Bikini and Nearby Atolls

Part 4. Paleontology

Fossil Calcareous Algae from Bikini Atoll

Smaller Foraminifera from Bikini Drill Holes

Larger Foraminifera and Smaller Diagnostic Foraminifera from Bikini Drill Holes

Fossil Corals from Bikini Drill Holes

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-M, N, O, P

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By J. HARLAN JOHNSON

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By RUTH M. TODD *and* RITA POST

Larger Foraminifera and Smaller Diagnostic Foraminifera from Bikini Drill Holes
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By JOHN W. WELLS

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

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Fossil Calcareous Algae From Bikini Atoll

By J. HARLAN JOHNSON

Bikini and Nearby Atolls, Marshall Islands

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-M

Descriptions of 20 species, including 4 that are new and 8 still living

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

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BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

FOSSIL CALCAREOUS ALGAE FROM BIKINI ATOLL

By J. HARLAN JOHNSON

ABSTRACT

Calcareous algae play a very important part in building the reefs and associated deposits at Bikini Atoll, and their remains are abundant in the beach rock and well samples.

The algae that could be identified are described. They belong to 8 genera and include 20 species, of which 4 are described as new. Of these, eight are forms found growing now on the modern reef.

The genera represented are *Lithothamnion*, 3 species; *Mesophyllum*, 1 species; *Lithophyllum*, 7 species; *Goniolithon*, 2 species; *Porolithon*, 4 species; *Lithoporella*, 1 species; *Amphiroa*, 1 species; *Halimeda*, 1 species).

The species described as new are *Lithothamnion bikiniensum, Lithophyllum oblongum, Lithophyllum kladosum, and Lithophyllum profundum.*

INTRODUCTION

As a member of the Bikini Resurvey Expedition of 1947, the author spent 6 weeks at Bikini Atoll studying the reefs and the work of calcareous algae in building the reefs. In later 1947 and throughout 1948 and early 1949 he studied specimens collected in the course of the expedition and the samples and cores obtained from the several wells drilled into Bikini island (for location of numbered drill holes see Geological Survey Profession Paper 260–J, fig. 123).

Calcareous algae play a very important part in building the reefs and associated deposits at Bikini Atoll. Studies of a number of strips across the reef indicate they contribute from 40 to 90 percent of the bulk of the reef. Laboratory studies of numerous hand specimens of the beach rock show about the same percentage of algal material. (See pls. 188, 189.) The distribution of the algae in the well samples is shown in the following table.

Occurrence of Calcareous Algae

	Present reef		Beach rock	Drill holes [Depths in feet]																												
	Lithothamnion ridge	Reef flat		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
Lithothamnion bikiniensum Johnson, n. sp																											X				
cf. *L. laminithallum* Johnson and Ferris																	X														
Mesophyllum aff. *M. prepulchrum* Johnson and Ferris																	X														
Lithophyllum oblongum Johnson, n. sp																							X	X	X	X					
kladosum Johnson, n. sp																									X	X	X				
cf. *L. fortunatum* Lemoine																												X			
profundum Johnson, n. sp																								X	X	X					
sp. A																X	X														
sp. B																	X														
sp. C							X																								
sp. D																X	X														
cf. *L. parvicellum* Johnson and Ferris																X															
Goniolithon frutescens Foslie		X	X																												
cf. *G. frutescens* Foslie																							X								
aff. *G. frutescens* (Foslie)								X																							
Porolithon craspedium (Foslie) Foslie	X		X																												
gardineri (Foslie) Foslie	X		X	X	X	X	X	X																							
marshallense Taylor	X		X	X	X	X	X	X																							
acquinoctiale (Foslie)	X	X	X																												
onkodes (Heyd) Foslie	X	X	X																												
Lithoporella melobesioides (Foslie) Foslie											X?																				
Amphiroa sp																	X														
Halimeda sp																							X								

The algal specimens belong to either of two groups, the red corallines and the green *Halimeda.*

The coralline algae are classified and subdivided as follows:

Class Rhodophyta
Family Corallinaceae
Subfamily Melobesieae
Genus *Archaeolithothamnion*
Genus *Lithothamnion*
Genus *Mesophyllum*
Genus *Lithophyllum*
Genus *Tenarea*
Genus *Goniolithon*
Genus *Porolithon*
Genus *Lithoporella* (Melobesia)
Subfamily Corallineae
Genus *Amphiroa*
Genus *Arthrocardia*
Genus *Corallina*
Genus *Jania*
Class Chlorophyta
Family Codiaceae
Genus *Halimeda*.

SYSTEMATIC DESCRIPTIONS

Class RHODOPHYTA
Family CORALLINACEAE
Subfamily MELOBESIEAE
Genus LITHOTHAMNION Philippi

Lithothamnion bikiniensum Johnson, n. sp.

Plate 190, figure 5

Crustose. Several thalli 0.009–0.06 mm thick superimposed to form a crust. Hypothallus thin, of curved rows of irregular rectangular cells measuring 0.012–0.022 (37) mm by 0.01–0.0018 mm. Perithallus composed of rectangular cells arranged in vertical rather than horizontal rows. Growth zones indistinct. Vertical partitions more strongly developed and continuous than the horizontal ones. Cells measure 0.011–0.023 mm long and 0.01–0.013 mm wide. Conceptacles unknown.

Age—Early Miocene.

Location.—Hole 2B, depth 2,410 feet, Bikini island.

Remarks.—This species belongs to the same group of encrusting Lithothamnium as *L. aggregatum* Lemoine; *L. roveretori* Airoldi, and *L. laminasium* Howe. All these are characterized by developing crusts formed of many superimposed thin thalli. Each thallus has a thin hypothallus with a more strongly developed perithallus.

Among previously described species the one closest to this is *L. aggregatum* Lemoine from the Oligocene of Algeria. However, *L. bikiniensum* has somewhat larger cells. Without a knowledge of the conceptacles, it seems wise to consider it as a different species.

Holotype slide USNM 51408.

Lithothamnion cf. L. laminithallum Johnson and Ferris

Plate 190, figure 7

Lithothamnion laminithallum Johnson and Ferris, 1950, Bernice P. Bishop Mus. Bull. 201, p. 12–13, pl. 9 A, B, E.

Fragments of thick crust probably a nodular mass. Consists of many superimposed thalli. Each thallus thin, composed of rows of cells measuring 11–15μ by 8–13μ.

Age.—Miocene.

Locality.—Hole 2A, depth, 1,320 feet.

Remarks.—Known only from several small fragments. The growth habit, appearance of tissue, and cell dimensions are very close to *L. laminithallum* described by Johnson and Ferris from the Miocene of Lau, Fiji Islands.

Genus MESOPHYLLUM Lemoine

Mesophyllum aff. M. prepulchrum Johnson and Ferris

Plate 191, figure 8

Mesophyllum prepulchrum Johnson and Ferris, 1950, Bernice P. Bishop Mus. Bull. 201, p. 15, pl. 5 A, B.

Thallus crustose or nodular with short stubby projections. Tissue shows strongly developed growth zones, each formed of crescentic layers. Cells of lower layers of each zone tend to be longer than in the upper layers of the zone. Cells rectangular, measuring 23–26μ by 12–14μ. Around margins of branches appears a perithallus of smaller nearly square cells, 11–14μ by 8–11μ. Conceptacles unknown.

Age.—Miocene.

Locality.—Hole 2A, depth 1,340 feet.

Remarks.—Represented by only one fragment. In appearance, growth habit, and cell dimensions, the tissue resembles that of *M. prepulchrum* except this specimen shows a better development of a marginal perithallus on the branch than was observed in the specimens from the Miocene of the Fiji Islands.

Genus LITHOPHYLLUM Philippi

Lithophyllum oblongum Johnson, n. sp.

Plate 191, figures 1–3

A branching form which develops large fairly long branches. The tissue consisted of a medullary hypothallus surrounded by a narrow marginal perithallus. The hypothallus formed of regular, arched rows of rectangular cells. Both the horizontal partitions (between the rows of cells) and the longitudinal partitions (between the cells) distinct. Cell measurements from numerous rows in three specimens tabulated below.

Specimen	Medullary hypothallus	Perithallus
	(*in* μ)	(*in* μ)
85 (b)	42–45 by 9–20	9–13 by 8–13.
85	36–44 by 10–19	10–14 by 8–13.
91	40–42 by 9–18	9–13 by 9–14.
Extremes	36–45 by 9–20	9–14 by 8–14.

Conceptacles unknown.

Age.—Miocene.

Locality.—Hole 2B, depths 2,040–2,350 feet.

Remarks.—This species is very close to *L. quadrangulum* Lemoine var. *welschi* (Lemoine, 1939, p. 96) but appears to have relatively narrower cells in both the hypothallus and perithallus. Without a knowedge of the conceptacles of the two forms, it is impossible to say whether they belong to the same species. *L. quadrangulum* is known from beds ranging in age from Eocene to Miocene and from many localities in France, Spain, and Algeria. Mme. Lemoine (1939) mentions a fragment from the Miocene of Persia. This unfortunately consists of only a fragment of hypothallus with much wider cells, 37–50μ by 10–30μ. Under the circumstances it seems wise to call this a new species, while recognizing a close relationship to *L. quadrangulum.*

Holotype, USNM 51399.

Lithophyllum kladosum Johnson, n. sp.

Plate 192, figures 1–8

Fragments of a strongly branching form with long, relatively thin branches containing a well-developed medullary hypothallus and a very thick marginal perithallus. Hypothallus of gently arched, wavy rows of long rectangular cells. Horizontal partitions irregular and not much stronger than the longitudinal. Perithallus built of short layers of squarish cells nearly perpendicular to the layers of the hypothallus. The cells show a considerable range in size, especially in different rows in other parts of the same specimen. The following table shows the results of measurements of a number of rows on a series of specimens.

Specimen	Medullary hypothallus	Perithallus
	(*in* μ)	(*in* μ)
89	36–54 by 10–15	16–21 by 10–14.
90 (a–1)	30–61 by 11–12	11–14 (18) by 12–19.
90 (a–3)	27–50 by 10–19	
90 (b–2)	41–54 by 9–16	11–16 by 13–19 (23).
91 (a–3)	32–43 by 9–17	13–20 by 11–15.
91 (d–2)	37–50 by 9–18	11–15 by 10–16.
92 (a–1)	31–52 by 10–15	10–16 by 8–14(19).
92 (a–2)	27–50 by 7–17(19)	11–19 by 10–15.
Extremes	27–61 by 7–19	10–21 by 8–23.
Average	36–52 by 9–16	12–18 by 10–16.

Conceptacles unknown.

Age.—Early Miocene.

Location.—Hole 2B, depths 2,205 and 2,455 feet.

Remarks.—This form differs considerably from any previously described Tertiary species. Apparently it is a strongly branching form with long, thin branches. The perithallus of the branches is unusually thick compared to the medullary hypothallus. The cells of the hypothallus are considerably longer than the average of the genus. It suggests a *Goniolithon* but lacks the (heterocyst) groups of large cells scattered through the tissue. The cell dimensions closely resemble material described by Lignac-Grutterink (1943, p. 290) from the Miocene of Indonesia under the name *Lithophyllum fosliei* (Heydr) Heydr. However, she does not give an illustration and does not mention whether it is a crustose or branching form. Obviously she considers it the same as the modern *Goniolithon fosliei* (Heydr) Foslie. This, however, is not only a true *Goniolithon* with heterocysts but also is stated to form thick crusts without branches; consequently, it differs from our form in those respects.

A number of fragments of this form were obtained from sample 89. Holotype, USNM 51396.

Lithophyllum cf. L. fortunatum Lemoine

Lithophyllum fortunatum Lemoine, 1928, Inst. Catalaña de Historia Natural. Bull. 2d ser., v. 8, p. 102–103.

Specimen consists of a fragment of a thick branch or mammilated crust. It consists mainly of medullary hypothallus. The perithallus worn off except on one corner.

Perithallus consists of rectangular cells regularly arranged in well-defined vertical and fairly good horizontal rows. Cells measure 0.018–0.037 mm long and 0.01–0.019 mm wide. Hypothallus cells in short horizontal rows. Between the hypothallus and perithallus, they curve sharply. Hypothallus cells measure 0.016–0.025 (36) mm long and 0.010–0.015 mm wide. Conceptacles unknown.

Age.—Early Miocene.

Locality.—Hole 2B, depth 2,503 feet.

Remarks.—The cell dimensions and general features approximate the form described by Lemoine (1928 b) from the Miocene of Spain. Without the conceptacles it is impossible to be sure they belong to the same species, but the tissue is so similar that they are tentatively put together.

Lithophyllum profundum Johnson, n. sp.

Plate 191, figures 5 to 7

Thallus branching, probably relatively long and slender. Medullary hypothallus medium-wide with strongly arched rows of cells. The cell rows slightly irregular in detail. In center the cells large and rectangular, near edges they become rapidly smaller. Cell size 0.027–0.041 mm long and 0.011–0.019 (21) mm wide. The perithallus of only medium width, composed of short rows of cells nearly perpendicular to the margin with poorly differentiated growth zones. Cells nearly

square, measuring 10–16μ long and 9–15μ wide. Conceptacles unknown.

Age.—Early Miocene.

Locality.—Hole 2B, depth 2,110–2,310 feet.

Remarks.—This species is close to *L. oblongum* and *L. quadrangularium* but differs in having more strongly arched, crescent-shaped rows of the medullary hypothallus and slightly different cell dimensions.

Holotype, USNM 51402.

Lithophyllum species A

Plate 190, figures 1 and 2

Numerous fragments which indicate a crustose form with mammillae or short stubby branches. Basal hypothallus apparently poorly developed, thin, and of small irregular cells. The bulk of the tissue of rectangular cells arranged in rows. Usually there are strongly developed growth zones. Crusts irregular and may consist of a number of superimposed thalli. The mammillae or branches show arched growth zones. A considerable range of cell dimensions, not only in the same growth zone but even in a single row. A summary of cell measurements of 17 specimens given in the following table. Conceptacles unknown.

Cell measurements

Specimen	Hole	Depth (in feet)	Perithallus (in μ)
51b	2A	1, 225	17–24 by 8–14
51b(2)	2A	1, 225	16–29 by 8–14
51d	2A	1, 225	19–26 by 8–15
51e(1)	2A	1, 225	16–19 by 8–14
51e(2)	2A	1, 225	15–28 by 6–12
51b	2A	1, 225	16–29 by 8–14
51b(2)	2A	1, 225	17–24 by 8–14
37	2A	1, 225	18–22 by 9–14
37b			17–22 by 6–10
41a	2B	1, 245	17–25 by 8–14
41e(1)	2B	1, 245	16–19 by 8–11
41e(3)	2B	1, 245	15–22 by 8–11
75a(2)	2B	1, 310	16–20 by 8–11
56	2A	1, 310	19–28 by 8–14
39c	2A	1, 340	18–28 by 7–12

Age.—Miocene.

Locality.—Holes 2A and 2B, depths 1.225–1,340.

Remarks.—This form was the most abundant of all found in the well samples. It is represented by numerous fragments, all somewhat worn and abraded. Practically all show only the central portion of the tissue. None show conceptacles. Without a knowledge of the conceptacles, basal hypothallus, and the outer margins of the tissue, it does not seem wise to apply a specific name.

Lithophyllum species B

Fragment of a thick crust or central portion of a large branch. Consists of long, narrow, rectangular cells arranged in regular, gently arched rows. Cells measure 26–41μ by 11–14μ. Basal hypothallus and marginal perithallus missing. Conceptacles unknown.

Age.—Miocene

Locality.—Hole 2B, depth 1,320 feet.

Remarks.—Known only from one badly worn fragment.

Lithophyllum species C

Plate 190, figure 6

Fragments of dense tissue composed of slightly wavy layers of rectangular cells. Both horizontal and vertical partitions well developed, but the horizontal partitions thickest. Cells measure 12–23μ by 6–11μ. Basal hypothallus and conceptacles unknown.

Age.—Pleistocene or Recent.

Locality.—Hole 2A, depth 420.

Remarks.—The texture and general appearance of the tissue suggest a species of *Porolithon*, but the specimen does not show any heterocrysts. Of the described species of *Porolithon*, *P. aequinoctiale* is closest in cell dimensions to this specimen but has slightly smaller cells. *P. gardineri* has slightly larger cells. The two species differ mainly in size of conceptacles. This specimen shows no conceptacles.

Lithophyllum species D

Plate 190, figures 3 and 4

Fragments of thick branches or mammillae. Basal hypothallus unknown. Tissue consists of irregular layers of rectangular cells arranged in growth zones. Horizontal partitions between layers much more pronounced than the transverse. Cells measure 13–18μ by 7–13μ. Conceptacles unknown.

Age.—Miocene.

Locality.—Hole 2A, depths 1,285 and 1,340 feet.

Remarks.—Represented only by several small fragments.

Lithophyllum cf. L. parvicellum Johnson and Ferris

Lithophyllum parvicellum Johnson and Ferris, 1949, Jour. Paleontology, vol. 23, no. 2, p. 195, pl. 39, fig. 3.

Fragments of an encrusting form. Hypothallus missing or badly worn. Perithallus of small rectangular cells, measuring 9–12μ by 9–11μ, arranged in regular rows. Conceptacles unknown.

Age.—Miocene.

Locality.—Hole 2B, depth 1,245 feet.

Remarks.—Only several badly worn fragments obtained. Appearance of tissue and cell dimensions re-

semble *L. parvicellum* described by Johnson and Ferris from western Java.

Genus GONIOLITHON Foslie

Goniolithon frutescens Foslie

Goniolithon frutescens Foslie, 1900, Calcareous Algae Funafuti: K. Norske Vidensk. Selsk. Skr., p. 9.
Foslie, 1907, Algologiske Notiser III: K. Norske Vidensk. Selsk. Skr., p. 18.
Foslie, 1907, Linnean Soc. London Trans. 5, pt. 2, p. 186.

Plant bushy with long delicate and fragile branches. Thallus includes a distinct, wide perithallus of somewhat irregularly disposed, rectangular cells. These are arranged in radial rows but do not form layers. Cells 0.013–0.023 mm long and 0.011–0.018 mm wide. Large, angular to rounded cells 0.022–0.031 mm in diameter scattered through the perithallus. Medullary hypothallus broad, compact, regular layers of cells 0.022–0.034 mm long and 0.015–0.021 mm wide. Conceptacles 0.0300–0.800 mm wide, 0.070–0.250 mm high.

Age.—Recent.

Remarks.—Common with corals on the inner portion of reef flats. Many fragments in the beach rock especially along the northern side of Bikini island.

Material attributed to this species, but without the large cyst cells, has been reported from rocks as old as Miocene in the Malayan Archipelago. Fragments belonging very close to this species, but not quite identical with it, were obtained from drill hole 2A at a depth of 475 feet. This specimen is described below.

Goniolithon cf. G. frutescens Foslie

Specimen a fragment of a short, thick branch, consisting mainly of the medullary hypothallus with only a little of the perithallus left along the abraded edges. Hypothallus of slightly wavy, arched layers of cells, which measure 0.021–0.032 mm long and 0.010–0.014 mm wide. Perithallus cells 0.016–0.019 mm long and 0.008–0.010 mm wide. Conceptacles unknown.

Age.—Early Miocene.

Location.—Hole 2B, depth 2,040 feet.

Remarks.—Our specimen consists essentially of medullary hypothallus, with nearly all the marginal perithallus worn off. Only a few rows of perithallus cells remain on one edge. The character of the tissue and the cell dimensions closely resemble the medullary hypothallus of the modern *Goniolothon frutescens.* In the absence of perithallus it is impossible to tell if the small groups of large cells characteristic of *Goniolithon* occur. The Bikini specimen certainly fits the description of Miocene material from the Malayn Archipelago attributed to this species of Lignac-Grutterink (1943, p. 292), but unfortunately is not illustrated in her report.

Goniolithon aff. G. frutescens Foslie

Plate 191, figure 4

A fragment of a branching form containing a well developed medullary hypothallus and a moderately thick marginal perithallus. Hypothallus of gently arched, fairly regular rows of rectangular cells 35–40μ by 9–20μ (24μ). Horizontal partitions as strong or stronger than the longitudinal partitions. Perithallus composed of longitudinal layers each built of short rows of nearly square cells measuring 10–14μ by 10–15μ. Conceptacles unknown.

Age.—Pleistocene?

Locality.—Hole 2A, depth 475–495 feet.

Remarks.—Only one fragment was obtained of this species. The tissue in general appearance and cell dimensions resembles the modern *Goniolithon frutescens* Foslie found on the flats of the reef at Bikini Atoll except for the occasional very large cells scattered through the tissue which characterize the modern Goniolithons. It closely resembles the description of the fossils described from Indonesia by Lignac-Grutterink (1943, p. 292) under the name of *Lithophyllum frutescens* Foslie. To date the scattered large cells characteristic of species of *Goniolithon* have been observed only in specimens of modern material or of questionable late Pleistocene age. Possibly it is a modern development, and material such as the specimen under discussion represents the ancestral form.

Genus POROLITHON Foslie

Porolithon craspedium (Foslie) Foslie

Plate 193, figures 1 to 5; plate 194, figure 5

Lithophyllum craspedium Foslie, 1900, Kgl. Norske Vidensk. Selsk. Skr. No. 5, p. 26 [1899].

Plants cushion-shaped, rounded, or flattened. Extremely massive and solid throughout; branches seldom more than ridges. Tissue shows a moderately thick perithallus not sharply demarked from the medullary hypothallus. Perithallus composed of cells in radial rows and distinct layers. Cells measure 0.007–0.012 mm long and 0.008–0.010 mm wide. Heterocyst cell groups common in the perithallus, with 6 to 12 cells in a cluster. Heterocyst cells 0.015–0.021 mm high and 0.009–0.017 mm wide. Medullary hypothallus more compact, less porous than perithallus; cells in fairly regular horizontal and less regular longitudinal rows. Cells measure 0.009–0.013 (19) mm long and 0.006–0.011 mm wide. Conceptacles, numerous oval, 0.170–0.250 mm long and 0.085–0.019 mm high. Pore small.

Age.—Recent.

Remarks.—The most massive of all modern forms and grows only in exposed parts of reef. Rare in the beach rock.

Porolithon gardineri (Foslie) Foslie

Plate 195, figures 3 and 4; plate 196, figures 1 to 4

Lithophyllum gardineri Foslie, 1907, Algologiske Notiser III: K. Norske Vidensk. Selsk. Skr. p. 30.

Plant crustose at base, developing branches and forming compact cushion-shaped growths toward the top. Tissue of branches includes a moderately thick perithallus surrounding a large medullary hypothallus. This hypothallus dense; cells in fairly regular transverse and longitudinal rows. Cells 0.09–0.030 mm long and 0.009–0.013 mm wide. Perithallus less dense; cells in radial rows, not in distinct layers. Cells 0.0075–0.019 mm long and 0.0095–0.011 mm wide. Heterocyst cells in groups of 8 to 20 common in the perithallus (usually 4 to 6 in row in a section). Heterocyst cells measure 0.028–0.035 mm high and 0.0095–0.018 mm wide. Conceptacles oval, 0.110–0.152 mm wide and 0.068–0.110 mm high.

Age.—Pleistocene and Recent.

Remarks.—This is probably the most common species along the reef margin (*Lithothamnion* ridge) at Bikini Atoll and adjoining atolls. It is abundant in the beach rock and fragments were recognized in the well cores and samples at depths from 35 to 440 feet.

Porolithon marshallense Taylor

Plate 197, figure 1

Porolithon marshallense Taylor, 1950, Plants of Bikini and other northern Marshall Islands, Mich. Univ. Press, p. 128–129, pls. 67, 76, fig. 1.

Plants large, composed of compact masses of erect, radiating branches. Tissue shows a vaguely delimited wide perithallus and a medullary hypothallus. Perithallus moderately compact; cells in fairly distinct radial rows and in 1-celled layers not too distinct. Cells measure 0.009–0.011 mm long and 0.007–0.010 (15) mm wide. Intercellular fusion with laterally communicating pits common. Heterocysts in groups of 10 to 20 (30), measuring 0.020–0.047 mm high and 0.009–0.015 (18) mm wide. Medullary hypothallus less dense, cell layers less clearly defined. Cells 0.009–0.0011 mm long and 0.007–0.010 mm wide. Conceptacles oval in section, 0.169–0.211 mm wide.

Age.—Pleistocene and Recent.

Remarks.—Common at Bikini Atoll and adjoining atolls. Abundant in the beach rock at Bikini island. Recognized in drill-hole cores and samples down to a depth of 445 feet.

Porolithon aequinoctiale (Foslie)

Lithophyllum aequinoctiale Foslie, 1909, Algologiske Notiser VI, K. Norkse Vidensk. Selsk. Skr., p. 46.

A branching form developing thick clumps. Branch tissue shows a broad medullary hypothallus and a relatively thin, usually poorly defined perithallus. Hypothallus, compact, shows a little zoning, cells in fairly well-defined transverse layers but not in clear longitudinal rows. Cells 0.013–0.022 mm high and 0.009–0.012 mm wide. Perithallus cells not in well-defined layers and usually not clear radial rows. Cells 0.009–0.019 mm long and 0.009–0.010 mm wide. Heterocysts in groups of 16 to 20, cells small, 0.022–0.038 mm high and 0.013–0.022 mm wide. Conceptacles 0.150–0.200 mm wide and 0.100–0.125 mm high.

Age.—Recent

Remarks.—Present in the modern reef in rather protected areas. Recognized in some samples of beach rock. Not recognized in drill-hole samples.

Porolithon onkodes (Heydrich) Foslie

Plate 194, figures 1 to 4

Porolithon onkodes Heydrich, 1897, Deutsche bot. gesell. Ber., Band 15, Heft 7, p. 410.

Plants encrusting. Hypothallus thin, usually containing only 1 to 5 layers of horizontally elongated cells 0.017–0.022 mm long and 0.006–0.010 mm wide. Perithallus often thick; cells in distinct vertical rows; horizontal rows usually not so definite. Cells 0.005–0.011 (21) high and 0.006–0.011 mm wide. Perithallus contains numerous groups of heterocyst cells, 4 to 12 in a row, size 0.007–0.017 mm wide and 0.018–0.034 mm high. Conceptacles numerous, oval to subreniform, 0.125–0.170 mm wide and 0.070–0.085 mm high.

Age.—Recent.

Remarks.—This is the only encrusting *Porolithon* described from the modern algal flora of Bikini Atoll. It is widespread in Bikini Atoll and neighboring atolls. Several fragments were recognized in the beach rock, and a piece closely related if not identical was obtained from drill hole 2A at a depth of 420 feet.

Genus LITHOPORELLA Foslie

This genus shows the simplest structure of any of the Melobesieae. The thallus consists of a single row of long cells.

Only a few specimens belonging to this genus were observed in the Bikini samples. This is rather surprising as the genus is abundantly represented in most collections of Tertiary and Quaternary (Pleistocene) material.

Lithoporella melobesioides (Foslie) Foslie

Plate 197 figures 2 and 3.

Mastophora melobesioides Foslie, 1903, K. Norske Vidensk. Selsk. Aarsber. for Aarsber. for 1902, p. 24.

Mastophora melobesioides Foslie, 1904, Siboga Exped. Mon. 61, p. 75–77, figs. 30–32.

Mastophora (Lithoporella) melobesioides Foslie, 1906, K. Norske Vidensk. Selsk. Skr., nr. 2, p. 27.

Mastophora (*Lithoporella*) *conjuncta* Foslie, 1907, K. Norske Vidensk. Selsk, Skr., nr. 6, p. 30.

Lithoporella melobesioides (Foslie) Foslie, 1909, K. Norske Vidensk. Selsk. Skr., nr. 2, p. 59.

Lithoporella atlantica Foslie, 1909, K. Norske Vidensk. Selsk. Skr., nr. 2, p. 59.

Lithoporella conjuncta Foslie, 1909, K. Norske Vidensk. Selsk. Skr., nr. 2, p. 59.

Lithoporella melobesioides (Foslie) Foslie. Foslie, 1919, Carnegie Inst. Wash. Pub. 291, p. 16–19.

Melobesia (*Lithoporella*) *melobesioides* Foslie. Lemoine, 1939, Mat. pour la Carte geologique de l'Algérie, 1er Sér., Paleont., no. 9, p. 108–110, figs. 78–79.

Lithoporella melobesioides (Foslie) Foslie. Lignac-grutterink, 1943, Geol. mijnb. genootsch. Nederland en Kolonein Verh., jagu 13, p. 292, pl. 2, fig. 8.

Lithoporella (*Melobesia*) *melobesioides* Foslie. Johnson and Ferris, 1949, Jour. Paleontology, v. 23, no. 2, p. 196, pl. 37, figs. 4, 5, and pl. 39, fig. 2.

Thin crustose thallus growing on and over other objects. A number of thalli may develop superimposed on one another.

Normally each thallus is formed of a single layer of cells, although they sometimes thicken around conceptacles and where a thallus branches. The cells are rectangular and larger than in most genera Melobesieae. The cells show great range in size even in a single specimen as the cell layers taper and swell. Cell dimensions: length 32 to 74μ, width 11 to 18μ, average 15 by 51μ. Two small conceptacle scars were observed, measuring 180 by 320μ and 120 by 140μ. These measurements fit well within those of the modern Pacific species.

Locality.—Hole 2A, sample 33.2, depth 800 feet(?).

Subfamily CORALLINEAE

Surprisingly few remains of articulated coralline algae were found in either the beach rock or in the cores and well cuttings in spite of the fact that living representatives (genus *Jania*) were observed a number of times on the reef flat. The only corallines obtained belong to the genus *Amphiroa*.

Genus AMPHIROA Lamouroux (emid. Weber van Bosse)

Amphiroa sp?

Plate 197, figure 4

Two badly frayed fragments attributed to this genus were obtained in rock flakes from one well sample. They are too small and worn to permit specific determination.

Age.—Miocene.

Locality.—Hole 2A depth 1,340.

Class CHLOROPHYTA

Family CODIACEAE

Genus HALIMEDA

The genus *Halimeda* is represented by a number of species. These have been described by William R. Taylor in the report on the botany of Bikini Atoll. Species of *Halimeda* grow in enormous numbers over wide areas of the lagoon bottom at Bikini Atoll. They were observed frequently on the reef flat usually on and between corals in the coral heads which grow so abundantly on the inner portion of the reef flat.

Remains of species of *Halimeda* were observed in a number of samples of beach rock (pl. 189, fig. 6). They are common in well samples obtained between 20 and 100 feet below the surface. One sample from hole 2 at a depth of 38 to 40 feet contained about 20 percent of *Halimeda* fragments. Another sample from a depth of 80 feet in the same boring contained nearly 10 percent of *Halimeda*. A very little material was obtained from depths below 100 feet, however, several well-fossilized fragments were obtained from hole 2, depth 1,900 feet. One of the specimens is illustrated in plate 197, figure 5.

HALIMEDA sp. A

Plate 197, figure 5

This well-preserved piece of a large *Halimeda* leaf is unfortunately too fragmentary to tell the original shape of the entire leaf and to determine the species.

Location.—Hole 2, depth, 1,900 feet.

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PLATES 188–197

PLATE 188

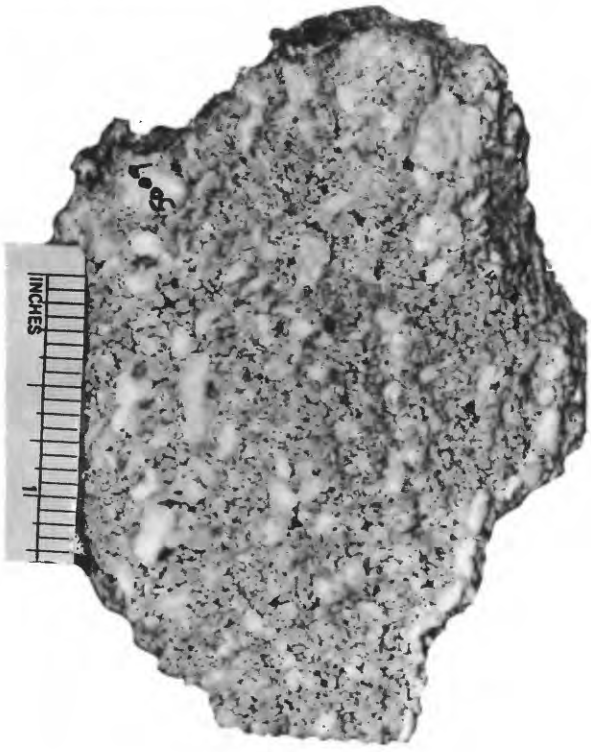
[Figure size indicated on plate]

FIGURE 1. Beach rock composed largely of Foraminifera and algae.

2. Beach rock from a portion of raised reef on the reef platform showing portion of a colony of *Porolithon gardineri* Foslie in position of growth. Space between the algal branches filled mainly with Foraminifera. North shore of Bikini island. USNM 51412.

3. Beach rock composed of fragments of algae (*Porolithon*, *Goniolithon*, and *Halimeda*) and Foraminifera. East end of Bikini island. USNM 51411.

4. Section of beach rock, showing fragments of *Porolithon* (black masses) and several types of Foraminifera. USNM 51413.



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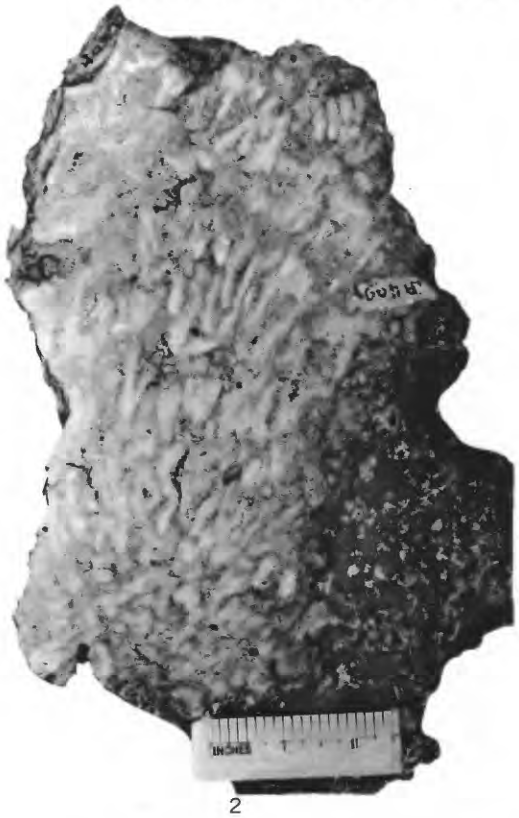

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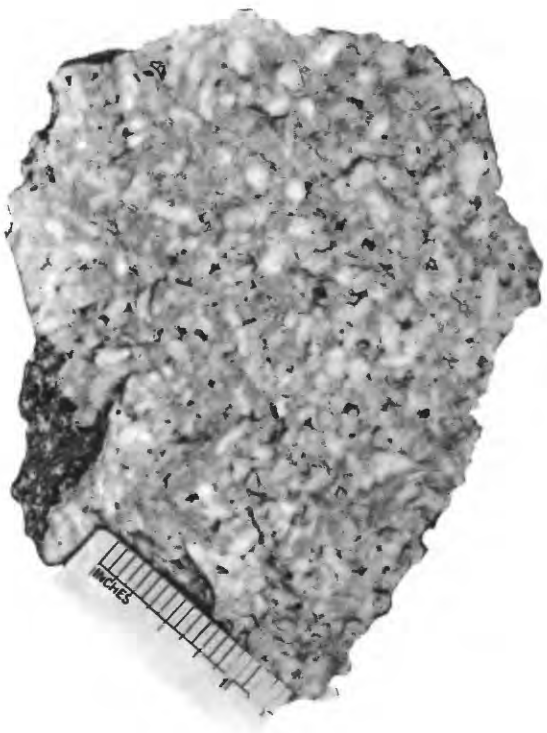

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BEACH ROCK

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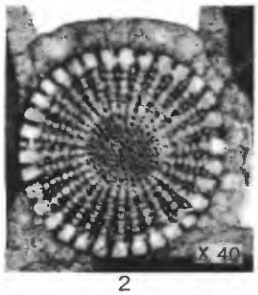

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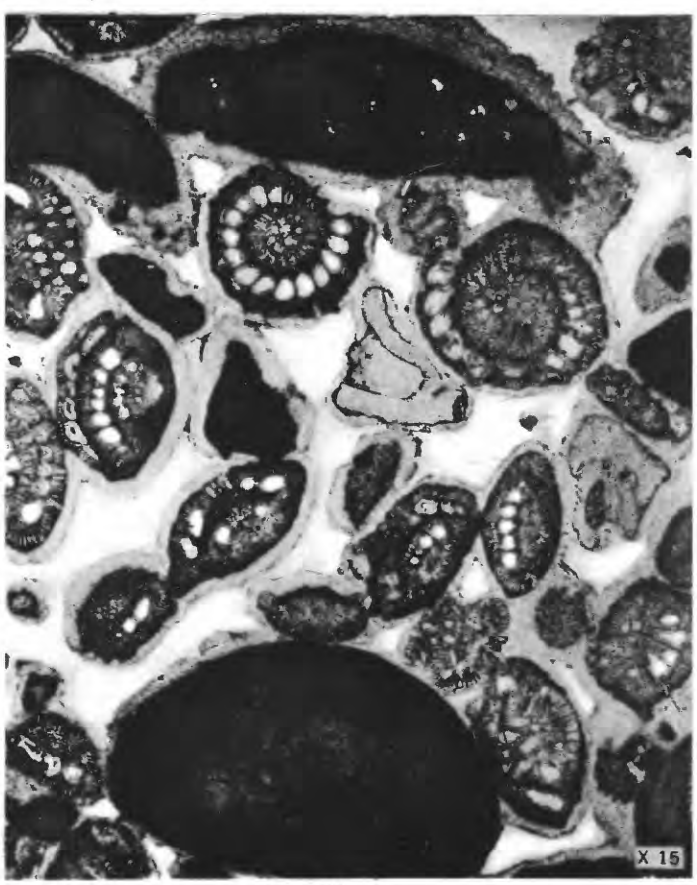

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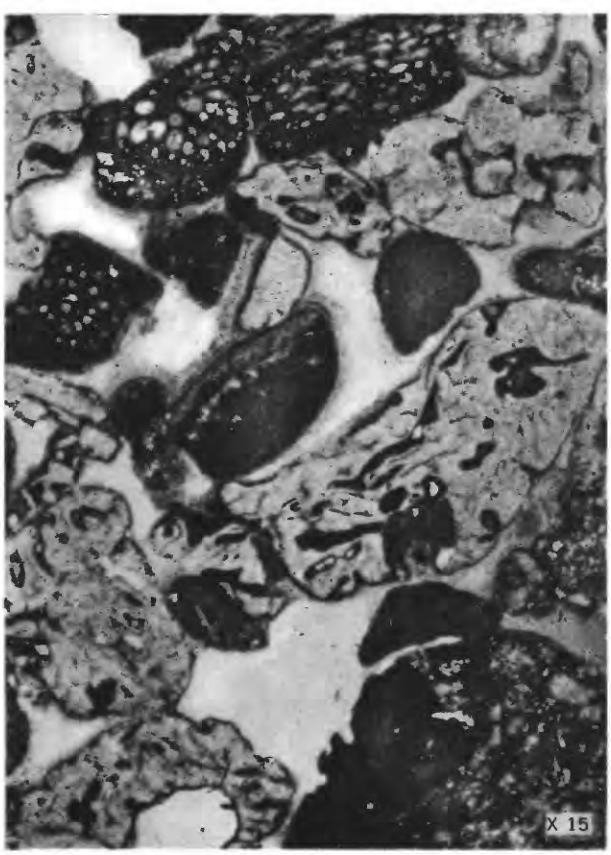

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ORGANISMS FORMING BEACH ROCK

PLATE 189

[Figure size indicated on plate]

FIGURE 1. A foraminifer and an oblique section of an echinoid spine. USNM 51414.

2. Section of an echinoid spine. USNM 51415.

3. Section of a shell fragment.

4. Section of a fragment of coral. USNM 51416.

5. Section of beach rock with Foraminifera, fragments of algae (black), and pieces of coral. USNM 51417.

6. Section of beach rock composed largely of coral (white), coralline algae (black), and *Halimeda* (black with white tubes) USNM 51418.

PLATE 190

[Figure size indicated on plate]

FIGURES 1–2. *Lithophyllum* sp. A (p. 540).
1. A section of the tissue, showing detail of medullary hypothallus. USNM 51405.
2. Another section of hypothallic tissue. USNM 51406.

3–4. *Lithophyllum* sp. D (p. 540).
3. Longitudinal section. USNM 51407.
4. Perpendicular section. USNM 51404.

5. *Lithothamnion bikiniensum* Johnson, n. sp. (p. 538). Detail of medullary hypothallus. Holotype, USNM 51408.

6. *Lithophyllum* sp. C (p. 540). Section of a fragment, showing details of the tissue. USNM 51409.

7. *Lithothamnion* cf. *L. laminithallum* Johnson and Ferris (p. 538.) Detail of a portion of the crust. USNM 51410.

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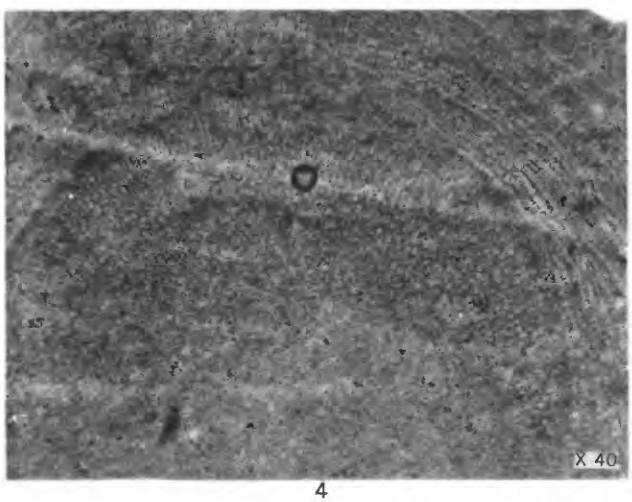

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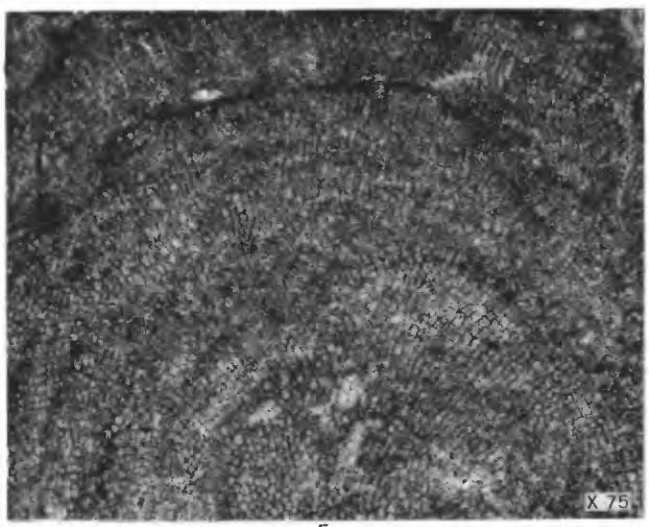

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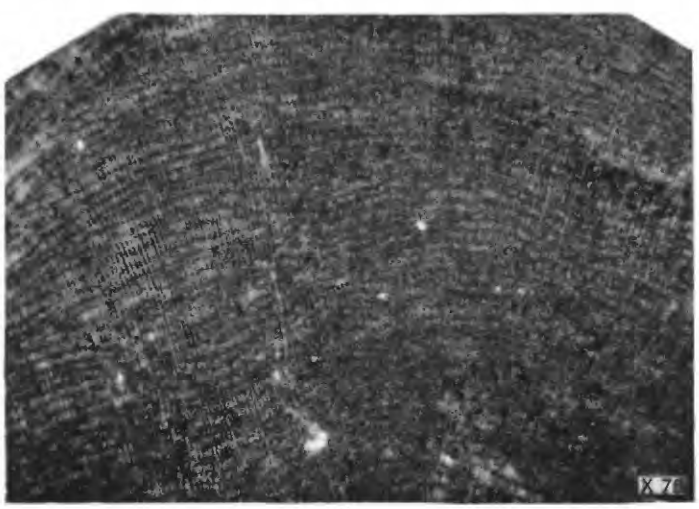

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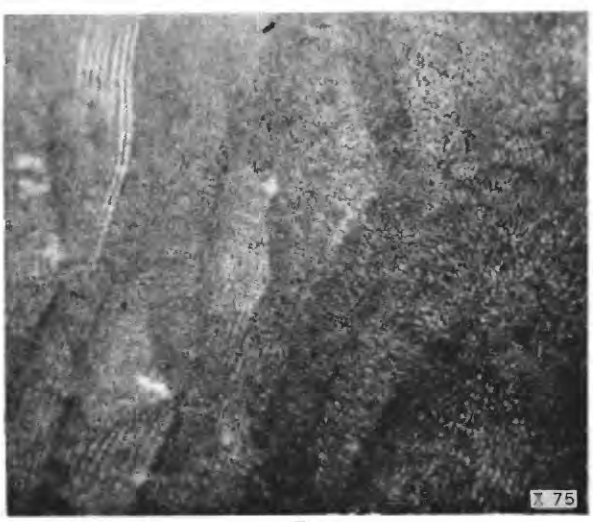

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LITHOPHYLLUM SP. A.; *LITHOPHYLLUM* SP. D.; *LITHOTHAMNION BIKINIENSUM* JOHNSON, N. SP.; *LITHOPHYLLUM* SP. C.; *LITHOTHAMNION* CF. *L. LAMINITHALLUM* JOHNSON AND FERRIS

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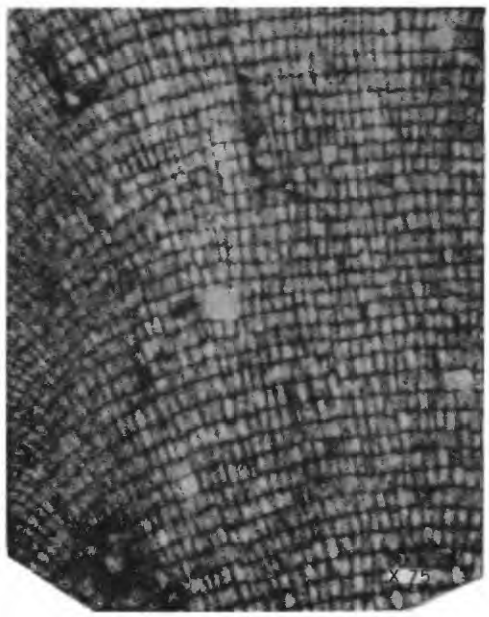

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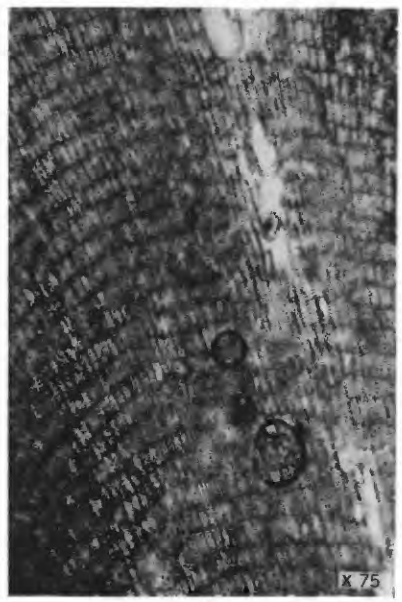

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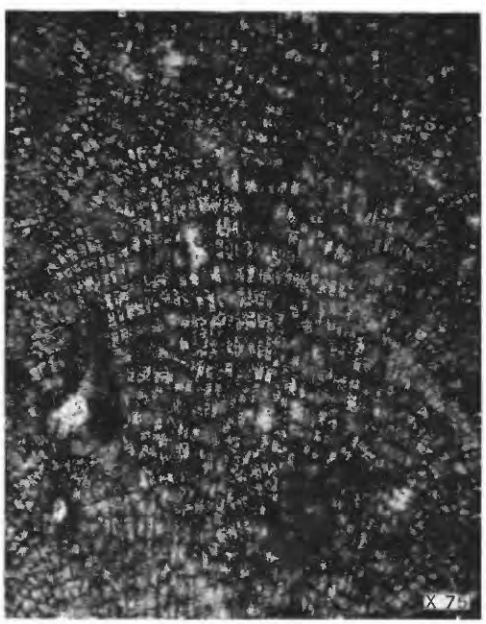

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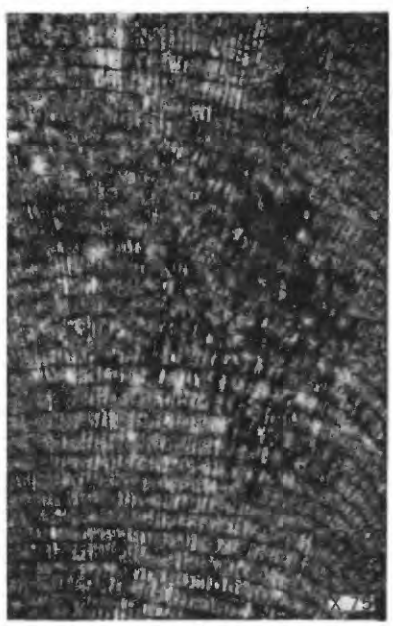

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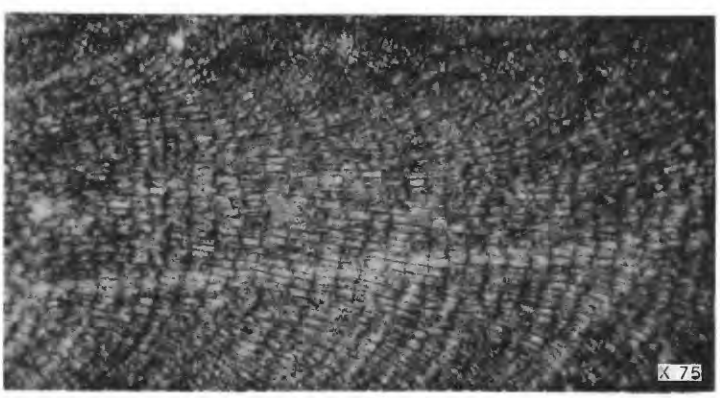

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LITHOPHYLLUM OBLONGUM JOHNSON, N. SP.; *GONIOLITHON* CF. *G. FRUTESCENS* FOSLIE; *LITHOPHYLLUM PROFUNDUM* JOHNSON, N. SP.; *MESOPHYLLUM* AFF. *M. PREPULCHRUM* JOHNSON AND FERRIS

PLATE 191

[Figure size indicated on plate]

FIGURES 1–3. *Lithophyllum oblongum* Johnson, n. sp. (p. 538).

1. A slightly oblique section, showing growth zones. USNM 51400.
2. A longitudinal section. Holotype, USNM 51399.
3. Longitudinal section, showing not only the medullary hypothallus but some of the marginal perithallus. USNM 51394.

4. *Goniolithon* cf. *G. frutescens* Foslie (p. 541).

5–7. *Lithophyllum profundum* Johnson, n. sp. (p. 539).

5. Detail of hypothallus. Holotype, USNM 51402.
6. Hypothallus and boundary with perithallus. USNM 51403.
7. Detail of medullary hypothallus. USNM 51399.

8. *Mesophyllum* aff. *M. prepulchrum* Johnson and Ferris (p. 538) detail of medullary hypothallus. USNM 51404.

PLATE 192

[Figure size indicated on plate

FIGURES 1–8. *Lithophyllum kladosum* Johnson, n. sp. (p. 539).

1. Long section of branch, showing medullary hypothallus and wide perithallus. USNM 51392.
2. Long section of a branch, showing medullary hypothallus and wide perithallus. USNM 51393.
3. Long section of a branch, showing both hypothallus and perithallus. USNM 51392.
4. Long section of a branch giving detail of perithallus. USNM 51395.
5. Section of a branch, showing both hypothallus and perithallus. Holotype; USNM 51396.
6. Detail of medullary hypothallus. USNM 51397.
7. Section through a curved branch. USNM 51398.
8. Detail of boundary between hypothallus and perithallus. USNM 51394.

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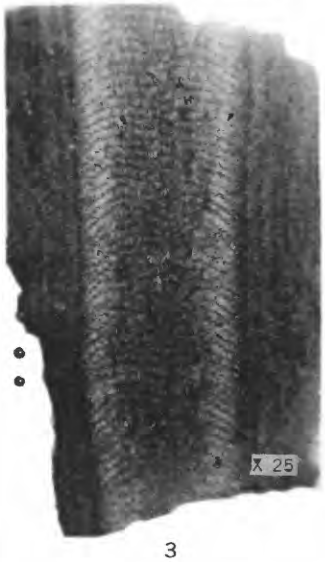

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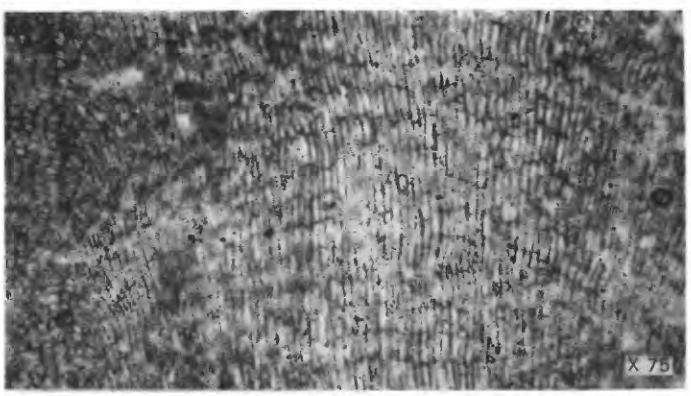

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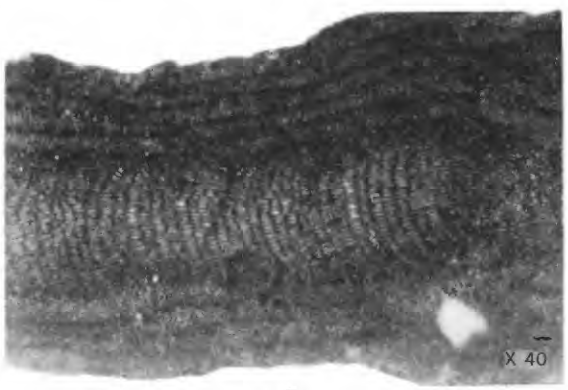

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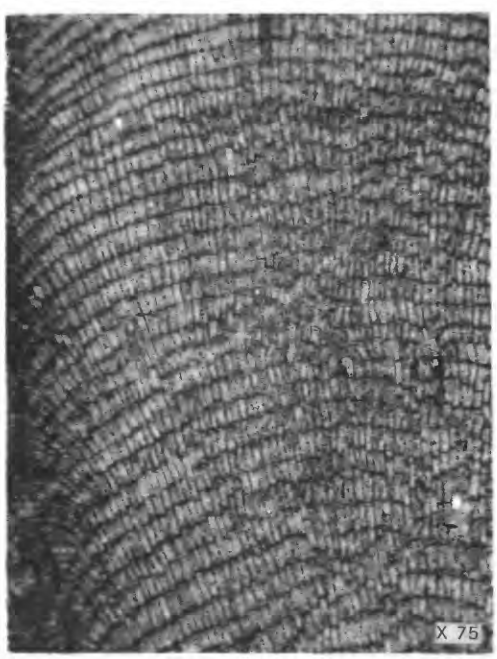

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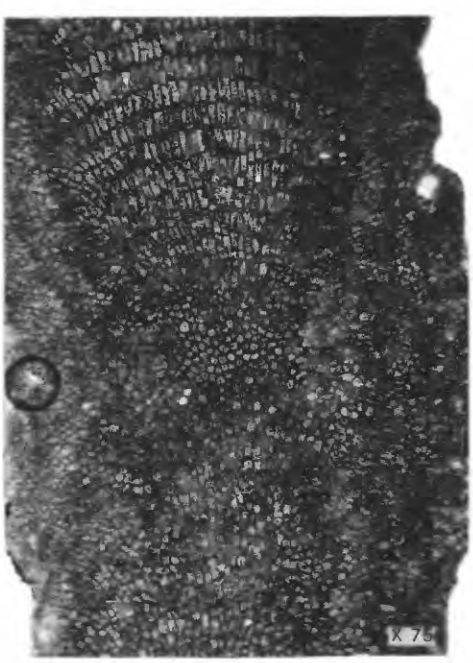

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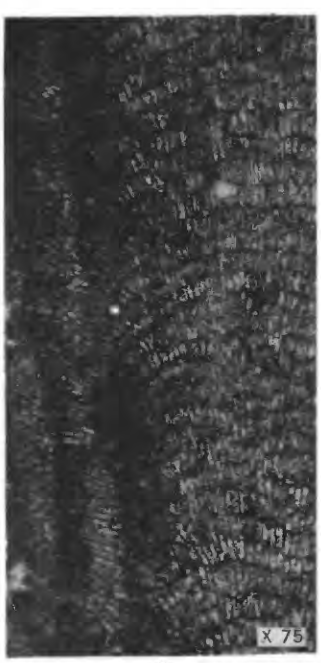

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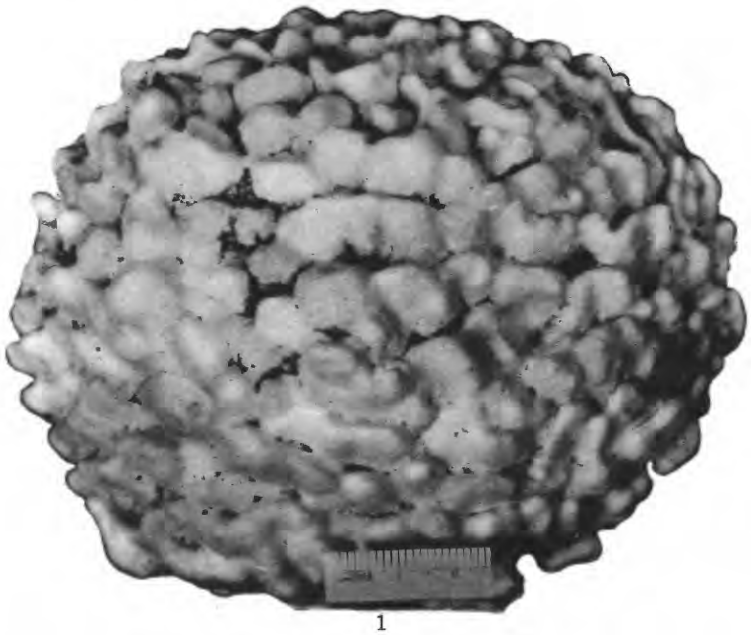
LITHOPHYLLUM KLADOSUM JOHNSON, N. SP.



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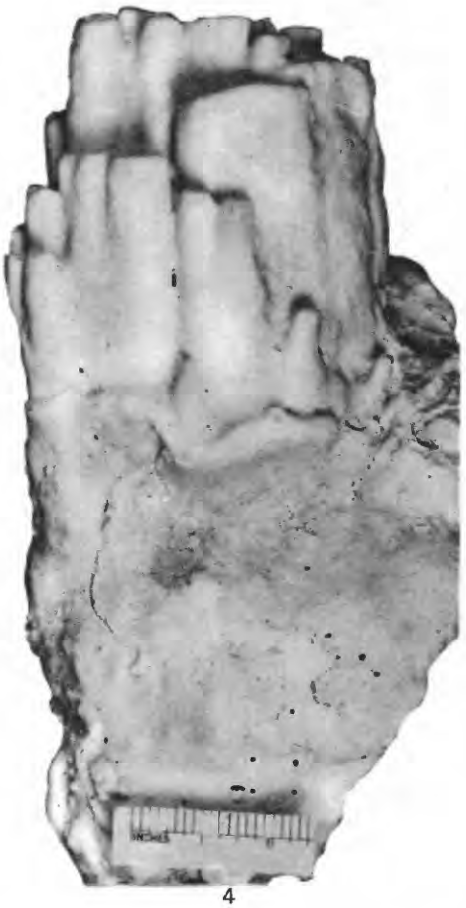

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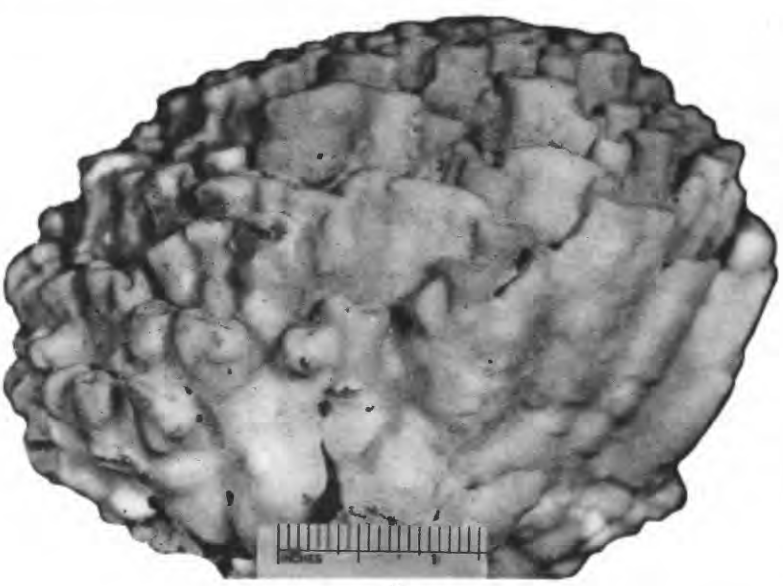

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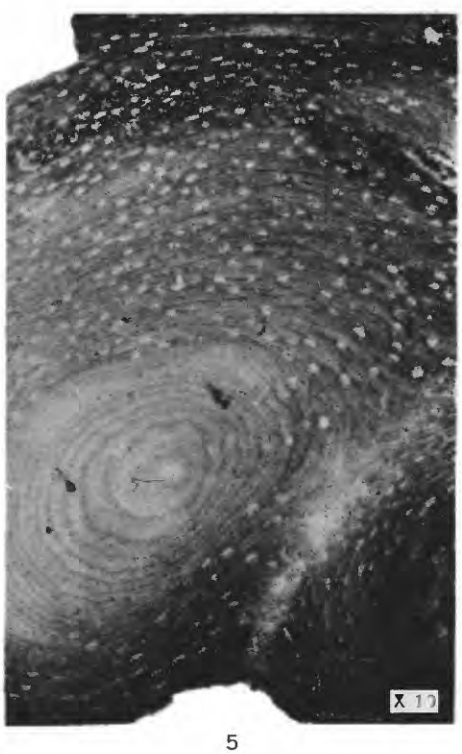

5

POROLITHON CRASPEDIUM FOSLIE

PLATE 193

[Figure size indicated on plate]

FIGURES 1–5. *Porolithon craspedium* Foslie (p. 541).

1. Top view of specimen from Bikini island. USNM 51419.
2. Side view of same specimen. USNM 51421
3. Section of the tissue parallel to growth. USNM 51422.
4. Side view of an elongated specimen. USNM 51420.
5. A section of tissue perpendicular to growth. USNM 51422.

PLATE 194

[Figure size indicated on plate]

FIGURES 1–4. *Porolithon onkodes* (Heydrich) (p. 542).

1. A crust encroaching upon a small specimen of *Porolithon gardineri* Foslie. Top view. Inner portion of *Lithothamnion* ridge. Bikini island.
2. Nodular masses from reef flat about 100 yards inside *Lithothamnion* ridge. Bikini island. USNM.
3. Top view of a crust. Inner side of *Lithothamnion* ridge. Bikini island. Specimen from Taylor Collection, University of Michigan.
4. A section of the tissue, with conceptacles and heterocysts. Slide 46–372, Taylor Collection, University of Michigan.

5. *Porolithon craspedium* Foslie (p. 541). A section of tissue, with heterocysts. USNM 51422.

X 2 1/3

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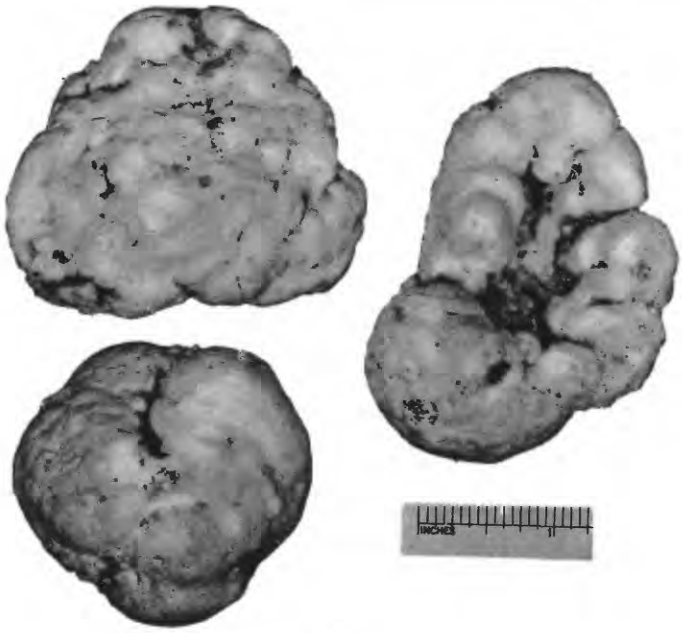

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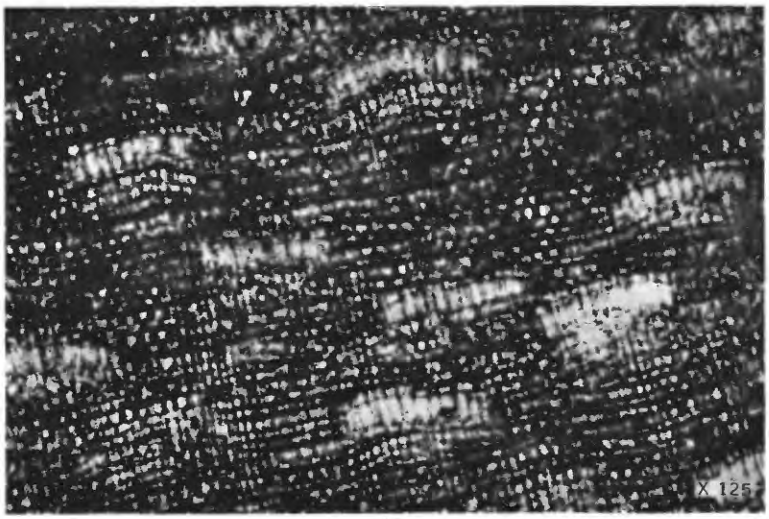
X 2 1/3

3

X 125

4



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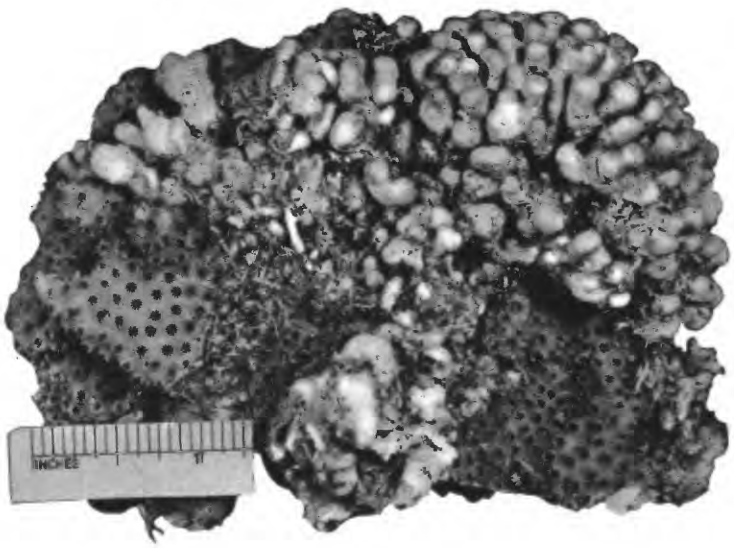
5

POROLITHON ONKODES (HEYDRICH), *POROLITHON CRASPEDIUM* FOSLIE



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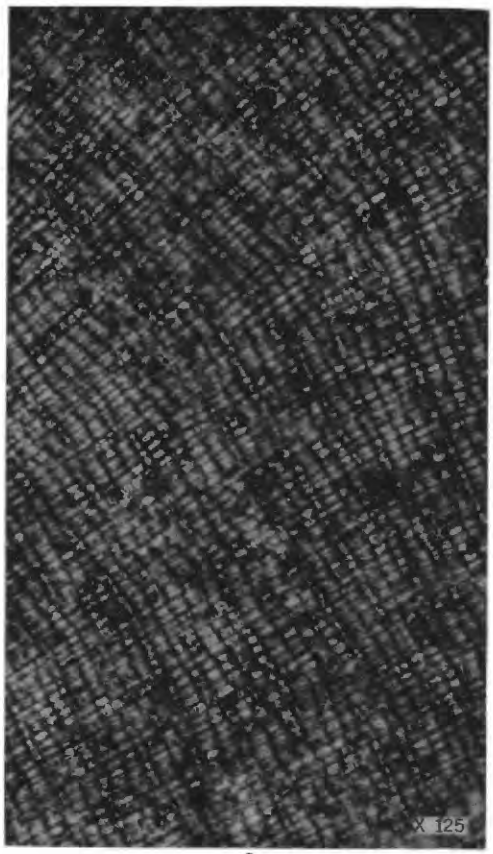

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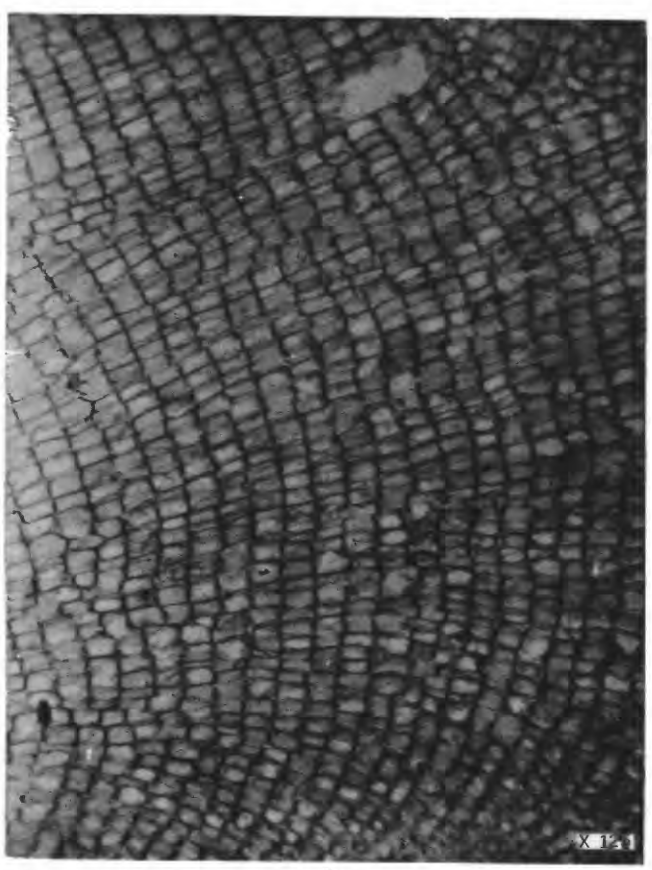

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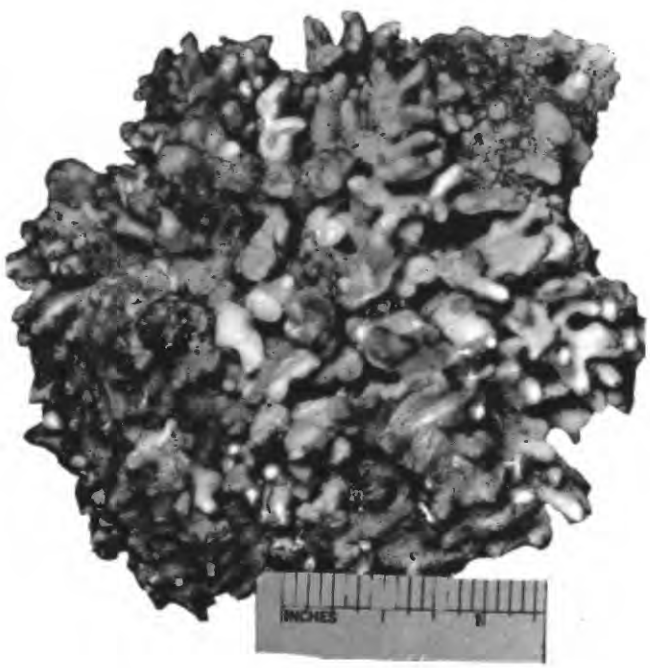


4

GONIOLITHON FRUTESCENS FOSLIE, *POROLITHON GARDINEREI* FOSLIE

PLATE 195

[Figure size indicated on plate]

FIGURES 1–2. *Goniolithon frutescens* Foslie (p. 541).

1. A colony associated with a coral; inner reef platform, Bikini island.
2. A section of tissue.

3–4. *Porolithon gardineri* Foslie (p. 542).

3. Section of tissue. Taylor Collection, University of Michigan. Slide 46–284.
4. A specimen partly overgrown by an encrusting alga probably *Porolithon onkodes* (Heydrich). Inner portion of *Lithothamnion* ridge of reef. Bikini island.

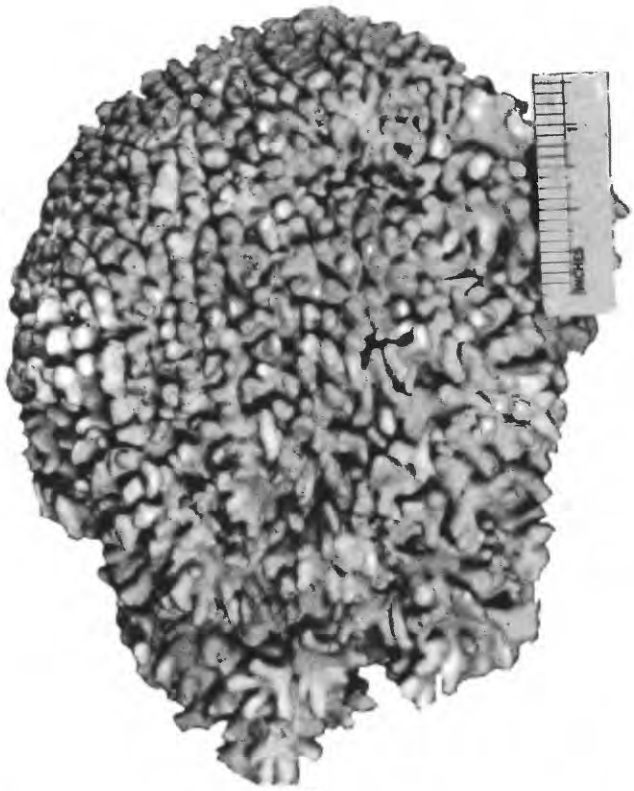
PLATE 196

[Figure size indicated on plate

FIGURES 1–4. *Porolithon gardineri* Foslie. (p. 542).

1. Side view of a small specimen from the *Lithothamnion* ridge, Bikini island.
2. Top view of a colony from the *Lithothamnion* ridge, Bikini island.
3. A longitudinal section of the tissue of a branch, showing medullary hypothallus and the perithallus with groups of heterocysts. Taylor Collection, University of Michigan, slide 46–491.
4. A section of a thick mass, showing irregular growth zones and groups of heterocysts.

1



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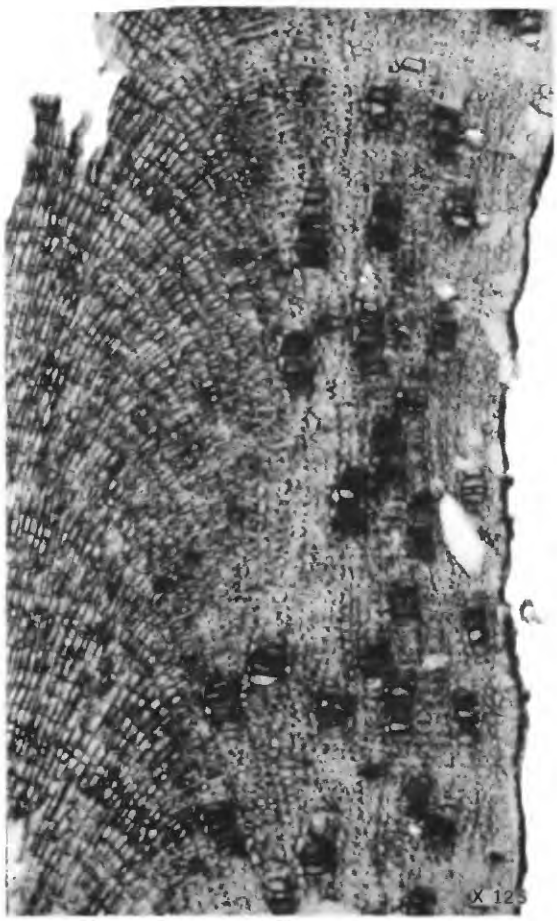

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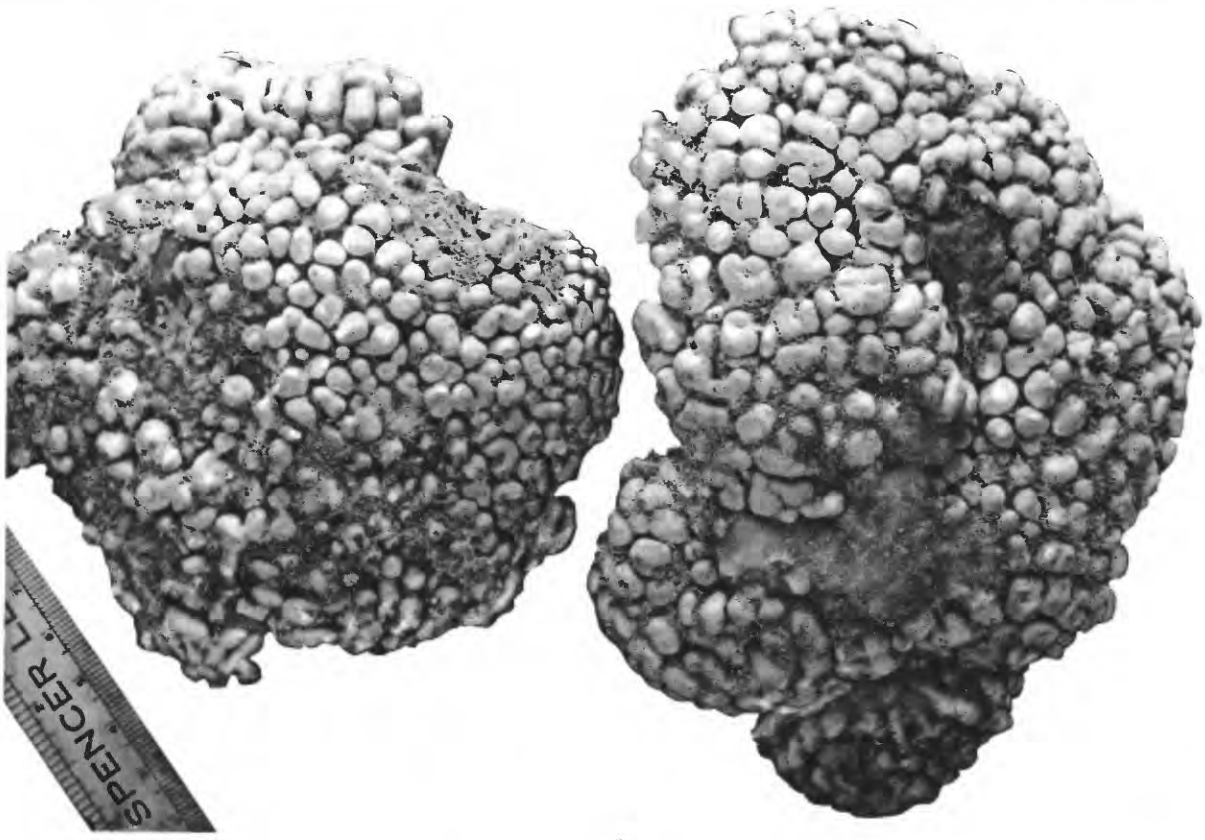
4

POROLITHON GARDINERI FOSLIE



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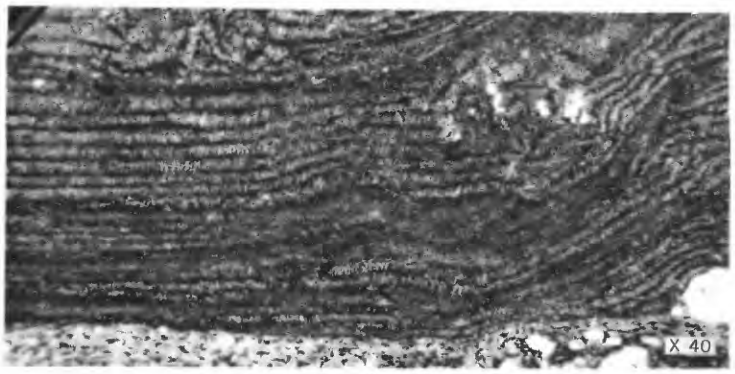

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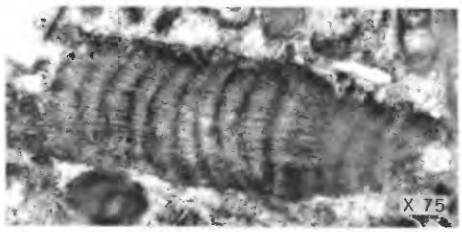

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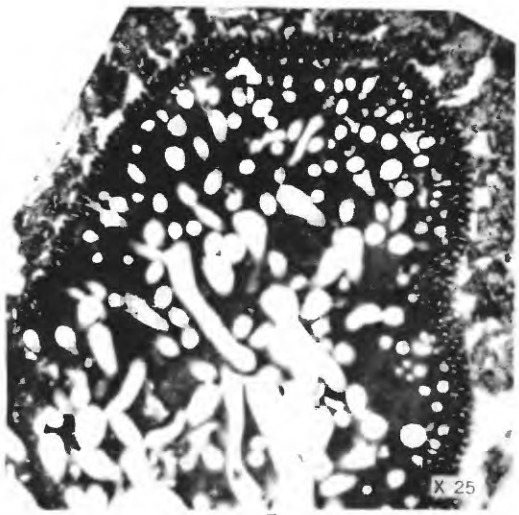

5

POROLITHON MARSHALLENSE TAYLOR, *LITHOPORELLA MELOBESIOIDES* (FOSLIE), *AMPHIROA* SP., *HALIMEDA* SP.

PLATE 197

[Figure size indicated on plate]

FIGURE 1. *Porolithon marshallense* Taylor (p. 542). Two hand specimens. Taylor Collection, University of Michigan.

2–3. *Lithoporella melobesioides* (Foslie) (p. 542).

2. Section of a crust, showing superimposed thalli. USNM 51389.

3. Section of a crust, showing superimposed thalli and scars of two conceptacles. USNM 51389.

4. *Amphiroa* sp. (p. 543). A badly worn fragment. USNM 51390.

5. *Halimeda* sp. (p. 543). A fragment. USNM 51391.

Smaller Foraminifera From Bikini Drill Holes

By RUTH TODD *and* RITA POST

Bikini and Nearby Atolls, Marshall Islands

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-N

Descriptions and illustrations of about 55 species of fossil Foraminifera, including 18 new species

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

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200. Rotaliidae, Globorotaliidae, and Cymbaloporidae.
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294856—54——3

BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

SMALLER FORAMINIFERA FROM BIKINI DRILL HOLES

By RUTH TODD and RITA POST

ABSTRACT

Smaller Foraminifera were studied as loose specimens and in thin sections from 5 holes drilled on Bikini Atoll. The deepest hole reached a depth of 2,556 feet. A few of the Recent forms, present in the upper parts of the holes, are mentioned. Exclusive of the Recent forms, about 55 other species and varieties are described and illustrated, of which 18 species are new, and 8 species and 2 varieties are indeterminate. A composite distribution chart of 60 species and varieties shows several tops of occurrence in the holes, corresponding to the stages as set up on the basis of larger Foraminifera. The hole apparently reached the Miocene at a depth of about 850 feet. The evidence for the top of the Oligocene is not conclusive and it is possible that Eocene was reached. The abundance of miliolid and peneroplid Foraminifera indicates deposition under shallow, warm conditions, probably not more than about 40 fathoms, throughout the entire section.

INTRODUCTION

The holes drilled on Bikini Atoll present a unique opportunity for studying both the age of the sediments underlying a coral atoll and the ecologic conditions under which the sediments were deposited.

Holes 1, 2, and 3, were shallow, drilled to 300, 190, and 118 feet respectively. Holes 2A and 2B were deeper, drilled to 1,346 and 2,556 feet respectively. For two of the shallow holes, species are listed together with notes regarding the changes in ecologic conditions. The two deeper holes were close together and were studied as one well. A distribution chart was constructed, showing the tops of occurrence of the significant species. This chart also includes the significant records from the shallower holes.

In nearly all cases, the cuttings were contaminated from above and thus many species known to be living in the Marshall Islands are found throughout the section. With a few exceptions, these are omitted from study. The reader is referred to Cushman, Todd, and Post, "Recent Foraminifera of the Marshall Islands," chapter H of the present report, for description of these species.

Our work has profited from discussions of our problems with Miss Irene Crespin of the Bureau of Mineral Resources, Canberra, Australia.

SHALLOW DRILL HOLES

Samples from the three shallow holes contain very abundant specimens of *Calcarina spengleri* (Gmelin) from the surface to 95 feet in hole 1, to 95 feet in hole 2, and to 63½ feet in hole 3. At these levels, this large reef-dwelling *Calcarina* is largely if not entirely replaced by *C. hispida* H. B. Brady, a species indicative of lagoon conditions and outer slope conditions to moderate depths. Another reef-dwelling form, *Marginopora vertebralis* Blainville, occurs in abundance at the top and decreases downward, but reappears in abundance at the top of the Miocene. *Baculogypsina sphaerulata* (Parker and Jones), a species characteristic of reefs but not found living in the Marshall Islands, is fairly abundant at 115 and 136 feet. Other species comprising the bulk of the Foraminifera present in the upper parts of the subsurface are *Amphistegina madagascariensis* D'Orbigny, *Heterostegina suborbicularis* D'Orbigny, *Homotrema rubrum* (Lamarck), and encrusting *Carpenteria*. *Rotalia calcar* (D'Orbigny) and *Calcarina delicata* Todd and Post, n. sp., are found as high as 179 and 184½ feet respectively.

Hole 2, situated on the lagoon side of the reef, differs from holes 1 and 3 in containing at the top a very rich foraminiferal fauna typical of the present fauna in Bikini Lagoon, with the addition of abundant worn specimens of *Calcarina spengleri* (Gmelin). This fauna persists to 95 feet. In the cuttings at 121 feet, *Baculogypsina sphaerulata* (Parker and Jones) first appears. In the core from 116 to 137 feet *Calcarina hispida* H. B. Brady is present without *C. spengleri* (Gmelin), corresponding to a similar change in holes 1 and 3. *Rotalia calcar* (D'Orbigny) is found in the core at 179–190′, its highest occurrence. No lists of Foraminifera are given for hole 2.

The combined evidence from the three shallow holes is as follows (from the surface downward):

1. A fauna dominated by *Calcarina spengleri* (Gmelin), indicating reef deposition, from the surface to about 95 feet.
2. A change from *C. spengleri* (Gmelin) to *C. hispida* H. B. Brady, indicating somewhat deeper water conditions (10 fathoms or deeper), below about 95 feet.

3. The occurrence of *Baculogypsina sphaerulata* (Parker and Jones), another reef-dwelling species, between about 115 and 136 feet.

4. The appearance of *Rotalia calcar* (D'Orbigny) and *Calcarina delicata* Todd and Post, n. sp., at about 179 feet.

LISTS OF SPECIES FOUND IN HOLES 1 AND 3

Hole 1

Depth: 300 feet.

Location: 2700 feet from outer reef edge.

Core 42½–53', sample 1–3–1, –1A, B: Consolidated pieces of coral with *Halimeda* and Foraminifera comprising about half the material.

Amphistegina madagascariensis D'Orbigny
Calcarina spengleri (Gmelin)—abundant

Core 53–63½', sample 1–4–1: Fragments of coral and cemented detritus containing *Halimeda* and Foraminifera.

Nonion pacificum (Cushman)—rare
Heterostegina suborbicularis D'Orbigny—rare
Marginopora vertebralis Blainville—common
Amphistegina madagascariensis D'Orbigny—abundant
Calcarina spengleri (Gmelin)—abundant
Anomalinella rostrata (H. B. Brady)—rare
Cibicides lobatulus (Walker and Jacob)—rare

Sample 1–4–2: Fragments of coral and cemented detritus containing Foraminifera and *Halimeda* segments.

Marginopora vertebralis Blainville
Reussella simplex (Cushman)—rare
Amphistegina madagascariensis D'Orbigny
Calcarina spengleri (Gmelin)—abundant
Tretomphalus planus Cushman—rare

Core 63½–74', sample 1–5–1: Fine-grained cemented limestone.

Spirillina sp.—rare
Amphistegina madagascariensis D'Orbigny (young specimen)
Calcarina spengleri (Gmelin)—abundant

Sample 1–5–8: Well cemented limestone. Cavities filled with friable white chalk.

Triloculina terquemiana (H. B. Brady)

Sample 1–5–10: Coral in cemented detritus. Thin section shows *Calcarina spengleri* (Gmelin), *Carpenteria, Homotrema,* and a high percentage of coral.

Elphidium cf. *E. milletti* (Heron-Allen and Earland)—rare
Reussella simplex (Cushman)—rare
Asterigerina sp.
Calcarina spengleri (Gmelin)—abundant

Core 74.5–85', sample 1–6–9: Partly altered coral with *Halimeda* and Foraminifera well cemented.

Amphistegina madagascariensis D'Orbigny—abundant
Calcarina spengleri (Gmelin) (very spiny and fresh looking)—abundant

Sample 1–6–12: Thin section shows many *C. spengleri,* much *Carpenteria,* and some *Homotrema.*

Core 85–95', sample 1–7–2: Coral fragments with some friable material in cavities. Material down to this depth probably accumulated on or near a reef as indicated by the abundance of unworn specimens of *Calcarina spengleri* (Gmelin).

Nonion pacificum (Cushman)
Asterigerina sp.
Calcarina spengleri (Gmelin) (very spiny)
Carpenteria proteiformis Goës

Cuttings about 95': This is the first appearance in the well of *Calcarina hispida* H. B. Brady, a species not found on the reef flats.

Valvulina davidiana Chapman—rare
Triloculina terquemiana (H. B. Brady)
Heterostegina suborbicularis D'Orbigny
Marginopora vertebralis Blainville
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady—rare
Calcarina spengleri (Gmelin)

Cuttings about 105': This seems to be a lagoonal fauna. The presence of *Baculogypsina sphaerulata* (Parker and Jones) may indicate an old reef level nearby.

Valvulina davidiana Chapman
Clavulina angularis D'Orbigny—rare
Hauerina diversa Cushman
Triloculina cf. *T. bassensis* Parr
Triloculina terquemiana (H. B. Brady)
Heterostegina suborbicularis D'Orbigny
Marginopora vertebralis Blainville
Borelis pulchra (D'Orbigny)
Asterigerina sp.
Asterigerina sp.
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady—abundant
Baculogypsina sphaerulata (Parker and Jones)—abundant
Cymbaloporetta squammosa (D'Orbigny)
Tretomphalus planus Cushman?
Cibicides lobatulus (Walker and Jacob)
Planorbulina acervalis H. B. Brady
Homotrema rubrum (Lamarck)

Cuttings about 116':

Textularia conica D'Orbigny—rare
Valvulina davidiana Chapman—rare
Quinqueloculina sulcata D'Orbigny—rare
Heterostegina suborbicularis D'Orbigny—rare
Marginopora vertebralis Blainville—rare
Calcarina hispida H. B. Brady—abundant
Baculogypsina sphaerulata (Parker and Jones)—abundant

Core 126½–137', sample 1–11–1A: Consolidated detritus with white, friable chalk filling the cavities.

Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady—rare

Core 137–158', sample 1–12–2: Piece of coral about 5 inches long with the pores filled with white chalk and *Halimeda* segments.

Elphidium advenum (Cushman)
Heterostegina suborbicularis D'Orbigny
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady
Calcarina spengleri (Gmelin)—as contamination?
Cymbaloporetta bradyi (Cushman)
Globigerinoides sacculifera (H. B. Brady)

Sample 1–12–4: Coral filled with white chalk.

Elphidium advenum (Cushman)
Marginopora vertebralis Blainville
Siphogenerina raphana (Parker and Jones)
Eponides sp.
Poroeponides cribrorepandus Asano and Uchio
Asterigerina sp.
Amphistegina madagascariensis D'Orbigny
Calcarina hipida H. B. Brady—abundant
Calcarina spengleri (Gmelin)—as contamination?
Epistominella tubulifera (Heron-Allen and Earland)
Globigerinoides sacculifera (H. B. Brady)

Core 158½–169', sample 1–13–4: Coral fragment with well cemented detritus.

Heterostegina suborbicularis D'Orbigny

TABLE 1.—*Distribution of smaller Foraminifera in two shallow drill holes*

[Key to Symbols: X=Present R=Rare (?)=Present, probably as contamination from above]

Sample numbers — Hole 1

Species	1-3-1	1-4-1	1-4-2	1-5-1	1-5-8	1-5-10	1-6-9	1-6-12	1-7-2	95 ft	105 ft	116 ft	1-11-1A	1-12-2	1-12-4	1-13-4	1-14-2	1-14-13	1-16-2	1-17-16	1-18-1	1-18-5	1-18-6A	1-18-7	1-19-1	1-19-3	1-20-1	1-21-1	1-21-7	1-22-8	1-22-13	268½ ft	1-23-17	1-24-7
Calcarina spengleri	X	X	X	X		X	X	X	X	X				(?)	(?)																			
Amphistegina madagascariensis	X	X	X	X			X			X	X		X	X	X	X	X	R		X		X	X	X	X	X	X	X	X	X	X	X		X
Marginopora vertebralis		X	X							X	X	R				X		X	X	X		X		X	X	X		X	X	X		X	X	X
Heterostegina suborbicularis		R								X	X	R		X	X	X	X							X										
Homotrema rubrum						X		X			X						X					X		X										
Nonion pacificum		R							X												X	X	X	X										
Anomalinella rostrata		R																																
Cibicides lobatulus		R									X																							
Reussella simplex			R			R																	X											
Tretomphalus planus			R								X																							
Spirillina sp.				R																														
Triloculina terquemiana					R					X	X													X			X							
Carpenteria proteiformis						X		X	R									X			X													
Elphidium cf. *E. milletti*						R																												
Asterigerina sp.						X			X		X				X						X	X		X										
Calcarina hispida										R	X	X	R	X	X										X		X					X		
Valvulina davidiana										R	X	R										X		X								X		
Clavulina angularis											R																							
Clavulina pacifica																																		
Hauerina diversa											X																							
Triloculina cf. *T. bassensis*											X																					X		
Triloculinella labiosa																																		
Spiroloculina angulata																																		
Borelis pulchra											X																							
Baculogypsina sphaerulata											X	X				X																X		
Cymbaloporetta squammosa											X																							
Planorbulina acervalis											X					X																		
Textularia conica												R																						
Quinqueloculina sulcata												R																				X		
Elphidium advenum														X	X																			
Cymbaloporetta bradyi														X																				
Globigerinoides sacculifera														X	X	X						X	X											
Siphogenerina raphana															X																			
Eponides sp.															X																			
Poroeponides cribrorepandus															X									X										
Epistominella tubulifera															X																			
Gypsina vesicularis																X																		
Textularia sp.																		X								X								
Miliolid Foraminifera																		X								X			X				X	
Nonion? sp.																		X																
Borelis? sp.																		X																
Rotalia calcar																		R	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Calcarina delicata																			X			X	X	X										
Triloculina kerimbatica																			X															
Quinqueloculina bidentata																				X														
Discorbis patelliformis																					X													X
Operculina sp.																						X												
Cibicides sp.																						X												
Acervulina inhaerens																						X												
Guttulina sp.																								X										
Globigerina? sp.																								X										
Cymbaloporetta? sp.																													X				X	
Miliolinella sp.																																	X	
Quinqueloculina neostriatula																																		X
Elphidium striatopunctatum																																		X

Sample numbers — Hole 3

Species	3-1-1	3-1-20	3-1-23	3-3-2	3-4-2	3-6-2	3-6-4	3-6-18	3-7-2	3-7-6	3-7-8	3-11-1
Calcarina spengleri	X	X	X	X		X	X	X				(?)
Amphistegina madagascariensis						X				X		
Marginopora vertebralis			X	X				X				
Heterostegina suborbicularis												
Homotrema rubrum	X		X	X	X							X
Nonion pacificum									X			
Anomalinella rostrata												
Cibicides lobatulus												
Reussella simplex												
Tretomphalus planus												
Spirillina sp.												
Triloculina terquemiana												
Carpenteria proteiformis					X				X	X	X	X
Elphidium cf. *E. milletti*												
Asterigerina sp.												
Calcarina hispida												
Valvulina davidiana												
Clavulina angularis												
Clavulina pacifica							X					
Hauerina diversa												
Triloculina cf. *T. bassensis*												
Triloculinella labiosa										X		
Spiroloculina angulata												X
Borelis pulchra												
Baculogypsina sphaerulata												
Cymbaloporetta squammosa												
Planorbulina acervalis												
Textularia conica												
Quinqueloculina sulcata												
Elphidium advenum												
Cymbaloporetta bradyi												
Globigerinoides sacculifera												
Siphogenerina raphana												
Eponides sp.												
Poroeponides cribrorepandus												
Epistominella tubulifera												
Gypsina vesicularis												
Textularia sp.												
Miliolid Foraminifera												
Nonion? sp.												
Borelis? sp.												
Rotalia calcar												
Calcarina delicata												
Triloculina kerimbatica												
Quinqueloculina bidentata												
Discorbis patelliformis												
Operculina sp.												
Cibicides sp.												
Acervulina inhaerens												
Guttulina sp.												
Globigerina? sp.												
Cymbaloporetta? sp.												
Miliolinella sp.												
Quinqueloculina neostriatula												
Elphidium striatopunctatum												

Marginopora vertebralis Blainville
Amphistegina madagascariensis D'Orbigny
Baculogypsina sphaerulata (Parker and Jones)
Globigerinoides sacculifera (H. B. Brady)
Planorbulina acervalis H. B. Brady
Gypsina vesicularis (Parker and Jones)

Core 169–179½′, sample 1–14–2: Coralliferous limestone with encrusting *Homotrema rubrum* (Lamarck) and poor specimens of *Heterostegina suborbicularis* D'Orbigny and *Amphistegina madagascariensis* D'Orbigny.

Sample 1–14–13: Well-consolidated limestone. The outline of a large *Textularia* is visible on the surface. In thin section the following are seen:

Miliolid Foraminifera
Nonion? sp.
Marginopora vertebralis Blainville—rare
Borelis? sp.
Rotalia calcar (D'Orbigny)—rare. This is its highest occurrence.
Amphistegina madagascariensis D'Orbigny—rare
Carpenteria
Halimeda is rare.

Core 184½–200½′, sample 1–16–2: Limestone and well-cemented Foraminifera.

Triloculina kerimbatica (Heron-Allen and Earland)
Marginopora vertebralis Blainville—abundant
Rotalia calcar (D'Orbigny)—abundant
Calcarina delicata Todd and Post, n. sp.

Core 200½–211′, sample 1–17–16: Well-cemented limestone containing some altered coral.

Quinqueloculina bidentata D'Orbigny
Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)

Thin section shows much coral and
Rotalia calcar (D'Orbigny)—abundant
Amphistegina

Core 211–232′, sample 1–18–1: Granular detrital limestone.

Nonion pacificum (Cushman)
Discorbis patelliformis (H. B. Brady)
Rotalia calcar (D'Orbigny)
Asterigerina sp.
Carpenteria

Sample 1–18–5: Fragments of detrital limestone.

Valvulina davidiana Chapman
Nonion pacificum (Cushman)
Operculina
Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)—abundant
Asterigerina sp.
Amphistegina madagascariensis D'Orbigny
Calcarina delicata Todd and Post, n. sp.
Globigerinoides sacculifera (H. B. Brady)
Cibicides
Acervulina inhaerens Schultze
Homotrema rubrum (Lamarck)

Sample 1–18–6A: Poorly consolidated detrital limestone.

Nonion pacificum (Cushman)
Reussella simplex (Cushman)
Rotalia calcar (D'Orbigny)—abundant
Amphistegina madagascariensis D'Orbigny
Calcarina delicata Todd and Post, n. sp.
Globigerinoides sacculifera (H. B. Brady)

Sample 1–18–7: Fragments of detrital limestone.

Valvulina davidiana Chapman
Triloculina terquemiana (H. B. Brady)
Guttulina sp.
Nonion pacificum (Cushman)
Heterostegina suborbicularis D'Orbigny
Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)—abundant
Poroeponides cribrorepandus Asano and Uchio
Asterigerina sp.
Amphistegina madagascariensis D'Orbigny
Calcarina delicata Todd and Post, n. sp.
Globigerina? sp.
Homotrema rubrum (Lamarck)

Core 232–242½′, sample 1–19–1: Detrital limestone.

Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady

Sample 1–19–3: Thin section shows:

Textularia
Miliolid Foraminifera—abundant
Marginopora vertebralis Blainville—common
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny

Core 242½–253′, sample 1–20–1: Limestone and coral with white chalk filling the pores.

Triloculina terquemiana (H. B. Brady)
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady

Core 253–263½′, sample 1–21–1: Fairly well consolidated detrital limestone. Some cavities are filled with calcite crystals.

Marginopora vertebralis Blainville—common
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny

Sample 1–21–7: Thin section shows:

Miliolid Foraminifera
Marginopora vertebralis Blainville—abundant
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny
Cymbaloporetta? sp.

Core 263½–269′, sample 1–22–8: Thin section shows:

Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny

Sample 1–22–13: Compact limestone.

Amphistegina madagascariensis D'Orbigny

Cuttings about 270′:

Valvulina davidiana Chapman
Quinqueloculina sulcata D'Orbigny
Triloculina cf. *T. bassensis* Parr
Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny
Calcarina hispida H. B. Brady
Baculogypsina sphaerulata (Parker and Jones)

Core 269–284½′, sample 1–23–17: Well-consolidated limestone.

Miliolinella sp.
Cymbaloporetta? sp.

Thin section shows:

Miliolid Foraminifera
Marginopora vertebralis Blainville
Rotalia calcar (D'Orbigny)

Core 284½–300′, sample 1–24–7: Dense but cavernous limestone.
Quinqueloculina neostriatula Thalmann
Elphidium striatopunctatum (Fichtel and Moll)
Marginopora vertebralis Blainville
Discorbis patelliformis (H. B. Brady)
Rotalia calcar (D'Orbigny)
Amphistegina madagascariensis D'Orbigny

Although *Calcarina spengleri* (Gmelin) is found in the core and cuttings below 95 feet, we assume that is its lowest occurrence, as below 95 feet it is found only in loose material, some of which is drill mud. In thin section it is not seen below 95 feet.

Hole 3

Depth: 118 feet
Location: South end of Bikini island, about 800 feet from the seaward margin of the reef and 8 feet above the reef flat.
Core 10.8–22′, sample 3–1–1: Hard, compact foraminiferal limestone.
Calcarina spengleri (Gmelin)—abundant
Homotrema rubrum (Lamarck)
Sample 3–1–20: Well-consolidated coralliferous limestone.
Calcarina spengleri (Gmelin)
Sample 3–1–23: Thin section shows:
Marginopora vertebralis Blainville
Calcarina spengleri (Gmelin)
Homotrema rubrum (Lamarck)
Halimeda segments
Core 32½–43′, sample 3–3–2: Coralliferous limestone in a matrix of *Halimeda* segments and Foraminifera.
Marginopora vertebralis Blainville
Calcarina spengleri (Gmelin)
Homotrema rubrum (Lamarck)
Core 43–53′, sample 3–4–2: Coralliferous limestone with *Carpenteria* and *Homotrema* encrusting the surface.
Core 58–63½′, sample 3–6–2: Coralliferous limestone in a matrix of *Halimeda* and Foraminifera.
Amphistegina madagascariensis D'Orbigny
Calcarina spengleri (Gmelin)—very abundant
Sample 3–6–4: Similar to sample 3–6–2.
Clavulina pacifica Cushman
Calcarina spengleri (Gmelin)
Sample 3–6–18: Coral and *Halimeda*.
Marginopora vertebralis Blainville
Calcarina spengleri (Gmelin)
Core 63½–68½′, sample 3–7–2: *Carpenteria* makes up almost 50 percent of the sample. The rest is *Halimeda*, *Lithothamnion*, and coral. No *Calcarina spengleri* (Gmelin).
Nonion pacificum (Cushman)
Sample 3–7–3: Similar to sample 3–7–2.
Sample 3–7–6: Coral with white chalk filling the pores. Some encrusting *Carpenteria*.
Triloculinella labiosa (D'Orbigny)
Amphistegina madagascariensis D'Orbigny
Sample 3–7–8: Coral. Some *Halimeda* and a small amount of encrusting *Carpenteria*.
Core 86′3″–96′9″, sample 3–11–1: Coralliferous limestone with encrusting *Carpenteria* and *Homotrema* on the surface.
Spiroloculina angulata Cushman
Calcarina spengleri (Gmelin)

Joshua I. Tracey considers this piece of core out of place. It may be a fragment of core that fell in from above. It is believed that *Calcarina spengleri* (Gmelin) does not occur as deep as this.

The material from 96′9″ to the bottom of the core is very consolidated limestone. No Foraminifera could be determined.

DEEP DRILL HOLES

Holes 2A and 2B, having been drilled closely adjacent to each other, are best studied as one hole. Hole 2A samples start at the depth where hole 2 samples end. Hole 2B samples do not start until 400 feet.

The highest sample in hole 2A, at 192–200½′, consists chiefly of the typical Recent lagoon fauna. This fauna together with abundant specimens of *Rotalia calcar* (D'Orbigny) and less frequent ones of *Calcarina delicata* Todd and Post n. sp. continues without much change down to sample 2A–25–15, 316–326½′, where a rather rich fauna including abundant planktonic forms is found. This change indicates an increase in accessibility to oceanic water but not necessarily an increase in depth.

Taking both holes 2A and 2B into consideration, there are several tops of occurrence between this level and about 850 feet, but no great change in the fauna.

Between 852 and 925 feet an easily recognizable break occurs which we believe to be the top of the Miocene. The following species are first encountered here:

Valvulammina marshallana Todd and Post, n. sp.
Peneroplis carinatus D'Orbigny
Spirolina sp.
Marginopora vertebralis Blainville [1]
Borelis schlumbergeri (Reichel)
Alveolinella quoii (D'Orbigny)
Tubulogenerina tubulifera (Parker and Jones)
Trimosina spinulosa (Millett)
Pavonina triformis Parr
Rotorbinella sp.

The above group of species suggests reef conditions. In addition the following species disappear or become less abundant at this level:

Rotalia beccarii (Linné), var.
Rotalia calcar (D'Orbigny)

Between 1145½ and 1209 feet there is another even more striking break which corresponds approximately to the top of Tertiary f_{1-2} as established on the basis of larger Foraminifera. This break is marked by the disappearance or decrease in frequency of the following:

Elphidium striatopunctatum (Fichtel and Moll)
Marginopora vertebralis Blainville (brown specimens)
Alveolinella quoii (D'Orbigny)
Reussella sp. C
Pavonina triformis Parr
Calcarina delicata Todd and Post, n. sp.

[1] Although Recent specimens of this species occur with decreasing frequency from the tops of the holes downward, dark-colored specimens, easily distinguishable from the Recent white ones, appear at this level fairly abundantly and indicate a reappearance in the hole of this species.

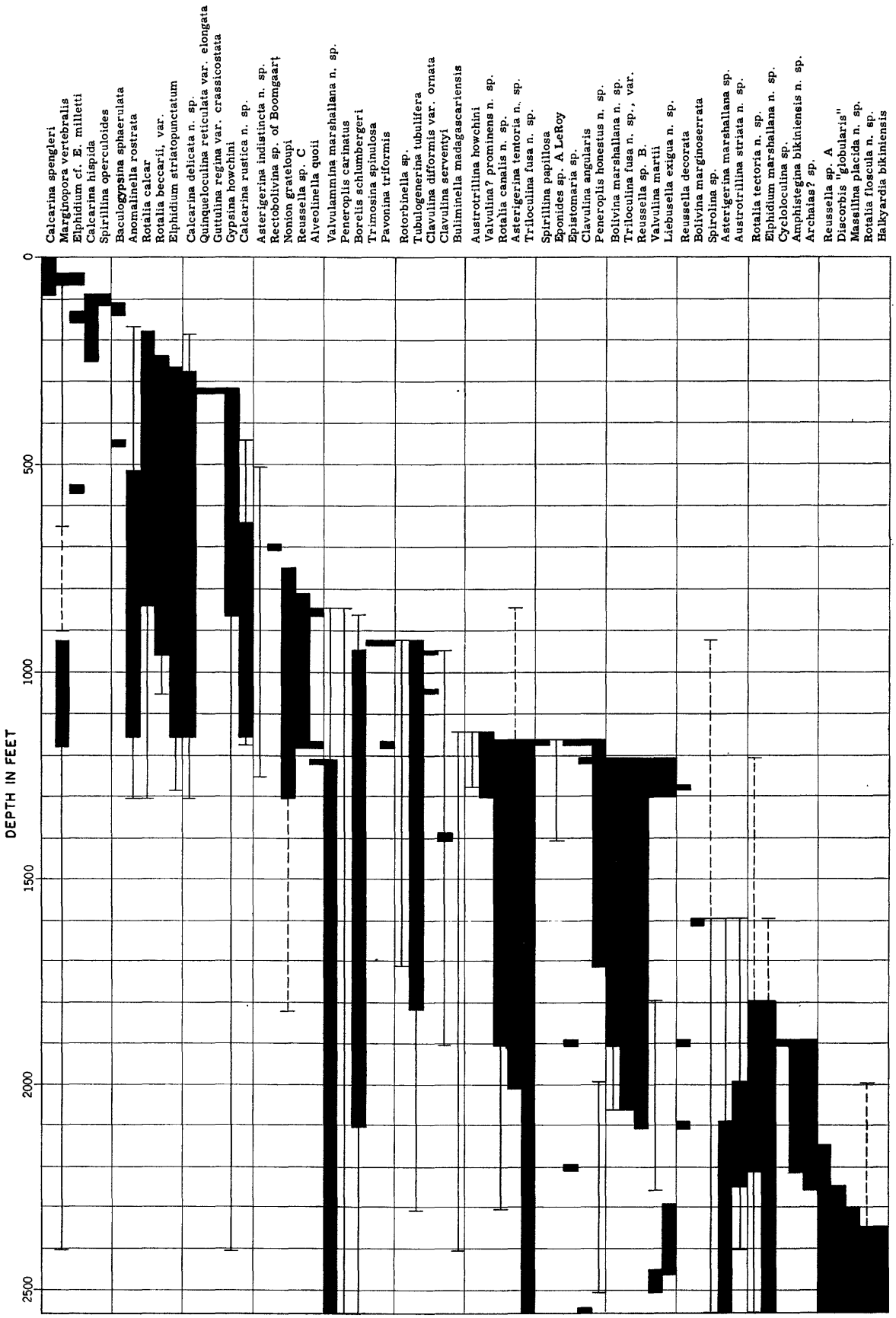

FIG. 166.—Composite distribution chart of diagnostic smaller Foraminifera in the Bikini drill holes.

Calcarina rustica Todd and Post, n. sp.
Anomalinella rostrata (H. B. Brady)

and by the first appearance of the following:

Valvulina martii Cushman and Bermudez
Valvulina ? prominens Todd and Post, n. sp.
Clavulina angularis D'Orbigny
Liebusella exigua Todd and Post, n. sp.
Triloculina fusa Todd and Post, n. sp.
Triloculina fusa Todd and Post, n. sp., var.
Austrotrillina howchini (Schlumberger)
Peneroplis honestus Todd and Post, n. sp.
Buliminella madagascariensis (D'Orbigny)
Bolivina marshallana Todd and Post, n. sp.
Reussella sp. B
Eponides sp. A of LeRoy
Rotalia canalis Todd and Post, n. sp.
Epistomaria sp.
Asterigerina tentoria Todd and Post, n. sp.

The above group of species suggests shallow or lagoonal conditions, but not reef conditions.

Downward in the hole the next apparent break is at about 1600 feet, which corresponds to the base of the *Miogypsinoides dehaarti* zone of Tertiary *e*. It is marked by the first appearance of the following species:

Austrotrillina striata Todd and Post, n. sp.
Bolivina marginoserrata LeRoy
Asterigerina marshallana Todd and Post, n. sp.

At 1800 feet a break is marked by the first apearance of:

Elphidium marshallana Todd and Post, n. sp.
Rotalia tectoria Todd and Post, n. sp.

and by the disappearance of *Tubulogenerina tubulifera* (Parker and Jones).

At about 1900 feet the smaller Foraminifera indicate another break which does not correspond to any of the zones based on larger Foraminifera. It is marked by the disappearance or decrease in abundance of the following species:

Clavulina serventyi Chapman and Parr
Bolivina marshallana Todd and Post, n. sp.
Rotalia canalis Todd and Post, n. sp.

and by the first appearance of:

Archaias? sp.
Amphistegina bikiniensis Todd and Post, n. sp.
Cycloloculina sp.

Near the bottom of hole 2B, between about 2150 and 2350 feet, the following species are first encountered:

Massilina placida Todd and Post, n. sp.
Reussella sp. A
Discorbis "globularis (D'Orbigny)"
Rotalia floscula Todd and Post, n. sp.
Halkyardia bikiniensis Cole

The appearance of *Rotalia floscula* and *Halkyardia bikiniensis* together at about 2350 feet corresponds to the top of Tertiary *c*(?) as indicated by the larger Foraminifera. The top of the Oligocene(?) and the top of Tertiary *d*(?) at about 2070 feet is not evident from the distribution of the smaller Foraminifera.

Ecologic conditions: Throughout the section, most of the species of smaller Foraminifera belong in genera found commonly under shallow or reef conditions in present day seas. The presence of planktonic species indicates that this area of deposition was open to oceanic water, probably more so at certain times.

LIST OF SAMPLES STUDIED

Hole 1. Cores and cuttings from 42½ feet to the bottom of the hole at 300 feet.
Hole 2. Cores from 43½ feet to the bottom of the hole at 190 feet.
Hole 3. Cores from 10.8 feet to 96 feet, 9 inches.
Hole 2A. Cores and cuttings from 192 to 1303 feet, mostly at 50 foot intervals.
Hole 2B. Cuttings from 400½ feet to the bottom of the hole at 2556 feet, mostly at 50 foot intervals.

SYSTEMATIC DESCRIPTIONS

Family VALVULINIDAE

Genus VALVULINA D'Orbigny, 1826

Valvulina martii Cushman and Bermudez

Plate 198, figure 1

Valvulina martii Cushman and Bermudez, Cushman Lab. Foram. Research Contr., v. 13, p. 7, pl. 5, figs. 1a, b, 1937.
Cushman, idem, Special Pub. 8, p. 9, pl. 1, figs. 19a, b, 1937.
Cole, Florida Geol. Survey Bull. 19, p. 22, pl. 1, fig. 12, 1941.
Applin and Jordan, Jour. Paleontology, v. 19, no. 2, p. 131 [list], 1945.
Cushman, Cushman Lab. Foram. Research Special Pub. 8A, p. 3, 1947.
Bermudez, idem, Special Pub. 25, p. 78, pl. 4, figs. 3, 4, 1949.

Specimens which seem to be identical with types of this species known from the Eocene of Cuba, Florida, and the Dominican Republic, are fairly common from 1209 to 1303½ feet and again between 2451 and 2503½ feet in Well 2B, and at 1240–1250½′ in hole 2A.

They are distinguishable from *V. davidiana* Chapman in the Recent sediments, by their slenderer test and irregular and strongly cut-in early portion.

Valvulina? prominens Todd and Post, n. sp.

Plate 198, figure 2

Test of medium size for the genus, rapidly enlarging from the acute initial end to the greatest diameter across the last whorl of chambers, apertural end convex and protruding; chambers few, distinct, rapidly increasing in size as added, slightly inflated, evenly rounded; sutures distinct, incised; wall finely arenaceous, smoothly finished; aperture rather large, apparently filled by an elongate tooth.

Length 0.75 to 1.00 mm, greatest diameter 0.50 to 0.75 mm.

Holotype (USNM 547744) from 1240–1250½′ in hole 2A, Bikini island, Marshall Islands.

The poor preservation and obscuring of the structures by matrix makes it impossible to be sure of the generic determination of this species. The tooth is visible in only two specimens and then indistinctly. In the other specimens the aperture appears as a rather large depressed area.

This species differs from other species of this genus in its smoothly rounded form throughout and its protruding apertural end.

The species is found in both wells with a short vertical range, from 11451½ to 13031½ feet, in the Tertiary f_{1-2} section.

Genus CLAVULINA D'Orbigny, 1826

Clavulina angularis D'Orbigny

Clavulina angularis D'Orbigny, Annales sci. nat., v. 7, p. 268, no. 2, pl. 12, fig. 7, 1826.
Cushman, Cushman Lab. Foram. Research Special Pub. 8, p. 19, pl. 2, figs. 29–33, 1937.

Rare specimens of a tricarinate form seem to belong to this widely recorded species.

Clavulina difformis H. B. Brady var. ornata Cushman

Clavulina difformis H. B. Brady var. *ornata* Cushman, Cushman Lab. Foram. Research Special Pub. 6, p. 25, pl. 4, figs. 4a, b, 1936; idem, Special Pub. 8, p. 24, pl. 3, figs. 11, 12, 1937.

Typical specimens were found at 946–956½′ and 1046–1051′ in hole 2A. The form is characteristic of shallow water.

Clavulina serventyi Chapman and Parr

Plate 198, figure 4

Clavulina serventyi Chapman and Parr, Royal Soc. West Australia Jour., v. 21, p. 5, pl. 1, figs. 7a, b, 1934–5.
Chapman, Royal Soc. South Australia Trans., v. 65, p. 192, 1941.
Cushman, Cushman Lab. Foram. Research Special Pub. 8A, p. 7, pl. 1, figs. 12a, b, 1947.

A few specimens seem to be close to this species known from the coast of Australia at 100 to 300 fathoms depth. They are smaller than the types and are all fragmentary. They are distinctive, even as fragments, in the coarse texture of the wall and circular section of the later chambers. They occur between 946 and 1891 feet in hole 2B, and a single specimen was found at 946–956½′ in hole 2A.

Genus VALVULAMMINA Cushman, 1933

Valvulammina marshallana Todd and Post, n. sp.

Plate 198, figure 3

Test of medium size for the genus, compressed, periphery rounded, lobulate; chambers few, elongate and curved, 5 or 6 in the last whorl, early ones very small and coiled in a small raised spire, later ones large and not much increasing in size; sutures distinct, depressed, strongly curved; wall composed of fairly coarse fragments, smoothly finished; aperture concealed under a large, irregular, and pitted mass of arenaceous material with numerous small openings under its edge.

Length 0.75 to 1.05 mm, breadth 0.62 to 0.80 mm, thickness 0.50 to 0.60 mm.

Holotype (USNM 547760) from 1209–1219½′ in hole 2B, Bikini island, Marshall Islands.

It is found fairly commonly from this level to the bottom of hole 2B, but only a single specimen was found above, at 852–862½′.

This species differs from *V. affinis* Cushman and Bermudez in its more compressed and more elongate test with a small but definitely raised spire of early chambers on the dosal side, and in having few chambers in the adult whorl.

This genus is most characteristic of Eocene beds but has also been reported from beds of late Oligocene and early Miocene age in Puerto Rico.

Genus LIEBUSELLA Cushman, 1933

Liebusella exigua Todd and Post, n. sp.

Plate 198, figures 5, 6

Test slender, elongate, very slightly enlarging toward the apertural end, the initial end unknown as all available specimens are fragmentary, circular in section; chambers numerous, low, not much increasing in size as added, not inflated; sutures distinct, slightly incised, irregularly lobed due to the overlapping of subsequent chambers over the earlier ones; wall very finely arenaceous, polished around the aperture, with 11 to 14 radiating partitions extending inward; aperture terminal, appearing radiate when slight erosion of the wall exposes the ends of the radiating partitions, sometimes nearly closed and complex or cribrate.

Length of longest fragmentary specimen 1.25 mm, diameter 0.44 to 0.55 mm.

Holotype (USNM 547775) from 2451–2461½′ in hole 2B, Bikini island, Marshall Islands, where specimens are fairly common. The species was also found more rarely at 1209–1219½′, 1293–1303½′, 2298½–2307′ and 2493–2503½′ in the same drill hole.

This species seems distinctive in its slender and very slightly tapering test. It differs from *L. jamaicensis*

(Cushman and Jarvis) in its cylindrical form and somewhat higher chambers.

Family MILIOLIDAE

Genus QUINQUELOCULINA D'Orbigny, 1826

Quinqueloculina reticulata (D'Orbigny) var. elongata LeRoy

Quinqueloculina reticulata (D'Orbigny) var. *elongata* LeRoy, Colorado School of Mines Quart., v. 36, no. 1, pt. 2, p. 71, pl. 5, figs. 13, 14, 1941.

Our specimens are very similar to LeRoy's figures but differ in being smaller. LeRoy described this variety from the late Tertiary of the Netherlands East Indies and it is considered late Miocene or early Pliocene in age.

In our material, it was found in only one sample, from 316–326½′ in hole 2A and is not abundant there.

Genus MASSILINA Schlumberger, 1893

Massilina placida Todd and Post, n. sp.

Plate 198, figures 11, 12

Test slightly longer than broad, compressed, periphery rounded, apertural end not projecting; chambers indistinct, last two comprising most of the surface; sutures not visible; wall with numerous, very fine, curved, longitudinal costae; aperture rounded with a slightly thickened rim, and a simple tooth.

Length 0.70 to 0.95 mm, breadth 0.55 to 0.75 mm, thickness 0.25 mm.

Holotype (USNM 547783) from 2298½–2307′ in hole 2B, Bikini island, Marshall Islands.

This species differs from *Massilina glabricostata* Cushman from the lower Oligocene of Mississippi in its larger and less compressed test, more numerous and finer costae over the entire surface of the test and the aperture having a tooth.

This species is restricted to the deepest part of hole 2B, from 2298½′ to the bottom, and should form a useful marker for that part of the section.

Genus TRILOCULINA D'Orbigny, 1826

Triloculina fusa Todd and Post, n. sp.

Plate 198, figure 7

Test of medium size for the genus, about equally tapering at basal and apertural ends, rounded triangular in transverse section; chambers elongate, slightly curved at the basal end, bluntly angled at the periphery; sutures indistinct, very little if at all depressed; wall unornamented; aperture circular, at the end of a short neck, probably with a simple tooth, but in the available specimens this is obscured by matrix.

Length 0.72 to 1.15 mm, breadth 0.40 to 0.60 mm.

Holotype (USNM 547791) from 1996½–2007′ in hole 2B, Bikini island, Marshall Islands. The species occurs fairly commonly to abundantly from 1167 feet to the bottom of the hole.

This species differs from *T. schreibersiana* D'Orbigny in the chambers being less embracing, often barely attaining the triloculine stage, and in the less inflated chambers with more sharply angled periphery.

Triloculina fusa Todd and Post, n. sp., var.

Plate 198, figure 8

Variety differing from the typical form in the chamber walls being corrugated by four to seven low and heavy transverse ridges, especially well developed on the periphery.

This variety occurs with but is much less common than the typical form.

Genus AUSTROTRILLINA Parr, 1942

Austrotrillina howchini (Schlumberger)

Trillina howchini Schlumberger, Soc. géol. France, 3d Sér. tome 21, p. 119, woodcut, fig. 1; pl. 3, fig. 6, 1893.
Chapman, Linnean Soc. New South Wales Proc., v. 32, p. 749, pl. 39, figs. 7–9, 1907 (1908); Royal Soc. Victoria Proc., v. 26, p. 169, pl. 16, fig. 4, 1913.
Silvestri, Soc. geol. italiana Boll., v. 39, p. 77, pl. 4, figs. 9, 10, 1920.
Van der Vlerk, Wetenschappelijke Mededeelingen, no. 9, p. 16, 1929.
Böckh and Viennot, Comptes Rendus Acad. Sci., tome 189, p. 1001, 1929.
Cushman, Cushman Lab. Foram. Research Special Pub. 4, pl. 14, fig. 12, 1933; idem, Special Pub. 5, pl. 15, fig. 4, 1933.
Crespin, Palaeont. Bull., no. 2, p. 6, pl. 1, figs. 1, 2, 1936.
Reichel, Eclogae geol. Helvetiae, v. 29, p. 136, 1936.
Silvestri, Palaeont. Ital., v. 32, suppl. 2, p. 81, pl. 5 (2), figs. 2, 3; pl. 6 (3), fig. 3, 1937.
Rao, Mysore Univ. Jour., sec. B-Sci., v. 2, pt. 2, p. 17, pl. 2, fig. 7, 1941.
Austrotrillina howchini Parr, Mining and Geol. Jour., v. 2, no. 6, p. 361, figs. 1–3, 1942.
Crespin, Commonwealth of Australia, Min. Res. Survey, Bull. 9 (Pal. Ser. No. 4), p. 77 (list), 1943.
Glaessner, Royal Soc. Victoria Proc., v. 55 (n. ser.), pt. 1, p. 68 [list], 1943.

This species occurs very rarely between 1145 and 1272 feet. The present specimens have been compared with one kindly furnished by Miss Irene Crespin of the Bureau of Mineral Resources at Canberra City, from the middle Miocene of a bore in NW. Victoria, and seem to be identical except smaller.

Austrotrillina striata Todd and Post, n. sp.

Plate 198, figure 9

Test slightly longer than broad, basal end rounded, apertural end very slightly projecting, triangular in

transverse section, peripheral angles rounded; chambers indistinct, curved, not inflated, quinqueloculine or triloculine; sutures indistinct, very slightly depressed; wall thick and alveolate on the outer portion of each chamber, thin and solid on the inner portion in contact with the previous whorl, surface of the wall polished and very finely striated longitudinally when well preserved, the alveolate character showing through the surface as a dark regularly mottled pattern, when eroded the wall appears coarsely punctate; aperture rather large, elongate, without a thickened rim or any internal tooth, but when the cribrate plate is absent, there appear to be numerous, small inward-projecting teeth from the outer border.

Length 0.90 to 1.00 mm, thickness 0.45 to 0.50 mm.

Holotype (USNM 547817) from 2049–2059½′ in hole 2B, Bikini island, Marshall Islands.

This species differs from *A. howchini* (Schlumberger) in its striated surface and the much coarser-textured alveolae, and in being less distinctly triangular in transverse section. It has a lower range in the hole than *A. howchini*.

Austrotrillina striata, n. sp., occurs very abundantly in the Bikini wells and many specimens show excellent preservation. Its highest occurence is at 1597½ feet but it does not become abundant until 1702½ feet and below in hole 2B. Its greatest abundance is from 1996½ to 2256 feet.

Family POLYMORPHINIDAE

Genus GUTTULINA D'Orbigny, 1839

Guttulina regina (H. B. Brady, Parker, and Jones) var. crassicostata Cushman and Ozawa

Guttulina regina (H. B. Brady, Parker, and Jones) var. *crassicostata* Cushman and Ozawa, U. S. Natl. Mus. Proc., v. 77, art. 6, p. 35, pl. 11, fig. 5, 1930.

Parr and Collins, Royal Soc. Victoria Proc., v. 50 (n. ser), pt. 1, p. 194, pl. 12. fig. 6, 1937.

Parr, Mining and Geol. Jour., v. 1, no. 4, p. 67, fig. 2, 1939.

Cushman, Great Barrier Reef Comm. Repts., v. 5, p. 114 (et seq.) [lists], pl. 11, fig. 4, 1942.

Crespin, Commonwealth of Australia, Min. Res. Survey, Bull. 9 (Pal. Ser. No. 4), p. 80 [list], 1943.

Only one specimen was found in the Bikini well material: at 316–326½′ in hole 2A. It is not entirely typical as compared with the types described from the lower Pliocene of Beaumaris, near Melbourne, Victoria. It differs in having a smaller test, finer costae, and less inflated chambers.

In the boring at Heron Island, Great Barrier Reef, Australia, specimens very similar to that from Bikini occurred in some abundance at the following depths: 465′, 475′, 488′, 506′, 528½′, 673′, 703′.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion grateloupi (D'Orbigny)

Plate 198, figure 10

Nonionina grateloupi D'Orbigny, Annales sci. nat., tome 7, p. 294, no. 19, 1826; (in De la Sagra), Histoire physique, politique et naturelle de l'Ile de Cuba, Foraminifères, p. 46, pl. 6, figs. 6, 7, 1839.

Nonion grateloupi Cushman, U. S. Natl. Mus. Bull. 104, pt. 7, p. 10, pl. 3, figs. 9–11; pl. 4, figs. 1–4, 1930; Florida Geol. Survey Bull. 4, p. 36, pl. 6, figs. 1–3, 1930; U. S. Geol. Survey Prof. Paper 191, p. 21, pl. 6, figs. 1–7, 1939.

Chapman, Royal Soc. South Australia Trans., v. 65, p. 181, 1941.

Dorsey, Maryland Dept. Geol., Mines and Water Resources, Bull. 2, p. 300, pl. 35, figs. 5a–c, 1948.

Boomgaart, Thesis Univ. Utrecht, p. 92, 1949.

Cuvillier and Szakall, Foram. Aquitaine, Prem. Part., p. 88, pl. 32, fig. 7, 1949.

Bermudez, Cushman Lab. Foram. Research Special Pub. 25, p. 165, pl. 11, fig. 15, 1949.

Specimens similar to those known from the Recent and Miocene of the Western Atlantic region occur fairly commonly in the middle part of the section, from 747 to 1303½ feet and rarely below, and are found in both holes.

Genus ELPHIDIUM Montfort, 1808

Elphidium marshallana Todd and Post, n. sp.

Plate 198, figure 13

Test of medium size for the genus, compressed, periphery bluntly acute, slightly lobulated at the last few chambers, unbones large and prominent but not much raised, darker in color than the rest of the test, marked by 4 or more large pits; chambers distinct, not much increasing in size as added, later ones slightly inflated, about 18 comprising the adult whorl; sutures distinct, slightly curved, bridged by about 8 short retral processes on each side of the test; wall smooth, thick; aperture a row of pores along the base of the apertural face.

Diameter 0.68 to 0.80 mm, thickness 0.30 to 0.37 mm.

Holotype (USNM 547841) from 1797–1807½′ in hole 2B, Bikini island, Marshall Islands. It was found only in hole 2B, from 1797 feet to the bottom, with a single specimen at 1597½–1608′.

This species differs from *E. discoidale* (D'Orbigny) in its test being flatter in the middle and less rounded on the periphery and the chambers not increasing so rapidly in size as added. It also somewhat resembles *E. rugosum* (D'Orbigny) but is larger and has more prominent unbones.

Elphidium cf. E. milletti (Heron-Allen and Earland)

Elphidium milletti Cushman, U. S. Natl. Mus. Bull. 161, pt. 2, p. 49, pl. 11, figs. 8a, b, 1933.

Fairly common specimens occur near the top of hole 2A. They seem, in their surface characters, to be the same, but differ in being larger, more inflated and irregular, and not as strongly lobulated along the periphery.

Elphidium striatopunctatum (Fichtel and Moll)

Nautilus striatopunctatus Fichtel and Moll, Testacea microscopica, p. 61, pl. 9, figs. a–c, 1798.

Elphidium striatopunctatum Cushman and Leavitt, Cushman Lab. Foram. Research Contr., v. 5, p. 19, pl. 4, figs. 5, 6, 1929.

Cushman, U. S. Geol. Survey Prof. Paper 191, p. 52, pl. 14, figs. 6, 7, 1939; Cushman Lab. Foram. Research Special Pub. 17, p. 9, pl. 2, figs. 4, 5, 1946.

This species occurs in some abundance in the upper parts of both wells. Specimens vary considerably in roundness of the periphery.

Cushman reported it from the Red Sea and noted that its distribution may be confined to very warm, shallow waters of the Red Sea and adjacent parts of the Indian Ocean.

Family PENEROPLIDAE

Genus PENEROPLIS Montfort, 1808

Peneroplis carinatus D'Orbigny

Plate 199, figure 3

Peneroplis carinatus D'Orbigny, Voyage dans l'Amérique méridionale, v. 5, Foraminifères, pt. 5, p. 33, pl. 3, figs. 7, 8, 1839.

Cushman, U. S. Natl. Mus., Proc., v. 59, p. 75, pl. 18, fig. 12; U. S. Natl. Mus. Bull. 104, pt. 7, p. 36, pl. 12, figs. 7–10; pl. 14, fig. 1, 1930.

Galloway and Heminway, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Ids., v. 3, pt. 4, p. 316, pl. 5, figs. 6a, b, 1941.

Bermudez, Cushman Lab. Foram. Research Special Pub. 25, p. 173, 1949.

Rather typical specimens occur infrequently from 852–862½′ to the bottom in hole 2B. The species is widely known in Recent seas and has been recorded from the Miocene of the Dominican Republic and the middle Oligocene to lower Miocene of Puerto Rico.

Peneroplis honestus Todd and Post, n. sp.

Plate 199, figure 1

Test planispiral, strongly compressed, involute in the young, becoming slightly evolute in the adult, periphery bluntly acute, entire in the young, slightly lobulated in the adult; chambers distinct, 9 or 10 comprising the adult whorl, rather rapidly increasing in length as added, not inflated, rather strongly overlapping the previous chamber and giving the impression of limbate sutures; sutures distinct, strongly curved, depressed, somewhat irregularly recurved at their inner ends; wall thick, ornamented with 12 to 15 concentric ridges on each side of the test; aperture in the young an irregular, triangular opening slightly above the base of the apertural face, in the adult lengthened into a long, irregularly serrate slit, in both cases bordered by a slightly raised rim.

Diameter 0.70 to 0.85 mm, thickness 0.30 to 0.33 mm.

Holotype (USNM 547888) from 1167–1177½′ in hole 2B, Bikini island, Marshall Islands, where it is fairly common. From this depth downward the species occurs in decreasing frequency nearly to the bottom of the hole.

This species is close to *P. mauii* Dorreen from the upper Eocene, Kaiatan stage, at Ethel Creek, Greymouth District, New Zealand, but differs in being larger and more strongly compressed, and in not having a tendency toward flaring, and in the aperture being raised above the base of the apertural face.

Genus SPIROLINA Lamarck, 1804

Spirolina sp.

Plate 199, figure 2

A very few specimens of *Spirolina*, unlike those known in the Recent sediments, occur in scattered samples from 925 feet to the bottom of hole 2B.

Genus ARCHAIAS Montfort, 1808

Archaias? sp.

Plate 202, figures 6, 7

Fairly common specimens, similar to that figured, are tentatively referred to this genus. They are restricted to the lower part of the section, from 1891 to 2256 feet in hole 2B and should form an excellent marker for that part.

Genus MARGINOPORA Blainville, 1830

Marginopora vertebralis Blainville

Plate 203, figures 3c, d

Marginopora vertebralis Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 412, pl. 69, fig. 6, 1834.

Specimens are found throughout both drill holes, but in varying abundance. Chalky white specimens are abundant at the top and persist, probably through contamination, to the bottom of hole 2B. These Recent and Pliocene or Pliocene forms begin to be much less abundant at about 650 feet. Then at 925 feet the species reappears in considerable abundance but is stained brownish. Below about 1180 feet the brownish forms are rarer, but are found nearly to the bottom of hole 2B.

The two forms are distinguishable on the basis of the color difference but otherwise seem to belong to the same species.

Family ALVEOLINELLIDAE

Genus BORELIS Montfort, 1808

Borelis schlumbergeri (Reichel)

Neoalveolina pygmaea schlumbergeri Reichel, Soc. pal. Suisse Mem., tome 59, p. 110, pl. 10, figs. 1–3; pl. 11, type struct. 6b, 1937.

Said, Cushman Lab. Foram. Research Special Pub. 26, p. 26, pl. 3, fig. 6, 1949.

Borelis pygmaeus schlumbergeri Hanzawa, Rept. Committee Treatise on Marine Ecology and Paleoecology, 1946–47, no. 7, p. 80 [list], p. 86, 1948.

Alveolina boscii Moebius (not Defrance), Foraminiferen von Mauritius, p. 79, pl. 3, figs. 13–15; pl. 4, fig. 1, 1880.

Alveolina longa Czjzek [not Egger], K. bayer. Akad. Wiss., Math.-naturh. Abt., Abh., Kl. 2, Band 18, p. 249, pl. 3, fig. 32, 1893.

Specimens are common to abundant from 862′ to the bottom of both holes. They range in shape from nearly spherical in the young individuals to fusiform, as elongate as 4 to 1, in adults. Specimens are less abundant in the lower part of the hole, below 2091′, and may be present there only by contamination from above.

Genus ALVEOLINELLA H. Douvillé, 1906

Alveolinella quoii (D'Orbigny)

Plate 202, figures 5, 8

Alveolina quoii D'Orbigny, Annales sci. nat., tome 7, p. 307, no. 7, pl. 17, figs. 11–13, 1826.

Alevolinella quoyi Hofker, Resultats Sci. Voyage Indes Orientales Neerlandaises, tome 2, fasc. 1, p. 5, pl. 1, figs. 3, 7, 1930; Siboga-Exped., Mon. 4a, p. 166, 1930.

Chapman, Great Barrier Reef Comm. Repts., v. 3, p. 33, 39 [lists], 1931.

Hofker, Vidensk. Medd. fra Dansk naturh. Foren., band 93, 1932, p. 107, 1933.

Cushman, U. S. Natl. Mus. Bull. 161, pt. 2, p. 68, pl. 19, fig. 10, 1933.

Chapman, Annals and Mag. Nat. History, 11th ser., v. 11, p. 107 [list], 1944.

Hanzawa, Rept. Committee Treatise on Marine Ecology and Paleoecology, 1946–47, no. 7, p. 85, 1948.

Alveolina boscii H. B. Brady [not Defrance], *Challenger* Rept., Zoology, v. 9, p. 222, pl. 17, figs. 7–12, 1884.

Alveolinella boscii van der Vlerk [not Defrance], Wetenschappelijke Mededeelingen, no. 9, p. 16, fig. 24, 1929.

Thalmann, Eclogae geol. Helvetiae, v. 24, p. 298, 1932.

Cushman, Cushman Lab. Foram. Research Special Pub. 5, pl. 25, figs. 13, 14, 1933.

A few specimens were found in three samples in hole 2B: 852–862½′, 1167–1177½′ and 1209–1219½′. They closely resemble Recent specimens that are known from shallow waters of the Indo-Pacific region but not found in the present sediments of the Marshall Islands.

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

Buliminella madagascariensis (D'Orbigny)

Bulimina madagascariensis D'Orbigny, Annales sci. nat., tome 7, p. 270, no. 17, 1826.

Fornasini, Accad. sci. Ist. Bologna Mem., ser. 6, v. 5, p. 47, pl. 1, figs. 13, 13a, 1908.

Cushman and Parker, Cushman Lab. Foram. Research Contr., v. 14, p. 94, pl. 16, figs. 19, 20, 1938.

Buliminella madagascariensis Cushman and Parker, U. S. Geol. Survey Prof. Paper 210–D, p. 68, pl. 17, figs. 15–17, 1947.

Said, Cushman Lab. Foram. Research Special Pub. 26, p. 26, pl. 3, fig. 14, 1949.

?Bulimina elegantissima D'Orbigny var. *fusiformis* Sidebottom [not Williamson], Royal Micros. Soc. Jour., 1918, p. 23, pl. 3, figs. 8–10.

Bulimina elegantissima Heron-Allen and Earland (not D'Orbigny), Linnean Soc. Jour., Zoology, v. 35, p. 620, pl. 35, figs. 23, 24, 1924.

Bulimina seminuda Heron-Allen and Earland [not Terquem], *Discovery* Repts., v. 4, p. 351, pl. 8, figs. 38–41, 1932.

Buliminella apiculata (Chapman) var. *hebetata* Cushman and Parker, Cushman Lab. Foram. Research Contr., v. 13, p. 40, pl. 4, figs. 11, 12, 1937.

Typical specimens were found rarely in hole 2A at 1145–1156′ and in hole 2B from 1167 to 2401½ feet.

Genus BOLIVINA D'Orbigny, 1839

Bolivina marginoserrata LeRoy

Plate 199, figure 6

Bolivina marginoserrata LeRoy, Natuurk. tijdschr. Ned.-Indië, v. 99, pt. 6, p. 247, pl. 4, figs. 8, 9, 1939.

A single specimen, here figured, seems very close to this species described from the Miocene of Central Sumatra. It was found at 1597½–1608′ in hole 2B.

Bolivina marshallana Todd and Post, n. sp.

Plate 199, figure 5

Test short and stout, broadly flaring, compressed, periphery rounded, indented, initial end blunt; chambers few, distinct, rapidly increasing in size as added, slightly inflated; sutures distinct, incised, straight, early ones somewhat obscured by ornamentation; wall very coarsely hispid over the early chambers, decreasing on the later chambers, last two chambers nearly smooth; aperture a large, broad, and rectangular opening into the apertural face, the wall of the last chamber curving down into the opening.

Length 0.30 to 0.40 mm, breadth 0.20 to 0.25 mm, thickness 0.12 to 0.17 mm.

Holotype (USNM 548007) from 1891½–1902′ in hole 2B, Bikini island, Marshall Islands, where it is fairly common. A few less well developed specimens

were also found between 1167 and 2059½ feet in the same hole.

This species differs from *B. sublobata* Cushman in its larger and more broadly flaring test and its larger and more distinct chambers.

Genus RECTOBOLIVINA Cushman, 1927

Rectobolivina sp. of Boomgaart

Plate 199, figure 4

Rectobolivina sp. Boomgaart, Thesis Univ. Utrecht, p. 116, pl. 9, figs. 6a, b, 1949.

A single specimen from hole 2B, at 694½–705′, seems identical with this form recorded from Pliocene to Miocene well samples of Bodjonegoro, Java.

Genus TUBULOGENERINA Cushman, 1927

Tubulogenerina tubulifera (Parker and Jones)

Plate 199, figure 7

Textularia (Bigenerina) tubulifera Parker and Jones, Annals and Mag. Nat. History, 3d ser., v. 11, p. 94, fig. 2 [in text], 1863.

Tubulogenerina tubulifera Cushman, Cushman Lab. Foram. Research Special Pub. 9, p. 215, pl. 24, figs. 14–16, 1937.

Clavulina eocaena Terquem [not Gümbel], Soc. géol. France Mém., 3d ser., tome 2, p. 121, pl. 12, figs. 35a, b, 1882.

Bigenerina conica Heron-Allen and Earland [part], Royal Micros. Soc. Jour., 1909, p. 329, pl. 16, fig. 1 [not figs. 2–6].

The specimens from Bikini were compared with topotypes from the Eocene of France and seem identical. They differ from *T. mooraboolensis* Cushman, in being smaller and in having a single row of tubes.

They appear to be restricted to the Miocene section of the hole.

Genus Reussella Galloway, 1933

Reussella decorata (Heron-Allen and Earland)

Plate 199, figure 8

Verneuilina decorata Heron-Allen and Earland, Royal Micros. Soc. Jour., 1924, p. 138, pl. 7, figs. 7–9.

Reussia decorata Parr, Royal Soc. Victoria Proc., v. 44, p. 13, pl. 1, fig. 22, 1932.

Reussella decorata Cushman, Cushman Lab. Foram. Research Special Pub. 7, p. 20, 1937; idem, Contr., v. 21, p. 36, pl. 6, figs. 15–18, 1945.

Rare specimens of this species described from the Miocene of "Filter Quarry," Victoria, Australia, were found in hole 2B at 1272–1282½′, 1891½–1902′, and 2091–2102′.

Reussella sp. A

Plate 199, figure 9

In the lower part of hole 2B, from 2143′ to the bottom, there are rare specimens of a species of *Reussella* which seems to be undescribed. They are small, compact, evenly tapering, with a smooth wall, and a nonspinose periphery. The chambers are few and large and the sutures distinct and limbate.

Reussella sp. B

Plate 199, figure 10

In the middle part of the section a species of *Reussella* is found that is distinctive in having definitely serrate peripheral angles. The test is rather short, composed of few chambers, and broadly flaring.

Reussella sp. C

Plate 199, figure 11

Between 810′ and 1167′, more abundant at the latter depth, another species of *Reussella* occurs. It resembles *R. simplex* (Cushman) in its conspicuous pores arranged in definite lines, but differs in lacking the peripheral spines characteristic of *R. simplex*.

Genus TRIMOSINA Cushman, 1927

Trimosina spinulosa (Millett)

Mimosina spinulosa Millett, Royal Micros. Soc. Jour., 1900, p. 548, pl. 4, figs. 12a, b.

Heron-Allen and Earland, Zool. Soc. London Trans., v. 20, p. 650, 1915.

Trimosina spinulosa Cushman, Cushman Lab. Foram. Research Contr., v. 21, p. 41, pl. 7, figs. 12a, b, 1945.

A few specimens of this Recent Indo-Pacific species were found in hole 2A at 925–935½′.

Genus PAVONINA D'Orbigny, 1826

Pavonina triformis Parr

Plate 199, figure 12

Pavonina triformis Parr, Royal Soc. Victoria Proc., v. 45, p. 29, pl. 7, figs. 1–3, 1933.

Crespin, Commonwealth of Australia, Min. Res. Survey, Bull. 9 (Pal. Ser. No. 4), p. 82 [list], 1943.

Cushman, Cushman Lab. Foram. Research Contr., v. 21, p. 46, pl. 8, figs. 2–5, 1945.

Pavonina flabelliformis Howchin [not D'Orbigny], Royal Soc. South Australia Trans. and Proc., v. 12, p. 7, 1889.

Heron-Allen and Earland, Royal Micros. Soc. Jour., 1924, p. 141, pl. 8, fig. 22.

Two specimens of this species, known from the Miocene and Oligocene of Australia, were found; one at 925–935½′ in hole 2A, and another at 1167–1177½′ in hole 2B. Its presence in the holes is of interest, as the same species was also found in a short core (7 inches) in 720 fathoms on Sylvania seamount adjoining Bikini Atoll.

Family ROTALIIDAE

Genus SPIRILLINA Ehrenberg, 1843

Spirillina operculoides Cushman

Spirillina operculoides Cushman, U. S. Natl. Mus. Bull. 71, pt. 5, p. 7, pl. 4, figs. 2a–c, 1915.

A single typical specimen was found in the sample from 95–116′ in hole 2A. The species was described from near the Hawaiian Islands at a depth of 34 fathoms and has not been recorded elsewhere.

Spirillina papillosa Cushman

Spirillina limbata H. B. Brady var. *papillosa* Cushman, U. S. Natl. Mus. Bull. 71, pt. 5, p. 6, pl. 2, figs. 4a–c, 1915.

Spirillina papillosa Ovey, Royal Micros. Soc. Jour., ser. 3, v. 67, 1947, p. 18, 1948.

A single typical specimen was found in the Tertiary f_{1-2} section at 1167–1177½′ in hole 2B. The form was described as a variety of *S. limbata* H. B. Brady and recorded from depths of 24, 234, and 108 fathoms in the Pacific.

Genus DISCORBIS Lamarck, 1804

Discorbis "globularis (D'Orbigny)"

Plate 199, figure 13

Discorbina globularis (D'Orbigny) Howchin, Royal. Soc. South Australia Trans. and Proc., v. 12, p. 12, 1889.

Heron-Allen and Earland, Zool. Soc. London Trans., v. 20, p. 694, pl. 51, figs. 36–39, 1915; Royal Micros. Soc. Jour., 1924, p. 169.

Discorbis globularis Chapman, Parr, and Collins, Linnean Soc. Jour., Zoology, v. 38 (no. 262), p. 562, pl. 8, figs. 7a–c, 1934.

Crespin, Commonwealth of Australia, Min. Res. Survey, Bull. 9 (Pal. Ser. No. 4), p. 78 (list), 1943.

Between 2246′ and the bottom of hole 2B, occurs a compact, rather inflated species of *Discorbis*. Although it is doubtful whether or not it is the same as D'Orbigny's Recent Atlantic form, "*Rosalina globularis*," it is apparently the same as those referred to *D. globularis* from the Miocene of Australia. The species is characterized by distinct perforations in the wall and fine radial markings on the ventral surface.

Genus EPONIDES Montfort, 1808

Eponides sp. A LeRoy

Plate 200, figure 1

Eponides sp. A LeRoy, Colorado School of Mines Quart., v. 36, no. 1, pt. 1, p. 40, pl. 3, figs. 7–9, 1941.

A few specimens seem very close to LeRoy's specimens from the late Tertiary of the Sangkoelirang Bay area, East Borneo. They are smaller but otherwise quite similar in the limbate ventural sutures and nearly bilaterally symmetrical test. They occur rarely in the middle part of hole 2B.

Genus ROTALIA Lamarck, 1804

Preliminary studies by various authors have indicated the presence of generic distinctions within species commonly included in this genus. Pending amplification of such studies, we prefer to retain the generic name *Rotalia*, using it in its broad sense to include forms that have been separated out as *Streblus* and *Turbinulina*, as well as those typical of the genotype, *Rotalia trochidiformis* Lamarck.

Rotalia beccarii (Linné) var.

Plate 200, figure 3

This variety differs from the typical form in having fewer chambers and fewer whorls (2½ whorls and 9–14 chambers in the last whorl), a relatively thicker test, a large and protruding umbilical plug, and a smooth, polished, unornamented wall, both dorsally and ventrally.

Diameter 0.50 to 0.90 mm, thickness 0.30 to 0.60 mm.

This form is found in the upper parts of both holes, 2A and 2B, between 242½ and 1051 feet, and should prove to be a good marker for this part of the section.

Rotalia calcar (D'Orbigny)

Plate 202, figure 1; plate 203, figures 2, 3a, b

Calcarina calcar D'Orbigny, Annales sci. nat., tome 7, p. 276, no. 1; Modèles, no. 34, 2e livraison, 1826.

Parker, Jones and H. B. Brady, Annals and Mag. Nat. History, 3d ser., v. 16, p. 24, pl. 3, fig. 87, 1865.

Germeraad (*in* Rutten and Hotz), Geol. Petr. and Pal. Results of Explorations in the island of Ceram, ser. 3, Geol., no. 2, p. 70, pl. 4, fig. 1, 1946.

Rotalia calcar Cushman, U. S. Natl. Mus. Bull. 100, v. 4, p. 350, pl. 71, figs. 3a, b, 1921.

Chapman, Great Barrier Reef Comm. Repts., v. 3, pp. 37–39 [lists], 1931.

Caudri, Tertiary Deposits of Soemba, p. 146, pl. 5, figs. 7–9, 1934.

LeRoy, Colorado School of Mines Quart., v. 36, no. 1, pt. 2, p. 84, pl. 7, figs. 1–3, 1941.

Calcarina nicobarensis Schwager, *Novara*-Exped., Geol. Theil, Band 2, p. 261, pl. 7, figs. 3, 114, 1866.

Test biconvex, periphery subacute, sharply serrate, chambers distinct, 10 to 12 comprising the adult whorl, narrow, elongate, angled at their peripheral ends; sutures indistinct on the dorsal side, distinct, deeply incised and radial on the ventral side; wall coarsely hispid throughout with a cluster of large papillae on and surrounding the umbilical plug; aperture a short and narrow slit near the base of the ventral face of the last-formed chamber, closer to the umbilicus than to the periphery, usually obscured by the hispid ornamentation.

Diameter 0.75 to 1.00 mm, thickness 0.36 to 0.50 mm.

Rotalia calcar is distinguishable from *Calcarina delicata* n. sp., with which it may be confused, in that the chambers of *R. calcar* are serrate around the periphery without the addition of spines, and also in the coarser surface ornamentation in *R. calcar*.

This species, known from the Recent and late Tertiary of the Indo-Pacific region, occurs in some numbers in the upper parts of the holes. Its highest occurrence is at about 179 feet in hole 1. At 305½–312′ in hole 2A specimens are well preserved but elsewhere they are well worn. In many of these worn specimens the umbilical plug seems to have been broken out, leaving a broadly open and depressed umbilicus. Such specimens resemble the form described as *Calcarina umbilicata* by Germeraad (3, Geol., no. 2, p. 71, pl. 4, figs. 2–5, 1946) from the "Young-Neogene" of Central Seran, D. E. I.

Chapman found this species rarely between 405 and 540 feet in the Michaelmas Reef boring.

Rotalia canalis Todd and Post, n. sp.

Plate 200, figure 4

Rotalia aff. *fijiana* LeRoy [not Cushman], Natuurk. tijdschr. Ned.-Indië, band 99, pt. 6, p. 255, pl. 5, figs. 21–23, 1939.

Test small for the genus, strongly convex ventrally, slightly convex dorsally, umbilical plug small and encircled by a deep groove, periphery bluntly angled in edge view, angled and indented in side view; chambers few, 6 to 8 in the last whorl; sutures radial and distinctly incised on the ventral side, indistinct but slightly depressed on the dorsal side; wall smooth except for a slight, low beading on the middle of the dorsal side and an occasional roughening around the ventral umbilicus, peripheral spines irregular, usually as extensions of the angular chambers; aperture a low, elongate slit along the base of the apertural face, not extending out to the periphery.

Diameter 0.40 to 0.60 mm, thickness 0.25 mm.

Holotype (USNM 548137) from 1167–1177½′ in hole 2B, Bikini island, Marshall Islands.

This species is common at its type locality and also occurs, but is rare, at deeper depths to 2298½–2307′, possibly extending its range through contamination of drill cuttings.

This species differs from *R. hamiltonensis* Parr described from the Pliocene of southeastern Australia in having more chambers and in the chambers being more deeply separated from one another, and in the more prominent spines. In this new species the previous whorls are more nearly obscured by the beaded ornamentation, than is true in *R. hamiltonensis*.

This form seems to be similar to the form from the Miocene, Tertiary *f*, of Central Sumatra which LeRoy referred to *Eponides fijiana* Cushman, placing the latter in the genus *Rotalia*. But reexamination of the type of *E. fijiana* indicates that that species does belong in *Eponides* and not *Rotalia*. Thus LeRoy's species, which is a *Rotalia*, requires another name.

Rotalia floscula Todd and Post, n. sp.

Plate 200, figure 5

Test of medium size for the genus, compressed, about equally biconvex, periphery subacute, serrate; chambers about 9 in the last whorl, later ones distinct because of their projection into points at the periphery, not much increasing in size as added; sutures indistinct and slightly depressed on the dorsal side, radial and slightly incised on the ventral side, umbilical plug a large, smooth knob surrounded by a groove; wall thick, smooth, and polished, occasionally with very short, blunt spines on the periphery at the projecting points of the chambers; aperture not observed.

Diameter 0.70 to 0.80 mm, thickness 0.32 to 0.40 mm.

Holotype (USNM 548146) from 2545½–2556′ in hole 2B, Bikini island, Marshall Islands.

This species differs from *R. mexicana* Nuttall from the upper Eocene of Mexico in its biconvex test, fewer chambers, and lack of ornamentation.

The species occurs commonly to abundantly in the lower part of hole 2B, from 2349′ to the bottom at 2556′.

Rotalia tectoria Todd and Post, n. sp.

Plate 202, figures 2–4

Test fairly large for the genus, somewhat compressed, ventral side more convex than the dorsal, periphery subacute, entire or very slightly lobulated; chambers indistinct, about 13 in the last-formed whorl, not inflated, increasing very little in size as added; sutures obscured on the dorsal side, radial and slightly incised on the ventral side, particularly at their inner ends, umbilical plug large, irregular, not projecting, surrounded by an incised groove; wall thick, highly ornamented throughout by low, short, irregular ridges and knobs the ridges being set parallel with the periphery of the test and the knobs mostly at the middle of both dorsal and ventral sides; aperture not observed.

Diameter 0.95 to 1.40 mm, thickness 0.50 to 0.60 mm.

Holotype (USNM 548154) from 2091–2102′ in hole 2B, Bikini island, Marshall Islands.

This species differs from *R. jabacoensis* Cushman and Bermudez from the upper Eocene of Cuba in its ornamentation being less knobby and the chambers less distinct. It resembles *R. mexicana mecatepecensis* Nuttall in its surface ornamentation but differs in that the

sutures are much less distinct and thus the structure is more obscured, particularly on the dorsal side. The species closely resembles *R. verriculata* Howchin and Parr from the lower Miocene of Victoria and South Australia but differs in being somewhat smaller and in the spinose ornamentation being less strongly developed and the dorsal sutures less deeply depressed.

This species occurs abundantly in the lower part of hole 2B, particularly between 1797 and 2206½ feet.

Genus ROTORBINELLA Bandy, 1944

Rotorbinella sp.

Plate 200, figure 2

Very rare specimens of a small species of this genus occur in the middle part of the section in hole 2B.

They resemble *R. caloosahatcheensis* (Cole) originally described as *Rotalia* from the Pliocene of Florida but do not show the distinct spiral suture on the dorsal side. They also resemble *R. finlayi* (Dorreen) originally described as *Discorbis* from the Eocene of New Zealand but do not have as many chambers in the last whorl. They also resemble *Discorbis cycloclypeus* Howchin and Parr from the Pliocene of Australia, but are very much smaller and have fewer (5 or 6) chambers in the last whorl.

Genus EPISTOMARIA Galloway, 1933

Epistomaria sp.

Three specimens of an apparently undescribed species of this genus were found in hole 2B, a young specimen at 1167–1177½′ and adults at 1891½–1902′ and at 2196–2206½′. They are distinctly and coarsely punctate, have 6½ chambers forming the last whorl, and are relatively high-spired and thick, but not rapidly expanding in size throughout the whorl.

Family AMPHISTEGINIDAE

Genus ASTERIGERINA D'Orbigny, 1839

Asterigerina indistincta Todd and Post, n. sp.

Plate 201, figure 1

Test about equally biconvex, ventral umbo large and projecting, periphery entire, subacute, surrounded by a limbate keel; chambers indistinct, 10 to 12 in the last whorl, very much curved on both dorsal and ventral sides, supplementary chambers relatively small, extending about ⅓ the distance to the periphery on the ventral side; sutures limbate, flush, strongly curved; wall very finely papillate throughout with an increase in coarseness of the papillae on the ventral side surrounding the aperture; aperture a very low slit extending from just inside the periphery about halfway to the umbo.

Diameter 0.85 to 1.05 mm, thickness 0.50 to 0.60 mm.

Holotype (USNM 548181) from 642–652½′ in hole 2B, Bikini island, Marshall Islands.

This species is distinguished from *A. marshallana* n. sp. in its more equally biconvex test, more strongly curved chambers, and smaller supplementary chambers. It occurs very rarely in the upper parts of both wells, above Tertiary *e*.

Asterigerina marshallana Todd and Post, n. sp.

Plate 201, figure 3

Test unequally biconvex, dorsal side flattened, thickness about ½ of diameter, periphery acute, keeled, slightly undulating; chambers very obscure, about 12 comprising the last whorl, not much increasing in size as added, 2½ to 3 whorls comprising the adult test; sutures indistinct except the spiral suture which is limbate; wall thick, apparently smooth except for the papillate ornamentation on the ventral side in front of the aperture; aperture not observed.

Diameter 0.75 to 1.00 mm, thickness 0.35 to 0.45 mm.

Holotype (USNM 548191) from 2545½–2556′ in hole 2B, Bikini island, Marshall Islands.

It occurs in the lower part of hole 2B, most abundantly at the bottom.

This species differs from *A. tentoria* n. sp. in its larger and flatter test, more numerous chambers, and sharp periphery.

Asterigerina tentoria Todd and Post, n. sp.

Plate 201, figure 2

Test nearly planoconvex, sharply conical, dorsal side very slightly convex, ventral umbo large and prominent, of clear shell material, thickness about ⅘ of diameter, periphery entire, subacute, limbate; chambers indistinct, 6 to 8 in the last whorl, very slightly increasing in size as added, supplementary chambers reaching about half way to the periphery on the ventral side; sutures indistinct, limbate, flush, straight and tangential on the dorsal side, spiral suture strongly limbate, ventral sutures of the supplementary chambers straight and radial, of the regular chambers slightly curved; wall smooth except for a roughened area on the ventral side just in front of the aperture, the roughness showing traces of a spiral arrangement concentric with the structure of the whole test; aperture not observed, in broken specimens showing a long, low opening under the edge of the ventral face of the chamber, extending from about midway nearly to the periphery.

Diameter 0.60 to 0.76 mm, thickness 0.40 to 0.50 mm.

Holotype (USNM 548207) from 1292–1303′ in hole 2A, Bikini island, Marshall Islands.

This species differs from *A. carinata* D'Orbigny in its heavier and more robust test, the chambers not much increasing in size as added, and the supplementary chambers not extending all the way out to the periphery It is distinguished from the other species of *Asterigerina* in the Bikini hole by its more sharply conical, nearly planoconvex test.

Asterigerina tentoria n. sp. is confined to the middle section of the holes from 1167 to 2007 feet, with a single specimen found at 852–862½′ in hole 2B.

Genus AMPHISTEGINA D'Orbigny, 1826

Amphistegina bikiniensis Todd and Post, n. sp.

Plate 201, figure 4

Test rather small for the genus, about equally biconvex, raised umbones of clear shell material on both sides, periphery entire, acute, with a limbate keel; chambers distinct, 12 to 15 in the last whorl, strongly curved, supplementary chambers peculiarly shaped in that they are strongly constricted at about the middle of each chamber, the whole chamber reaching nearly to the periphery; sutures distinct, limbate, not raised, ventral sutures of the supplementary chambers nearly radial, of the regular chambers very strongly curved, dorsal ones with a distinct angle or two angles separated by a U-shaped reentrant; wall smooth and polished except over the ventral area surrounding the aperture where it is coarsely papillate with the papillae arranged in curving lines concentric with the periphery of the test; aperture not observed.

Diameter 0.85 to 1.25 mm, thickness 0.40 to 0.50 mm.

Holotype (USNM 548215) from 2143½–2154′ in hole 2B, Bikini island, Marshall Islands.

This species differs from the Recent *A. madagascariensis* D'Orbigny in its smaller size, less prominent ventral umbones, and relatively flatter test. It appears to have a short range as it is found only between 1891 and 2206½ feet in hole 2B.

Family CALCARINIDAE

Genus CALCARINA D'Orbigny, 1826

Calcarina delicata Todd and Post, n. sp.

Plate 201, figures 5, 6

Test compressed, dorsal side slightly convex, ventral umbilicus large, open, and deeply depressed, periphery irregularly serrate in addition to the peripheral spines; chambers indistinct, about 12 in the last whorl, narrow, elongate, inflated on the ventral side, not much increasing in size as added; sutures slightly depressed on the dorsal side, more so on the ventral, radial; wall irregularly and coarsely papillate on the dorsal side, ornamented around the periphery by 12 to 15, or occasionally more, large blunt spines, in most cases one to a chamber and parallel with the plane of coiling of the test but with an occasional extra spine protruding at an angle to the others, test when well preserved finely hispid throughout, including the large peripheral spines; aperture not observed.

Diameter, exclusive of spines, 0.70 to 0.90 mm, thickness 0.40 to 0.50 mm.

Holotype (USNM 548221) from 400½–411′ in hole 2B, Bikini island, Marshall Islands.

This species seems to be closely related to the Recent species, *C. hispida* H. B. Brady, but is distinguished from it by its distinctly serrate periphery and the spines having a less tendency to be haphazard. More of the chambers are distinct on the ventral side and on the dorsal side it is possible in some cases to see the spiral suture. Apparently the supplementary skeleton is not well developed.

This species appears in abundance in both wells near the top and should prove to be a good marker of that part of the section. Its highest occurrence is in the sample at 184½–200½′ in hole 1.

Calcarina rustica Todd and Post, n. sp.

Plate 201, figure 7

Test globular, thickness nearly equal to diameter, periphery broadly rounded; chambers not visible from the surface, sutures not visible; wall thickly covered throughout by short, heavy, coarse, blunt spines, the test further ornamented by numerous (10 to 20) large spines irregularly distributed around the periphery, in diverging planes; aperture not observed.

Diameter, exclusive of spines, 0.60 to 0.90 mm, thickness 0.40 to 0.75 mm.

Holotype (USNM 548248) from 1145–1156′ in hole 2A, Bikini island, Marshall Islands.

This species seems closely related to that described as *C. gaimardi* D'Orbigny from various localities in the Pacific. It differs in being more globular and in not having a widely open aperture.

It occurs rather rarely in the upper parts of the wells. Its very coarse surface ornamentation serves to distinguish it from *C. delicata* n. sp. and from the Recent species of *Calcarina* which contaminate the drill cuttings.

Genus BACULOGYPSINA Sacco, 1893

Baculogypsina sphaerulata (Parker and Jones)

Orbitolina sphaerulata Parker and Jones, Annals and Mag. Nat. History, 3d ser., v. 6, p. 33, No. 8, 1860.

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Tinoporus baculatus H. B. Brady (not Montfort), *Challenger* Rept., Zoology, v. 9, p. 716, pl. 101, figs. 4–7, 1884.

This Recent shallow water species is not found living in the Marshall Islands but is found fairly commonly between 115 and 136 feet in hole 2A, and in the cuttings from 105 feet and deeper from hole 1. It was also found in the borings at Michaelmas Cay and Heron Island on the Great Barrier reef and to a depth of 373 feet in the Funafuti drill hole.

Family CYMBALOPORIDAE

Genus HALKYARDIA Heron-Allen and Earland, 1919

Halkyardia bikiniensis Cole

Plate 200, figure 7

Halkyardia bikinensis Cole, Chapter O of the present report, p. 564, pl. 210, figs. 1–5, 1954.

This species occurs from 2349′ to the bottom of hole 2B and is a good marker for that part of the section.

Family GLOBOROTALIIDAE

Genus CYCLOLOCULINA Heron-Allen and Earland, 1908

Cycloloculina sp.

Plate 200, figure 6

Three small specimens of this genus were found at 1891½–1902′ in hole 2B. They seem to be undescribed, but are inadequate for formal description. The chambers are smaller and the texture of the wall is finer than in *C. annulata* Heron-Allen and Earland. In the present specimens there is no indication of the radial crenulations around the periphery present in most species of this genus. Instead, the plane of the test is slightly undulating and the peripheral edge somewhat lobulated. The genus is known only from Eocene to Miocene.

Family ANOMALINIDAE

Genus ANOMALINELLA Cushman, 1927

Anomalinella rostrata (H. B. Brady)

Truncatulina rostrata H. B. Brady, *Challenger* Rept., Zoology, v. 9, p. 668, pl. 94, figs. 6a–c, 1884.

This Recent species is found rarely to abundantly in the upper parts of both holes, above Tertiary *e*.

Family PLANORBULINIDAE

Genus GYPSINA Carter, 1877

Gypsina howchini Chapman

Plate 201, figures 8, 9

Gypsina howchini Chapman, Royal Soc. Victoria Proc., v. 22, p. 291, pl. 2, figs. 4a, b; pl. 3, figs. 3–5, 1910; idem, v. 26, p. 172, 1913.

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This species described from the Miocene, Batesford limestone, of Victoria, Australia, occurs rather abundantly in both holes, less abundantly below the Pliocene and Pleistocene. Many specimens show evidence of attachment, apparently on some kind of slender stems.

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PLATE 198

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3. *Valvulammina marshallana* Todd and Post, n. sp. Holotype, USNM 547760, × 45. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view. Hole 2B, 1209–1219½′. (p. 554)

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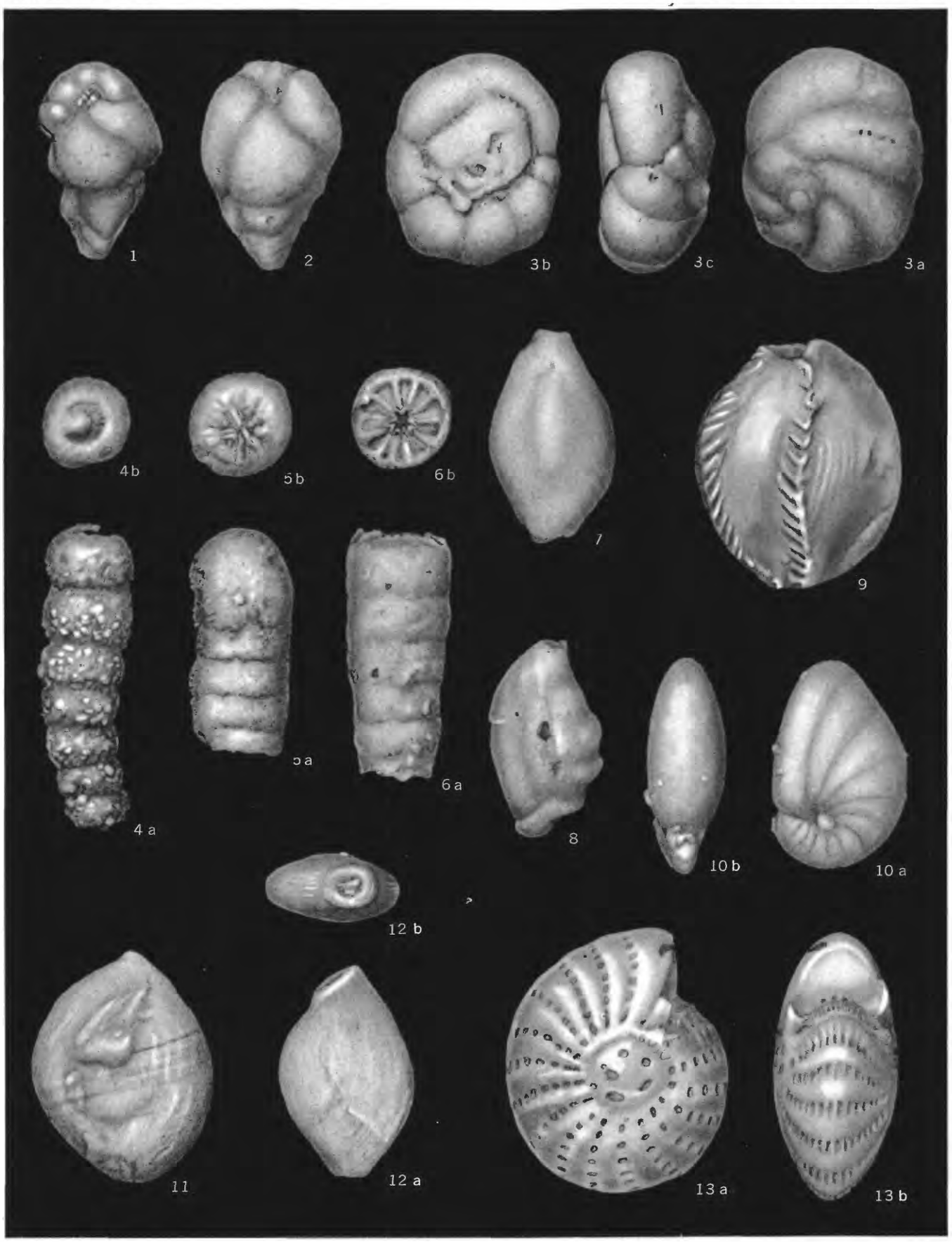
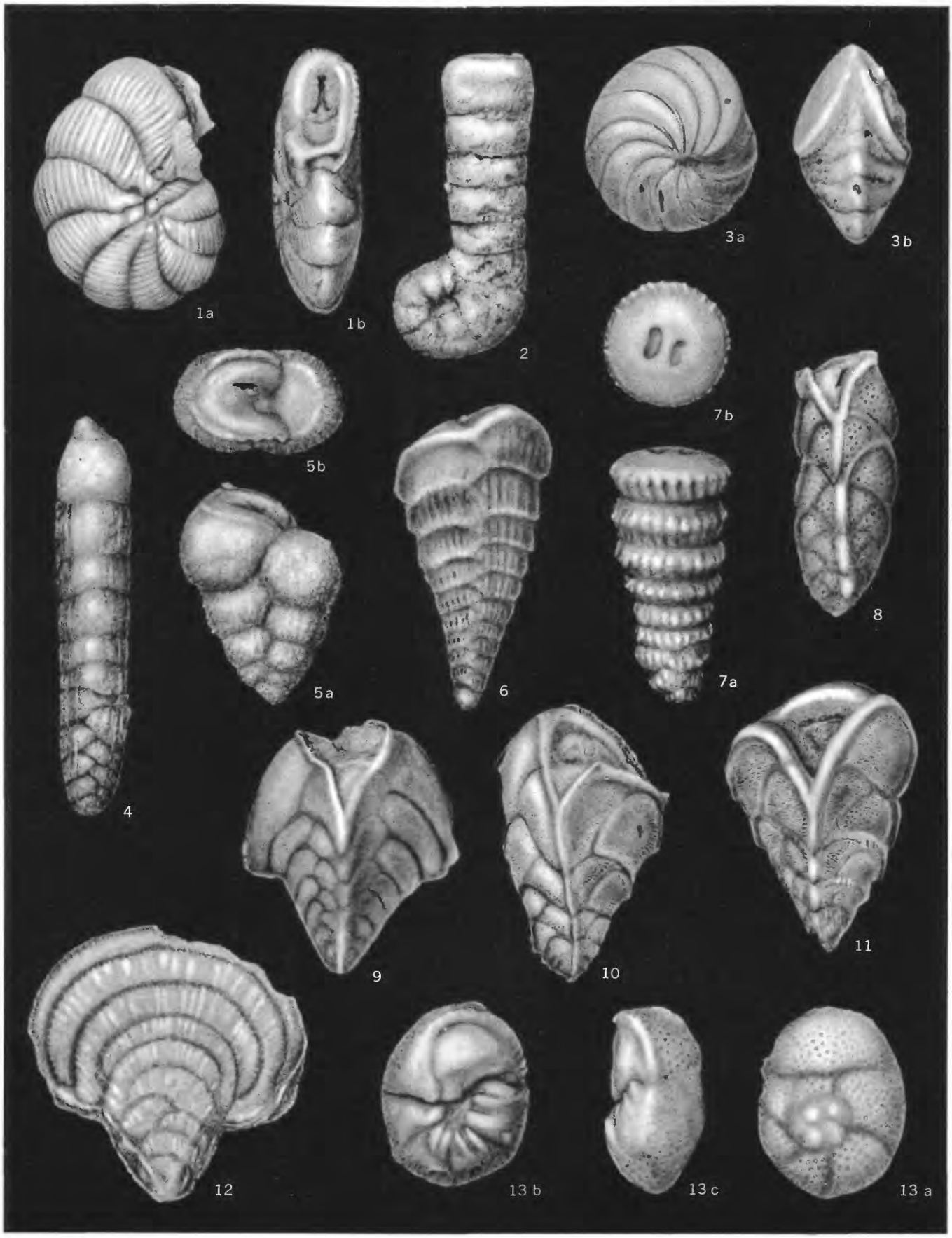


VALVULINIDAE, MILIOLIDAE, NONIONIDAE



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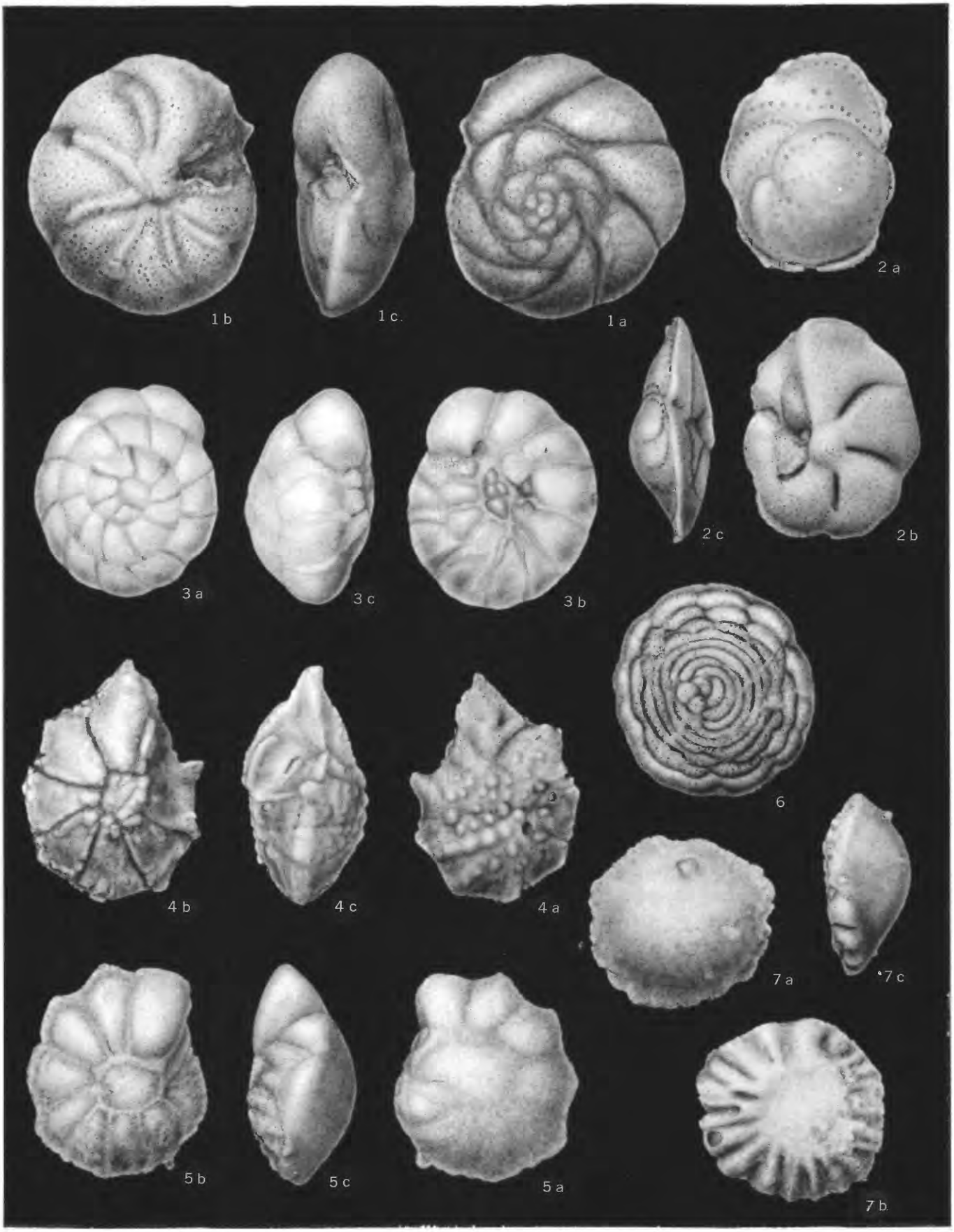
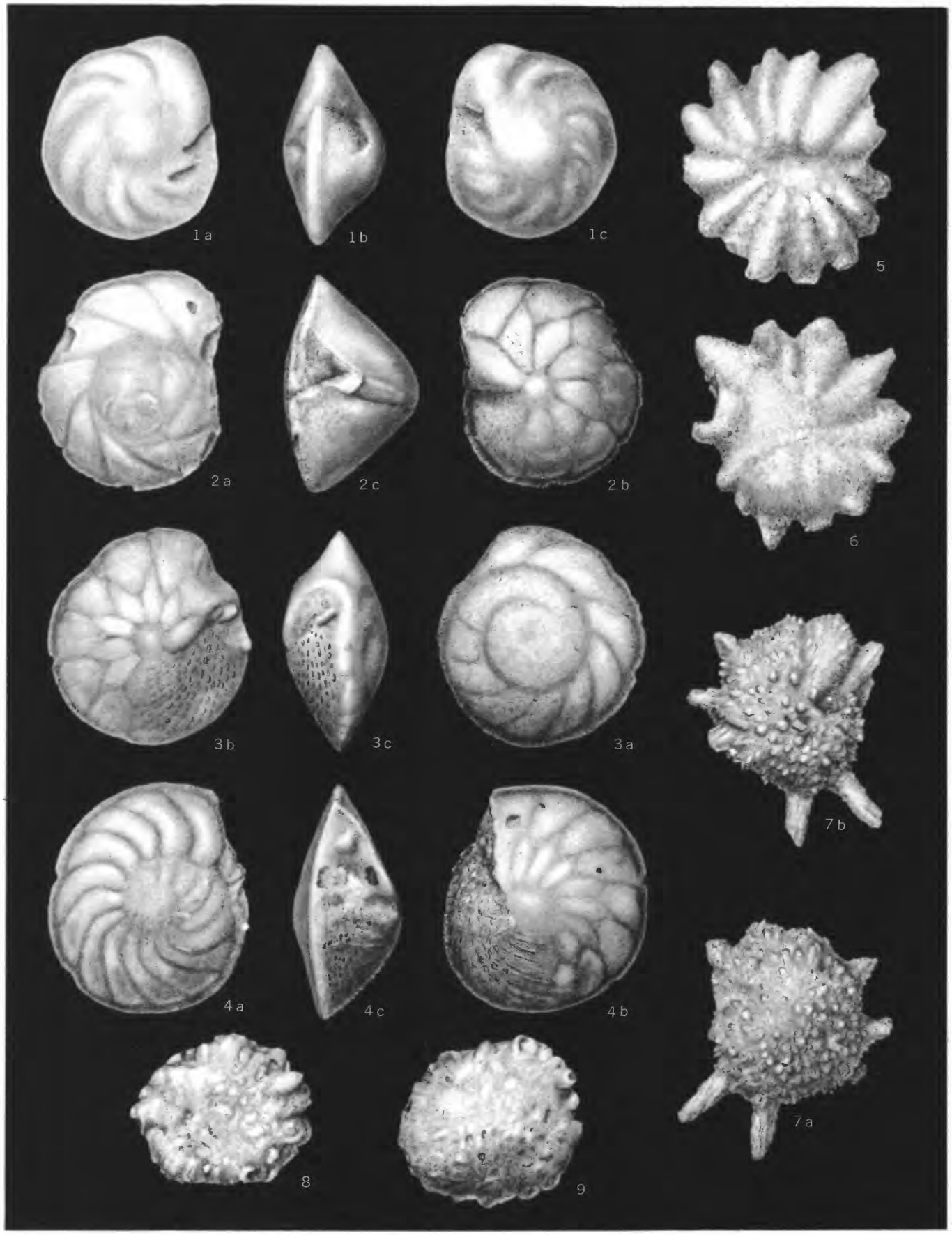


ROTALIIDAE, GLOBOROTALIIDAE, AND CYMBALOPORIDAE



AMPHISTEGINIDAE, CALCARINIDAE, AND PLANORBULINIDAE

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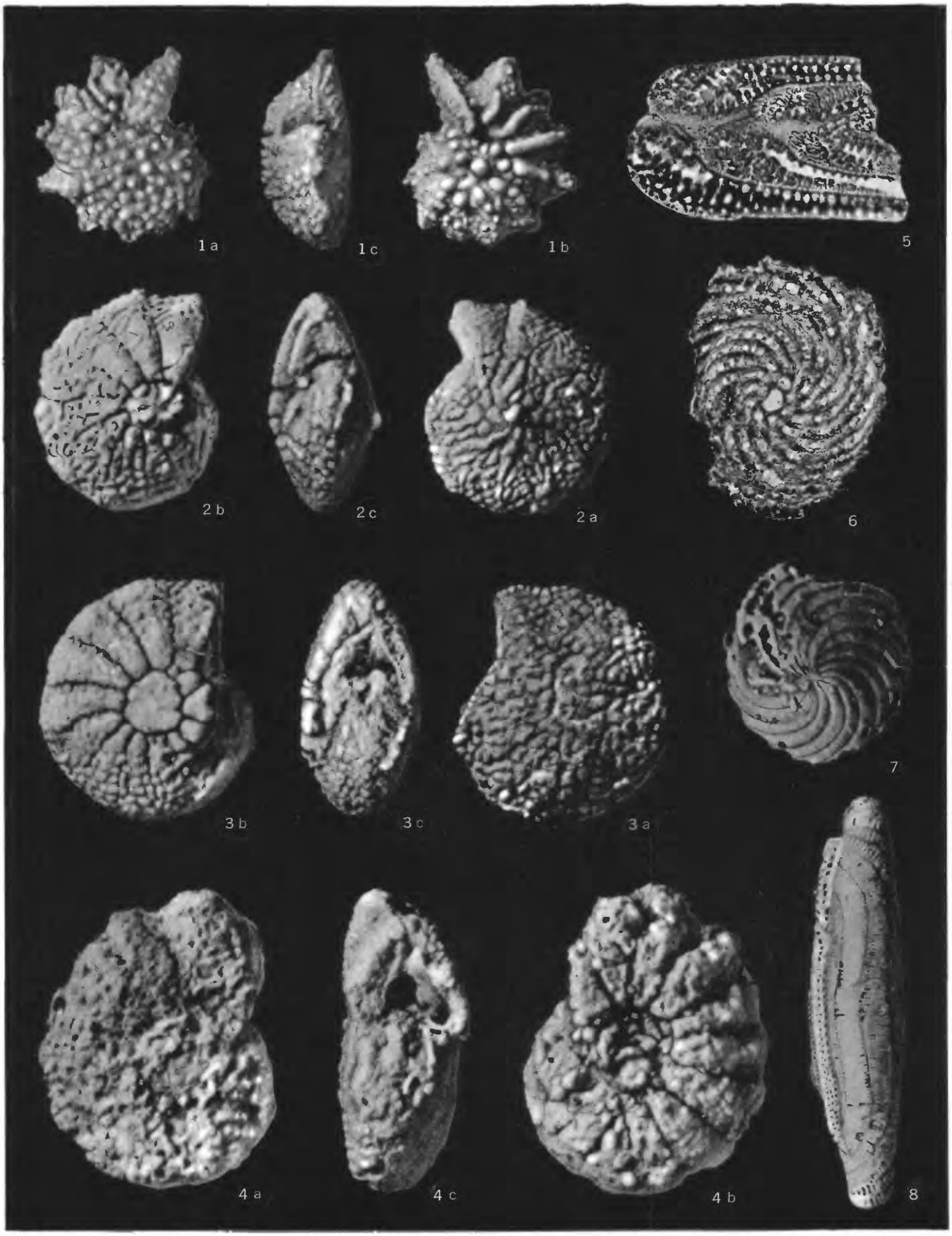
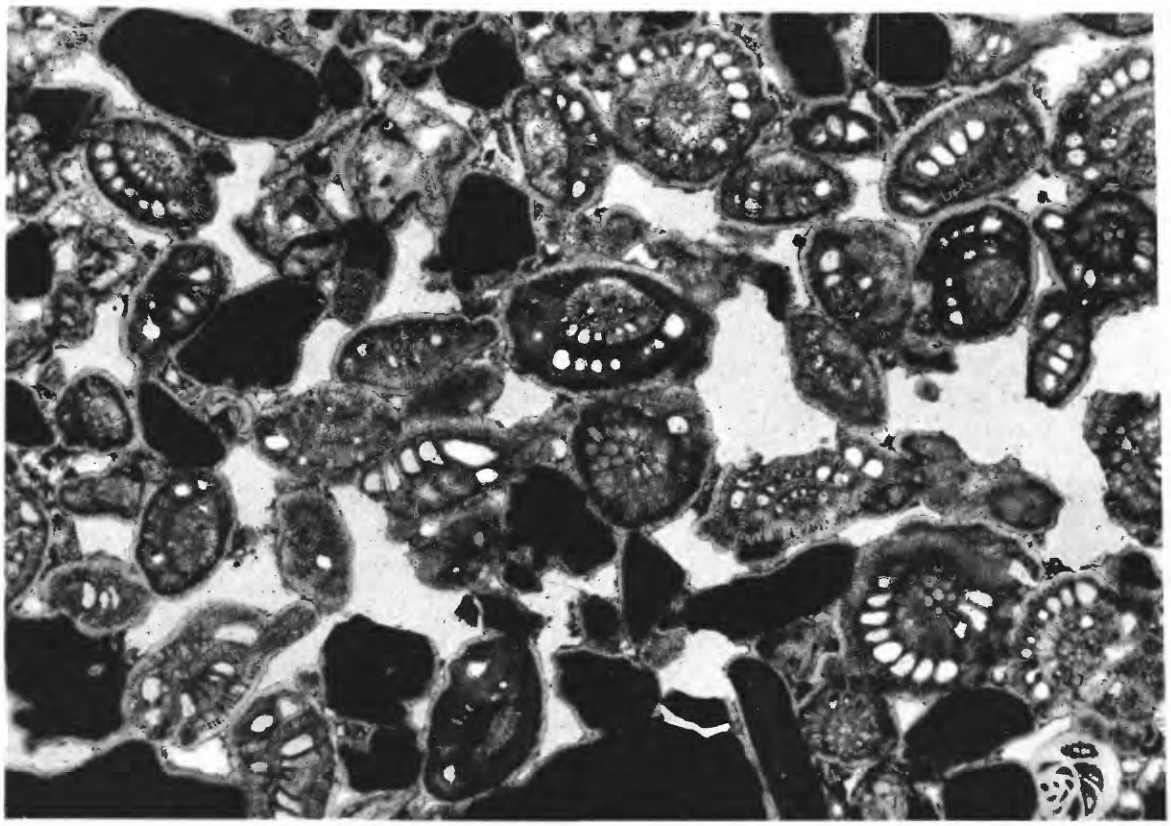
6, 7. *Archaias?* sp. 6, USNM 547910, × 40. Thin section. Hole 2B, 2049–2059½′. 7, USNM 547909, × 40. Hole 2B, 1891½–1902′. (p. 557)



PENEROPLODAE, ALVEOLINELLIDAE, AND ROTALIIDAE



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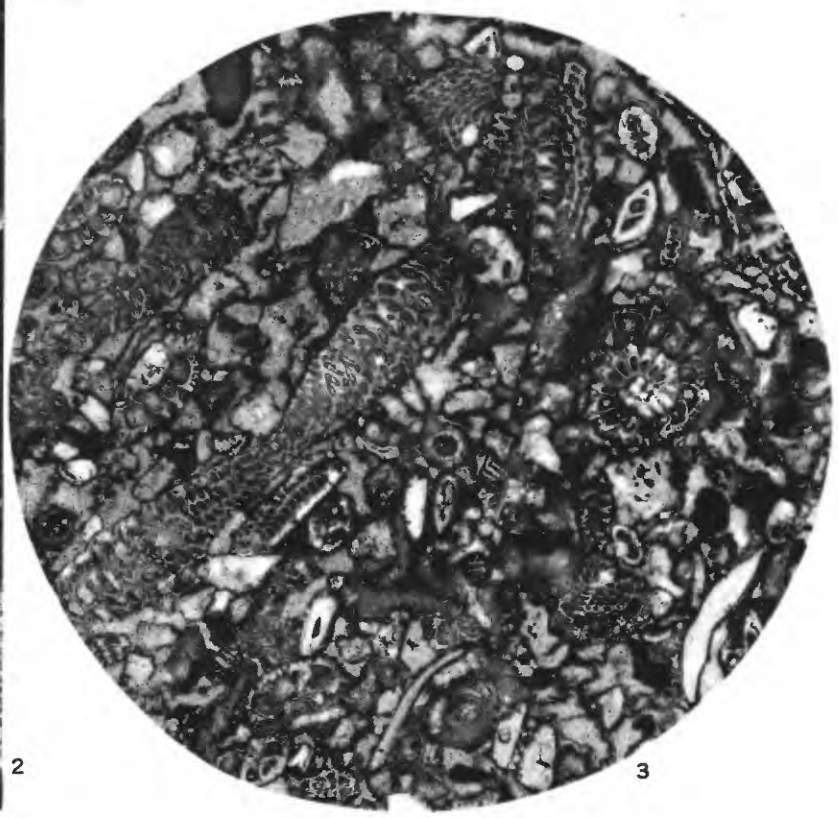

3

FORAMINIFERA IN THIN SECTIONS OF CORE MATERIAL

PLATE 203

FIGURE 1. Thin section of a well-cemented piece of core from hole 3, 1st core run, sample 3–1–2, consisting mainly of *Calcarina spengleri* (Gmelin) and fragments of *Lithothamnion*. The cement is a thin coating of acicular aragonite around each grain. The coating of cement is more clearly visible around the dark grains of *Lithothamnion*. × 14.5.

2. *Rotalia calcar* (D'Orbigny) in thin section from hole 2, 11th core run, sample 2–11–15 (a), × 80. The matrix is recrystallized to finely granular calcite.

3. Thin section of rock from hole 2, 11th core run, sample 2-11-15 (a), × 20. *a*, *Rotalia calcar* (D'Orbigny) in horizontal section. (Same specimen as shown in figure 2.) *b*, *Rotalia calcar* (D'Orbigny) in vertical section. *c*, *d*, *Marginopora vertebralis* Blainville. *d*, Specimen showing development of the test in three planes, rather than the usual one. *e*, Miliolid Foraminifera?

Larger Foraminifera and Smaller Diagnostic Foraminifera From Bikini Drill Holes

By W. STORRS COLE

Bikini and Nearby Atolls, Marshall Islands

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-O

Descriptions and illustrations of about 40 fossil Foraminifera, including 13 new species and 1 new variety

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1954

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BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

LARGER FORAMINIFERA AND SMALLER DIAGNOSTIC FORAMINIFERA FROM BIKINI DRILL HOLES

By W. Storrs Cole

ABSTRACT

Thirty-seven species and two varieties of diagnostic Foraminifera from the Bikini test holes 2A and 2B are described, discussed and illustrated. Twenty-four species and one variety are referred to previously described species, and thirteen species and one variety are new.

The stratigraphic section encountered is: 0–850 feet, Recent, Pleistocene and Pliocene; 850–2070 feet, Miocene; 2070–2556 feet Oligocene (?). Although it is not possible to subdivide the uppermost 850 feet, the Miocene section is subdivided according to the Indo-Pacific time scale as follows: 850–1030 feet, Tertiary *g*; 1030–1130 feet, Tertiary f_3; 1130-1380 feet, Tertiary f_{1-2}; 1380–2070 feet, Tertiary *e*. Three zones are present in Tertiary *e*: 1380–1590 feet, *Miogypsinoides dehaartii* zone; 1590–1720 feet, *Spiroclypeus margaritatus* zone, and 1720–2070, feet, *Eulepidina formosa* zone.

The evidence of the top of the Oligocene is not strong and consists mainly of the appearance of a new species of *Eulepidina*. The section between 2070 and 2349 feet is assigned tentatively to Tertiary *d*. At 2349 feet a new species of the genus *Halkyardia*[1] is found. This stratigraphically restricted genus, previously known only from the Eocene, has been found recently in definitely Tertiary *c* deposits in the Molucca Islands. It is on this evidence that the zone from 2349 to 2556 feet (which is the bottom of the hole) is assigned to Tertiary *c*.

INTRODUCTION

During a resurvey of Bikini Atoll (Operation Crossroads) in the summer of 1947, five test holes were drilled on Bikini island. A brief description of the drilling operations, the materials encountered and a comparison with drill holes on other atolls has been given by Ladd, Tracey and Lill (1948).

Foraminifera were separated from the samples from two of these wells, designated 2A and 2B, under the supervision of Mr. J. I. Tracey, Jr. These specimens are the basis of the present report. Some of the samples were examined by the writer, but in the time available he was able to examine only some of the most critical samples.

[1] This same species of *Halkyardia* recently has been found on Saipan in association with unquestioned upper Eocene, Tertiary *b*, genera of larger Formanifera. This portion of Bikini 2B may prove to be Eocene rather than Oligocene.

Although this report deals mainly with so-called larger Foraminifera, smaller Foraminifera whose identification may require thin sections are included. The thin sections and the photomicrographs of these were made by the writer.

All the specimens studied are deposited in the collection of the U. S. National Museum.

Bikini hole 2A was drilled to a depth of 1346 feet and Bikini hole 2B to 2556 feet. Samples were collected at about 10-foot intervals. Continuous samples from 195 feet to 1346 feet were available from hole 2A, and samples from 400½ feet to 2556 feet, with exception of the interval from 957 to 1167 feet, were studied from hole 2B. In the interval from 957 to 1167 feet in hole 2B one composite sample from 1020 to 1100 feet was supplied.

Because the wells were drilled by rotary methods, and core recovery was limited by physical difficulties, the exact ranges of the species were not determinable. Therefore only the first appearance of a species is recorded.

Many East Indian species are inadequately described and poorly illustrated. Many species are illustrated by a single photomicrograph, or at most by two or three. These inadequacies in the literature have vastly complicated the identification of the Bikini specimens.

Individuals within a single species vary tremendously so that a complete understanding of a species requires a great many thin sections. This variability is demonstrated in the systematic portion of this work. Vaughan (1933, pp. 6–8) in his classic Studies of American species of Foraminifera of the genus *Lepidocyclina* was one of the first workers to emphasize the need for large suites of specimens to demonstrate adequately the variability within single species.

STRATIGRAPHY

RECENT, PLEISTOCENE, AND PLIOCENE

Thirty-seven species and two varieties were found, including four Recent species. Twenty-four species

and one variety are referred to named species and thirteen species and one variety are described as new. The geographic and stratigraphic occurrence of the previously named species is shown in table 1. Their distribution throughout the drill holes (table 2) is such that satisfactory correlation may be made for most of their lengths.

From the top down to a depth of 852 feet in Bikini holes 2A and 2B, the most significant species is *Cycloclypeus carpenteri* H. B. Brady. Although this species is living, it occurs also as a fossil in the Pliocene and Pleistocene. These intervals in the wells are referred to the Pliocene and Pleistocene as the evidence is not sufficient to allow further subdivision.

Eventually, it may be possible to refer the lower portion of this section to the Miocene. At 694 feet in Bikini hole 2A and at 705 feet in Bikini hole 2B a new species of *Operculinoides* is encountered. The preservation of these specimens, however, resembles that of others from the upper portions.

TABLE 1.—*Geographic and stratigraphic distribution of the previously named species*

[*c–f*, Pacific region Tertiary stages; *R*, Recent; C, Chattian; *P*, Pleistocene]

	Australia	Borneo	Christmas Island	Guam	Java	Kita Daito Zima (North Borodino Island)	Lau Islands, Fiji	Mayotte Island	Moluccas Islands	Papua	Philippine Islands	Ryukyu Islands	Soemba	Soembawa	Sumatra
Austrotrillina howchini	*f*	*e–f* (?)			*e*	*e* (?)			*e*						
Borelis schlumbergeri								*R*							
Cycloclypeus carpenteri					*g–R*										
Flosculinella globulosa					*f*									*f*	
Gypsina vesicularis									*c–R*						
Heterostegina suborbicularis												*P–R*			
Lepidocyclina (Nephrolepidina) orientalis					*f*										
parva		*e–f*		*e*	*e*								*f*		*e*
sumatrensis inornata		*e–f*			*e–f*		*f*								*e*
verrucosa					*e–f*										
Lepidocyclina (Eulepidina) formosa		*e*	*e*		*e*				*e*	*e*	*e*				*e*
gibbosa											*e*				
planata		*e*													*e*
Lepidocyclina flexuosa		*e–f*													
Marginopora vertebralis					*f–R*										
Miogypsina (Miogypsina) borneensis		*e–f*				*e* (?)									
indonesiensis		*f*													
Miogypsinoides borodinensis						C (?)									
cupulaeformis		*f*													
dehaartii									*e*						*e*
ubaghsi		*e*													
Spiroclypeus leupoldi		*e*	*e*		*e*						*e*				*e*
margaritatus		*e*									*e*				
yabei		*e*													

MIOCENE

Tertiary g.—At a depth of 852 feet in both holes another new species of *Operculinoides* occurs. The preservation of these specimens is different from that of specimens from zones higher in the drill hole, but similar to specimens found below.

In the zone that is assigned to Tertiary *g* (uppermost Miocene) largely on position, two other species of Foraminifera of the type considered in this report occur: *Borelis schlumbergeri* (Reichel) and *Marginopora vertebralis* Quoy and Gaimard at 925–935½ feet in Bikini drill hole 2A. As this is a core sample, their occurrence here is not due to contamination. However, these species have been reported from the Recent and do not supply absolute evidence for stratigraphic correlation.

Tertiary f_3.—The first larger Foraminifera of special significance occurs at a depth of 1030–1035½ feet in Bikini hole 2A where specimens of *Miogypsinoides* occur. These specimens appear to resemble *M. cupulaeformis* (Zuffardi-Comerci) (1929, p. 147) described from deposits of supposed Burdigalian age on Borneo.

Moreover, these specimens are apparently the same as those identified as *Miogypsina neodispansa* (Jones and Chapman) by Cole (1945b, p. 297) from Vanua Mbalavu, Lau Islands, Fiji. At Vanua Mbalavu *M. cupulaeformis* is associated with *Cycloclypeus indopacificus terhaari* Tan (1932, p. 71–73) a variety characteristic of the Vindobonian. Some difficulty was encountered in reconciling the ranges of these two species on Vanua Mbalavu as *M. neodispansa* is definitely a Tertiary *e* species. But, the change in identification more nearly satisfies the reported stratigraphic position of this species.

TABLE 2.—*Distribution of species in Bikini drill holes at indicated depths, in feet*

	2A												2B																							
	195	673–678½	694–705	852–857	914–919½	925–935½	977–988	1030–1035½	1082½–1088	1135–1145½	1166½–1177	1240–1250½	705–715	715–726	852–862½	883½–894	1020–1100	1167–1177½	1293–1303½	1387½–1398	1398–1408½	1534½–1545	1587–1597½	1597½–1608	1660½–1671	1723½–1734	1744½–1755	1818½–1828	1849½–1860	1933½–1949	1954½–1965	1996½–2007	2070–2080½	2133–2143½	2349–2359½	2545½–2556
Austrotrillina howchini (Schlumberger)																															X					
Borelis schlumbergeri (Reichel)				X		X																													X	
Calcarina spengleri (Gmelin)	X																																			
Cycloclypeus carpenteri H. B. Brady		X												X																						
Flosculinella globulosa L. Rutten																																		X		
Gypsina vesicularis (Parker and Jones)																																				X
Halkyardia bikiniensis Cole, n. sp																																		X		
Heterostegina nigripustula Cole, n. sp																											X									
pusillumbonata Cole, n. sp																												X								
suborbicularis d'Orbigny	X																													X						
Lepidocyclina (*Nephrolepidina*) *augusticamera* Cole, n. sp																						X														
bikiniensis Cole, n. sp																						X														
unipilaris Cole, n. var																					X															
cubiculirhomboidea Cole, n. sp									X																											
orientalis van der Vlerk											X							X																		
parva Oppenoorth																							X													
pumilipapilla Cole, n. sp									X																											
sumatrensis inornata L. Rutten												X							X																	
verrucosa Scheffen																																		X		
(*Eulepidina*) *abdopustula* Cole, n. sp																																				
formosa Schlumberger																									X											
gibbosa Yabe																										X										
planata Oppenoorth																																X				
Lepidocyclina flexuosa L. Rutten																						X														
Marginopora vertebralis Quoy and Gaimard	X				X	X																														
Miogypsina (*Miogpsina*) *borneensis* Tan										X								X																		
indonesiensis Tan										X								X																		
Miogypsinoides borodinensis (Hanzawa)																								X												
cupulaeformis (Zuffardi-Comerci)								X																												
dehaartii van der Vlerk																				X																
grandipustulosa Cole, n. sp																							X													
ubaghsi Tan																									X											
Operculina lucidisutura Cole, n. sp					X											X																				
Operculinoides amplicuneata Cole, n. sp				X										X																						
bikiniensis Cole, n. sp							X										X																			
rectilata Cole, n. sp			X										X																							
Spiroclypeus leupoldi van der Vlerk																								X												
margaritatus (Schlumberger)																								X												
yabei van der Vlerk																									X											

At 1082½–1088 feet in Bikini hole 2A the first specimens of *Lepidocyclina* appear. Two species are present, *L.* (*Nephrolepidina*) *orientalis* van der Vlerk and *L.* (*N.*) *sumatrensis inornata* Rutten. *L.* (*N.*) *orientalis* marks the Preangerian stage or Tertiary f_3 of East Indian Archipelago, and in light of present knowledge this stage contains the highest known *Lepidocyclina*-bearing beds of the East Indian section. (Glaessner, 1943, p. 61)

Tertiary f_{1-2}.—At 1135–1145½ feet in Bikini hole 2A there are specimens of *Miogypsina* which are referred to *M.* (*Miogypsina*) *indonesiensis* Tan and *M.* (*M.*) *borneensis* Tan. At 1167–1177½ feet in Bikini hole 2B a fauna composed of *L.* (*N.*) *parva* Oppenoorth, *Miogypsina* (*Miogypsina*) *indonesiensis* Tan and *M.* (*M.*) *borneensis* Tan is encountered. Although the range of these species is given as Aquitanian and Burdigalian, it would appear from the occurrences of known Aquitanian species at lower horizons in the well that this portion should be classified as Burdigalian, or Tertiary f_{1-2}.

Abundant specimens of a *Lepidocyclina* identified as *L.* (*N.*) *verrucosa* Scheffen occur at 1240–1250½ feet in Bikini well 2A and at 1293–1303½ feet in Bikini hole 2B. This species is reported from both Tertiary *e* and *f*.

Tertiary e.—At 1387½–1398 feet in Bikini hole 2B there are abundant specimens of *Miogypsinoides dehaartii* van der Vlerk and a new species of *Lepidocyclina*, *L. cubiculirhomboidea*. As *M. dehaartii* is an Aquitanian species, the top of this stage is placed at this depth.

Although new species of *Lepidocyclina* appear at 1534½-1545 feet in Bikini hole 2B, an important faunal break occurs at 1597½–1608 feet in Bikini hole 2B with the first occurrence of the genus *Spiroclypeus*. Two species occur, *S. leupoldi* van der Vlerk and *S. margaritatus* (Schlumberger). Moreover, *Miogypsinoides borodinensis* (Hanzawa) and a new species, *M. grandipustula*, occur in this sample with a new species of *Lepidocyclina*, *L.* (*Nephrolepidina*) *pumilipapilla*.

At 1723½–1734 feet in Bikini hole 2B the first specimens of the subgenus *Eulepidina* of the genus *Lepidocyclina* occur. All the *Lepidocyclina* above this depth are referred to the subgenus *Nephrolepidina*.

Other important occurrences are a species of *Spiroclypeus*, *S. yabei* at 1671–1681½ feet in Bikini hole 2B and *Heterostegina* represented by two new species, first occurring at 1818–1828½ feet in Bikini hole 2B.

It appears that the Aquitanian, Tertiary *e*, in this hole could be subdivided in faunal zones as follows:

Depth in feet	*Zone*
1380–1590	*Miogypsinoides dehaartii*
1590–1720	*Spiroclypeus margaritatus*
1720–2350	*Eulepidina*

OLIGOCENE

Tertiary d(?).—There is a strong possibility that the *Eulepidina* zone should be subdivided, with the part from about 2070 feet in Bikini hole 2B down to the first appearance of *Halkyardia* separated from the upper portion. The depth 2070 feet marks the appearance of *L.* (*Eulepidina*) *abdopustula* n. sp.

The lower portion of the *Eulepidina* zone may represent Tertiary *d*. If so, the main zones of the Tertiary from *d* to *g* are represented in the Bikini holes.

Tertiary c(?).—At 2349 to 2359½ feet in Bikini hole 2B small specimens of *Halkyardia* are found, a most interesting occurrence as the genus *Halkyardia* in Europe occurs in the middle Eocene. It is known from the Molucca Islands (Bursch, 1947, p. 29–34), associated with undoubtedly Oligocene species and from New Zealand where the age of the deposits is in question (Parr, 1934, p. 144, 145; Findlay and Marwick, 1940, p. 97, 111; 1948, p. 23). The deposits in New Zealand have been referred to the lower Miocene and upper Oligocene, but at present these rocks are tentatively classified as Kaiatan (upper Eocene).

As no other species except *Gypsina vesicularis* (Parker and Jones) were found between this sample and the bottom of the hole, the question cannot be answered definitely that this hole actually penetrated the Oligocene. However, the available evidence suggests that the Oligocene has been reached and that the hole ended in the Oligocene.

The following table presents a summary of the divisions which have been made in the Bikini holes:

Correlation of the Bikini drill holes

Depth (feet)	Thickness (feet)	Stratigraphic divisions	Zone
Recent, Pleistocene, and Pliocene			
0.850	850		
Miocene			
850–1030	180	Tertiary *g*	
1030–1130	100	Tertiary f_3	
1130–1380	250	Tertiary f_{1-2}	
1380–1590	210		*Miogypsinoides dehaartii* zone
1590–1720	130	Tertiary *e*	*Spiroclypeus margaritatus* zone
1720–2070	350		*Eulepidina formosa* zone
Oligocene(?)			
2070–2349	280	Tertiary *d*(?)	
2349–2556	206	Tertiary *c*(?)	

COMPARISON WITH OTHER DRILL HOLES

Although test holes have been drilled on Funafuti Atoll, Ellice Islands, the Great Barrier reef and Mara-

toea near Borneo, the only comparable drill hole is the one on Kita-Daita-Zima (North Borodino Island) drilled by the Japanese in 1934–1936. This hole reached a depth of 431.67 meters (1416 feet).

Hanzawa (1940, p. 757–765) reports five faunal zones from this well as follows:

Age	Zone	Depth (meters)
Pleistocene and Pliocene	1	0–103.49
Aquitanian	2	103.49–116.41
	3	116.41–209.26
	4	209.26–394.98
Chattian	5	394.98–431.67

Lepidocyclina (*Nephrolepidina*) appears in zone 3 and *Spiroclypeus* is recorded only from zone 4. The eulepidine type of *Lepidocyclina* was not found.

The occurrence of Chattian is based on the appearance of a new species of *Miogypsinella=Miogypsinoides* as the chief fossil of zone 5. Inasmuch as this same species, *M. borodinensis* (Hanzawa), is found in the Bikini hole 2B in association with *Spiroclypeus* and a considerable distance above the first appearance of *Eulepidina*, the age assigned to the zone 5 of the Kita-Daito-Zima (North Borodino Island) well appears to be incorrect. This hole, in the writer's opinion, ends definitely in the Aquitanian, Tertiary *e*.

There is a correspondence in the appearance of genera in the North Borodino Island hole and the Bikini holes in that the nephrolepidine type of *Lepidocyclina* and *Miogypsina sensu stricto* appear first, followed by *Miogypsinoides* of the *M. dehaartii* type at greater depths and finally *Spiroclypeus* and *Miogypsinoides* of the *M. borodinensis* type. This general succession is found in Bikini hole 2B. From the information available it would appear that the North Borodino Island well did not penetrate sufficiently deep to encounter the *Eulepidina* zone.

Several species are common to the two holes: *Miogypsina* (*Miogypsina*) *borneensis* Tan, *Miogypsinoides borodinensis* (Hanzawa), *Austrotrillina howchini* (Schlumberger) and *Spiroclypeus margaritatus* (Schlumberger).

DESCRIPTION OF SPECIES

Family MILIOLIDAE

Genus AUSTROTRILLINA Parr, 1942

Austrotrillina howchini (Schlumberger)

Plate 210, figures 6–9

1893. *Trillina howchini* Schlumberger, Bull. Soc. Géol. France, ser. 3, v. 21, p. 119, text-fig. 1; pl. 3, fig. 6.

1942. *Austrotrillina howchini* (Schlumberger). Parr, Mining and Geol. Jour., Australia, v. 2, p. 361, figs. 1–3.

In the description of the genus *Austrotrillina* Parr records that the aperture is doubtfully cribrate. The Bikini specimens are excellently preserved so that the exact nature of the aperture could be observed. The aperture is bounded by a slightly elevated **U**-shaped lip which surrounds three sides of the aperture. The fourth side, facing the second chamber, is without a lip. The aperture is covered by a plate penetrated by several small pores that are especially well developed along the margins of the plate.

First appearance.—At a depth of 1954½–1965 feet in Bikini hole 2B.

Discussion.—Hanzawa (1940, p. 793) states that this species is found only in the Aquitanian stage in the western Pacific. Crespin (1943, p. 66), however, reports "it has been shown that *Austrotrillina howchini*, previously considered typical of '*e*' stage, has its type locality in the *Lepidocyclina* beds at Hamilton which are upper middle Miocene in age." Glaessner (1943, chart) gives the range of the genus *Austrotrillina* as Chattian, Aquitanian and Burdigalian, that is, Tertiary *d*, *e* and f_{1-2}.

The occurrence of this species in Bikini hole 2B is definitely Tertiary *e* as it is associated with *Spiroclypeus* and *Eulepidina*.

Family CAMERINIDAE

Genus OPERCULINOIDES Hanzawa, 1935

Specimens referred to this genus have not been reported from the Indo-Pacific region. However, certain specimens from the Bikini wells have the same features as American species that are commonly placed in this genus. The distinction between certain forms placed in this genus and others that are referred to the genus *Camerina* is extremely tenuous.

At present there seems to be a gradation between some small specimens that are referred to *Camerina* and others that are referred to the genus *Operculinoides*. More precise definitions are needed for these two genera.[2]

Operculinoides amplicuneata Cole, n. sp.

Plate 204, figures 7–10, 16–18

Test biconvex with a relatively sharp edge; surface ornamentation consisting of a relatively large umbonal area of clear shell material with a diameter of about 0.8 mm that is flush with the surface of the test and from which radiate slightly raised sutures of clear shell material; the sutures may be either straight and radial with a slight recurvature at their distal ends, or slightly wavy throughout their length; diameter from 2.2 to 2.4 mm; thickness about 1.3 mm.

[2] Criteria for distinguishing between these genera have been published (Cole, 1953, p. 27–46).

Embryonic apparatus bilocular, initial chamber subcircular with diameters of 80 by 100 μ; second chamber reniform with diameters of 45 by 100μ; thickness of the outer wall of the embryonic chambers about 20μ.

The test consists of 3¾ coils with 8 chambers in the initial whorl and 20 chambers in the final volution. The chamber walls are straight and radial with a slight recurvature at their distal ends.

Transverse sections show on either side of the embryonic chambers a plug of shell material that expands outward so that the surface diameter may be as much as 1.0 mm. This corresponds to the umbonal area of clear shell material seen on the exterior of the test.

First appearance.—At a depth of 852–857 feet in Bikini hole 2A; at a depth of 852–862½ feet in Bikini hole 2B.

Discussion.—The description of this species is based on specimens from a depth of 862½–873 feet in Bikini hole 2B. Eroded, chalky specimens from a depth of 852–857 feet in Bikini hole 2B are referred to this species and illustrated as figures 7, 9, 10, plate 204. These specimens have thicker side walls than the better preserved specimens from Bikini hole 2B, but otherwise have the same features.

This species is similar to the one that occurs at greater depths in the wells and to which the specific name *O. bikiniensis* is given. However, *O. amplicuneata* has a smaller diameter with fewer chambers in both the first and final volutions. It is thicker through the center and the axial plug is much larger.

This species belongs to the type referred by most authors to *O. ammonoides* (Gronovius), an extremely variable species. However, certain specimens in a given population of *O. ammonoides* possess evolute whorls and distinctive surface ornamentation. The Bikini specimens are constant in character in all the individuals examined.

Operculinoides bikiniensis Cole, n. sp.

Plate 204, figures 19–23

Test involute, compressed lenticular with a bluntly rounded periphery; surface ornamentation consisting of an irregular mass of clear shell material at the umbos of the test from which radiate to the periphery a number of discontinuous, slightly sinuous, lines of clear shell material. These areas and the lines of clear shell material are nearly flush with the surface of the test.

Measurements of 6 specimens follows:

	Median sections			Transverse sections		
Height—mm	2. 8	2. 6	2. 76	2. 3+	3. 0	2. 6+
Width—mm	2. 54	2. 4	2. 6			
Thickness—mm				0. 94	1. 04	0. 96
Diameter of initial chamber—μ	80	80	60	100	90	100
Diameters of second chamber—μ	40 x 100	60 x 100	40 x 80			
Number of volutions	3¾	4	4⅛			
Number of chambers in final volution	24	30	25			
Surface diameter of umbonal plug—mm				0. 46	0. 8	0. 44

The chamber walls as viewed in median sections are straight and radial except near their distal ends where they are slightly recurved. The proximal ends of the chamber walls are clubshaped and the apertural passage between the end of the chamber wall and the revolving partition appears in many well-oriented median sections.

First appearance.—At a depth of 977½–988 feet in Bikini hole 2A; at a depth of 1020–1100 feet in Bikini 2B.

Discussion.—There is a resemblance to certain specimens referred by various authors to *Operculina ammonoides* (Gronovius). The median section resembles the specimen figured by Yabe and Hanzawa (1925, p. 49–51) from Apia Harbor, Upolu, Samoa Islands. This specimen was identified first as *O. venosa* (Fichtel and Moll), but later Hanzawa (1939, p. 229) changed the identification to *O. ammonoides.*

Externally, the Bikini specimens are very similar to certain ones figured by Bannink (1948) as *O. ammonoides* (see especially Bannink's figure 116, plate 13). Bannink (1948, p. 115) in a statistical analysis of species of the genus *Operculina* believes that "the data about the number of chambers in the first coil are important in marking evolution." However, in the specimens studied by Bannink the highest number of chambers in the first volution is 8, whereas the specimens from Bikini have 10 or 11.

Bannink gives the range of *O. ammonoides* in the Netherlands East Indies as Tertiary e_{4-5} to Recent, but claims that by statistical means to be able to recognize various races of this basic species which developed at various horizons of geological time.

The specimens from Bikini not only have more chambers in the initial whorl, but they are larger. The Bikini specimens do not have the beading typical of certain individuals in any population of *O. ammonoides.*

Operculinoides rectilata Cole, n. sp.

Plate 204, figures 11–15; plate 205, figures 15–17

Megalospheric form.—Test small, thick with a bluntly rounded periphery; surface smooth, apparently devoid of ornamentation; diameter from 2.2 to 2.7 mm; thickness about 1.4 mm.

Embryonic chambers bilocular; initial chamber subcircular with diameters of 80 by 100 μ; second chamber reniform with diamters of 60 by 140 μ; outer wall of the embryonic chambers thick with a thickness of about 40 μ.

The adult test is composed of 4 volutions with 9 chambers in the initial coil and 24 chambers in the final volution. The chamber walls are nearly straight and radial although some have a very minor recurvature at their distal ends. The revolving wall is thick with a thickness of 120 μ.

Transverse sections show that the outer wall of the test is thick and that the various coils are fused into continuous masses on each side of the embryonic chambers. Pillars are not present.

Microspheric form.—Similar to the megalospheric form, but larger with a diameter of 3.4 to 4.0 mm and a thickness of about 1.2 mm.

First appearance.—At a depth of 694–705 feet in Bikini hole 2A; at a depth of 705–715½ feet in Bikini hole 2B.

Discussion.—The nearly parallel sides of the test, as seen in transverse sections, is a characteristic and constant feature of this species.

There is a slight resemblance to certain individuals that have been called *O. venosa* (Fichtel and Moll). Hanzawa (1939, pp. 225–232) believes that most of the specimens identified as *O. venosa* should be called *O. ammonoides* (Gronovius) which is an extremely variable species. The Bikini specimens are all very constant in the features displayed and none of them possess the evolute character and beaded sutures which characterize, at least, certain individuals of *O. ammonoides*. Therefore, the specimens from the Bikini hole are described as a new species.

Genus OPERCULINA d'Orbigny, 1826

Operculina lucidisutura Cole, n. sp.

Plate 204, figures 1–6

Test compressed or with an eccentric umbo surrounded by a thin, compressed rim. Surface ornamentation consists of an umbonal mass of shell material from which radiate rather broad, slightly raised sutures of clear shell material. The sutures are straight and radial except near their distal ends where many of them become recurved. In most specimens the periphery is bounded by a band of clear shell material into which the distal ends of the sutures fuse. The height is from 1.9 to 2.5 mm; the width is 1.6 to 2.1 mm; the thickness through the umbo is about 0.6 mm; the thickness of the rim is 0.12 to 0.44 mm.

A specimen with a height of 2.4 mm and a width of 2.0 mm has a spherical initial chamber with an internal diameter of 60 μ. The second chamber is reniform with internal diameters of about 40 by 100 μ. There are 10 chambers in the first volution and 21 chambers in the final volution. The chamber walls are straight and radial until the distal ends are approached where sharp recurvature occurs. The revolving wall is thick. There are 3 volutions in the adult test.

Transverse sections show an umbonal plug on each side of the embryonic chambers. The surface diameter of these plugs is from 140 to 240 μ. On either side of the umbonal plugs there are several small pillars with surface diameters of 40 to 100 μ.

First appearance.—At a depth of 914–919½ feet in Bikini hole 2A; at a depth of 883½–894 feet in Bikini hole 2B.

Discussion.—This species belongs to the same group as does *O. complanata* (Defrance) and *O. bartschi* Cushman. *O. lucidisutura* is more involute than typical specimens of *O. complanata*. Its smaller size and surface ornamentation separate it from *O. bartschi*.

Genus HETEROSTEGINA d'Orbigny, 1826

Heterostegina nigripustula Cole, n. sp.

Plate 209, figures 1–8

Test thickest over the embryonic chambers, thence thinning rather regularly to the periphery, surface ornamented by slightly projecting papillae which are larger and closer spaced on the inflated portion than on the flange. Several papillae are more or less fused directly over the embryonic chambers to form an umbonal boss. The flange papillae have diameters of 60 to 80 μ; the papillae on the inflated portion have a diameter of about 160 μ and the umbonal boss has a diameter of about 460 μ. The wall of the test is dull white, whereas the papillae are dark grey, thus they become very conspicuous features on the surface of these tests. The height of the test is 3.4 to 3.9 mm; the width is 2.9 to 3.2 mm, and the thickness is 1.36 to 1.7 mm.

The initial chamber of the embryonic apparatus is subcircular with internal diameters of 260 by 280 μ in median sections and internal diameters of 190 by 240 to 260 by 300 μ in transverse sections. The second chamber is reniform with internal diameters of 130 by 340 μ

in median sections and internal diameters of 190 by 240 μ in transverse sections. The distance across both chambers is 340 to 380 μ.

There are about 2½ coils with the first chamber after the embryonic chambers undivided, the second divided into three chamberlets, the third chamber divided into four chamberlets and the fourth divided into seven chamberlets.

In transverse sections pillars occur, closely grouped in the area over the embryonic chambers and irregularly scattered in the other portions of the test. The pillars taper rapidly as they approach the median layer. In general, the umbonal pillars penetrate to the median layer, but the pillars outside of this zone often penetrate only a portion of the distance to the median layer.

In most of the transverse sections there are open spaces between the covering walls which resemble lateral chambers. In some sections these are more apparent than in others, although all the transverse sections show this feature.

First appearance.—At a depth of 1818–1828½ feet in Bikini hole 2B.

Discussion.—This species most nearly resembles *Heterostegina borneensis* van der Vlerk (1929, p. 16). It differs from that species in possessing pseudo-lateral chambers and a much larger operculine chamber following the embryonic chambers. The pillars in specimens from Saipan assigned to *H. borneensis* are much more regular in development and scattered more evenly throughout the test.

Heterostegina pusillumbonata Cole, n. sp.

Plate 206, figures 3–9

Test thin, compressed, fragile with a small eccentrically located umbo surrounded by a wide rim. Surface ornamentation consists of a group of umbonal pustules from which radiate arcuate, beaded sutures outlining the curved chamber walls. Chamberlet sutures do not show unless the surface of the specimen is moist. The pustules at the center of the umbonal area are very close together and give the appearance of being virtually in contact. These pustules have a surface diameter of about 140 μ. This cluster of pustules is surrounded by smaller pustules with diameters of about 100 μ and distinctly separated from each other. The sutural beads have diameters of about 60 μ. The height of an average specimen is 3.4 mm; the width is 2.4 mm; the diameter of the umbo is 1.0 mm; the thickness through the umbo is 0.7 mm; and the thickness through the rim is 0.3 mm.

The embryonic chambers are bilocular with a subcircular initial chamber followed by a reniform chamber. There is one operculine chamber following the embryonic chambers. The first heterostegine chamber is divided into 2 or 3 chamberlets.

In one median section the initial chamber has internal diameters of 160 by 200 μ; the second chamber has internal diameters of 100 by 200 μ; the distance across both chambers, including the walls, is 360 μ, and the operculine chamber has internal diameters of 40 by 180 μ. In the other available median section the initial chamber has diameters of 140 by 180 μ; the second chamber has internal diameters of 65 by 200 μ; the distance across both chambers is 300 μ, and the operculine chamber has internal diameters of 50 by 180 μ.

In a transverse section the distance across both chambers, including the walls, is 300 μ and the height of the chambers, including both walls is 240 μ.

The test is composed of 2 to 2¼ whorls. The chambers and their chamberlets gradually increase in size as they are added, but there are irregularities particularly in the radial diameters. Chamberlets of the final chambers have radial diameters from 140 to 200 μ and tangential diameters from 80 to 100 μ.

Small pillars, crowded together, are present over the embryonic chambers. Smaller pillars are scattered irregularly through the remainder of the side walls.

First appearance.—At a depth of 1849½–1860 feet in Bikini hole 2B.

Discussion.—This species resembles somewhat *H. praecursor* Tan (1932, p. 133–135) but is smaller than that species, has a larger and more developed umbo, and has numerous umbonal pillars. Internally, the two species are strikingly different.

Heterostegina suborbicularis d'Orbigny

Plate 205, figures 5–8

1826. *Heterostegina suborbicularis* d'Orbigny, Ann. Sci. Nat., v. 7, p. 305.
1880. *Heterostegina curva* Moebius, Merresfauna Insel Mauritius, p. 105, pl. 13, figs. 1–6.
1925. *Heterostegina depressa* Yabe and Hanzawa [*not* d'Orbigny] Tohoku Imp. Univ., Sci. Rep., ser. 2 (Geol.), v. 7, pp. 53–55, pl. 8, figs. 5, 6; pl. 9, figs. 4–7; pl. 10, fig. 4.
1933. *Heterostegina suborbicularis* d'Orbigny. Cushman, U. S. Natl. Mus. Bull. 161, pt. 2, p. 58, pl. 17, figs. 6*a*, *b*.
1933. *Heterostegina curva* Moebius. Cushman, idem, pl. 17, figs. 1–5.

Through the upper section of the holes, specimens of *Heterostegina* occur. The preservation of the specimens indicates that some are living forms present as contamination and others are fossil. All, however, appear to represent this species.

This species is characterized by a large number of operculine chambers, of which there are about 19 in the megalospheric generation and about 34 in the microspheric generation.

Genus SPIROCLYPEUS H. Douvillé, 1905

Spiroclypeus leupoldi van der Vlerk

Plate 208, figures 1–19

1925. *Spiroclypeus leupoldi* van der Vlerk, Wetensch. Meded. No. 3, p. 14, 15, pl. 2, fig. 16; pl. 5, figs. 41, 48.
1926. *Spiroclypeus globulus* Nuttall, Quart. Jour. Geol. Soc. London, v. 82, p. 36, 37, pl. 5, figs. 5–7, text fig. 1.
1929. *Spiroclypeus leupoldi* van der Vlerk and Wennekers, Eclog. Geol. Helvet., v. 22, p. 167, pl. 16, figs. 7a–d.
1931. *Spiroclypeus leupoldi* van der Vlerk. Krijnen, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 9, p. 90, pl. 3, figs. 1–3.
1937. *Spiroclypeus leupoldi* van der Vlerk. Tan, De Ing. Ned.-Indië. 4. Mijnbouw en Geol. 4 Jaarg., p. 182, 183.

Test small, evenly biconvex, or with an eccentrically situated unbonal area surrounded by a gently sloping rim; surface ornamentation consisting of minute pustules from each of which radiate at approximately 120° angles 3 slightly raised sutures. The sutures bound polygonal or rudely hexagonal shaped areas which represent the surface expression of the lateral chambers. In unweathered specimens the pustules and sutures are composed of clear shell material, and the intervening areas are covered by dense shell material. In weathered specimens the distinction between materials is destroyed largely, and the pustules and sutures appear only as slightly raised areas. In the unweathered and especially in the worn specimens the external wall of certain of the lateral chambers is removed which results in the formation of polygonal-shaped pits. The pustules have surface diameters of 40 to 80 μ with those of the greater diameter located in the central area. Measurements of heights and thickness through the center follow:

Depth——feet	1597½–1608				1639½–1650	1660½–1671	1671½–1681½	1681½–1692
Height——mm	2. 1+	2. 7	2. 06+	2. 7	2. 0+	2. 4+	2. 1+	2. 54+
Thickness——mm	1. 1	0. 8	1. 0	1. 2	1. 28	1. 6	1. 0	1. 02
Shape	Inflated lenticular.	Compressed lenticular.	Slight rim.	Lenticular	Inflated lenticular.	Slight rim.	Marked rim.	Marked rim.

The embryonic apparatus is bilocular with the initial chamber circular to subcircular. The second chamber is reniform. The first chamber after the initial chambers is undivided and large. Measurements of the embryonic and succeeding chambers follow:

Depth——feet	1597½–1608	1650–1660½	1681½–1692	1681½–1692
Initial chamber——μ	160 x 180	140 x 160	190 x 200	150 x 180
Second chamber——μ	80 x 300	70 x 200	90 x 280	75 x 210
Operculine chamber——μ	80 x 320	60 x 200	90 x 280	60 x 260
Number of chamberlets in first heterostegine chamber	2	3	5	4

Median sections show from 2¼ to 2½ whorls. The chamberlets increase in size toward the periphery. Peripheral chamberlets have a radial diameter of about 140 μ and tangential diameters of 60 to 80 μ.

The median chambers have an internal height of 30 to 40 μ. The height of the median layer, including the floor and roof, is about 90 μ.

The lateral chambers are arranged in rather regular tiers. The cavities of the lateral chambers are low, appressed, but distinct and open. The juncture of two tiers of lateral chambers is marked by a thickening of the shell material which produces a pillarlike structure. The ends of these thickened areas appear on the surface of the test as pustules. Measurements of critical features of the transverse sections follow:

Depth (feet)——mm	1597½–1608				1639½–1650	1660½–1671	1671–1681½	1681½–1692
Thickness——mm	0. 8	1. 0	1. 1	1. 2	1. 28	1. 6	1. 0	1. 02
Number of lateral chambers to a tier on each side of the center	6	6	7	9	9	11	8	6
Length of lateral chambers——μ	100–120	100–120	80–160	80–140	100–140	140–200	100–200	100–140
Height of lateral chambers——μ	10	20	20	20	20	30–40	20–35	20–30
Thickness of floors and roofs——μ	40	20–40	20–40	20–40	40	20–40	20–40	20

First appearance.—At a depth of 1597½–1608 feet in Bikini drill hole 2B.

Age reported elsewhere.—Aquitanian, Tertiary *e*.

Discussion.—This species was described from beds located in the northeastern portion of the Netherlands sector of Borneo (Van der Vlerk, 1925, p. 14, 15).

Krijnen (1931, p. 90) in a review of the genus illustrates and gives measurements of specimens referred to this species. Tan (1937, p. 182, 183) discusses this species briefly and places it in the group which he designates the reticulate forms.

In median sections the most striking feature is the large operculine chamber following the embryonic apparatus. This is shown in the illustration given by Krijnen and in the specimens figured in this report. In transverse section the absence of heavy pillars and the arrangement of the lateral chambers in regular tiers are the most striking features. However, the thickening of the lateral chamber walls at the juncture of the tiers produces a feature which resembles a pillar, and some difficulty is encountered in distinguishing these transverse sections from those of other species.

In the collections of the U. S. National Museum there were three specimens labelled *Spiroclypeus leupoldi* van der Vlerk (USNM 545,009) from locality 3, Tidoengsche Landen, East Borneo. With the permission of the Museum authorities one of these specimens was made into a median section, another furnished a transverse section (figures 6, 7, plate 208), and the third was retained for the external appearance.

A description of these specimens follows: A specimen with a diameter of 1.8 mm and a thickness of 1.4 mm has shallow, polygonal pits with diameters of about 140 μ covering the exterior. The walls separating these pits have a thickness of 80 to 160 μ. Pillars are not present.

A specimen with a diameter of 1.6 mm was utilized for a median section. The initial chamber is subcircular with diameters of 135 by 150 μ. The second chamber is reniform with diameters of 60 by 180 μ. There is one operculine chamber with diameters of 80 by 200 μ. The first heterostegine chamber has four chamberlets.

The chamberlets have considerable variation in size. Small ones have radial diameters of about 60 μ and tangential diameters of about 60 μ. Large ones have radial diameters of about 140 μ and tangential diameters of about 80 μ.

A transverse section was made from a specimen with a height of 2.0+ mm and a thickness of 1.2 mm. The initial chamber only is exposed in this section, and it has a diameter of 120 μ.

The lateral chambers are arranged in regular tiers. There are about 10 chambers to a tier on either side of the embryonic apparatus. The chamber cavities are low, appressed between thick roofs and floors. Chambers over the center and at the periphery of the test have a length of about 80 to 120 μ and a height of about 20 μ. The roofs and floors have a thickness of about 25 to 40 μ.

Pillars are not present, but the thickened wall between the lateral chambers presents the appearance of pillars.

The equatorial layer has a height of 35 μ at the center of the test and a height of 50 μ at the periphery of the test.

Spiroclypeus margaritatus (Schlumberger)

Plate 206 figures 10–25; plate 207, figures 15, 16

1902. *Heterostegina margaritata* Schlumberger, Geol. Reichs-Mus., Leiden, Samml., v. 6, p. 252–253, pl. 7, fig. 4.

1925. *Spiroclypeus margaritatus* (Schlumberger). Yabe and Hanzawa, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 8, p. 627–630, text figs. 1–3.

1931. *Spiroclypeus margaritatus* (Schlumberger). Krijnen, *idem.* v. 9, p. 89, pl. 1, figs. 1–3.

1937. *Spiroclypeus margaritatus* (Schlumberger). Tan, De Ing. in Ned.-Indië. 4. Mijnbouw en Geol. 4 Jaarg., p. 182, pl. 2, fig. 12; pl. 3, fig. 9; pl. 4, figs. 6, 7.

1940. *Spiroclypeus margaritatus* (Schlumberger). Hanzawa, Jubilee Publ. in commemoration of Prof. H. Yabe's 60th birthday, p. 789, 790, pl. 42, figs. 3–9.

Test small, inflated to evenly biconvex, bordered by a narrow rim. Surface ornamentation in unweathered specimens consists of slightly raised pustules of lustrous shell material of irregular shape with surface diameters in the umbonal area of about 200 μ. The pustules become smaller and more nearly circular toward the flange of the test. From each pustule sutures of the same type of shell material radiate to enclose polygonal areas of dense shell material. On portions of the flange the sutures of the rectangular chamberlets of the median layer show. Weathered specimens have the same ornamentation, but there is not the contrast in shell material between the pustules and sutures and the intervening areas. The polygonal areas in many specimens are in the form of pits produced by the destruction of the outer wall of the lateral chambers which underlie each of the polygonal areas. Measurements of heights and thickness through the center follow:

Depth—feet	1597½–1608					1639½–1650	1671–1681½
Height—mm	2.2+	1.84+	2.4+	2.4+	2.9+	2.5+	3.0+
Thickness—mm	0.98	1.2	1.56	1.6	1.5	1.52	1.46
Shape	Lenticular	Lenticular	Slight rim	Lenticular	Slight rim	Slight rim	Slight rim.

The embryonic apparatus is bilocular with the initial chamber spherical to subspherical. The second chamber is reniform. The first chamber after the embryonic chambers is simple and moderate in size. Measurements of the embryonic apparatus and succeeding chambers follow:

Depth—feet	1597½–1608			1639½–1650
Initial chamber—μ	160 x 180	230 x 280	180 x 240	220 x 240
Second chamber—μ	70 x 240	120 x 270	65 x 200	100 x 300
Operculine chamber—μ	60 x 160	60 x 180	60 x 100	80 x 160
Number of chamberlets in first heterostegine chamber	5	4	4	5

Median sections show from 2 to 2¼ whorls. The chamberlets increase in size toward the periphery. Peripheral chamberlets have a radial diameter of about 100 μ and tangential diameters of 70 to 90 μ.

The median chambers have an internal height of about 40 μ. The height of the median layer, including the floor and roof, is from 160 to 200 μ.

The lateral chambers are arranged in regular tiers between the pillars, but in the portions of the test where pillars are not developed chambers from one tier overlap those of adjacent tiers. The chamber cavities are low, slitlike, but open and distinct. The roofs and floors are thick. Heavy pillars occur especially over the embryonic apparatus. Measurements of critical features of the transverse sections follow:

Depth (feet)	1597½–1608					1639½–1650	1671–1681½
Thickness—mm	0. 98	1. 2	1. 56	1. 6	1. 5	1. 52	1. 46
Number of lateral chambers to a tier on each side of the center	6	7	6	7	6	6	6
Length of lateral chambers—μ	100	100	100–160	80–160	80–140	100–140	120–180
Height of lateral chambers—μ	20	20	20	20	20	20–40	20–30
Thickness of roofs and floors—μ	40–50	40–60	40–100	40–80	60–80	40–80	60–140
Surface diameter of pillars—μ	80–100	100–180	140–280	120–340	140–240	140–220	200–260

First appearance.—At a depth of 1597½–1608 feet in Bikini hole 2B.

Age reported elsewhere.—Aquitanian, Tertiary *e*.

Discussion.—This species is distinguished from *S. leupoldi* with which it is associated by the possession of large, heavy pillars, the thick roofs and floors of the lateral chambers and the moderate size of the operculine chamber.

As there is confusion in the definition of the species of *Spiroclypeus*, the discussion which follows attempts to define certain specimens available to the writer for comparison with the Bikini material.

Douvillé (1905, p. 462–464) refers specimens of *Spiroclypeus* from Hikun on the Tabalong River, SE. Borneo to the species *S. pleurocentralis* (Carter). The illustrations given by Douvillé consist of two external views and one transverse section.

In the collection of the U. S. National Museum there are three specimens from this locality which from their external appearance are the same as the ones illustrated by Douvillé. From these specimens one median and one transverse section (plate 206, figures 1, 2), was made; the remaining specimen was preserved intact for the external appearance.

A description of these specimens follows: Test biconvex, with or without a narrow rim; surface ornamentation consisting of slightly raised, rather large pustules with surface diameters of 180 to 200 μ scattered irregularly over the surface, but especially well developed on the umbonal area; diameter 1.9 to 2.8 mm; thickness 1.5 mm.

The embryonic chambers are large, the initial chamber has diameters of 450 by 560 μ; the second chamber has diameters of 240 by 600 μ. There is one operculine chamber with diameters of 80 by 460 μ. The first heterostegine chamber contains 3 chamberlets. On the other side of the embryonic chambers opposite the operculine chamber is a subsidiary chamber with diameters of 80 by 220 μ.

Chamberlets of the median layer have tangential diameters of about 180 μ and radial diameters of about 60 to 100 μ.

In transverse section the embryonic chambers have a length of 540 μ and a height of 260 μ.

The lateral chambers are low, appressed between very thick roofs and floors. The lateral chambers do not occur in regular tiers, but are scattered and overlapping. There are about 6 layers of lateral chambers on each side of the embryonic chambers. The length of the lateral chambers varies considerably, the shorter ones have a length of about 80 μ and the longer ones a length of about 200 μ. The height of the lateral chambers is about 20 μ. The thickness of the floors and roof is from 40 to 80 or more μ.

Pillars are irregularly scattered throughout the transverse section. These pillars have surface diameters of 200 to 300 μ.

Tan (1937, p. 183) in writing of the specimens illustrated by Douvillé states: "Douvillé's *Spir.? pleurocentralis* cannot be exactly identified at the moment, it may be a *Spir. margaritatus*, whereas the section of Douvillé's fig. 9 may have been made from a reticulate *Spiroclypeus*."

Although the specimens in the U. S. National Museum have the same external appearance as the specimens illustrated by Douvillé (1905) as figures 7 and 8, the transverse section made from one of these specimens is not at all similar to the transverse section illustrated by Douvillé as figure 9. As Tan has indicated, this transverse section has the appearance of a *Spiroclypeus* of the *leupoldi* group.

Krijnen (1931, p. 89, 90) considers the Netherland East Indian specimens should be referred to *pleurocentralis* and that the species named *yabei* by van der Vlerk (1925, p. 16) should be a synonym of this species. Tan (1937, p. 183, 190) however, retains the name *yabei* and assumes the position that *S. pleurocentralis* of Carter may not even represent a *Spiroclypeus* inasmuch as this species is very poorly described and figured.

Van der Vlerk (1925, p. 16, 17) in the type description of the species, *S. tidoenganensis*, describes and illustrates in this species a very large embryonic apparatus which resembles that of the specimens from Hikun. It is almost certain that these specimens should be referred to *S. tidoenganensis*.

Spiroclypeus yabei van der Vlerk

Plate 207, figures 1–14; plate 208, figures 20–26

1925. *Spiroclypeus yabei* van der Vlerk, Wetensch. Meded. No. 3, p. 16, pl. 2, fig. 19; pl. 5, figs. 40, 50.

1931. *Spiroclypeus pleurocentralis* Krijnen [not *Orbiculina pleurocentralis* Carter 1857]. Krijnen, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 9, p. 89–90, pl. 1, figs. 8–10.

1937. *Spiroclypeus yabei* van der Vlerk. Tan, De Ing. in Ned.-Indië: 4. Mijnbouw en Geol. 4 Jaarg. p. 182, 183, pl. 1, figs. 5, 6; pl. 3, figs. 10, 11; pl. 4, figs. 8–10.

Test with an eccentrically located inflated portion that merges imperceptibly with the flange. Surface ornamentation consists of papillae rather closely spaced and projecting on the inflated area and farther apart, smaller and nearly flush with the surface on the flange. Slight weathering so etches the surface that the pillar heads are brought out in strong relief in areas so affected. On these portions of the test ridgelike walls of the lateral chambers interconnect between the projecting pillars to form a polygonal mesh of pits with the pillars at the corners of the polygons. The papillae on the inflated portion have surface diameters of 140 to 200 μ, whereas those on the flange have diameters of about 100 μ. The height of typical specimens is from 3.2 to 4.1 mm and the width is from 3 to 3.8 mm. The thickness through the inflated portion is 0.9 to 0.96 mm and the umbonal area is 1.6 to 2.0 mm in diameter.

Associated with the specimens described above are a few specimens which show slight differences. These specimens are here described: Test with an eccentrically located, strongly demarked, inflated area which is bordered by a relatively narrow flange. These specimens have a height and a width of about 3 mm with the diameter of the umbonal area from 1.8 to 2 mm. The thickness through the inflated portion is 1.3 to 1.44 mm. The umbonal area is thickly studded with papillae with surface diameters from 200 to 280 μ. An occasional papilla has a surface diameter of about 500 μ.

Measurements of the internal features of the two types are given in the following tables. Type I is the specimens with the less inflated tests, and type II is the specimens with the sharply inflated umbonal area.

Transverse sections

	Type I		Type II	
Diameter—mm	3. 2+	3. 4+	2. 7+	2. 8+
Thickness—mm	0. 9	0. 96	1. 3	1. 44
Diameter of umbo—mm	1. 6	1. 8	2. 0	1. 8
Flange width at base of test—mm	0. 4	0. 5	Broken	0. 6
Flange thickness at base of test—mm	0. 2	0. 22	----------	0. 3
Flange width at top of test—mm	1. 2	1. 0	Broken	Broken
Flange thickness at top of test—mm	0. 26	0. 28	----------	----------
Distance across both embryonic chambers—μ	300	----------	240	280
Diameters of initial chamber—μ	----------	180x200	----------	180x220
Diameters of second chamber—μ	----------	----------	----------	80x120
Thickness of wall of embryonic chambers—μ	40	----------	40	40
Number of lateral chambers on each side of equatorial layer	6, 5	6, 4	8	5, 8
Height of lateral chambers—μ	20	20	20	20
Length of lateral chambers—μ	100–180	100–200	100–160	220
Thickness of floors and roofs of lateral chambers—μ	40	40–60	40–60	25–80; av. 60
Surface diameters of pillars—μ	60–100	80–100	120–240	200–400
Internal thickness of equatorial layer—μ	50	60	40	50

Median sections

	Type I		Type II	
Height mm	3. 2+	3. 2+	2. 4+	2. 9+
Width mm	3. 5+	3. 0+	2. 2+	2. 6+
Number of coils	2½	2½	2¼	2⅛
Diameter across both embryonic chambers μ	320	280	320	320
Diameters of initial chamber μ	220 x 240	170 x 200	200 x 240	200 x 220
Diameters of second chamber μ	100 x 260	80 x 220	100 x 220	100 x 260
Number of undivided chambers	1	1	1	1
Number of chamberlets in first subdivided chamber	5	5	----------	----------

Although in the original sorting of this lot of specimens, it was thought two species might be present, the internal features are so similar that the conclusion was reached that only one species is represented. Also, careful study of a number of specimens has demonstrated that there is gradation between the extremes originally selected to represent the two types.

First appearance.—At a depth of 1660½–1671 feet in Bikini hole 2B.

Age reported elsewhere.—Aquitanian, Tertiary *e*.

Discussion.—Krijnen (1931, p. 90) places *S. yabei* in syonymy under *S. pleurocentralis* (Carter), but Tan (1937, p. 183) states "we are not all sure, whether Carter's species even belongs to *Spiroclypeus*." The original description of *S. yabei* is incomplete and the illustrations are poor.

However, the preparations of the Bikini specimens more nearly resemble *S. yabei* in the details that could be ascertained than any other described species. There are, however, certain resemblances between vertical sections of the thinner specimens from the Bikini well and specimens described from Aintab, Turkish Syria by Henson (1937, p. 51–52) as *Spiroclypeus blanckenhorni* variety *ornata* Henson. Henson separates this variety from *S. yabei* by the absence of granules on the marginal flange, a difference of doubtful taxonomic value.

Genus CYCLOCLYPEUS W. B. Carpenter, 1856

Cycloclypeus carpenteri H. B. Brady

Plate 205, figures 9–14

1856. *Cycloclypeus* sp. H. B. Carpenter, Philos. Trans., v. 146, p. 555–562, pl. 29, figs. 10–12; pl. 30, figs. 1, 3, 4; pl. 31, figs. 2–6, 8–10.

1881. *Cycloclypeus carpenteri* H. B. Brady, Quart. Jour. Micros. Soc., n. ser., v. 21, p. 66, 67.

At a depth of 673 to 678½ feet in Bikini drill hole 2A a small lenticular specimen was found. This specimen has a diameter of 2.8 mm.

The embryonic chambers consist of a subcircular initial chamber with internal diameters of 120 μ. The second chamber is reniform with diameters of 100 by 230 μ. The distance across both chambers is 240 μ. There is one operculine chamber followed by 3 heterostegine chambers.

At a depth of 841½–847 feet in Bikini hole 2A there was found a larger specimen with a diameter of 3.4 mm. This specimen has a narrow rim surrounding a flat, lenticular central area. The central area is ornamented by concentric rows of pustules with surface diameters of about 40 μ. These pustules are flush with the surface of the test except in the areas where the surface of the test has been slightly abraided, in which places the pustules show clearly. The rim is ornamented by the rectangular sutures of the equatorial chambers.

In Bikini hole 2B specimens of this genus were found from 715 to 862 feet. These specimens resemble the ones from Bikini hole 2A but are slightly larger. The diameter of these specimens is 3.8 to 4.1 mm and the thickness through the center is approximately 1.0 mm.

The embryonic chambers are destroyed largely by the calcitic filling of the chambers. However, the diameter across both of the embryonic chambers is about 200 μ in one specimen and 240 μ in another. There is one operculine chamber in both of these specimens, but one of the specimens has 4 heterostegine chambers and the other has 6.

In a vertical section the height of the embryonic chambers is 200 μ and the length is 320 μ. The equatorial layer at the center of the test has a height of 40 μ and at the periphery a height of 120 μ. In all of these specimens the walls covering the equatorial layer are laminated, but devoid of pillars.

Age reported elsewhere.—Tertiary *g* to Recent.

Discussion.—Two Recent species have been named, *C. carpenteri* and *C. guembelianus*. *C. carpenteri* is described as possessing pillars, whereas *C. guembelianus* is devoid of pillars. The type specimens must be restudied before the exact relationship of these two species can be determined.

Family PENEROPLIDAE

Genus MARGINOPORA Quoy and Gaimard in Blainville, 1830

1840. *Amphisorus* Ehrenberg, Abhand. k. Akad. Wiss. Berlin, for 1838 [1840], p. 130, pl. 3, fig. 3.

Marginopora vertebralis Quoy and Gaimard

Plate 210, figures 10–13; plate 211, figures 3–29

1830. *Marginopora vertebralis* Quoy and Gaimard in Blainville, Dict. Sci. Nat., v. 60, p. 377.

1834. *Marginopora vertebralis* Quoy and Gaimard *in* Blainville's Manuel d'Actinologie, p. 412, 413, pl. 69, figs. 6; 6a–c.

In the core sample at 925–935½ feet occur numerous, well-preserved specimens that were identified from their external appearance as *Marginopora vertebralis* Quoy and Gaimard. As thin section were made of these specimens, certain differences in the internal structures between specimens which appeared to be the same externally were noted.

Some specimens possess a single layer of chambers with one large pore, others have a similar structure for a variable distance from the embryonic chambers, but the chambers of the outer annuli possess two pores for each chamber, whereas others have a sequence of chambers with one pore followed by others with two pores and ultimately in the outer annuli the chambers have three or more pores. In these specimens the outer annuli appear to be composed of three layers. Certain other specimens have chambers with two pores immediately after the embryonic chambers which are followed by chambers with multiple pores, and the chambers apparently occur in three layers rather than a single one.

It was impossible in most cases to predict from the external appearance the internal structure which would be encountered in the vertical sections. However, it was noted that as a general rule the larger specimens possess the more complicated internal structures. The equatorial sections of all specimens were similar.

The features shown by these specimens are those which characterize three genera: *Sorites*, *Amphisorus* and *Marginopora*. Therefore, it was decided that Recent species of these genera should be investigated as far as possible.

Specimens identified by Cushman as *Orbitolites marginalis* (Lamarck)=*Sorites marginalis* (Lamarck) from *Albatross* station D5133 (USNM 15796) were obtained from the U. S. National Museum. An equatorial and a vertical section of these specimens are illustrated on plate 211, figures 1, 2.

Cushman (1917, p. 93) gives an accurate illustration and description of the embryonic apparatus and succeeding chambers. These chambers are arranged in simple planispiral coil between the embryonic chambers and the annular chambers. This arrangement is different from that present in the Bikini specimens and serves as a certain indication of the genus *Sorites*.

However, the distinction between *Amphisorus* and *Marginopora* was not at all clear. *Amphisorus* is defined as having typically two rows of chambers with apertures in a double alternating line along the periphery, whereas *Marginopora* has two layers of chambers between which occurs an inner series of chamberlets. The apertures in *Marginopora* occur in more or less vertical rows on the periphery with a horizontal row above and below.

In my collection there are specimens of "*Orbitolites*" from Ibo Bay, northeast of Kerimbo Island, Portuguese East Africa purchased from Mr. Arthur Earland. Heron-Allen and Earland (1915, p. 604–606) list from this locality *Orbitolites marginalis*, *O. duplex* and *O. complanata*.

Cushman (1930, p. 51) states:

I have examined the types of *Amphisorus hemprichii* in the Ehrenberg collection in Berlin, and it seems that Carpenter's species (*O. duplex*) is a synonym in which case Ehrenberg's name will take precedence.

The Recent species which for many years was called "*Orbitolites complanata*" is referred to *Marginopora vertebralis* Quoy and Gaimard by recent authors. Thus, in the samples from Ibo Bay there is found *Sorites marginalis*, *Amphisorus hemprichii* and *Marginopora vertebralis*.

The specimens of *Sorites marginalis* could be recognized readily by the arrangement of the intermediate chambers between the embryonic chambers and the annular chambers. But, the specimens which were selected to illustrate *A. hemprichii* and *M. vertebralis* proved to be as confusing to identify generically as did the specimens from the Bikini drill hole.

Recent specimens from the reef off the village of Odomari, Okinawa-Shima, Ryukyu Islands, collected by Dr. A. R. Loeblich, Jr., of the U. S. National Museum, and from the reef flat on the windward side of Bikini collected by Dr. John W. Wells, of Cornell, were available for study.

The classic illustrations of Carpenter (1856, p. 181–236) show that the specimens illustrated in the present report are almost exactly like Carpenter's drawings. Carpenter writes:

* * * the Orbitolite with a single stratum of cells (*O. marginalis* of Lamarck, *Sorites* of Ehrenberg), that with a double stratum (*Amphisorus* of Ehrenberg), and that with multiple strata (*Marginopora* of Quoy and Gaimard, *Orbiculina Tonga* of Professor Williamson), are fundamentally the same forms, developed in three different modes.

Later, Carpenter (1883, p. 25) created the species *duplex* for the species which he assumed to have a "double stratum." However, he states in a footnote that

* * * I fell into the error of supposing that the doubling of the series of pores indicates the existence, not only of two tiers of chamberlets, but of two annular canals. There is * * * strictly speaking, but a single series of chamberlets, although there is frequently a want of continuity between the upper and lower portions of each cylindrical cavity.

Carpenter proves without doubt that in certain specimens of "*Orbitolites complanata*" (=*Marginopora vertebralis*) that the "simple plan" is followed by the "duplex plan" which in turn is succeeded by the "complex plan."

At a single station specimens can be found that exhibit throughout their length the "simple plan." Others show initially the "simple plan" which is followed by the "duplex plan". Still others have the "simple and duplex plans" with the "complex plan" developed in the final annuli. Finally, certain specimens omit the "simple plan", and the "duplex plan" occurs immediately following the embryonic chambers to be succeeded by the "complex plan", whereas a few specimens show the "complex plan" starts immediately adjacent to the embryonic chambers.

To assign these specimens to different genera or even to different species would appear to be a violation of the intimate relationships which appear from the large suite of specimens available. There are no critical structures on which either generic or specific characters can be based.

Therefore, the generic name *Amphisorus* must become a synonym of *Marginopora*. *Sorites* is a valid genus that can be separated from *Marginopora* by the type of chambers immediately following the embryonic chambers.

The specimens encountered in the Bikini cores are identical with the Recent forms. Therefore, in the entire lot of specimens under consideration only one species is present, *M. vertebralis*.

The fossil specimens recovered from the Bikini hole not only came from cores, but these specimens had a distinctive brown color. Throughout all the samples from the drill holes, numerous unstained white specimens were found which represent Recent ones which contaminated the samples from the drilling fluid.

Discussion.—Van der Vlerk (1924, p. 26, 27) figures specimens assigned to this species from Tertiary *f* of Java (Njalindoeng beds). These specimens are classified correctly. There are reports of this species from the Eocene of Indo-Pacific region, but the identification of these specimens should be checked.

Family ALVEOLINELLIDAE

Genus BORELIS Montfort, 1808

Borelis schlumbergeri (Reichel)

Plate 209, figures 10–18

1937. *Neoalveolina pygmaea schlumbergeri* Reichel, Schweizerische Palaeont. Gesell. Abhand., Band 59, p. 110–112, pl. 10, figs. 1–3; pl. 11, fig. 6, b.

Test small, fusiform, slightly inflated in the central area and tapering very slightly to the bluntly rounded ends; circular in cross section throughout the length of the test. Measurements of 9 specimens follow:

Length (in millimeters)	Diameter at center (in millimeters)	Ratio of diameter to length
1. 2	0. 48	2. 5
1. 3	. 4	3. 2
1. 4	. 4	3. 6
1. 34+	. 54	2. 5
1. 54	. 42	3. 6
1. 56	. 44	3. 5
1. 7	. 5	3. 4
1. 86	. 56	3. 3
2. 0	. 46	4. 3
Av. 1.54	0. 466	3. 3

The adult test is composed of 8 volutions, the first 3 of which comprise the nearly globular central portion. The 5 later volutions are axially elongated to produce the ultimate external shape of the test.

The details of the embryonic apparatus are illustrated by figures 17, 18, plate 209. The initial chamber has a diameter of about 40 μ.

The number of chamberlets per millimeter in the final volutions of the test is 30 to 36.

First appearance.—At a depth of 852–857 feet (core 36–1) in Bikini hole 2A.

Discussion.—These specimens are so similar to the Recent form from Mayotte Island, northwest of Madagascar, described by Professor M. Reichel, that there is little hesitation to assign them to the same species. In the Recent specimens two have a ratio of diameter to length of 1 : 3.3, one has a ratio of 1 : 3.0, and another 1 : 2.2. The average ratio is 1 : 2.9, for the four specimens measured. However, 1 : 3.3 would be nearer the average ratio if the evidence of the two adult specimens is considered.

The Recent form has 30 chamberlets per millimeter, whereas the Bikini specimens have 30 to 36 chamberlets per millimeter. The Miocene species, *B. pygmaeus* Hanzawa (1947), has 22 to 28 chamberlets per millimeter.

Hanzawa states that chief differences between *B. pygmaeus* and *B. schlumbergeri* are the smaller number of chamberlets per millimeter and the greater number of chambers in the last whorl in *B. pygmaeus*. The Bikini specimens with 30 to 36 chamberlets per millimeter and 5½ chambers in the final volution more nearly resemble *B. schlumbergeri*. *B. pygmaeus* and *B. schlumbergeri* have about 11 volutions in the adult test, whereas the specimens under discussion have only 8 or 9.

There were a number of random thin sections of *B. pygmaeus* available for comparison with the Bikini specimens. These specimens of *B. pygmaeus* were collected on Saipan Island by Dr. Josiah Bridge of the U. S. Geological Survey.

It is entirely possible to distinguish these specimens from the Bikini specimens as the specimens from Saipan are larger, with fewer chamberlets per millimeter and more chambers in the final volution. However, it should be indicated that the differences may be caused by ecological conditions rather than specific or varietal change.

The Recent specimens were dredged from depths of 137 meters and 411 meters.

Genus FLOSCULINELLA Schubert, 1910

Flosculinella globulosa L. Rutten

Plate 209, figure 9

1917. *Alveolinella (Flosculinella) globulosa* L. Rutten, Geol. Reichs-Mus. Leiden, Samml., Band 2, p. 277, pl. 5, figs. 140–141.

Test small with a diameter and height of about 1.0 mm; 14 chambers appear externally in the final volution, each chamber with a width of about 180 μ, measured in the center.

First appearance.—At a depth of 2133–2143½ feet in Bikini hole 2B.

Age reported elsewhere.—Burdigalian, Tertiary *f*.

Discussion.—This species may represent caving from a higher horizon in the well.

Family CALCARINIDAE

Genus CALCARINA d'Orbigny, 1826

Calcarina spengleri (Gmelin)

Plate 205, figures 1–4

1788. *Nautilus spengleri* Gmelin *in* Linnaeus, Syst. Nat. ed. 13, p. 3371, No. 10.
1826. *Calcarina spengleri* (Gmelin). D'Orbigny, Ann. Sci. Nat., v. 7, p. 276.
1884. *Calcarina spengleri* (Gmelin). H. B. Brady, Challenger Reports (Zool.), v. 9, p. 712, pl. 108, figs. 5–7.
1919. *Calcarina defrancii* Cushman [not d'Orbigny, 1826] U. S. Natl. Mus. 100, v. 1, pt. 6, p. 365, pl. 44, fig. 2.

Throughout the samples from the Bikini drill holes, numerous Recent specimens of this species occur. They are illustrated because they are a common constituent of the samples. These specimens are found because of contamination of the drilling fluid with Recent organisms, but some of them are undoubtedly fossils as they occur in the sediments to a depth of 95 feet. However, it is impossible to distinguish the fossil and Recent specimens even by color.

Family CYMBALOPORIDAE

Genus HALKYARDIA Heron-Allen and Earland, 1919

Halkyardia bikiniensis Cole, n. sp.

Plate 210, figures 1–5

Test concavoconvex to planoconvex, the dorsal side regularly and evenly convex, but the ventral side either with a shallow, low umbilicus or a nearly flat base. The dorsal side is without ornamentation, but the ventral side has a central round area of coarsely perforated shell material beyond which occurs a zone having radiating slightly elevated ridges of clear shell material separated by slight depressions. This zone represents the appearance at the periphery of the test of the middle chambered zone, which appears between the perforated zones in axial sections. The diameter at the base is from 0.7 to 1.24 mm.

An axial section was made of a specimen with a basal diameter of 1.24 and a total height of 0.48 mm. The thickness of the test at the center is 0.38 mm and the height of the umbilicus is 0.1 mm.

There are three zones to the test, an upper and a lower zone of coarsely tubulated shell material between which occurs a zone of chambers that start at the embryonic chambers and expand slowly as they approach the base of the test.

The upper tubulated zone has a thickness of 75 μ above the embryonic chambers and thins progressively toward the base of the test. The lower tubulated zone has a thickness of 220 μ below the embryonic chambers, and it thins toward the periphery of the test.

The chambers of the middle zone expand from the embryonic chambers and appear on the base of the test as a wide zone without a covering of tubulated shell material, but elsewhere they are enclosed between this material. The chambers of the middle zone have a length of about 200 μ; an internal height of 30 μ; floors and roofs with a thickness of 20 μ at the base of the test where they are best developed. There are about 12 chambers on each side of the embryonic chambers in axial section.

The embryonic chambers, as viewed in axial section, consist of two subequal chambers with an internal height of 40 μ and an internal length of 80 μ. In a horizontal section the embryonic chambers are bilocular with a diameter across both chambers of about 95 μ. One chamber appears to be slightly larger than the other. The larger chamber has diameters of 50 by 60 μ and the smaller chamber has diameters of 40 by 40 μ.

From the embryonic chambers small polygonal chambers arranged in virtually straight lines radiate to a

band of coarsely tubulated material that comprises the peripheral zone in this thin section.

A second horizontal section was made, which cuts the test below the embryonic chambers. In this section a central coarsely tubulated zone is followed by a zone of chambers that in turn is surrounded by the peripheral zone of coarsely tubulated material.

First appearance.—At a depth of 2349–2359½ feet in Bikini well 2B.

Discussion.—The type of the genus, *Cymbalopora radiata* variety *minima* Liebus, is from the middle Eocene of Yugoslavia. Cushman (1948, p. 309) in his textbook gives the range of the genus as Eocene. Glaessner (1945, p. 152) in his book gives the range as middle Eocene to Oligocene.

Bursch (1947, p. 29–34) found specimens of *Halkyardia* in deposits referred to the upper Eocene and the lower Oligocene on Great Kei, Molucca Islands. He identifies these specimens with the European species, *H. minima* (Liebus).

Bursch apparently overlooked the article by Parr (1934, p. 144, 145) in which a new species of *Halkyardia* was described under the name *H. bartrumi* from deposits on Chalky Island, SW. New Zealand. Parr, on the basis of abundant *Amphistegina*, assigned these deposits to the Miocene.

Recently, Findlay and Marwick (1940, p. 97, 111) in a discussion of the ranges of certain Foraminifera state that they believe these deposits on Chalky Island should be assigned to the Kaiatan (upper Eocene).

The specimens from New Zealand and from Great Kei have large embryonic chambers, and the cavity of the chambers in the median layer is high and open. The specimens from Bikini have low cavities in the median chambers.

Family PLANORBULINIDAE

Genus GYPSINA Carter, 1877

Gypsina vesicularis (Parker and Jones)

Plate 210, figures 14, 15

1860. *Orbitolina concava* Lamarck, variety *vesicularis* Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, v. 6, pp. 31, 38.
1947. *Gypsina vesicularis* (Parker and Jones). Bursch, Schweizerische Palaeont. Gesell. Abhand., v. 65, p. 42, 43, pl. 3, fig. 1; pl. 5, fig. 2; text fig. 15.

In the deepest samples from Bikini hole 2B are a few specimens that resemble this species. The preparations were not satisfactory for detailed studies.

Family ORBITOIDIDAE

Genus LEPIDOCYCLINA Gümbel, 1870

Subgenus NEPHROLEPIDINA H. Douvillé, 1911

Lepidocyclina (Nephrolepidina) augusticamera Cole, n. sp.

Plate 217, figures 1–5

Several *Lepidocyclina* with nephrolepidine embryonic chambers, short spatulate equatorial chambers, and low appressed lateral chambers in regular tiers were encountered in the lower samples from Bikini hole 2B. Measurements of thin sections of these specimens follow:

Horizontal sections

Depth—feet	1933½–1949	2154–2164½	2164½–2175
Diameter—mm	2.0	2.7	2.5
Embryonic chambers:			
Internal diameters of initial chamber—μ		180 x 220	220 x 310
Internal diameters of second chamber—μ		160 x 390	180 x 430
Distance across both chambers—μ	220	360	420
Thickness of outer wall—μ	20	30	30
Equatorial chambers:			
Tangential diameter—μ	65	70–80	60
Radial diameter—μ	65	60–70	50

The equatorial chambers are short spatulate in form with tangential and radial diameters about equal.

Vertical section

Depth—feet	2164½–2175
Diameter—mm	2.6
Thickness—mm	1.4
Embryonic chambers:	
Internal length—μ	360
Internal height	
Thickness of outer wall—μ	30
Equatorial layer:	
Height at the center—μ	80
Height at the periphery—μ	150
Lateral chambers:	
Number on each side of equatorial layer at center	12
Length—μ	180
Height—μ	20–30
Thickness of roofs and floors—μ	20

The lateral chambers are arranged in regular tiers. The chamber cavities are low, appressed between relatively thick floors and roofs. The floors and roofs are straight.

No pillars are present although there is a slight thickening at the junctures of the tiers of lateral chambers which gives the appearance of small pillars.

First appearance.—At a depth of 1933½–1949 feet in Bikini hole 2B.

Discussion.—The pattern of the equatorial chambers in this species is similar to that of *L.* (*Eulepidina*) *formosa.* Certain features of the vertical section also suggest that species, but the embryonic chambers are definitely nephrolepidine. These specimens may be *L. formosa* with nephrolepidine embryonic chambers. It is

well established that there is gradation in the same species between eulepidine and nephrolepidine type of embryonic chambers.

However, this gradation has not been demonstrated to my knowledge in *L. formosa*. Therefore, it was decided to create a new specific name for these rare specimens from the Bikini drill hole. Certainly, these specimens are markedly different from any nephrolepidine types described from the Indo-Pacific area.

Lepidocyclina (Nephrolepidina) bikiniensis Cole, n. sp.

Plate 214, figures 1–8

Test evenly biconvex, surface ornamentation consisting of 4 to 7 apical papillae with the remainder of the test covered by a reticulate mesh which consists of shallow pits surrounded by flat-topped polygonal ridges. The papillae, which have diameters of 200 to 300 μ, form a rude circle at the apex of the test with occasionally a single papilla outside of the group. The papillae are elevated and composed of clear shell material as are the ridges that bound the shallow pits. The pits are floored by dull white shell material so that there is a marked contrast between the pits on one hand and the ridges and papillae on the other. The diameter is from 2.4 to 3.0 mm and the thickness is from 1.0 to 1.3 mm.

The embryonic chambers are nephrolepidine. In one specimen the initial chamber has internal diameters of 120 by 180 μ and the second chamber has internal diameters of 120 by 340 μ. The internal distance across both chambers is 260 μ. The outer wall of the chambers has a thickness of 40 μ. Another specimen has an initial chamber with internal diameters of 150 by 190 μ and the second chamber has internal diameters of 120 by 300 μ. The outer wall has a thickness of 30 μ. There are four periembryonic chambers, two of which with internal diameters of 50 by 120 μ occur at either end of the partition dividing the embryonic chambers and the other two with internal diameters of about 40 by 180 μ are on the periphery of the second embryonic chamber. Vertical sections show the height of the embryonic chambers to be 140 to 180 μ.

The equatorial chambers are short spatulate, with curved outer walls and pointed inner ends. Typical chambers near the periphery have radial diameters and tangential diameters of about 70 μ. The internal height of the equatorial chambers near the center of the test is about 30 μ and at the periphery about 80 μ. The thickness of the roof and floor is about 18 μ.

The lateral chambers are large, open, and rectangular, and occur in regular tiers although some overlapping from one tier to another occurs. At the center are about 10 lateral chambers to a tier on each side of the embryonic apparatus. Lateral chambers over the center and at the periphery of the test have lengths of 200 to 300 μ and heights of 30 to 40 μ. The thickness of the roofs and floors is about 20 μ.

Pillars are present only in the central area of the test, and there they appear only when the section accidentally cuts the pillars of the apical crown. Thus, pillars may appear on one side of a vertical section and not on the other, or some vertical sections may be devoid of pillars. Where the pillars are present they taper regularly inward and have their origin directly above the equatorial layer.

First appearance.—At a depth of 1534½–1545 feet in Bikini hole 2B.

Discussion.—The external appearance of this new species is similar to that of *Lepidocyclina angulosa* Provale in that there is an apical crown of papillae arranged in a rude circle around the apex of the umbo. This appearance resulted in a preliminary identification of the specimens as *L. angulosa*.

Some vertical sections (fig. 1, pl. 214) made from these specimens seemed to confirm the tentative identification. Comparison of the figure of the Bikini specimen with the type vertical section of *angulosa* (Provale, 1909, pl. 2, fig. 13) shows the same features developed in each specimen.

However, a detailed analysis of the equatorial sections reveals that the Bikini specimens are not the same as *L. angulosa*. In the type equatorial section of *L. angulosa* the equatorial chambers are arranged in circles and in shape they are elongate spatulate or elongate hexagonal, whereas in the Bikini specimens the chambers are short with curved outer walls and pointed inner ends or short hexagonal.

Although confirmation is needed, apparently species that possess elongate spatulate or elongate hexagonal equatorial chambers are typical of Tertiary *f*. Chambers of this type are illustrated by figures 9, 10, plate 214, from specimens identified as *L. angulosa* from Vanua Mbalavu, Lau Islands, Fiji and Poeloe Balamlangan, Cenoorden Borneo. The equatorial chambers of *L. bikiniensis*, enlarged to the same size as those of *L. angulosa* are shown as figure 6, plate 214.

The equatorial chambers of *L. bikiniensis* resemble those of *L. ferreroi* Provale. This latter species in some individuals developes an external form similar to that of *L. angulosa*. However, these individuals are associated normally with specimens that exhibit the stellate shape and heavy papillae of the type specimens. Inasmuch as typical specimens of *L. ferreroi* do not occur in the material from the Bikini test well, it is desirable to refer these specimens to a new species.

Lepidocyclina (Nephrolepidina) bikiniensis unipilaris Cole, n. var.

Plate 214, figures 11–14, 18

Test evenly biconvex, surface ornamentation consisting of one prominent apical papilla with a surface diameter of about 300 μ and with the remainder of the surface of the test covered by a reticulate mesh composed of pits bounded by flat-topped polygonal ridges. Diameter of the test about 2.8 mm and the thickness is 1.2 to 1.3 mm.

The embryonic chambers are nephrolepidine. The initial chamber has internal diameters of 170 by 250 μ in one specimen and 160 by 200 μ in another. The second chamber has internal diameters of 140 by 350 μ in one specimen and 160 by 260 μ in another. The distance across both chambers is 320 μ in each specimen. The thickness of the outer wall is about 25 μ and the dividing wall between the chambers has a thickness of about 15 μ.

A large periembryonic chamber lies on either side of each end of the dividing wall between the embryonic chambers. These chambers have internal diameters of about 35 by 160 μ. Two smaller periembryonic chambers with internal diameters of about 30 by 130 μ are found on each side of the second embryonic chamber.

The equatorial chambers are short spatulate, with curved outer walls and pointed inner ends. Chambers near the periphery of the test have radial diameters of 50 to 60 μ and tangential diameters of about 40 μ. In vertical sections the internal height of the equatorial chambers near the center of the test is about 40 μ and at the periphery about 60 μ. The floors and roofs of these chambers have a thickness of about 20 μ.

The lateral chambers are large, open, rectangular, and occur in regular tiers. There are 9 or 10 lateral chambers to a tier on each side of the equatorial layer at the center of the test. There is a regular decrease in the number of lateral chambers to a tier toward the periphery of the test so that at the periphery the equatorial layer is covered by a single layer of lateral chambers. Lateral chambers over the center and at the outer ends of the tiers have lengths of 140 to 280 μ and heights of 30 to 40 μ. The thickness of the roofs and floors is about 25 μ.

In well-oriented vertical sections a single heavy pillar is found in the center on each side of the equatorial layer. These pillars have surface diameters of 300 to 400 μ and taper regularly toward the embryonic chambers at which point they have a diameter of about 100 μ.

First appearance.—At a depth of 1534½–1545 feet in Bikini hole 2B.

Discussion.—There are specimens in association with *L. bikiniensis* that resemble it except that they possess one central papilla instead of an apical circle of papillae. These specimens are considered to be worthy of a varietal designation.

Caudri (1939, p. 203–207) in a discussion of *L. inflata* Provale, which species is supposed to be characterized by a single pillar, states that single pillars characterize forms of several species and that gradation between specimens with numerous apical papillae to those with only one occurs frequently.

She suggests that such end forms be called the *inflata* variety of the particular species in which the gradation occurs; for example, *L. angulosa inflata*; *L. verrucosa inflata*. Such a terminology would lead to confusion, and, therefore, it is preferable to designate each end form by a distinct varietal name.

Lepidocyclina (Nephrolepidina) cubiculirhomboidea Cole, n. sp.

Plate 213, figures 10–19

Test biconvex, with or without a very narrow rim. Surface ornamentation consists of a group of apical papillae with smaller papillae scattered irregularly over the area beyond the crown of apical papillae. The diameter is from 1.6 to 2.6 mm and the thickness is from 0.8 mm to 1.2 mm.

The details of the internal structure follow:

Horizontal section

Diameter mm	2.1	2.6	2.5
Embryonic chambers:			
Diameters of initial chamber μ		160 x 200	230 x 290
Diameters of second chamber μ		140 x 260	140 x 340
Distance across both chambers μ	220	300	380
Thickness of the outer wall μ	18	20	20
Equatorial chambers:			
Radial diameter μ	60	60	60–100
Tangential diameter μ	40	40	40

The embryonic chambers are nephrolepidine in type. The four rather large periembryonic chambers are placed so that a periembryonic chamber is found at either end of the partition dividing the embryonic chambers, and the other two are on each side of the central line through the embryonic chambers on the exterior wall of the larger chamber. The largest periembryonic chamber has diameters of 60 by 180 μ.

The equatorial chambers near the center of the test are small, with radial and tangential diameters of 40 μ. These chambers are diamond shaped. As the periphery of the test is approached, the radial diameter of the chambers increases although the tangential diameter remains constant. In certain of the peripheral equatorial chambers, the shape becomes hexagonal with the long axis of the chamber radial. These chambers have a radial diameter of 100 μ and a tangential diameter of 40 μ.

Vertical sections

Diameter mm	1. 6	1. 7	2. 0	2. 12	2. 4
Thickness mm	0. 8	0. 9	1. 2	1. 0	1. 04
Embryonic chambers:					
Internal length μ	200	220	220	200	240
Internal height μ	140	155	150	150	190
Thickness of outer wall μ	20	20	20	10	20
Equatorial layer: [1]					
Height at center μ	60	60	80	80	60
Height at periphery μ	90	100	100	100	100
Lateral chambers: [2]					
Number on each side at center μ	7	10	10	11	12
Length μ	140	120–180	120	110–160	90–160
Height μ	25	25–30	40	35–40	30
Thickness of floors and roofs μ	10–20	10–15	15–20	10–20	10
Surface diameter of pillars μ	120	100–120	160	120	100

[1] Measurement includes floor and roof.
[2] Chambers directly over the center and in the external layers.

The lateral chambers are open, with rectangular cavities. The floors and roofs are thin and straight. The lateral chambers are arranged in regular tiers. Pillars are irregularly present, particularly in the central area of the test.

First appearance.—At a depth of 1398–1408½ feet in Bikini hole 2B.

Discussion.—This species resembles *L. japonica* Yabe, especially the illustrations given of specimens from Borneo referred to this species by van der Vlerk. (1929, p. 24). Hanzawa (1931, p. 163), however, states that the specimens from Borneo are "to be distinguished from the typical one by means of the different nature of its nucleoconch and median chambers." Caudri (1939, p. 211) is of the opinion that van der Vlerk was correct in assigning the specimens from Borneo to *L. japonica.*

L. japonica possesses a thick fibrous-walled embryonic apparatus with the larger chamber virtually embracing the second chamber. The equatorial chambers are short spatulate to hexagonal.

L. cubiculirhomboidea has a relatively thin-walled embryonic apparatus with the larger chamber slightly, if at all, embracing the second chamber. The equatorial chambers are diamond shaped to radially elongate hexagonal.

Thin sections of specimens from Lau, Fiji, (Cole, 1945, p. 288) referred to *L. japonica* were available for comparison with the Bikini specimens. These specimens from Lau, Fiji, closely resemble illustrations of *L. japonica* given by Yabe, Hanzawa and Caudri. The Bikini specimens differ from these in the form of the embryonic apparatus and the shape of the equatorial chambers. There are differences also in the vertical sections, but these are less pronounced.

Inasmuch as the Bikini specimens are readily distinguished from specimens believed to be typical *L. japonica*, a new name is proposed for these specimens. It is entirely possible that the specimens from Borneo studied by van der Vlerk are the same as the Bikini specimens. As far as can be observed the features are the same.

Lepidocyclina (Nephrolepidina) orientalis van der Vlerk

Plate 215, figures 11–21

1924. *Lepidocyclina munieri* Lem. and R. Douvillé, var. *orientalis* van der Vlerk, Wetensch. Meded. No. 1, p. 22, 23, pl. 4, figs. 5–8.
1924. *Lepidocyclina sumatrensis* Brady, var. *eulepidinacea* van der Vlerk, *idem.*, p. 23, pl. 4, figs. 9–12.
1928. *Lepidocyclina (Trybliolepidina) orientalis* van der Vlerk, *idem*, No. 8, p. 33, 34, figs. 11*a*, *b*.
1928. *Lepidocyclina (Trybliolepidina) talahabensis* van der Vlerk, *idem*, p. 39, figs. 13*a*, *b*.
1932. *Lepidocyclina spatiosa* Scheffen, *idem*, No. 19, p. 39, pl. 9, figs. 1–3.
1939. *Lepidocyclina talahabensis* van der Vlerk. Caudri, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 12, p. 207–209, pl. 8, figs. 47–49.
1949. *Lepidocyclina (Nephrolepidina) makiyamai* Morishima, Jour. Paleontology, v. 23, p. 212–213, pls. 44, 45.

Test small, individuals ranging from evenly biconvex through some that have a slightly inflated central area bordered by a narrow rim to individuals with a definitely inflated central portion bordered by a distinct rim. The number and distribution of the papillae differ from specimen to specimen. Some individuals have few and very inconspicuous papillae, whereas others have small, but prominent papillae, especially in the central area. The remainder of the test is covered by a polygonal mesh which bounds polygonal shallow pits.

The embryonic chambers are extremely variable from those which appear to be nearly lepidocycline sensu stricto to others which are trybliolepidine. Between these are others that are nephrolepidine in type.

Horizontal sections

Diameter mm	2.3	2.2	2.2	2.16
Embryonic chambers:				
Internal diameters of initial chamber μ	90 x 115	100 x 100	110 x 160	100 x 120
Internal diameters of second chamber μ	80 x 200	60 x 180	65 x 160	60 x 130
Distance across both chambers μ	180	165	180	180
Thickness of outer wall μ	30	30	25	20
Equatorial chambers:				
Tangential diameter μ	40	30–40	30	30–40
Radial diameter μ	80	60	60–80	60–80

The equatorial chambers are short spatulate at the center of the test, but become elongate spatulate toward the periphery. The radial diameter of these elongate chambers is about twice the tangential diameter. The arrangement of the rows of chambers suggests that encountered in certain radiate species.

Vertical sections

Diameter mm	2.9	2.3	2.24
Thickness mm	1.1	1.28	1.3
Embryonic chambers:			
Internal length μ	130	195	220
Internal height μ	90	125	155
Thickness of outer wall μ	25	30	25
Equatorial layer:			
Height at center μ	80	60	60
Height at periphery μ	140	120	120
Lateral chambers:			
Number on each side of equatorial layer at center	7	11	10
Length μ	180–260	200	80–120
Height μ	40	20–40	40–50
Thickness of roofs and floors μ	20	20	20
Surface diameter of pillars μ	80	100	80–120

The lateral chambers have large open cavities with moderately thick roofs and floors. In two of the vertical sections the lateral chambers over the center of the test are long, but in the other available section they are short. The lateral chambers are arranged in regular tiers. Small thin pillars are irregularly scattered throughout the test.

First appearance.—At a depth of 1082½–1088 feet in Bikini hole 2A.

Age reported elsewhere.—Tertiary f_3.

Discussion.—*L. orientalis* and *L. talahabensis* were described by van der Vlerk from the same locality in Java. All available evidence indicates that these two species should be combined. As the specific name *L. orientalis* appears first in the original publication, it is used for the combined species.

In a discussion of stratigraphic correlation in the Indo-Pacific region, Glaessner (1943, p. 61 and chart), following Oostingh, places beds containing *L. orientalis* in the Preangerian stage or Tertiary f_3. This stage is correlated with the European combined Helvetian and Tortonian. Glaessner (1943, p. 61) also indicates that "no distinctive larger Foraminifera are found in post-Preangerian beds."

Lepidocyclina (Nephrolepidina) parva Oppenoorth

Plate 212, figures 1–28; plate 217, figures 12–14; plate 222, figures 1–3

1918. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 2, p. 255, pl. 8, figs. 11–12; pl. 9, fig. 9.
1918. *Lepidocyclina* (*Nephrolepidina*) *atjehensis* Oppenoorth, *idem*, p. 255, 256, pl. 9, figs. 1–3.
1918. *Lepidocyclina* (*Nephrolepidina*) *angulosa* Provale. Oppenoorth, *idem*, p. 253, pl. 9, figs. 4, 6 (*not* fig. 5).
1928. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. van der Vlerk, Wetensch. Meded. No. 8, p. 34, figs. 24*a*, *b*.
1928. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. van der Vlerk, *idem*, No. 9, p. 24, figs. 22, 47*a*, *b*.
1930. *Lepidocyclina* (*Nephrolepidina*) *melanesiana* Hanzawa, Tohoku Imp. Univ., sci. rep., ser. 2 (Geol.), v. 14, p. 93, pl. 26, figs. 3–5, 8, 11–14, 17; pl. 27, figs. 3–5, 9–13, 16.
1930. *Lepidocyclina* (*Nephrolepidina*) *ferreroi* Provale. Hanzawa, *idem*, p. 92, 93, pl. 26, fig. 18; pl. 27, figs. 11–12.
1930. *Lepidocyclina* (*Nephrolepidina*) *douvillei* Yabe and Hanzawa. Hanzawa, *idem*, p. 91, 92, pl. 26, fig. 9; pl. 27, figs. 6, 13–15.
1934. *Lepidocyclina parva* Oppenoorth. Caudri, Tertiary deposits of Soemba, Amsterdam, p. 104, 105.
1939. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. Cole, Jour. Paleontology, v. 13, p. 188, pl. 23, figs. 1–7.

In 1918 Oppenoorth described a fauna from Atjeh on the north coast of Sumatra. Two closely related forms in this fauna were designated *L.* (*N.*) *parva* and *L.* (*N.*) *atjehensis*. *L. parva* has been reported and illustrated by subsequent authors from other localities, but *L. atjehensis* is known only from its type locality.

L. parva is a small form with open rectangular lateral chambers, either without pillars or with very weakly developed ones. *L. atjehensis* is a larger form with papillae as much as 1000 μ in diameter. A vertical section of *L. atjehensis* has not been published, therefore the exact details of the vertical section are unknown. However, the equatorial chambers of these species are similar and both have nephrolepidine embryonic chambers. The embryonic chambers of *L. parva* are smaller and the outer wall is thicker when compared to those of *L. atjehensis*.

Specimens were found at a depth of 1167–1177½ feet in Bikini hole 2B that are identical with specimens from Guam, previously identified as *L. parva* (Cole, 1939,

p. 188). At greater depths in Bikini hole 2B coarsely pustulate specimens are found, equatorial sections of which are entirely similar to those of *L. parva*. However, in vertical section these specimens show heavy, well-developed pillars. These specimens resemble *L. atjehensis*.

Although it was possible to distinguish small individuals with fine pillars from larger individuals with coarse pillars, certain intermediate specimens were recovered. Therefore, it became apparent that a complete gradation could be established from *L. parva* at one end of the series to *L. atjehensis* at the other.

A similar relationship exists between the American species *L.* (*Lepidocyclina*) *yurnagunensis* and its variety *morganopsis* as Vaughan (1933, p. 23) has pointed out in the statement "the variety differs solely by its more greatly developed pillars, which terminate in pustules on the surface."

Although it might be possible to refer certain of the specimens under discussion to *L. parva* and others to *L. parva* variety *atjehensis*, there would be a group of specimens of intermediate character that could not be placed with certainty under one designation or the other. Therefore, it appears logical to suppress the specific name *L. atjehensis* and to expand the definition of the species *L. parva* to include the larger, coarsely pustulose, heavy pillared forms.

A description of the specimens referred at first to *L. parva* follows. The specimens on which this description is based are illustrated on plate 212, figures 1, 2, 17, 18.

Test with a flattened umbonal area, thence sloping regularly and evenly to a narrow, thin rim. Most of surface of test ornamented by shallow polygonal pits bounded by slightly raised ridges of clear shell material. Sutures marking juncture of walls of equatorial chambers with surface of test appear on rim. Diameter of test 2.0 to 2.2 mm; thickness through center approximately 0.7 mm; width of rim 0.1 to 0.14 mm; polygonal shaped pits with diameters of 60 to 80 μ.

The embryonic apparatus is relatively thick walled and nephrolepidine in type. At least 4 distinct periembryonic chambers are present: one at each end of the dividing partition between the chambers and one on each side of the large, embracing chamber.

The initial chamber has internal diameters of 100 by 140 μ and the second one diameters of 110 by 250 μ. The internal distance across both chambers is 220 μ. The external distance across both chambers is 300 μ. The thickness of the outer wall of the embryonic chambers is about 40 μ. The largest periembryonic chamber has internal diameters of 25 by 80 μ. The wall of this chamber has a thickness of about 20 μ.

In one vertical section the embryonic chambers have a height, including the outer wall, of 170 μ and a length of 220 μ. In another vertical section the height of the embryonic chambers is 190 μ and the length is 260 μ. This section is more nearly centered than the other one.

Most of the equatorial chambers are rhombic in shape, but some near the center of the test have curved outer walls and pointed inner ends. Typical rhombic chambers have radial and tangential diameters of about 40 μ. The height of the equatorial layer, including the thickness of the floor and roof, is about 60 μ at the center of the test and 85 μ at the periphery.

There are 8 to 9 lateral chambers to a tier on each side of the test over the embryonic chambers. The number of chambers to a tier decreases regularly toward the rim, which is not covered by lateral chambers. The lateral chambers have open, rectangular chamber cavities, except those near the center of the test which possess slit like cavities. Well-developed lateral chambers have lengths of 120 μ and heights of 35 μ. The roofs and floors have thicknesses of 8 to 15 μ.

Pillars are absent in some specimens; others have scattered thin fragile pillars with surface diameters of 40 μ.

A description follows of the external appearance of specimens which were identified originally as *L. atjehensis*.

Megalospheric form.—The test is biconvex without a rim. An irregular group of prominent papillae occurs over the apical area and spread outward toward the margins of the test. In a specimen with a diameter of 2.0 mm, the diameter of the papillate area is 1.2 mm. The larger papillae have surface diameters of 200 μ, and smaller papillae have diameters of 100 μ. Most of the papillae are raised distinctly above the surface of the test. The remainder of the surface of the test is covered by a polygonal mesh of clear shell material representing the sutures of the vertical walls of the lateral chambers. The opaque areas within the mesh represent the roofs of the lateral chambers. Where these roofs have been destroyed polygonal pits occur.

Measurements of vertical and equatorial sections follow. Certain of these specimens were tentatively identified as *L. parva* and others as *L. atjehensis* before the gradation between these supposedly distinct species was established.

Vertical sections

Depth—feet	1440–1450	1650–1660½	1744½–1755	1755–1765½	1765½–1776	1776–1786½	1807½–1818	1818–1828½	1818–1828½	1818–1828½	1986–1996½	2049–2059½
Diameter—mm	3+	2.1	2.24	2.54+	2.24+	2+	2.6+	2+	1.8+	1.8+	3.0	2+
Thickness—mm	1.26	1.32	1.0	1.32	1.26	1.3	1.42	1.24	1.14	1.2	1.96	1.3
Embryonic chambers												
Internal length—μ	280	200	230	300	250	220	460	240	260	210	350	220
Internal height—μ	205	120	160	180	185	170	280	250	215	140	220	180
Thickness of outer wall—μ	20	20	25	20	30	20	30	40	20	30	40	40
Equatorial chambers:												
Height at center—μ	80	60	70	80	80	80	90	80	80	80	85	60
Height at periphery—μ	130	100	120	140	130	100	140	120	120	120	140	120
Lateral chambers:												
Number on each side of equatorial layer at center	14	12	10	11	10	14	10	10	9	8	15	12
Length—μ	160-200	160	120-200	160-200	160	100	120-200	120-160	160	50-170	140-180	120
Height—μ	20-30	40	40	30-40	35-40	20	20-25	30	30-40	40-50	40	20-30
Thickness of floors and roofs—μ	10	10	15	20	10-20	10	10	15	10-15	20	15	10-20
Surface diameter of pillars—μ	100-160	160-180	100-140	60-120	100	220-400	180-320	260	140	100-220	160-380	180-260

Horizontal sections

Depth—feet	1440–1450	1440–1450	1744½–1755	1765½–1776	1797–1807½	1818–1828½	1818–1828½	1818–1828½	1818–1828½	2017½–2028
Diameter—mm	2.2	2.8	2.1	2.2+	2.1	1.64	1.6	2.14	1.64	2.5
Embryonic chambers:										
Diameters of initial chamber—μ	120 x 180	100 x 150	120 x 170	120 x 240	140 x 220	140 x 190	120 x 180	180 x 230	140 x 190	140 x 190
Diameter of second chamber—μ	80 x 260	80 x 220	90 x 240	160 x 220	120 x 260	110 x 270	115 x 210	120 x 280	110 x 270	120 x 280
Distance across both chambers—μ	220	200	220	290	280	260	240	320	260	280
Thickness of outer wall—μ	20	20	20	20	20	25	30	40	25	30
Equatorial chambers:										
Tangential diameter—μ	30	30	20-30	20-30	20-30	40	30	30	40	30
Radial diameter—μ	30	30-40	20-40	30-40	30-40	50	40	40	50	40

Microspheric form.—The test lenticular, thickest in the center from which point it slopes gradually and regularly to the bluntly rounded periphery. Conspicuous raised papillae occur, decreasing in size toward the periphery of the test. The papillae in the central area have diameters of about 160 μ and they are rather widely separated. In the areas between the papillae there is a distinct, slightly raised mesh of clear shell material which bounds polygonal areas of opaque shell material. The diameter is about 4.0 mm and the thickness is about 1.3 mm.

The equatorial chambers are diamond shaped, increasing in size from the center to the periphery. Peripheral equatorial chambers have radial and tangential diameters about equal and measuring about 40 μ.

In vertical sections the equatorial layer is definite with conspicuous roof and floor walls. The height of this layer at the center is about 70 μ and at the periphery about 120 μ, the measurements including the thickness of the floor and roof.

The lateral chambers occur in rather regular tiers with about 17 chambers to a tier on each side of the equatorial layer at the center of the test. The lateral chambers have open cavities with straight roofs and floors. Chambers over the center and at the periphery have lengths of 120 μ and heights of 20 μ. The thickness of the floors and roofs is about 10 μ.

Heavy pillars are found in the central area. These pillars have surface diameters from 100 to 200 μ. In the section available these pillars do not penetrate to the equatorial layer.

First appearance.—At a depth of 1166½–1177 feet in Bikini hole 2A; at a depth of 1167–1177½ feet in Bikini hole 2B.

Age reported elsewhere.—Tertiary *e* and *f*.

Discussion.—In the same article in which Oppenoorth described *L. parva* and *L. atjehensis* he figures on plate 9, figure 6, a vertical section of a microspheric form which he identifies as *L.* (*N.*) *angulosa* Provale. This specimen has the features that characterize the microspheric specimens from the Bikini hole 2B. These specimens are without doubt the microspheric form of *L. parva*.

In 1930 Hanzawa (1930, p. 93) offered the name *L.* (*Nephrolepidina*) *melanesiana* for small specimens with rhombic equatorial chambers, but possessing thin pillars. In the same material there are other specimens with heavy pillars which Hanzawa referred to *L.* (*N.*) *ferreroi* Provale. Both of these forms, which show the same chaarcteristics as the suite of specimens from the Bikini hole 2B, should be referred to *L. parva*.

Microspheric specimens with features similar to those of the microspheric specimens from the Bikini hole 2B occur with the specimens which Hanzawa referred to *L. melanesiana* and *L. ferreroi*. These microspheric specimens from Java were identified as *L.* (*N.*) *douvillei* Yabe and Hanzawa. From information available at present, these specimens should be considered to be the microspheric form of *L. parva*.

L. parva is reported by van der Vlerk (1928, p. 34) to be restricted to Tertiary *e*. The faunal association in Java described by Hanzawa indicates that these deposits represent Tertiary *e*. On Guam (Cole, 1939, p. 188) *L. parva* is associated with *Spiroclypeus* in deposits which were assigned to Tertiary *e*. Umbgrove, (1931, p. 69) however, gives its stratigraphic range as Tertiary *e* and *f*. Caudri (1934, p. 105) in a discussion

of the occurrence of this species in Soemba states that "*L. parva*, here as on NE. Borneo, is found in Tertiary *f*."

These observations suggest that *L. parva* has an extended stratigraphic range from Tertiary *e* into Tertiary *f*. Caudri (1939, p. 197) recognizes that *L. sumatrensis*, *L. parva* and *L. atjehensis* are closely related species. However, she believes that *L. parva* is probably a small flat variety of *L. sumatrensis*, whereas *L. atjehensis* is a distinct, separate species confined to the Tertiary *e*. As there is such perfect gradation in the Bikini specimens from the small, flat practically pillarless specimens to the larger specimens with heavy pillars, it appears that *L. parva* and *L. atjehensis* should be combined.

As *L. parva* and *L. atjehensis* occur together at the type locality of the species, and as *L. parva* has been reported from Tertiary *e* and *f*, the extension of the range of *L. atjehensis* into Tertiary *f* is to be expected. This is all the more reasonable as *L. atjehensis* was previously known only from its type locality.

Lepidocyclina (Nephrolepidina) pumilipapilla Cole, n. sp.

Plate 214, figures 15–17, 19; plate 215, figures 1–8

Test of moderate size, central portion inflated, merging gradually into a narrow, encircling rim. The apex of the test has a group of small papillae covering an area with a diameter of approximately 1.0 mm. In a given individual these papillae are the same size, but there is variation in the diameters of the papillae between individuals. In the specimens examined the papillae have diameters of 60, 80 and 100 μ. The remainder of the test with the exception of the rim is covered by a polygonal mesh composed of sutures of clear shell material that bound areas of opaque shell material. The outer portion of the rim is not covered by lateral chambers and the pattern of the equatorial chambers shows.

Horizontal sections

Depth—feet	1702½–1713	1818–1828½		1828½–1839	
Diameter—mm	3. 0	2. 6	2. 2	2. 5	2. 4+
Embryonic chambers:					
Diameters of initial chamber—μ	120 x 160	190 x 260	130 x 220	155 x 200	200 x 280
Diameters of second chamber—μ	100 x 230	140 x 380	120 x 320	120 x 280	175 x 360
Distance across both chambers—μ	230	350	260	280	380
Thickness of the outer wall—μ	20	30	20	20	30
Equatorial chambers:					
Radial diameter—μ	65	50	60	65	65
Tangential diameter—μ	40	40	40	45	45

The embryonic chambers are nephrolepidine with well-developed periembryonic chambers, one of which occurs at each end of the partition dividing the two embryonic chambers. Two other periembryonic chambers are present, one at each side of the larger embryonic chamber.

The equatorial chambers are diamond shaped, with the radial diameter slightly greater than the tangential diameter.

In vertical sections the equatorial layer is comparatively thin at the center of the test. It expands gently and regularly until near the periphery at which place an abrupt expansion occurs. The thick floors and roofs of the equatorial layer make it a distinct feature. In the expanded peripheral zone the chambers of the equatorial layer become multiple.

Vertical sections

Depth—feet	1702½–1713		1818–1828½		1828½–1839	
Diameter—mm	2. 74+	2. 76+	2. 4+	3. 0+	2. 6+	2. 8
Thickness—mm	0. 92	1. 2	1. 0	1. 3	1. 16	1. 26
Embryonic chambers:						
Internal length—μ	290	220	290	360	290	260
Internal height—μ	200	170	210	260	200	140
Thickness of outer wall—μ	20	23	20	20	20	20
Equatorial layer:						
Height at center—μ	65	65	65	90	60	60
Height at periphery—μ	160	200	180	260	140	180
Lateral chambers:						
Number on each side at center	9	11	7	10	10–12	12
Length—μ	40–160	80–180	40–100	100–200	80–200	80–100
Height—μ	20–40	20–40	40–45	20–45	25–40	20–35
Thickness of roofs and floors—μ	15	10–18	5–18	10–18	10–20	10–15
Surface diameter of pillars—μ	80	100	100	60–80	80	100

The lateral chambers have open, distinct, relatively high cavities with very thin, straight or slightly convex floors and roofs. The lateral chambers in the central area of the test are arranged in fairly regular tiers, but a few larger chambers overlap two tiers, producing irregularity. The lateral chambers beyond the central area are smaller and arranged in regular tiers with practically no overlap from one tier to another.

The pillars are small and occur very infrequently in the vertical sections in the central area of the test.

First appearance.—At a depth of 1597½–1608 feet in Bikini hole 2B.

Discussion.—This species belongs to the group of *L.* (*Nephrolepidina*) *verbeeki* Newton and Holland. It is smaller than *L. verbeeki*, with the papillae localized in the apical area, not evenly distributed over the entire surface. The peripheral equatorial chambers in this species are diamond shaped, whereas those of *L. verbeeki* tend to the spatulate form. In vertical sections *L. verbeeki* shows a wider rim and more regular arrangement of the lateral chambers in the central area of the test.

Lepidocyclina (Nephrolepidina) sumatrensis inornata L. Rutten

Plate 215, figure 22

1914. *Lepidocyclina sumatrensis* Brady, var. *inornata* L. Rutten, Geol. Reichs-Mus. Leiden, Samml., ser. 1, v. 9, p. 294, 295, pl. 22, figs. 6–8.

1939. *Lepidocyclina sumatrensis* (Brady), var. *inornata* L. Rutten. Caudri, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 12, p. 189, 190, 195, 196, pl. 7, figs. 36, 37, 40, 41.

Test biconvex with a bluntly rounded edge. Surface devoid of any ornamentation.

The one available specimen was made into a vertical thin section. A description of this thin section follows: The diameter is 3.2 mm and the thickness through the center, 2.0 mm. The embryonic chambers have an internal length of 260 μ and an internal height of 160 μ. The outer wall is thick and fibrous. The thickness of this wall is about 60 μ. The equatorial layer is thin at the center of the test, but expands rapidly in the peripheral zone. At the center of the test the equatorial layer has a height of 80 μ and at the periphery a height of 200 μ, these measurements included the thickness of the floors and roofs. The lateral chambers are arranged in regular tiers. There are about 16 chambers to a tier on each side of the embryonic chambers in the center of the test. These chambers have extremely thin roofs and floors with large, open cavities. Typical lateral chambers over the center have a length of 100 μ, a height of 40 μ, and roofs and floors with a thickness of 10 μ. True pillars are not present.

First appearance.—At a depth of 1082½–1088 feet in Bikini hole 2A.

Age reported elsewhere.—Tertiary *e* and *f*.

Discussion.—There is grave danger in identifying specimens from a vertical section alone. However, the general features shown by the one available thin section are so similar to illustrations and descriptions of this variety of *L. sumatrensis* that the Bikini specimen is assigned to it with little hesitation.

Lepidocyclina (Nephrolepidina) verrucosa Scheffen

Plate 213, figures 1–9

1932. *Lepidocyclina verrucosa* Scheffen, Wetensch. Meded. No. 21, p. 33, 34, pl. 7, figs. 2–4.

1939. *Lepidocyclina verrucosa* Scheffen. Caudri, Genootsch. Nederl, en Kol., Verh, Geol. Mijnbouwk, geol. ser., v. 12, p. 179–185, figs. 26–30, 42, 46.

Test evenly biconvex, sloping regularly from the slightly flattened umbonal area to the bluntly rounded peripheral portion. A few specimens have a mere suggestion of a narrow rim, but most of them have none. There is an apical crown of small papillae that are virtually flush with the surface in unweathered specimens, but stand out rather prominently in slightly weathered ones. The remainder of the test is covered with a mesh of polygonal shallow pits representing the weathered lateral chambers. Measurements of typical specimens follow:

Vertical sections

Specimen	1	2	3	4
Diameter mm	2. 94	3. 3	2. 7	2. 8
Thickness mm	1. 6	1. 66	1. 7	1. 6
Number of lateral chambers on each side of equatorial layer at center	16	16	15	----------
Embryonic apparatus:				
Internal height μ	140	160	160	150
Internal length μ	240	220	200	220
Thickness of walls μ	20	40	40	40
Equatorial layer:				
Height at center μ	60	80	80	60
Height at periphery μ	160	120	100	120
Lateral chambers:				
Length μ	180–200	160–200	140–180	140–220
Height μ	40	40	40	40
Thickness of roofs and floors μ	15	20	20	20
Surface diameter of pillars μ	100–240	180	180–220	180–200

Horizontal sections

Specimen	1	2	3
Diameter mm	2. 6	2. 6	3. 0
Embryonic chambers:			
Diameters of initial chamber μ	180 x 230	140 x 200	160 x 230
Diameters of second chamber μ	95 x 265	125 x 300	120 x 300
Distance across both chambers μ	280	280	280
Thickness of outer wall μ	40	40	40
Equatorial chambers:			
Radial diameter μ	60	60	----------
Tangential diameter μ	40	40	----------

First appearance.—At a depth of 1240–1250½ feet in Bikini hole 2A; at a depth of 1293–1303½ feet in Bikini hole 2B.

Age reported elsewhere.—Tertiary *e* and *f*.

Subgenus EULEPIDINA H. Douvillé, 1911

Lepidocyclina (Eulepidina) abdopustula Cole, n. sp.

Plate 215, figures 9, 10; plate 218, figures 7–11

Test with an inflated central area, sloping regularly from this area to the periphery. None of the specimens available has a rim. The apical area is covered with irregularly spaced elevated, conspicuous papillae. These papillae have surface diameters of 200 to 300 μ. Beyond the area of concentrated papillae occur smaller, less raised and more scattered papillae. The diameter is from 3.0 to 4.4 mm and the thickness is from 1.5 to 2.24 mm.

Horizontal sections

Depth feet	2070–2080½	2246–2256½
Diameter mm	3. 0	4. 4
Embryonic chambers:		
Internal diameters of initial chamber μ	220 x 280	280 x —
Internal diameters of second chamber μ	170 x 480	— x 420
Distance across both chambers μ	420	400
Thickness of outer wall μ	35	35
Equatorial chambers:		
Tangential diameter μ	60	60
Radial diameter μ	50	70

The shape of the equatorial chambers ranges from curved outer walls with pointed inner ends to regularly hexagonal. Chambers of the first type occur near the center of the test and those of the second type occur in the peripheral areas. However, there is intermingling of the two kinds, especially in the outer rows of chambers.

Vertical sections

Depth feet	2102–2112	2070–2080½	
Diameter mm	3. 1	3. 8	3. 6+
Thickness mm	1. 56	2. 24	1. 8
Embryonic chambers:			
Internal length μ	430	320	--------
Internal height μ	250	200	--------
Thickness of outer wall μ	25	40	--------
Height of equatorial layer:			
At center μ	100	120	100
At periphery μ	130	120	120
Lateral chambers:			
Number on each side of the equatorial layer	15	21	14
Length μ	100–140	120–200	140–200
Height μ	20	20	20
Thickness of floors and roofs μ	20	20	20
Surface diameter of pillars μ	180–240	100–140	120–260

The lateral chambers are low and appressed, with the thickness of the floors and roofs about equal to the height of the chamber openings. In some areas the lateral chambers occur in rather regular tiers, but in other areas there is considerable overlap from one tier into adjacent ones.

The pillars are irregularly developed and scattered unevenly through the test, with the greatest concentration in the central area. Many of the pillars have their greatest diameter about halfway from the equatorial layer to the surface of the test. Some of the pillars seem to stop before the surface of the test is reached so that several layers of lateral chambers cover these pillars. Most of the pillars start a short distance above the equatorial layer so that lateral chambers occur between the proximal ends of the pillars and the equatorial layer. Thus, some pillars are entirely internal.

First appearance.—At a depth of 2070–2080½ feet in Bikini hole 2B.

Discussion.—This species differs from *L. formosa* by the development of pillars and by the more appressed lateral chambers, which are frequently not aligned in regular tiers. From *L. papuaensis* Chapman this species differs in the smaller size of the embryonic apparatus, the less regular alignment of the lateral chambers, the heavier and more irregularly developed pillars and the more inflated central area of the test.

Lepidocyclina (Eulepidina) formosa Schlumberger

Plate 216, figures 1–16; plate 217, figures 9–11; plate 218, figures 1, 3, 4

1902. *Lepidocyclina formosa* Schlumberger, Geol. Reichs-Mus., Leiden, Samml., Band 6, p. 251–252, pl. 7, figs. 1–3.

1918. *Lepidocyclina (Eulepidina) stereolata* Oppenoorth, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., Band 2, p. 254, pl. 7, figs. 1–6.

Suites of specimens based on size and external appearance were selected at various depths on the assumption that several different species were represented. Of these various groups of specimens thin sections were prepared, descriptions drawn up and tentative names assigned. In three such groupings three distinct species were recognized provisionally: *L. formosa* Schlumberg-

er, *L. stereolata* Oppenoorth and a supposedly new species.

As the study of these specimens progressed, it became apparent that there was a perfect gradation from one group to the next and that it was impossible to draw any boundaries which would serve to separate one from the other.

A description of specimens in each of the groups is given so that the eventual correlation of the specimens under one specific name may be appreciated. The first specimens to be described are those which were identified originally as *L. formosa.*

Test with a strongly inflated central portion which is bordered by a rim. Diameter from 3+ mm to 4.2+ mm; thickness from 1.4 to 2.0 mm. Surface ornamentation pronounced, consisting of a mesh of deep, faintly polygonal pits, separated by flat-topped ridges. Pit diameters from 160 to 200 μ and ridges with thicknesses of 80 to 160 μ.

Embryonic chambers eulepidine, with relatively thick outer wall. Diameters of large chamber 350 by 420 μ. Diameters of small chamber 220 by 260 μ. Small chamber attached through a distance of 240 μ. Thickness of the outer chamber wall 40 to 55 μ.

Equatorial chambers arcuate at center of test, becoming short spatulate as periphery is approached. These chambers with radial and tangential diameters of about 80 μ.

Measurements of vertical sections follow:

Vertical sections

Depth—feet	1723½–1734		1923–1933½		1986–1996½
Diameter—mm	3. 9+	2. 8+	3. 8+	4. 2+	3. 0+
Thickness—mm	1. 8	1. 8	1. 92	1. 46	1. 7
Embryonic chambers:					
Internal length—μ	500	580	320	300	580
Internal height—μ	240	270	200	220	300
Thickness of wall—μ	45	40	40	20	40
Lateral chambers:					
Number on each side of embryonic chambers	14	14	18	14	15
Length—μ	120–180	140–200	200–220	100–140	120–180
Height—μ	35–40	20–40	30–50	30–40	20–50
Thickness of floors and roofs—μ	10–20	10–20	10	10	20
Equatorial layer:					
Height at center—μ	60	60	55	45	55
Height at periphery—μ	----------	----------	100	100	----------

The lateral chambers are arranged in regular tiers and the tiers are separated by the juncture of the thickened roofs and floors of the lateral chambers of one tier joining those of the adjacent one. Pillars are absent. The chamber cavities are open and rectangular except for slightly pointed ends. The roofs and floors are slightly thinner at the center than at the sides. The ends of the roofs and floors are greatly thickened.

First appearance.—At a depth of 1723½–1734 feet in Bikini hole 2B.

Age reported elsewhere.—Tertiary *e.*

A description of specimens identified as *L. stereolata* follows:

The test has a highly inflated central portion surrounded by a rim. The rim is broken in the available specimens so that its proportions cannot be determined. Surface ornamentation consists of an apically situated area of clear, smooth shell material with a diameter of about 1.1 mm beyond which occurs a polygonal mesh of clear shell material that bounds either polygonal pits or areas of opaque shell material. At the angles of the polygonal mesh are small rounded areas of clear shell material that are darker in color than the remainder of the mesh. The specimen figured to show the external appearance has a diameter of 3.+ mm and a thickness of 3.3 mm.

No equatorial sections were made, but the embryonic chambers are eulepidine and the equatorial chambers are short spatulate to hexagonal.

Three vertical sections were available for study. Measurements of these follow:

Vertical sections

Depth—feet	1986–1996½	2038½–2049	
Diameter—mm	3. 2+	3. 36+	2. 5+
Thickness—mm	2. 14	2. 6	2. 0
Embryonic chambers:			
Internal length—μ	500	420	430
Internal height—μ	290	160	----------
Thickness of outer wall—μ	60	50	----------
Equatorial layer:			
Height at the center—μ	90	100	90
Height at the periphery—μ	180	140	120
Lateral chambers:			
Number on each side of equatorial layer	17	16	10
Length—μ	200	180–200	300
Height—μ	45	30–40	40
Thickness of floors and roofs—μ	20	20–40	25
Surface diameter of apical areas of clear shell material—μ	600–1000	1600	800

The apical areas of clear shell material project inward in the vertical sections to form large masses in the interior of the test. In two of the specimens these masses extend virtually to the equatorial layer, but in the

third specimen they extend inwardly for only about one-half the distance. In this specimen the masses of clear shell material separate at this point into three prongs of shell material that separately extend to the equatorial layer and are between normal lateral chambers.

Toward the margins of the test the lateral chambers are separated by small masses of shell material which extend from the equatorial layer to the surface of the test, or the lateral chambers occur without such separation between the individual tiers.

These masses of clear shell material represent an unusual thickening of the end walls of the lateral chambers rather than true pillars. In the apical area these masses fuse into a solid plug that destroys the lateral chambers.

The lateral chambers in the marginal zones and in the center where the thickening does not occur are in regular tiers and normal in appearance.

Some specimens do not have the apical mass of clear shell material. On these specimens the surface is covered by a polygonal mesh of clear shell material that either bounds polygonal pits or areas of opaque shell material.

However, vertical sections of these specimens show thickened walls between the tiers of lateral chambers, especially in the central area of the test. Moreover, in one of these specimens on one side at the apical periphery the thickened walls of the lateral chambers spread so that they are virtually in contact.

First appearance.—At a depth of 1986–1996½ feet in Bikini hole 2B.

A description of the specimens assigned tentatively to a new species follows:

The test has an inflated central area surrounded by a rim of variable width. The surface of the test is covered by a polygonal mesh of clear shell material which encloses polygonal pits. At the corners of the polygonal mesh there are small rounded areas of clear shell material from which the ridges of the mesh radiate. These rounded areas represent the surface expression of the thickened juncture lines between the tiers of lateral chambers. Typical pillar heads do not appear.

Although the embryonic chambers are classed as eulepidine, there is a slight projection outward of the common wall between the initial and its enclosing chamber. This projection outward of the initial chamber is not sufficient, however, to classify the chambers under the term nephrolepidine. It is well known that eulepidine and nephrolepidine types of embryonic apparati intergrade within the same species.

Horizontal sections

Depth—feet	2154–2164½	2246–2256½
Diameter—mm	3.+	2.6+
Embryonic chambers:		
Internal diameters of initial chamber—μ	220 x 280	180 x 220
Internal diameters of second chamber—μ	200 x 500	150 x 380
Distance across both chambers—μ	430	340
Thickness of outer wall—μ	40	30
Equatorial chambers:		
Tangential diameter—μ	70	70
Radial diameter—μ	60	50

The equatorial chambers near the center have curved outer walls and pointed inner ends. Near the circumference of the test they become short spatulate or hexagonal.

Vertical sections

Depth—feet	2154–2164½			2164–2175	2214½–2225
Diameter—mm	3. 1+	3. 3+	2. 9+	2. 7+	3. 4+
Thickness—mm	1. 32	1. 32	1. 36	0. 98	1. 4
Embryonic chambers:					
Internal length—μ	430	360	440	400	360
Internal height—μ	290	240	350	160	240
Thickness of outer wall—μ	45	30	40	40	25
Equatorial layer:					
Height at center—μ	100	100	100	90	80
Height at periphery—μ	160	150	120	140	120
Lateral chambers:					
Number on each side of equatorial layer	8	9	10	8	10
Length—μ	160	150–200	200	140–200	160–200
Height—μ	40–60	40	30	40–45	20–40
Thickness of floors and roofs—μ	20	15–20	20	20	20

The lateral chambers are in regular tiers. They possess open, rectangular cavities. Thickened areas occur between the tiers of lateral chambers, but these areas are not true pillars.

Discussion.—*L. formosa* was described from Teweh, Borneo and *L. stereolata* was found in northern Sumatra. These localities are referred to the Aquitanian, Tertiary *e*.

Inspection of the illustrations given of the specimens from Bikini reveals a progressive series from the specimens that were assigned to a new species to those identified as *L. stereolata*. This gradation is so gradual, yet

perfect, that it is impossible to separate these groups into distinct species, therefore they are all included under the specific name, *L. formosa.*

Yabe (1919, p. 42) described under the name *L. monstrosa* a *Lepidocyclina* with "a ring of chamberlets with thickened walls." Later an excellent illustration of a specimen referred to this species is given by Yabe and Hanzawa (1929, p. 165). This specimen has the type of internal structure possessed also by specimens from Bikini that have the large apical plugs caused by the fusion of the thickened walls.

Lepidocyclina (Eulepidina) gibbosa Yabe

Plate 217, figures 15–18; plate 218, figure 2

1919. *Lepidocyclina (Eulepidina) gibbosa* Yabe, Tohoku Imp. Univ. Sci. Rep., ser. 2 (Geol.), v. 5, p. 46, pl. 6, figs. 3, 4c, 7c(?).

The test has an inflated evenly biconvex central portion which is surrounded by a flat relatively thin rim. The diameter is from 4.5 to 7.2 mm; the thickness through the center from 2.0 to 2.6 mm. The surface is ornamentated by large, polygonal deep pits with diameters of 200 to 340 μ. These pits are separated by walls 100 to 140 μ thick.

The embryonic chambers are large, thick walled, and eulepidine in type. The large chamber has diameters of 700 by 780 μ and the small chamber has diameters of 420 by 420 μ. The small chamber is attached for a distance of 200 μ. The thickness of the outer wall is 80 μ.

The equatorial chambers are short spatulate. Well-developed chambers have radial and tangential diameters of about 80μ.

Measurements of vertical sections follow:

Vertical sections

Depth ---- feet	1881–1891½	1891½–1902	1923–1933½
Diameter ---- mm	5.2+	5+	4.4+
Thickness ---- mm	2.0	2.6	2.3
Embryonic chambers:			
Internal length ---- μ	860	940	700
Internal height ---- μ	400	480	300
Thickness of wall ---- μ	60	60	80
Lateral chambers:			
Number on each side of the embryonic chambers	11	15	11
Length ---- μ	240–400	300–400	260–340
Height ---- μ	40–55	40–60	60–70
Thickness of floors and roofs ---- μ	20	20	15–20
Equatorial layer:			
Height at the center ---- μ	70	100	80
Height at the periphery ---- μ	100	130	140

The cavities of the lateral chambers are large and open, but have pointed ends. The roofs and floors of the lateral chambers are thin at the center, but thicken at each end. The thickened ends of the floors and roofs of one tier of chambers join those of the next adjacent tier on each side to produce a columnlike structure between the tiers of chambers. However, pillars are not present. The lateral chambers are arranged in very regular tiers.

First appearance.—At a depth of 1744½–1755 feet in Bikini hole 2B.

Age reported elsewhere.—Tertiary *e.*

Discussion.—This species was named by Yabe (1919, p. 46) and some specimens from the Philippine Islands, previously referred to *L. formosa* Schlumberger by Douvillé (1911, p. 72) are placed under this specific name. The best specimen figured by Douvillé has a diameter of about 5.7 mm. The pits on the surface have diameters of 200 to 400 μ and the intervening walls have thicknesses of 100 to 180 μ.

The external appearance of the specimens from the Bikini hole is very similar to that of the specimens from the Philippines. All of these specimens are very similar to specimens of *L. formosa* except that the lateral chambers are larger, have heavier roofs and floors, and the surface pits are coarser and have thicker intervening walls.

As these specimens are readily distinguishable from those considered to be *L. formosa*, they are referred to Yabe's species. However, these specimens may represent only one variation of *L. formosa* a highly variable species similar to the American species *L. favosa* Cushman. Vaughan (1933, p. 38) and Cole (1945a, p. 41–43) have indicated in studies of this species that many of the names proposed for variants do not serve any useful purpose as all degrees of development can be found in one lot of specimens.

It is noteworthy that the *L. gibbosa* type of specimens apparently either occur at the same horizon with the typical *L. formosa* type of specimens, or in closely related horizons in most localities examined. It may be that slightly different ecological or chemical conditions cause the development of the coarser structure which characterizes *L. gibbosa.*

Lepidocyclina (Eulepidina) planata Oppenoorth

Plate 217, figures 7, 8; plate 218, figures 5, 6

1918. *Lepidocyclina (Eulepidina) planata* Oppenoorth, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 2, pp. 254, 255, pl. 8, figs. 7–10.

Test compressed with a slightly inflated umbonal area which has a diameter of 2.6 to 3.8 mm. The inflated portion is bordered by a rim into which it merges gradually. The surface of the test is covered by a raised polygonal mesh whose ridges have a width of about 100 μ. Relatively deep polygonal to rudely hexagonal pits occur between the ridges of the mesh. The diameter of a complete specimen would be 6 millimeters or more as only broken fragments were recovered. The largest specimen has a diameter of 4.5 mm, and this

specimen consists mainly of the umbonal area with a narrow portion of the rim preserved on one side.

Horizontal section

Depth	feet	2235½-2246
Diameter	mm	4.+
Embryonic chambers:		
Distance across both chambers	μ	600
Thickness of outer wall	μ	80
Equatorial chambers:		
Tangential diameter	μ	80
Radial diameter	μ	80

The equatorial chambers are of two types, those with curved outer walls and pointed inner ends predominate, but intermingled with these are others which are short spatulate. The spatulate chambers are more abundant near the periphery of the test.

Vertical section

Depth	feet	2154-2164½
Diameter	mm	3.4+
Thickness	mm	1.14
Embryonic chambers:		
Internal length	μ	820
Internal height	μ	380
Thickness of outer wall	μ	70
Equatorial layer:		
Height at center	μ	160
Height at periphery	μ	180
Lateral chambers:		
Number on each side of equatorial layer		7
Length	μ	120-200
Height	μ	40
Thickness of floors and roofs	μ	25

The lateral chambers are arranged in definite tiers. The rectangular chamber cavity is open and bounded by relatively heavy floors and roofs. The line of juncture between the tiers of lateral chambers is thickened giving the appearance of pillars. However, true pillars are not present.

First appearance.—At a depth of 1996½–2007 feet in Bikini hole 2B.

Age reported elsewhere.—Tertiary *e*.

Discussion.—These specimens fall within the range of variation of a much larger suite of specimens from Saipan which have been identified as *L. planata*, which is characterized by a large thick-walled embryonic apparatus and relatively few open regularly aligned lateral chambers whose floors and roofs are about half as thick as the height of the chamber cavity.

L. papuaensis Chapman (1915, p. 297) is a closely related species with a large, thick-walled embryonic apparatus. However, *L. papuaensis* has more numerous lateral chambers with somewhat thinner floors and roofs.

A large suite of specimens might demonstrate that these two species could be brought together under one name. The equatorial sections of the specimens referred to *L. planata* are identical with those of *L. gibbosa*, but the vertical sections are different in that the lateral chambers of *L. gibbosa* are higher, with coarser roofs and floors.

Sufficient material was available to prove that *L. stereolata* should be considered one of the forms of *L. formosa* although it would have been impossible to reach this conclusion without very abundant and well-preserved specimens. Therefore, it is entirely possible that *L. planata* is only another variation in the very plastic species, *L. formosa*.

Lepidocyclina flexuosa L. Rutten

Plate 217, figure 6

1911. *Orbitoides (Lepidocyclina) flexuosa* L. Rutten, Kon. Akad. van Weten. Te Amsterdam, v. 9, p. 1132, 1133, text fig. 3.
1914. *Lepidocyclina flexuosa* L. Rutten, Geol. Reichs-Mus. Leiden, Samml., ser. 1, v. 9, p. 304, pl. 23, figs. 6–8.
1939. *Lepidocyclina flexuosa* L. Rutten. Caudri, Genootsch. Nederl. en Kol., Verh. Geol. Mijnbouwk, geol. ser., v. 12, p. 172–175, pl. 6, figs. 22–25 (references).

A single vertical section from a depth of 1587–1597½ feet reveals the following characteristics: The diameter is more than 3.4 mm as the edges of the specimen are broken; the thickness through the center is 1.9 mm; the height of the equatorial layer at the center is 50 μ and at the periphery 100 μ, these measurements including the thickness of the floor and roof; the lateral chambers are arranged in regular tiers with about 18 chambers to a tier on each side of the equatorial layer at the center of the test; the lateral chambers adjacent to the equatorial layer have low, appressed cavities, but those at the periphery have open cavities and are rectangular; these chambers have a length of 100 μ, a height of 20 μ and the floors and roofs have a thickness of 15 μ; heavy pillars with a surface diameter of about 200 μ occur in the central area of the test.

Age reported elsewhere.—Tertiary *e* and *f*.

Family MIOGYPSINIDAE Tan

Genus MIOGYPSINA Sacco, 1893

Subgenus MIOGYPSINA Sacco, 1893

Miogypsina (Miogypsina) borneensis Tan

Plate 220, figures 9–21

1936. *Miogypsina borneensis* Tan, De Ing. in Ned.-Indië. 4 Mijnbouw en Geol. 3 Jaarg. p. 50–51, pl. 1, figs. 18, 19; pl. 2, figs. 1, 2.
1940. *Miogypsina borneensis* Tan. Hanzawa, Jubilee Publ. in commemoration of Prof. H. Yabe's 60th birthday, p. 783–785, pl. 41, figs. 11–23.

Test flabelliform to subcircular in outline, normally thickest adjacent to the initial portion and thence sloping regularly to the bluntly rounded anterior edge. In certain specimens the length and breadth are equal, in

others the length is slightly greater than the breadth and in some the reverse of this is found. The surface of the test is ornamented by slightly projecting and rather evenly distributed papillae which have an average surface diameter of about 60 μ. External measurements of typical specimens follow:

Specimen	1	2	3	4	5	6
Length mm	2.8	2.6	2.6	2.3	2.5	2.5
Breadth mm	2.6	3.0	2.6			
Thickness mm				1.0	0.9	0.94

The embryonic apparatus is bilocular and composed of a subcircular initial chamber, with internal diameters of 100 by 140 μ in one specimen and 120 by 130 μ in another specimen, and a kidney-shaped to subcircular second chamber with internal diameters of 100 by 120 μ in one specimen and 80 by 180 μ in another. The internal distance across both embryonic chambers in three specimens is 220, 260 and 280 μ. The outer wall of the embryonic chambers is about 20 μ thick. The embryonic chambers are situated virtualy at the apex of the test; the distance between the embryonic chamber wall and the edge of the test is from 20 to 140 μ of which the last measurement is probably the normal distance.

The available thin sections do not satisfactorily show the periembryonic chambers. However, in one thin section these chambers are partly exposed. In this section the embryonic chambers seem to be partly surrounded by a coil of roughly quadrangular chambers of which 8 appear in the section.

The normal equatorial chamber is diamond shaped, with a radial diameter of 120 μ and a tangential diameter of 70 μ. There are both smaller and larger equatorial chambers scattered throughout the equatorial layer. The equatorial layer has a height of about 160 μ, this measurement including the thickness of the floor and roof.

The vertical sections were not very satisfactory because the preservation is poor. Apparently, there are about 6 layers of lateral chambers on each side of the equatorial layer at the thickest portion of the test, just anterior of the initial end. There is a regular reduction in the number of lateral chambers so that at the distal side of the test the equatorial layer is covered by only one layer of lateral chambers. The lateral chambers are more appressed in the thicker portion of the test and become open with higher cavities toward the periphery. The appressed lateral chambers have a length of 60 to 80 μ, a height of the cavity of 20 μ, and floors and roofs of 20 to 40 μ thickness. The open lateral chambers have a length of 100 μ, a height of the cavity of 40 to 60 μ, and floors and roofs of about 20 μ thickness.

Small cylindrical pillars are scattered rather evenly throughout the test. These pillars have a surface diameter of 40 to 80 μ. They taper but slightly if at all as they approach the equatorial layer.

First appearance.—At a depth of 1135–1145½ feet in Bikini hole 2A; at a depth of 1167–1177½ feet in Bikini hole 2B.

Age reported elsewhere.—Higher Aquitanian, Tertiary *e* and lowest Burdigalian, Tertiary *f*.

Discussion.—Specimens identified as this species in the deep well on Kita-Daito-Zima (North Borodino Island) were made available through the kindness of Dr. S. Hanzawa. A median and a vertical section of these specimens are illustrated for comparison with the specimens from the Bikini drill hole.

Certain specimens in the Bikini holes agree in all features with *Miogypsina thecidaeformis* (Rutten) illustrated by Umbgrove (1927, pl. 2, figs. 1, 2, 4). Tan includes these specimens in his definition of *M. borneensis*. Hanzawa (1940, p. 784) points out correctly that the microspheric specimen illustrated by Umbgrove (1927, pl. 2, fig. 3) has hexagonal equatorial chambers near the distal margin of the test. But, Hanzawa retains these specimens in the synonymy under *M. borneensis*.

As microspheric specimens were not found in the population of the Bikini hole, the structures of this generation could not be observed. However, the megalospheric specimens resemble the illustrations given by Umbgrove, Tan and Hanzawa. It is noteworthy that Tan recognizes in his definition of *M. borneensis* that hexagonal equatorial chambers may be present.

Miogypsina (Miogypsina) indonesiensis Tan

Plate 219, figures 1–15; plate 220, figure 22

1936. *Miogypsina indonesiensis* Tan, De Ing. in Ned.-Indië. 4. Mijnbouw en Geol. 3 Jaarg. p. 54, 55, pl. 2, figs. 3–6.

Test in plan view fan-shaped, initial end bluntly rounded, from which point the sides of the test flare to the broadest portion, anterior end elliptic; posterior edge in cross section rounded, anterior edge wedge-shaped, greatest thickness at or just posterior to the center of the test.

The surface ornamentation may be divided into several types. A specimen 2.0 mm long by 2.3 mm wide has pustules thickly but irregularly scattered over the

surface. The pustules have surface diameters from 60 to 100 μ in diameter with the larger ones predominating. Polygonal pits intervene between the pustules. A specimen 4.1 mm long by 4.1 mm wide has closely spaced, evenly distributed papillae that have a surface diameter of about 120 μ. These papillae are raised and separated from each other by marked depressions. A specimen 3.0 mm long by 2.8 mm wide has papillae of two distinct sizes scattered evenly over the surface. The larger papillae have surface diameters of about 70 μ and the smaller have diameters of 20 to 40 μ. From these papillae radiate sutures of clear shell material which bound rhombic areas between the papillae. A specimen 4.1 mm long by 3.8 mm wide has fine papillae whose surface diameters are about 60 μ scattered evenly over the surface. These papillae are nearly flush with the surface of the test. From each papilla sutures of clear shell material radiate so that they bound rhombic areas between the papillae. Although there are size and surface ornamentation differences, the thin sections demonstrate that these specimens are megalospheric forms and belong to the same species.

A specimen 1.8 mm long has a thickness of 0.64 mm and a specimen 3.0 mm long has a thickness of 1.0 mm.

The embryonic chambers are bilocular with periembryonic chambers arranged around their periphery. Measurements of certain elements of the embryonic chambers are given in the following table. Originally, two kinds of specimens were distinguished, those with fine papillae and those with coarse ones. These types are described separately in the table.

Drill hole	2B	2B	2A	2A
Depth—feet	1177½–1188	1177½–1188	1135–1145½	1135–1145½
Type of papillae	coarse	coarse	coarse	fine
Size (length x width)—mm	2.2 x 1.9	3.0 x 2.8	3.4 x 3.1	3.7 x 3.8
Diameters of initial chamber—μ	160 x 170	120 x 130	130 x 140	140 x 140
Diameters of second chamber—μ	200 x 300	130 x 200	120 x 180	160 x 230
Distance across both chambers—μ	400	270	300	320
Thickness of outer wall—μ	20	20	20	20
Distance of the second chamber from the periphery of the test—μ	80	40	160	100
Illustration (plate, figure)	219, 6	219, 8	220, 22	219, 9

The equatorial chambers are arcuate, rhombic or elongate hexagonal. All of these types may occur in the same specimen, or one type may predominate. Measurements of the different types of chambers from the same specimen follow: arcuate, radial diameters, 40 to 80 μ, tangential, 40 to 60 μ; rhombic, radial diameters 40 to 120 μ, tangential 50 to 80 μ; hexagonal, radial 120 to 160 μ, tangential 80 to 100 μ.

The measurements of typical vertical sections are given in the following table.

Vertical sections

Well	2B	2A	2A
Depth—feet	1167–1177½	1135–1145½	1135–1145½
Type of papillae	coarse	coarse	fine
Length—mm	1.8	3.0	3.4
Thickness—mm	0.64	1.0	0.92
Embryonic chambers:			
Distance across both chambers—μ	290	290	330
Greatest height of the chambers—μ	150	130	155
Distance from periphery of the test—μ	100	140	80
Height of the equatorial chambers—μ	50	40–80	60–70
Lateral chambers:			
Number on each side of the equatorial layer	4	10	8
Length—μ	60–80	40–80	60–120
Height—μ	20–30	20–30	20–55
Thickness of floors and roofs—μ	15–35	20	20–50
Surface diameter of pillars—μ	60–80	80–120	40–100

The lateral chambers are open, with slightly curved roofs and floors. They may occur in regular tiers between the pillars, but normally there is overlapping from one tier to the adjacent ones.

First appearance.—At a depth of 1135–1145½ feet in Bikini hole 2A; 1167–1177½ feet in Bikini hole 2B.

Age reported elsewhere.—Higher Aquitanian, Tertiary *e* and lower Burdigalian, Tertiary *f*.

Genus MIOGYPSINOIDES Yabe and Hanzawa, 1928

Miogypsinoides borodinensis (Hanzawa)

Plate 221, figures 6–8

1940. *Miogypsinella borodinensis* Hanzawa, Jubilee Publ. in commemoration of Prof. H. Yabe's 60th birthday, p. 768, 775, 779, 780, pl. 39, figs. 1–9.

Megalospheric form.—Test small with a broadly rounded initial end, thence flaring to the broadest portion of the test which is just beyond the initial portion. Distal edge of the test crenulated, representing the outgrowth of some of the equatorial chambers. Small, closely spaced, slightly raised papillae occur uniformly scattered over the surface of the test. The length is from 1.2 to 1.3 mm and the width at the widest portion is 1.1 to 1.2 mm.

The embryonic chambers are bilocular, the initial chamber has a diameter of about 80 μ; the second chamber has diameters of 50 by 90 μ and the distance across both chambers is 150 μ. The thickness of the outer wall is 20 μ.

The embryonic chambers are followed by a coil of periembryonic chambers which makes 1½ volutions around the initial chambers. There are about 9 chambers in the first volution and about 15 chambers in the periembryonic series. In the first volution the fifth to seventh chambers occur at the proximal edge of the test.

The equatorial chambers are polygonal in plan and extremely variable in size.

A vertical section assigned to this species has a length of 1.14 mm, a thickness through the initial end of 0.42 mm and a thickness through the equatorial chambers of 0.34 mm.

The embryonic chambers have a length of 140 μ and a height of 60 μ.

Pillars with a surface diameter of 80 to 100 μ appear on the dorsal side over the embryonic chambers. The ventral pillars are not observed in this section.

Microspheric form.—The microspheric specimens are larger than the megalospheric ones. A typical microspheric specimen has a length of 2.0 mm and a width of 1.4 mm at the broadest portion.

The embryonic chambers are extremely small and bilocular, with a diameter across both chambers of about 25 μ. There are 3½ coils of periembryonic chambers around the equatorial chambers with 39 or more chambers in all the coils.

The equatorial chambers are similar to those of the megalospheric form.

First appearance.—At a depth of 1597½–1608 feet in Bikini hole 2B.

Age reported elsewhere.—Chattian.

Discussion.—These specimens are so similar to those described from the North Borodino Island test well that there is no hesitation in assigning them to that species.

M. borodinensis occurs in the North Borodino Island well in Zone 5 (394.98 to 431.67 meters). Hanzawa assigns this zone to the Chattian, mainly on the basis that Aquitanian fossils occur in Zone 4 and that *M. borodinensis* is closely related to *M. complanata* Schlumberger, an Aquitanian and Chattian species.

As *M. borodinensis* occurs in the Bikini test hole with undoubted Aquitanian species, and as the base of the Aquitanian in the Bikini hole is far below the occurrence of *M. borodinensis* in this well, it seems reasonable to conclude that *M. borodinensis* is an Aquitanian species.

Hanzawa (1940, p. 764, 765) remarks that "It is odd in the present material, no specimens of *Eulepidina* are found * * *". If the record of the Bikini hole is correct, *Eulepidina* first appears 126 feet below the first occurrence of *M. borodinensis*. It is most probable that the North Borodino Island well did not reach the *Eulepidina* zone.

Miogypsinoides cupulaeformis (Zuffardi-Comerci)

Plate 222, figures 4–11

1929. *Miogypsina cupulaeformis* Zuffardi-Comerci, Soc. Geol. Ital., Boll., v. 47 (1928), p. 142, pl. 9, figs. 12, 13, 20.

Test with a nearly straight initial side and a semicircular distal side, wider than long; surface ornamentation consisting of coarse raised papillae with surface diameters of about 140 μ, sharply demarked by depressed areas which surround each papilla. An average specimen has a length of 3.2 mm; a width of 4.0 mm and a thickness of 1.4 mm. The thickest portion of the test is slightly in front of the initial edge, whence the test thins toward the distal side.

The equatorial layer is flat over most of the area of the test, but near the initial side the equatorial layer curves sharply downward, therefore satisfactory preparations of the embryonic chambers were not obtained. Partial preparations demonstrate that the embryonic chambers are small and surrounded by 1½ to 2 coils of periembryonic chambers. The entire embryonic apparatus has a diameter of about 300 μ. The periembryonic chambers are subquadrate and the larger ones have diameters of 60 by 100 μ.

The equatorial chambers normally are rhombic, but various other shapes occur. Average chambers have radial diameters of about 100 μ and tangential diameters of about 80 μ.

The equatorial layer increases in height from the initial to the distal portion of the test. At the initial portion the height is about 60 μ and at the distal portion the height may be 180 μ.

The walls which cover the equatorial layer are composed of pillars which fuse and separate in an irregular manner. The pillars are composed of alternate layers of light and dark shell material which give to them a varved appearance. In some specimens the irregularity of the pillars and the open spaces between the pillars is such that the wall has a spongy appearance.

First appearance.—At a depth of 1030–1035½ feet in Bikini hole 2A.

Age reported elsewhere.—Burdigalian.

Discussion.—In the collections from the Lau Islands, Fiji, there occurred, in the Miocene, specimens which were referred to *Miogypsina neodispansa* (Jones and Chapman) (Cole, 1945a, p. 297). Certain specimens in the Bikini holes when thin sections were prepared revealed features that were so similar to the specimens from Vanua Mbalavu, Lau, that those specimens were recalled immediately. As far as can be determined the specimens from Bikini represent the same species as those from Lau, Fiji.

The specimens from Lau, Fiji, were studied from random thin sections made from the matrix material. With the oriented thin sections of the Bikini specimens available, a reevaluation became possible. Lateral chambers are not present in specimens from either locality, therefore the specimens belong to the genus *Miogypsinoides*.

Although the type figures are not adequate, all of the specimens under discussion closely resemble the specimens from Borneo that were named *Miogypsina cupulaeformis*. Van der Vlerk (1929, p. 24, 25) identified certain specimens from Borneo as *Miogypsina abunensis* Tobler. Tan (1936, p. 52) states that he believes

that these specimens are the same as *Miogypsina cupulaeformis*. At the same time Tan transfers the species *cupulaeformis* from the genus *Miogypsina* to the genus *Miogypsinoides* and gives two additional illustrations of the equatorial layer.

Although the additional figures and remarks shed more light on this species, an adequate characterization has not been produced. Therefore, there must be some doubt concerning the absolute identification of the specimens from Lau and Bikini with the specimens from Borneo. However, the shape of the equatorial chambers and the occurrence of strong pillars in all of these specimens suggest that they should be grouped together.

M. cupulaeformis occurs in the Burdigalian in the East Indies.

Miogypsinoides dehaartii van der Vlerk

Plate 220, figures 1–8

1924. *Miogypsina dehaartii* van der Vlerk, Eclog. Geol. Helvet., v. 28, p. 429–432, text figs. 1–3.

Test in plan view with a more or less straight initial side with the remainder of the outline of the test circular. In the center of the initial side a hemispherical bulge marks the position of the embryonic apparatus. The test is normally slightly wider than long and the thickest portion lies almost immediately in front of the external bulge produced by the embryonic apparatus. The surface is ornamented by very slightly raised, irregular, polygonal pustules. These pustules are best developed over the thickest portion of the test. The length of the test is 1.8 to 2.0 mm; the width is 2.0 to 2.5 mm; the thickness at the thickest portion is about 1.0 mm.

The embryonic chambers are bilocular, with 8 to 9 periembryonic chambers of subquadrate shape arranged around the initial chambers in such a manner that the initial chambers are completely enclosed by the periembryonic ones except for a small distance along the periphery of the test.

The initial chamber is spherical with an internal diameter of about 140 μ. The second chamber is subspherical with internal diameters of approximately 80 by 100 μ. The outer wall of the embryonic apparatus has a thickness of 40 μ. The distance across both chambers including the outer walls is about 300 μ.

The first periembryonic chamber is situated at the end of the dividing wall between the two initial chambers. This periembryonic chamber, as viewed in equatorial section, has a curved outer wall, and the inner walls are apparently those of the initial chambers themselves. The second periembryonic chamber has the subquadrate shape typical of the periembryonic chambers. The fourth or fifth periembryonic chamber represents the largest one of the series. Chambers on either side of the largest chamber decrease progressively in size and tend to have semicircular outer walls, particularly at each end of the partial coil.

The equatorial chambers have rude rhombic shapes with rounded rather than pointed corners. There is considerable difference in size in these chambers, but the average chambers have radial diameters of about 80 μ and tangential diameters of about 120 μ. In vertical sections the internal height of the equatorial chambers is about 180 μ. There is communication between the equatorial chambers by stoloniferous openings. These openings have diameters of about 20 μ and three or more appear in some chamber walls.

The walls over the equatorial layer are without lateral chambers. These walls are composed of laminae one on top of the other, with a light layer alternating with a darker layer. Pillars are not present.

First appearance.—At a depth of 1387½–1398 feet in Bikini hole 2B.

Age reported elsewhere.—Aquitanian, Tertiary *e*.

Miogypsinoides grandipustula Cole, n. sp.

Plate 221, figures 1–4, 19–22; plate 222, figure 12

Megalospheric form.—The young stage presents the appearance of a coarsely pustulate species of a rotalid. The surface is covered with closely crowded, large, distinctly raised papillae, the largest of which have a surface diameter of 100 μ. The diameter of these specimens is 0.9 to 1.4 mm and the thickness is about 0.7 mm.

An equatorial section shows a bilocular embryonic apparatus with a nearly spherical initial chamber with a diameter of 130 μ. The second chamber has diameters of 55 by 90 μ. The distance across both chambers is 210 μ. The thickness of the outer wall is 30 μ.

The embryonic chambers are followed by 2⅛ coils of subquadrate periembryonic chambers. There are 9 chambers in the first volution and a total of 26 chambers in the periembryonic series.

The available sections show only the initial development of the equatorial chambers. These appear as small secondary chambers at the juncture between two of the periembryonic chambers on the distal edge of the rotalid coil.

A vertical section of rotalid specimen shows bilocular embryonic chambers with a length of 250 μ and a height of 160 μ. Heavy pillars occur both on the dorsal and ventral sides.

A vertical section of an individual with well-developed equatorial chambers shows initially the same features as the rotalid specimen. However, this mature specimen has heavy walls covering the equatorial chambers. These walls are composed largely of closely

spaced pillars between which occur vertical canals or pores.

Microspheric form.—Test fan-shaped in plan view, undulate to selliform, initial end bluntly rounded, greatest width near the distal edge. Surface ornamentation consists of coarse papillae between which occur finer papillae. On one specimen the coarse papillae have surface diameters of about 180 μ and the finer papillae have diameters of about 80 μ. Another specimen has coarser papillae with diameters of 100 μ and finer papillae with diameters of 60 μ. The length is about 2 mm; the width is about 2.3 mm; and the thickness is about 1.0 mm.

The preparations of the initial chambers are not satisfactory. The initial chambers apparently are bilocular and very small with, a diameter across both chambers of not more than 40 μ. These chambers are followed by approximately 2 coils of subquadrangular periembryonic chambers with around 19 chambers in the entire series. The diameter of the entire embryonic apparatus is about 440 μ. The largest periembryonic chamber has diameters of 80 to 120 μ.

The equatorial chambers range in shape from rhombic to polygonal. Although the size varies normal chambers have diameters of about 100 μ.

In vertical sections the equatorial layer is observed to be curved from the initial end to the distal portion of the test and to gradually increase in height. At the initial end the internal height of the equatorial layer is about 60 μ and at the distal end the height is 180 μ.

The walls covering the equatorial layer are composed of fibrous appearing material with the long axis of the fibers at right angles to the equatorial plane. Conical pillars penetrate these fibrous layers from the exterior of the test. Some of these pillars penetrate to the equatorial layer, others reach only ¾ the way to the equatorial layer and certain ones only extend ½ the distance from the exterior to the equatorial layer. Well-developed pillars have a surface diameter of about 120 μ.

First appearance.—At a depth of 1597½–1608 feet in Bikini hole 2B.

Discussion.—This species is distinguished readily from either *M. borodinensis* or *M. ubaghsi* by the large, closely spaced and distinctly raised papillae. Vertical sections of *M. grandipustula* show thick walls covering the equatorial chambers. These walls are composed largely of pillars. *M. borodinensis* and *M. ubaghsi* have relatively thin walls over the equatorial chambers with the pillars not a conspicuous feature of these walls.

Miogypsinoides ubaghsi Tan

Plate 221, figures 5, 9–18; plate 222, figures 13–15

1936. *Miogypsinoides ubaghsi* Tan, De Ing. in Ned.-Indië. 4. Mijnbouw en Geol. 3 Jaarg. p. 47, 48, pl. 1, figs. 1–7.

1940. *Miogypsinella ubaghsi* (Tan). Hanzawa, Jubilee Publ. in commemoration of Prof. H. Yabe's 60th birthday, p. 767, 768, 775, text fig. 4.

Megalospheric form.—Test small, slightly wider than long, fan-shaped, initial portion in plan view rounded, thence rapidly flaring to the widest portion of the test, distal portion with a crenulated margin representing the outgrowth of the equatorial chambers; surface ornamentation consists of large pustules over the initial portion and finer, closer spaced pustules over the distal portion.

The initial chambers are bilocular, the first chamber is nearly spherical and the second chamber is reniform. The initial chambers are followed by subquadrate periembryonic chambers arranged so that they form virtually two coils. The periembryonic chambers gradually increase in length as they are added for about 1½ volutions at which point they decrease gradually in length to the end of the coil. The revolving wall is thick and has imbedded in it small pillars whose heads form surface pustules.

Measurements of 5 equatorial sections follows:

Equatorial sections

Depth—feet	1660½–1671	1671–1681½	1723½–1734	1744½–1755	1818–1828½
Greatest length—mm	1. 3	1. 32	1. 1	1. 26	1. 16
Greatest width—mm	1. 16	1. 14	1. 24	1. 0	1. 0
Embryonic chambers:					
Diameters of initial chamber—μ	90 x 100	120 x 130	100 x 100	120 x 100	80 x 80
Diameters of second chamber—μ	70 x 120	70 x 130	40 x 80	160 x 120	40 x 100
Distance across both chambers—μ	180	200	160	200	140
Thickness of outer wall—μ	30	30	20	20	20
Periembryonic chambers:					
Number of coils	2	1⅞	1⅞	1¾	2
Chambers in first volution	9	10	9	9	10
Total number of periembryonic chambers	20	23	22	20	24
Equatorial chambers:					
Radial diameter—μ	----------	160	140–160	100–160	180
Tangential diameter—μ	----------	120	100–160	100–140	120

After the fourteenth to about the seventeenth periembryonic chamber there is a small secondary chamber formed at the peripheral edge of the test and between the next succeeding periembryonic chamber two secondary chambers are formed. These represent the first equatorial chambers.

The later equatorial chambers have curved outer walls and pointed inner ends.

Measurements of 3 typical vertical sections follow:

Vertical sections

Depth—feet	1723½–1734	1744½–1755	1818–1828½
Length—mm	1.32	1.12	1.34
Thickness through initial portion—mm	0.64	0.5	0.6
Thickness through distal portion—mm	0.64	0.48	0.4
Embryonic chambers:			
Length—μ	130	160	
Height—μ	90	100	110
Internal height of equatorial layer—μ	200	160	180
Surface diameter of pillars on dorsal side over embryonic chambers—μ		60–100	100
Surface diameter of pillars on ventral side over embryonic chambers—μ	100	60–80	80–120
Surface diameter of pillars over equatorial chambers—μ	40–60	50–60	60

Microspheric form.—Test with a smaller initial end than that of the megalospheric form and with coarse surface pustules more or less uniformly scattered over the surface of the test.

The initial chambers are very small and all the available sections do not show these chambers clearly. There are three volutions of periembryonic chambers around the initial chambers with about 40 subquadrate chambers in the coils.

The shape and development of the equatorial chambers is similar to those of the megalospheric generation.

First appearance.—At a depth of 1660½–1671 feet in Bikini hole 2B.

Age reported elsewhere.—Aquitanian, Tertiary *e*.

Discussion.—Tan's illustrations of this species are not satisfactory. However, the specimens from the Bikini test hole possess in exact duplication all the structures which can be ascertained by a study of the illustrations of the type specimens.

Hanzawa considers that specimens of this type have features that distinguish them from the genus *Miogypsinoides* and so he offered the name *Miogypsinella* for species of this type. However, the writer believes that these types should be retained in the genus *Miogypsinoides*.

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PLATES 204–222

PLATE 204

FIGURES 1–6. *Operculina lucidisutura* Cole, n. sp. (p. 575).

1–3. External views, × 10; 2, cotype: USNM 547,427*a*; 1, Bikini hole 2B, at a depth of 946½–957 feet; 2, 3, Bikini hole 2A, at a depth of 925–935½ feet (core).

4, 5. Transverse sections, × 20; 5, cotype: USNM 547,427*b*; 4, Bikini hole 2B, at a depth of 946½–957 feet; 5, Bikini hole 2A, at a depth of 935½–946 feet (core).

6. Median section, × 20; cotype: USNM 547, 427*c*; Bikini hole 2A, at a depth of 946½–957 feet.

7–10, 16–18. *Operculinoides amplicuneata* Cole, n. sp. (p. 573).

7, 18. External views, × 10; 18, cotype, the specimen on the right: USNM 547,428*a*; 7, Bikini hole 2A, at a depth of 852–857 feet; 18, Bikini hole 2B, at a depth of 862½–873 feet.

8, 9, 17. Median sections; 8, × 10; 9, 17, × 20; 17, cotype: USNM 547,428*b*: 8, 9, Bikini hole 2A, at a depth of 852–857 feet; 17, Bikini hole 2B, at a depth of 826½–873 feet.

10, 16. Transverse sections, × 20; 16, cotype: USNM 547,428*c*; 10, Bikini hole 2A, at a depth of 852–857 feet; 16, Bikini hole 2B, at a depth of 862½–873 feet.

11–15. *Operculinoides rectilata* Cole, n. sp. (p. 575).

11, 13. External views, × 10; 13, cotype: USNM 547,429*a*; 11, Bikini hole 2B, at a depth of 736½–747 feet; 13, Bikini hole 2A, at a depth of 694–705 feet (core).

12, 14. Transverse sections, × 20, to illustrate the large umbonal plug and the parallel sides of the test; 14, cotype: USNM 547,429*b*; 12, Bikini hole 2B, at a depth of 736½–747 feet; 14, Bikini hole 2A, at a depth of 694–705 feet (core).

15. Median section, × 20; cotype: USNM 547,429*c*; Bikini hole 2A, at a depth of 694–705 feet (core).

19–23. *Operculinoides bikiniensis* Cole, n. sp. (p. 574).

19, 20. Transverse sections, × 20; 19, cotype: USNM 547,430*b*; Bikini hole 2B, at a depth of 1020–1100 feet.

21, 22. Median sections, × 20; 22, cotype: USNM 547,430*c*; Bikini hole 2B, at a depth of 1020–1100 feet.

23. External views, × 10; upper right specimen, cotype: USNM 547,430*a*; Bikini hole 2B, at a depth of 1020–1100 feet.

PLATE 205

Figures 1–4. *Calcarina spengleri* (Gmelin). (p. 584.)

1–3. External views, × 10, of uneroded specimens to illustrate peripheral spines; 1, Bikini hole 2A, at a depth of 195 feet; 2, from the reef flat on the windward side of Bikini island from water with a depth of 6 inches at low water, collected by John W. Wells; 3, from a reef off the village of Odomari, Okinawa-Shima, Ryukyu Islands, collected by A. R. Loeblich, Jr.; 2, 3, introduced for comparison.

4. External view, × 10, of an eroded specimen, the spines of which have been removed; specimens of this type were the commonest element of contamination in the samples; Bikini hole 2A, at a depth of 195 feet.

5–8. *Heterostegina suborbicularis* d'Orbigny. (p. 576.)

5. Median section, × 20, of a microspheric individual; Bikini hole 2A, at a depth of 535½–541 feet.

6, 7. Median sections, × 20, of megalospheric individuals; Bikini hole 2B, at a depth of 474–484½ feet.

8. Transverse section, × 20, of a microspheric individual; Bikini hole 2B, at a depth of 474–484½ feet.

9–14. *Cycloclypeus carpenteri* H. B. Brady. (p. 581.)

9. External view, × 10, to illustrate the even development of the surface pustules; Bikini hole 2A, at a depth of 841½–847 feet.

10, 14. Vertical sections, × 20; Bikini hole 2B; 10, at a depth of 715–726 feet; 14, at a depth of 852½–862 feet.

11–13. Equatorial sections; 11, × 40; 12, 13, × 20; 11, from Bikini hole 2B, at a depth of 852½–862 feet; 12, from Bikini hole 2A, at a depth of 673½–678 feet; 13, from Bikini hole 2B, at a depth of 736½–747 feet.

15–17. *Operculinoides rectilata* Cole, n. sp. (p. 575.)

15. Transverse section, × 20, of a microspheric individual to illustrate the flat, parallel sides of the test; Bikini hole 2A at a depth of 721–726 feet.

16. Median section, × 20, of a microspheric individual; Bikini hole 2B, at a depth of 736½–747 feet.

17. Median section, × 20, of a megalospheric individual; Bikini hole 2B, at a depth of 736½–747 feet.

PLATE 206

Figures 1, 2. *Spiroclypeus tidoenganensis* van der Vlerk. (p. 579).

1. Median section × 20, to demonstrate the very large embryonic chambers; Hikun on the Tabalong River, S. E. Borneo, USNM 545,010; originally identified by H. Douvillé as *S. pleurocentralis* (Carter); introduced for comparison with *S. margaritatus* (Schlumberger).
2. Transverse section, × 20, to demonstrate the very thick floors and roofs of the lateral chambers. A companion specimen to the one illustrated as figure 1.

3–9. *Heterostegina pusillumbonata* Cole, n. sp. (p. 576).

3–5. External views, × 10, to show ornamentation; 4, cotype, USNM 547,431*a*, Bikini hole 2B; 3, at a depth of 1923–1933½ feet; 4, 5, at a depth of 1891½–1902 feet.

6, 7. Transverse sections, × 20; 7, cotype: USNM 547,431*b*; Bikini hole 2B; 6, at a depth of 1923–1933½ feet; 7, at a depth of 1891½–1902 feet.

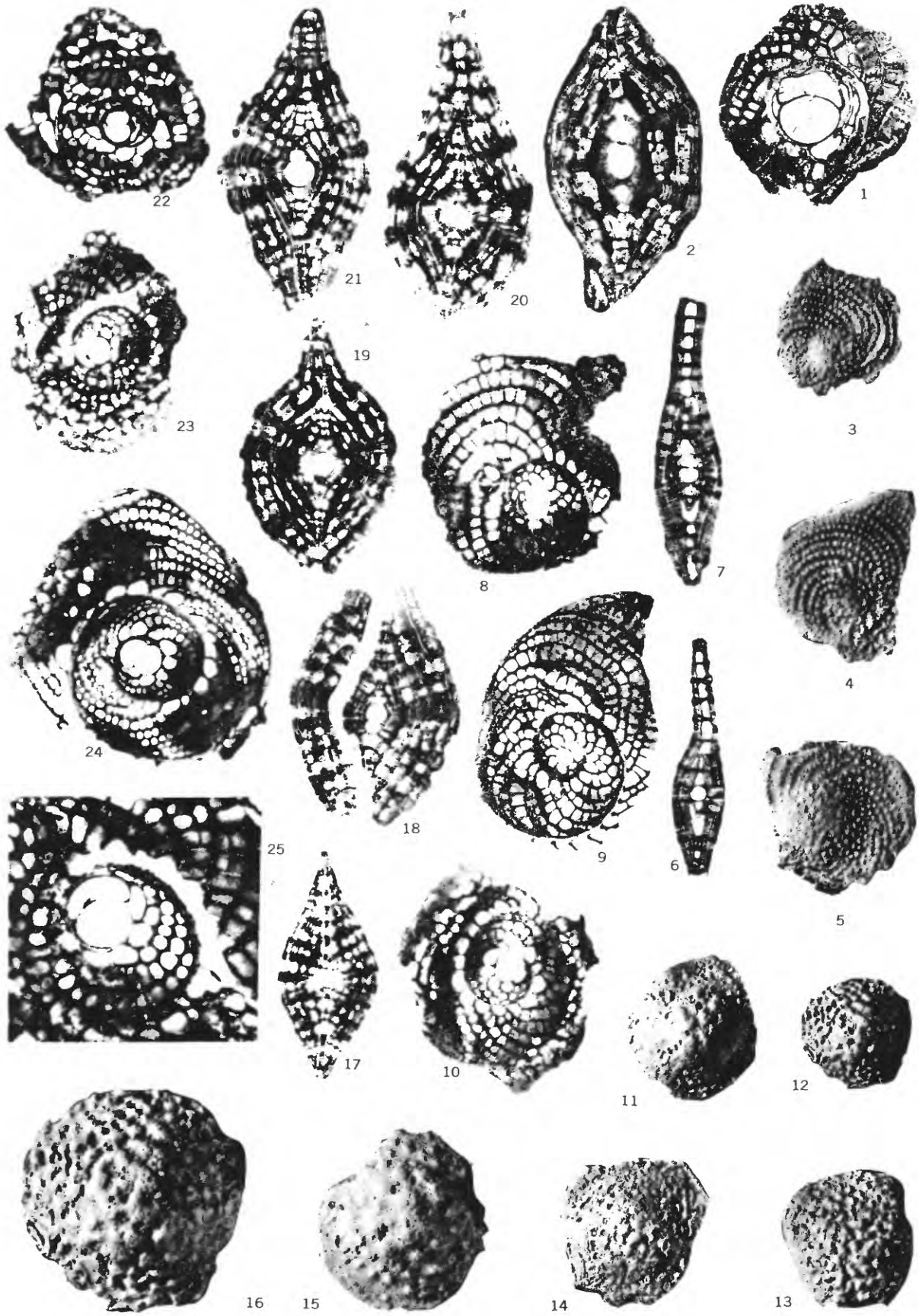
8, 9. Median sections, × 20; 9, cotype: USNM 547,431*c*; Bikini hole 2B; 8, at a depth of 1923–1933½ feet; 9, at a depth of 1891½–1902 feet.

10–25. *Spiroclypeus margaritatus* (Schlumberger). (p. 578.)

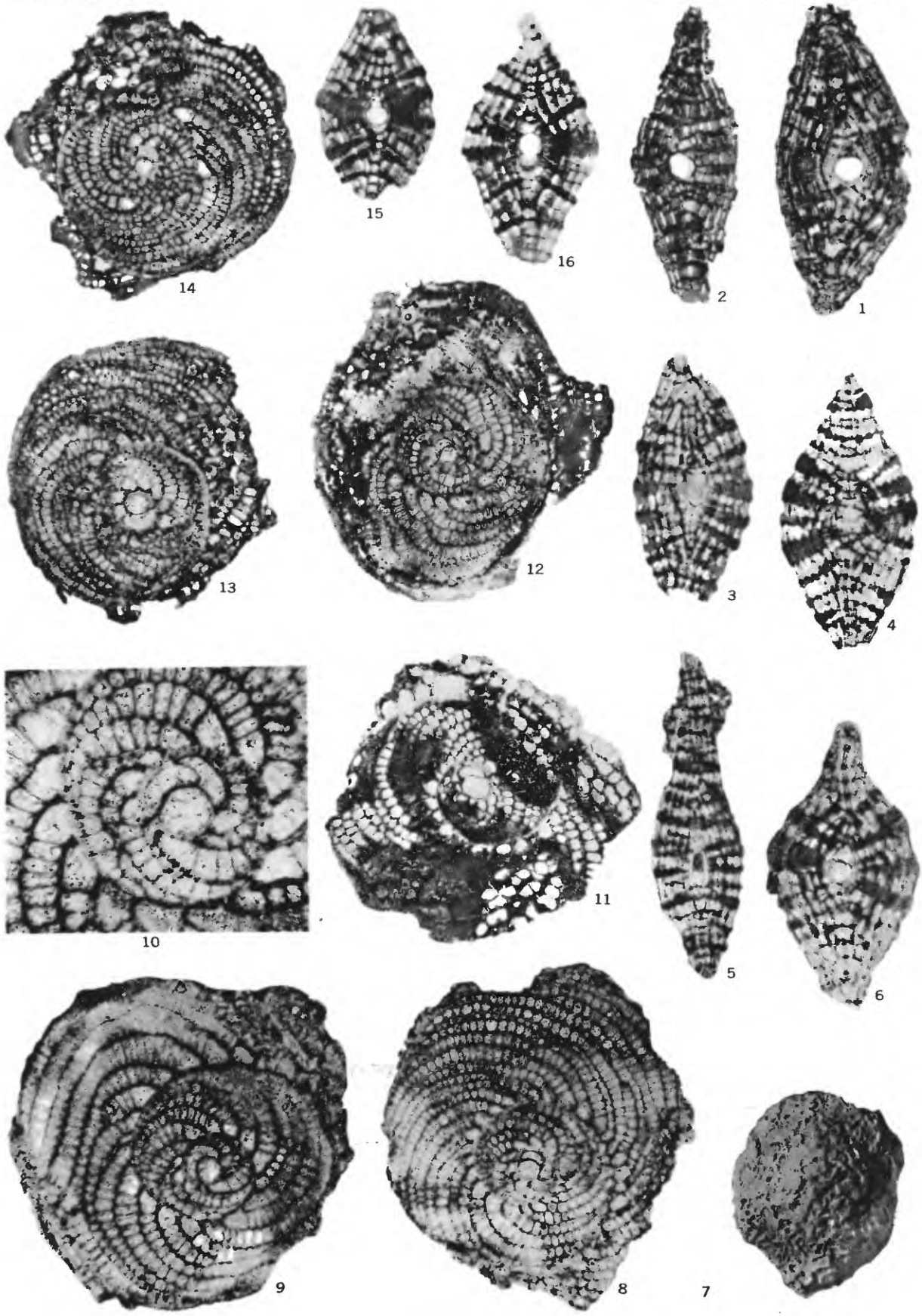
10, 22–25. Median sections to demonstrate the small operculine chamber that follows the embryonic chambers; 10, 22–24, × 20; 25 × 40; 25 an enlarged portion of figure 23; Bikini hole 2B; 10, 22, 24, at a depth of 1597½–1608 feet; 23, at a depth of 1639½–1650 feet.

11–16. External views to show the pustulate nature of the surface of the test; 11–15, × 10; 16, × 20; 16, is an enlargement of the specimen, figure 12; Bikini hole 2B; 11, 14, at a depth of 1660½–1671 feet; 12, 13, 15, 16, at a depth of 1597½–1608 feet.

17–21. Transverse sections, × 20, to demonstrate the variability in shape and the distribution of the heavy pillars; Bikini hole 2B; 17, 18, 21, at a depth of 1597½–1608 feet; 19, at a depth of 1639½–1650 feet; 20, at a depth of 1671–1681½ feet.



SPIROCLYPEUS AND *HETEROSTEGINA*



SPIROCLYPEUS

PLATE 207

Figures 1–14. *Spiroclypeus yabei* van der Vlerk. (p. 580)

1–6. Transverse sections, × 20, to demonstrate differences in inflation in various individuals; Bikini hole 2B; 1, at a depth of 1829½–1839 feet; 2, at a depth of 1755–1765½ feet; 3, at a depth of 1765½–1776 feet; 4–6, at a depth of 1786½–1797 feet.

7. External view, × 10; Bikini hole 2B, at a depth of 1671–1681½ feet.

8–14. Median sections to demonstrate the thick-walled embryonic apparatus, the large operculine chamber and the median chambers divided into chamberlets; 8, 9, 11–14, × 20; 10, × 40, represents a portion of the specimen illustrated as figure 9; Bikini hole 2B; 8–10, at a depth of 1786½–1797 feet; 11, at a depth of 1671–1681½ feet; 12, 13, at a depth of 1828½–1839 feet; 14, at a depth of 1755–1765½ feet.

15, 16. *Spiroclypeus margaritatus* (Schlumberger). (p. 578)

Transverse sections, × 20; Bikini hole 2B, at a depth of 1597½–1608 feet.

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PLATE 208

Figures 1–19. *Spiroclypeus leupolai* van der Vlerk. (p. 577)

1–5. External views; 1–4, × 10; 5, × 20; Bikini hole 2B; 1, 4, at a depth of 1597½–1608 feet; 2, 5, at a depth of 1650–1660½ feet; 3, at a depth of 1639½–1650 feet.

6. Transverse section, × 20, of USNM 545,009 from loc. 3, Tidoengsche Landen, East Borneo, introduced for comparison with the Bikini specimens.

7. Median section, × 20, of another specimen from the same locality as the specimen illustrated by figure 6.

8–15. Transverse sections, × 20, to illustrate the variation which occurs between different individuals; Bikini hole 2B; 8, at a depth of 1639½–1650 feet; 9, at a depth of 1660½–1671 feet; 10, 11, 14, 15, at a depth of 1597½–1608 feet; 12, at a depth of 1681½–1692 feet; 13, at a depth of 1671–1681½ feet.

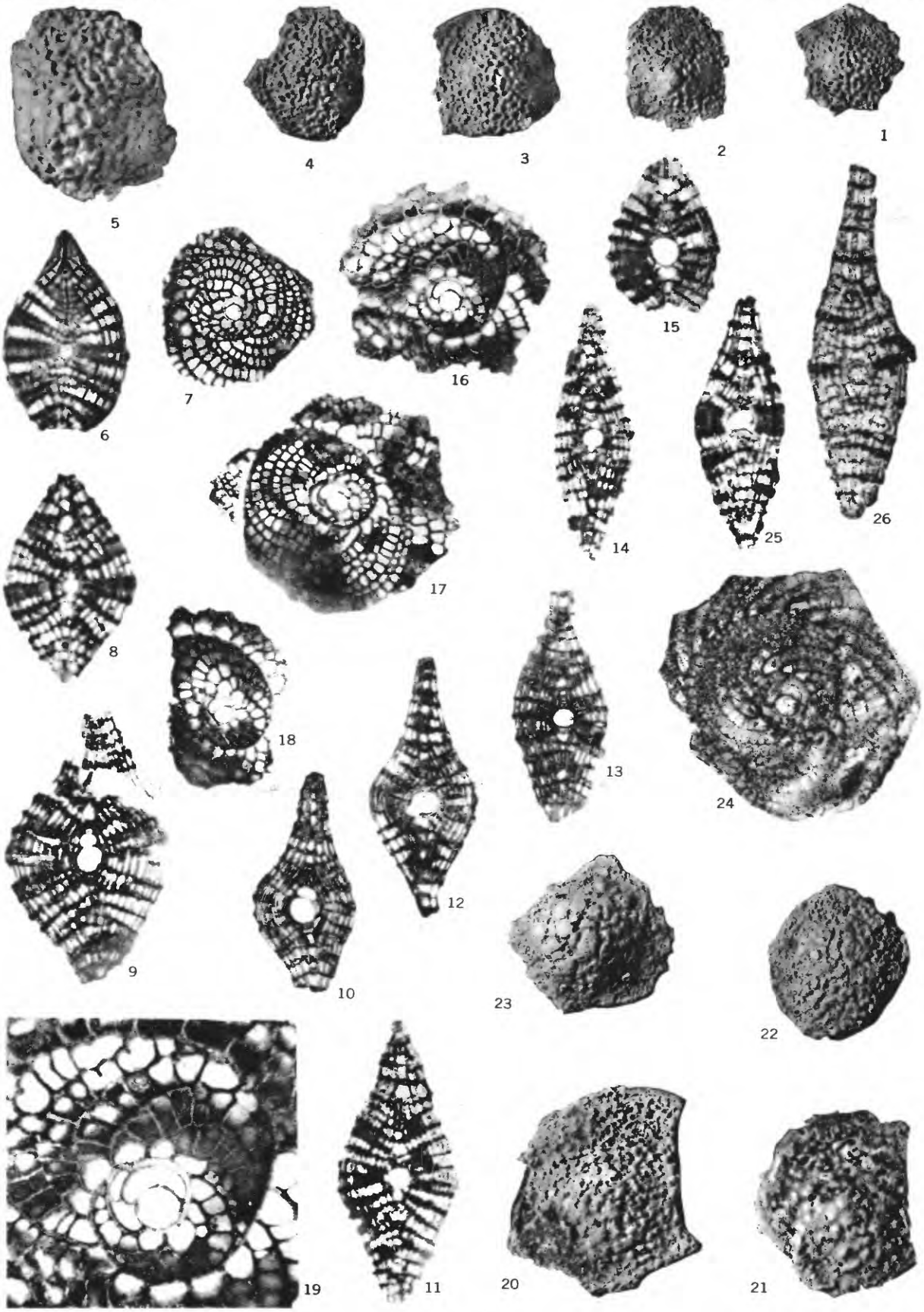
16–19. Median sections; 16–18, × 20; 19, × 40; 19, an enlargement of the initial chambers of the specimen represented by figure 16; note the extremely elongate operculine chamber in all of these specimens; Bikini hole 2B; 16, 18, 19, at a depth of 1681½–1692 feet; 17, at a depth of 1597½–1608 feet.

20–26. *Spiroclypeus yabei* van der Vlerk. (p. 580)

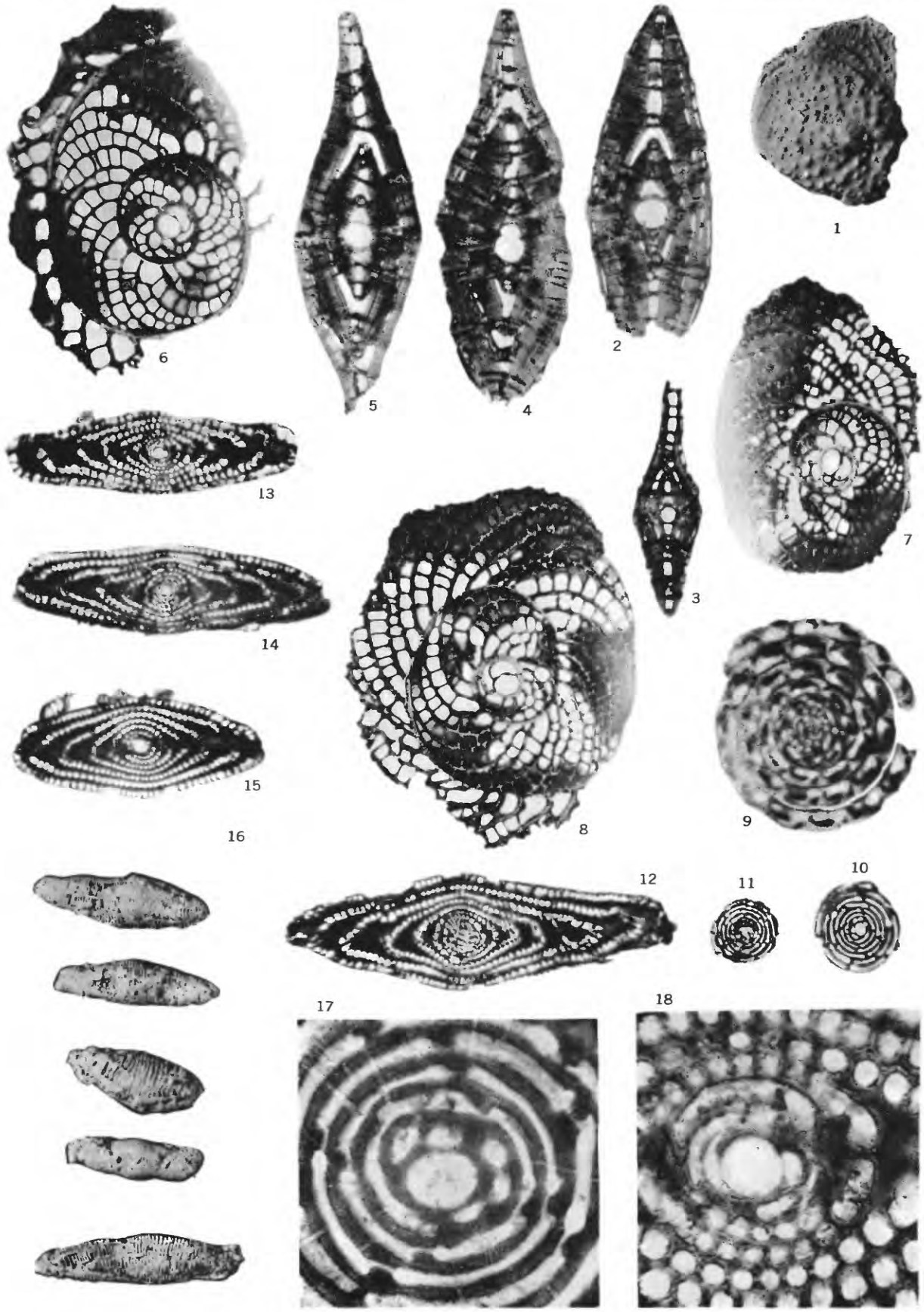
20–23. External views, × 10; 20, a compressed individual, the transverse section of which would resemble that shown as figure 26; 23, a strongly inflated individual with large surface pustules, the transverse section of which would resemble that shown as figure 6, plate 4; Bikini hole 2B; 20, 21, 23, at a depth of 1786½–1797 feet; 22, at a depth of 1755–1765½ feet.

24. Median section, × 20, illustrating the characteristic heavy outer wall of the embryonic chambers; Bikini hole 2B, at a depth of 1786½–1797 feet.

25, 26. Transverse sections, × 20; Bikini hole 2B; 25, at a depth of 1828½–1839 feet; 26, at a depth of 1786½–1797 feet.



SPIROCLYPEUS



HETEROSTEGINA, *FLOSCULINELLA*, AND *BORELIS*

PLATE 209

Figures 1–8. *Heterostegina nigripustula* Cole, n. sp. (p. 575)

1. External view, × 10; cotype, USNM 547,432*a*; Bikini hole 2B, at a depth of 1986–1996½ feet.

2–5. Transverse sections, × 20, to show the open spaces which resemble lateral chambers and the variable development in different individuals; 4, cotype, USNM 547,432*b*; Bikini hole 2B; 2, at a depth of 1818–1828½ feet; 3–5, at a depth of 1860–1870½ feet.

6–8. Median sections, × 20; 6, cotype, USNM 547,432*c*; Bikini well 2B, at a depth of 1860–1870½ feet.

9. *Flosculinella globulosa* L. Rutten (p. 584)

Transverse section, × 40; Bikini hole 2B, at a depth of 2133–2143½ feet.

10–18. *Borelis schlumbergeri* (Reichel). (p. 583)

10, 11. Transverse sections, × 40; Bikini hole 2B, at a depth of 925–935½ feet (core).

12–15. Axial sections, × 40; Bikini hole 2B, at a depth of 925–935½ feet (core).

16. External views, × 20; Bikini hole 2B, at a depth of 925–935½ feet (core).

17. Enlargement, × 225, of the central area of the specimen illustrated as figure 10.

18. Enlargement, × 225, of the central area of the specimen illustrated as figure 13.

PLATE 210

Figures 1–5. *Halkyardia bikiniensis* Cole, n. sp. (p. 584)

1. Axial section, × 40, to illustrate the embryonic chambers and the middle layer of chambers covered by coarsely porous zones on each side; cotype, USNM 547,433*b*; Bikini hole 2B, at a depth of 2380½–2391 feet.
2. Transverse section, × 40, just below the apex to expose the embryonic chambers; cotype, USNM 547,433*c*; Bikini hole 2B, at a depth of 2401½–2412 feet.
3. Transverse section, × 40, slightly below the embryonic chambers; Bikini hole 2B, at a depth of 2401½–2412 feet.
4. Transverse section, × 225, to illustrate the bilocular embryonic chambers and the chambers of the median zone; this is an enlargement of the central area of the specimen illustrated as figure 2; Bikini hole 2B, at a depth of 2401½–2412 feet.
5. External views, × 20, of four specimens; the specimens on the left show the dorsal view and those on the right illustrate the ventral view; cotype, upper right specimen, USNM 547,433*a*; Bikini hole 2B, at a depth of 2401½–2412 feet.

6–9. *Austrotrillina howchini* (Schlumberger). (p. 573)

6. External views, × 20, of slightly eroded specimens which show the alveolate, thick walls; Bikini hole 2B, at a depth of 1944–1954½ feet.
7. Transverse section, × 40, which illustrates the thick alveolate outer walls and the triloculine arrangement of the chambers; Bikini hole 2B, at a depth of 2038½–2048 feet.

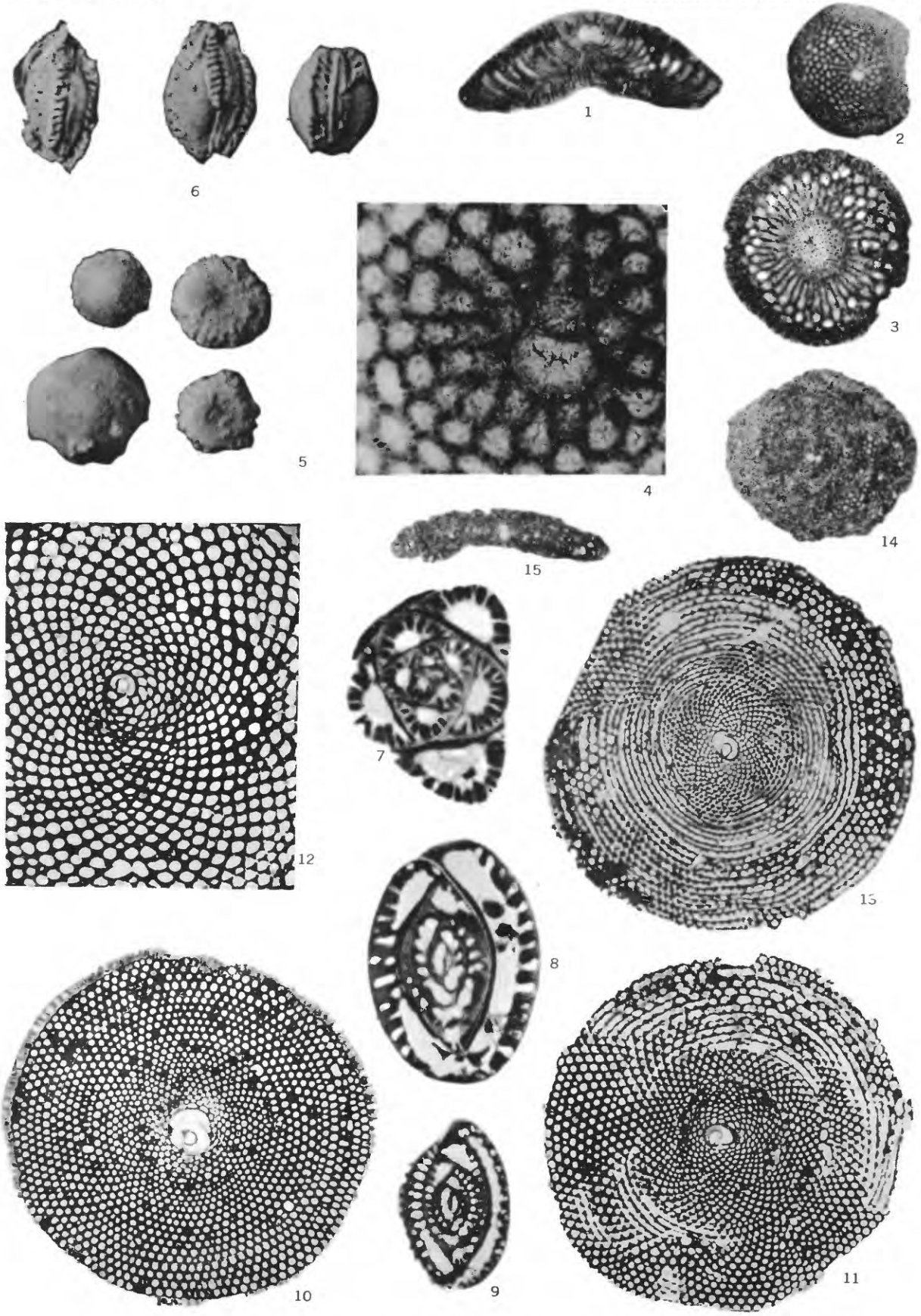
8, 9. Axial sections; 8, × 40; 9, × 20; Bikini hole 2B; 8, at a depth of 2049–2059½ feet; 9, at a depth of 1954½–1965 feet.

10–13. *Marginopora vertebralis* Quoy and Gaimard (p. 582)

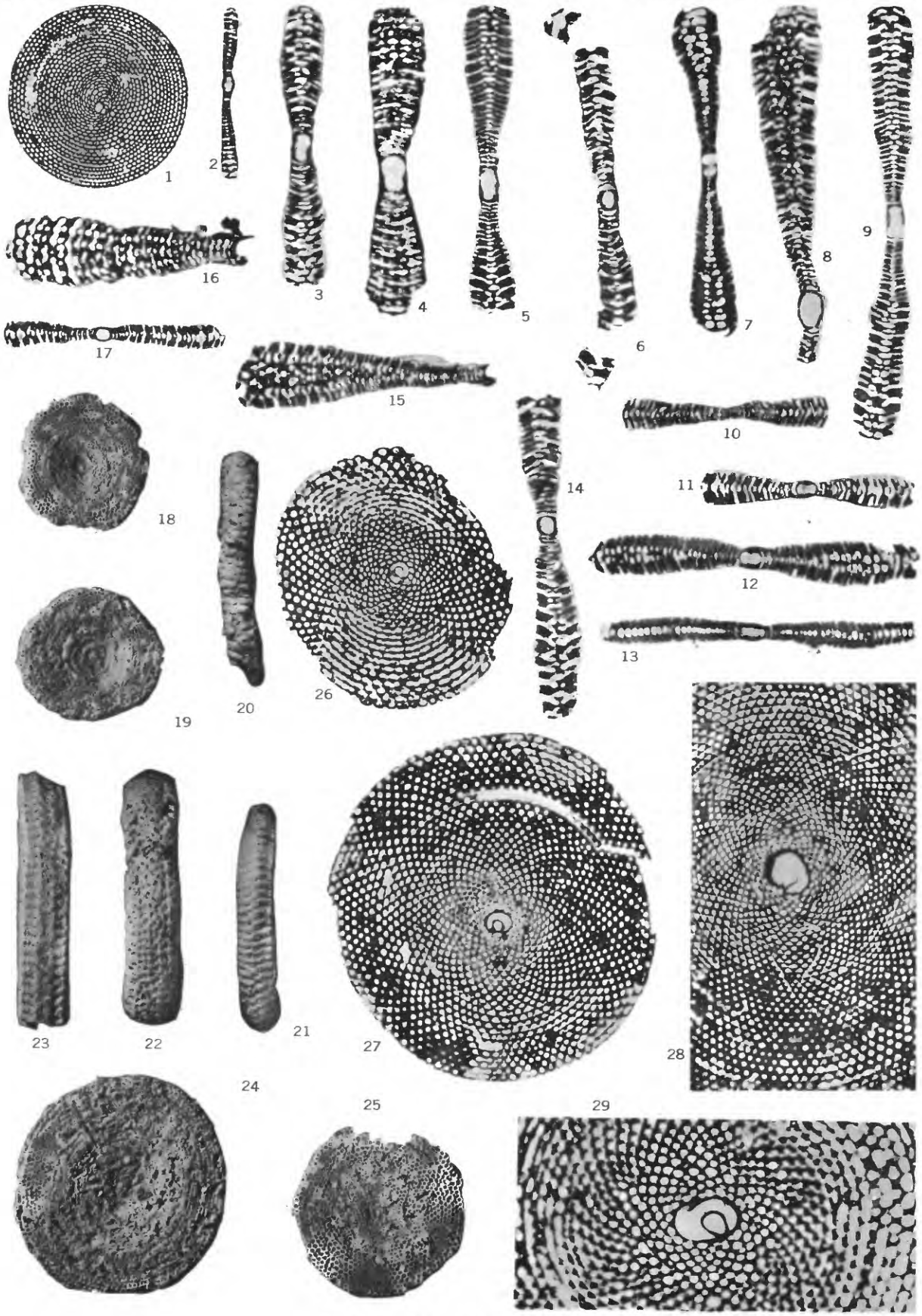
10–13. Equatorial sections; 10, 11, 13, × 20; 12, × 40; 10, from Materno Island, Ibo Bay, Portuguese East Africa; 11, from the reef flat on the windward side of Bikini island from water with a depth of 6 inches at low water, collected by John W. Wells; 12, 13, Bikini hole 2A, at a depth of 195 feet.

14, 15. *Gypsina vesicularis* (Parker and Jones). (p. 585)

14. Equatorial section, × 20; Bikini hole 2B, at a depth of 2545½–2556 feet.
15. Transverse section, × 20; Bikini hole 2B, at a depth of 2545½–2556 feet.



HALKYARDIA, AUSTROTRILLINA, MARGINOPORA, AND *GYPSINA*



SORITES AND *MARGINOPORA*

PLATE 211

Figures 1, 2. *Sorites marginalis* (Lamarck). (p. 582)

1. Equatorial section to illustrate the planispirally coiled chambers between the embryonic apparatus and the annular chambers, × 20; *Albatross* station D5133.
2. Vertical section, × 20; *Albatross* station D5133.

3–29. *Marginopora vertebralis* Quoy and Gaimard. (p. 582)

3–17. Vertical sections, × 20; 6, 10, 11, 13, 17, "simple type" with one pore; 3, 5, 7, 9, 12, 14, "duplex type" with one pore in the initial annular chambers and two pores in the later annular chambers; 4, 8, 15, 16, "complex type" with multiple pores in the later annular chambers; 3, 6, 14, from the reef flat on the windward side of Bikini island from water with a depth of 6 inches at low water, collected by John W. Wells; 4, 11, 16, 17, from Bikini hole 2A, at a depth of 925–935½ feet (core); 7, 13, from Bikini hole 2A, at a depth of 195 feet; 12, from Bikini hole 2A, at a depth of 904–905 feet (probably caving); 5, 9, from Materno Island, Ibo Bay, Portuguese East Africa; 8, 10, 15, from a reef off the village of Odomari, Okinawa-Shima, Ryukyu Islands, collected by A. R. Loeblich, Jr.

18, 19. External views, × 10; Bikini hole 2A, at a depth of 195 feet.

20–23. Edge views to illustrate apertures, × 20; 20, "simple type" with one aperture; 21, 23, "duplex type" with double apertures; 22, "complex type" with numerous apertures; 20–22, from Bikini hole 2A, at a depth of 925–935½ feet (core); 23, from Materno Island, Ibo Bay, Portuguese East Africa.

24, 25. External views, × 10; Bikini hole 2A, at a depth of 925–935½ feet (core).

26–29. Equatorial sections, × 20; 26–28, from Bikini hole 2A, at a depth of 925–935½ feet (core); 29, from Bikini hole 2A, at a depth of 195 feet (probably caving).

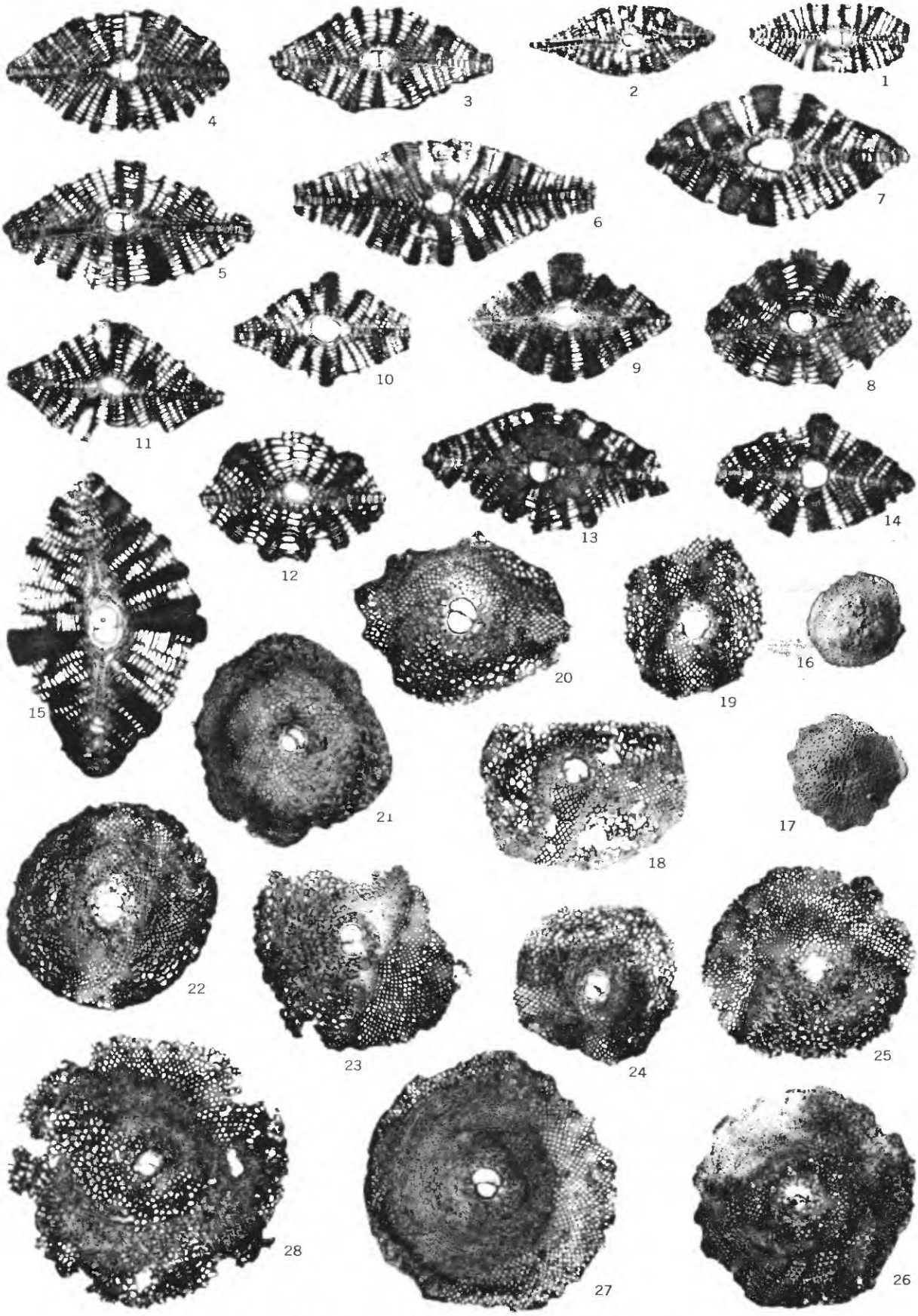
PLATE 212

Figures 1–28. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. (p. 589)

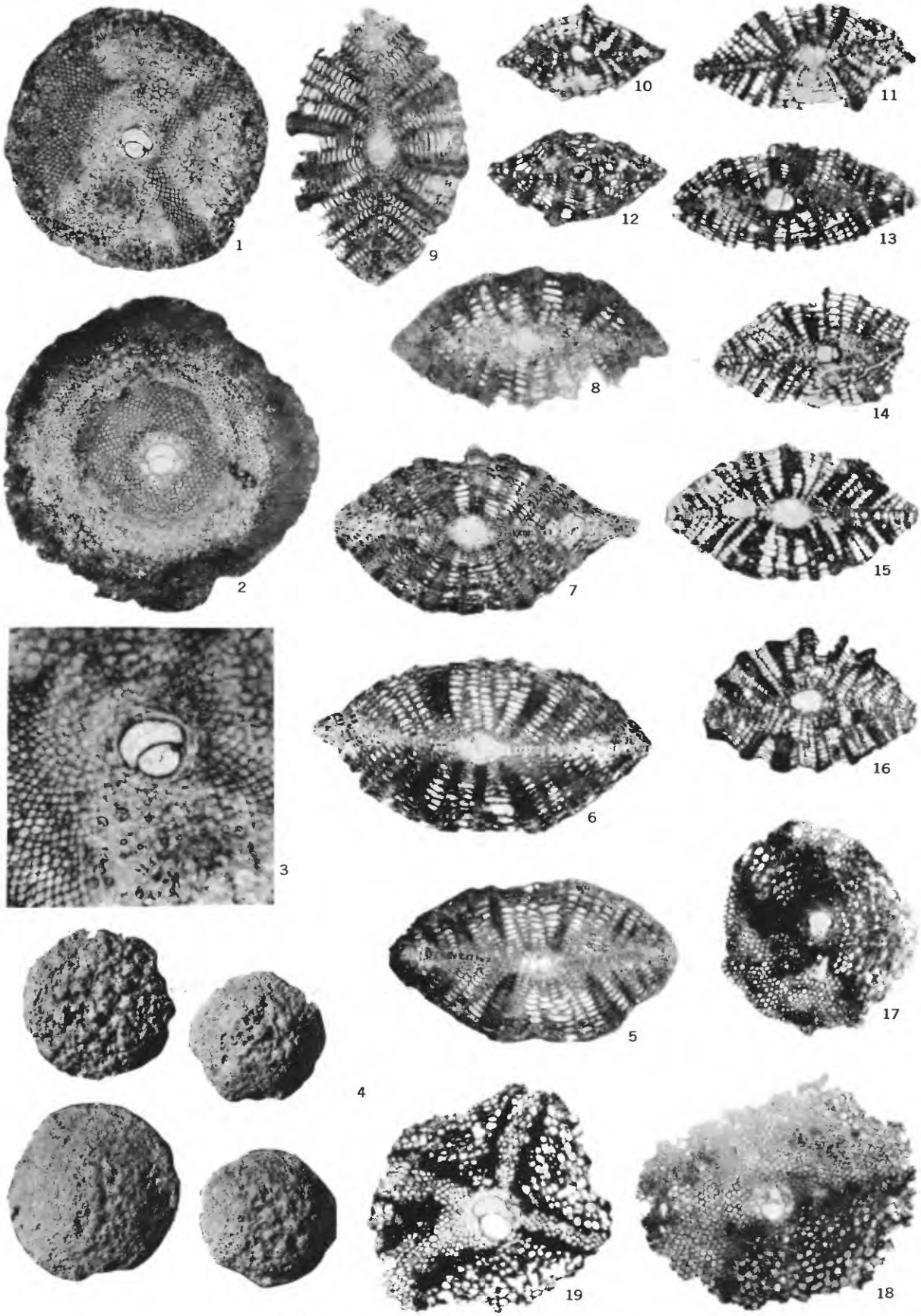
1–15. Vertical sections, × 20, to illustrate the gradation from small individuals with extremely weak pillars (typical *L. parva*) to robust individuals with strong pillars (*L. atjehensis*); Bikini hole 2B; 1, 2, at a depth of 1167–1177½ feet; 3, at a depth of 1744½–1755 feet; 4, at a depth of 1765½–1776 feet; 5, at a depth of 1755–1765½ feet; 6, at a depth of 1440–1450 feet; 7, at a depth of 1807½–1818 feet; 8, at a depth of 2049–2059½ feet; 9, at a depth of 1776–1786½ feet; 10, 12, 14, at a depth of 1818–1828½ feet; 11, at a depth of 1650–1660½ feet; 13, at a depth of 2017½–2028 feet; 15, at a depth of 1986–1996½ feet.

16, 17. External views, × 10, to show a specimen with very small papillae (typical *L. parva*) and another of intermediate character between *L. parva* and *L. atjehensis* with an apical crown of small papillae; Bikini hole 2B; 16, at a depth of 1650–1660½ feet; 17, at a depth of 1167–1177½ feet.

18–28. Equatorial sections, × 20, to illustrate the embryonic apparatus and the very regular diamond-shaped equatorial chambers; Bikini hole 2B; 18, at a depth of 1167–1177½ feet; 19, 20, 24, at a depth of 1818–1828½ feet; 21, at a depth of 1293–1303½ feet; 22, at a depth of 1797–1807½ feet; 23, at a depth of 1765½–1776 feet; 25, at a depth of 1744½–1755 feet; 26, 28, at a depth of 1440–1450 feet; 27, at a depth of 2017½–2028 feet.



LEPIDOCYCLINA (NEPHROLEPIDINA)



LEPIDOCYCLINA (NEPHROLEPIDINA)

PLATE 213

Figures 1–9. *Lepidocyclina* (*Nephrolepidina*) *verrucosa* Scheffen. (p. 593)

1–3. Equatorial sections to illustrate the embryonic apparatus and equatorial chambers; 1, 2, × 20; 3, × 40; Bikini hole 2B, at a depth of 1303½–1314 feet.

4. External views of 4 specimens to show the size and distribution of the papillae, × 10; Bikini hole 2B, at a depth of 1303½–1314 feet.

5–9. Vertical sections × 20; Bikini hole 2B, at a depth of 1303½–1314 feet.

10–19. *Lepidocyclina* (*Nephrolepidina*) *cubiculirhomboidea* Cole, n. sp. (p. 587)

10–16. Vertical sections, × 20; 11, cotype, USNM 547,434*a*; 10–14, Bikini hole 2B, at a depth of 1398–1408½ feet; 15, Bikini hole 2B, at a depth of 1408½–1419 feet; 16, Bikini hole 2B, at a depth of 1818–1828½ feet.

17–19. Equatorial sections, × 20; 19, cotype, USNM 547,434*a*; Bikini hole 2B, at a depth of 1398–1408½ feet.

PLATE 214

FIGURES 1–8. *Lepidocyclina (Nephrolepidina) bikiniensis* Cole, n. sp. (p. 586)

1–3. Vertical sections, × 20; 1, a section which encountered some of the apical papillae; 2, 3, sections which miss the apical papillae; 2, cotype, USNM 547,435*b*; 1, Bikini hole 2B, at a depth of 1818–1828½ feet; 2, 3, Bikini hole 2B, at a depth of 1671–1681½ feet.

4–7. Equatorial sections; 4, 5, 7, × 20; 6, × 40; 6, portion of the specimen illustrated by fig. 5, enlarged to show the shape of the equatorial chambers; 5, cotype, USNM 547,435*c*; 4, Bikini hole 2B, at a depth of 1818–1828½ feet. 5–7, Bikini hole 2B, at a depth of 1671–1681½ feet.

8. External views of 4 specimens to show the apical group of papillae, × 10; specimen in the upper left corner, cotype, USNM 547,435*a*; Bikini hole 2B, at a depth of 1671–1681½ feet.

9, 10. *Lepidocyclina (Nephrolepidina) angulosa* Provale. (p. 586)

9. Portion of an equatorial section, × 40, to illustrate the embryonic apparatus and the elongate, spatulate equatorial chambers, introduced for comparison with *L. (N.) bikiniensis*; station 34, Vanua Mbalavu, Lau Islands, Fiji.

10. Portion of an equatorial section, × 40, to demonstrate the elongate, spatulate equatorial chambers which apparently characterize this species; Poeloe Balamlangan, Cenoorden Borneo, from a collection presented by Mrs. Helen Jeanne Plummer.

11–14, 18. *Lepidocyclina (Nephrolepidina) bikiniensis unipilaris* Cole, n. var. (p. 587)

11, 12. Vertical sections, × 20, to show the single, strong, centrally placed pillars on each side of the embryonic apparatus; 12, cotype, USNM 547,436*b*; Bikini hole 2B, at a depth of 1534½–1545 feet.

13, 18. Equatorial sections, × 20, to demonstrate the embryonic chambers and the equatorial chambers; 13, cotype, USNM 547,436*c*; Bikini hole 2B, at a depth of 1534½–1545 feet.

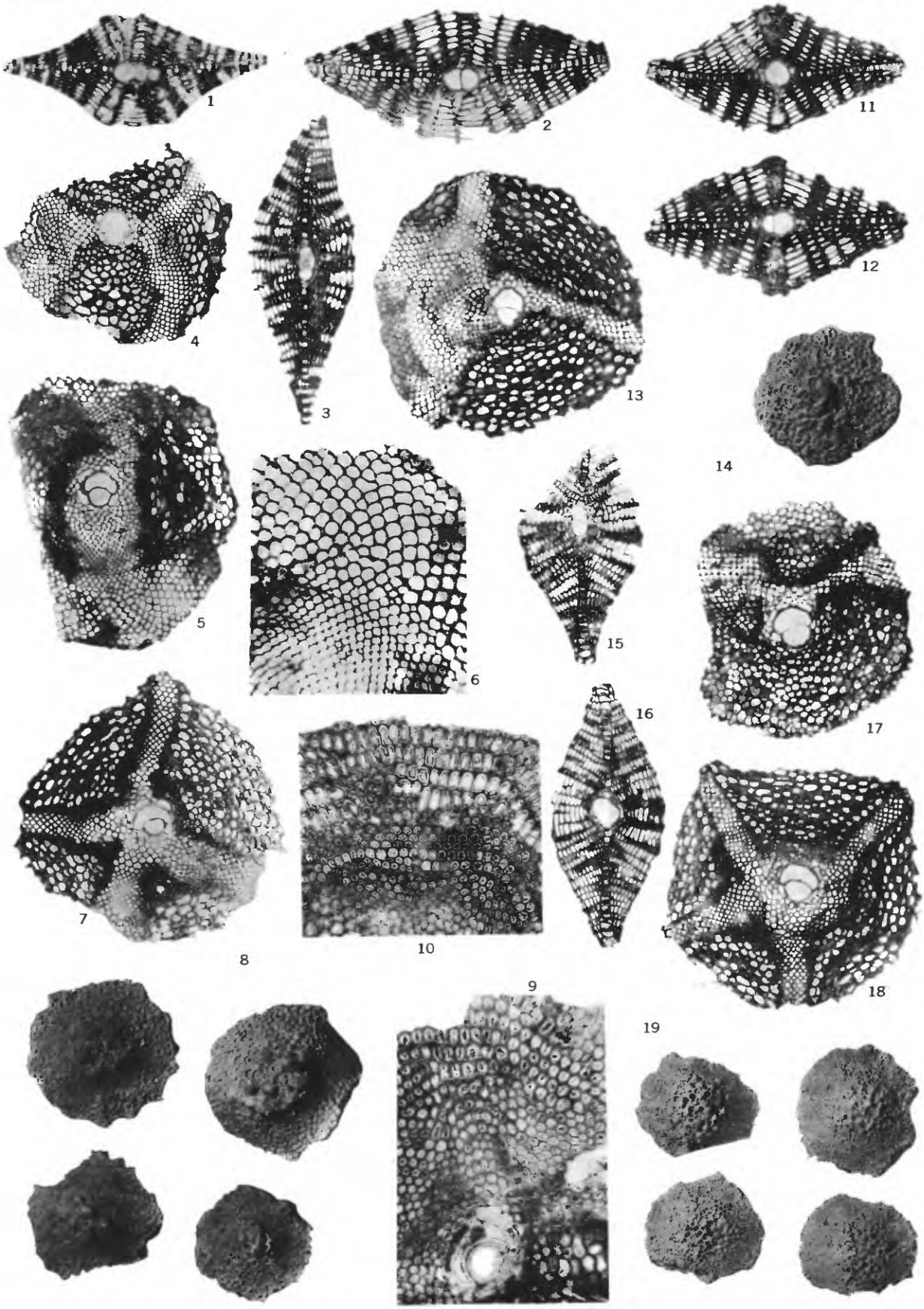
14. External view, × 10, to show the single well developed papilla; cotype, USNM 547,436*a*; Bikini hole 2B, at a depth of 1534½–1545 feet.

15–17, 19. *Lepidocyclina (Nephrolepidina) pumilipapilla* Cole, n. sp. (p. 592)

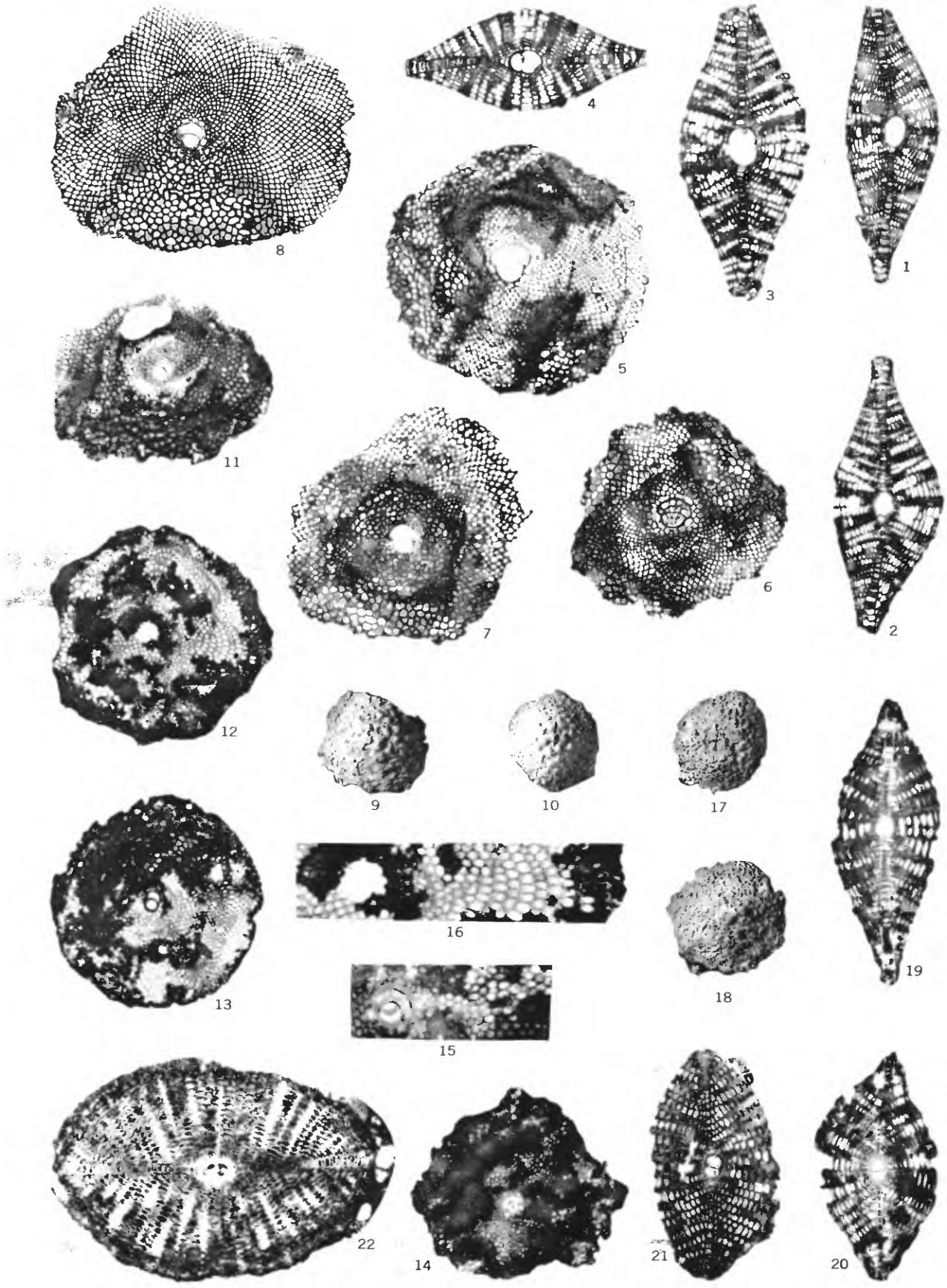
15, 16. Vertical sections, × 20, to show the large, open lateral chambers and the rapid expansion of the equatorial layer at the periphery of the test; 16, cotype, USNM 547, 437*b*; Bikini hole 2B, at a depth of 1828½–1839 feet.

17. Equatorial section, × 20, to show the embryonic apparatus and the diamond-shaped equatorial chambers; cotype, USNM 547, 437*c*; Bikini hole 2B, at a depth of 1828½–1839 feet.

19. External views, × 10, of 4 specimens; the specimen in the upper right corner, cotype, USNM 547, 437*a*; Bikini hole 2B, at a depth of 1828½–1839 feet.



LEPIDOCYCLINA (NEPHROLEPIDINA)



LEPIDOCYCLINA (NEPHROLEPIDINA) AND *LEPIDOCYCLINA (EULEPIDINA)*

PLATE 215

Figures 1–8. *Lepidocyclina* (*Nephrolepidina*) *pumilipapilla* Cole, n. sp. (p. 592).

1–4. Vertical sections, ×20; Bikini hole 2B; 1, 2, at a depth of 1702½–1713 feet; 3, 4, at a depth of 1818–1828½ feet.

5–8. Equatorial sections, ×20; Bikini hole 2B; 5, 6, at a depth of 1818–1828½ feet; 7, at a depth of 1828½–1839 feet; 8, at a depth of 1702½–1713 feet.

9, 10. *Lepidocyclina* (*Eulepidina*) *abdopustula* Cole, n. sp. (p. 594).

9, 10. External views, ×5, to show the apical crown of well developed papillae; 10, cotype, USNM 547,438*a*; Bikini hole 2B; 9, at a depth of 2070–2080½ feet; 10, at a depth of 2112–2122½ feet.

11–21. *Lepidocyclina* (*Nephrolepidina*) *orientalis* van der Vlerk (p. 588).

11–16. Equatorial sections; 11–14, ×20; 15, 16, ×40; the variable shape of the embryonic chambers is illustrated and the elongate, spatulate equatorial chambers; 15, an enlargement of a portion of the specimen represented by figure 14; 16, an enlargement of a portion of the specimen represented by figure 12; 11–16, Bikini hole 2A, at a depth of 1082½–1088 feet.

17, 18. External views, ×10; Bikini hole 2A, at a depth of 1082½–1088 feet.

19–21. Vertical sections, ×20; Bikini hole 2A, at a depth of 1082½–1088 feet.

22. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis inornata* L. Rutten (p. 593).

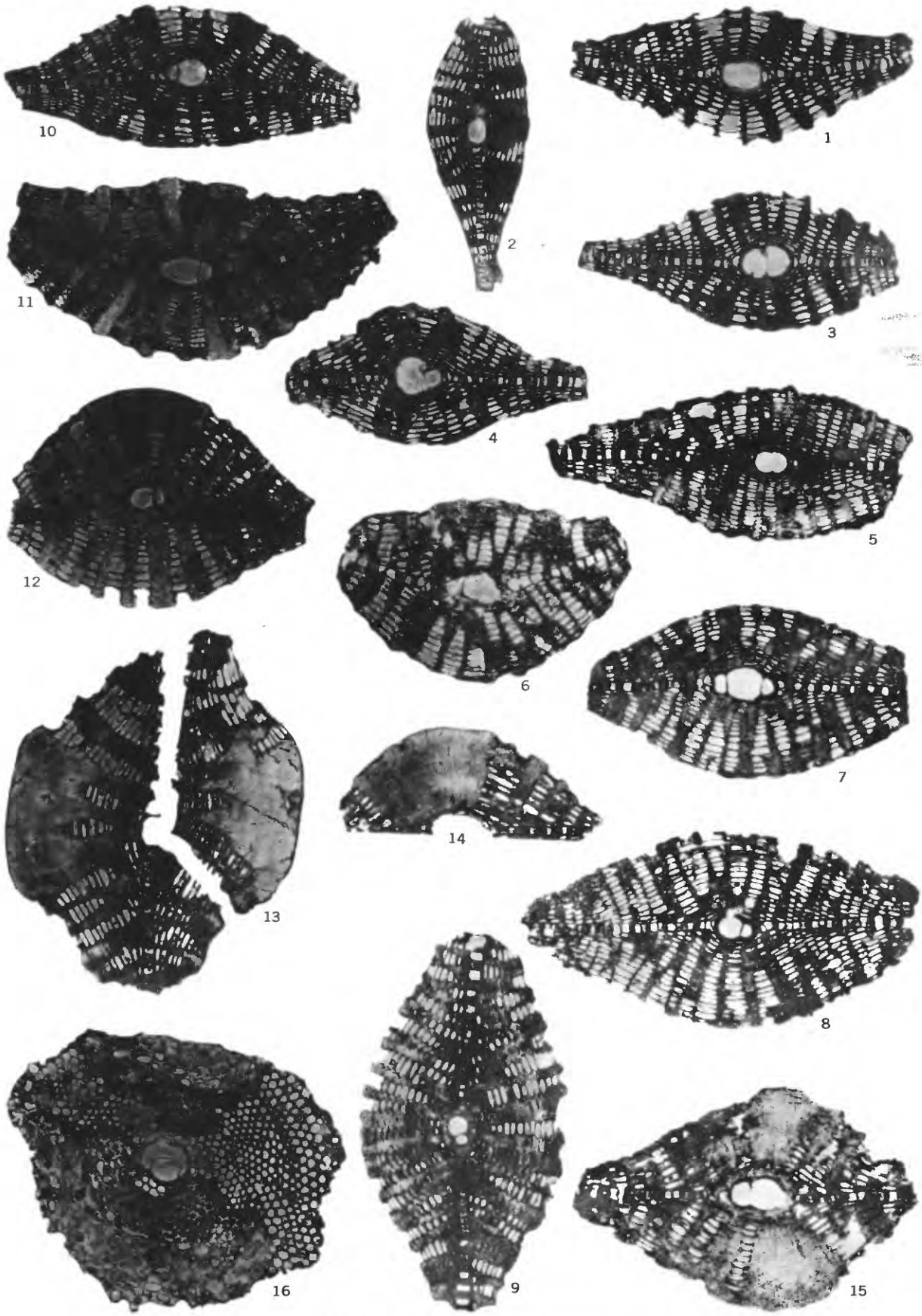
Vertical section, ×20, to show the thick-walled embryonic chambers and the lateral chambers arranged in regular tiers without pillars; the appearance of pillars is caused by a thickening of the ends of the lateral chambers; Bikini hole 2A, at a depth of 1082½–1088 feet.

PLATE 216

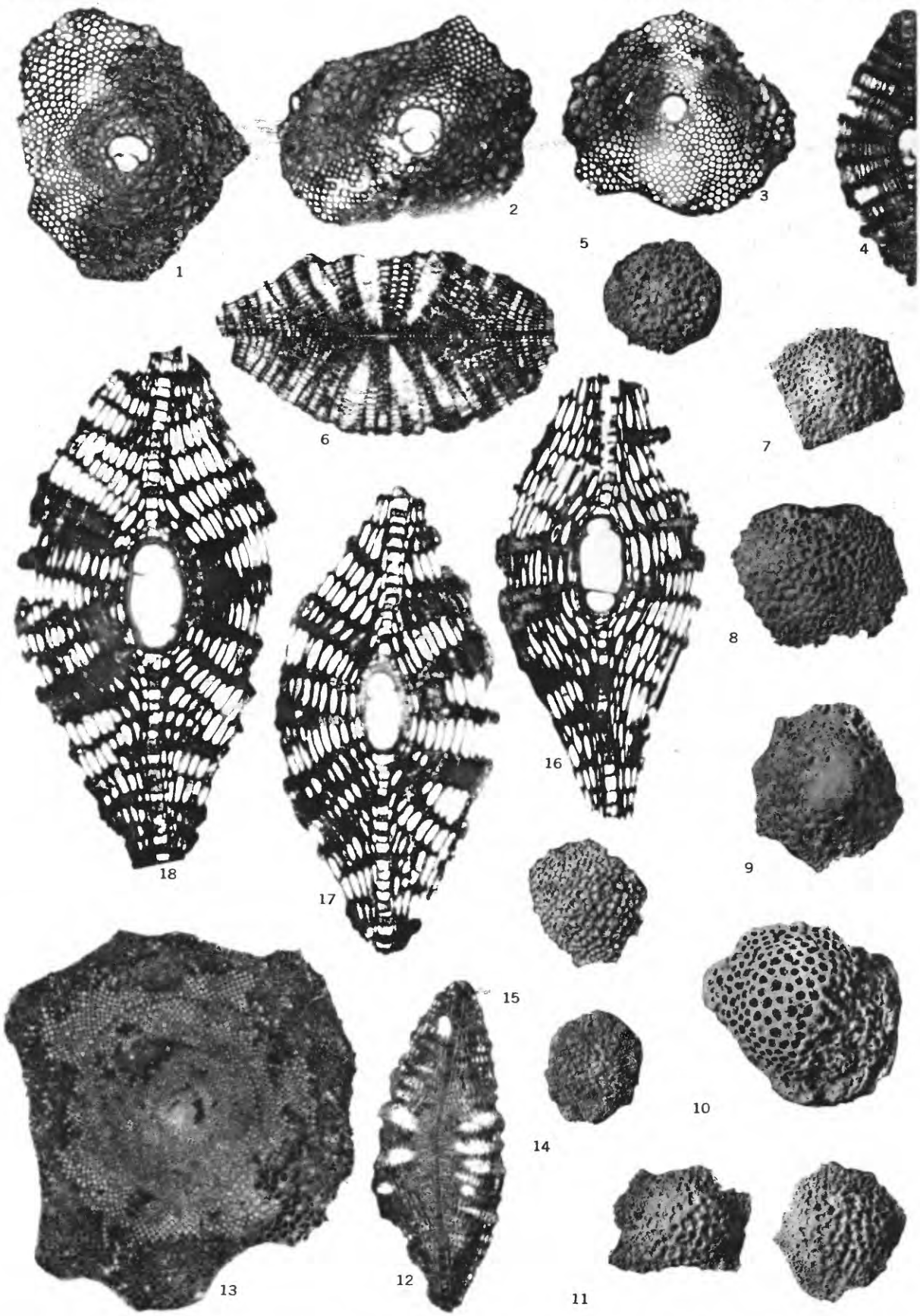
Figures 1–16. *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger (p. 594).

1–15. Vertical sections, ×20, of specimens to illustrate the gradation from individuals with lateral chambers in regular tiers without pillars to those in which the side walls of the lateral chambers are so thickened that their mass occupies a large portion of the apical areas of the tests; 5, 7, 8, individuals that would be classified as typical *L. formosa;* 15, an individual that would have been identified as *L. stereolata;* Bikini hole 2B; 1, 3, 4, at a depth of 2154–2164½ feet; 2, at a depth of 2164–2175 feet; 5, 8, at a depth of 1923–1933½ feet; 6, 11, at a depth of 1723½–1734 feet; 7, 15, at a depth of 1986–1996½ feet; 9, at a depth of 1975½–1986 feet; 10, at a depth of 2214½–2225 feet; 12–14, at a depth of 2038½–2049 feet.

16. Equatorial section, ×20, of the type of individual represented by figure 8; Bikini hole 2B, at a depth of 1923–1933½ feet.



LEPIDOCYCLINA (EULEPIDINA)



LEPIDOCYCLINA (*NEPHROLEPIDINA*) AND *LEPIDOCYCLINA* (*EULEPIDINA*)

PLATE 217

FIGURES 1–5. *Lepidocyclina* (*Nephrolepidina*) *augusticamera* Cole, n. sp. (p. 585)

1–3. Equatorial sections, × 20, to illustrate the nephrolepidine embryonic chambers and the short, spatulate equatorial chambers; 1, cotype, USNM 547,439*b*; Bikini hole 2B; 1, at a depth of 2154–2164½ feet; 2, at a depth of 2164½–2175 feet; 3, at a depth of 1933½–1949 feet.

4. Vertical section, × 20; this specimen was ground to the equatorial plane to ascertain the characters of this zone; cotype, USNM 547, 439*c*; Bikini hole 2B, at a depth of 2164½–2175 feet.

5. External view, × 10; cotype, USNM 547,439*a*; Bikini hole 2B, at a depth of 2154–2164½ feet.

6. *Lepidocyclina flexuosa* L. Rutten. (p. 598)

Vertical section, × 20, of a microspheric individual; Bikini hole 2B, at a depth of 1587–1597½ feet.

7, 8. *Lepidocyclina* (*Eulepidina*) *planata* Oppenoorth. (p. 597)

7, 8. External views to show the large surface pits and complete lack of papillae; 7, × 5; 8, × 10; Bikini hole 2B; 7, at a depth of 1996½–2007 feet; 8, at a depth of 2143½–2154 feet.

9–11. *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger. (p. 594)

9–11. External views, × 10; 9, this type of specimen would have a vertical section similar to the ones illustrated as figures 13–15 on plate 13; 10, this type of specimen would have a vertical section similar to the ones illustrated as figures 5–8 on plate 13; 11, this type of specimen would have a vertical section similar to those illustrated as figures 1–3 on plate 13; Bikini hole 2B; 9, at a depth of 1986–1996½ feet; 10, at a depth of 1923–1933½ feet; 11, at a depth of 2143½–2154 feet.

12–14. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. (p. 589)

12. Vertical section, × 20, of a microspheric specimen; Bikini hole 2B, at a depth of 2070–2080½ feet.

13. Equatorial section, × 20, of a microspheric individual to show the rhombic equatorial chambers; Bikini hole 2B, at a depth of 1996½–2007 feet.

14. External view, × 5, of a microspheric specimen to show the well-developed papillae; Bikini hole 2B, at a depth of 1839–1849½ feet.

15–18. *Lepidocyclina* (*Eulepidina*) *gibbosa* Yabe. (p. 597)

15. External view, × 5, to illustrate the large surface pits and the thick intervening walls; Bikini hole 2B, at a depth of 1881–1891½ feet.

16–18. Vertical sections, × 20, to illustrate the very large, open lateral chambers and the fibrous, thick-walled embryonic chambers; Bikini hole 2B; 16, at a depth of 1881–1891½ feet; 17, at a depth of 1923–1933½ feet; 18, at a depth of 1891½–1902 feet.

PLATE 218

FIGURES 1, 3, 4. *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger. (p. 594).

1. Median section, × 20, of a specimen similar to the one illustrated as figure 12, plate 13; Bikini hole 2B, at a depth of 1986–1996½ feet.

3, 4. Median sections, × 20, of specimens similar to the one illustrated as figure 1, plate 13; Bikini hole 2B; 3, at a depth of 2154–2164½ feet; 4, at a depth of 2246–2256½ feet.

2. *Lepidocyclina* (*Eulepidina*) *gibbosa* Yabe. (p. 597).
Natural equatorial section, × 10; Bikini hole 2B, at a depth of 1881–1891½ feet.

5, 6. *Lepidocyclina* (*Eulepidina*) *planata* Oppenoorth. (p. 597).

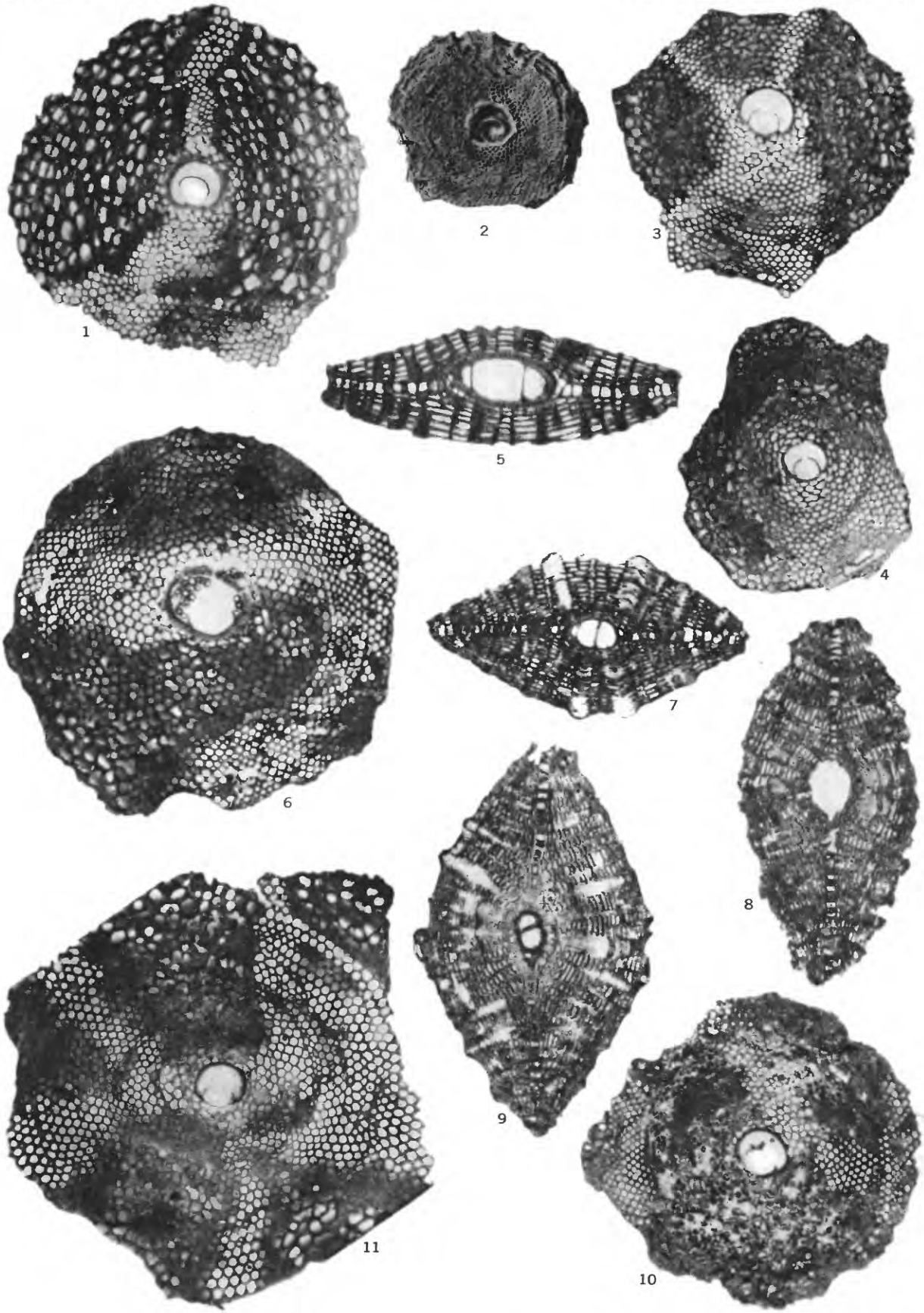
5. Vertical section, × 20, to show the large, thick-walled embryonic chambers and the low, open lateral chambers; Bikini hole 2B, at a depth of 2154–2164½ feet.

6. Equatorial section, × 20, to show the large, thick-walled embryonic apparatus and the equatorial chambers; Bikini hole 2B, at a depth of 2235½–2246 feet.

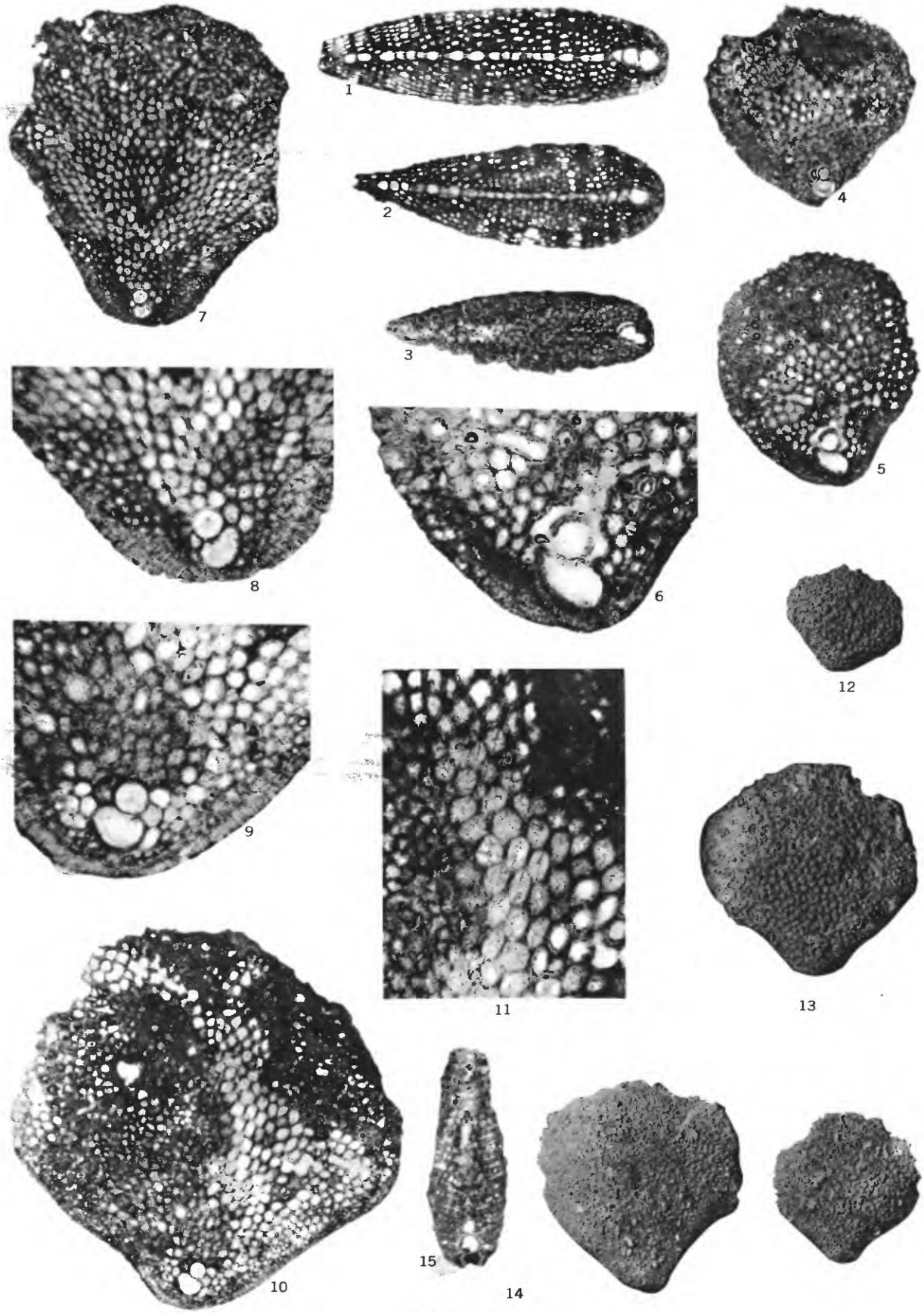
7–11. *Lepidocyclina* (*Eulepidina*) *abdopustula* Cole, n. sp. (p. 594).

7–9. Vertical sections, × 20, to demonstrate the irregular development of heavy pillars, and the low, appressed lateral chambers with thick floors and roofs; 9, cotype, USNM 547,438*b*; Bikini hole 2B; 7, at a depth of 2102–2112 feet; 8, 9, at a depth of 2070–2080½ feet.

10, 11. Equatorial sections, × 20; 10, cotype, USNM 547,438*c*; Bikini hole 2B; 10, at a depth of 2070–2080½ feet; 11, at a depth of 2246–2256½ feet.



LEPIDOCYCLINA (EULEPIDINA)



MIOGYPSINA

PLATE 219

FIGURES 1–15. *Miogypsina* (*Miogypsina*) *indonesiensis* Tan. (p. 599).

1–3, 15. Vertical sections, × 20; 1, represents the type with fine surface pustules; 2, represents the type with coarse surface pustules; 1, 2, Bikini hole 2A, at a depth of 1135–1145½ feet; 3, 15, Bikini hole 2B, at a depth of 1167–1177½ feet.

4–11. Equatorial sections; 4, 5, 7, 10, × 20; 6, 8, 9, 11, × 40; the embryonic apparatus and the equatorial chambers of various individuals; 5, 7, represent the type with coarse surface pustules; 10, represents the type with fine pustules; 11, demonstrates the development of hexagonal-shaped equatorial chambers; 5–8, Bikini hole 2B, at a depth of 1177½–1188 feet; 9–11, Bikini hole 2A, at a depth of 1135–1145½ feet.

12–14. External views, × 10; 12, 13, specimens with coarse pustules; 14, specimens with fine pustules; Bikini hole 2B; 12–14, at a depth of 1167–1177½ feet.

PLATE 220

Figures 1–8. *Miogypsinoides dehaartii* van der Vlerk. (p. 602).

1. External view, × 10; Bikini hole 2B, at a depth of 1398–1408½ feet.

2–5. Equatorial sections, × 20; Bikini hole 2B, at a depth of 1398–1408½ feet.

6–8. Vertical sections, × 20; Bikini hole 2B, at a depth of 1398–1408½ feet.

9–21. *Miogypsina* (*Miogypsina*) *borneensis* Tan. (p. 598).

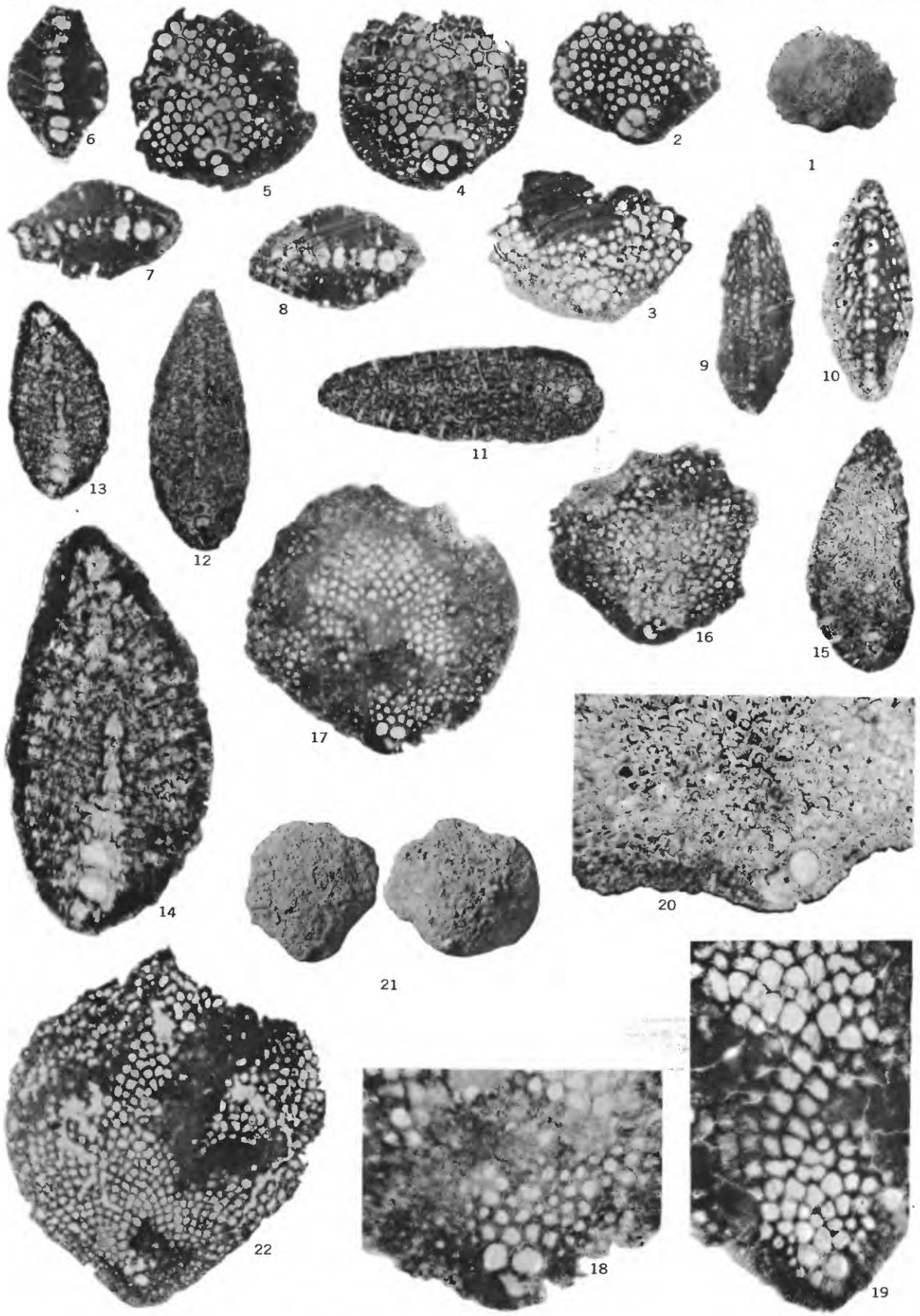
9–15. Vertical sections; 9–13, 15, × 20; 14, × 40; 9, Bikini hole 2B, at a depth of 1219½–1230 feet; 10, Kita-Daito-Zima (North Borodino Island) hole, at a depth of 268.74–274.79 meters, specimen presented through the courtesy of Dr. S. Hanzawa, introduced for comparison; 11–15, Bikini hole 2B, at a depth of 1303½–1314 feet.

16–20. Equatorial sections; 16, 17, × 20; 18–20, × 40; 19, a companion specimen to the one illustrated as figure 10; 16, 20, Bikini hole 2B, at a depth of 1219½–1230 feet; 17, 18, Bikini hole 2B, at a depth of 1303½–1314 feet.

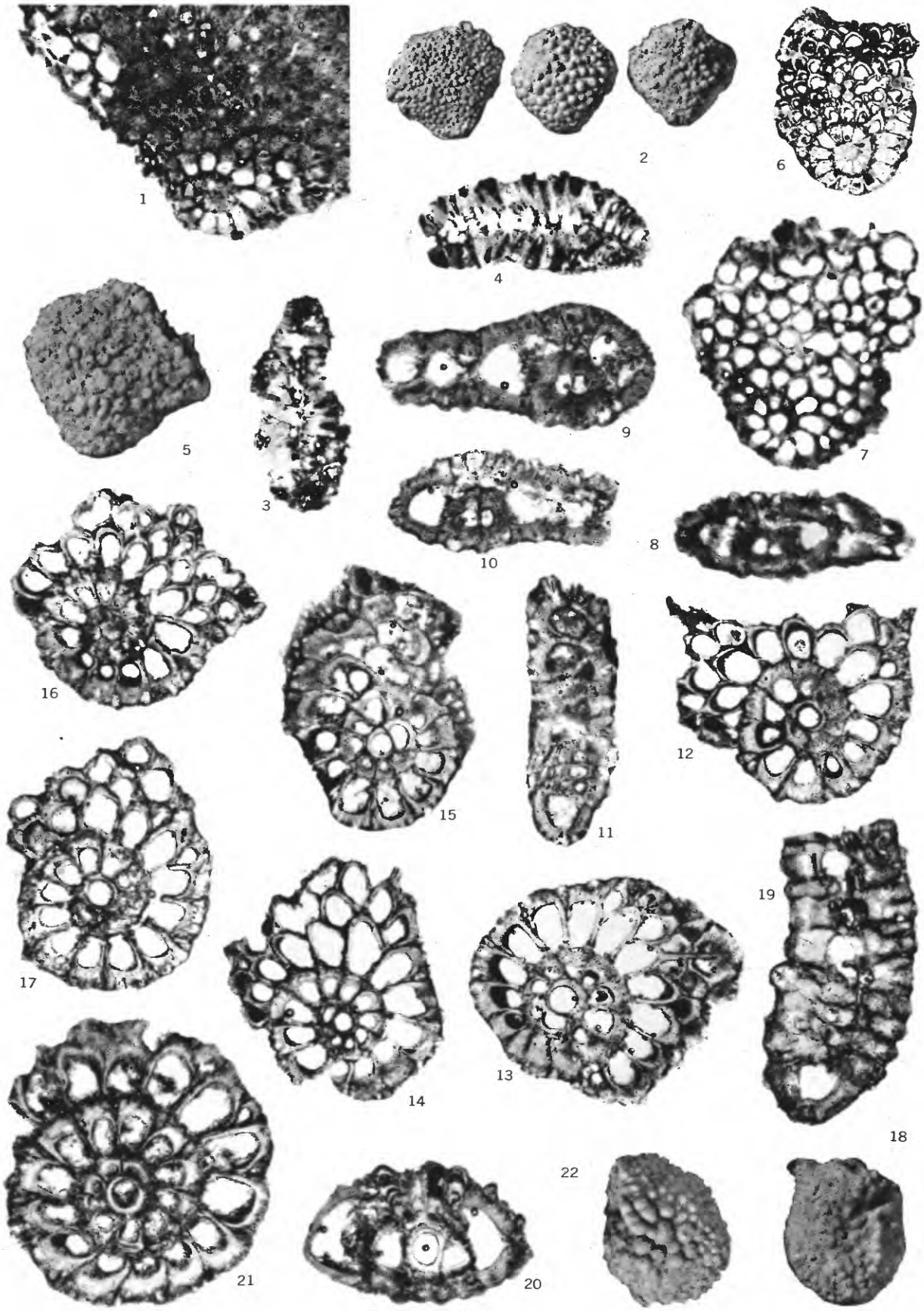
21. External views, × 10, of two specimens; Bikini hole 2B, at a depth of 1303½–1314 feet.

22. *Miogypsina* (*Miogypsina*) *indonesiensis* Tan. (p. 599)

Equatorial section, × 20; Bikini hole 2A, at a depth of 1135–1145½ feet.



MIOGYPSINA AND *MIOGYPSINOIDES*



MIOGYPSINOIDES

PLATE 221

Figures 1–4. *Miogypsinoides grandipustula* Cole, n. sp. (p. 602)

1. Embryonic apparatus, × 40, of a microspheric individual; Bikini hole 2B, at a depth of 1597½–1608 feet.
2. External views, × 10, of three microspheric specimens to illustrate differences in shape and surface ornamentation; Bikini hole 2B, at a depth of 1597½–1608 feet.

3, 4. Vertical sections, × 20, of microspheric specimens; Bikini hole 2B, at a depth of 1597½–1608 feet.

5. *Miogypsinoides ubaghsi* Tan. (p. 603)

External view, × 30, of a microspheric specimen, introduced for comparison with the microspheric specimens of *M. grandipustula* n. sp.; Bikini hole 2B, at a depth of 1744½–1755 feet.

6–8. *Miogypsinoides borodinensis* (Hanzawa). (p. 600)

6. Equatorial section, × 20, of a microspheric individual; Bikini hole 2B, at a depth of 1723½–1734 feet.
7. Equatorial section, × 40, of a megalospheric individual; Bikini hole 2B, at a depth of 1597½–1608 feet.
8. Vertical section, × 40, of a megalospheric individual; Bikini hole 2B, at a depth of 1671–1681½ feet.

9–18. *Miogypsinoides ubaghsi* Tan. (p. 603)

9–11. Vertical sections, × 40; Bikini hole 2B; 9, at a depth of 1818–1828½ feet; 10, at a depth of 1744½–1755 feet; 11, at a depth of 1723½–1734 feet.

12–17. Equatorial sections, × 40; Bikini hole 2B; 12, 16, at a depth of 1723½–1734 feet; 13, at a depth of 1671–1681½ feet; 14, at a depth of 1818–1828½ feet; 15, at a depth of 1660½–1671 feet; 17, at a depth of 1744½–1755 feet.

18. External view, × 30; Bikini hole 2B, at a depth of 1660½–1671 feet.

19–22. *Miogypsinoides grandipustula* Cole, n. sp. (p. 602)

19. Vertical section, × 40, of a megalospheric individual to illustrate the heavy pillars and the vertical canals; cotype, USNM 547,440*b*; Bikini hole 2B, at a depth of 1671–1681½ feet.
20. Vertical section, × 40, of a very young megalospheric individual which possesses only rotalid features and is without equatorial chambers; Bikini hole 2B, at a depth of 1818–1828½ feet.
21. Equatorial section, × 40, of a specimen which shows the development of a few equatorial chambers at the distal margin of the rotalid coils; cotype, USNM 547,440*c*; Bikini hole 2B, at a depth of 1818–1828½ feet.
22. External view, × 30, of a specimen with only rotalid development with the characteristic heavy pillars; cotype, USNM 547,440*a*; Bikini hole 2B, at a depth of 1744½–1755 feet.

PLATE 222

Figures 1–3. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. (p. 589)

1–3. External views, × 10, of 3 papillate specimens to illustrate the progressive development of heavy papillae in individuals of this species; Bikini hole 2B; 1, at a depth of 1398–1408½ feet; 2, at a depth of 1786½–1797 feet; 3, at a depth of 1996½–2007 feet.

4–11. *Miogypsinoides cupulaeformis* (Zuffardi-Comerci). (p. 601)

4. External view, × 10, to illustrate the extremely papillose character of the exterior of the test; Bikini hole 2A, at a depth of 1035½–1040½ feet.

5–8. Vertical sections, × 20, to show the heavy pillars with vertical canals between them and the equatorial layer which characteristically curves downward in the initial portion; Bikini hole 2A; 5, at a depth of 1035½–1040½ feet; 6, 7, at a depth of 1030–1035½ feet; 8, at a depth of 1040½–1046 feet.

9–11. Equatorial sections, × 20, to illustrate the shape of the equatorial chambers; 10, the embryonic and periembryonic chambers show in part in this specimen; Bikini hole 2A; 9, at a depth of 1035½–1040½ feet; 10, 11, at a depth of 1040½–1046 feet.

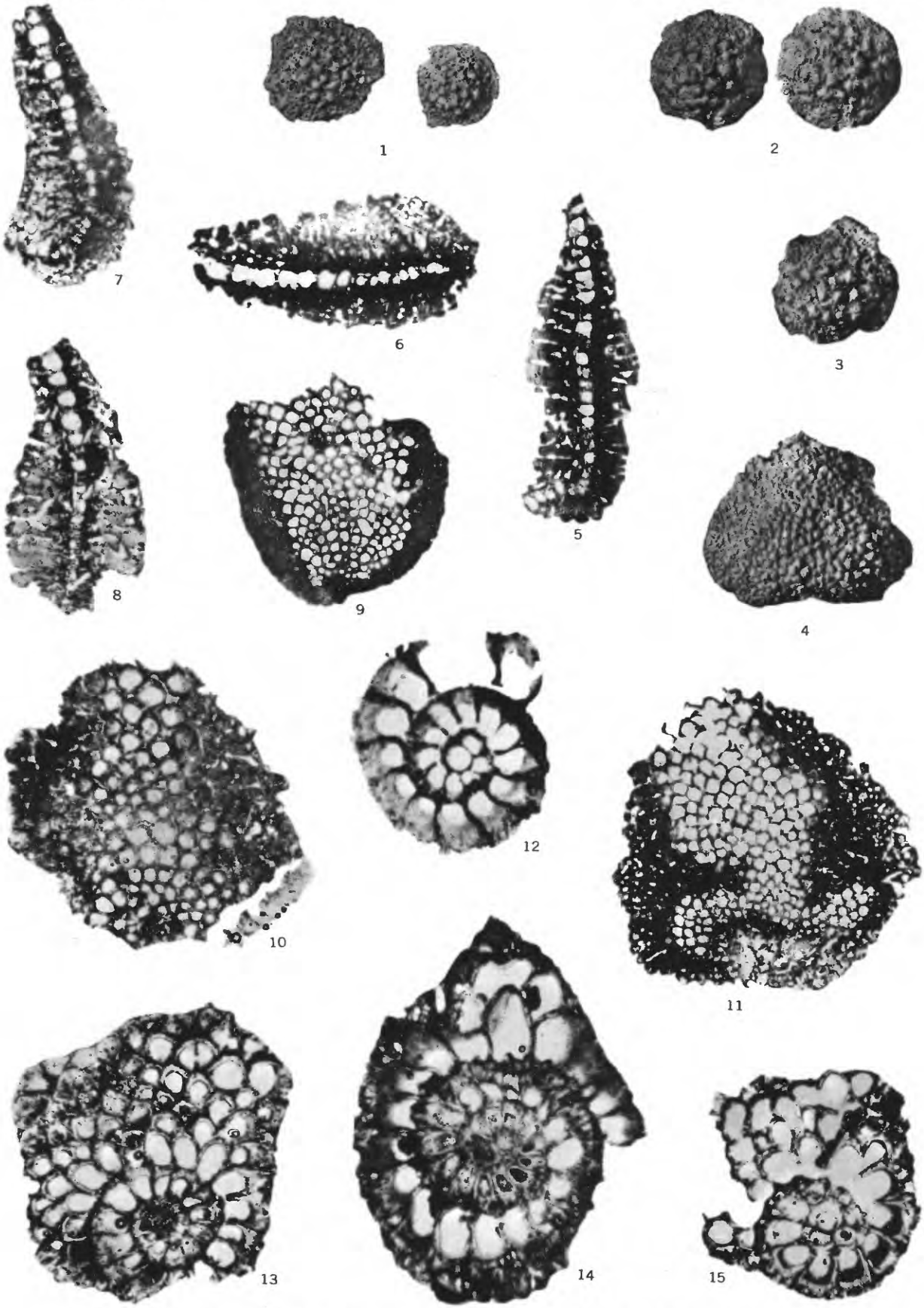
12. *Miogypsinoides grandipustula* Cole, n. sp. (p. 602)

Equatorial section, × 40, of an individual which has only the rotalid stage; Bikini hole 2B, at a depth of 1723–1734 feet.

13–15. *Miogypsinoides ubaghsi* Tan. (p. 603)

13, 14. Equatorial sections, × 40, of microspheric individuals; Bikini hole 2B, at a depth of 1818-1828½ feet.

15. Equatorial section, × 40, of a megalospheric individual; Bikini hole 2B, at a depth of 1818–1828½ feet.



LEPIDOCYCLINA (*NEPHROLEPIDINA*) AND *MIOGYPSINOIDES*

Fossil Corals From Bikini Atoll

By JOHN W. WELLS

Bikini and Nearby Atolls, Marshall Islands

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-P

A description of corals from drill holes on Bikini Atoll

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BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

FOSSIL CORALS FROM BIKINI ATOLL

By JOHN W. WELLS

ABSTRACT

Many specimens of fossil corals were found in the cuttings and cores from the test borings made at Bikini Atoll in 1947. They occurred mainly at two horizons: in the upper 350 feet and in a richly fossiliferous zone between 700 and 1,000 feet. Scattered specimens were found at practically all horizons down to at least 2,070 feet, in places constituting 5 to 20 percent of the samples, but these are usually too poorly preserved to be determined. The corals from above 350 feet are not sufficiently well preserved or complete for specific identification, and it is doubtful if other than Recent species are involved. The well-preserved material from the horizon between 700 and 1,000 feet includes a fauna of 22 species representing 13 genera of corals, indicating an horizon nearly equivalent to the Tertiary f_3 (middle Miocene) horizon of Indonesia, and a *Dictyaraea* lagoon facies rather than a surface reef facies.

INTRODUCTION

A number of specimens of corals were found in the cuttings and cores from two of the test borings made at Bikini Atoll in 1947. These two drill holes, numbered 2A and 2B (see U. S. Geol. Survey Prof. Paper 260–J, fig. 123), were located on the west side of Bikini island and showed almost identical sections.

The corals occur at two principal horizons in the sections: in the upper 350 feet and in a richly fossiliferous zone between 700 and 1,000 feet, especially between 925 and 975 feet. Corals, principally *Acropora* sp., *Porites* sp., and *Seriatopora* sp., were found between these horizons, in places constituting 5–20 percent of the cuttings. A few corals were found at depths between 1,000 and 1,100 feet, as shown in figure 167. Indeterminable scattered fragments of corals occur below 1,100 feet and are fairly numerous at 1,500–1,755 and again at 2,070 feet. The specimens from above 350 feet are not sufficiently well preserved or complete in most cases for specific identification, and it is doubtful if other than Recent species are involved. The well-preserved but fragmentary specimens from the lower horizon represent not only an older and different fauna but a different phase ("facies"), and they constitute the principal subject of this report.

CORALS FROM THE UPPER ZONE (PLIOCENE AND PLEISTOCENE)

Corals were first ecountered and recovered from a depth of 45 feet. From 45 to 350 feet they were common in the porous reef limestones. Many are unaltered, but in places they are poorly preserved as molds or are either completely recrystallized or chalky in texture. The species and genera are listed on figure 167. All are common reef forms found on present-day Indo-Pacific reefs.

CORALS FROM THE LOWER ZONE (MIOCENE)

Beginning at about 725 feet, a new and distinctive coral fauna of a nonsurface reef type makes its appearance and is especially well represented between 925 and 975 feet, as shown on figure 167. The specimens are well preserved with little alteration in structure except for a chalky appearance of the surface. All are fragmentary, but fortunately most are types in which details of growth form are less important than other details in specific determination. Sixteen species are represented, six of them by material too incomplete for more than generic assignment.

The fossil coral fauna with which the Bikini assemblage has the closest relations is that from the Miocene Menkrawit and Domaring beds (f_3–g) of the Mangkalihat Peninsula, Borneo, described by Umbgrove (1929):

Species	Bikini assemblage	Menkrawit bed	Domaring bed
Cyphastrea microphthalma	×		
Cyphastrea sp. cf. *C. progoensis*	×		
Cyphastrea sp	×		
Acropora sp	×		
Stylophora sp. cf. *S. mordax*	×		
Cycloseris sp	×		
Porites sp. cf. *P. capricornis*	×		
Porites sp	×		
Galaxea sp	×		
Millepora sp	×		
Seriatopora ornata	×		×
Alveopora polyacantha	×		×
Seriatopora micrommata	×	×	×
Dictyaraea micrantha	×	×	×
Stylophora pistillata	×	×	
Seriatopora delicatula	×	×	
Astreopora sp	×	×	
Acropora duncani		×	
Montipora micropora		×	
Cycloseris borneensis		×	
Porites amplectens		×	
Deltocyathus leupoldi		×	
Heliopora coerulea		×	

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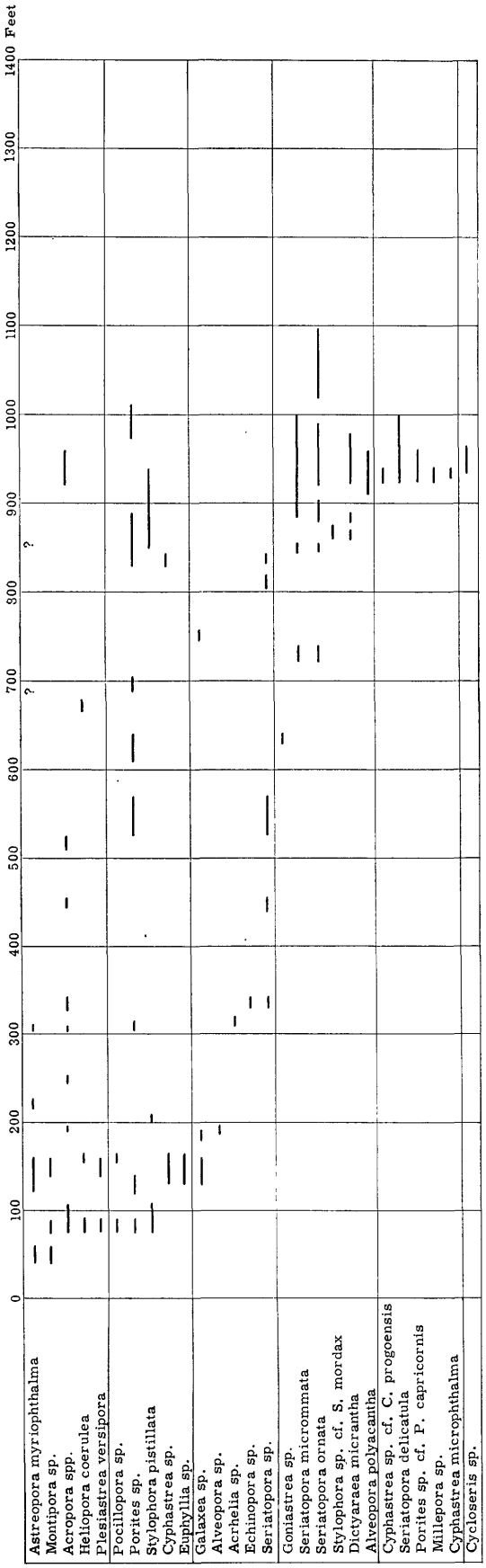

FIGURE 167. Distribution of corals in Bikini borings. Coral fragments to 2,556 feet are indeterminable.

The similarities between these faunas are actually greater than the above listing might indicate. The dominant forms of all three faunas, especially the Bikini and Menkrawit faunas, are those species which they all have in common; the other species in most cases are represented by a few or only single specimens.

Umbgrove interpreted the Menkrawit and Domaring faunas, consisting mostly of slender-branching forms, as representing muddy environments—the "tediously uniform fauna of embranched corals that we find before the muddy estuaries along the coast of Poeloe Boenjoe" (1929, p. 73). Much the same aspect is found in the coral fauna of atoll lagoons, where sedimentation is not heavy but illumination and water agitation are too low to support many surface reef types. The two faunas are thus representative of two different ecological situations, which however impress much the same aspect on the coral assemblages.

The age of this coral fauna is of great interest, and it is possible to determine it with some degree of accuracy with respect to the Indonesian Tertiary. If we accept as valid and applicable to the Bikini section the stratigraphic concept that, descending in the Indonesian sections, the first appearance of autochthonous lepidocycline Foraminifera marks the top of the middle Miocene (f_3: Van Bemmelen, 1949, p. 83), then this boundary occurs at about 1,080 feet in the Bikini section, according to W. S. Cole's study of the larger Foraminifera. On this basis the beds from 1,030 feet (first appearance of *Miogypsinoides*) upwards to about 700 feet should represent the upper Miocene (g). The probability of this being correct is great, but there remains the disturbing possibility, too often overlooked in such instances, that the 700- to 1,000-foot zone represents a middle Miocene phase that is conducive to an abundance of corals and lack of larger Foraminifera, as the opposite of this relation seems true in depths below 1,100 feet, where corals lack and large Foraminifera are abundant.

Turning to the corals from between 700 and 1,000 feet for evidence of age, the significant data are shown on figure 168. It is at once evident that these beds are not older than middle Miocene (f_3), with respect to the Indonesian subdivisions, and that they may be as young as early Pliocene (h_1), disregarding implications of possible phase differences. Six of the sixteen species listed on figure 167 as occurring in this depth zone: *Acropora* spp., *Porites* spp., *Seriatopora* sp., *Cyphastrea* sp., *Cycloseris* sp., and *Millepora* sp., are not included on figure 168 because the species are indeterminable and as genera they range from Eocene to Recent, leaving 10 species as a basis for age conclusions.

From the standpoint of age inference by comparison of similar assemblages, the evidence here is very strong for approximate synchrony of the Bikini and Menkrawit beds, with an age of late f_3 or early g. (Latest middle Miocene or earliest upper Miocene.)

In several papers Umbgrove (1946a, 1946b, 1946c, 1946d; summarized in Van Bemmelen, 1949, p. 95) has analyzed the percentages of species of living corals in the Indonesian Tertiary deposits, with general results as follows:

Percentages of Recent Species of Corals in Indonesian Tertiary

	Percent
Pleistocene and Recent	70–100
Pliocene (*h*)	50–70
Upper Miocene (*g*)	30–50
Lower and middle Miocene (*f*)	10–30
Oligocene and lower Miocene (*e*)	0–10

percentages should be considered, that of the effect of phase ("facies"). As previously indicated, the Bikini fauna, while composed of hermatypic corals, is not a typical surface-reef fauna but that of a lagoonal environment. Umbgrove (1946d, p. 28, 29; 1950, p. 63) recognized the potential fallacy of using percentages based on faunas from different phases and noted that where ahermatypic corals are present lower percentages of Recent species are obtained. He stressed that his percentage values were based upon analyses of true shallow-water reef faunas.

Umbgrove did not include percentage values of faunas of other phases, such as the Menkrawit beds, because he felt that the collections of corals were too small to establish significant figures. The Bikini fauna, however, is contained in a relatively large and representative collection and is one normally low in species and

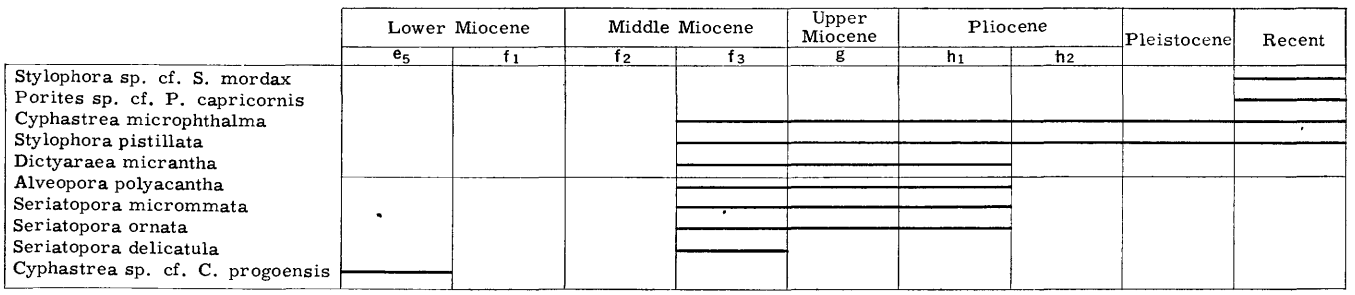

FIGURE 168.—Ranges of coral species from depths ranging from 725–1,100 feet in Bikini Atoll borings.

Since all of the species from the Bikini borings are closely allied to or identical with Indonesian forms with no apparent provincial or exotic aspect to the assemblage, comparison of the percentage of composition of the faunas of the two areas seems reasonable, although the number of species involved in the Bikini fauna is small for any but the broadest conclusions.

As shown in figure 168, 4 of the 10 species found in the borings, or 40 percent, are Recent forms. This would indicate a synchrony of the 700- to 1,000-foot part of the Bikini section with the Upper Miocene (*g*) of Indonesia, a result wholly in harmony with the result obtained by inference from the physical position of these beds above the beds determined as middle Miocene (f_3) on the basis of Foraminifera.

More rigorous restriction of species considered, involving elimination from consideration of species not closely identified, such as *Cyphastrea* sp. cf. *C. progoensis*, *Stylophora* sp. cf. *S. mordax*, and *Porites* sp. cf. *P. capricornis*, reduces the total to 7 and the percentage of Recent species drops to 28½, which suggests the upper part of f_3, a not unlikely position.

Before accepting these convenient and seemingly logical results, however, another aspect of the use of rich in individuals. The restricted percentage of 28½ obtained above may well be significant. As a partial test of its value, we may take the percentage of Recent species in the middle Miocene Mankawit beds. The writer is not inclined to include in a percentage analysis of this fauna such forms as *Acropora duncani*, *Porites amplectens*, and *Montipora micropora*. These are not sufficiently well known to be certain that they do not actually represent Recent species. Fossil forms of these three genera are extremely difficult, if not impossible, to characterize satisfactorily. Of the remaining total of 7 identifiable species, 2 or 28½ percent are Recent, and once again the evidence favors a late f_3 or early g age for the Bikini fauna.

Summarizing the evidence for the age of the beds between 700 and 1,000 feet in the Bikini borings:

1. Position with respect to foraminiferal horizons indicates *g* (earlier upper Miocene).
2. Known ranges of coral species indicate not older than f_3 (latest middle Miocene) and not younger than h_1 (lower Pliocene).
3. Comparison with fauna of the Menkrawit beds suggests f_3.

4. On the basis of 28½ percent of Recent species, the age, either by comparison with the Menkrawit beds or Umbgrove's general scale based on surface reef faunas, falls nearer f_3 than g.

SYSTEMATIC DESCRIPTIONS

Class ANTHOZOA Ehrenberg, 1834
Subclass ZOANTHARIA de Blainville, 1830
Order SCLERACTINIA Bourne, 1900
Suborder ASTROCOENIIDA Vaughan and Wells, 1943
Family POCILLOPORIDAE Gray, 1842
Genus STYLOPHORA Schweigger, 1819

Stylophora pistillata (Esper), 1797

Plate 223, figure 1

Stylophora pistillata (Esper). Umbgrove, 1946, K. Akad. Wetensch, Amsterdam Afd. Natuurk. Proc. Sec. Sci., v. 48, p. 4. [Synonymy of fossil forms.]

Eleven fragments of this well-known Indo-Pacific late Cenozoic and Recent species were found at depths 847–935½ feet in Bikini 2A.

Distribution.—Middle and upper Miocene (f_3–g), Indonesia; Pliocene to Recent, Indo-Pacific.

Stylophora sp. cf. S. mordax (Dana), 1846

Stylophora mordax (Dana). Yabe, Sugiyama, and Eguchi, 1936, Tōhoku Imp. Univ. Sci. Repts., 2d ser., special v. 1, p. 15, pl. 3, fig. 2. [Synonymy.]

A single fragment, probably of this species, was found in the core from 862½–872½ feet in Bikini 2A.

Distribution.—Recent, tropical Pacific.

Genus SERIATOPORA Lamarck, 1816

Seriatopora delicatula Felix, 1921

Plate 223, figure 2

Seriatopora delicatula Felix, 1921, Palaeontologie von Timor, Lief. 9, no. 15, p. 48, pl. 4, figs. 1, 2.
Felix, 1927, Fossilium Catalogus, Animalia, pars 35, p. 454.
Umbgrove, 1929, Dienst Mijnbouw Nederlandsch-Indië Wetensch. Meded., no. 9, p. 65, pl. 1, figs. 13–15.

Many fragments of a thin-stemmed *Seriatopora* from depths 925–958½ feet in Bikini 2A represent this species. There is much variation in the calices, as pointed out by Felix, but they are all very small (0.5 millimeter), with the columella weakly developed or even absent, the calicular margins marked by prominent costal ridges, and narrow septa.

Distribution.—Middle Miocene (f_3), *Borneo.*

Seriatopora ornata Felix, 1921

Plate 223, figures 3–5

Seriatopora ornata Felix, 1921, Palaeontologie von Timor, Lief. 9, no. 15, p. 50, pl. 5, figs. 7, 7a.
Gerth, 1923, Geol. Reichsmus. Leiden Samml., 1st ser., v. 10, p. 95.
Umbgrove, 1929, Dienst Mijnbouw Nederlandsch-Indïe Wetensch. Meded., no. 9, p. 64, pl. 1, figs. 11, 12, 16, 17.
?Seriatopora irregularis Gerth, 1921, Geol. Reichsmus. Leiden Samml. neue folge 1, p. 421, pl. 66, figs. 13–15.

Many fragments of this distinctive species come from depths 731–988 feet, Bikini 2A, and one typical piece was found in a cutting from 1,020–1,100 feet, Bikini 2B.

One very small fragment from 2,524½–2,535 feet in Bikini 2A appears to be this species. However, this came from a cutting sample, and it may well have come from much higher up in the section.

Distribution.—Middle Miocene to lower Pliocene (f_3–h_1) Java and Borneo.

Seriatopora micrommata Felix, 1921

Plate 223, figures 6, 7

Seriatopora micrommata Felix, 1921, Palaeontologie von Timor, Lief. 9, no. 15, p. 49, pl. 5, figs. 6,6a.
Gerth, 1923, Geol. Reichsmus Leiden Samml., 1st ser., v. 10. p. 96.
Umbgrove, 1929, Dienst Mijnbouw Nederlandsch-Indie. Wetensch, Meded., no. 9, p. 65.

Many fragments of branches represent this species, which is very closely related to the slender-branched form of the common *S. hystrix* of the Indo-Pacific. Indeed, there seems to be no significant difference, except that the calices of *S. hystrix* are slightly smaller, rarely as much as 0.5 millimeter, and more closely spaced on the branches. The specimens came from depths of 726–1,009 feet in Bikini 2A, and 956½–967 feet in Bikini 2B.

Distribution.—Middle Miocene to lower Pliocene (f_3–h_1), Java and Borneo.

Family ACROPORIDAE Verrill, 1902
Genus ACROPORA Oken 1815

Acropora spp.

Plate 223, figures 8, 8a, 8b

Fragments of branches of this protean genus are common in core and cutting samples from Bikini 2A, at depths ranging from 925–956½ feet, but little can be done with them. The specimen figured on plate 223, figure 8a, is very similar to *A. duncani* (Reuss) (1867, p. 171, pl. 2, fig. 2) from the Miocene of Java and

Borneo, but identification of Recent species of *Acropora* is very difficult even with complete colonies, and it is impossible on the basis of such fragments as these. *A. duncani* is merely a name applied to Miocene Indonesian corals and does not represent a species.

Several of the fragments show some details suggestive of *A. formosa* (Dana), a common and characteristic lagoon and quiet water type.

Distribution.—Eocene to Recent, Indo-Pacific and West Indies.

Suborder FUNGIIDA Duncan, 1884

Family FUNGIIDAE Dana, 1946

Genue CYCLOSERIS Milne-Edwards and Haime, 1949

Cycloseris sp.

Plate 223, figure 9, 9a

Fragments and young individuals of *Cycloseris* were found at depths ranging from 935½ to 967 feet in Bikini 2A.

Although a number of species of this genus have been described from the Tertiary of Indonesia (Gerth, 1931, p. 139–140), the present material is too fragmentary or juvenile for any specific identification.

Distribution.—Eocene to Recent, Indo-Pacific.

Family PORITIDAE Gray, 1842

Genus PORITES Link, 1807

Porites cf. P. capricornis Rehberg, 1892

Plate 224, figure 1, 1a.

Porites capricornis Rehberg. Umbgrove 1940. Rijksmuseum natuurlijke Historie Leiden: Zool. Meded., no. 22, p. 306, pl. 33, fig. 3; pl. 35, fig. 1. [Synonymy.]

One very well-preserved fragment and several worn bits of branching *Porites* occurred at depths of 925–967 feet in Bikini 2A. The branches are cylindrical or compressed, between 5 and 8 millimeters in diameter. The calices are polygonal, nearly flush, between 1.25 and 1.5 millimeters in diameter, and bounded by thin walls composed of one ring of trabecular elements. Immediately within the wall is a second ring, and a third is formed by the palar elements near the columella. The 12 septa are normally arranged on the poritid plan with no trident structure on the "ventral" directive. They are 8 pali; 7 of the lateral pairs and ventral directive and its laterals are strongly developed, that of the dorsal directive weak. The columellar tubercle is small and lies below the level of the palar ring, and all structures are minutely spined or frosted.

Of the two principal groups of species of ramose Indo-Pacific *Porites*, those of *P. nigrescens* and *P. andrewsi*, this form is associated with the latter and is very close to if not the same as *P. capricornis*, the only difference being that the pali are less developed in the Bikini specimens. *P. andrewsi* has much smaller calices and two trabecular elements on the septa between wall and pali.

Distribution.—Recent: Palau Islands, Penju Islands (North Celebes).

Genus DICTYARAEA Reuss, 1867

Type species (subsequent designation, Gregory, 1925): *Dictyaraea micrantha Reuss*, 1867. *Novara* Exped. Geol. Teil 2, p. 75. Miocene, Java.

The position of this genus has been a puzzle since it was described by Reuss, who originally placed it in the Poritidae. In 1912 Oppenheim placed it near *Stylophora* and *Madracis*. Gerth (1925) considered it a synonym of *Goniopora*. In the same year Gregory selected *D. micrantha* as genotype. Felix (1927, 1929) included it in the Seriatoporidae. Umbgrove, (1929) placed it near or next to *Goniopora*. Vaughan and Wells (1943, p. 350) erred grievously when they suggested the genus was not scleractinian but possibly a stylasteridian, on the basis of Wells' study of imperfect material in the British Museum.

Examination of the specimens from the Bikini borings shows clearly the poritid structure of this curious coral and the correctness of Reuss' original assignment. Worn specimens are deceiving, for the structures become secondarily thickened. Unworn fragments represent pieces of stems composed of a highly porous meshwork of trabeculae and synapticulae. The corallites, which are subcylindrical or subpolygonal in outline, are bounded by simple walls formed by a palisade of trabeculae linked by stout synapticulae, usually free and spinelike (var. *spinosa*) on their upper ends when unworn. Some corallitess have an additional palisade between adjacent walls, and the wall is 3 trabecular pillars thick. The 12 septa are arranged on the *Porites* plan: 2 directives, 1 of them with a flanking pair of secondaries forming a triplet, with 2 pairs of lateral pairs on primaries and secondaries. There is a palar tubercle for each lateral pair and 1 for each lateral septum of the triplet, a total of 6, with a central columellar tubercle. There appears also to be a trabecular pillar for each primary septum between the wall and palar pillar. The mural palisades are composed of trabecular pillars corresponding to all 12 septa with sometimes a few more. The lateral pairs of septa are grouped near the directive which they flank, leaving a prominent gap between each lateral pair and giving an additional bilateral aspect to the elongate calyx.

This is the basic structural plan of *Dictyaraea*, and it indicates a close relationship to *Porites* rather than to *Goniopora* or *Alveopora*. However, very rarely

can the typical poritid structure be made out in specimens. In nearly all corallites secondary thickening of synapticulae and trabecular pillars has obliterated the smaller septa, and the palar and columellar tubercles are fused into a solid central area. Further, in nearly all calices the septa are very irregularly developed.

In view of the varying effects of secondary thickening of the structures of this coral, the two "species," *D. micrantha* and *D. anomala*, of Reuss are probably the same, and *D. micrantha* var. *spinosa* Gerth merely represents nearly perfectly preserved specimens.

The genus is known only from the Miocene of the Malaysian area. It has been reported by Felix with *Alveopora polyacantha* from the Pliocene of New Guinea and Java, but Umbgrove (1929, p. 68–69) believes these are instances of remanié Miocene specimens in Pliocene strata.

Dictyaraea micrantha Reuss, 1867

Plate 224, figure 2

Dictyaraea micrantha Reuss, 1867, *Novara* Exped. Geol., Teil 2, p. 176, pl. 2, fig. 6; pl. 3, figs. 1, 2.
Felix, 1927, Fossilium Catalogus, Animalia, Pars 35, p. 460. [Synonymy.]
Umbgrove, 1929, Dienst Mijnbouw Nederlandsch-Indïe Wetensch. Meded., no. 9, p. 68, pl. 1, figs. 1–10.
Dictyaraea micrantha Reuss var. *spinosa* Gerth, 1921, Geol Reichsmus. Leiden Samml., neue folge, v. 1, abt. 2, p. 435.
Dictyaraea anomala Reuss, 1867, *Novara* Exped. Geol., Teil 2, p. 177, pl. 3, figs. 3–5.
Felix, 1927, Fossilium Catalogus, Animalia, Pars 35, p. 459.

More than 40 specimens of this species, all broken stem fragments, were recovered from cores and cuttings from Bikini 2A between depths of 857 and 988 feet, and from Bikini 2B, depth 956½–967 feet.

Distribution.—Middle Miocene to lower Pliocene (f_3–h_1), Indonesia.

Genus ALVEOPORA Quoy and Gaimard in de Blainville, 1830

Alveopora polyacantha Reuss, 1867

Plate 224, figure 3

Alveopora polyacantha Reuss, 1867, *Novara* Exped. Geol., Teil 2, p. 178, pl. 3, figs. 5, 6.
Felix, 1927, Fossilium Catalogus, Animalio, Pars 35, p. 468. [Synonymy.]
Umbgrove, 1946, Jour. Paleontology, v. 20, p. 540, pl. 80, fig. 3; pl. 82, fig. 1. [Synonymy.]
Alveopora brevispina Reuss, 1867, *Novara* Exped. Geol., Teil 2, p. 178, pl. 3, fig. 6.

Twelve specimens of this well-known species were found between depths ranging from 914 to 956½ feet in Bikini 2A.

Distribution.—Middle Miocene to lower Pliocene (f_3–h_1), Java; Borneo.

Suborder FAVIIDA Vaughan and Wells, 1943
Family FAVIIDAE Gregory, 1900
Subfamily MONTASTREINAE Vaughan and Wells, 1943
Genus CYPHATREA Milne-Edwards and Haime, 1949

Cyphastrea microphthalma (Lamarck), 1816

Cyphastrea microphthalma Umbgrove, 1946, Jour. Paleontology, v. 20, p. 524, pl. 77, fig. 5. [References.]

Four small fragments, three badly worn and one nearly unworn, from cuttings between 935½ and 946 feet in Bikini 2A, represent this common species.

Distribution.—Middle Miocene to Recent, Java; Borneo; Indo-Pacific.

Cyphastrea sp. cf. C. progoensis, 1933

Cyphastrea progoensis Gerth, 1933, Dienst Mijnbouw Nederlandsch-Indïe Wetênsch. Meded., no. 25, p. 29, pl. 4, fig. 1.

Two small fragments about 1 centimeter square each, with 3–4 calices, agree well with Gerth's description, except that the calices are slightly larger, 2–2.5 millimeters. The third cycle of septa is only very weakly developed as faint ridges near the rims of the calices. The two specimens came from depths ranging from 925–935½ feet in Bikini 2A.

Distribution.—Lower Miocene (e_5), Java.

Class HYDROZOA Huxley, 1856
Order MILLEPORINA Hickson, 1899
Genus MILLEPORA Linnaeus, 1758

Millepora sp.

Plate 224, figure 4

Two types of *Millepora* can be recognized in fragments from depths 925–940 feet in Bikini 2A: a thin, encrusting form found on pieces of *Alveopora polyacantha* and bits of a slender branching type.

It is impractical to identify species of this genus from such inadequate material, the specific characters in this genus lying in the growth form.

Distribution.—Eocene to Recent, Indo-Pacific and West Indies.

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PLATES 223–224

PLATE 223

[All specimens are natural size and from hole 2A, Bikini, unless otherwise indicated]

FIGURE 1. *Stylophora pistillata* (Esper) (p. 612).
Depth 935 feet.

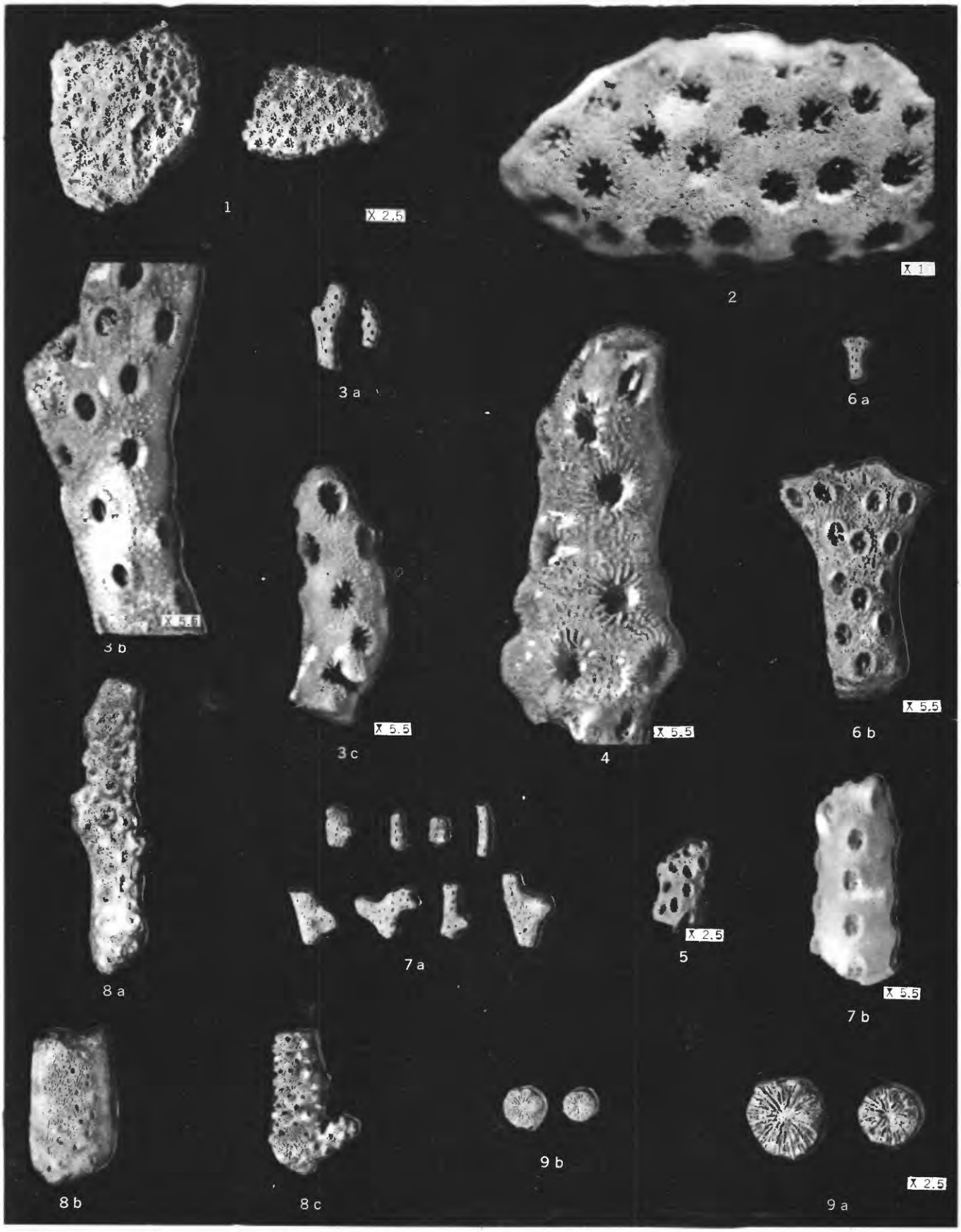
2. *Seriatopora delicatula* Felix (p. 612).
Depth 925–935½ feet.

3–5. *Seriatopora ornata* Felix (p. 612).
3, 3a, 3b. Depth 935½ feet.
4. Depth 937 feet.
5. Depth 935½ feet.

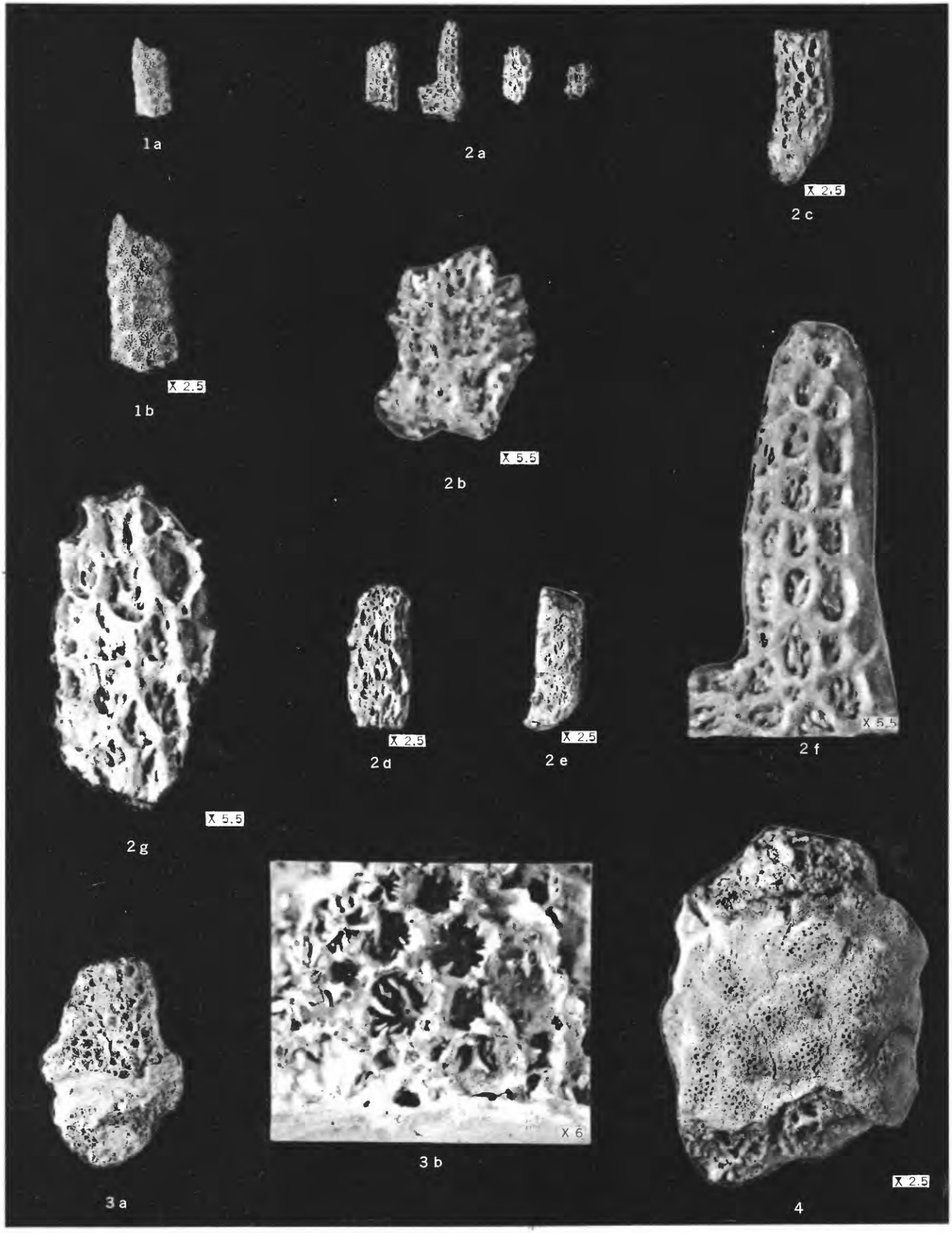
6–7a. *Seriatopora micrommata* Felix (p. 612).
6, 6a. Depth 935½ feet.
7, 7a. Depth 935½ feet.

8–8b. *Acropora* sp. (p. 612).
Depth 946–956½ feet.

9, 9a. *Cycloseris* sp. (p. 613).
Depth 935½ feet.



STYLOPHORA, SERIATOPORA, ACROPORA, AND *CYCLOSERIS*



PORITES, DICTYARAEA, ALVEOPORA, AND *MILLEPORA*

PLATE 224

[All specimens are natural size and from hole 2A, Bikini, unless otherwise indicated]

FIGURES 1, 1a. *Porites* sp. aff. P. *capricornis* Rehberg (p. 613).
Depth 935½ feet.

2–2f. *Dictyaraea micrantha* Reuss (p. 613).
2, 2a, 2e, 2f. Depth 935½ feet.
2b, 2c, 2d. Depth 956½–967 feet.

3, 3a. *Alveopora polyacantha* Reuss (p. 614).
Depth 937 feet.

4. *Millepora* sp. (p. 614).
Depth 935½ feet.

○