Geology of Saipan Mariana Islands

Part 3. Paleontology

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-E-J

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Geology of Saipan, Mariana Islands

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Discoaster and Some Related Microfossils

By M. N. BRAMLETTE

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The first attempt to assign ages to strata on the basis of forms of Discoaster *and related small planktonic organisms*

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DISCOASTER AND SOME RELATED MICROFOSSILS

By M. N. Bramlette

ABSTRACT

This report is the first to attempt age assignments of strata on the basis of the forms of *Discoaster* and some related small planktonic organisms. Recent investigations have suggested their stratigraphic value, and results of the present work on samples from Saipan further substantiate this application.

Little value would be derived from premature discussion of the systematics of such poorly understood organic objects. Only some of the more diagnostic forms are discussed and tabulated in a distribution table. This tabulation indicates a marked difference between the earlier and later Tertiary samples of Saipan. Age assignment of samples to the late Eocene and Miocene is based on known occurrences of these fossils elsewhere. These age relationships were subsequently found to agree with other evidence in all but two samples, both of which had very meager assemblages. The assemblage in one of these two samples may well include reworked material.

INTRODUCTION

Application to stratigraphic paleontology of certain very small (2–20 microns) and little known organisms requires a few introductory remarks, at least, on their general characteristics and occurrence.

Much scientific investigation of Recent coccolithophores has been accomplished, because these minute planktonic algae are an important element of the life at the surface of the oceans. Sorby in 1861 recognized that the coccoliths forming much of the Cretaceous chalk were the skeletal remains of these calcareous algae. A few of the fossil forms have been described, but no attempt has been made to use them in stratigraphic correlation. Some of these forms have well-known Recent representatives in the oceans, and others seem to be extinct.

Some forms, largely if not entirely extinct, that may be closely related to the Recent coccolithophores have been known under the "generic" name *Discoaster*. Tan Sin Hok (1927, p. 114–122, fig. 2) first used this name and described several forms from the late Tertiary of Indonesia. Though the systematic position of the discoasters is uncertain and they were regarded by Ehrenberg (1854) as inorganic "Crystalldrusen," it is now evident that they are the skeletal remains of planktonic organisms. They cannot be quite certainly classed even as Protista, or single-cell organisms of the plant or animal kingdoms.

The name *Discoaster* is applied to isolated skeletal parts with various stellate forms—either with separately extended rays or as radiate petals forming a disc. Presumably more than one of these occurred as external plates as with modern coccolithophores or possibly as separated internal spicules. Polarized light shows them formed as single or unit crystals of calcite, rather than as delicate radiating fibers of calcite as in the coccoliths or plates of typical coccolithophores. The form described by J. Lecal (1952) from a single specimen from a plankton sample of the Meditteranean seems very questionably assigned to *Discoaster*, because the skeletal parts are described as of amorphous (isotropic) material rather than calcite. A form of *Discoaster* resembling the rather poorly characterized species *D. aster* is found sporadically in Quaternary ocean-bottom sediments and may be yet living, though most species are certainly extinct.

Deflandre (1952) has recently presented an interpretation of the systematic position of *Discoaster*, and forms apparently related, and included them in his Class Coccolithophorides. However, certain forms of dinoflagellates, such as *Gymnaster*, have two spicules shaped like discoasters; and though composed of opal in this genus, such skeletal parts are reported to be soluble in acetic acid in some other genera of the same family among the dinoflagellates and are perhaps calcite.

Much taxonomic work remains to be done on these organisms, and little was attempted in the present study, only the forms from Saipan that have been described elsewhere being considered. Work to date on samples from various parts of the Tertiary in many places in the world (Bramlette and Riedel, 1954, p. 385–403) has indicated that the three genera or subgenera of Tan Sin Hok (1927) (his treatment as genera or subgenera is not consistent) are not satisfactory groupings nor are most of his species and varietal groups. The different "species" of discoasters from Saipan are included, therefore, under the one "generic" designation *Discoaster*. This is merely expedient, as knowledge of these forms is not yet adequate for a systematic hierarchy even of one such as that of Croneis (1938) based on the Roman Army groupings.

Examination with a variable phase-contrast microscope is of much help in identification, as some of the confusing effects of refracted light can thus be eliminated. Discrimination of more distinctive features in these minute forms may eventually prove possible and permit less "lumping" of forms and consequently of their stratigraphic distribution.

Notes on some of the commoner forms from Saipan, or of those which are already recognized as diagnostic for certain parts of the Tertiary, are presented along with illustrations of most of them. All of these have been either described as new species or discussed further elsewhere (Bramlette and Riedel, 1954, p. 385–403). Table 1 includes an indication of relative abundance, though this seems of little or no significance in some samples because it is evidently influenced by degree of solution and recrystallization of these constituents.

DISCUSSION OF SPECIES IDENTIFIED FROM SAIPAN

DISCOASTERS

Discoaster pentaradiatus Tan Sin Hok, emend. Bramlette and Riedel

Discoaster pentaradiatus Tan Sin Hok, emend. Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 401, pl. 39, fig. 11; text figs. 2a, b.

This delicate form was adequately illustrated by Tan Sin Hok (1927, p. 118, text fig. II, fig. 14). Though 5 rays seem dominant in this species, 6 rays form a common variant. The 6-ray variant resembles *D. challengeri*, but the difference in the bifurcating ends of the rays is apparent in Tan's figure, and this is believed to be more diagnostic. This species is also generally more delicate than *D. challengeri*. Present data indicate that it is a widespread form but probably restricted to the early Pliocene and Miocene, and it seems less common in the early Miocene.

Discoaster brouweri Tan Sin Hok

Plate 61, figure 1

The Saipan form illustrated can be identified as Tan's species (1927, p. 120, text fig. II, fig. 8a, b.) His idealized sketch does not show the considerable enlargement of the central area by widening of the rays at their central juncture, but this is somewhat variable as indicated by specimens from a part of Tan's original sample, which was kindly supplied by Dr. Ubaghs, of Delft, Netherlands. The downward curvature of rays ranges considerably, as does their thickness, and 5 ray forms occur much less commonly than the normal 6 rays. This form is abundant and widespread in Miocene strata, particularly in those of the upper Miocene. It extends up into the Pliocene.

Discoaster brouweri Tan Sin Hok var

A form similar to *D. brouweri* (except that the rays are generally very thin or delicate) is here classed as a mere variant of the above species. They are not always associated, however, and it may prove to be best separated at least as a subspecies. It is common in Miocene strata, especially in the upper part, and throughout most of the Pliocene. Some data suggest that its upper limit may help serve as a tentative upper limit of the Pliocene, in the Pacific region at least, even though no satisfactory boundary is yet possible.

Discoaster challengeri Bramlette and Riedel

Plate 61, figure 2

Discoaster challengeri Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 401, pl. 39, fig. 10.

This form from Saipan is illustrated in plate 61, figure 2, and it was also figured by Tan Sin Hok (1927, p. 111, fig. 3), though he did not name it or mention it otherwise. His figure may have been taken from an illustration in the *Challenger* Report (Murray and Renard, 1891, pl. 11, fig. 4). It is considered the same as Tan's *D. molengraaffi* var. *gamma* (1927, p. 120–121, text-fig. II, fig. 11). His var. *gamma* is not closely related, however, to his *D. molengraaffi*, and thus required a new name. This thin-rayed form with 6 (rarely 5) rays, bifurcating at their tips, also ranges considerably from more delicate to more robust forms than that illustrated. It is flatter or has much less downward bend of the rays than *D. brouweri*. The arrangement of rays like two superposed triradiate forms shown in Tan's illustration of *D. molengraaffi* var. *gamma* occurs only as an unusual variant among specimens in the part available of Tan's original sample. The same unusual variations, and even of single triradiate variants, is evident in several different species. Examination of many samples from many areas makes it evident that these occasional variants of several species cannot be grouped as the different genus or subgenus which Tan classed as *Hemidiscoaster*. *D. challengeri* is very common in Miocene strata of many regions, and its lower range seems to extend down into the upper Oligocene.

Discoaster challengeri Bramlette and Riedel var

Plate 61, figure 3

Discoaster challengeri Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 401, pl. 39, fig. 10.

The figured specimen from Saipan illustrates a common form at Saipan and elsewhere. The thickness of rays and general degree of robustness of *Discoaster challengeri* range considerably, and the species might thus include the form here indicated and listed as a variety. It is thus differentiated because it is the dominant if not the only type in many samples of strata that have been variously assigned to the early Miocene and late Oligocene. It may prove best separated as a subspecies.

Discoaster aster Bramlette and Riedel

Plate 61, figure 4

Discoaster aster Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 400, pl. 39, fig. 7.

This robust form has either 5 or, more commonly, 6 rays and is ordinarily rather rugose. Both the width and the thickness of rays are marked, and it seems closely related to *D. woodringi*, especially in this very robust character, though the rays are better separated and more pointed than those of *D. woodringi*. The general form is similar to Ehrenberg's *Actiniscus stella* (1854, pl. 20, fig. 47), but this was evidently something entirely different with an opaline skeleton. It is generally sparsely represented but occurs throughout most of the Tertiary, though apparently more common in the lower half of the Tertiary.

Discoaster woodringi Bramlette and Riedel

Plate 61, figure 5

Discoaster woodringi Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 400, pl. 39, figs. 8a, b.

The specimen from Saipan illustrates the usual form of this rather variable species. Five-ray individuals are rare compared with the normal six rays. It is unusually robust, both in thickness and especially in the width of rays, so that there is typically no complete separation between rays except very near the periphery. Despite range in width and degree of separation of rays, this seems a distinctive form. It is well illustrated by Deflandre (1934, p. 65, figs. 20, 21) from its abudant occurrence in the Oligocene strata of Jérémie, Haiti. He called it *D. brouweri* var. *delta* from similarity to the form named by Tan Sin Hok, but even if identical with the form shown in Tan's idealized sketch, it clearly seems to be not closely related to Tan's *D. brouweri*. Though forms apparently belonging within the range of variation of this species occur throughout much of the Eocene and Oligocene of various regions, and to a less extent even in the later Tertiary, it is the dominant or nearly sole form of *Discoaster* in some Oligocene strata.

Discoaster deflandrei Bramlette and Riedel

Plate 61, figure 6

Discoaster deflandrei Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 399. pl. 39, fig. 6.

This species somewhat resembles robust variants of the form illustrated in plate 61, figure 3, as *D. challengeri* var., at least in the six heavy rays bifurcating at the ends; but the rays do not show parallelism of sides, as those in plate 61, figures 2 and 3; and even the bifurcating ends are somewhat different. Little or no evidence of down bend of the rays is evident in side views. Considerable variation may make recognition of subspecies desirable throughout the wide stratigraphic range from early Miocene down into at least the late Eocene, but all variants are tentatively included here.

Discoaster barbadiensis Tan Sin Hok, emend., Bramlette and Riedel

Plate 61, figure 10

Discoaster barbadiensis Tan Sin Hok, emend., Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 398, pl. 39, figs. 5a, b.

This common and widespread Eocene form seems to be the same as that so named by Tan Sin Hok (1927, p. 119) merely from the original figures of the Barbados specimens by Jukes-Brown and Harrison (1892, p. 178, figs. 4–6). In side view it appears quite different from Jukes-Brown and Harrison's original figure of *D. barbadiensis*, but many samples from Barbados have been examined and show that the central stem generally extends up from a somewhat concave surface rather than as a prolongation of a convex surface. The vertical view is similar to both the figures of Jukes-Brown and Harrison and of Tan Sin Hok. The rays show little separation except at the periphery, and the number is not constant but is most commonly 9 to 11 in specimens from Saipan and other upper Eocene strata elsewhere. Otherwise rather similar forms average a few more rays in some earlier Eocene strata. Even including forms that may prove distinctly different from *D. barbadiensis*, this general type seems characteristic of the Eocene and is apparently the most abundant and widespread form from the Eocene in many parts of the world.

Discoaster saipanensis Bramlette and Riedel

Plate 61, figure 7

Discoaster saipanensis Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 398, pl. 39, fig. 4.

This illustrated form from Saipan is considered distinct from that called *D. barbadiensis*. This vertical view cannot show well the extended stem similar to that shown in the side view of *D. barbadiensis* (pl. 61, fig. 10). However, not only do the number of rays average less than in *D. barbadiensis* but they are more separated and shaper pointed. The two species are usually associated in the upper Eocene, but *D. saipanensis* does not appear as early in the Eocene.

Discoaster tani Bramlette and Riedel

Plate 61, figure 8

Discoaster tani Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 397, pl. 39, fig. 1.

The species figured, and especially occasional variants with thinner rays, somewhat resembles some common forms in the Miocene. The rays show a distinct downward curve as in *D. brouweri* but do not taper outward. Rather, they are squared off at the tips, with a slight notch usually apparent at the end. Five rays are usual and six rays rare. Similar forms with six rays are more common, however, in some Eocene strata elsewhere. A slight suggestion of nodes on the sides of some arms is shown by most specimens, as in the illustration. This and the following subspecies have been noted in upper Eocene strata of such widely separated areas as New Zealand, Alabama, and Trinidad.

Discoaster tani nodifer Bramlette and Riedel

Discoaster tani nodifer Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 397, pl. 39, fig. 2.

This subspecies likewise has 5 or 6 arms, and perhaps more commonly 6 though the sparsity of individuals in Saipan and elsewhere make this uncertain. The conspicuous and regularly arranged pairs of nodes along the arm make this a distinctive form, though otherwise similar to *D. tani*, and the latter shows commonly a slight and irregular development of such nodes.

COCCOLITHS AND SOME DOUBTFULLY RELATED FORMS

The complete skeletal remains forming the coccosphere of the common modern forms of coccolithophores are seldom preserved intact, but disaggregate into the isolated elements. These isolated coccoliths, depending on their general form, are designated in a vernacular sense as placoliths, rhabdoliths, and lopadoliths. *Tremalithus* is a "form genus" name used by Kamptner for some fossil forms of placoliths which cannot be assigned as yet to known genera, and has been applied to the following mentioned species.

Tremalithus eopelagicus Bramlette and Riedel

Plate 61, figure 9

Tremalithus eopelagicus Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 392, pl. 38, figs. 2a, b.

Only this unusually large and thus distinctive form of coccolith is illustrated and separately shown in table 1, though a few other distinctive but undescribed forms among the Coccolithophoridae proper were listed during the examination of samples. This form appears to be the same as one illustrated by Jukes-Brown and Harrison (1892, p. 178, fig. 8) from the early Tertiary of Bardados. View of the other side is similar except for another slightly smaller concentric line representing the outer edge of the lower plate. As with many coccoliths of this general type, the form is like a shirt stud, but the two plates in this species are so closely appressed that the thick connecting tube is discernible in side view only through the thin curved edges of the plates.

The coccolith resembles that from one of the modern forms which, among others, have been included (sensu lato) under the name *Coccolithus pelagicus* (Wallich), but it is of larger size than the modern forms and distinctly more appressed than the original figures by Wallich indicate for his *Coccosphaera pelagica* (1877, pl. 17, figs. 9D, 10D). It seems probable that this species may be assigned eventually to the genus *Coccolithus*. It is common in the upper Eocene and lower Oligocene but probably occurs also in strata of somewhat earlier and later ages.

Rhabdoliths and lopadoliths

The elongate forms of coccolith (rhabdoliths), are more common in the warmer parts of the oceans at present and so possibly in earlier times. Two distinctive forms of rhabdolith were noted rarely in the Eocene of Saipan, but similar forms are common in the early Tertiary elsewhere although their stratigraphic distribution remains poorly defined. None were observed in the Moicene of Saipan though forms rather similar to those of the modern *Rhabdosphaera claviger* Murray and Blackman (1898, p. 438, 439, pl. 15, figs. 13, 14) are common in some other Miocene deposits.

The forms of coccolith included as lopadoliths are commonly barrel shaped, though also commonly of rather different shape on different parts of an individual of such species as *Scyphosphaera apsteini* Lohmann (1902, p. 132, pl. 4, figs. 26–30). No attempt at the difficult and questionable assignment even to genera seemed now advisable. The lopadoliths do not seem to occur commonly before the late Oligocene or early Miocene elsewhere, and only in strata assigned to the Miocene of Saipan. Nearly spherical forms seem commoner in the earlier strata with more elongate forms dominant in the later Miocene elsewhere.

Thoracosphaera sp.

Comparatively large (20–30 microns) spherical forms composed of many polygonal elements were placed under the generic name *Thoracosphaera* by Kamptner (1927, p. 180). These relatively thick-walled and robust forms do not usually disaggregate but retain their spherical form. They appear rather similar through much of the Tertiary, though different from the modern form. No attempt to differentiate species is made here.

Ceratolithus sp.

Peculiar small forms resembling a horseshoe except that the ends are tapering or pointed belong in Kamptner's "genus" *Ceratolithus*, which is figured by Deflandre (1952, p. 468, fig. 364E). Such forms are common in modern ocean deposits, but the living organism from which they are derived is yet unknown. They are also common in some Pliocene strata but are unknown before the Miocene. Some difference is apparent between the Recent form and earlier ones besides the more robust character of early forms, but no differentiations are attempted here. *Ceratolithus* was noted in only one Miocene sample from Saipan, and it was rare in that.

Braarudosphaera bigelowi (Gran and Braarud) Deflandre

The pentagonal plates included under this name by Deflandre (1947) resemble those forming a dodecahedral test which was originally named *Pontosphaera bigelowi*. Oblique sutures divide the pentagonal plates into five segments, each of which is a unit crystal of calcite, as seen with polarized light. Only superficially, in outline, does it somewhat resemble *D. woodringi*. The latter is formed of a single unit crystal of calcite, as are all specimens included under *Discoaster*. *B. bigelowi* seems to have ranged from the Recent back to the Late Cretaceous, at least, and it has been observed to be most abundant in the Eocene.

Braarudosphaera discula Bramlette and Riedel

Braarudosphaera discula Bramlette and Riedel, 1954, Jour. Paleontology, v. 28, no. 4, p. 394, pl. 38, fig. 7.

This form is similar to *B. bigelowi*, except that it is more circular in outline, generally smaller, and the sutures extend radially out to the angles of the pentagonal plates—the pentagonal shape is commonly discernible even though the outline is nearly circular. B. Klumpp (1953, p. 381, text fig. 2 (3); pl. 16, figs. 3, 4) has described a rather similar form from the Eocene of Germany under the name *Pemma rotundum*. This form might better be included under *Braarudosphaera* but is different from *B. discula* in showing on each segment of the pentalith a central knob with a fine perforation through it. *B. discula* is abundant in some Eocene strata, though rare in the Eocene of Saipan.

INTERPRETATIONS OF THE AGE OF STRATA ON SAIPAN

As a test of the stratigraphic applications of *Discoaster* and related microfossils, samples from Saipan were examined without previous knowledge of the formational units involved or of other evidence on the age of the strata. The microfossils here reported on were found in 21 of these samples. The following interpretations of age consider exclusively the evidence from this independent study, except for remarks on a few samples, two of which were subsequently found to be in disagreement with other data on their age. The distribution table was subsequently rearranged under the formational headings and ages designated in Chapter A (Cloud Schmidt, and Burke, 1956), which should be consulted for general discussion of the stratigraphy.

Two very distinct groupings of these microfossils are evident in the tabulation. All six samples from the Donni sandstone member of the Tagpochau limestone include some forms which, as indicated in the discussion of the species, have been found only in the Miocene of other regions and a few others which elsewhere appear to be limited to strata of late Oligocene and later Tertiary age. Though diagnostic forms are rare in four of these samples, these seem to afford, nevertheless, evidence for a Miocene age assignment.

TABLE 1.—*Distribution of discoasters, coccoliths, and some doubtfully related forms in Saipan samples*

[Key to symbols: a, abundant; c, common; f, few; r, rare]

	Eocene										Oligocene: Fina-sisu formation		Miocene: Tagpochau limestone								
	Hagman formation: Conglomerate-sandstone facies						Densinyama formation						Donni sandstone member						Transitional facies		Marly facies
							Conglomerate-sandstone facies			Limestone-conglomerate facies											
	S365	S367	S385	S420	S596	S598	S26	S212	S215	S194	C85	S662	B333	B335	C69	S25	S452a	S621	S666	S701	C136
General occurrence of discoasters	c	f	c	f	r	f	a	r	r	c	r	r	r	r	r	c	r	c	r	a	r
General occurrence of coccoliths	a	f	c	c	r	f	c	r	r	f	r	r	r	r	r	f	------	f	r	a	------
Discoaster pentaradiatus	------	------	------	------	------	------	------	------	------	------	------	------	------	r	r	r	------	r	------	------	------
brouweri	------	------	------	------	------	------	------	------	------	------	r	r	------	------	------	f	r	r	------	------	------
brouweri var	------	------	------	------	------	------	------	------	------	------	------	------	r	r	r	f	------	------	------	------	------
challengeri	------	------	------	------	------	------	------	------	------	------	------	------	r	------	r	c	r	f	------	------	------
challengeri var	------	------	------	------	------	------	------	------	------	------	r	r	------	r	------	f	f	f	------	------	------
Lopadoliths	------	------	------	------	------	------	------	------	------	------	------	------	------	------	r	f	r	f	------	------	------
Ceratolithus sp	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	r	------	------	------	------	------
Discoaster aster	r	------	------	------	------	r	------	------	r	------	r	------	------	------	------	------	r	------	------	f	r
woodringi	r	------	r	r	------	?r	------	------	------	------	r	r	------	------	------	------	------	------	r	a	r
deflandrei	r	r	r	r	?r	------	f	------	------	?r	?r	------	------	------	------	------	------	------	------	------	r
saipanensis	f	f	f	r	r	------	c	------	r	r	------	------	------	------	------	------	------	------	r	------	------
barbadiensis	a	c	a	c	r	f	a	r	f	c	------	------	------	------	------	------	------	------	?r	------	------
tani	f	r	f	f	------	f	c	------	r	r	------	------	------	------	------	------	------	------	------	------	------
tani nodifer	r	------	?r	r	------	r	r	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Braarudosphaera bigelowi	r	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	r
discula	------	------	r	------	r	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Tremalithus eopelagicus	f	f	f	r	r	r	f	?r	f	r	------	------	------	------	------	------	------	------	------	------	------
Thoracosphaera sp	r	r	r	r	------	------	r	------	------	r	------	------	------	r	------	r	r	f	------	------	------
Rhabdoliths	------	------	------	------	------	------	r	------	------	------	------	------	------	------	------	------	------	------	------	------	------

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TABLE 2.—*Localities referred to and equivalent type numbers*

Field nos.	USGS paleobotany loc. nos.	Species for which types are illustrated	USGS algae type nos. (plesiotypes)	USNM nos. (holotypes)
Hagman formation—Eocene				
S365	D247			
S367	D248			
S385	D249			
S420	D250	*Discoaster deflandrei* Bramlette and Riedel	D130	
S596	D252			
S598	D253			
Densinyama formation—Eocene				
S26	D244	*Discoaster barbadiensis* Tan Sin Hok	D124	
		Discoaster saipanensis Bramlette and Riedel		624837
		Discoaster tani Bramlette and Riedel		624838
		Tremalithus eopelagicus Bramlette and Riedel.	D123	
S212	D245			
S215	D246			
S194	D217			
Fina-sisu formation—Oligocene				
C85	D241			
S662	D255			
Tagpochau limestone—Miocene				
B333	D238			
B335	D239			
C69	D240			
S25	D243			
S452a	D251			
S621	D254	*Discoaster brouweri* Tan Sin Hok	D125	
		Discoaster challengeri Bramlette and Riedel	D126	
		Discoaster challengeri Bramlette and Riedel var.	D127	
S666	D256			
S701	D257	*Discoaster aster* Bramlette and Riedel	D128	
		Discoaster woodringi Bramlette and Riedel	D129	
C136	D242			

Finer discrimination of other forms, including various coccoliths not differentiated in this paper, might permit somewhat more precise placement within the Miocene, but this does not seem justified from the data available. A few samples from Indonesia suggest correlation with those classed there as Tertiary *f*. Samples from the Caribbean region suggest correlation with those usually classed there as early Miocene.

Samples C85 and S662 contained only a few identifiable specimens, two of which range throughout much of the Tertiary. These samples, however, were originally assigned to either the Miocene or to age equivalents of Caribbean strata that are usually classed as late Oligocene. Subsequent information from the foraminiferal studies suggests a correlation with the older strata that are ordinarily considered upper Oligocene.

Sample S701 presents a serious conflict in the original interpretation of age with the evidence from other sources subsequently available. This sample contains abundant coccoliths and discoasters, but only of a few species of coccoliths and only two forms of *Discoaster*. Both forms of *Discoaster* are now known to have a long time range. The great abundance of these few forms only might well suggest some unknown ecologic control. A nearly identical assemblage has, however, been found in Oligocene strata in several other regions, and the sample was originally assigned to the Oligocene. Better evidence from other fossils, however, supports a Miocene age for sample S701. This is the first in several hundred samples studied to date, suggesting that which may be expected in nearly any fossil group—a repetition with time of similar assemblages (commonly with abundant fossils but relatively few species).

Sample C136 has too few identifiable forms to justify any age assignment. Though S666 likewise has very rare forms, it was originally assigned to the Eocene because of a specimen of *Discoaster saipanensis* and a doubtful one of *D. barbadiensis*. Elsewhere in Saipan and many other regions, these forms seem restricted to the Eocene. Other evidence indicates a Miocene age for this sample (S666), and it seems probable that these rare specimens were reworked from the Eocene. Reworking seems much more probable than an extended time range, because it would seem a peculiar coincidence if here where all forms are so rare is found an extended range not known from many abundant assemblages elsewhere.

The first 10 samples in table 1 are assigned to the upper Eocene. The identity of the forms occurring in the 10 samples suggests little difference in age within this late Eocene of Saipan. The mere abundance of occurrence seems obviously related, in part, to the state of preservation of the samples.

Distinctive forms of these 10 samples, such as *Discoaster barbadiensis*, *D. saipanensis*, *D. tani*, and *D. tani nodifer*, are found in Eocene strata of many other regions. Forms included with *D. barbadiensis* occur throughout the Eocene elsewhere, though these differ considerably and infraspecific groups may prove desirable. *D. tani* seems to be more restricted to a higher part of the Eocene, and *D. tani nodifer* and *D. saipanensis* are as yet known only in the upper Eocene. Nearly all the Eocene discoasters of Saipan and the big coccolith (*Tremalithus eopelagicus*) occur, among other places, in the upper Eocene marl of Hospital Hill, Trinidad.

LITERATURE CITED

Bramlette, M. N., and Riedel, W. R., 1954, Stratigraphic value of discoasters and some other microfossils related to Recent coccolithophores: Jour. Paleontology, v. 28, no. 4, p. 385–403, pls. 38, 39; 3 text figs.

Cloud, P. E., Jr., Schmidt, R. G., and Burke, H. W., 1956, Geology of Saipan, Mariana Islands: U. S. Geol. Survey Prof. Paper 280-A [1957].

Croneis, C. G., 1938, Utilitarian classification for fragmentary fossils: Jour. Geology, v. 46, no. 7, p. 975–984.

Deflandre, Georges, 1934, Les Discoastéridés, microfossiles calcaires *incertae sedis:* Soc. franç. Microscopie Bull., v. 3, no. 2, p. 59–67, figs. 1–31.

——— 1947, *Braarudosphaera* nov. gen., type d'une famille nouvelle de Coccolithophoridés actuels à éléments composites: Acad. Sci. Paris Comptes rendus, tome 225, p. 439–441, figs. 1–5.

——— 1952, Traité de Zoologie: Grassé, Paris, v. 1, fasc. 1, p. 439–470, ed. Masson.

Ehrenberg, C. G., 1854, Mikrogeologie. Das erden und felsen schaffende wirken des unsichtbar kleinen selbstständigen lebens auf der Erde: L. Voss, Leipzig, p. xxviii, 374, and 88; atlas of 31 [90] p., 41 pls.

Jukes-Brown, A. J., and Harrison, J. B., 1892, The geology of Barbados, Part 2, The oceanic deposits: Geol. Soc. London Quart. Jour., v. 48, p. 170–226, figs. 1–9.

Kamptner, Erwin, 1927, Beitrage zur Kenntnis adriatischer Coccolithophoriden: Archiv für Protistenkunde, Band 58, p. 173–181, figs. 1–6.

Klumpp, B., Beitrag zur Kenntnis der Mikrofossilien des Mittleren und Oberen Eozan: Palaeontographica, Band 103, Abt. A, Lief. 5–6, p. 377–406, pls. 16–20.

Lecal, J., 1952, Sur un Protiste Pélagique Rattachable aux Discoastéridés: Arch. Zool. Exp. et Générale, tome 89, no. 2, p. 51–55, Paris.

Lohmann, H., 1902, Die Coccolithophoridae, eine Monographie der Coccolithen bildenden Flagellaten, zugleich ein Beitrag zur Kenntnis des Mittelmeerauftriebs: Archiv für Protistenkunde, Band 1, p. 89–164, pls. 4–6, 6 tables.

Murray, George, and Blackman, V. H., 1898, On the nature of the Coccospheres and Rhabdospheres: Royal Soc. London Philos. Trans., v. 190, ser. B, p. 427–441, pls. 15–16.

Murray, John, and Renard, A. F., 1891, Report on deep-sea deposits, based on the specimens collected during the voyage of H. M. S. *Challenger* in years 1872 to 1876: *Challenger* Rept., Deep-sea deposits, 525 p., 29 pls.

Sorby, H. C., 1861, On the organic origin of the so-called "Crystalloids" of the Chalk: Annals and Mag. Nat. History, 3d ser., v. 8, p. 193–200, figs. 1–5.

Tan Sin Hok, 1927, Over de sammenstelling in het onstaan van krijt-en mergelgesteensten van de Mollukken: Jaarb. mijnwezen Ned.-Indië (1926), p. 1–165, 16 pls.

Wallich, G. C., 1877, Observations on the Coccosphere: Annals and Mag. Nat. History, 4th ser., v. 19, p. 342–350, pl. 17.

INDEX

[Italic numbers indicate descriptions]

PLATE 61

PLATE 61

[Figs. 7, 8, 10 are drawings by W. R. Riedel. All figures × 3,300]

FIGURE 1. *Discoaster brouweri* Tan Sin Hok (p. 248).
USGS fossil algae type D125; field loc. S–621; somewhat oblique view showing curvature of rays.

2. *Discoaster challengeri* Bramlette and Riedel (p. 248).
USGS fossil algae type D126; field loc. S–621.

3. *Discoaster challengeri* Bramlette and Riedel, var. (p. 248).
USGS fossil algae type D127; field loc. S–621.

4. *Discoaster aster* Bramlette and Riedel (p. 249).
USGS fossil algae type D128; field loc. S–701.

5. *Discoaster woodringi* Bramlette and Riedel (p. 249).
USGS fossil algae type D129; field loc. S–701.

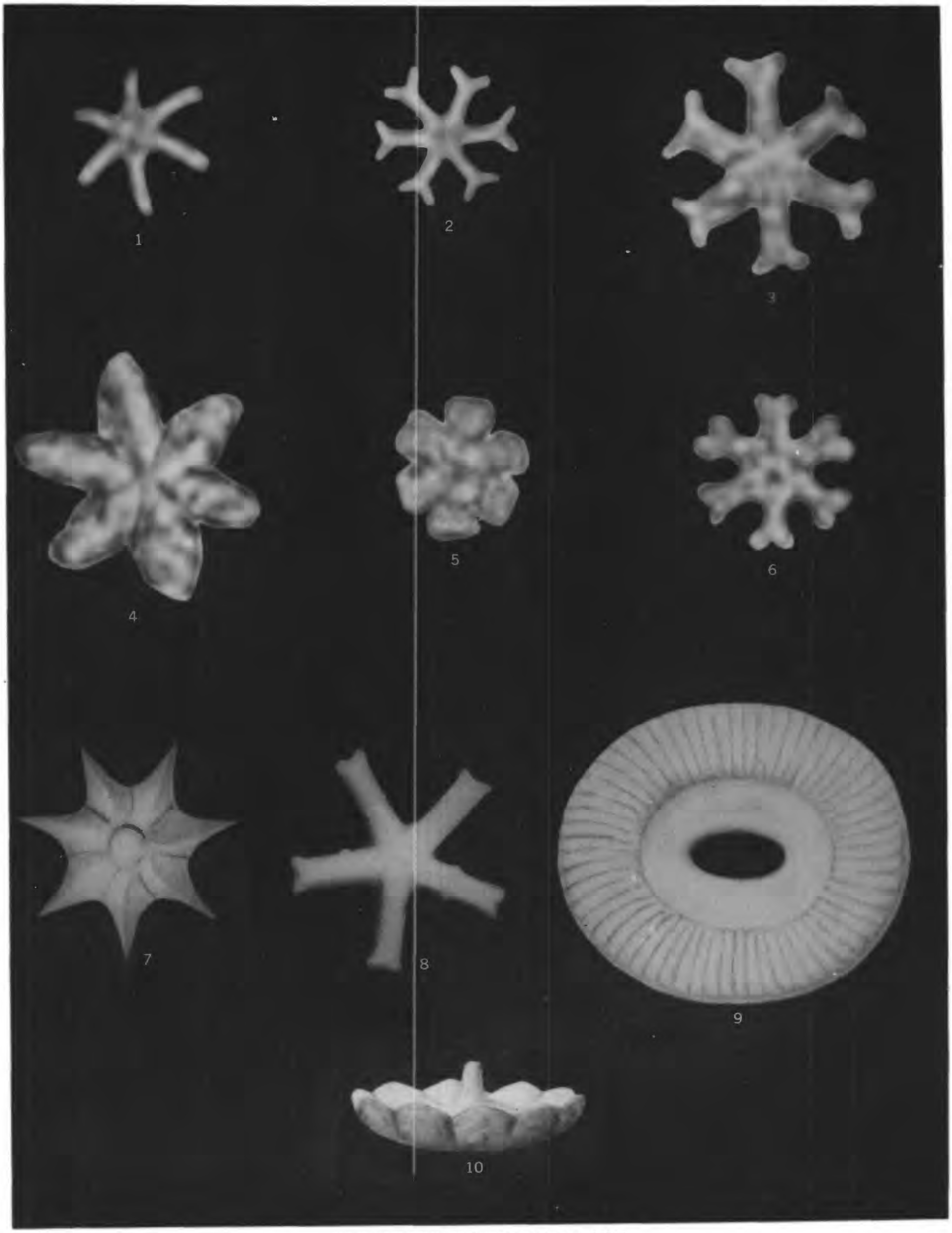
6. *Discoaster deflandrei* Bramlette and Riedel (p. 249).
USGS fossil algae type D130; field loc. S420.

7. *Discoaster saipanensis* Bramlette and Riedel (p. 249).
Holotype, USNM 624837; field loc. S26.

8. *Discoaster tani* Bramlette and Riedel (p. 250).
Holotype, USNM 624838; field loc. S26.

9. *Tremalithus eopelagicus* Bramlette and Riedel (p. 250).
USGS fossil algae type D123; field loc. S–26.

10. *Discoaster barbadiensis* Tan Sin Hok (p. 249).
USGS fossil algae type D124; field loc. S–26; side view.



DISCOASTER AND *TREMALITHUS*