heliolithus riedeli*, *Discoaster multiradiatus*, and *Discoaster tribrachiatus* Zones. Stradner (1963) has found it to range through the Oichinger Schichten of Salzburg (Zones A, B, C, D) into the *Discoaster multiradiatus* Zone. At Pont Labau this species first appears in the *Fasciculithus tympaniformis* Zone; is rare in the *Heliolithus kleinpelli* Zone; becomes common again at the top of the *Discoaster gemmeus* Zone; and remains common through the *Discoaster multiradiatus* Zone.

HELIORTHUS JUNCTUS (Bramlette & Sullivan)

Zygolithus junctus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 150, Pl. 6, fig. 11a,b; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 187, Pl. 7, fig. 15; ——, 1965, *ibid.*, v. 53, p. 38.

Remarks.—This species is distinguished by having a very narrow central X.

Occurrence.—Originally described (Bramlette & Sullivan, 1961) from the *Heliolithus riedeli* Zone of the Lodo Formation in California, this species is found sporadically in the *Discoaster multiradiatus* Zone.

Genus NEOCOCCOLITHES Sujkowski, 1931

NEOCOCCOLITHES PROTENUS (Bramlette & Sullivan)
Pl. 199, figs. 19–21; Pl. 201, fig. 9

Zygolithus protenus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 150, Pl. 6, fig. 15a,b.

Chiphragmalithus protenus (Bramlette & Sullivan). SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 179, Pl. 1, fig. 1; ——, 1965, *ibid.*, v. 53, p. 30.

Remarks.—The construction of the rim is similar to that of *Heliorthus*. The X-shaped

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central structure is composed of broad laths. Sullivan (1964, 1965) placed this species in the genus *Chiphragmalithus* because of the similarity of the rim in polarized and transmitted light. *Chiphragmalithus*, however, has a very high rim, and may prove to have a different structure. *Neococcolithes protenus* evidently evolved into *N. lososnensis* Sujkowski.

Maximum diameter.—6μ.

Minimum diameter.—4.5μ.

Hypotypes.—UI-H-2674, 2749.

Occurrence.—*Neococcolithes protenus* was first described (Bramlette & Sullivan, 1961) from the Lodo Formation of California, where it was found in the *Discoaster multiradiatus* Zone. At Pont Labau it also is restricted to the *Discoaster multiradiatus* Zone.

Family CALCIOSOLENLIACEAE Kamptner, 1937
Genus SCAPHOLITHUS Deflandre, 1954
SCAPHOLITHUS APERTUS n. sp.
Pl. 201, figs. 11,12,14

Diagnosis.—A species of *Scapholithus* having a central solid rod extending almost to the ends of the scapholith.

Description.—The scapholiths have a rhomboidal rim which is asymmetrical about the long axis. About 12 thin laths extend from the rim to the center, which is occupied by a rod proceding almost from one end of the central opening to the other.

Remarks.—This species is distinctive when studied in the electron microscope, but the characteristic features are so small that it is extremely difficult to distinguish it from other scapholiths in the light microscope.

The trivial name suggests the relatively open structure of the scapholith.

Length.—4.5μ.

Width.—2μ–2.5μ.

Holotype.—UI-H-2675 (Pl. 201, fig. 12).

Paratypes.—UI-H-2676, 2677.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 834 (*Discoaster multiradiatus* Zone).

Occurrence.—This species is found only at level 834 at Pont Labau (*Discoaster multiradiatus* Zone).

SCAPHOLITHUS RHOMBIFORMIS n. sp.
Pl. 201, figs. 13,16–18

Diagnosis.—A species of *Scapholithus* having thick boxlike rhomboidal scapholiths.

Description.—The rim of the scapholith is composed of fused rhombs and is thickened on one side. The rim forms a boxlike frame. The concave central area has 16 to 18 laths extending out from the thickened rim to join along a line of concresence in the longitudinal axis. The laths coming from opposite sides of the scapholith are slightly offset (that is, of the "alternans" type). Between the laths, narrow slits perforate the scapholith.

Remarks.—Although distinctive when studied in the electron microscope, the scapholiths are too small to be determined in the light microscope.

The trivial name refers to the rhomboidal outline of the scapholith.

Length.—6μ.

Width.—3μ.

Holotype.—UI-H-2680 (Pl. 201, fig. 17).

Paratypes.—UI-H-2678, 2679, 2681.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 827 (*Discoaster multiradiatus* Zone).

Occurrence.—This species is found only at level 827 at Pont Labau (*Discoaster multiradiatus* Zone).

Order ORTHOLITHAE Deflandre, 1952
Family THORACOSPHAERACEAE Schiller, 1930
Genus THORACOSPHAERA Kamptner, 1927
THORACOSPHAERA SAXEA Stradner
Pl. 203, fig. 5

Thoracosphaera saxea STRADNER, 1961, Erdöl-Zeitschr. für Bohr-u. Fördertechnik, v. 77, no. 3, Pl. 84, text-fig. 71; ——, *in* GOHRBANDT, 1963, Sixth World Petroleum Cong., Sec. 1, Paper 4, p. 9, Pl. 3, fig. 3; ——, 1963a, Geol. Gesell. Wien, Mitt. v. 56. no. 1, p. 78, Pl. 10, fig. 8.

Remarks.—This species is characterized by the irregular elements which form a "jigsaw" pattern. Electron microscopic investigation shows that the elements are highly irregular and indicates that the surface of the sphere is rugose.

Hypotype.—UI-H-2688.

Occurrence.—Found throughout the section at Pont Labau, this species, as well as the other nominal species of *Thoracosphaera*, has little straigraphic value.

THORACOSPHAERA DEFLANDREI Kamptner
Pl. 203, fig. 8

Thoracosphaera deflandrei KAMPTNER, 1956, Österr. Bot. Zeitschr., v. 103, no. 4, p. 448–456,Text-figs. 1–4; STRADNER, 1961, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 77, no. 3, p. 84, Text-fig. 74; ——, 1963, Sixth World Petroleum Cong., Sec. 1, Paper 4, p. 9, Pl. 3, fig, 2; ——, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 78, Pl. 10, figs. 9,10.

Remarks.—Electron microscopic investigation supports the observations on the structure of this species that were made by Kamptner (1956). The coccosphere is composed of numerous polygonal elements that have raised centers and depressed sutures. No perforations are visible.

Diameter.—25μ.

Hypotype.—UI-H-2689.

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Occurrence.—This species is found throughout the section at Pont Labau and ranges through the Paleocene and Eocene.

Family BRAARUDOSPHAERACEAE Deflandre, 1947
Genus BRAARUDOSPHAERA Deflandre, 1947
BAARUDOSPHAERA BIGELOWI (Gran & Braarud)
Pl. 202, figs. 12, 16, 20

Pontosphaera bigelowi GRAN & BRAARUD, 1935, Biol. Board Canada, Jour., v. 1, p. 338, Fig. 67
Braarudosphaera bigelowi (Gran & Braarud). DEFLANDRE, 1947, Acad. Sci. Paris, Compte Rendu, v. 225, p. 439, Text-figs. 1–5; KAMPTNER, 1952, Mikroskopie, v. 7, no. 7–8, p. 236, Text-fig. 15a,b; DEFLANDRE, 1954, Ann. Paléontologie, v. 40, p. 51, Pl. 10, figs. 8–12, Pl. 13, figs. 7–9; KAMPTNER, 1954, Archiv für Protistenkunde, v. 100, no. 1, p. 46, Text-figs. 46,47; BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, no. 4, p. 393–394, Pl. 38, fig. 6a,b; GARDET, 1955, Pub. Service Carte Géol. Algérie, Bull. 5, p. 520, Pl. 7, figs. 64,65a,b; MARTINI, 1958, Senckenbergiana Lethaea, v. 39, no. 5–6, p. 355, Pl. 2, fig. 6a,b; MANIVIT, Lab. Géologie Appliquée Algér, Pub., ser. 2, Bull. 25, p. 24, Pl. 4, fig. 1; STRADNER, 1959, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 75, no. 12, p. 482, Text-figs. 63,64,68: MARTINI, 1960, Umschau Fortschr. Wiss. u. Technik, no. 13, p. 396, Text-fig. 9; ——, 1960, Hess. Landesamt Bodenf., Notizbl, v. 88, p. 73, Pl. 8, fig. 1; ——, 1960, Photographie u. Wiss., v. 9, p. 31, Text-figs. 1–3; STRADNER, 1960, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 76, no. 12, p. 430, Text-fig. 1; BÁLDI-BEKE, Földrajzi Kozlemények, v. 90, no. 2, Pl. 14, fig. 8; ——, 1961, Magyar Állami Földtani Intézet, Évi Jelentese, no. 1, Pl. 2, fig. 3; BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 153, Pl. 8, figs. 1a,b,2–5; MARTINI, 1961, Natur u. Volk, v. 91, p. 335–339, Text-figs. 1–6; STRADNER, *in* STRADNER & PAPP, 1961, Wien Geol. Bundesanstalt, Jahrb., Sdrbd. 7, p. 116–117, Pl. 37, figs. 1–3, Text-fig; 12/1; HAY & TOWE, 1962, Science, v. 137, no. 3528, p. 427, Text-fig. 1; BENEŠOVÁ & HANZLÍKOVÁ, 1964, Věst. Ustřed. Úst. Geol., v. 37, no. 2, Pl. 3, fig. 19; STRADNER *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt. v. 56, no. 1, p. 78, Pl. 10, figs. 6,7; BRÖNNIMANN & RIGASSI, 1963, Eclogae Geol. Helvetiae, v. 56, no. 1, Pl. 14, fig. 2a,b; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 188, Pl. 8, fig. 1a,b; BRAMLETTE & MARTINI (part), 1964, Micropaleontology, v. 10, no. 3, p. 305; SULLIVAN, 1965, California Univ. Pubs. Geol. Sci., v. 53, p. 39.

Remarks.—This well-known species, having regular pentaliths, has a long range, extending from the base of the Tertiary to the Recent. At the Cretaceous—Tertiary boundary, it replaces *Braarudosphaera imbricata* Manivit (Pl. 202, figs. 9–11) which ranges through most of the Cretaceous.

Diameter.—9μ.

Hypotype.—UI-H-2754.

Occurrence.—Reported from Paleocene and lower and middle Eocene strata from many parts of the world, this species is found sporadically throughout the section at Pont Labau but is most common in the *Markalius astroporus* and *Cruciplacolithus tenuis* Zones.

BAARUDOSPHAERA DISCULA Bramlette & Riedel
Pl. 202, figs. 13–15

Braarudosphaera discula BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, no. 4, p. 394, Pl. 38, fig. 7; —— & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 153, Pl. 8, figs. 6a,b,7; STRADNER, *in* STRADNER & PAPP, 1961, Wien Geol. Bundesanstalt, Jahrb., Sdrbd. 7, p. 117, Text-fig. 12/3; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 188, Pl. 8, fig. 2a,b; ——, 1965, *ibid.*, v. 53, p. 39, Pl. 8, figs. 1a,b,3a,b.

Remarks.—This species is distinguished from *B. bigelowi* by its rounded outline.

Diameter.—9μ.

Hypotype.—UI-H-2755.

Occurrence.—Reported from Paleocene and lower and middle Eocene strata from many parts of the world, this species is found sporadically throughout the section at Pont Labau but is most common in the *Markalius astroporus* and *Cruciplacolithus tenuis* Zones.

Genus MICRANTHOLITHUS Deflandre, 1950
MICRANTHOLITHUS BRAMLETTEI Deflandre

Micrantholithus bramlettei DEFLANDRE, 1954, Ann. Paléontologie, v. 40, p. 167, Pl. 13, fig. 22, Text-fig. 117; MARTINI, 1961, Senckenbergiana Lethaea, v. 42, no. 1–2, p. 6, Pl. 1, fig. 12; BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 154, Pl. 9, fig. 2a,b. SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 188, Pl. 8, fig. 3a,b.

Remarks.—This species is distinguished by ribs adjacent to the sutures, producing a trilobate periphery for each segment of the pentalith.

Occurrence.—This species was found in the Lodo Formation of California (Bramlette & Sullivan, 1961) in the *Discoaster multiradiatus* and *Discoaster tribrachiatus* Zones. It is very rare at Pont Labau but has been found in the very top of the *Discoaster multiradiatus* Zone.

MICRANTHOLITHUS sp.
Pl. 202, figs. 17–19

Remarks.—Some nondescript, rare, and poorly developed specimens of *Micrantholithus* have been seen.

Diameter.—10μ.

Hypotype.—UI-H-2756.

Occurrence.—Isolated specimens are found at Pont Labau throughout the section.

Genus BIANTHOLITHUS Bramlette & Martini, 1964
BIANTHOLITHUS SPARSUS Bramlette & Martini

Biantholithus sparsus BRAMLETTE & MARTINI, 1964. Micropaleontology, v. 10, no. 3, p. 305, Pl. 4, figs. 21–24.

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Remarks.—This species has not yet been observed by using the electron microscope but has been encountered in the light microscope. The specimens from Pont Labau agree with the published photomicrographs.

Occurrence.—This species was originally recorded (Bramlette & Martini, 1964) as sparsely present in type Danian strata and in southwestern France and Alabama. It is rare in the *Markalius astroporus* Zone at Pont Labau and is found (probably reworked) randomly and locally at higher levels.

Family GONIOLITHACEAE Deflandre, 1957
Genus GONIOLITHUS Deflandre, 1957
GONIOLITHUS cf. G. FLUCKIGERI Deflandre
Pl. 202, figs. 4,5

Remarks.—Pentaliths showing no obvious sutures and which are heliolithid between crossed nicols are apparently related to *Goniolithus fluckigeri*.

Diameter.—7μ.

Hypotype.—UI-H-2751.

Occurrence.—*Goniolithus fluckigeri* was originally described from the Oligocene and has been reported in strata of late Eocene age. Pentaliths of this type are rare in sample GAN 781 (*Cruciplacolithus tenuis* Zone).

Family FASCICULITHACEAE n. fam.

Diagnosis.—Subcylindrical calcareous nannofossils composed of wedge-shaped segments having their thin edges meeting at the center; one end of the cylinder is concave, the other pointed or flat; surface may be highly ornamented; interference figure in side view between crossed polarizers showing a dark line in the axis of the cylinder, but extinction of the sides is incomplete; an interference cross can be observed in end view.

Genus FASCICULITHUS Bramlette & Sullivan, 1961
FASCICULITHUS SCHAUBI n. sp.
Pl. 203, figs. 2,4,7,10; Pl. 204, figs. 1–3,5–7

Diagnosis.—A species of *Fasciculithus* having a complex prismatic base surmounted by a pyramid only half the height of the base.

Description.—The base is roughly prismatic, having six concave sides bearing vertical rows of pits, each row having four pits. Between the pits are ridges, and between the rows of pits are ribs forming the edges of the prism. The pyramid surmounting the base is smooth but stubby and only about half the height of the base. The surface of the base opposite the pyramid is slightly concave.

Remarks.—This species is readily distinguished from *Sphenolithus radians* Deflandre by the stubby pyramid and its appearance between crossed polarizers. It resembles *F. involutus* Bramlette & Sullivan in the sculpture of the base, but the latter lacks the pyramid.

The trivial name honors H. Schaub, Naturhistorisches Museum, Basel, Switzerland.

Height.—7–10μ.

Diameter.—5–8μ.

Holotype.—UI-H-2690 (Pl. 203, fig. 10).

Paratypes.—UI-H-2691–2693, 2757, 2758.

Locus typicus.—Pont Labau.

Stratum typicum.—GAN 834 (*Discoaster multiradiatus* Zone)

Occurrence.—This species is restricted to the *Discoaster multiradiatus* Zone.

EXPLANATION OF PLATE 205

Illustrations are of electron micrographs of carbon replicas, ×4500.

FIGS. *1–3*—*Discoaster gemmeus* Stradner. *1*, Hypotype, UI-H-2704, GAN 822, oblique view of facies inferior. *2*, Hypotype, UI-H-2705, GAN 822, facies inferior. *3*, Hypotype, UI-H-2706, GAN 822, oblique view of facies inferior.

4,5,7,8—*Fasciculithus tympaniformis* Hay & Mohler. *4*, Hypotype, UI-H-2701, GAN 795, side view. *5*, Hypotype, UI-H-2700, GAN 822, oblique side view. *7*, Hypotype, UI-H-2699, GAN 822, oblique side view. *8*, Holotype, UI-H-2698, GAN 822, oblique side view.

6,9—*Discoaster nobilis* Martini. *6*, Hypotype, UI-H-2702, GAN 822, facies laevogyre. *9*, Hypotype, UI-H-2703, GAN 827, facies laevogyre.

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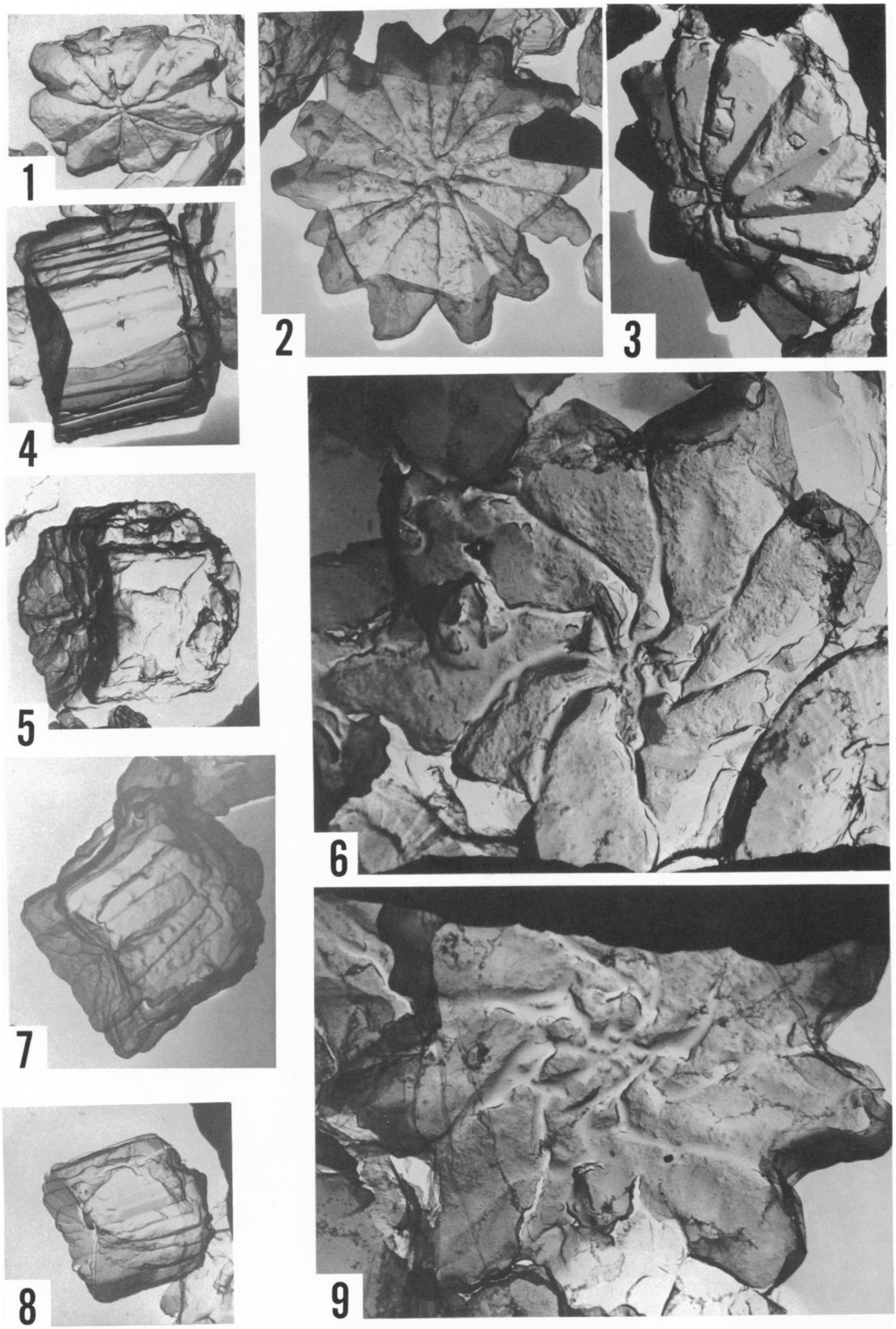

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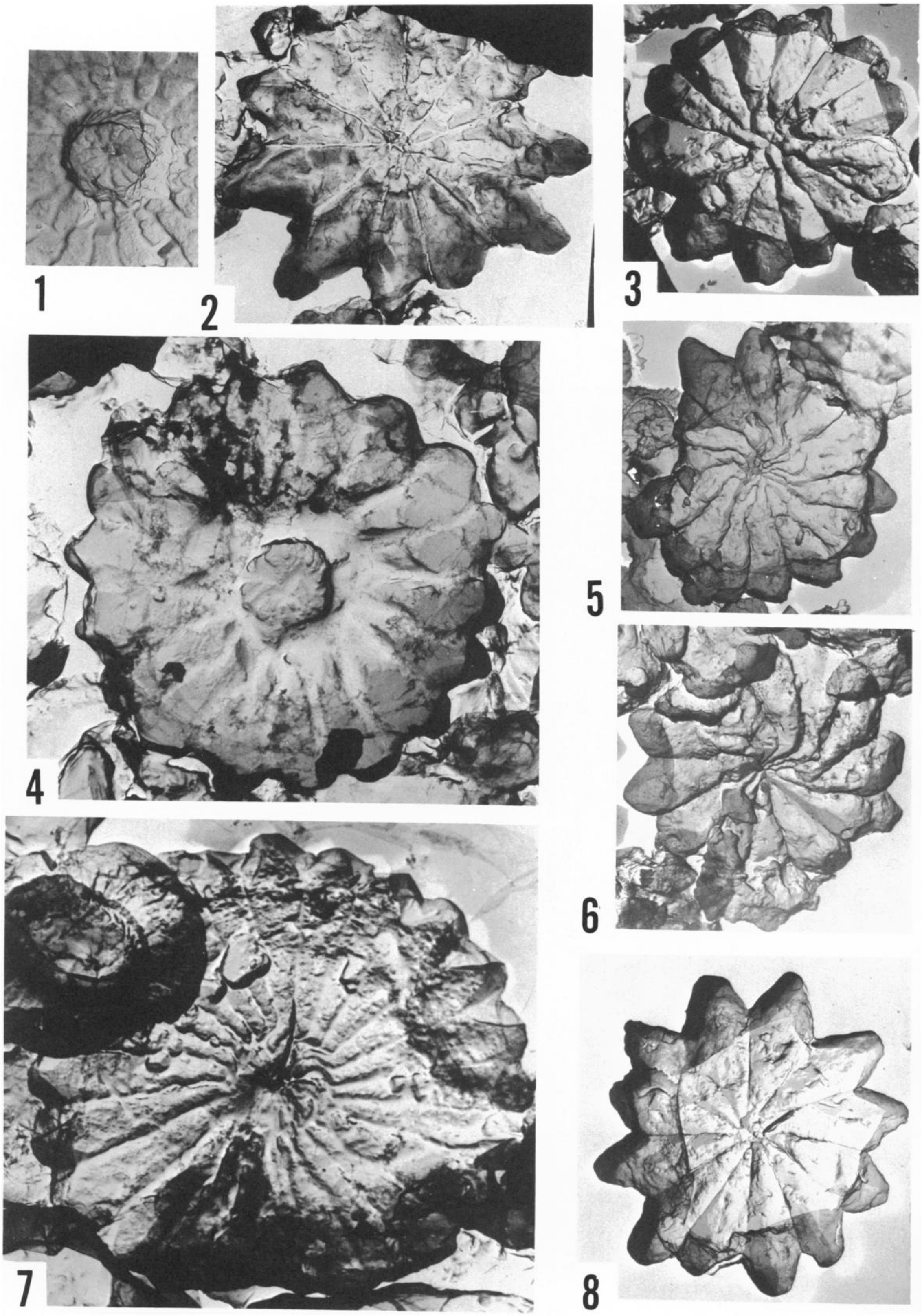

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FASCICULITHUS INVOLUTUS Bramlette & Sullivan

Pl. 203, figs. 1,3,6,9; Pl. 204, figs. 4,8,9

Fasciculithus involutus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 164, Pl. 14, figs. 1a-c,2a,b,3a,b,4a,b,5a,b; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 79, Pl. 10, figs. 14,15; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 193, Pl. 12, fig. 9a,b; ——, 1965, *ibid.*, v. 53, p. 44.

Remarks.—The structure of this species is very difficult to understand if only light micrographs are available. Bramlette & Sullivan (1961) described these forms as "of short cylindrical shape, appearing as a bundle of short rods with two or three encircling bands suggestive of a much shortened fascis." Electron micrographs reveal that these fossils are short polygonal prisms having one end slightly pointed and the other end concave. The center of the pointed end is formed by a hexagonal plug, and from the corners of this plug ribs radiate out to the corners of the prism. The ribs extend down the sides of the prism, where they may be joined by as many as six additional ribs. The spaces between the ribs are deeply notched, and the notches are arranged in circlets around the prism. The concave end has not been clearly observed but appears to be smooth.

Diameter.—5–8μ.

Height.—5μ.

Hypotypes.—UI-H-2694–2697, 2759.

Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from the Lodo Formation of California, where it was found commonly in the *Discoaster tribrachiatus* Zone. In Austria, Stradner (1963) has found this species to range from Zone D of the Oichinger Schichten upward through the Zones E and F (that is, the *Heliolithus riedeli*, *Discoaster multiradiatus*, and *Marthasterites tribrachiatus* Zones). At Pont Labau *Fasciculithus involutus* is common throughout the *Discoaster multiradiatus* Zone.

FASCICULITHUS TYMPANIFORMIS Hay & Mohler

Pl. 204, figs. 10–15; Pl. 205, figs. 4,5,7,8

Fasciculithus tympaniformis MAY & MOHLER, in press*, Gulf Coast Assoc. Geol. Soc., Trans.

Description.—A short subcylindrical object having one end slightly pointed and the other end concave. The cylinder is constructed of about 16 wedges; these are arranged so that their thin edges meet in the center, and the thick ends form the outer surface of the cylinder. The surface of the cylinder is smooth.

Remarks.—This species is readily distinguished from *F. involutus* in lacking the sculpture that is characteristic of that species.

Diameter.—5–7μ.

Height.—5–6μ.

Hypotypes.—UI-H-2699–2701, 2760, 2761.

Occurrence.—This species is found commonly throughout the *Fasciulithus tympaniformis*, *Heliolithus kleinpelli*, and *Discoaster gemmeus* Zones at Pont Labau. This species apparently has a relatively narrow stratigraphic range and is a good index fossil.

Family DISCOASTERACEAE Tan Sin Hok, 1927

Genus DISCOASTER Tan Sin Hok, 1927

DISCOASTER aff. D. ASTER Bramlette & Riedel

Remarks.—Specimens resembling *Discoaster aster* Bramlette & Riedel have been encountered.

* This paper will be distributed late in October 1967.

EXPLANATION OF PLATE 206

Illustrations are of electron micrographs of carbon replicas, ×4500.

FIGS. *1,4,7*—*Discoaster multiradiatus* Bramlette & Riedel. *1*, Hypotype, UI-H-2714, GAN 827, showing detail of stem. *4*, Hypotype, UI-H-2713, GAN 827, facies inferior. *7*, Hypotype, UI-H-2712, GAN 837, facies superior.

2—*Discoaster mediosus* Bramlette & Martini. Hypotype, UI-H-2711, GAN 827, plan view.

3,5,6,8—*Discoaster gemmeus* Stradner. *3*, Hypotype, UI-H-2707, GAN 822, facies inferior. *5*, Hypotype, UI-H-2708, GAN 822, facies superior. *6*, Hypotype, UI-H-2709, GAN 822, facies superior, *8*, Hypotype, UI-H-2710, GAN 822, facies inferior.

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They are nondescript forms having short, bluntly terminated arms.

Occurrence.—The specimens were found at Pont Labau in the upper part of the *Discoaster gemmeus* Zone.

DISCOASTER BINODOSUS Martini, 1958

Discoaster binodosus MARTINI, 1958, Senckenbergiana Lethaea, v. 39, no. 5–6, p. 361, Pl. 4, fig. 18b; STRADNER, 1959, Fifth World Petroleum Cong., Sec. 1, Paper 60, p. 1085, Text-figs. 18,19; MARTINI, 1961, Senckenbergiana Lethaea, v. 42, no. 1–2, p. 12, Pl. 3, fig. 25; BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 158, Pl. 11, fig. 1a,b; STRADNER, *in* STRADNER & PAPP, 1961, Wien Geol. Bundesanstalt, Jahrb., Sdrbd. 7, p. 66, Pl. 4, figs. 1–7, Pl. 5, figs. 1–6, Text-fig. 8/4; BENEŠOVÁ & HANZLÍKOVÁ, 1962, Věst. Ustřed. Úst. Geol., v. 37, p. 125, Pl. 4, fig. 20; STRADNER, 1962, Wien Geol. Bundesanstalt, Verh., no. 2, p. 181, Pl. 1, figs. 1–6; BRÖNNIMANN & RIGASSI, 1963, Eclogae geol. Helvetiae, v. 56, no. 1, Pl. 12, fig. 1a,b; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 79, Pl. 11, figs. 1–3; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 189, Pl. 11, fig. 5; ——, *ibid*., v. 53, p. 41.

Remarks.—This discoaster is distinguished by having six to eight separated rays having pointed terminations that are flanked by two lateral nodes.

Occurrence.—Originally described (Martini, 1958) from the late Eocene of northwest Germany, this species is found rarely in the lower part of the *Discoaster multiradiatus* Zone at Pont Labau. Bramlette & Sullivan (1961) reported it from the *Discoaster tribrachiatus* Zone in the Lodo Formation.

DISCOASTER DELICATUS Bramlette & Sullivan

Discoaster delicatus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 159, Pl. 11, fig. 3; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 190, Pl. 10, figs. 10–12; ——, 1965, *ibid*., v. 53, p. 41.

Occurrence.—Originally described (Bramlette & Sullivan, 1961) from the *Heliolithus riedeli* Zone of the Lodo Formation in California, this species is found sporadically throughout the *Discoaster multiradiatus* Zone at Pont Labau.

DISCOASTER NOBILIS Martini
Pl. 204, fig. 16; Pl. 205, figs. 6,9

Discoaster nobilis MARTINI, 1961, Senckenbergiana Lethaea, v. 42, no. 1-2, p. 11, Pl. 2, fig. 23, Pl. 5, fig. 51.

Discoaster falcatus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 159–160, Pl. 11, figs. 14a,b,15; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci. v. 44, no. 3, p. 190, Pl. 11, figs. 10–12; ——, 1965, *ibid*., v. 53, p. 42.

Remarks.—Specimens from Pont Labau agree closely with the types. Electron micrographs reveal a crude construction, as is typical of discoasters. The sutures are deeply incised.

Diameter.—20μ.

Hypotypes.—UI-H-2702, 2703, 2762.

Occurrence.—This species was originally described (Martini, 1961) from exposures along the Gan—Rebenacq Road. In the Lodo Formation of California, it ranges through the *Heliolithus riedeli* and *Discoaster multiradiatus* Zones and becomes rare in the *Discoaster tribrachiatus* Zone. At Pont Labau, it is common in the *Discoaster multiradiatus* Zone.

DISCOASTER GEMMEUS Stradner
Pl. 204, figs. 19–21; Pl. 206, figs. 3,5,6,8

Discoaster gemmeus STRADNER, 1959, Fifth World Petroleum Cong., Sec. 1, Paper 60, p. 1086, Text-fig. 21; ——, 1959, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 75, p. 479, Text-fig. 40; STRADNER, *in* STRADNER & PAPP, 1961 Wien Geol. Bundesanstalt, Jahrb., Sdrbd. 7, p. 77, Pl. 12, figs. 1,2,4,8, Text-fig. 8.13; ——, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 79, Pl. 11, figs. 4,5.

Remarks.—This abundant species has commonly been overlooked because of its small size. The disc is composed of 10 to 15 segments. Each segment bears a medial ridge on both sides of the disc. From this ridge the flat surfaces of the segment, which apparently represent crystal faces, slope down to the adjacent suture. The sutures are straight on one side of the disc [*facies inferior* of Stradner, *in* Stradner & Papp (1961)] and are curved centrally on the other side [*facies superior* of Stradner, *in* Stradner & Papp (1961)]. This species, which is the oldest true discoaster, is also very primitive in that the calcite crystal faces are not suppressed.

Diameter.—7–11μ.

Hypotypes.—UI-H-2707–2710, 2764–2766.

Occurrence.—First described from the Paleocene of Austria. This distinctive species is abundant at Pont Labau, ranging from sample 820 to 826 (that is, the *Discoaster gemmeus* Zone) appearing again (reworked) in the top of the *Discoaster multiradiatus* Zone. Although not reported, it is common in the Lodo 6+1 sample of Bramlette & Sullivan (1961) (*Heliolithus riedeli* Zone).

DISCOASTER HELIANTHUS Bramlette & Sullivan

Discoaster helianthus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 160, Pl. 11, fig. 18a,b; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 191, Pl. 10, fig. 7; ——, 1965, *ibid*., v. 53, p. 42, Pl. 10, fig. 7.

Remarks.—Specimens that were observed in the light microscope agree with the published illustrations. Electron micrographs of this species have not yet been obtained.

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Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from the *Heliolithus riedeli* Zone in California. At Pont Labau it is rare in the *Discoaster gemmeus* Zone.

DISCOASTER LENTICULARIS Bramlette & Sullivan

Discoaster lenticularis BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 160, Pl. 12, figs. 1a,b,2; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 191, Pl. 11, fig. 1; ——, 1965, *ibid.*, v. 53, p. 42, Pl. 10, fig. 10.

Remarks.—Specimens that were seen in the light microscope closely resemble published illustrations. Electron micrographs have not been obtained of this relatively rare species.

Occurrence.—This species was originally described (Bramlette & Sullivan, 1961) from California, where it is locally common in the *Discoaster multiradiatus* Zone. It is rare (reworked?) in the *Discoaster tribrachiatus* Zone in California. At Pont Labau, it is rare in the *Discoaster multiradiatus* Zone.

DISCOASTER MEDIOSUS Bramlette & Sullivan
Pl. 204, figs. 17,18; Pl. 206, fig. 2

Discoaster mediosus BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 161, Pl. 12, figs. 7a,b,8; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 191, Pl. 11, fig. 13; ——, 1965, *ibid.*, v. 53, p. 42.

Remarks.—This species, displaying the characteristic short, narrow extentions of the rays beyond the disc, is easily recognized in electron micrographs. The central part of the surface of each ray bears a broad depression, and the sutures are bordered by low ridges. A circlet of nodes near the center forms a distinctive feature which can be recognized in the light microscope.

Diameter.—13μ.

Hypotypes.—UI-H-2711, 2763.

Occurrence.—Originally described (Bramlette & Sullivan, 1961) from the *Discoaster multiradiatus* Zone and lower part of the *Discoaster tribrachiatus* Zone of the Lodo Formation in California, this species is found in the upper part of the *Discoaster multiradiatus* Zone at Pont Labau.

DISCOASTER MULTIRADIATUS Bramlette & Riedel
Pl. 204, fig. 22; Pl. 206, figs. 1,4,7

Discoaster multiradiatus BRAMLETTE & RIEDEL, 1954, Jour. Paleontology, v. 28, no. 4, p. 396, Pl. 38, fig. 10; HILTERMANN, 1956, Erdoel und Kohle, v. 9, p. 752, Text-fig. 15; STRADNER, 1958, Erdöl-Zeitschr. für Bohr- u. Fördertechnik, v. 74, no. 6, p. 181, Text-fig. 4; ——, 1959, Fifth World Petroleum Congr., Sec. 1, Paper 60, p. 1082, Text-fig. 1; MARTINI, 1960, Umschau Fortschr. Wiss. u. Technik, no. 13, Text-figs. 1,10; BÁLDI-BEKE, 1960, Földrajzi Közlemények, v. 90, no. 2, p. 222, Pl. 14, fig. 17; MARTINI, 1960, Hess. Landesamt Bodenf., Notizbl., v. 85, p. 75, Pl. 8, fig. 9; BRAMLETTE & SULLIVAN, 1961, Micropaleontology, v. 7, no. 2, p. 161, Pl. 12, fig. 10; MARTINI, 1961, Senckenbergiana Lethaea, v. 42, no. 1–2, p. 9, Pl. 2, fig. 19; STRADNER, *in* STRADNER & PAPP, 1961, Wien Geol. Bundesanstalt, Jahrb., Sdrbd. 7, p. 98–99, Pl. 29, figs. 1–7, Text-figs. 9/9,9/16,24/1; BENEŠOVÁ & HANZLIKOVÁ, 1962, Věst. Ustřed, Ušt. Geol., v. 37, no. 2, Pl. 3, fig. 5; STRADNER, *in* GOHRBANDT, 1963a, Geol. Gesell. Wien, Mitt., v. 56, no. 1, p. 80, Pl. 11, figs. 6,7; BRÖNNIMANN & RIGASSI, 1963, Eclogae geol. Helvetiae, v. 56, no. 1, Pl. 10, fig. 1a,b; SULLIVAN, 1964, California Univ. Pubs. Geol. Sci., v. 44, no. 3, p. 191–192, Pl. 10, figs. 8,9; ——, 1965, *ibid.*, v. 53, p. 43, Pl. 10, figs. 13,15.

Remarks.—Many electron micrographs have been taken of this extremely abundant species. Of particular interest is the nature of the central stem, which shows a heliolithid arrangement of the elements between crossed nicols as suggested by Stradner (1961). The stem is constructed of numerous small segments which are dextrally imbricate. The surfaces of the rays are flat and probably represent crystal faces. The sutures are depressed.

Hypotypes.—UI-H-2712–2714, 2767.

Occurrence.—This widespread and excellent index fossil was originally described from the Velasco Shale of Mexico. It has been found in the Lodo Formation of California, where Bramlette & Sullivan (1961) distinguished a *D. multiradiatus* Zone. It is found in Paleocene strata in many parts of the world. At Pont Labau it ranges from GAN 827 through GAN 837.

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