Geology of Saipan Mariana Islands

Part 3. Paleontology

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-E-J

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By J. Harlan Johnson

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Geology of Saipan, Mariana Islands

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Calcareous Algae

By J. HARLAN JOHNSON

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Twenty-four of the eighty-eight species-groups listed or described are new; a brief consideration is given to algae as rock builders and index fossils

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GEOLOGY OF SAIPAN, MARIANA ISLANDS

CALCAREOUS ALGAE

By J. Harlan Johnson

ABSTRACT

This report deals with the Cenozoic calcareous algae from Saipan, including a selection of Recent forms. Most of these are red algae, but a few are green. Altogether 18 genera and 88 species-groups are listed or described, only 73 species are designated by formal systematic names. All of the genera and most of the species are found as fossils. The names of 1 genus (*Paraporolithon*) and 24 species are new with this report.

Brief consideration is given to the importance of the calcareous algae as rock builders, in stratigraphic correlation, and for paleoecologic interpretation. It is concluded that their greatest present use is in paleoecology. They are of limited use in stratigraphy; however, their value to this field will increase as more records are compiled and as their stratigraphic and geographic distribution is better worked out.

INTRODUCTION

The calcareous algae are those algae which have developed the ability to secrete or deposit calcium carbonate within or around their tissues. Their remains occur abundantly in most of the limestones of Cenozoic age on Saipan, at places being so abundant as to form an appreciable part of the rock.

Fossil calcareous algae also occur in the limestones found on many other Pacific islands, although not ordinarily described or discussed by geologists and paleontologists. These algae are at present most useful for the information they give about the conditions under which the enclosing sediments were formed. They will probably prove more useful for dating and correlation when sequences of collections have been studied from many more localities to determine their geographic and stratigraphic range in the Pacific. The work at Saipan contributes a useful local sequence to such a study, because the algae occur in limestones associated with larger Foraminifera about whose stratigraphic distribution much is known.

This report is based on a study of selected slides from a collection of more than 2,000 large thin sections of limestones from over 1,200 localities of known stratigraphic position. The area of the individual sections averages about 5 square inches. From the many fragments a few specimens which contained most of the necessary structural features were selected for description.

Inasmuch as this study is based mainly on thin sections, a conservative nomenclatural approach is taken. As much material as possible is attributed, with due qualification, to previously described species; and new species are not proposed unless they appeared clearly distinguishable and could be based on adequate material.

Fortunately several collections of Recent algae were made in connection with the Saipan field work. Laboratory study of selected material from these collections has added considerably to the writer's knowledge of the range of species variation and growth forms and has assisted in understanding and describing the fossil species.

ACKNOWLEDGMENT

Doris L. Low reviewed the manuscript for inconsistencies and put it into order for final typing and technical review; her assistance is gratefully acknowledged.

MAJOR GROUPS OF CALCAREOUS ALGAE

The Rhodophyta (red algae) and Chlorophyta (green algae) include most of the lime-depositing algae that form readily identifiable fossils. They include all of the forms discussed in this report, as indicated in the following table.

TABLE 1.—*Genera of calcareous algae found in the Cenozoic deposits of Saipan*

	Family	Subfamily	Genus
Rhodophyta (Red algae)	Corallinaceae	Melobesioideae (Crustose corallines)	*Archaeolithothamnium* *Dermatolithon* *Goniolithon* *Lithophyllum* *Lithoporella* *Lithothamnium* *Melobesia* *Mesophyllum* *Paraporolithon* (new) *Porolithon*
		Corallinoideae (Articulated corallines)	*Amphiroa* *Arthrocardia* *Calliarthron* *Corallina* *Jania*
Chlorophyta (Green algae)	Codiaceae		*Halimeda* *Microcodium*
	Dasycladaceae		*Cymopolia*

The coralline algae differ from most other calcareous algae in that the calcium carbonate is secreted within and between the cell walls as well as (ordinarily) being deposited around the plant tissues. The fossil corallines show recognizable and specifically identifiable microstructure such as the shape and arrangement of the cells.

The calcareous green algae show varied calcification. In *Halimeda* the tissue itself is calcified, starting most strongly at the outer surface and working toward the interior. In some specimens the entire tissue is calcified, in others only the outer part. Among the calcified Dasycladaceae, on the other hand, the lime is deposited around the tissue, forming molds of the plants and plant segments.

STRUCTURE, TERMINOLOGY, AND SYSTEMATIC DISTINCTION

The entire coralline algal plant is termed the **thallus.** Among the subfamily Melobesioideae or inarticulate corallines, the **thallus** is composed of two types of tissue—the **hypothallus** and the **perithallus** (pl. 37). The basal part of the plant is ordinarily composed of cells of a different size and arranged somewhat differently from the tissue above. This is known as the **basal hypothallus** (pl. 37, figs. 7–12). In some genera of the crustose corallines (especially *Lithophyllum*) and among the articulated corallines, the central part of the branches and stems shows a similar development which is called the **medullary hypothallus** (pl. 37, figs. 1–3). Above the basal hypothallus of encrusting forms, the tissue is composed of cells of a different size than the hypothallus, and they are characteristically arranged in regular rows and layers. This is the **perithallus** (pl. 37, figs. 7–12). A similar tissue forms around the outside of branches (pl. 37, figs. 1–3).

Among the articulate corallines, the thallus characteristically consists of a small basal crust from which arise many branching stems, forming small, commonly bushy tufts. The branches are segmented, consisting of alternations of uncalcified and calcified segments (pl. 37, fig. 3), which are respectively called **nodes** (or **genicula**) and **segments** (or **intergenicula** or **internodes**). Both nodes and segments consist of a central or medial part built up of rows of long cells and a thin, outer dermal or cortical part.

All coralline algae reproduce by **spores.** These develop in spore cases or **sporangia** (pl. 37, fig. 10). In most genera, the sporangia are grouped together in large cases known as **conceptacles** (pl. 37, figs. 7, 8). The different genera have characteristic morphology not only in the structure of the perithallus and hypothallus but even more importantly in the structure and arrangement of the conceptacles. The species are differentiated on the basis of differences in cell size and arrangement, the size and shape of the conceptacles, and peculiarities in the texture and structure of the tissue as well as the growth habit of the plant in general. The conceptacles of the articulate corallines, however, form externally or in the growing tips of the plant. These are uncalcified and thus are seldom found among fossils, creating special difficulty in their classification.

Among the green algae, *Halimeda* develops as small bushy plants which ordinarily consist of numerous branching stems formed of numerous fan-shaped leaflike segments growing end to end. These segments separate easily after the death of the plant and ordinarily occur separately in the fossil state. Classification into species is based on nature of branching and grouping of the branches and on size and shape of the individual segments.

The family Dasycladaceae also form small bushy plants. The individual thallus may be simple or branched, or it may consist of a number of segments one upon the other. The thallus consists of a **central stem** from which arise whorls of **primary branches** which radiate out much like the spokes of a wheel. The primary branches may bear **secondary branches,** and these in turn may develop **tertiary branches.** The **sporangia,** or spore cases, may develop within the central stem or upon some of the branches. Many genera and species are based on variations in all of these features. Calcification is erratic and external forming crusts about the critical structures which themselves are not preserved as fossils.

GEOLOGIC WORK OF CALCAREOUS ALGAE

Calcareous algae are important both as contributors to the clastic limestones and because of the part they play in building the framework of reefs.

A study of the limestones on Saipan indicates that the algae rank with the Foraminifera in the volume of material contributed to the rock. In selected samples studied, the algal fraction ranges from 5 percent of the volume to 68 percent, averaging around 18–20 percent. Among the algae the most important rock builders are the corallines, both articulate and inarticulate types, and the green alga *Halimeda*. The Dasycladaceae are too rare on Saipan to be of importance as rock builders there.

Most of the limestones studied contain coralline algae. Crustose forms predominate in some; and articulate, in others. Commonly both are found in the same limestone.

In some rocks *Halimeda* is so abundant as to form true *Halimeda* limestones. In a few of the specimens studied, they formed up to 65 percent of the rock by volume, and commonly they make up 12–18 percent. In those rocks containing abundant *Halimeda*, coralline algae tend to be rare.

In reef building, the coralline algae alone are important, and those species which form compact encrusting or massive structures do most of the work. They assist in the formation of the reefs in three ways: (1) by actually contributing to the volume of the reef mass, (2) by binding together the coral heads and fragments of other organisms, thus making a more compact mass, and (3) by protecting the reef from erosion. Around the outer margin of the reef, particularly where the surf is strong, there forms a strong growth of coralline algae which has been referred to in some publications as the algal ridge or "*Lithothamnion* ridge." This consists of a great development of encrusting, knobby, and branching types (mainly *Porolithon*) which form a strong surficial crust around the reef, protecting it from wave erosion.

ALGAE AS INDICATORS OF AGE AND ENVIRONMENT

The many and careful studies by Mme. Lemoine of material from France and the regions around the Mediterranean have shown that the coralline algae have considerable possibilities as local zone markers. She discusses this at some length among the conclusions at the end of her work on the fossil algae of Algeria (Lemoine, 1939), showing that the algal floras known in the Mediterranean region from the different epochs of the Cenozoic era are quite distinct. Only a few of the Cretaceous species continue into the Eocene, whereas the Miocene floras are distinctly different from those of the Eocene and Oligocene. She concludes that the different species have value in correlating distant areas to period and even to epoch, but only in local regions can they be used for detailed stratigraphic correlation.

The same is true at Saipan. No Eocene species is recorded from the Miocene, and very few Miocene species have been recognized in higher beds. Most of the Pleistocene forms are still living in the adjoining seas, however; and representatives of the genus *Porolithon* are unknown from definitely pre-Pleistocene rocks.

Outside of the Mediterranean region, sufficient work has not been done on fossil algae to give us a knowledge of their time range. Until such work is done, the algae can be of only limited use for correlation. Such specific application as they presently appear to have is summarized in Professional Paper 280–A (Cloud, Schmidt, and Burke, 1957).

Algae can be very useful in paleoecology. In present seas the crustose types of coralline algae are found from the intertidal zone commonly down to a depth of about 200 meters and even deeper in the tropics. Those forming thin crusts or sheetlike masses seem to range from tide level down to more than 100 meters (Lemoine, 1940, p. 86). On the other hand, those which develop as masses of long branches seldom occur at depths greater than 10 or 15 meters. The articulated corallines grow from about tide level down to depths not exceeding 80 meters and do not appear abundant at depths greater than 20 or 25 meters. In addition to depth and light penetration, their distribution is considerably affected by agitation of water, nature of the bottom, presence or absence of sediment in suspension, and salinity of the water. These factors in their relation to the distribution of modern lime-secreting algae have been discussed by a number of botanists, and their results have been ably summarized by Mme. Lemoine (1940).

Green algae also have a relatively shallow depth range. Mme. Lemoine (1940, p. 125) has shown that the presence of Dasycladaceae in abundance indicates shallow water and commonly a muddy or silty bottom. They are most abundant in depths down to 10 meters and are rarely found at depths below 25 meters. Similarly, *Halimeda* thrives best in relatively shallow waters from about tide level down to depths of 15 or 20 meters, although some species grow at depths of over 120 meters.

STRATIGRAPHIC DISTRIBUTION OF THE SAIPAN ALGAE

The stratigraphic distribution of the species and genera of fossil algae found on Saipan is tabulated in table 2.

TABLE 2.—*Stratigraphic distribution of fossil algae of Saipan*

[Numerals indicate total number of localities from which material was studied]

	Eocene						Miocene						Pleistocene				Recent—(X indicates presence)
	Hagman formation—Conglomerate-sandstone facies	Densinyama formation		Matansa limestone			Tagpochau limestone						Mariana limestone			Tanapag limestone	
		Conglomerate-sandstone facies	Limestone-conglomerate facies	Transitional facies	Pink facies	White facies	Transitional facies	Tuffaceous facies	Marly facies	Rubbly facies	Equigranular facies	Inequigranular facies	Rubbly facies	Massive facies	*Halimeda*-rich facies		
Archaeolithothamnium:																	
Division 1:																	
A. chamorrosum Johnson, n. sp.			1		1												
A. cf. *A. fijiensis* Johnson and Ferris												1					
A. lauense Johnson and Ferris												1					
A. megasporum Johnson, n. sp.													1				
A. oulianovi Pfender				1		2											
A. puntiense Airoldi														2			
A. taiwanensis Ishijima											2	2					
Division 2:																	
A. cf. *A. liberum* Lemoine			1	1													
A. cf. *A. lugeoni* Pfender												1					
A. myriosporum Johnson, n. sp.									1			2					
A. saipanense Johnson, n. sp.			1		3	1											
Lithothamnium:																	
Division 1:																	
L. cf. *L. abrardi* Lemoine	1		2		2												
L. cf. *L. aggregatum* Lemoine			1	1	1												
L. cf. *L. bourcarti* Lemoine								1				2					
L. cf. *L. engelhartii* Foslie														1			
L. cf. *L. fumigatum* Foslie												1					
L. funafutiense Foslie															1		
L. ladronicum Johnson, n. sp.												1					
L. lichenoides (Ellis and Sollander) Foslie														1			
L. cf. *L. nanosporum* Johnson and Ferris						2											
L. saipanense Johnson, n. sp.												1					
L. subtile Conti												2					
L. tagpotchaense Johnson, n. sp.			1														
L. tanapagense Johnson, n. sp.														1		1	
L. sp. B									1								
L. sp. D												1					
Division 2:																	
L. crispithallus Johnson, n. sp.			4														
L. sp. A	1		1		1												
Division 3:																	
L. cf. *L. aucklandicum* Foslie														1			
L. cf. *L. crispatum* Hauck												1					
L. cymbicrusta Johnson, n. sp.			4														
L. cf. *L. disarmonicum* Conti									1								
L. cf. *L. mirabile* Conti												1					
L. moreti Lemoine						1											
L. undulatum Capeder												1					
L. wallisium Johnson and Tafur			1		1	1											
L. sp. C						1											
Division 4:																	
L. cf. *L. lecroixi* Lemoine												1					
L. cf. *L. madagascariense* Foslie														1			
L. marianae Johnson, sp. n.			1		4	1											
L. sp. E	1																
Mesophyllum:																	
M. pacificum Johnson, n. sp.										1							
M. savornini Lemoine												1					
M. cf. *M. vaughanii* (Howe) Lemoine				1													
Lithophyllum:																	
Division 1:																	
L. megacrustum Johnson and Ferris													1	3			
L. ovatum (Capeder) Lemoine			4			1											
L. cf. *L. racemus* (Lamarck) Foslie														1			
L. stefaninii Airoldi														2			
L. yendoi Foslie														1			
L. sp. A					1	2						2					
Division 2:																	
L. prelichenoides Lemoine								1	1			2					
Division 3:																	
L. expansum Philippi														2			
L. cf. *L. roveretoi* Airoldi														1			
Division 4:																	
L. glangeaudi Lemoine												1					
L. kotschyanum (Unger) Foslie																	X
L. moluccense Foslie														1			X
Goniolithon:																	
G. frutescens Foslie																	X
G. reinboldi Weber van Bosse and Foslie																	X
G. sp. A														1			
G. sp. B														1			

TABLE 2.—*Stratigraphic distribution of fossil algae of Saipan*—Continued

	Eocene						Miocene						Pleistocene				
	Hagman formation—Conglomerate-sandstone facies	Densinyama formation		Matansa limestone			Tagpochau limestone						Mariana limestone			Tanapag limestone	Recent—(X indicates presence)
		Conglomerate-sandstone facies	Limestone-conglomerate facies	Transitional facies	Pink facies	White facies	Transitional facies	Tuffaceous facies	Marly facies	Rubbly facies	Equigranular facies	Inequigranular facies	Rubbly facies	Massive facies	*Halimeda*-rich facies		
Porolithon:																	
P. craspedium (Foslie) Foslie														2		2	X
P. onkodes (Heydrich) Foslie															2		X
Paraporolithon, Johnson, n. gen.:																	
P. saipanense Johnson, n. sp.												1					
Lithoporella:																	
L. melobesioides (Foslie) Foslie		2	3		3	2			4	2	2	5	2	2	2	2	X
Melobesia:																	
M.? cuboides Johnson, n. sp.			3		1												
Dermatolithon:																	
D. nitida Johnson, n. sp.			4			1						1					
D. saipanese Johnson, n. sp.										2		5					
D. sp.															2		
Calliarthron:																	
C. antiquum Johnson, n. sp.												2					
Jania:																	
J. vetus Johnson, n. sp.												6					
J. sp. A	1																
J. sp. B										1		1					
J. species undetermined		1	1	2	2	4			2	1	1	10	1	2	1	3	
Amphiroa:																	
A. foliacea Lamouroux															1		
A. fragilissima (Linnaeus) Lamouroux														3			
A. sp.																	X
Arthrocardia:																	
A. species undetermined					1	1						2					
Corallina:																	
C. matansa Johnson, n. sp.	1				2	1											
C. neuschelorum Johnson, n. sp.												7					
C. prisca Johnson, n. sp.	1		5		5	5											
C. species undetermined	4		6	8	8	12			5	3	8	15					
Cymopolia:																	
C. delicata Johnson, n. sp.												2					
C. pacifica Johnson, n. sp.			1			7											
C. saipania Johnson, n. sp.												4					
Halimeda:																	
H. gracilis Harvey forma *lata* Taylor																	X
H. opuntia Lamouroux forma *triloba* Barton																	X
H. species undetermined	2		5	3	8	5	1		4	1	5	12			10	12	
Microcodium:																	
M. sp.												4					

LOCALITIES

The collecting localities to which reference is made in this report are given on the locality finding map (pl. 4) by Cloud, Schmidt, and Burke. The localities are grouped by number and geologic age beneath the finding list on this locality finding map.

Table 3 gives the equivalent field and permanent catalog numbers of material herein described and illustrated (first two columns). The last three columns apply only to type and figured specimens.

TABLE 3.—*Field and permanent catalog numbers for fossil algae*

USGS paleobotanical locality	Field number on locality-finding map (pl. 4)	USGS type algae [1]	Type of new species	Other figured specimens
D90	B82	a3-1a		*Lithoporella melobesioides* (Foslie) Foslie.
D91	B90	a4-1a		*Lithophyllum prelichenoides* Lemoine.
D92	B107	a5-1a, a5-1b, a5-2a, a5-2b		*Cymopolia saipania* Johnson, n. sp.
		a5-3a	*Cymopolia saipania* Johnson, n. sp.	
D93	B153	a6-1a	*Archaeolithothamnium myriosporum* Johnson, n. sp.	
D94	B171	a7-1a, a7-1b, a7-2a, a106-1b		*Microcodium* sp.
		a7-1c, a7-1d, a7-2b, a7-3b		*Cymopolia delicata* Johnson, n. sp.
		a7-3a	*Cymopolia delicata* Johnson, n. sp.	
D95	B189	a9-1a, a9-1b		*Halimeda* sp.
D96	B197	a10-1a		*Lithothamnium* cf. *L. mirabile* Conti.

[1] Specimens having USNM numbers are on Foraminifera slides.

TABLE 3.—*Field and permanent catalog numbers for fossil algae*—Continued

USGS paleo-botanical locality	Field number on locality-finding map (pl. 4) [1]	USGS type algae [1]	Type of new species	Other figured specimens
D97	B199	a11–1a a11–1b, a11–1c, a11–1d, a11–1e, a11–2a, a20–1a, a27–1a. a11–2b	*Cymopolia pacifica* Johnson, n. sp.	*Cymopolia pacifica* Johnson, n. sp. *Lithophyllum ovatum* (Capeder) Lemoine.
D98	B205	a12–1a	*Lithothamnium ladronicum* Johnson, n. sp.	
D99	B214	a13–1a		*Mesophyllum savornini* Lemoine.
D100	B226	a14–1a		*Goniolithon* sp. B.
D101	B227	a15–1a		*Lithophyllum* cf. *L. racemus* (Lamarck) Foslie.
D102	B229	a16–1a		*Archaeolithothamnium puntiense* Airoldi.
D103	B232	a17–1a		*Lithothamnium* cf. *L. aucklandicum* Foslie.
D104	B235	a18–1a		*Porolithon craspedium* (Foslie) Foslie.
D105	B245	a19–1a		*Dermatolithon saipanense* Johnson, n. sp.
D106	B269			
D107	B271			
D108	B279	a22–1a	*Dermatolithon saipanense* Johnson, n. sp.	
D109	B282	a23–1a		*Lithophyllum expansum* Philippi.
D110	B286			
D111	B287	a25–1a a25–1b		*Lithophyllum stefaninii* Airoldi. *Lithophyllum* cf. *L. roveretoi* Airoldi.
D112	B297	a28–1a		*Archaeolithothamnium lauense* Johnson and Ferris.
D113	B310	a29–1a	*Corallina neuschelorum* Johnson, n. sp.	
D114	B319	a30–1a a30–1b		*Lithophyllum megacrustum* Johnson and Ferris. *Lithophyllum yendoi* Foslia.
D115	B321	a32–1a a32–2a		*Archaeolithothamnium puntiense* Airoldi. *Goniolithon* sp. A.
D116	B325	a34–1a		*Archaeolithothamnium taiwanensis* Ishijima.
D117	B334	a35–1a		*Porolithon craspedium* (Foslie) Foslie.
D118	B403	a24–1a		*Archaeolithothamnium taiwanensis* Ishijima.
D119	B415	a68–1a	*Jania vetus* Johnson, n. sp.	
D120	B427	a38–1a, a38–1b		*Corallina neuschelorum* Johnson, n. sp.
D121	C2			
D122	C4	a40–1a, a40–1b a39–1a a40–2a a40–2b		*Lithothamnium subtile* Conti. *Lithothamnium* cf. *L. bourcarti* Lemoine. *Lithothamnium* cf. *L. crispatum* Hauck. *Lithothamnium* cf. *L. lecroixi* Lemoine.
D123	C10	a42–1a a42–2a		*Archaeolithothamnium* cf. *A. liberum* Lemoine *Mesophyllum* cf. *M. vaughanii* (Howe) Lemoine.
D124	C12	a44–1a a44–2a		*Lithothamnium* sp. C. *Lithothamnium moreti* Lemoine.
D125	C13	a45–1a a45–2a		*Archaeolithothamnium oulianovi* Pfender. *Lithothamnium wallisium* Johnson and Tafur.
D126	C16	a47–1a	*Calliarthron antiquum* Johnson, n. sp.	
D127	C24	a48–1a a48–2a a48–2b	*Lithothamnium saipanense* Johnson, n. sp.	*Halimeda* sp. *Lithophyllum prelichenoides* Lemoine.
D128	C27	a51–1a		*Lithothamium* cf. *L. disarmonicum* Conti.
D129	C49	a52–1a a53–1a a53–1b		*Porolithon onkodes* (Heydrich) Foslie. *Amphiroa foliacea* Lamouroux. *Lithothamnium funafutiense* Foslie.
D130	C50	a54–1a a54–1b	*Lithothamnium tanapagense* Johnson, n. sp.	*Lithothamnium tanapagense* Johnson, n. sp.
D131	C65	a55–1a a55–1b, a55–1c, a55–2a a55–2b		*Lithothamnium* cf. *L. madagascariense* Foslie. *Amphiroa fragilissima* (Linnaeus) Lamouroux. *Lithophyllum moluccense* Foslie.
D132	C67	a59–1a		*Amphiroa fragilissima* (Linnaeus) Lamouroux.
D133	C81	a60–1a a60–2a a60–2b		*Lithothamnium* cf. *L. engelhartii* Foslie. *Lithothamnium lichenoides* (Ellis and Sollander) Foslie. *Lithoporella melobesioides* (Foslie) Foslie.
D134	C93	a63–1a, a63–2a		*Archaeolithothamnium* cf. *A. fijiensis* Johnson and Ferris.
D135	C98	a64–1a		*Lithothamnium undulatum* Capeder.
D136	C103			*Halimeda* sp.
D137	C138			
D138	S5	a67–1a	*Mesophyllum pacificum* Johnson, n. sp.	
D141	S20	a70–1a		*Lithothamnium* sp. B.
D142	S74			
D143	S88	a73–1a a73–2a a72–1a	*Lithothamnium crispithallus* Johnson, n. sp. *Lithothamnium marianae* Johnson, n. sp.	*Lithothamnium marianae* Johnson, n. sp.
D144	S90	a75–1a	*Lithothamnium tagpotchaense* Johnson, n. sp.	
D145	S101	a76–1a		*Lithophyllum ovatum* (Capeder) Lemoine.
D146	S125	USNM 624732	*Melobesia? cuboides* Johnson, n. sp.	
D147	S133	USNM 624736 USNM 624514 USNM 624514		*Dermatolithon nitida* Johnson, n. sp. *Lithothamnium cymbicrusta* Johnson, n. sp. *Corallina prisca* Johnson, n. sp.
D148	S150			
D149	S164	a84–1a		*Lithothamnium* sp. D.
D150	S166	a85–1a a85–2a		*Lithophyllum glangeaudi* Lemoine. *Archaeolithothamnium myriosporum* Johnson, n. sp.
D151	S170	USNM 624520 USNM 624511		*Lithothamnium* cf. *L. abrardi* Lemoine. *Lithothamnium cymbicrusta* Johnson, n. sp.
D152	S189	a89–1a a89–2a a89–2b	*Corallina prisca* Johnson, n. sp.	*Cympolia pacifica* Johnson, n. sp. *Lithothamnium crispithallus* Johnson, n. sp.
D153	S205	a91–1a		*Lithothamnium* cf. *L. fumigatum* Foslie.
D154	S208	a92–1a a92–2a	*Dermatolithon nitida* Johnson, n. sp.	*Corallina neuschelorum* Johnson, n. sp.
D155	S222	a93–1a		*Lithothamnium wallisium* Johnson and Tafur.
D156	S241	USNM 624477	*Corallina matansa* Johnson, n. sp.	
D157	S242	a95–1a a95–2a	*Archaeolithothamnium saipanense* Johnson, n. sp.	*Archaeolithothamnium saipanense* Johnson, n. sp.
D158	S254	a96–1a		*Corallina matansa* Johnson, n. sp.
D159	S258	a97–1a a97–1b a97–1c	*Lithothamnium cymbicrusta* Johnson, n. sp.	*Archaeolithothamnium* cf. *A. liberum* Lemoine. *Lithothamnium cymbicrusta* Johnson, n. sp.
D160	S259	a99–1a a99–2a		*Archaeolithothamnium chamorrosum* Johnson, n. sp. *Archaeolithothamnium saipanense* Johnson. n. sp.
D161	S271	a100–1a		*Corallina prisca* Johnson, n. sp.
D162	S287	a101–1a, a83–1a		*Lithothamnium* cf. *L. aggregatum* Lemoine.

[1] Specimens having USNM numbers are on Foraminifera slides.

TABLE 3.—*Field and permanent catalog numbers for fossil algae*—Continued

USGS paleobotanical locality	Field number on locality-finding map (pl. 4) [1]	USGS type algae [1]	Type of new species	Other figured specimens
D164	S318	a103–1a		*Lithophyllum* sp. A.
D165	S319	a104–1a		*Corallina prisca* Johnson, n. sp.
D166	S336	a105–1a		*Lithothamnium* cf. *L. abrardi* Lemoine.
D167	S339	a106–1a		*Microcodium* sp.?
D168	S341	USNM 624462		*Archaeolithothamnium saipanense* Johnson, n. sp.
D169	S342	a108–1a		*Lithothamnium* sp. A.
		a108–1b		*Corallina prisca* Johnson, n. sp.
D170	S471	a109–1a		*Lithophyllum* sp. A.
D171	S511	a110–1a		*Corallina neuschelorum* Johnson, n. sp.
D172	S585	USNM 624603		*Archaeolithothamnium taiwanensis* Ishijima.
D173	S604	a112–1a		*Melobesia? cuboides* Johnson, n. sp.
		a112–2a		*Lithothamnium* cf. *L. aggregatum* Lemoine.
		USNM 624735	*Archaeolithothamnium chamorrosum* Johnson, n. sp.	
D174	S677	a113–1a	*Archaeolithothamnium megasporum* Johnson, n. sp.	
		a113–1b		*Archaeolithothamnium megasporum* Johnson, n. sp.
D175	S103	a77–1a		*Jania* sp. A.
		a77–1b		*Lithothamnium* cf. *L. abrardi* Lemoine.
				Lithothamnium sp. E.
D177	B22			
D178	B29			
D179	B51			
D180	B53			
D181	B56	a115–1a		*Archaeolithothamnium oulianovi* Pfender.
D182	B61			
D183	B67	a116–1a		*Cymopolia pacifica* Johnson n. sp.
D184	B80			
D185	B88			
D186	B109			
D187	B150			
D188	B172	a133–1a		*Cymopolia saipania* Johnson, n. sp.
D189	B177	a7–1e		*Cymopolia delicata* Johnson, n. sp.
D190	B188			
D191	B192			
D192	B213			
D193	B267			
D194	B304			
D195	B312			
D196	B339			
D197	B354			
D198	B356			
D199	B358			
D200	B378			
D201	B399			
D202	C14			
D203	C21	a134–1a		*Lithothamnium wallisium* Johnson and Tafur.
D204	C23	a135–1a		*Dermatolithon saipanense* Johnson, n. sp.
D205	C47			
D206	C52			
D207	C54			
D208	C59			
D209	C80	a54–1c		*Lithothamnium tanapagense* Johnson, n. sp.
D210	C111			
D211	C125	a136–1a		*Lithophyllum prelichenoides* Lemoine.
D212	C144			
D214	S6			
D215	S24			
D216	S132			
D217	S194	a41–1a		*Lithothamnium crispithallus* Johnson, n. sp.
D218	S223			
D219	S262			
D220	S309	a102–1a, a102–1b, a102–1c		*Archaeolithothamnium* cf. *A. lugeoni* Pfender.
D221	S310	a90–1a		*Corallina prisca* Johnson, n. sp.
D222	S311			
D223	S338			
D224	S340			
D225	S345			
D226	S349	a88–1a		*Archaeolithothamnium oulianovi* Pfender.
D227	S359			
D228	S378			
D229	S421			
D230	S611			
D231	S691			*Porolithon onkodes* (Heydrich) Foslie.
D233	S337	a31–1a		*Lithothamnium marianae* Johnson, n. sp.
		a31–2a		*Lithothamnium* sp.
		a82–1a		*Lithoporella melobesioides* (Foslie) Foslie.
D277	C62	a43–1a		*Jania* sp. B.
D278	C128	a36–1a		*Jania* sp. B.
D378	B72	a33–1a		*Archaeolithothamnium* sp.
		a138–1a		*Lithophyllum* sp.
D380	S163	a26–1a, a26–1b		*Corallina prisca* Johnson, n. sp.
D381	B289			
D382	B329			
D383	B330	a21–1a, a21–2a		*Cymopolia pacifica* Johnson, n. sp.
D385	S251			*Lithoporella melobesioides* (Foslie) Foslie.
D433	Johnson coll. near B144.	a137–1a		*Lithoporella melobesioides* (Foslie) Foslie.
D435	Johnson coll. near S268.	a139–1a		*Lithothamnium* sp.
D438	S307			
D439	B135			
D440	B217			
D441	B301			
D442	C126			
D443	C133	a66–1a	*Paraporolithon saipanense* Johnson, n. gen., n. sp.	
D444	C137			
D445	C142			
D446	S687			

[1] Specimens having USNM numbers are on Foraminifera slides.

TABLE 4.—*Localities of collections of living material*

USGS paleobotanical locality	Ecology locality (see Cloud, 1956) or brief site description (unnumbered sites are Johnson's collections)	USGS type algae	Figured specimens
D176	Traverse *A*, station *1*	a114	*Lithophyllum kotschyanum* forma *subtilis* Foslie.
D213	Traverse *D*, station *7*	a98	*Lithophyllum kotschyanum* forma *typica* Foslie.
D260	Traverse *B*, station *1b*	a81	*Lithophyllum moluccense* forma *pygmaea* Foslie.
D261	Traverse *C*, station *7a*	a78, a78-1a	*Lithophyllum moluccense* forma *typica* Foslie.
D262	Traverse *D*, station *4*		
D263	Traverse *D*, station *5*		
D264	Traverse *D*, station *6*		
D266	Traverse *D*, station *8*		
D267	Near shore toward north end of fringing reef moat, western Saipan. Essentially ecology Loc. *8b*.	a74	*Goniolithon frutescens* Foslie.
D268	200 feet southwest of D267. Essentially ecology Loc. *8b*	a69	*Goniolithon frutescens* Foslie.
D269	Northwest coast of Saipan (grid area V-38 on locality map)	a62	*Lithophyllum moluccense* forma *flabelliformis* Foslie.
D270	Reef patch at east side of Mañagaha Islet, Tanapag lagoon	a56	*Halimeda opuntia* forma *triloba* Barton.
D271	Outer edge of barrier reef southwest of ecology Loc. *Fx*	a58	*Halimeda gracilis* Harvey.
D272	Loc. *8*	a61	*Porolithon onkodes* (Heydrich) Foslie.
D273	Fringing reef at Fañunchuluyan beach, northeast Saipan. Essentially ecology Loc. *9*.	a49	*Goniolithon reinboldi* Weber van Bosse and Foslie.
D274	Reef at Obyan Point. Specific data lacking	a50, a50-1a	*Porolithon craspedium* (Foslie) Foslie.
D279	Southeast coast of Saipan. Specific data lacking	a37	*Amphiroa* sp.
D437	Inner edge of barrier reef near ecology Loc. *Fx*	a57	*Halimeda gracilis* Harvey forma *lata* Taylor.

SYSTEMATIC DESCRIPTIONS

RHODOPHYTA (RED ALGAE)

Family CORALLINACEAE (coralline algae)

Subfamily MELOBESIOIDEAE (crustose corallines)

Characteristically the plants are strongly calcified. They show a great variety of growth forms. Some consist of a single layer of cells; others form multilayered crusts more than a centimeter thick. The crusts may be smooth, covered by protuberances, or branched. Some species develop loose branches or aggregates of branches. A key to the tribes and genera follows.

Key to the tribes and genera of crustose coralline algae

I. Sporangia not collected into conceptacles (tissue many layered, with hypothallus and perithallus)—*Archaeolithothamnium.*

II. Sporangia collected into conceptacles.
- A. Roof of sporangial conceptacles perforated by few to many pores (thallus self-sustaining, not parasitic)—Tribe Lithothamnieae.
  - 1. Hypothallus a single layer of cells, at least in part; thallus epiphytic. Hypothallic cells in section are square or somewhat elongated horizontally—*Melobesia.*
  - 2. Hypothallus of many layers of cells.
    - a. Hypothallus coaxial (arched rows or layers of cells—*Mesophyllum.*
    - b. Hypothallus of curved rows of cells.
      - (1). Sporangial conceptacles superficial or subimmersed—*Lithothamnium.*
      - (2). Sporangial conceptacles deeply immersed—*Clathromorphum.*
- B. Roof of sporangial conceptacles perforated by a single pore—Tribe Lithophylleae.
  - 1. Megacells present.
    - a. Hypothallus consists of single layer of cells.
      - (1). Hypothallic cells vertically and obliquely elongated—*Hydrolithon.*
      - (2). Hypothallic cells square or nearly so—*Fosliella.*
    - b. Hypothallus of several to many layers of cells.
      - (1). Megacells in lenses or horizontal clusters—*Porolithon.*
      - (2). Megacells singly or in vertical rows—*Goniolithon.*
      - (3). Megacells in both horizontal and vertical clusters—*Paraporolithon.*
  - 2. Megacells absent.
    - a. Hypothallus composed of cubic cells.
      - (1). Thallus of several layers of cells—*Heteroderma.*
      - (2). Thallus of many layers of cells, not epiphytic—*Lithophyllum.*
    - b. Hypothallus of one or two layers of obliquely elongated cells.
      - (1). Thallus characteristically epiphytic or epizoic commonly expanding locally to two or more layers with perithallic cells nearly equidimensional—*Dermatolithon.*
      - (2). Thallus prostrate, epiphytic or epizoic often superimposed—single layered except immediately around conceptacles. Cells vertically elongated—*Lithoporella.*

Genus ARCHAEOLITHOTHAMNIUM Rothpletz, 1891

This genus, like most of the other genera of crustose coralline algae, has a tissue containing both a hypothallus and a perithallus. Commonly the hypothallus is thin as compared with the perithallus. The characteristic and most easily recognized generic feature is that the sporangia are not segregated in conceptacles but are distributed in lenses or layers throughout the tissue (pl. 37, fig. 10 and pl. 38).

Archaeolithothamnium reached its zenith during the Late Cretaceous and Eocene. Since then it has gradually declined, although about a dozen species still survive in the present warm seas. In most regions it forms an important element of the Eocene algal floras; consequently, it was a surprise to find it only sparingly represented in the Eocene material from Saipan.

In Saipan collections it occurs most abundantly in the limestones of Miocene age where many fragments and a number of large crusts were observed. Only 7 specimens belonging to 2 species were noted in the limestones of Pleistocene(?) age.

The species of the genus *Archaeolithothamnium* may be roughly separated into three divisions on the basis of growth form. These divisions are (1) simple crusts usually thin, (2) crusts with warty protuberances or mammillae (in some species, the crusts are most of the plant and the protuberances are of less importance; in others, the crust is merely the introductive growth from which develop large and much more important protuberances), and (3) truly branching forms (not found on Saipan). These usually develop in a more or less rounded mass consisting of irregular branches radiating from the center. The branches are normally fairly long and irregular. Commonly they have blunt or nearly blunt ends. In longitudinal section they may show a well-formed medullary hypothallus.

Of these, division 1 is by far the most common and includes about two-thirds of the Saipan species. Division 2 comes next, while species belonging to division 3 are very rare and are not represented in the Saipan collections.

Table 5 illustrates their range of characteristics and observed locality distribution.

TABLE 5.—*Measurements (in microns) and distribution of Saipan species of* Archaeolithothamnium [1] *(based on random sections)*

[Dimensions in mu (1μ=0.001 mm)]

Species	Hypothallus cells		Perithallus cells		Sporangia		USGS paleobotanical localities	Age
	Length	Width	Length	Width	Height	Diameter		
Division 1—Simple crusts (ordinarily thin—in some instances with many layers superimposed)								
A. chamorrosum Johnson, n. sp.	19–30	10–14	10–17	10–15	30–64	30–37	D160, D173	Eocene.
cf. *A. fijiensis* Johnson and Ferris	10–16	8–13	9–16	7–12	80–127	45–80	D134	Miocene.
lauense Johnson and Ferris	Absent	----------	12–17	9–12	137–182	72–107	D112	Miocene.
megasporum Johnson, n. sp.	13–15	8–12	12–19	9–12	130–155	81–85	D174	Pleistocene.
oulianovi Pfender	10–16	6–10	9–14	7–10	46–90	32–63	D125, D181, D226	Eocene.
puntiense Airoldi	10–17	6–11	8–14	6–12	76–92	40–61	D102, D115	Pleistocene.
taiwanensis Ishijima	9–11(?)	9–12	7–14	8–12	55–80	40–65	D116, D118, D172, D212	Miocene.
Division 2—Crusts with warty protuberances or mammillae								
A. cf. *A. liberum* Lemoine	----------	----------	12–27	9–15	45–70	12–27	D123, D159	Eocene.
cf. *A. lugeoni* Pfender	13–21	7–14	10–18	9–15	60–80	33–65	D220	Miocene.
myriosporum Johnson, n. sp.	11–20	9–16	8–25	11–17	40–65	28–54	D93, D150, D228	Miocene.
saipanense Johnson, n. sp.	11–17	8–13	(6)9–16	9–12	70–140	50–90	D157, D160, D168, D173, D180	Eocene.

[1] Division 3—Highly branching forms are not represented in Saipan collections.

Division 1—Simple crusts

Archaeolithothamnium chamorrosum Johnson, n. sp.

Plate 39, figures 3, 6

Description.—Thallus crustose may encrust or enclose various objects. Tissue fairly regular in texture, with suggestions of growth zones in some specimens. Hypothallus thin to moderately developed, consisting of curved rows of rectangular cells which measure 18μ–30μ in length by 10μ–14μ in width. Perithallus formed of regular rows of rectangular cells, 10μ–15μ by 9μ–16μ. Side walls distinct, but cross partitions thin. Sporangia commonly oval, but some spherical, 29μ–37μ in diameter and 30μ–64μ in height.

Remarks.—This species is similar to *A. hemchandrai* K. S. Rao from India, but differs in having larger cells and smaller sporangia.

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation and pink facies of Matansa limestone. USGS paleobotanical localities D160 and D173.

Holotype.—USNM 624735 (Foraminifera slide).

Archaeolithothamnium cf. A. fijiensis Johnson and Ferris

Plate 47, figures 4, 5

Archaeolithothamnion fijiensis Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 10, pl. 1, figs. B, C, E.

Description.—Thallus forms an irregular crust. Hypothallus moderately developed, consisting of horizontal to curved rows of cells which measure 10μ–16μ by 8μ–13μ. Perithallus tissue fairly regular, with pronounced vertical rows of cells. Vertical partitions well defined, horizontal partitions ordinarily thin cells 9μ–16μ by 7μ–12μ. Sporangia rounded, characteristically about 1½ times higher than wide. Dimensions 80μ–127μ high and 45μ–80μ wide.

Remarks.—In shape and dimensions of cells and sporangia, the specimens here considered closely resemble *A. fijiensis* from the Miocene. They do not, however, show the irregular and contorted areas of perithallic tissue that characterize the typical form. Fragments and thin crusts referred to this species occur in a number of the Saipan slides.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D134.

Archaeolithothamnium lauense Johnson and Ferris

Plate 46, figure 7

Archaeolithothamnion lauensum Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 11, pl. 1, figs. A, D.

Description.—Thallus crustose; hypothallus thin or absent. Perithallus forms a regular compact tissue. Cells 12μ–17μ by 9μ–12μ. Sporangia egg shaped, 137μ–182μ in height, 72μ–107μ in diameter, closely packed in a well-defined layer.

Remarks.—In general appearance of the tissue and cell dimensions, *A. lauense* is very close to *A. fijiensis* but differs decidedly in the size of the sporangia. With heights of 140μ–200μ, they are the largest of any Tertiary species of the genus and are the most distinctive feature of this species. The one specimen observed agrees in all respects with the type material from the Miocene of Lau, Fiji.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D112.

Archaeolithothamnium megasporum Johnson, n. sp.

Plate 53, figures 1, 2

Description.—Thallus a thin irregular crust usually less than half a centimeter thick. Surface probably warty. Hypothallus thin, consisting of only a few irregular layers of cells 13μ–15μ by 8μ–12μ. Perithallus formed of rows of cells with well-defined vertical partitions and poorly defined horizontal partitions. Cells 12μ–19μ by 9μ–12μ. Sporangia large, oval to round, crowded into irregular zones or lenses. Size 130μ–155μ in height by 81μ–85μ in diameter.

Remarks.—This species is similar to *A. lauense* Johnson and Ferris, known from the Miocene of Fiji and also found on Saipan. It differs slightly in all dimensions and in size and arrangement of sporangia, which are in well-defined rows in *A. lauense* instead of the irregular zones or lenses of the present species.

Occurrence.—Pleistocene, rubbly facies of Mariana limestone. USGS paleobotanical locality D174.

Holotype.—USGS algae a113–1a.

Archaeolithothamnium oulianovi Pfender

Plate 38, figure 5; plate 39, figures 4, 5

Archaeolithothamnion oulianovi Pfender, 1926, Soc. española historia nat. Bol., v. 26, p. 325, pl. 10.

Description.—Thallus develops a thin crust, 350μ–500μ thick, composed of irregular rows of cells and with sporangia irregularly disposed throughout the tissue. Hypothallus poorly developed, 55μ–75μ thick, consisting of a few layers of irregular cells. Layers ordinarily oblique to base. Cells measure 6μ–10μ by 10μ–16μ. Perithallus does not show regular pattern characteristic of most species of *Archaeolithothamnium*. Shows irregular growth zones each formed of rows of cells with poorly developed horizontal partitions, which are not at the same level in adjoining rows. Cells measure 7μ–10μ by 9μ–14μ. Sporangia circular to oval, measure 46μ–90μ in height and 32μ–63μ in diameter. Occur isolated or in clusters in the tissue but not in regular rows.

Remarks.—This species is distinctive because of the irregular development of the perithallus, which suggests *Lithothamnium* rather than normal *Archaeolithothamnium*, and because of the very irregular arrangement of the sporangia. The Saipan specimens fit Pfender's description except that they show less range in length of the cells of the hypothallus.

Occurrence.—Upper Eocene, white and transitional facies of Matansa limestone. USGS paleobotancial localities D125, D181, and D226. Previously described from the Eocene of Spain.

Archaeolithothamnium puntiense Airoldi

Plate 53, figures 3, 4

Archaeolithothamnion puntiense Airoldi, 1933, Palaeontographia Italica, Mem. Paleont., v. 33 (new ser. v. 33), p. 83, pl. 7, fig. 1.

Description.—Thallus forms irregular crusts. May develop one upon another to form an irregular incrustation over a centimeter thick. Hypothallus thin, consists of a few rows of irregular cells 11μ–17μ by 6μ–11μ. Perithallus consists of fairly regular rows of cells, with vertical partitions more pronounced than the horizontal. Cells of perithallus rectangular 9μ–11μ by 7μ–11μ, with suggestions of thin irregular growth zones. Sporangia mostly long oval; some subquadrate with rounded corners, 76μ–92μ in height and 40μ–61μ in diameter.

Remarks.—In dimensions and detailed appearance in section, the specimens described from Saipan compare closely with the description and sketch of Airoldi's species from Somaliland and are regarded as conspecific with it. The cell dimensions and size of sporangia are close to those of the modern *A. sibogae* described by Weber Van Bosse and Foslie from the East Indies, but the growth habit is entirely different. *A. sibogae* has prominent long branches.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS Paleobotanical localities D102 and D115.

Archaeolithothamnium taiwanensis Ishijima

Plate 46, figures 4–6

Archaeolithothamnion taiwanensis Ishijima, 1942, Taiwan Tijaku Kizi, v. 13, no. 4, p. 2, fig. 2.

Description.—Thallus a thin crust which may encrust other organisms, or several superimposed thalli may form irregular mass. Hypothallus thin or absent, consisting at most of only a few irregular rows of cells. Cell measurements approximate 9μ–11μ by 9μ–12μ. Perithallus formed of regular rows of rectangular cells 7μ–14μ by 8μ–12μ. In most specimens vertical partitions better defined than the horizontal. Sporangia round-ovoid, 55μ–80μ in height and 40μ–65μ in diameter, moderately spaced in well-defined rows. Following table gives measurements in microns of four specimens found in random sections (two are figured).

USGS paleobotanical locality	Hypothallus cells		Perithallus cells		Sporangia	
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	Diameter (in μ)	Height (in μ)
D172	?	6 x 8	7–12	8–11	72–82	52–63
D116	10–12	?	9–12	8–12	65–81	55–56
D118	Absent		11–14	10–12	72–80	57–65
D212	9–11	9–12	7–13	8–9	52–61	35–41
Range	9–11	9–12	7–14	8–12	52–82	40–65

Remarks.—Ishijima's brief description of this species gives only generalized dimensions of the cells and the sporangia, and his illustration is poor. However, an examination of the type indicates it to be the same species as the abundant Saipan material here described, the apparently thick crust formed by Ishijima's type really consisting of several superimposed thalli. Although the general dimensions and appearance of the tissue in slides strongly resembles the modern *A. ertythraeum* Rothpletz, there is little evidence of the many strong warty surface projections which characterize the modern species. *A. taiwanesis* is the commonest Miocene *Archaeolithothamnium* in the Saipan collection.

Occurrence.—Lower Miocene, inequigranular and granular facies of Tagpochau limestone. USGS paleobotanical localities D116, D118, D172, and D212.

Division 2—Crusts with warty protuberances or mammillae

Archaeolithothamnium cf. A. liberum Lemoine

Plate 39, figures 1, 2

Archaeolithothamnium liberum Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 61, pl. 1, fig. 14, fig. 26, p. 62.

Description.—Thallus nodular, probably mammillated, apparently growing free on the bottom. Hypothallus absent or very poorly developed. Perithallus shows a fairly regular tissue composed of rows of rectangular cells with well-developed side walls but poorly developed horizontal partitions near top and bottom of thallus. Cells measure 9μ–15μ by 12μ–27μ. Sporangia oval, 45μ–70μ in height and 31μ–56μ in diameter, and occur moderately spaced in well-defined rows.

Remarks.—Represented by two specimens which closely resemble Lemoine's species from Algeria in growth habit and general appearance of the tissue although differing slightly in cell dimensions.

Occurrence.—Upper Eocene, transitional facies of Matansa limestone and limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D123 and D159.

Archaeolithothamnium cf. A. lugeoni Pfender

Plate 47, figures 1–3

Archaeolithothamnion lugepni Pfender, 1926, Soc. española historia nat. Bol., v. 26, p. 324, pls. 9, 12.
Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, figs. 14, 15.

Description.—Thallus appears to develop as a mammillated crust, possibly a nodular mass composed of superimposed thalli. Hypothallus well developed, formed of curved rows of cells 13μ–21μ by 7μ–14μ. Perithallus of regular rows of cells 10μ–18μ by 9μ–15μ. Sporangia abundant, egg shaped, in regular rows, 60μ–80μ in height and 33μ–65μ in diameter.

Remarks.—This form closely resembles *A. lugeoni* Pfender in appearance, growth habit, size of perithallic cells, and sporangia. It does not exactly fit the cell dimensions of that species, however.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D220.

Archaeolithothamnium myriosporum Johnson, n. sp.

Plate 46, figures 1–3

Description.—Crust with mammilae or short thick branches. Hypothallus absent or poorly developed; cells measure approximately 11μ–20μ by 9μ–16μ. Perithallus tissue regular; cells 8μ–25μ by 11μ–17μ. Sporangia abundant, closely packed in regular rows, 40μ–65μ in height and 28μ–54μ in diameter. Measurements of selected specimens are given below.

USGS paleobotanical locality	Hypothallus cells		Perithallus cells		Sporangia	
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	Diameter (in μ)	Height (in μ)
D93	----------	12–16	8–25	12–17	40–24	28–38
D228	17–22	(?)	10–17	11–13	49–53	28–49
D150	11–20	9–16	9–16	11–16	57–65	31–54

Remarks.—This species closely resembles material described by Lignac-Grutterink from the Miocene of the Dutch East Indies under the name *A. affine* Howe but differs in having smaller sporangia. In the Saipan specimens, the sporangia are more abundant and more closely packed. It is quite different from the Oligocene *A. affine* described by Howe from the West Indies, which shows a distinct medullary hypothallus in the branches having a tissue with alternating rows of cells of different lengths. Neither of these features occurs in *A. myriosporum*. This is one of the most distinctive of the Miocene species observed by the writer. It is also one of the most abundant in the Saipan collections.

Occurrence.—Lower Miocene, inequigranular and marly facies of Tagpochau limestone. USGS paleobotanical localities D93, D150, and D228.

Holotype.—USGS algae a6–1a.

Archaeolithothamnium saipanense Johnson, n. sp.

Plate 38, figures 1–4, 6

Description.—Thallus develops a thick crust, probably with mammelons. Tissue regular, with many regularly spaced rows of sporangia. Hypothallus thin (13μ–20μ), ordinarily of only a few curved rows of cells 8–13μ by 11–17μ. Perithallus 0.9–6 mm thick; tissue regular, consisting of rows of rectangular cells with well-defined and regularly spaced horizontal and vertical walls, cells (6) 9–16μ by 9–12μ. Sporangia elliptical to nearly circular in section, commonly abundant and closely packed. In a few specimens where sporangia are sparse they tend to be more nearly circular and widely spaced.

Remarks.—This species is characterized by small nearly square cells and relatively large sporangia. In general appearance of the tissue and growth habit, it suggests *A. intermedium* Raineri and *A. nummuliticum* (Gümbel) Rothpletz, but differs in cell dimensions and size of sporangia. Lignac-Grutterink (1943, p. 287) described a variable form from the Dutch East Indies under the name *A. intermedium* Raineri, one Eocene specimen of which is very similar to this species.

Occurrence.—Upper Eocene, white and pink facies of Matansa limestone and limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D157, D160, D168, D173, and D180.

Holotype.—USGS algae a95–1a.

Tribe LITHOTHAMNIEAE

Genus LITHOTHAMNIUM Philippi, 1837

Lithothamnium has a tissue formed of many layers of cells which normally are differentiated into a hypothallus and a perithallus. Commonly the hypothallus consists of curved rows of cells, but in a few species it has a coaxial development similar to that common in the genus *Lithophyllum*. The conceptacles are characterized by many openings in the roof.

Lithothamnium occurs abundantly in the Cenozoic limestones on Saipan. It is represented by 30 species, most of which are encrusting forms.

For convenience, the species are arranged in four divisions based on growth habit.

Division 1—Simple crusts.
Division 2—Free (unattached) crusts.
Division 3—Crusts with warty protuberances or mammillae.
Division 4—Strongly branching forms.

The dimensions and distribution of the species occurring on Saipan are given in the following table.

TABLE 6.—*Measurements (in microns) and distribution of Saipan species of* Lithothamnium *(from random sections)*

Species	Hypothallus cells		Perithallus cells		Conceptacle		USGS paleobotanical localities	Age
	Length	Width	Length	Width	Diameter	Height		
Division 1—Simple crusts (commonly thin—many may occur superimposed)								
L. cf. *L. abrardi* Lemoine	16–39	9–18	9–30	8–13	-----	-----	D142, D151, D166, D175, D223	Eocene.
cf. *L. aggregatum* Lemoine	12–26	7–15	8–24	10–16	-----	-----	D148, D162, D173	Eocene.
cf. *L. bourcarti* Lemoine	11–28	7–10	14–18	8–10	-----	-----	D121, D122, D202	Miocene.
cf. *L. engelhartii* Foslie	17–23	5–7	8–12	9–11	210+	133	D133	Pleistocene.
cf. *L. fumigatum* Foslie	9–11	6–9	6–10	6–9	427	142	D153	Miocene.
funafutiense Foslie	-----	-----	6–14	6–9(13)	540–600	220–230	D129	Pleistocene.
ladronicum Johnson, n. sp	20–23	7–12	9–13	7–9	403	125	D98	Miocene.
lichenoides (Ellis and Sollander Foslie	40–62	6–14	7–23	7–12	390–527+	-----	D133	Pleistocene.
cf. *L. nanosporum* Johnson and Ferris	10–22	10–18	10–20	10–18	102–204	62–92	D106, D107	Eocene.
saipanense Johnson, n. sp	11–35	9–15	8–12	6–11	492	114	D127	Miocene.
subtile Conti	17–21	11–14	12–14	10–11	214–271	90–117	D122, D186	Miocene.
tagpotchaense Johnson, n. sp	14–18	10–12	13–20	6–11	300±	140–150	D144	Eocene.
tanapagense Johnson, n. sp	-----	-----	14–25	12–18	295–375	116–142	D130, D209	Pleistocene.
sp. B	8–15	9–12(16)	12–20	9–15	260	87	D141	Miocene.
sp. D	22–27	12–16	11–20	12–16	450+	240	D149	Miocene.
Division 2—Free crusts								
L. crispithallus Johnson, n. sp	9–15	8–13	6–16	6–12	279–685	125–160	D143, D145, D152, D217	Eocene.
sp. A	13–18	7–10	6–12	8–10	Unknown	Unknown	D148, D169, D175	Eocene.
Division 3—Crusts with warty protuberances or mammillae								
L. cf. *L. aucklandicum* Foslie	18–28	9–13	8–10	6–8	205–312	125–145	D103	Pleistocene.
cf. *L. crispatum* Hauck	14–19	7–9	10–13	8–10	174–220	80–100	D122	Miocene.
cymbicrusta Johnson, n. sp	12–13	8–12	6–16	8–11	304–425	100–185	D147, D151, D154, D159	Eocene.
cf. *L. disarmonicum* Conti	11–15	11–13	11–18	10–12	392	179	D128	Miocene.
cf. *L. mirabile* Conti	25–30	10–17	12–17	10–15	424–490	180–192	D96	Miocene.
moreti Lemoine	11–15	7–11	7–9	7–8	327	106	D124	Eocene.
undulatum Capeder	11–17	6–8	7–17	7–8	-----	-----	D135	Miocene.
wallsium Johnson and Tafur	-----	-----	8–19	7–11(17)	195–360	113–135	D125, D155, D203	Eocene.
sp. C	12–15	8–12	10–22	8–16	442	175	D124	Eocene.
Division 4—Strongly branching forms								
L. cf. *L. lecroixi* Lemoine	12–20	7–9	8–13	8–11	250–650	60–90	D122	Miocene.
cf. *L. madagascariense* Foslie	9–20	9–12	-----	-----	213–235	-----	D131	Pleistocene.
marianae Johnson, n. sp	13–20	10–12	10–24	7–13	270–686	135–190	D142, D143, D161, D223, D225, D233.	Eocene.
sp. E	23–53	9–14	-----	-----	-----	-----	D175	Eocene.

Division 1—Simple Crusts

Lithothamnium cf. L. abrardi Lemoine

Plate 41, figures 6, 7; plate 42, figures 1, 5

Lithothamnion abrardi Lemoine, 1934, Czechoslovakia, Statní Geol. Ústav, Věstník r. 9, c. 5, p. 274, fig. 3.

Description.—Thallus a thin crust, composed of a well-developed hypothallus and a poorly developed perithallus. Hypothallus of curved rows of irregular rectangular cells measuring 16μ–39μ in length and 9μ–18μ in width. Perithallus thin, consisting of rectangular cells 9μ–30μ high and 8μ–13μ wide in moderately regular rows. Conceptacles not observed.

Remarks.—The cell dimensions, appearance, and growth habit agree very closely with specimens described as *L. abrardi* by Lemoine (1934, p. 274) from the Carpathian region of central Europe and from Algeria. Because conceptacles are absent in the specimens studied, it seems advisable to class the material only provisionally with Lemoine's species.

Occurrence.—Upper Eocene, conglomerate-sandstone facies of Hagman formation, limestone-conglomerate facies of Densinyama formation, and pink facies of Matansa limestone. USGS paleobotanical localities D142, D175, D151, D166, and D223.

Lithothamnium cf. L. aggregatum Lemoine

Plate 40, figures 2, 4

Lithothamnion aggregatum Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 66, pl. 1, fig. 12, fig. 27, p. 79.

Description.—Thallus encrusting, several superimposed thalli may form a crust. Hypothallus slightly to moderately developed, consisting of curved rows of round to rectangular cells 12μ–26μ by 7μ–15μ. Several examples of secondary hypothalli forming scar tissue were observed. Perithallus 330μ–500μ thick; tissue regular with distinct horizontal and vertical partitions between the cell rows; cells 8μ–24μ by 10μ–16μ. Conceptacles unknown.

Remarks.—In growth habit and cell dimensions, this species closely resembles *L. aggregatum* described by Lemoine from the Oligocene of Algeria. In the absence of conceptacles it is inadvisable to make a firm specific assignment. The form described, however, is abundant in the Saipan collections.

Occurrence.—Upper Eocene, pink and transitional facies of Matansa limestone and limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D148, D162, and D173.

Lithothamnium cf. L. bourcarti Lemoine

Plate 49, figure 5

Lithothamnion bourcarti Lemoine, 1923, Soc. géol. France Bull., ser. 4, v. 23, p. 277–279, fig. 3.

Description.—Thallus forms a crust of well-developed hypothallus and perithallus. Hypothallus about 0.1 mm thick, formed of curved rows of cells 11μ–28μ by 7μ–10μ. Perithallus tissue regular, cells 14μ–18μ by 8μ–10μ. No conceptacles observed.

Remarks.—Lemoine (1923) described *L. bourcarti* from the Miocene of Albania as a basal crust from which developed long branches. This fragment of a crust from Saipan exactly fits Lemoine's description of the basal crust. However, without a knowledge of the branches (if any) and conceptacles, it is not possible to be sure that they belong to the same species.

Occurrence.—Lower Miocene, tuffaceous and inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D121, D122, and D202.

Lithothamnium cf. L. engelhartii Foslie

Plate 53, figure 8

Lithothamnion engelhartii Foslie, 1900, K. norske vidensk. selsk. Skr., no. 5, p. 18.
Foslie and Printz, 1929, K. norske vidensk, selsk, Museet. Mon., p. 40, pl. 7, figs. 12–18.

Description.—Thalli form thin crusts, which may grow one upon another to form a thick mass. Hypothallus prominent with strongly curved, almost coaxial cell rows; cells 17μ–23μ by 5μ–7μ. Perithallus thin, composed of cells 8μ–12μ by 9μ–11μ. Conceptacle 210μ by 133μ, which probably does not indicate total diameter.

Remarks.—The illustrated specimen is the only one found in the Saipan collection, but this consists of several superimposed thalli. The growth habit, poor development of the perithallus, dimensions of hypothallic cells, and small size of conceptacles agree with Foslie's description of *L. engelhartii*, but he does not give dimensions of the perithallic cells.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D133.

Lithothamnium cf. L. fumigatum Foslie

Plate 47, figure 8

Lithothamnion fumigatum Foslie, 1901, K. norske vidensk. selsk. Skr., no. 6, p. 7.
Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 41, pl. 4, figs. 1–2.

Description.—Thallus a thin crust, with a moderately developed hypothallus and relatively thick perithallus. Hypothallus irregular, consisting of curved rows of rounded cells 9μ–11μ by 6μ–9μ. Perithallus formed of regular rows of small rectangular cells 6μ–10μ by 6μ–9μ. Conceptacle 427μ by 142μ.

Remarks.—In growth habit and conceptacle size, this form strongly suggests the modern *L. fumigatum* Foslie, differing only in having slightly larger cells.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D153.

Lithothamnium funafutiense Foslie

Plate 54, figure 3

Lithothamnion funafutiense Foslie, 1900, K. norske vidensk. selsk. Skr., no. 1, p. 5.
Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 41, pl. 12, figs. 3, 4.

Description.—Thallus an irregular crust. Hypothallus absent. Perithallus a fairly regular dense tissue with cells 6μ–14μ by 6μ–9μ. Conceptacles flattened, 540μ–600μ in diameter and 220μ–230μ in height.

Remarks.—Represented in the Saipan collection by a few fragments of irregular crusts in which the hypothallus is absent or badly abraded. In growth habit, cell dimensions, and size of conceptacles, it closely fits Foslie's description.

Occurrence.—Pleistocene, *Halimeda*-rich facies of Mariana limestone. USGS paleobotanical locality D129.

Lithothamnium ladronicum Johnson, n. sp.

Plate 47, figure 9

Description.—Thallus a thin crust. Hypothallus about half of the crust, consisting of curved rows of rounded cells 20μ–23μ by 7μ–13μ. Perithallus shows distinct growth zones, cells 9μ–13μ by 7μ–9μ. Conceptacles hemispherical, 403μ in diameter and 125μ in height.

Remarks.—This species strongly suggests the modern *L. lemniscatum* Foslie but has smaller hypothallic cells and a slightly more strongly developed hypothallus.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D98.

Holotype.—USGS algae a12–1a.

Lithothamnium lichenoides (Ellis and Sollander) Foslie

Plate 54, figure 1

Lithophyllum lichenoides Ellis and Sollander. Philippi, 1837, Archiv. fur Naturgeschichts herausgegeben von Dr. Wiegmann, Band 3, p. 389.
Lithothamnium lichenoides (Ellis and Sollander). Heydrich, 1897, Deutsche Bot. Gesell. Ber., Band 15, p. 412.
Foslie, 1900, K. norske vidensk. selsk. Skr., no. 5, p. 12.
Lithothamnion lichenoides (Ellis and Sollander). Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 43.

Description.—Thallus a thin crust of rather irregular tissue. Both hypothallus and perithallus show unusual range in cell dimensions. Hypothallus cells 40μ–62μ long by 6μ–14μ wide. Perithallus cells 7μ–23μ by 7μ–12μ. Conceptacles 390μ–525μ in diameter, which, however, probably does not represent the maximum diameter.

Remarks.—Represented in the Saipan collection by several poor specimens. The most remarkable thing about the species is the great range in cell size. The Saipan specimens fall within the range of variation indicated in Foslie's quite loose description.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D133

Lithothamnium cf. L. nanosporum Johnson and Ferris

Lithothamnion nanosporum Johnson and Ferris, 1949, Jour. Paleontology, v. 23, no. 2, p. 194, pl. 37, fig. 2.

Description.—Thallus a thick crust, consisting of a poorly developed hypothallus and a well-developed perithallus. Hypothallus formed of a few curved rows of rounded rectangular cells about the same size as those of the perithallus. Perithallus composed of regular rows of rectangular cells measuring 10μ–20μ. Conceptacles numerous, small, 102μ–204μ in diameter, and 62μ–92μ in height.

Remarks.—In appearance and growth habit this form is very similar to *L. nanosporum* from the Eocene of Borneo. It differs slightly in cell dimensions, and in having a poorly developed hypothallus.

Occurrence.—Upper Eocene, white facies of Matansa limestone. USGS paleobotanical localities D106 and D107.

Lithothamnium saipanense Johnson, n. sp.

Plate 49, figure 3

Description.—Thallus a thin crust with a well-developed hypothallus and a moderate perithallus. Hypothallus consists of curved rows of cells 11μ–35μ by 9μ–15μ. Perithallus contains regular rows of cells 8μ–12μ by 6μ–11μ. Conceptacle 492μ by 114μ.

Remarks.—This species suggests *Lithothamniun* sp. C described from the upper Eocene of Saipan but differs in the nature of the hypothallus and somewhat in cell dimension.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D127.

Holotype.—USGS algae a48–2a.

Lithothamnium subtile Conti

Plate 47, figures 6, 7; plate 1, figure 8

Lithothamnion subtile Conti, 1943, Palaeontographia Italica, Mem. Palaeont., v. 41 (new ser. v. 11), p. 49, pl. 6, fig. 1.

Description.—Thallus a thin, regular crust. Sometimes several thalli are superimposed. Hypothallus plumose, well developed, consists of strongly curved rows of cells 17μ–21μ by 11μ–14μ. Perithallus rather thin, irregular around conceptacles; cells 12μ–14μ by

10μ–11μ. Conceptacles relatively short and high, 214μ–271μ in diameter and 90μ–117μ in height.

Remarks.—In growth habit, general appearance, nature of hypothallus, perithallus, and conceptacles, as well as dimensions of perithallic cells and conceptacles, the figured specimen from locality D122 (C4) agrees with Conti's description and drawings. The hypothallic cells of the Saipan specimen are slightly longer.

The specimen from D186 (B109) agrees with Conti's species in appearance of tissue, cell dimensions, and size of conceptacles, but differs in growth form. The Saipan species develops short stubby branches, while the Mediterranean form was described as a thin crust.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D122 and D186.

Lithothamnium tagpotchaense Johnson, n. sp.

Plate 37, figure 7; plate 39, figure 7

Description.—Thallus thin, encrusting. Hypothallus thin, but distinct, consisting of 5 or 6 rows of rounded cells 14μ–18μ by 10μ–12μ. Perithallus irregular; vertical partitions of cell rows distinct; horizontal partitions not well defined; cells 13μ–20μ by 6μ–11μ. Conceptacles about 300μ in diameter and 140μ–150μ in height.

Remarks.—Resembles *L. cymbicrusta* Johnson, n. sp., but differs in structure of hypothallus and cell dimensions.

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation. USGS paleobotanical locality D144.

Holotype.—USGS algae a75–1a.

Lithothamnium tanapagense Johnson, n. sp.

Plate 53, figures 6, 7; plate 54, figure 2

Description.—Thallus a thin crust, ordinarily less than 350μ thick. Hypothallus absent or limited to a row of cells. Perithallus consists of well-defined rows of rectangular cells elongated horizontally, 14μ–25μ long and 12μ–18μ high. Conceptacles strongly arched, 295μ–375μ in diameter, 116μ–142μ in height.

Remarks.—In growth habit, cell dimensions, and size of conceptacles, this species suggests *L. fragilissimum* Foslie. It differs decidedly, however, in the development of the hypothallus, *L. fragilissimum* having a thick coaxial hypothallus.

Occurrence.—Pleistocene, Tanapag limestone and massive facies of Mariana limestone. USGS paleobotanical localities D130 and D209.

Holotype.—USGS algae a54–1b.

Lithothamnium sp. B

Plate 40, figure 5

Description.—Thallus thin, encrusting. Hypothallus poorly developed or absent, consisting at most of a few curved rows of irregular cells that measure 8μ–15μ in length and 2μ–12μ in width. Perithallus of rather irregular layers of cells, 12μ–20μ long and 9μ–15μ wide. Conceptacles 260μ in diameter and 87μ in height.

Remarks.—In habit and appearance, this species belongs in the same group as *L. aggregatum* Lemoine from the Oligocene of Algeria and *L. leptum* Johnson and Ferris from the Miocene of Fiji. It differs from the latter in having smaller conceptacles and slightly different cell dimensions. *L. aggregatum* has relatively longer, narrower cells and larger conceptacles.

Occurrence.—Lower Miocene, marly facies of Tagpochau limestone. USGS paleobotanical locality D141.

Lithothamnium sp. D

Plate 48, figure 1

Description.—Crustose thallus consists of a well-developed hypothallus and perithallus. Hypothallus almost coaxial. Cells rectangular 22μ–27μ by 12μ–16μ. Perithallus rather irregular, cells 11μ–20μ by 12μ–16μ. Conceptacles have a diameter of at least 450μ, height 240μ.

Remarks.—This form was observed on only one slide which may cut the crust obliquely. The well-developed almost coaxial hypothallus combined with the irregular perithallic tissue is distinctive; but without certain conceptacle size, and with the cell measurements not certain, it seems inadvisable to propose a formal specific name.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D149.

Division 2—Free Crusts

Lithothamnium crispithallus Johnson, n. sp.

Plate 42, figures 6–8

Description.—Thallus slender, curved, branching, sometimes hooked, apparently attached at first then growing free. Hypothallus well-developed, 90μ–125μ thick, consisting of curved rows of cells 9μ–15μ by 8μ–13μ. Perithallus thin but irregular, thickening around conceptacles. Cells rectangular 6μ–16μ by 6μ–12μ. Conceptacles large, wide, and flattened, 279μ–685μ in diameter, 125μ–160μ in height. Slides show considerable range in diameter of conceptacle, probably because many do not cut through center. Several slides show conceptacles crowded with numerous long, slender sporangia.

Remarks.—In cell dimensions and size of conceptacles, this suggests *L.* aff. *L. bonfilli* Lemoine reported from the Eocene of India by K. Sripada Rao. It differs in growth habit, however. The cell dimensions are close to *L. borneoense* Johnson and Ferris from the Eocene of Borneo, but differ in conceptacle size and growth habit. *L. crispithallus* is fairly common in the Saipan collection.

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D143, D145, D152, and D217.

Holotype.—USGS algae a73–1a.

Lithothamnium sp. A

Plate 40, figures 8, 9

Description.—Thallus a thin foliate crust 100μ–175μ thick which probably grew free or partly free of substratum. Free margins probably laminated. Hypothallus well developed, forming one-third to one-half of crust's thickness. Consists of curved rows of irregular, rounded to rectangular cells 13μ–18μ long by 7μ–10μ wide. Perithallus formed of fairly regular rows of cells with well-defined vertical partitions and poorly marked horizontal ones; cells rectangular, 6μ–12μ by 8μ–10μ. Conceptacles unknown.

Remarks.—This species is one of the most abundantly represented Eocene forms of the genus *Lithothamnium* in the Saipan collections. In growth habit and cell dimensions, it differs appreciably from any previously described, lower Tertiary *Lithothamnium.* However, without a knowledge of the conceptacles, it seems inadvisable to name it.

Occurrence.—Upper Eocene, pink facies of Matansa limestone, limestone-conglomerate facies of Densinyama formation, and conglomerate-sandstone facies of Hagman formation. USGS paleobotanical localities D148, D169, and D175.

Division 3—Crusts With Warty Protuberances or Mammillae

Lithothamnium cf. L. aucklandicum Foslie

Plate 53, figure 9

Lithothamnion aucklandicum Foslie, 1907, Kinorske vidensk Selsk. Skr., no. 6, p. 18.

Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 39, pl. 4, fig. 17.

Description.—A single specimen in the Saipan collections approximately fits Foslie's rather brief description of *L. aucklandicum.* Thallus either a thick crust or a crust with warty protuberances. Hypothallus well developed with strongly curved rows of cells, 18μ–28μ by 9μ–13μ. Perithallus shows distinct, irregular growth zones, cells 8μ–10μ by 6μ–8μ. Conceptacles small but numerous, 205μ–312μ by 125μ–145μ.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D103.

Lithothamnium cf. L. crispatum Hauck

Plate 48, figure 4

Lithothamnium crispatum Hauck, 1878, Botanische Zeitschr., 28 Jahrg., p. 289, pl. 3, figs. 1–4.

Lithothamnion crispatum Hauck. Lignac–Grutterink, 1943, Geol.-mijnb. genootsch. Nederland en Kolonien Verh., Geol. ser., jagu 113, p. 288, fig. 4.

Description.—Thallus a thick irregular crust, possibly with short stubby branches. Hypothallus poorly developed, consisting of a few curved rows of irregular cells 14μ–19μ by 7μ–9μ. Perithallus thick with irregular growth zones, cells 10μ–13μ by 8μ–10μ. Conceptacles abundant, 174μ–220μ in diameter and 80μ–100μ in height.

Remarks.—The cell dimensions and conceptacle size fit the material described by Lignac–Grutterink from the Miocene of the East Indies. However, there is some question whether the Saipan specimen represents a strongly branching form like those described from the East Indies.

It also suggests, and the dimensions approximately fit, *L. peleense* Lemoine from the Miocene of Martinique which is a crustose torm.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D122.

Lithothamnium cymbicrusta Johnson, n. sp.

Plate 40, figures 1, 6, 7; plate 41, figure 8

Description.—Thallus a thin crust 200μ–300μ thick. Hypothallus well developed, consisting of rows of cells apparently curving gradually from center to both top and bottom of hypothallus. It thus suggests a coaxial type, but with horizontal cell rows rather than vertical. Hypothallus as thick or thicker than normal perithallus; cells 12μ–13μ by 8μ–15μ. Perithallus thin, of regular rows of square to rectangular rows of cells 6μ–16μ by 8μ–11μ. Conceptacles singly or in cluster in little knobs raised above general level of crust, measure 304μ–425μ in diameter and 100μ–185μ in height.

Remarks.—This species differs appreciably from any Eocene species of *Lithothamnium* desciibed to date, both in the structure of the hypothallus and in the concentration of the conceptacles in raised knobs. It somewhat suggests *L. reveretoi* described by Airoldi from the Oligocene of the Canary Islands but differs in several details.

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D147, D151, D154, and D159.

Holotype.—USGS algae a97–1b.

Lithothamnium cf. L. disarmonicum Conti

Plate 49, figure 6

Lithothamnion disarmonicum Conti, 1943, Palaeontographia Italica, Mem. Palaeont., v. 41 (new ser. v. 11), p. 49, pl. 6, fig. 1.

Description.—Fragment of a thick crust which may or may not have borne branches. Hypothallus moderately but irregularly developed, cells 11μ–15μ by 11μ–13μ. Perithallic tissue fairly regular, composed of rows of rectangular cells 11μ–18μ by 10μ–12μ. Conceptacle 392μ by 179μ.

Remarks.—This form agrees with Conti's description of *L. disarmonicum* from the Miocene of Italy, except that the Saipan species has a more regular perithallic tissue.

Occurrence.—Lower Miocene, marly facies of Tagpochau limestone. USGS paleobotanical locality D128.

Lithothamnium cf. L. mirabile Conti

Plate 48, figure 3

Lithothamnion mirabile Conti, 1943, Palaeontographia Italica Mem. Palaeont., v. 41 (new ser. v. 11), p. 43, pl. 5, fig. 2; pl. 8, fig. 2.

Description.—A single fragment from Saipan fits Conti's description of *L. mirabile* for nature of tissue and cell dimensions. Conti's specimen did not show conceptacles, however. Saipan specimen a fragment of a thick crust or knob, with a basal hypothallus having cells 25μ–30μ by 10μ–17μ. Perithallus consists of irregular zones of layers of rectangular cells 12μ–17μ by 10μ–15μ. Conceptacle chambers 424μ–490μ in diameter by 180μ–192μ in height.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D96.

Lithothamnium moreti Lemoine

Plate 38, figure 7

Lithothamnion moreti Lemoine, 1927, Mus. Natl. histoire nat. Bull., v. 6, p. 547, fig. 2.

Description.—Thallus a thin crust from which develop warty growths or small branches. Hypothallus thin, ordinarily consisting of only a few rows of irregular cells 11μ–15μ by 7μ–11μ. Perithallus of rows of small square cells 7μ–9μ by 7μ–8μ. The one conceptacle observed measured 327μ by 106μ.

Remarks.—In appearance, growth habit, and dimensions of cells and conceptacle, this species exactly fits the form described by Lemoine from the upper Eocene of France, Italy, and Algeria.

Occurrence.—Upper Eocene, white facies of Matansa limestone. USGS paleobotanical locality D124.

Lithothamnium undulatum Capeder

Plate 48, figure 2

Lithothamnium undulatum Capeder, 1900, Malpighia, v. 14, p. 178, pl. 5, fig. 6.
Lemoine, 1926, Cong. Soc. Savantes Sci, 1925, Comptes Rendus, p. 246–247, fig. 4.

Description.—Thallus a crust with nodes. Basal hypothallus well developed, consisting of curved rows of cells 11μ–17μ by 6μ–8μ. Patches of hypothallic tissue appear in perithallus, especially around conceptacle scars. Perithallus irregular and contorted, with considerable range of cell size in different patches of tissue; cells 7μ–17μ by 7μ–8μ. Conceptacle spaces present; but as only edges were cut by section, full size not known.

Remarks.—The single Saipan specimen assigned to *L. undulatum* exactly fits the material ascribed to this species by Lemoine (1926) from the Miocene of France, Spain, and Italy.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D135.

Lithothamnium wallisium Johnson and Tafur

Plate 41, figure 5; plate 42, figures 3, 4

Lithothamnion wallisium Johnson and Tafur, 1952, Jour. Paleontology, v. 26, p. 538, pl. 62, fig. 3.

Description.—A crust developing thick mammelons or short branches. Hypothallus thin or absent. Perithallus tissue consists of many lenticular growth zones, cells 8μ–19μ by 7μ–11μ. Conceptacles abundant, many showing sporangia. Conceptacles 195μ–360μ in diameter and 113μ–135μ in height.

Remarks.—In appearance, cell dimensions, and size of conceptacles, this Saipan species agrees with the form described by Johnson and Tafur from the Eocene of Peru, although in the Peruvian material some of the conceptacles attain a greater diameter.

Occurrence.—Upper Eocene, white and pink facies of Matansa limestone and limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D125, D155, and D203.

Lithothamnium sp. C

Plate 42, figure 2

Description.—Crust with slight nodes or warts. Hypothallus moderately developed, consisting of curved rows of cells measuring 12μ–15μ by 8μ–12μ. Perithallus of fairly regular rows of cells 10μ–22μ by 8μ–16μ. Conceptacle chamber 442μ by 175μ.

Remarks.—Represented by one fragment, the section of which probably cuts the hypothallus obliquely.

Occurrence.—Upper Eocene, white facies of Matansa limestone. USGS paleobotanical locality D124.

Division 4—Strongly Branching Forms

Lithothamnium cf. L. lecroixi Lemoine

Plate 48, figures 5, 6

Lithothamnion lecroixi Lemoine, 1917, Soc. géol. France Bull., ser. 4, v. 17, p. 269–271, figs. 17, 18 [1918].

Description.—Plant starts as a thin crust from which develop short, thick branches. Basal hypothallus moderately developed with cells 12μ–20μ by 7μ–9μ. Perithallus and branches consist of gently arched zones of cells 8μ–13μ by 8μ–11μ. Conceptacles wide and flat, numerous, measuring 250μ–650μ in diameter and 60μ–90μ in height; many show individual sporangia.

Remarks.—In growth habit and dimensions this form closely agrees with the species described by Lemoine (1917) from the Miocene of Martinique.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D122.

Lithothamnium cf. L. madagascariense Foslie

Plate 53, figure 5

Lithothamnion madagascariense Foslie, 1906, K. norske vidensk. selsk. Aaraberetning för 1905

Foslie and Printz, 1929, K. norske vidensk. selsk. Skr., no. 2, p. 43, pl. 14, fig. 15.

Description.—Strongly branched form with branches consisting essentially of medullary hypothallus. Tissue shows growth zones. Cells 9μ–20μ by 9μ–12μ. Conceptacles abundant, flattened, 213μ–235μ across with maximum diameter probably greater.

Remarks.—Foslie does not clearly distinguish between his species *L. madagascariense* and *L. erubescens,* and the latter includes many varieties. The species were distinguished mainly by the growth form and the size, shape, and position of the conceptacles on the growing plant, while the cell dimensions were only casually considered. This creates difficulty in comparison with thin sections of fossil material.

The Saipan material fits the description of either of Foslie's species, but because of the small size of the conceptacles, it is provisionally referred to *L. madagascariense.*

Occurrence.—Pleistocene, pink massive facies of Mariana limestone. USGS paleobotanical locality D131.

Lithothamnium marianae Johnson, n. sp.

Plate 41, figures 1–3

Description.—Thallus develops long bifurcating branches. Tissue shows strong saucer- or lens-shaped growth zones. Hypothallus poorly developed, absent on some specimens, composed of cells 13μ–20μ by 10μ–12μ. In branches, growth zones formed of slightly curved rows of cells. Cells rectangular and show considerable range in size, both from one end of a row to the middle, and from the lower layer to the upper layer in a zone. Cell size 10μ–24μ by 7μ–13μ. Conceptacles abundant. Size 270μ–686μ in diameter and 135μ–190μ in height.

Remarks.—This is the only abundant Eocene branching *Lithothamnium* in the Saipan collections.

In growth habit and cell dimensions, this species resembles *L. ficheuri* Lemoine from the Oligocene of Algeria. It differs, however, in the shape and arrangement of the cells, which are oval and of two sizes in *L. ficheuri* and rectangular in *L. mariane.*

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation and both pink and white facies of Matansa limestone. USGS paleobotanical localities D142, D143, D161, D223, D225, and D233.

Holotype.—USGS algae no. a73–2a.

Lithothamnium sp. E

Plate 41, figure 4

Description.—Slender, irregularly branching form. Thallus consists entirely of hypothallus formed of radially arranged rows of rectangular cells. Length of individual cells differs, measuring 23μ–53μ in length by 9μ–14μ in width (average about 44μ by 12μ). Conceptacles unknown.

Remarks.—Differs appreciably in appearance and cell dimensions from any previously described lower Tertiary species.

Occurrence.—Upper Eocene, conglomerate-sandstone facies of Hagman formation. USGS paleobotanical locality D175.

Genus MESOPHYLLUM Lemoine, 1928

Structurally this genus lies between *Lithothamnium* and *Lithophyllum.* It has tissue similar to *Lithophyllum,* but the large, many apertured conceptacles are like those of *Lithothamnium.* In most species the tissue shows strong growth zones.

The genus includes both encrusting and branching species. Its known geologic range is from the Eocene to the present.

Mesophyllum pacificum, Johnson, n. sp.

Plate 52, figure 7

Description.—Thallus of long, narrow branches with pronounced growth zones, each zone consisting of arched rows of cells, 10–12 rows to a zone. Cells rectangular, sometimes rounded, 13μ–22μ by 8μ–12μ. Conceptacles near center of growth zones, measuring 340μ–490μ in diameter and 200μ–280μ in height.

Remarks.—The growth form strongly suggests *M. commune* Lemoine from the Miocene of the western Mediterranean region, but the species differ slightly in cell dimensions. In *M. commune* the conceptacles appear to have formed along the margins of the branches, while in *M. pacificum* they were terminal.

Occurrence.—Lower Miocene, rubbly facies of Tagpochau limestone. USGS paleobotanical locality D138.

Holotype.—USGS algae a67–1a.

Mesophyllum savornini Lemoine

Plate 52, figure 8

Mesophyllum savornini Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 83, figs. 43–46.

Description.—Thallus a crust from which rise short stubby branches. Hypothallus poorly developed or abraded on the Saipan specimens. Perithallic tissue shows strong growth zones composed of regular arched rows of cells. Cells show considerable range in size both from the center to the margin of a growth zone and from the lower to the upper layers of a zone, 13μ–29μ by 9μ–12μ. Conceptacle chamber 642μ in diameter and 181μ in height.

Remarks.—In appearance of tissue and dimension of cells and conceptacles, this specimen agrees with Lemoine's type from the Miocene of Algeria.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D99.

Mesophyllum cf. M. vaughanii (Howe) Lemoine

Plate 44, figure 12

Lithothamnium vaughanii Howe, 1918, U. S. Natl. Mus. Bull. 103, p. 6–8, pl. 7, figs. 1, 2; pl. 8.

Mesophyllum vaughanii (Howe). Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 89, pl. 1, figs. 2, 8, 11, 15.

Description.—Thallus starts as crust and develops branches that consist essentially of medullary tissue showing strong growth zones. Each zone consists of 5 or 6 rows of rectangular cells 21μ–30μ long by 9μ–15μ wide. Conceptacle chamber 504μ in diameter and 144μ in height.

Remarks.—Represented in the Saipan collection by one fragment of a branch. In appearance, cell dimension, and conceptacle size, it closely fits the description of *Mesophyllum vaughanii* (Howe, 1918) from the Eocene of the Panama Canal Zone.

Occurrence.—Upper Eocene, transitional facies of Matansa limestone. USGS paleobotanical locality D123.

Tribe LITHOPHYLLEAE

Genus LITHOPHYLLUM Philippi, 1837

In this genus the tissue consists of both hypothallus and perithallus. Characteristically the basal hypothallus is coaxial; that is, formed of regularly curved or arched rows of cells. In some instances, however, it consists of a few irregular or curved rows of cells. The perithallus is formed of regular rows of cells. Branching species have a well-developed coaxial medullary hypothallus surrounded by a thinner marginal perithallus. The sporangia are collected in conceptacles which are pierced by a single large opening in the roof for the escape of spores.

Lithophyllum is abundant in the Saipan collections, where it is represented by 12 species.

For convenience in study the species are arranged in four divisions, which, like those of *Lithothamnium*, are based on the growth habit.

Division 1—Simple crusts.
Division 2—Crusts free (unattached) or nearly free.
Division 3—Crusts with warty protuberances of mammillae.
Division 4—Strongly branching forms.

The dimensions and distribution of the species occurring on Saipan are given in the table below.

TABLE 7.—*Measurements (in microns) and distribution of Saipan species of* Lithophyllum *(from random sections)*

Species	Hypothallus cells		Perithallus cells		Conceptacle		USGS paleobotanical localities	Age
	Length	Width	Length	Width	Height	Diameter		
Division 1—Simple crusts (commonly thin—a number may be superimposed)								
L. megacrustum Johnson and Ferris	-----	-----	23–59	10–18	284–507	90–175	D100, D114, D133, D174	Pleistocene.
ovatum (Capeder) Lemoine	12–38	7–15	6–21	6–11	210–330	120–130	D97, D145, D152, D159, D216	Eocene.
cf. *L. racemus* (Lamarck) Foslie	14–15	9–13	12–17	8–15	400–560	130–150	D101	Pleistocene.
stefaninii Airoldi	9–21	9–15	7–16	8–11	140–200	85–95	D110, D111	Pleistocene.
yendoi Foslie	5–7	6–9	6–9	6–9	150–165	75–81	D114	Pleistocene.
sp. A	15–21	8–13	7–12	7–9	-----	-----	D127, D164, D165, D170, D233	Eocene, Miocene.
Division 2—Crusts free or nearly free								
L. prelichenoides Lemoine	14–34	7–21	9–16	7–16	189–283	87–118	D91, D127, D141, D211	Miocene.
Division 3—Crusts with warty protuberances or mammillae								
L. expansum Philippi	-----	-----	7–14	9–17	350–420	250–270	D102, D109	Pleistocene.
cf. *L. roveretoi* Airoldi	11–22	6–11	5–9	6–9	385–472	120–156	D111	Pleistocene.
Division 4—Strongly branching forms								
L. glangeaudi Lemoine	{15–22 14–18	6–9 8–12}	8–12	8–12	-----	-----	D150	Miocene.
kotschyanum (Unger) Foslie	11–18	7–14	9–18	7–12	250–450	-----	D176, D213	Recent.
moluccense Foslie	42–78	8–16	14–21	6–11	240–260	90–110	D131, D260, D261, D262, D263, D264, D269	Pleistocene, Recent.

Division 1—Simple crusts

Lithophyllum megacrustum Johnson and Ferris

Plate 54, figure 8; plate 55, figure 1

Lithophyllum megacrustum Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 16, pl. 7, figs. D, E.

Description.—Thallus, a relatively thick crust, several centimeters thick. Hypothallus poorly developed or missing on figured specimens. Perithallus of regular rows of long rectangular cells. Partitions separating cell rows quite distinct, as are cell walls. Cells oblique to the row walls in many specimens. In some areas of the tissue, there is a suggestion of alternate rows of cells of slightly different lengths. Cells range in size from 23μ–59μ by 10μ–18μ.

Many conceptacle cavities scattered through the tissue. Many small irregular cells around the conceptacles. Conceptacles 284μ–507μ in diameter and 90μ–175μ in height.

Remarks.—The Saipan material agrees in general appearance, growth habit, and peculiar tissue structure with the type material from the Pleistocene of Lau, Fiji. It differs in ordinarily having somewhat shorter cells and slightly larger conceptacles.

Occurrence.—Pleistocene, massive and rubbly facies of Mariana limestone. USGS paleobotanical localities D100, D114, D133, and D174.

Lithophyllum ovatum (Capeder) Lemoine

Plate 45, figures 4, 8

Lithothamnium ovatum Capeder, 1900, Malpighias, v. 14, p. 177, pl. 6, figs. 5 a, b.

Lithophyllum ovatum (Capeder) Lemoine, 1926, Cong. Soc. Savantes Sci., 1925, Comptes Rendus, p. 245–246, fig. 3.

Airoldi, 1932, Palaeontographia Italica, Mem. Palaeont., v. 33 (new ser. v. 3), p. 70, pl. 10 [1933].

Description.—Thallus encrusting; commonly several are superimposed. Hypothallus 76μ–216μ thick, of well-developed semicircular rows of cells. Perithallus 360μ–580μ thick with cells in well-developed rows with strong horizontal partitions. Measurements from random sections, for selected specimens follow (all from USGS paleobotanical locality D97).

Hypothallus cells		Perithallus cells		Conceptacles (in μ)
Height (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	
9–11	7–12	8–15	6–10	225–270 x 95–102
14–31	7–14	9–14	6–11	None
12–33	9–14	6–11	7–9	210 x 120
20–38	8–15	11–21	7–11	330 x 130

Remarks.—In general appearance, growth habit, cell dimensions, and size of conceptacles, this species agrees with Lemoine's description (1926, p. 245) of the type material from the Oligocene of Italy. The maximum length of the hypothallic cells in the Saipan material, however, is somewhat less.

Occurrence.—Upper Eocene, limestone-conglomerate facies of Densinyama formation and white facies of Matansa limestone. USGS paleobotanical localities D97, D145, D216, D152, and D159.

Lithophyllum cf. L. racemus (Lamarck) Foslie

Plate 55, figure 9

Millepora racemus Lamarck, 1818, Histoire naturelle des animaux sans vertébrés: Paris, p. 203.

Lithophyllum racemus (Lamarck) Foslie, 1898, K. norske vidensk. selsk. Skr., no. 3., p. 9.

Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 37, pl. 63, figs. 14–21.

Description.—Thallus encrusting, ordinarily thin. Thick crusts and nodular masses may be formed of many superimposed thalli. Hypothallus absent or poorly developed and of a type unusual in genus *Lithophyllum*. It consists of a row or two of irregular cells, 14μ–15μ by 9μ–13μ parallel to the underlying surface. Each cell develops laterally a curved row of cells which abruptly flattens into typical perithallic tissue. Perithallus consists of tissue of square to rectangular cells with fairly regular horizontal and vertical partitions between cell rows. Cells 12μ–17μ by 8μ–15μ. Conceptacles distributed irregularly, 400μ–560μ in diameter and 130μ–150μ in height.

Remarks.—*L. racemus* is common in the Mediterranean and has been reported from several localities in the Red Sea and along the coast of Siam. It has also been described from Pleistocene deposits of Calabria, Sicily, and Somalia. Several thick, irregular crustose masses in the Saipan collections agree with this modern Mediterranean species, except they have considerably larger conceptacles (diameter 412μ–560μ instead of 150μ–325μ).

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D101.

Lithophyllum stefaninii Airoldi

Plate 54, figure 4

Lithophyllum stefaninii Airoldi, 1933, Palaeontographia Italica, Mem. Palaeont., v. 32, supp. 1, p. 90, pl. 8, fig. 2.

Description.—Thallus encrusting. Thick crusts and nodular masses formed of many superimposed thalli. Hypothallus thin to moderately developed, with ovoid to rectangular cells, 9μ–12μ by 9μ–15μ. Perithallus moderately regular, cells 7μ–16μ by 8μ–11μ. Conceptacles, small, in part bean shaped, 140μ–200μ in diameter and 85μ–95μ in height.

Remarks.—The Saipan specimens have slightly smaller perithallic cells than described by Airoldi (1933, p. 90–91) for the type from the Pleistocene of Somalia.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical localities D110 and D111.

Lithophyllum yendoi Foslie

Plate 54, figure 8

Lithophyllum yendoi Foslie. Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 61–62, pl. 11, figs. 1–4.

Description.—Thallus a thin crust on other algae or objects. Hypothallus thin, consisting of curved rows of cells 5μ–7μ by 6μ–9μ. Perithallus of fairly regular rows of square cells 6μ–9μ by 6μ–9μ. Conceptacle chambers 150μ–165μ in diameter and 75μ–81μ in height.

Remarks.—The Saipan specimen closely fits Foslie's description of this widespread modern Pacific species. It is characterized by the growth habit and unusually small cells and conceptacles.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D114.

Lithophyllum sp. A

Plate 43, figure 3, 5

Description.—Thallus a thin crust consisting of a well-developed hypothallus and perithallus. Hypothallus coaxial, with cells 15μ–21μ by 8μ–13μ. Perithallus of regular layers of cells 7μ–12μ by 7μ–9μ. No conceptacles observed.

Remarks.—Thin crusts of this type are quite abundant in the Saipan Eocene limestones, and a few pieces of what appear to be the same form were found in the Miocene. Unfortunately no fertile specimens were found. It does not seem advisable to name the species without a knowledge of the conceptacles.

Occurrence.—Upper Eocene, both white and pink facies of Matansa limestone. Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D127, D164, D165, D170, and D233.

Division 2—Crusts free or nearly free

Lithophyllum prelichenoides Lemoine

Plate 49, figures 1, 2

Lithophyllum prelichenoides Lemoine, 1917, Soc. géol. France Bull., ser. 4, v. 17, p. 262, figs. 8, 9 [1918].

Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 99, figs. 65–66, p. 107.

Description.—Thallus a crust or leafy plate, possibly free or partly unattached, consists mainly of a well-developed strongly coaxial hypothallus up to 300μ thick. In younger specimens, only hypothallus is present. In old specimens a thin perithallus develops on one or both sides of hypothallus. Hypothallic cells measure 14μ–34μ by 7μ–21μ. Perithallus consists of regular rows of nearly square cells 9μ–16μ by 7μ–16μ. Seldom more than 8 layers of cells present unless conceptacles have developed, in which case perithallus thickens around conceptacles. Conceptacles 189μ–283μ in diameter, 87μ–118μ in height. Cells of both hypothallus and perithallus display considerable range in size as shown by the measurements below.

USGS paleobotanical localities	Hypothallus cells		Perithallus cells		Conceptacles	
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	Diameter (in μ)	Height (in μ)
D91	14–28	8–12	5–13	7–10	283	118
D127	16–29	7–10	8–12	7–9	189	87
D141	21–31	11–21	9–16	9–16	Absent	
D211	24–34	11–13	7–13	11–14	Absent	

Remarks.—This is one of the most abundant forms of *Lithophyllum* in the Miocene of Saipan. It belongs to a very widely distributed species. It has been observed in slides from the Miocene of Los Negros Island and the writer described similar material from Borneo under the name *L.* cf. *prelichenoides*. Lemoine has described the same species from Algeria, Spain, Hungary, Albania, and Martinique.

Occurrence.—Lower Miocene, inequigranular, tuffaceous, and marly facies of Tagpochau limestone. USGS paleobotanical localities D91, D127, D141, and D211.

Division 3—Crusts with warty protuberances or mammillae

Lithophyllum expansum Philippi

Plate 54, figure 5

Lithophyllum expansum Philippi, 1837, Archiv. für Naturgeschichte herausgegeben von Dr. Wiegmann, Band 3, no. 1, p. 389.

Rainer, 1923, Nuova Notarisia, v. 35, p. 34–35, figs. 6, 7.

Description.—Plant a thin crust with warty or mammillated surface. Hypothallus thin or absent, when present consisting of one or at the most two layers of irregular cells. Perithallus formed of fairly regular rows of rectangular cells measuring 7μ–14μ by 9μ–17μ. Conceptacles 350μ–420μ in diameter and 250μ–270μ in diameter with a single large aperture.

Remarks.—The growth habit, nature of tissue and cell, and conceptacle dimensions of the specimens studied support unqualified assignment to the Mediterranean and Red Sea species *L. expansum*.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical localities D102 and D109. Fragments were observed in specimens from several other localities.

Lithophyllum cf. L. roveretoi Airoldi

Plate 55, figure 8

Lithophyllum roveretoi Airoldi, 1933, Palaeontographia Italica, Mem. Palaeont., v. 33 (new ser. v. 3), p. 92–93, pl. 8, fig. 4, text fig. 11.

Description.—Thallus a thick crust with protuberances or possibly branches. Hypothallus well developed, almost coaxial, consisting of regularly curved rows of cells 11μ–22μ by 6μ–11μ, averaging 9μ by 17μ. Perithallus thick, somewhat irregular, showing poorly defined growth zones; cells square, 5μ–9μ by 6μ–9μ. Conceptacles rather wide and gently arched, measuring 472μ by 140μ, 436μ by 156μ, and 385μ by 120μ.

Remarks.—This form closely fits the description given by M. Airoldi (1933, p. 92–93) for *Lithophyllum roveretoi* from the Pleistocene of Somalia. However, Airoldi's type was a crust with strong branches. It is uncertain whether tbis form developed such branches.

Occurrence.—Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D111.

Division 4—Strongly branching forms

Lithophyllum glangeaudi Lemoine

Plate 49, figure 7

Lithophyllum glangeaudi Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 102–103, pl. 2, fig. 15, text fig. 70.

Description.—Thallus a thin crust from which rise strong branches. Basal crust consists mainly of hypothallus, moderately coaxial, of cells 15μ–22μ by 6μ–9μ. Above it is a thin perithallus consisting of 2 or 3 rows of nearly square cells, about 8μ–12μ across. Branches show strong growth zones, consisting of 5–8 rows of rectangular cells, 14μ–18μ by 8μ–12μ. Conceptacles not observed.

Remarks.—In general appearance, growth habits, and cell dimensions, the Saipan specimen fits the description and illustrations of Lemoine's material from the Miocene of the Mediterranean Region.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D150.

Lithophyllum kotschyanum (Unger) Foslie

Plate 57, figure 1; plate 58, figure 1

Lithophyllum kotschyanum Foslie, 1909, K. norske vidensk.selsk. Skr., no. 2, p. 34.

Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 35, pl. 65, figs. 1–6.

Description.—Plant a compact bushy or hemispherical mass of branches up to 6 inches in diameter. Branches thick, irregular, frequently bifurcating and commonly fuse. Ends rounded to wedge shaped. Plants grow firmly attached to some hard object.

Section of a branch shows well-developed medullary hypothallus and perithallus. Hypothallus wide, composed of arched layers of rectangular cells that differ in length even in same layer, from 11μ–18μ long and in width from 7μ–14μ. Perithallus fairly regular, with cells 9μ–18μ by 7μ–12μ. Vertical partitions between cell rows distinct, but horizontal partitions thin and often indistinct. Conceptacles 250μ–450μ in diameter with flattened tops (average 325μ).

Remarks.—This species develops a great variety of growth forms. All show similar microstructure and have the same size cells and conceptacles. However, the range of growth forms is so great that specimens from the opposite ends of the series could easily be mistaken for entirely different species.

Foslie named and described five growth forms. Two of them are recognized in the Saipan collections, *L. typica* and *L. subtilis*.

Occurrence.—Recent, living in barrier-reef lagoon west of Saipan. USGS paleobotanical localities D213 and D176.

Lithophyllum moluccense Foslie

Plate 54, figures 6, 7; plate 58, figures 2–5

Lithophyllum moluccense Foslie, 1901, K. norske vidensk. selsk. Skr. no. 6, p. 24.

Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 67, pl. 12.

Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 36, pl. 50.

Description.—Thallus strongly branching, bushy, in most specimens forming compact nearly hemispherical masses commonly about 3½ inches in diameter but may attain a diameter of 6 or 7 inches. Plant normally grows firmly attached to some hard object, particularly coral or old reef rock. However, mature plants may become detached. Branches bifurcate at wide angle (75°–110°). Ends gently rounded or blunt. Surface of young branches appears smooth and shining.

Three varieties or growth forms occur in the Saipan collections: these have been named *typica*, *pygmaea*, and *flabelliformis* by Foslie. Form *typica* develops strong relatively long and thick branches which are rather widely spaced (pl. 58, fig. 4). Form *pygmaea* has short slender tightly packed branches (pl. 58, fig. 2). In typical specimens these forms are quite distinct, but in a large collection intermediate specimens are found. In the Saipan collections, the form *pygmaea* is the most abundant, and *flabelliformis*, the rarest.

A longitudinal section of a branch shows it to contain a well-developed medullary hypothallus and a marginal perithallus. The hypothallus forms 50–65 percent of the diameter of the branch, being from 500μ to 1,600μ thick. It consists of alternating layers of rectangular long and short cells; the short ones 14μ–28μ by 4μ–14μ, the long ones 36μ–58μ long and 9μ–16μ wide. These lengths are measured at the center of the row—the cells become smaller at the edges. The marginal perithallus is from 400μ to 850μ thick. In the outer layers it has smaller nearly square cells. They measure 10μ–20μ in length and 6μ–12μ in width (average 18μ by 10μ). Conceptacle chambers 190μ–315μ in diameter (average 250μ–275μ).

Remarks.—This is the most abundant Recent species collected on Saipan. Fossils occur in the Pleistocene Mariana limestone.

Occurrence.—Recent, living reefs along the west, northwest, and south coasts of Saipan, near the outer edge of the reef platform. USGS paleobotanical localities D260, D261, D262, D263, D264, and D269. Pleistocene, pink massive facies of Mariana limestone; USGS paleobotanical locality D131.

Genus GONIOLITHON Foslie, 1900

Goniolithon differs from *Lithophyllum* only in the possession of megacells that occur singly or in short vertical columns one megacell wide in the perithallic tissue. Several widely distributed living species are found in the tropical Pacific, including both encrusting and branching forms. Fossil species have been described from beds as old as Pliocene, and fragments showing typical generic features have been reported but not described from strata as old as Miocene.

Goniolithon frutescens Foslie

Plate 59, figure 4; plate 60, figure 3

Goniolithon (*Cladolithon*) *frutescens* Foslie, 1900, K. norske vidensk. selsk. Skr., no. 1, p. 9–10.
Goniolithon frutescens Foslie. Foslie, 1900, The fauna and geography of the Maldive and Laccadive Archipelagoes, p. 468, pl. 35, figs. 5–6.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 53, pl. 10, figs. 10–11.

Description.—Forms bushy hemispherical tufts or loose rounded masses. Branches long and delicate, commonly irregular and slightly twisted, fused at base, separated for most of their length. Plant starts attached to some solid object, such as coral, another crustose alga, or a pebble. Later some become detached and grow freely on bottom. Surface dull, nearly smooth or somewhat irregular. Specimens fragile, branches separating and breaking easily. All Saipan specimens belong to Foslie's form *typica* which has long loosely packed branches.

Branches have distinct medullary hypothallus and marginal perithallus. In longitudinal section medullary hypothallus forms 50–70 percent of diameter of branch and is composed of flat to slightly curved layers of rectangular cells. These cell layers fairly uniform in size and regular in arrangement. Cells measure 20μ–34μ in length and 12μ–23μ in width in section, with fairly thick walls. Perithallus 300μ–500μ thick, rather irregular and consists of irregular layers of cells 12μ–23μ long and 9μ–14μ wide. Large megacells irregularly distributed throughout perithallic tissue, commonly have rounded corners, may be barrel shaped, occur singly or end to end in clusters of 2, 3, or rarely 4 (doubtlessly dependent on location of section) perpendicular to cell layers. The few conceptacles observed have a diameter of 350μ–450μ.

Remarks.—An interesting feature of this species is the occurrence in many specimens of patches of secondary hypothallus developed as scar tissue over conceptacles and injured areas. Such developments can occur in all crustose coralline algae, but they seem to develop more abundantly in the genus *Goniolithon*, especially this species, than any other group studied by the author.

Occurrence.—Recent, lives abundantly in the very shallow water along the northwest coast of Saipan, especially where the barrier-fringing reef narrows down to meet the shore, and well back on the reef flat west of Obyan Point on the southwest coast. USGS paleobotanical localities D267 and D268.

Goniolithon reinboldi Weber van Bosse and Foslie

Plate 59, figure 5

Goniolithon reinboldi Weber van Bosse and Foslie. Foslie, 1901, K. norske vidensk. selsk. Skr., no. 6, p. 5.
Weber van Bosse and Foslie, 1904, *Siboga*-Expedite Mon. 61, p. 49, fig. 21; pl. 10.

Description.—Plant starts as thin crust on hard object, commonly coral, then develops wide warty excrescences which may be widely or closely spaced and may form rounded nodular masses. Hypothallus thin, from 1 to 6 rows of elongated cells. Most of tissue is perithallus, of unusual and distinctive structure. Thin irregular perithallic layers of irregularly arranged rounded cells 15μ–20μ across have lengths ranging from 15μ–33μ. Rare megacells scattered irregularly through perithallus measure around 30μ–40μ in length and 27μ–29μ in diameter. Conceptacles very abundant internally, numerous on surfaces of most specimens, small, round in plan, and in vertical section rounded and very high relative to diameter. Conceptacle chambers commonly measure 240μ–400μ in diameter and 150μ–225μ in height. Thin streaks of secondary hypothallic scar tissue may occur over conceptacles, resulting from bits of foreign matter or wounds in tissue.

Remarks.—This species is easily recognized in section by its characteristic perithallic structure. It is widely distributed in the Indian Ocean and the tropical Pacific.

Occurrence.—Recent, living along fringing-reef edge at Fañunchuluyan beach and east Obyan. USGS paleobotanical locality D273.

Goniolithon sp. A

Plate 56, figure 2

Description—Hypothallus well developed, coaxial, about 210μ thick, cells 40μ–48μ by 11μ–15μ. Secondary hypothallic scar tissue occurs within perithallus in several places. Perithallic tissue regular except for presence of numerous megacells which occur in vertical rows. Perithallic cells 12μ–21μ by 12μ–18μ. Megacells 27μ–34μ by 12μ–18μ. Conceptacle 934μ by 311μ.

Occurrence—The single unassigned but distinctive fragment described above is from the Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D115.

Goniolithon sp. B

Plate 56, figure 1

Description.—Thinly encrusting, or, less commonly, with several superimposed thalli forming thick irregular crust. Hypothallus moderately developed, indistinctly coaxial; cells 27μ–28μ by 11μ–16μ. Perithallus contains numerous megacells, ordinarily in vertical groups of three. Perithallic cells 10μ–19μ by 10μ–13μ. Megacells 15μ–21μ by 10μ–19μ. Conceptacles unknown.

Remarks.—In general appearance and growth habit, this unassigned species conforms to Foslie's description of *G. myriocystum* (*in* Weber van Bosse and Foslie, 1904, p. 45–46). The megacells are much larger and less abundant in Foslie's species, however.

Occurrence.—Fragments from the one locality in the Saipan collection are Pleistocene, massive facies of Mariana limestone. USGS paleobotanical locality D100.

Genus POROLITHON Foslie, 1909

Porolithon differs from *Lithophyllum* primarily in the possession of lenticular groups of megacells. These are one megacell high and parallel the subhorizontal or concentric normal cell rows. The horizontal grouping of the megacells distinguishes *Porolithon* from *Goniolithon*, in which they occur singly or in short vertical columns. Another feature distinctive of *Porolithon* is the common presence of lateral pores between adjoining cells.

The genus contains both encrusting and branching species. It is abundantly represented today in the tropical Pacific by a relatively small number of widely distributed species. Fossils are known only from the Pleistocene.

Porolithon craspedium (Foslie) Foslie

Plate 56, figures 4, 5; plate 59, figures 1–3

Lithophyllum craspedium Foslie, 1900, K. norske vidensk. selsk. Skr., no. 5, p. 26, 27.
Lithophyllum (*Porolithon*) *craspedium* Foslie. Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 43, 44.
Lithophyllum craspedium Foslie. Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 33, pl. 69, figs. 1–7.
Porolithon craspedium (Foslie) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. Ser., v. 18, p. 126–128, pls. 64, 65.

Description.—Thallus cushion shaped to subconical, massive, solid throughout. Living plants may have a grayish tinge. Surfaces are smooth to slightly rough, semilustrous. Branches thick, poorly developed, forming rounded knobs or slight ridges. Conceptacles small, submersed, hardly showing on the surface.

Tissue but slightly differentiated into perithallus and medullary hypothallus. Basal hypothallus absent or only slightly developed. Tissue of rectangular perithallic cells 11μ–15μ long and 7μ–12μ wide. Cells in distinct horizontal layers and less distinct vertical rows. Disklike lenses of megacells in section 6–12 in a row, presumably depending on orientation of megacell lenses with reference to section. Individual megacells 16μ–36μ in height and 7μ–17μ in diameter. Conceptacles abundant, small with flattened tops, 200μ–270μ in diameter.

Remarks.—The Saipan specimens of *P. craspedium* resemble the type material except in having slightly larger conceptacles. In growth form they are close to Foslie's form *subtilis*, in which the branches are reduced to slight knobs.

Occurrence.—Recent, the few living specimens collected at Saipan are from the fringing reef at Obyan Point on the south coast; USGS paleobotanical locality D274. Pleistocene specimens are from the massive facies of the Mariana limestone and from the Tanapag limestone; USGS paleobotanical localities D104, D117, D191, and D230.

Porolithon onkodes (Heydrich) Foslie

Plate 55, figures 6, 7; plate 59, figure 6

Lithothamnion onkodes Heydrich, 1897, Deutsche Bot. Gesell. Ber., Band 15, p. 6, fig. 11.
Heydrich, 1897, Bibliotheca Botanica, v. 41, p. 410.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 57, pl. 11.
Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon, p. 67, figs. 1–8.
Porolithon onkodes (Heydrich) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. Ser., v. 18, p. 125, pls. 9, 61–63.

Description.—Occurs as thin incrustations 250μ–4.5 mm thick, or repeated superimposed thalli may form very thick crusts. Surface smooth to rough with a dull or semidull luster. Thin crusts conform to irregularities of subsurfaces; thick ones flat or gently rounded.

Living representatives studied have thin hypothallus that consists of 1–10 curved layers of horizontally elongated cells 11μ–28μ long and 6μ–11μ wide. Secondary hypothallic scar tissue of similar nature, but slightly thicker, observed. Perithallus forms bulk of crust, consists of well-defined vertical rows of cells, 9μ–13μ by 6μ–9μ. Megacells occur in lenticular clusters that appear 4–12 cells in a row in thin section. Megacells 25μ–36μ long and 7μ–10μ thick. Conceptacles abundant, 200μ–300μ in diameter and with flattened tops.

Fossil fragments here referred to this species have poorly developed hypothallus consisting of cells 11μ–21μ by 8μ–11μ. Perithallus forms most of tissue in these specimens, composed of somewhat irregular rows of cells 7μ–12μ by 8μ–11μ. Throughout tissue, many groups of megacells 6–9 in a cluster, measuring 17μ–27μ by 12μ–18μ. Conceptacle chambers usually small, 96μ–100μ in diameter and 32μ–42μ in height, although in one specimen a conceptacle 180μ–81μ was measured.

Remarks.—The Recent Saipan specimens agree with Foslie's descriptions of the species in all features. However, they show slightly larger conceptacles than those described by Taylor from Bikini and adjoining atolls of the Marshall Islands.

The species occurs in moderate abundance along and near the outer edge of the Saipan reefs. It is probably the most widely distributed living encrusting *Porolithon* of the Pacific.

Occurrence.—Recent, outer edge of reefs; USGS paleobotanical locality D272. Pleistocene, *Halimeda*-rich facies of Mariana limestone; USGS paleobotanical localities D129 and D231.

Genus PARAPOROLITHON Johnson, n. gen.

The new genus *Paraporolithon* resembles *Lithophyllum*, as do *Goniolithon* and *Porolithon*, except for its possession of megacells in the perithallic tissue. Its emgacells, however, occur not only in short horizontal lenticular clusters, such as characterize the genus *Porolithon*, but also singly or in vertical groups as in *Goniolithon*.

Genotype (and only presently known species).—*Paraporolithon saipanense* Johnson, n. sp., lower Miocene, Tagpochau limestone.

Paraporolithon saipanense Johnson, n. sp.

Plate 52, figures 4, 5

Description.—Thallus a crust 200μ–480μ thick. Hypothallus poorly coaxial 150μ–300μ thick, composed of rectangular cells 12μ–25μ long and 8μ–12μ wide. Perithallus of well-defined layers of cells 12μ–15μ long and 8μ–13μ wide. Partitions between cell layers pronounced. Large megacells 48μ–60μ high and 13μ–17μ wide. Sections through horizontal clusters show 4–8 cells in a row, commonly 5. Smaller megacells 14μ–30μ high and 14μ–22μ wide, usually occur singly but in parts of the section, 2 or 3 occur one above the other.

Remarks.—This species and genus is described on the basis of a single specimen found on a single slide in the Saipan collection and brought to the author's attention by Preston Cloud. No other specimens were found in the Saipan material, but the author has since then seen specimens that show the same generic features from rocks of the same age on Guam. The genus is probably commoner than would appear from this record and should be kept watch for as a possible indicator of lower Miocene (Tertiary *e*).

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical locality D443.

Holotype.—USGS algae a66–1a.

Genus LITHOPORELLA Foslie, 1909

The genus *Lithoporella* is characterized by having thalli which form very thin crusts (ordinarily less than 100μ thick) attached to other calcareous algae, corals, Foraminifera, bryozoa, or other organisms. Many superimposed thalli may form thick crusts or nodular masses. Similar masses have been observed to consist of alternating *Lithoporella* thalli and incrusting Foraminifera, or rarely bryozoa. The conceptacles are similar to those of *Lithophyllum*.

Each thallus of *Lithoporella* is formed by a single layer of long cells, except around the conceptacles where they thicken and several layers of smaller cells may be present. Because most of the fossil specimens observed in thin sections are infertile, the only feature ordinarily available for paleontological classification is the size of the cells. Classification is further hampered by the great differences in cell lengths even in the same specimen and by the range in size of conceptacles, where present. These ranges are given in the résumé of the characteristics of the principal modern species listed below.

L. melobesioides Foslie: cells 25μ–85μ by 15μ–30μ. Conceptacles 600μ–1,000μ.

L. *atlantica* Foslie: cells 32μ–60μ by 18μ–40μ. Conceptacles 500μ–800μ.

L. conjuncta Foslie: cells 36μ–55μ by 14μ–30μ. Conceptacles 400μ–800μ.

These species show such great and overlapping variation that they could easily be considered as representing one variable species.

The same is true of the observed fossils, and because most of them fall within the range of *Lithoporella* *melobesioides* Foslie, they are here attributed to that species, which thus attains a range from Eocene to Recent. The Miocene material falls within the limits of *L. melobesioides* except that the few conceptacles observed are smaller. The Pleistocene specimens show the greatest range in cell size and proportions. Some are almost square, while others are very long and narrow, yet they form a continuously overlapping series. (See tables following).

Lithoporella melobesioides (Foslie) Foslie

Plate 37, figure 5; plate 43, figures 1, 2; plate 49, figure 4; plate 56, figure 6

Mastophora (*Lithoporella*) *melobesioides* Foslie. Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 73–77, figs. 30–32.

Melobesia (*Lithoporella*) *melobesioides* Foslie. Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 108–110, figs. 78, 79.

Lithoporella melobesioides (Foslie) Foslie. Lignac-Grutterink, 1943, Geol.-mijnb. genootsch. Nederland en Kolonien Verh., Geol. ser., jagu 113, p. 292–293, pl. 2, fig. 8.

Lithoporella (*Melobesia*) *melobesioides* (Foslie) Foslie. Johnson and Ferris, 1949, Jour. Paleontology, v. 23, no. 2, p. 196–197, pl. 37, figs. 4–5; pl. 39, fig. 2.

Lithoporella melobesioides (Foslie) Foslie. Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 18, pl. 8, fig. A.

Description.—Thallus consisting of single layer of large rectangular cells that encrust algae and other objects. Several superimposed thalli may form a crust. Cells rectangular with rounded corners, much higher than wide. Cell walls are usually thick. Cell dimensions differ greatly even in same specimen as shown below.

Measurements of Eocene specimens

USGS paleobotanical localities	Cell dimensions		Conceptacles (in μ)
	Height (in μ)	Width (in μ)	
D179	39–62	17–29	Absent
	31–48	11–20	Absent
	54–61	11–15	Absent
D181	39–52	13–40	182–535 x 88–99
D224	56–76	13–24	Absent
D233	32–55	12–24	Absent
	43–58	15–28	Absent
D233	39–60	17–35	300–560 x 95–107
	41–50	13–23	
	40–85	10–22	270–98
D438	48–52	14–27	Absent

Measurements of Miocene specimens

USGS paleobotanical localities	Cell dimensions		Conceptacles (in μ)
	Height (in μ)	Width (in μ)	
D90	33–86	15–28	452–533 x 145–185
D127	39–69	11–22	Absent
D439	29–66	17–29	289 x 134
D440	39–63	18–26	485–515 x 155–187
D441	45–53	13–24	400 x 186
	45–88	15–31	450–650 x 140–180
D442	45–61	14–31	Absent
D443	47–67	12–20	Absent
D444	45–59	14–41	Absent
	40–63	18–37	Absent
D445	50–69	19–22	579–623 x 245–275
D446	65–78	12–18	400 x 100

Measurements of Pleistocene specimens

USGS paleobotanical localities	Cell dimensions		Conceptacles (in μ)
	Height (in μ)	Width (in μ)	
D132	21–27	16–22	720 x 312
D133	24–64	7–12	243 x 85
	27–45	9–18	210–540 x 120–320
D206	25–33	15–32	294 x 118
D447	37–63	19–32	Absent
D448	23–30	9–12	234 x 85
	26–45	10–18	100 x 32
D449	44–60	15–34	445 x 110
	27–78	7–17	110–152 x 32–55
D450	20–68	7–17	Absent

Occurrence.—Specimens assigned to this species are extremely abundant in the Saipan collections from Eocene to Recent and at many localities. The specimens observed ranged from tiny fragments to large thick crusts. They occur in all the limestones.

Genus MELOBESIA Lamouroux, 1812

Thallus forms a very thin crust, one to several layers of cells thick. Cells cubic or slightly wider than high. Conceptacles having several to many pores in the roof.

Known from Eocene to Recent, but represented by only a single Eocene species in the Saipan collection.

Melobesia? cuboides Johnson, n. sp.

Plate 43, figures 6, 7

Description.—Thallus very thin crust formed of single layer of cells; cells square or slightly elongated horizontally thin section. Thalli appear to be attached at point of first growth, but later parts may be free. Commonly several thalli superimposed to form thin crusts or nodular masses. Cells 13μ–26μ by 10μ–23μ. Conceptacles unknown. The table below gives cell dimensions of five specimens.

USGS paleobotanical locality	Cell dimensions	
	Length (in μ)	Width (in μ)
D146	13–20	13–20
D147	14–20	13–23
D152	17–26	10–21
D173	13–20	10–20
D173	16–21	12–20

Remarks.—This species is characterized by its relatively small nearly square cells which contrast with the larger rectangular cells with rounded corners that characterize the similar but much commoner *Lithoporella melobesioides*. Based on the nature of the cells alone, the species described is considered to be a *Melobesia*. However, this is uncertain in the absence of knowledge of the conceptacles.

Occurrence—Upper Eocene, limestone-conglomerate facies of Densinyama formation and pink facies of

Matansa limestone. USGS paleobotanical localities D146, D147, D152, and D173.

Holotype.—USNM 624732 (Foraminifera slide).

Genus **DERMATOLITHON** Foslie, 1899

Plants belonging to this genus develop thin crusts that are circular or irregular in outline. They grow on other algae, coral, shell, and other hard objects. Thalli may grow one on another. Hypothallus of 1 or 2 rows of cells that are vertically and obliquely elongated. Perithallus of a few layers of nearly cubic cells. Conceptacles slightly to strongly convex, with a single aperture in the roof.

Representatives of this genus are known from Eocene to Recent. Modern representatives are widely distributed in the Pacific area.

Dermatolithon nitida Johnson, n. sp.

Plate 57, figures 2, 3

Description.—Thallus thin, encrusting. Hypothallus of a single layer of vertically elongated cells 40μ–75μ long and 13μ–25μ wide. Perithallus 2 or 3 layers thick, of nearly cubic cells measuring 12μ–22μ by 19μ–35μ. Conceptacles small, strongly arched, 215μ–350μ in diameter. Table below gives measurements of six specimens.

Measurements, in microns, of six specimens of Dermatolithon nitida *Johnson, n. sp.*

USGS paleobotanical locality	Hypothallic cells		Perithallic cells		Conceptacles	
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	Diameter (in μ)	Height (in μ)
D216	40–50	13–25	19–25	24–25	------	------
D147	50–74	14–20	------	------	90	216
D151	------	------	12–17	19–27	207	247
D154	------	------	14–18	25–27	{136 190	208 300
D124	------	------	11–17	28–36	107	273
D170	------	------	13–17	23–30	{265 331 333	------ ------ ------

Remarks.—This delicate species is believed to be the first representative of the genus to be described from rocks of Eocene age.

Occurrence.—Upper Eocene, impure limestone-conglomerate facies of Densinyama formation and white facies of Matansa limestone. Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D124, D147, D151, D154, D170, and D216.

Holotype.—USGS algae a92–2a.

Dermatolithon saipanense Johnson, n. sp.

Plate 57, figures 4, 6

Description.—Thallus a thin crust. Hypothallus of one or rarely two layers of elongated cells 35μ–75μ high and 17μ–35μ wide (average about 60μ by 20μ). Perithallus of square or vertically elongated cells averaging about 25μ in diameter and up to 35μ in length. Conceptacles chambers 500μ–600μ in diameter, with strongly arched roof. Measurements of 10 specimens are given below.

Measurements of 10 specimens of Dermatolithon saipanense *Johnson, n. sp.*

USGS paleobotanical localities	Hypothallic cells		Perithallic cells		Conceptacles (in μ)
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	
D204	{------ 59–71 35–61	------ 21–37 17–24	13–22 16–22 16–21	20–24 23–30 21–26	Absent Absent Absent
D127	------	------	12–17	20–30	Absent
D210	40–49	17–23	16–24	19–27	Absent
D211	------	------	17–24	24–29	Absent
D105	------	------	21–22	23–35	------
D108	35–65	19–23	19–23	23–33	{252 x 376 293 x 588
D201	------	------	{14–27 14–22	20–25 22–28	------ ------

Remarks.—The dimensions given in the table can be considered only approximate, as the sections cut irregular crusts at fortuitous angles. However, they give an idea of magnitude. No comparable Recent species are known.

Occurrence.—Lower Miocene, inequigranular and rubbly facies of Tagpochau limestone. USGS paleobotanical localities D105, D108, D127, D201, D204, D210, and D211.

Holotype.—USGS algae a22–1a.

Dermatolithon sp.

Several specimens of *Dermatolithon* were observed in limestones of Pleistocene age. As all were in oblique sections, cell measurements could not be made, and specific determination was not possible.

Occurrence.—Pleistocene, *Halimeda*-rich facies of Mariana limestone. USGS paleobotanical localities D206 and D207.

Subfamily **CORALLINOIDEAE** (articulate corallines)

Fragments of articulate coralline algae are abundant in many of the Cenozoic limestones on Saipan, at places contributing importantly to the total bulk of the rock. Difficulty in their study arises mainly from the fact that the classification of modern forms is based largely on the position and nature of the conceptacles, which are rarely found in the fossils. The growth habit and method of branching is also emphasized in classification, but most of the fossil specimens consist of single segments (articuli), and an individual modern plant may contain segments having a variety of shapes and sizes.

The factors utilized in the provisional key to genera given below have facilitated the classification of the specimens into genera, but subdivision into species is even more difficult and uncertain. Comparison with described species of fossils is especially difficult. Some of the fossil "species" have been based on hopelessly inadequate material and are quite unrecognizable.

KEY TO ARTICULATE CORRALINE ALGAE

By Preston E. Cloud, Jr.

[This key was originally prepared on June 21, 1952, as an aid to work then in progress. Being found useful it is published here with the permission of its compiler, who calls attention to the fact that it is based largely on papers by A. V. Manza (1937, 1940).]

The key is based mainly on features of segments (articuli) as seen in approximately axial thin-sections and thus regularly available to paleontologists. Nonessential but possibly helpful information in the key is separated by parentheses. Misinterpretation of thin-sections that are oriented at random must be guarded against. Among material so far studied, specimens that show nodes, conceptacles, and branching patterns are increasingly rare in the order given. Conceptacles should, however, be found commonly where rooted in the latral hypothallus (*Cheilosporum*), occasionally where terminal and rarely where lateral and restricted to the perithallus. Attachment scars of conceptacles that are lateral and wholly external are not likely to be recognizable in thin-section but should be looked for in free specimens that may be found in marly, argillaceous, or tuffaceous deposits.

Provisional key to the genera of articulate coralline algae

I. Segments (articuli) consisting of a single tier of long cells—*Lithothrix*.
II. Segments consisting of several or many tiers of cells.
  A. Cells of individual tiers flexuous and interlacing. (Conceptacles invariable lateral, immersed in tissue, forming warts on surface. Nodes consisting of a single row of cells.)—*Calliarthron*.[1]
  B. Cell walls straight and cells regular in form.
    1. Boundaries between cell tiers irregular. (Cells commonly subrectangular to subrhombic and appearing to fan toward margins, but in some species much elongated and not conspicuously fanned. Cell tiers generally of subequal height, but in some instances with both high and low tiers, which appear as long and short cell rows in thin section. Segments mostly narrowly cylindrical and delicate in appearance. Conceptacles invariably terminal and uncommon in fossils. Branching strictly dichotomous.)—*Jania*.[1]
    2. Boundaries between cell tiers mostly regular or nearly so. (Cells for the most part narrowly elongated, giving the impression of extending from one tier to another as essentially straight and parallel filaments.)
      a. Cells in high (long) and low (short) tiers variously alternating. (One to five tiers of high cells separated by one of low cells is characteristic. Perithallus is prominent. Conceptacles are invariably lateral and thus rare in fossils. Segments cylindrical or compressed. Nodes commonly short and inconspicuous.)—*Amphiroa*.[1,2]
      b. Cells in tiers of approximately uniform height.
        (1). Cell tiers flattened in central part, curving down abruptly at the margins. (Perithallus commonly conspicuous. Conceptacles invariably terminal and uncommon in fossils. Branching regularly pinnate.)—*Arthrocardia*.[1]
        (2). Cell tiers evenly arcuate.
          (a). Conceptacles rooted in lateral hypothallus, on upper lobes of segments, commonly producing wartlike protuberances. (Segments commonly clavate, and of oval, round, flattened, or hexagonal outline. Branching commonly bifid.)—*Cheilosporum*.
          (b). Conceptacles mainly external, terminal or lateral. (Lateral conceptacles not penetrating perithallus. Terminal conceptacles occasionally found imbedded in centers of fossil segments.) Where data are lacking for closer identification beyond this step, specimens are arbitrarily referred to *Corallina*. Fossil *Corallina* thus may include representatives of any or all the genera below.
            i. Conceptacles both terminal and lateral—*Joculator*.
            ii. Conceptacles either terminal only or lateral only.
              a. Conceptacles all terminal, uncommon in fossils.
                aa. Branching wholly or partly pinnate. (Dichotomous to trichotomous or irregular. Perithallus weakly developed. Segments mainly clavate to flattened *Halimeda*-like.)—Carollina.[1]
                bb. Branching regularly and persistently pinnate—*Duthiea*.
              b. Conceptacles all lateral, rare in fossils.
                aa. Nodes of more than one tier of cells. (Branching in radial whorls or trifid. Perithallus thin and inconspicuous.)—*Metagoniolithon*.
                bb. Nodes of only one tier of cells. (Perhaps only one genus here.)
                  aaa. Segments cylindrical, round in transverse section—*Pachyarthron*.
                  bbb. Segments compressed, flattened oval in transverse section—*Bossea*.

Genus CALLIARTHRON Manza, 1937

This genus differs from other known genera of articulate corallines in that the cells of the hypothallus are flexuous and interlacing. The conceptacles are located along the lateral margins of the segments.

The first fossil record of the genus is here announced, *C. antiquum* Johnson, n. sp., from the lower Miocene Tagpochau limestone.

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[1] Genus represented by fossils on Saipan.
[2] Genus restricted to Pleistocene and Recent on Saipan.

Calliarthron antiquum Johnson, n. sp.

Plate 52, figures 1 and 9

Description.—Several fragments apparently belonging to the genus *Calliarthron* were found in the limestones of Miocene age. A specimen containing 3 attached segments is 2.26 mm long and 0.908 mm wide. The 3 segments contain 10, 8, and 8 tiers of cells. Nodes measure 0.312 by 0.578 mm and 0.320 by 0.571 mm. Hypothallic cells at center of rows attain lengths of 50μ–64μ averaging about 57μ. Marginal perithallic cells small, measuring 10μ–15μ in length and 6μ–10μ in width. Conceptacles small and marginal. One conceptacle scar measures 135μ in length and 72μ in width.

Remarks.—The specimen described is the first fossil representative of the genus to be recorded. As it is also well preserved and distinctive, it merits a new specific name.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D126 and D153.

Holotype.—USGS algae a47–1a.

Genus JANIA Lamouroux, 1812

The plants consist of masses of slender dichotomously branching fronds. Each frond is a series of slender segments formed of tiers of hypothallic cells surrounded by a narrow perithallus that is characteristically restricted to a single layer of small rectangular cells. The hypothallic cells tend to be wider in proportion to length than in most genera of articulate corallines. In many instances, they are elongately wedge shaped in section, and the successive tiers of cells tend to meet along irregular lines.

Living *Jania* occurs widely in the tropic and temperate seas, where it is represented by many species. Fossil representatives are known from rocks as old as Late Cretaceous. Although not abundant as a fossil on Saipan, fragments of *Jania* were found in beds from Eocene to Pleistocene in age.

Jania vetus Johnson, n. sp.

Plate 52, figure 2

Description.—Well-preserved segments of *Jania* from the limestones of early Miocone age of Saipan provide the dimensions in table below. The variation shown is believed to be within that attributable to a single species, but differs from that of described forms known to the author.

Measurement of four specimens of Jania vetus *Johnson, n. sp.* *(from random sections)*

USGS paleobotanical localities	Size segment		Hypothallic cells		Perithallic cells	
	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)	Length (in μ)	Width (in μ)
D119 {	1,260	260	60–78	17–30	13–17	18–30
	2,320	320	54–73	21–46	----------	----------
D194	2,270	302	57	20	16–23	25–32
D200	1,000	496	65	22	----------	----------

Remarks.—No other Miocene species of *Jania* has been described from the Pacific region, although Johnson and Ferris (1950, p. 21) mention a fragment from the Miocene of Lau, Fiji.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D119, D185, D194, D196, D199, and D200.

Holotype.—USGS algae a68–1a.

Jania sp. A

Plate 39, figure 8

Description.—Form represented in limestones of Eocene age by many small segments; most are quite incomplete. One fairly complete segment measured 1 mm in length and 160μ–200μ in diameter. Hypothallic cells of same specimen 32μ–40μ long and 11μ–16μ wide. Perithallic cells nearly square, 12μ–20μ by 11μ–16μ. Conceptacles unknown.

Occurrence.—Upper Eocene, conglomerate-sandstone facies of Hagman formation. USGS paleobotanical locality D175.

Jania sp. B

Plate 52, figures 3, 6

Description.—Small worn segments of *Jania* observed in slides of Miocene limestone are referred to this form. Largest segment 1.26 mm long. Hypothallic cells from middle of cell rows of several specimens measured 40μ–60μ in length and 9μ–14μ in width. Marginal perithallic cells 12μ–18μ by 8μ–12μ. One specimen (pl. 52, fig. 3) shows terminal cavity which may represent an eroded conceptacle.

Occurrence.—Lower Miocene, rubbly and inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D277 and D278.

Genus AMPHIROA Lamouroux

Plants are clusters of segmented fronds that branch dichotomously or trichotomously at regular intervals. Conceptacles are lateral. Segments are cylindrical to flattened, or show a thicker center and thinner margins. Within the well-developed hypothallus of individual segments one or more tiers of long cells alternate with single tiers of shorter ones. Marginal perithallus moderately to well developed.

Representatives of the genus are known from the Miocene to the present and are abundant in modern warm seas. Abundant in the Pleistocene limestones of Saipan, but not observed in the older limestones.

Amphiroa foliacea Lamouroux

Plate 37, figure 2

Amphiroa foliacea Lamouroux, 1824, Zoologie 3, p. 628, pl. 93, figs. 2, 3.
Weber van Bosse, 1904, *Siboga*-Expeditie Mon. 61, p. 92–93, pl. 14, figs. 1–11.

Description.—Segments nearly cylindrical, slightly flattened. Medullary hypothallus consists of 3 or 4 layers of long cells (30μ–45μ long) alternating with 1 layer of short cells (11μ–24μ long). Cells of hypothallus merge gradually into those of cortical or marginal perithallus. Hypothallic cells in curved rows. Perithallic cells square or nearly so, measuring 8μ–12μ on a side. Conceptacles not present.

Remarks.—In general appearance and in arrangement and dimensions of cells, these fragments from Saipan correspond to the modern Pacific species *A. foliacea.*

Occurrence.—Pleistocene, *Halimeda*-rich facies of Mariana limestone. USGS paleobotanical locality D129.

Amphiroa fragilissima (Linnaeus) Lamouroux

Plate 37, figure 1; plate 55, figures 2–4

Corallina fragilissima Linnaeus, 1767, Systema naturae: Stockholm, ed. 12, v. 1, p. 1305.
Amphiroa fragilissima (Linnaeus) Lamouroux, 1816, Histoire des polypiers coralligenes flexibles: Caen, p. 298.
Weber van Bosse, *in* Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 89–91, pl. 14, fig. 5.
Manza, 1940, Philippine Jour. Sci., v. 71, No. 3, p. 299.

Description.—Segments cylindrical and many times longer than wide. Medullary hypothallus composed of 4 or 5 layers of long cells, alternating with 1 or 2 layers of shorter cells. Division between medullary hypothallus and cortical perithallus abrupt and clearly defined. Hypothallic rows nearly flat. Conceptacle scars indicate diameter about 300μ. Measurements of selected specimens are given below.

Measurements of five specimens of Amphiroa fragilissima *(Linnaeus) Lamouroux (from random sections)*

USGS paleobotanical localities	Segments		Medullary hypothallus		Cortical perithallic cells	
	Length (in μ)	Width (in μ)	Length of long cells (in μ)	Length of short cells (in μ)	Length (in μ)	Width (in μ)
D131	{ 3,092	490	63±	24+	18–28	7–9
	2,940	480	59–68	14–28	25–32	7–11
D132	----------	489	45–58	13–26	19–34	7–9
D131	----------	180	54–68	32–34	24–30	8–11
D208	----------	630	53–67	16–42	12–24	9–11

Remarks.—This variable species is extremely widespread in the tropical Pacific at present. The described specimens from the Pleistocene of Saipan correspond well to the descriptions given by Madame Weber van Bosse (*in* Weber van Bosse and Foslie, 1904).

Occurrence.—Pleistocene, pink massive facies of Mariana limestone. USGS paleobotanical localities D131, D132, and D208.

Amphiroa sp.

Plate 60, figure 1

Description.—Plants are small bushy tufts 3–5 cm wide, composed of very delicate fronds about 1 cm long and up to 2 mm wide. Individual fan-shaped segments show flattened central ridge and wide lateral wings. Width commonly about twice as great as length along central axis. No conceptacles observed in specimens collected.

Occurrence.—Recent, abundant on rocky surfaces just below low tide level along west coast of Saipan.

Genus ARTHROCARDIA Decaisne (emend. Areschoug)

Among the hundreds of individual segments of articulated coralline algae observed in the slides of limestones from Saipan occasional segments believed assignable to *Arthrocardia* were observed. They occur in limestones of both Eocene and Miocene age. The specimens are too few and scattered to merit naming but are mentioned for the record.

Genus CORALLINA Linnaeus, 1758

The plants are clusters of segmented stems which branch at close intervals, ordinarily in a plane. Branching typically pinnate (dichotomous to trichotomous or irregular). Perithallus weakly developed and inconspicuous, the greater part of the individual segment consisting of hypothallic tissue. Segments mainly clavate, flattened cylindrical, or flattened *Halimeda*-like but varying widely in shape. Conceptacles lateral or terminal. Abundant and widespread at present in warm and temperate seas, and has been found as far north as latitude 70°. Fossils known from the Eocene to the present. Abundant in many of limestones of Eocene and Miocene age from Saipan.

Corallina matansa Johnson, n. sp.

Plate 44, figures 3, 4

Description.—Fronds consist of moderately wide, flattened, sharply tapering segments. Each segment consists mainly of tiers of hypothallic tissue with narrow but noticeable marginal perithallus. Hypothallic cells in center of tiers measure from 50μ to 69μ in length with average of about 60μ. Perithallic cells rectangular, 9μ–25μ long by 7μ–11μ wide. Dimensions of selected specimens are given below.

Measurements of five specimens of Corallina matansa *Johnson, n. sp. (from random sections)*

USGS paleobotanical localities	Size segment: Length (in μ)	Size segment: Width (in μ)	Length of hypothallic cells (in μ)	Perithallic cells: Length (in μ)	Perithallic cells: Width (in μ)	Tiers of cells in segment	Size node: Length (in μ)	Size node: Width (in μ)
D175	1,070	270	53–69			37		
	1,118	320	53–69			24		
D158	675	297	58–65			21	138	169
D222	680	201	55–66	14–20	8–11	12	180	129
D156	1,080	703	52–64	9–25	7–11	17		

Remarks.—The cell dimensions of this form are close to those of *Corallina grandis* K. Sripada Rao (1943, p. 286), but the Saipan species does not have nearly as well developed a perithallus. The cell dimensions also are about the same as *Corallina delicatula* Johnson and Ferris (1949, p. 197). However, *C. delicatula* has smaller, flatter segments, which usually taper less than the specimens described above.

Occurrence.—Upper Eocene, conglomerate-sandstone facies of Hagman formation and both pink and white facies of Matansa limestone. USGS paleobotanical localities D156, D158, D175, and D222.

Holotype.—USNM 624477 (Foraminifera slide).

Corallina neuschelorum Johnson, n. sp.

Plate 37, figure 3; plate 50, figures 1–4

Description.—Fronds consisting of flattened clavate segments; each segment mainly of hypothallic tissue. Cells in center of tier 47μ–102μ long, averaging 79μ–91μ. Perithallus but slightly developed, cells measuring 9μ–16μ long and 8μ–13μ wide. Table below gives measurements, and other statistical details.

Measurements of seven specimens of Corallina neuschelorum *Jonhson, n. sp. (from random sections)*

USGS paleobotanical localities	Size segment: Length (in μ)	Size segment: Width (in μ)	Node: Length (in μ)	Node: Width (in μ)	Hypothallic cells: Maximum length (in μ)	Perithallic cells: Length (in μ)	Perithallic cells: Width (in μ)	Approximate number of cells in a tier	Number of cell tiers in a segment
D182	1,290	445	223	321	73–102	9–13	8–11	34–39	12
D113	487	331	192	224	47–82	15–21	9–11	33	6
D195	980	512	162	245	55–90	9–13	8–12	33–36	7
	710	435	185	389	57–91	11–13	11	28–33	6
D120	510	623	156	534	52–89	13	9	34	7
	718	574	385	423	65–100	13–16	11–13	74	8
D197	350	370	210	350	64–97	10–13	9–11	35	7

Remarks.—The only previously described Miocene *Corallina* is *C. crossmanni* Lemoine, originally recorded from Martinique. Lignac-Grutterink (1943) applies the same name to a series of specimens from the Dutch East Indies ranging in age from Eocene to Pleistocene. All of the latter's specimens have cell dimensions which fall within the range of Lemoine's species.

Remains of *Corallina* are very abundant in the Tagpochau limestone. The series of specimens in the table have dimensions and ratios which fall in a fairly consistent pattern and differ from Grutterink's material in having wider cells. They are considered to represent a distinct species, here named *neuschelorum* in honor of Sherman and Virginia Neuschel.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. UGSG paleobotanical localities D113, D120, D171, D182, D195, D197, and D198.

Holotype.—USGS algae a29–1a.

Corallina prisca Johnson, n. sp.

Plate 37, figure 4; plate 40, figure 10; plate 44, figures 1, 2, 7–11

?*Corallina crossmani* Lignac-Grutterink [not Lemoine] [part?]. Lignac-Grutterink, 1943, Geol.-mijnb. genootsch. Nederland en Kolonien Verh., Geol. ser., jagu 113, p. 294.

Description.—Fronds composed of slender, in part slightly flattened, nearly cylindrical segments. Segments consist of hypothallic tissue with an inconspicuous perithallus ordinarily limited to 1 or 2 layers of small cells. Hypothallic cells toward centers of tiers range from 72μ to 102μ in length, averaging from 80μ to 90μ. Perithallic cells nearly square, measuring 10μ–22μ in length by 7μ–13μ in width. Measurements and other statistical data are given in the following table.

Measurements of 19 specimens of Corallina prisca *Johnson, n. sp. (from random sections)*

USGS paleobotanical locality	Size segment		Hypothallic cells	Perithallic cells		Tiers of cells in segments	Size of node (in μ)
	Length (in μ)	Width (in μ)	Length (in μ)	Length (in μ)	Width (in μ)		
D107	735	267	76–108	10–12	8–11	10	----------
	690	320	100	--------	8–10	8	203–223
	1,105	283	73	--------	--------	13	267–245
D144	1,125	285	80–98	15–20	9–12	36	315–225
D148	680	129	88	--------	--------	14	129–202
D152	540	226	67–82	16–23	9–11	21	158–175
D161	358	135	84	14–14	8–10	10	91–86
D165	480	207	72–97	14–18	7–10	10	183–165
D169	785	320	80–110	--------	7–13	8	311–169
D173	410	144	72–92	18–23	8–11	12	107–116
	780	340	68–108	21	14	15	111–140
D175	410	180	90–120	--------	--------	21	120–120
	690	160	84–92	--------	--------	8	----------
D179	780	290	70–110	--------	--------	10	227–223
D218	280	261	81	13–15	7–10	----------	153–216
D219	1,180	243	73	14–19	9–13	21	----------
D221	1,020	250	65–90	15–22	8–12	13	----------
D222	1,155	101	67–90	15–20	8–11	11	260–234
D224	630	206	77–88	14–23	8–12	11	115–111

Four terminal segments believed to represent *C. prisca* contain what are probably first conceptacles of Eocene *Corallina* to be illustrated (pl. 44, figs. 1, 2, 7).

Remarks.—The average cell size of *C. prisca* differs from any previously described species for which cell dimensions are given. However, 1 or 2 of the probably heterogeneous assemblage of specimens listed by Lignac-Grutterink (1943, p. 294) from Borneo under the name *C. crossmani* Lemoine have about the same dimensions as *C. prisca* and may be referable to that species. The type material of *C. crossmani*, described by Lemoine (1917, p. 265) from the Miocene of Martinique, has wider, flatter, and more clavate segments.

Occurrence.—Upper Eocene, both pink and white facies of Matansa limestone; limestone-conglomerate facies of Densinyama formation; and conglomerate-sandstone facies of Hagman formation. USGS paleobotanical localities D107, D144, D147, D148, D152, D161, D165, D169, D173, D175, D179, D218, D219, D221, D222, and D224.

Holotype.—USGS algae 289–2b.

CHLOROPHYTA (GREEN ALGAE)

Family DASYCLADACEAE

Genus CYMOPOLIA Lamouroux, 1816

The dasycladacean genus *Cymopolia* includes small heavily calcified plants formed of a series of rounded cushion shaped or short cylindrical segments. Each segment consists of a thick central stem from which whorls of slender primary branches develop at regular intervals. Each primary branch then gives rise to a tuft of secondary branches. The spherical to nearly cylindrical sporangia are located within the cluster of secondary branches on a short modified secondary branch.

The genus is known from Late Cretaceous to Recent, and Recent species are restricted to tropical or subtropical waters.

Cymopolia delicata Johnson, n. sp.

Plate 51, figures 1–6

Description.—Plant consists of series of small cylindrical to conical segments which are rounded at top and ordinarily considerably longer than wide.

Segment has thick central stem which tapers slightly in diameter from base to top. Stem diameter 50–60 percent of segment diameter. Primary branches long and slender, about 28–32 to a whorl. Secondary branches slender and appear to develop 4 to a tuft. Sporangia small and spherical to elongated oval in section, occur among secondary branches, ordinarily separated from end of primary branch by a short stem. Apparent dimensions of specimens from USGS paleobotanical locality D94 are given in the following table.

Measurements of illustrated specimens of Cymopolia delicata *Johnson, n. sp., from USGS paleobotanical locality D94*

Illustration	Size segment (in mm)	Central stem diameter (in mm)	Primary branch		Secondary branch diameter (in μ)	Sporangia	
			Diameter (in μ)	Length (in μ)		Diameter (in μ)	Length (in μ)
Pl. 51, fig. 6	0.8 x 0.6	Top 0.20	20	38	17	25	50
		Base .35	28	45	25	28	63
Pl. 51, fig. 3	------------	Top .18	25	--------	20	30	--------
		Base .20	37	--------	25	50	--------
Pl. 51, fig. 1	1.5 x 1.0	Top .25	25	30	18	30	42
		Base .43	32	52	27	43	58

Remarks.—This species differs appreciably from any previously described Miocene *Cymopolia.* Its most distinctive feature is the long relatively slender branches.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D94 and D189.

Holotype.—USGS algae a7–31.

Cymopolia pacifica Johnson, n. sp.

Plate 45, figures 1–12

Description.—Plant consists of series of short cylindrical segments with rounded ends. Each segment contains a thick central stem from which develop 4–6 whorls of primary branches. Each of these whorls contains from 32 to 40 branches arranged like spokes of a wheel. Primary branches thicken at outer end. Tufts of 4–6 secondary branches develop from the ends of the primary branches. Sporangia egg shaped and located within the tufts of secondary branches. One specimen (pl. 45, fig. 4) shows sporangia filled with spherical objects, presumably spores. Apparent dimensions of specimens from USGS paleobotanical locality D97 are given in the following table.

Measurement of four specimens of Cympolia pacifica *Johnson, n. sp., from USGS paleobotanical locality D97*

Size segment (in mm)	Central stem diameter (in mm)	Primary branch diameter (in μ)	Secondary branch diameter (in μ)	Sporangia (in μ)
1.8 x 2.0 [1]	Widest 0.7; Base .6	28, 37, 50, 28		Diam. 130, 100, 140, 143.
2.8 diam	.9	55, 45, 38, 41	30, 38, 28, 25, 30	293 x 155. 305 x 160. 250 x 162. 265 x 172.
2.1 diam	.6	Base 35–53; Top 70–80	28 to 31	288 x 180. 450 x 163. 330 x 163. 303 x 133.
1.3 x 1.8	.6	30–50	23 to 25	

[1] Illustrated on plate 45, figure 5.

Remarks.—This species is represented by over 25 specimens. It is the first Eocene *Cymopolia* to be described from the Pacific area. It is probably close to *C. edwardsi* described by Morellet and Morellet from the Eocene of England, but differs in size and the much larger number of primary branches in a whorl. Both species show the enlargement of the primary branches toward their outer end, a feature of *C. tibetica* described by Lucien Morellet (1916) from the upper Cretaceous (Maestrichtian) of Tibet.

Occurence.—Upper Eocene, white facies of Matansa limestone and limestone-conglomerate facies of Densinyama formation. USGS paleobotanical localities D97, D152, D177, D183, D184, D227, D381, and D383. It is especially abundant at locality D97.

Holotype.—USGS algae a11–a1.

Cymopolia saipania Johnson, n. sp.

Plate 51, figures 7–12

Description.—Plant consists of series of short cylindrical segments, one above the other. Segments rounded at top and bottom, wider than long; some segments apple shaped.

Each segment consists of thick central stem from which whorls of primary branches develop at regular intervals. There appear to be from 16 to 24 primary branches in a whorl and from 4 to 8 whorls to a segment, most frequently 5 or 6. Each primary branch gives rise to tufts of secondary branches. Each tuft contains from 4 to 6 and probably 8 secondary branches. Spherical to egg-shaped sporangia developed at ends of primary branches where surrounded by tuft of secondary branches. Apparent dimensions of specimens from USGS paleobotanical locality D92 are given in following table.

Measurements of specimens of Cymopolia saipania *Johnson, n. sp., from USGS paleobotanical locality D92*

Size segment (in mm)	Diameter of central stem (in mm)	Diameter of primary branch (in μ)	Diameter of secondary branch (in μ)	Sporangia	
				Length (in μ)	Diameter (in μ)
2.2 x 1.4	0.5	80, 88, 88, 50, 53	15, 13, 25	175 250 265	125 185 200
0.6 diameter	0.3				
1.4 x 0.8	Top 0.4; Base 0.5	42, 33, 30	Ends 30, 33; Base 18, 17		

Remarks.—This species strongly suggests the modern *Cymopolia vanbosse* Solmes in growth habit and appearance. However, it has larger sporangia, and in general its dimensions are greater. It somewhat resembles some of the pieces of the highly variable *C. miocaenica* (Karrer) Morellet described by the Morellets (1926, p. 224–225) from Hungary but differs in the size, shape, and position of the sporangia.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. Abundant at USGS paleobotanical localities D92, D187, D188, and D189.

Holotype.—USGS algae a5–3a.

Family CODIACEAE

Genus HALIMEDA Lamouroux, 1812

Halimeda plants are bushy tufts of segmented branching stems or fronds. The segments may be broad and leaflike, flattened, subcylindrical, or even subconical. The older segments become strongly calcified. Calcification seems to work from the outside in and is commonly incomplete. The modern species are based largely on branching habit, shape of segments, and structure of the node. The fossils consists almost without exception of individual segments which it is not possible to assign to species, especially from fragments in thin sections.

Halimeda remains are found in all of the limestones from Saipan. At places they contribute importantly to the construction of the rock. They are abundant on the submerged flats of some of the modern fringing reefs and in the lagoon areas. Two Recent species are described and illustrated. Some fragments from limestones of Miocene and Pleistocene age are also figured (pl. 44, figs. 5, 6; pl. 55, fig. 5; and pl. 56, fig. 3).

Halimeda gracilis Harvey forma lata Taylor

Plate 60, figures 4, 5

Halimeda gracilis Harvey. Barton, 1901, *Siboga*-Expeditie Mem. 60, p. 22, pl. 3, figs. 28–32.

Halimeda gracilis Harvey forma *lata* Taylor, 1950, Mich. Univ. Studies, Sci. Ser., v. 18, p. 83–84, pl 42.

Description.—Plants bushy, branching more or less in a plane. Segments commonly crowded below.

Segments rounded or kidney shaped, thick, and moderately calcified. Upper segments 1.0–2.3 cm broad and 1.0–1.6 cm wide, commonly thinner than lower ones.

Occurrence.—Recent, lives in holes and openings on reef along west side of Saipan but not abundant there.

Halimeda opuntia Lamouroux forma triloba Barton

Plate 60, figure 2

Halimeda opuntia Lamouroux, 1812, Soc. Philomat. Sci. Bull. 3, p. 186.

Halimeda opuntia forma *triloba* Barton, 1901, *Siboga*-Expeditie Mem. 60, p. 20, pl. 2, fig. 20.

Taylor, 1950, Mich. Univ. Studies, Sci. Ser., v. 18, p. 81–82, pl. 40, fig. 2.

Description.—Plants bushy, without a distinct stem, attached at several points by rhizoids. Branching irregular or opposite, not in single plane. Branches long, flat, consisting of calcified segments connected by flexible joints. Lower segments commonly 7–10 mm wide and long, strongly trilobed; lobes nearly cylindrical, flattened around edges; upper lobes less strongly indented and flatter.

Occurrence.—Recent, common in the lagoon at Tanapag Harbor and in shallow pools on the submerged fringing reef flats on the southwestern and southern coasts of Saipan.

Genus MICROCODIUM Gluck, 1912

Microcodium sp

Plate 50, figures 5–9

Discussion.—The structures called *Microcodium* are subcylindrical to lobulate (and possibly spherical) masses that consist of relatively large cuneiform cells which radiate out from a circular or elliptical center.

There is considerable doubt as to the systematic position of this problematical fossil alga. Heinrich Glück (1912) considered it to belong among the green algae of the family Codiaceae. Julius Pia (1927, p. 60) accepts it as algal but expresses doubt that it belongs among the Codiaceae. Louls Emberger (1944, p. 65) agrees with Pia. Johnson (1953, p. 86) on the basis of new material from France, Italy, Spain, Saipan, and Kita-daitō-jima concurs as to its probably algal nature, but is uncertain about its systematic position.

The type material came from the Miocene of Bavaria. Since then, similar structures have been reported from the Miocene of Algeria; the Eocene of France, Italy and Switzerland; and the Oligocene of France. The writer has observed it in slides of limestone of Miocene age from the Kita-daitō-jima cores. It is abundant in the limestones of Miocene age of Saipan at a number of localities.

Occurrence.—Lower Miocene, inequigranular facies of Tagpochau limestone. USGS paleobotanical localities D94, D192, D193, and D167.

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[Italic numbers indicate descriptions]

PLATES 37–60

PLATE 37

FIGURE 1. *Amphiroa fragilissima* (Linnaeus) Lamouroux (p. 238).
Segment of an articulate coralline (*h*=medullary hypothallus, *p*=marginal perithallus). Note the alternations of tiers of long and short cells, ordinarily 4 long, 1 short. Pleistocene, Mariana limestone, pink massive facies; loc. D131 (C65); USGS algae a55–2a.

2. *Amphiroa foliacea* Lamouroux (p. 238).
Same structure as in figure 1. Note in this species the alternations of tiers of cells follows the pattern 2 long, 1 short, or 2 long, 1 medium, 1 short. Pleistocene, Mariana limestone, *Halimeda*-rich facies; loc. D129 (C49); USGS algae a53–1a.

3. *Corallina neuschelorum* Johnson, n. sp. (p. 239).
Part of a frond, with 3 segments (*h*) and 2 nodes (*n*). Upper Eocene, Densinyama formation, limestone-conglomerate facies; loc. D154 (S208); USGS algae a92–1a.

4. *Corallina prisca* Johnson, n. sp. (p. 239).
Showing a terminal conceptacle (*c*). A *Lithoporella* has grown over the upper part. Upper Eocene, Densinyama formation, limestone-conglomerate facies; loc. D147 (S133); USNM 624514 (Foraminifera slide).

5. *Lithoporella melobesioides* (Foslie) Foslie (p. 234).
Sections through thin thalli each composed of a single layer of large cells. Lower Miocene; loc. D433; USGS algae a137–1a.

6. *Lithophyllum* (p. 227).
A crustose specimen showing hypothallus (*c*), perithallus (*p*), and conceptacle (*c*). Upper Eocene, Matansa limestone, white facies; loc. D378 (B72); USGS algae a138–1a.

7. *Lithothamnium tagpotchaense* Johnson, n. sp. (p. 223).
An encrusting *Lithothamnium*, with hypothallus (*h*), perithallus (*p*), and conceptacle (*c*) containing sporangia chambers. Upper Eocene, Densinyama formation, limestone-conglomerate facies; loc. D144 (S90); holotype, USGS algae a75–1a.

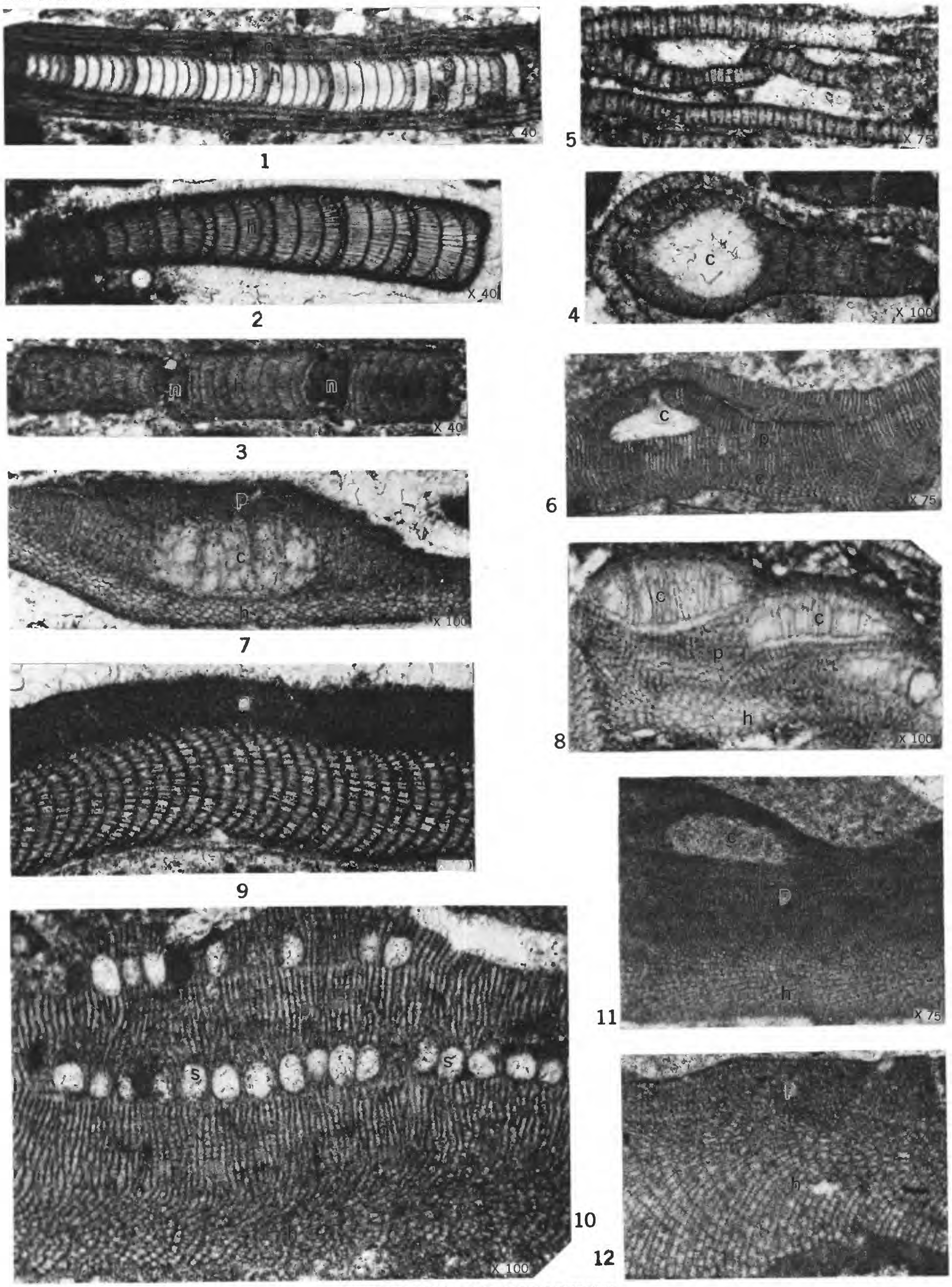
8. *Lithothamnium subtile* Conti (p. 222).
Hypothallus (*h*), perithallus (*p*), and sporangia-filled conceptacles (*c*). Lower Miocene, Tagpochau limestone, inequigranular facies; loc. D122 (C4); USGS algae a40–1a.

9. *Lithophyllum.*
With a well-developed coaxial hypothallus (*h*), and a perithallus (*a*). Lower Miocene, Tagpochau limestone; loc. D211 (C125); USGS Algae a136–1a.

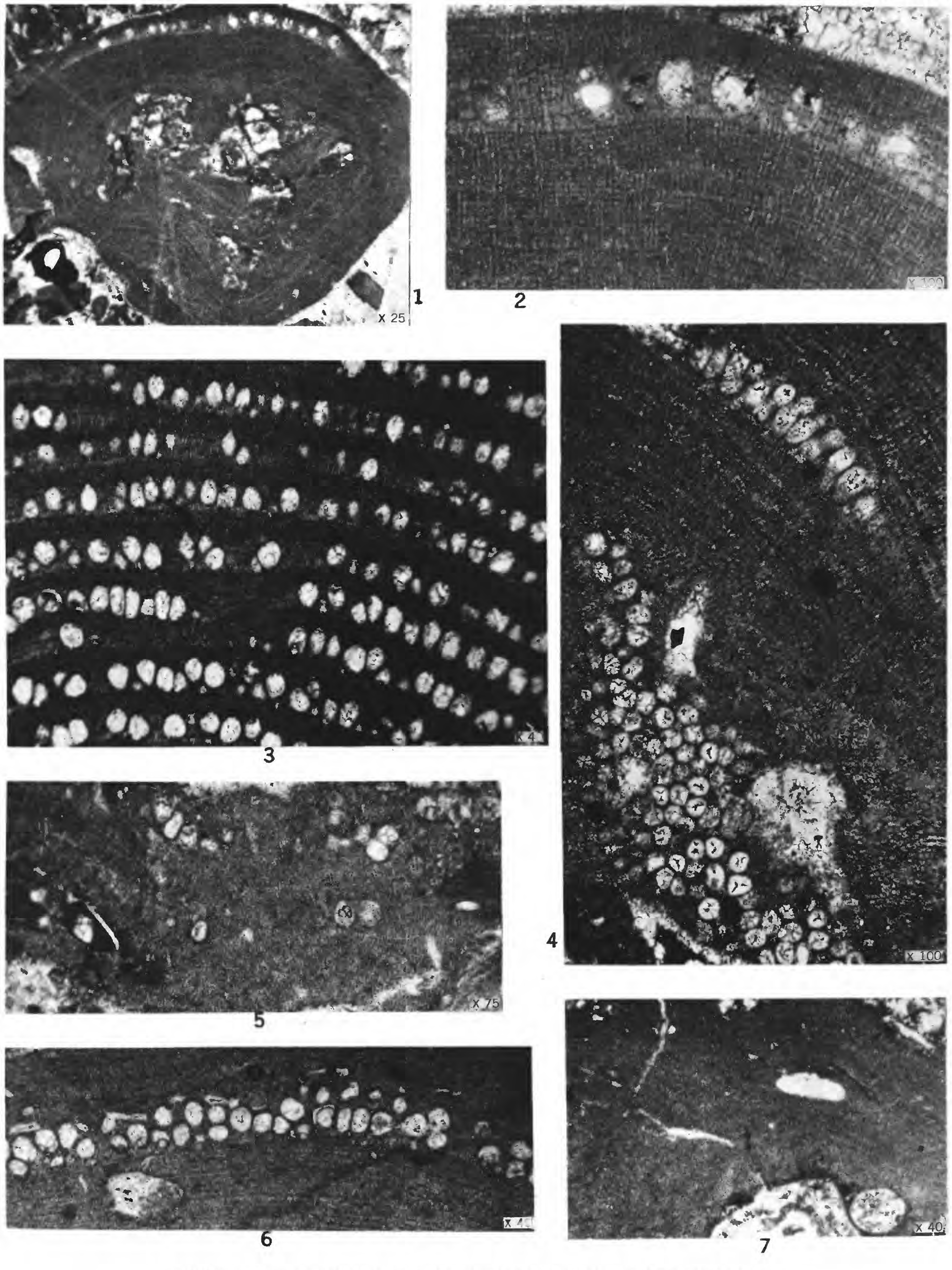
10. *Archaeolithothamnium.*
Showing hypothallus (*h*), perithallus (*p*), and rows (layers) of sporangia (*s*). Upper Eocene, Matansa limestone, white facies; loc. D378 (B72); USGS algae a33–1a.

11. *Lithothamnium* sp. (p. 220).
With hypothallus (*h*), perithallus (*p*), and conceptacle (*c*). Upper Eocene, Matansa limestone; loc. D435, near field loc. S268; USGS algae a139–1a.

12. *Lithothamnium* sp. (p. 220).
Thick hypothallus (*h*) and a thin perithallus (*p*). Upper Eocene, Matansa limestone, pink facies; loc. D233 (S337); USGS algae a31–2a.



STRUCTURE AND DEFINITIONS



UPPER EOCENE *ARCHAEOLITHOTHAMNIUM* AND *LITHOTHAMNIUM*

PLATE 38

FIGURES 1–4, 6. *Archaeolithothamnium saipanense* Johnson, n. sp. (p. 220).

1. A general view of a section through a nodular crust. Matansa limestone, pink facies; loc. D157 (S242); USGS algae a95–2a.
2. A detail of the above showing perithallic tissue and a row of sporangia chambers.
3. A detail of the tissue showing numerous rows of sporangia. Matansa limestone, pink facies; loc. D157 (S242); holotype, USGS algae a95–1a.
4. A section across a crust. In lower left a layer of sporangia is cut nearly perpendicular while in upper right a layer is cut almost parallel. Matansa limestone, pink facies; loc. D168 (S341); USNM 624462 (Foraminifera slide).
6. Perithallic tissue and sporangia chambers in a nearly basal section. Densinyama formation, limestone-conglomerate facies; loc. D160 (S259); USGS algae a99–2a.

5. *Archaeolithothamnium oulianovi* Pfender (p. 218).

Section slightly oblique showing tissue and sporangia. Matansa limestone, white facies; loc. D181 (B56); USGS algae a115–1a.

7. *Lithothamnium moreti* Lemoine (p. 225).

A small hypothallus at base. Perithallic tissue and a conceptacle chamber also shown. Matansa limestone white facies; loc. D124 (C12); USGS algae a44–2a.

PLATE 39

FIGURES 1, 2. *Archaeolithothamnium* cf. *A. liberum* Lemoine (p. 219).

1. A section showing the tissue and three rows of sporangia. Densinyama formation, limestone-conglomerate facies; loc. D159 (S258); USGS algae a97–1a.
2. A section through a plant. Matansa limestone, transitional facies; loc. D123 (C10); USGS Algae no. a42–1a.

3, 6. *Archaeolithothamnium chamorrosum* Johnson, n. sp. (p. 217).

3. Detail of an encrustation showing hypothallus (at base), perithallus and a row of sporangia (at top). Densinyama formation, limestone-conglomerate facies; loc. D160 (S259); USGS algae a99–1a.
6. Hypothallus (curved rows at base), perithallus, and several rows of small sporangia. Matansa limestone, pink facies; loc. D173 (S604); holotype, USNM 624735 (Foraminifera slide).

4, 5. *Archaeolithothamnium oulianovi* Pfender (p. 218).

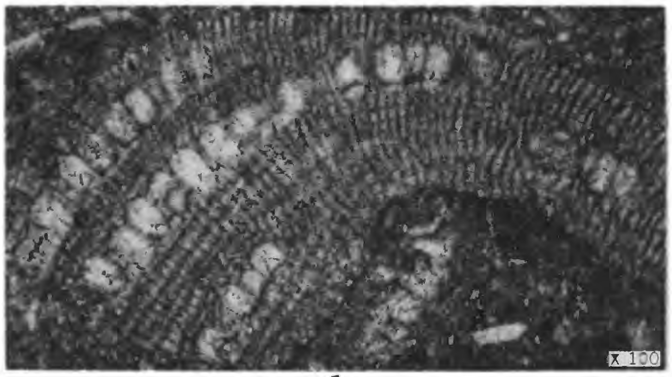
4. Section of a thin crust. Matansa limestone, white facies; loc. D125 (C13); USGS algae a45–1a.
5. Detail of a crust showing hypothallus (left), perithallus, and sporangia. Matansa limestone, transitional facies; loc. D226 (S349); USGS algae a88–1a.

7. *Lithothamnium tagpotchaense* Johnson, n. sp. (p. 223).

Showing small but distinct hypothallus, perithallus and a conceptacle with sporangia. Densinyama formation limestone-conglomerate facies; loc. D144 (S90); holotype, USGS algae a75–1a.

8. *Jania* sp. A (p. 237).

A nearly complete segment. Hagman formation, conglomerate-sandstone facies; loc. D175 (S103); USGS algae a77–1a.



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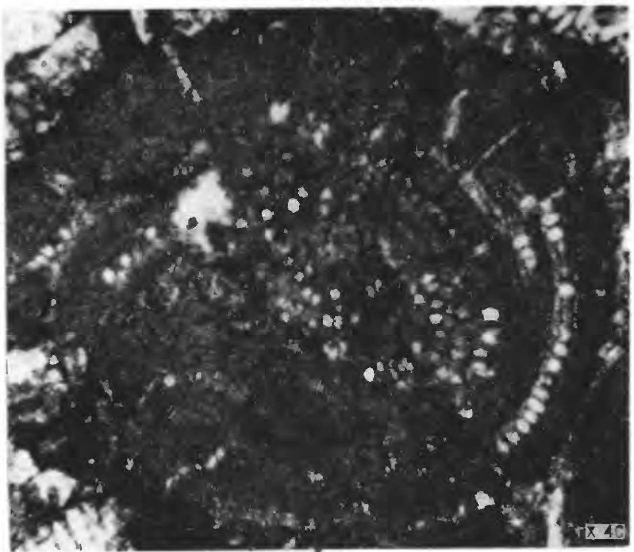

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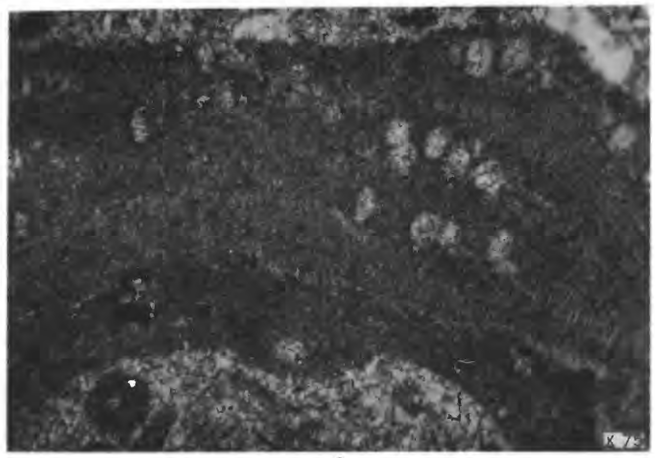

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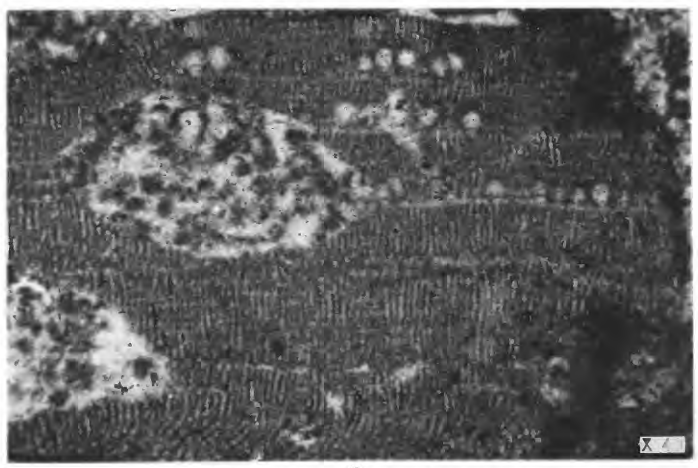

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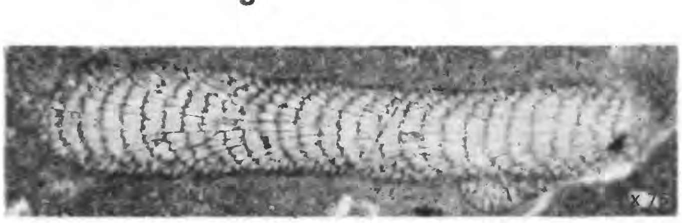

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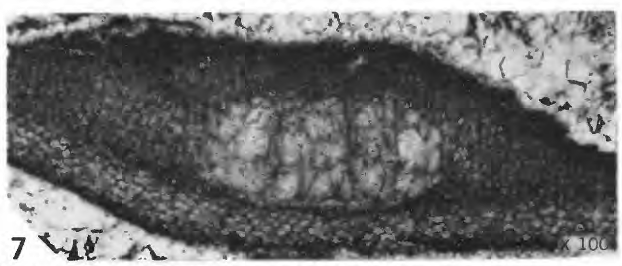
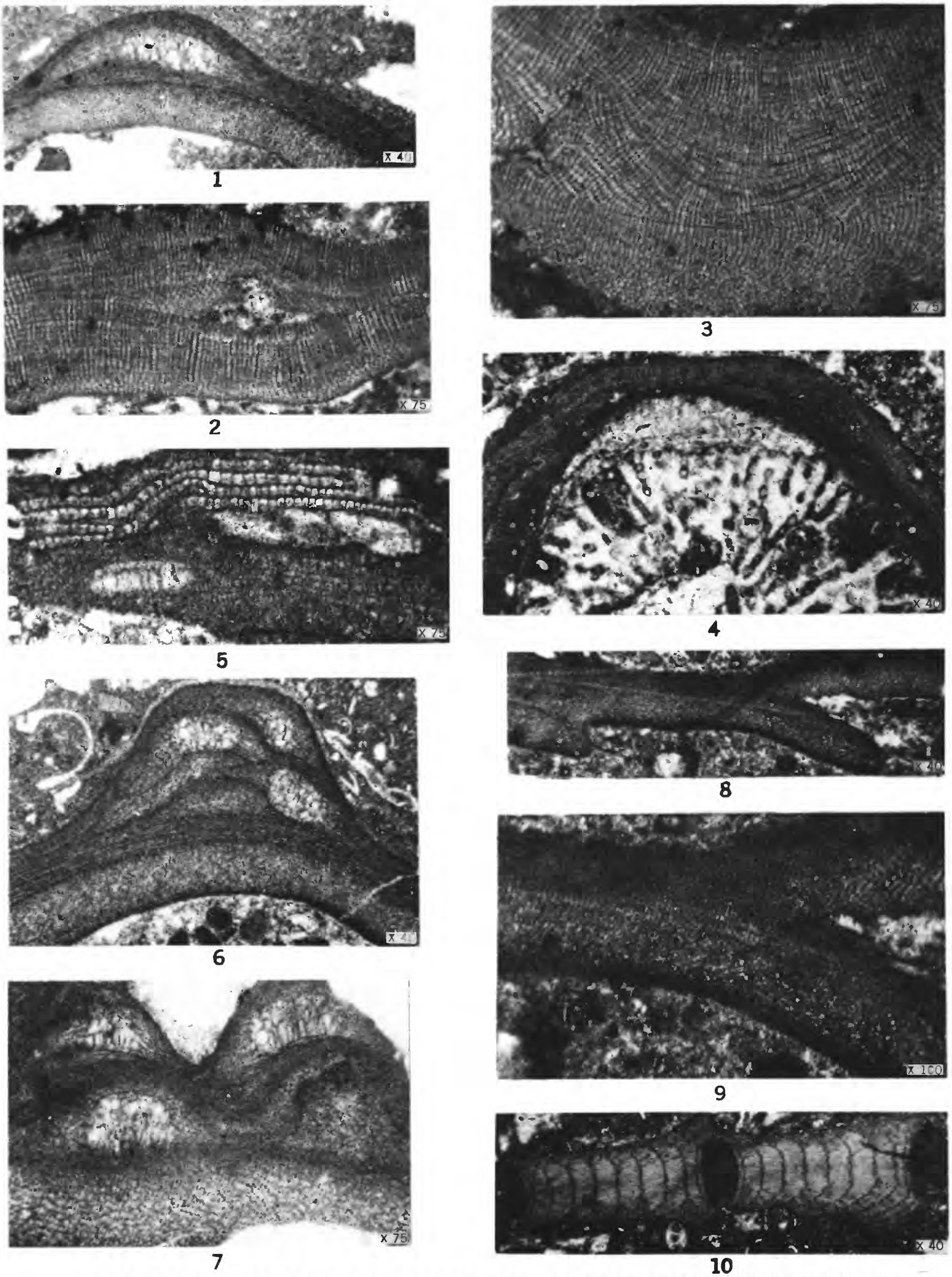


7

UPPER EOCENE *ARCHAEOLITHOTHAMNIUM*, *LITHOTHAMNIUM*, AND *JANIA*



UPPER EOCENE AND LOWER MIOCENE *LITHOTHAMNIUM* AND UPPER EOCENE *CORALLINA*

PLATE 40

FIGURES 1, 6, 7. *Lithothamnium cymbicrusta* Johnson, n. sp. (p. 224).

1. Section showing a well-developed hypothallus, a moderately developed perithallus, and a conceptacle with sporangia. Densinyama formation, limestone-conglomerate facies; loc. D159 (S258); holotype, USGS algae a97–1b.
6. A crust showing hypothallus, perithallus, and a protuberance containing several conceptacles. Densinyama formation, limestone-conglomerate facies; loc. D159 (S258); USGS algae a97–1c.
7. Another specimen showing the same features in greater detail. Densinyama formation, limestone-conglomerate facies; loc. D151 (S170); USNM 624511 (Foraminifera slide).

2–4. *Lithothamnium* cf. *L. aggregatum* Lemoine (p. 221).

2. Section through a crust showing thin hypothallus at base, a secondary hypothallus developed as scar tissue near center, and perithallic tissue. Matansa limestone, pink facies; loc. D173 (S604); USGS algae a112–2a.
3. Hypothallus at base, and irregular perithallic tissue above. Matansa limestone, transitional facies; loc. D162 (S287); USGS algae a83–1a.
4. Thin crust coating a coral. Matansa limestone, transitional facies; loc. D162 (S287); USGS algae a101–1a.

5. *Lithothamnium* sp. B (p. 223).

Fragment of crust showing perithallus and a conceptacle. Above it several thin superimposed thalli of *Lithoporella*. Tagpochau limestone, marly facies; loc. D141 (S20); USGS algae a70–1a.

8, 9. *Lithothamnium* sp. A (p. 224).

8. Showing basal hypothallus, the perithallus and character of branching. Matansa limestone, pink facies; loc. D169 (S342); USGS algae a108–1a.
9. Same specimen showing details of hypothallus and perithallus.

10. *Corallina prisca* Johnson, n. sp. (p. 239)

Matansa limestone, pink facies; loc. D169 (S342); USGS algae a108–1b.

PLATE 41

FIGURES 1–3. *Lithothamnium marianae* Johnson, n. sp. (p. 226).

1. A slightly oblique section through a branch showing the strongly zoned tissue and four conceptacles with sporangia. Matansa limestone, pink facies; loc D233 (S337); USGS algae a31–1a.
2. A section nearly parallel to axis of branch, showing the growth zones in the tissue and four conceptacles. Densinyama formation, limestone-conglomerate facies; loc. D143 (S88); holotype, USGS algae a73–2a.
3. A section nearly perpendicular across a branch. Densinyama formation, limestone-conglomerate facies; loc. D143 (S88); USGS algae a72–1a.

4 *Lithothamnium* sp. E (p. 226).

A section showing an unusual type of tissue which consists almost entirely of hypothallus. Hagman formation, conglomerate-sandstone facies; loc. D175 (S103). Specimen lost or misplaced.

5. *Lithothamnium wallisium* Johnson and Tafur (p. 225).

Section through a mammelon showing character of tissue and conceptacle chambers. Densinyama formation, limestone-conglomerate facies; loc. D155 (S222); USGS Algae no. a93–1a.

6, 7. *Lithothamnium* cf. *L. abrardi* Lemoine (p. 221).

6. Detail of hypothallus and perithallus. Hagman formation, conglomerate-sandstone facies; loc. D175 (S103); USGS algae a77–1b.
7. General view of same specimen showing several superimposed crusts.

8. *Lithothamnium cymbicrusta* Johnson, n. sp. (p. 224).

Detail showing tissue and a conceptacle with sporangia. Near center is a secondary hypothallus developed as scar tissue. Densinyama formation, limestone-conglomerate facies; loc. D147 (S133); USNM 624514 (Foraminifera slide).

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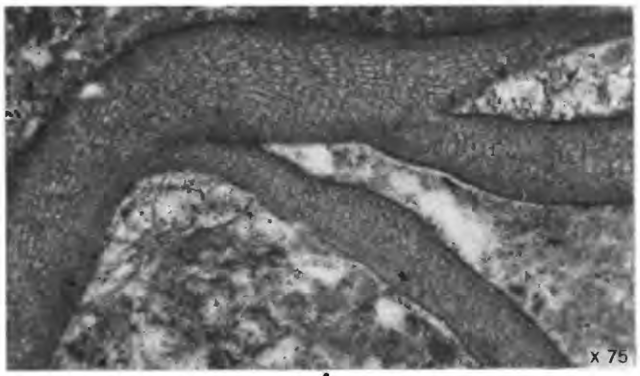

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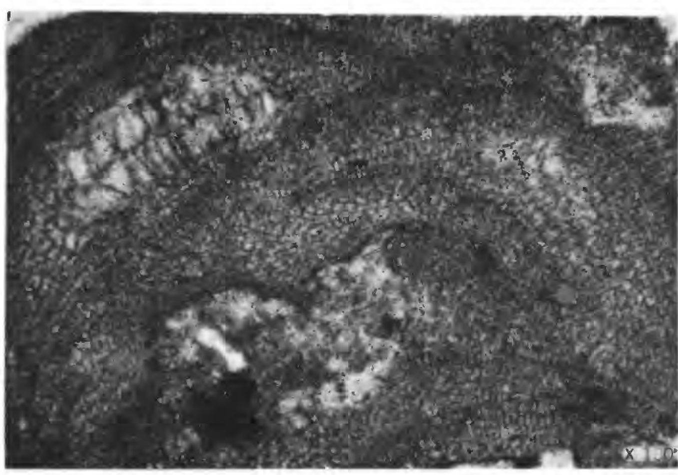

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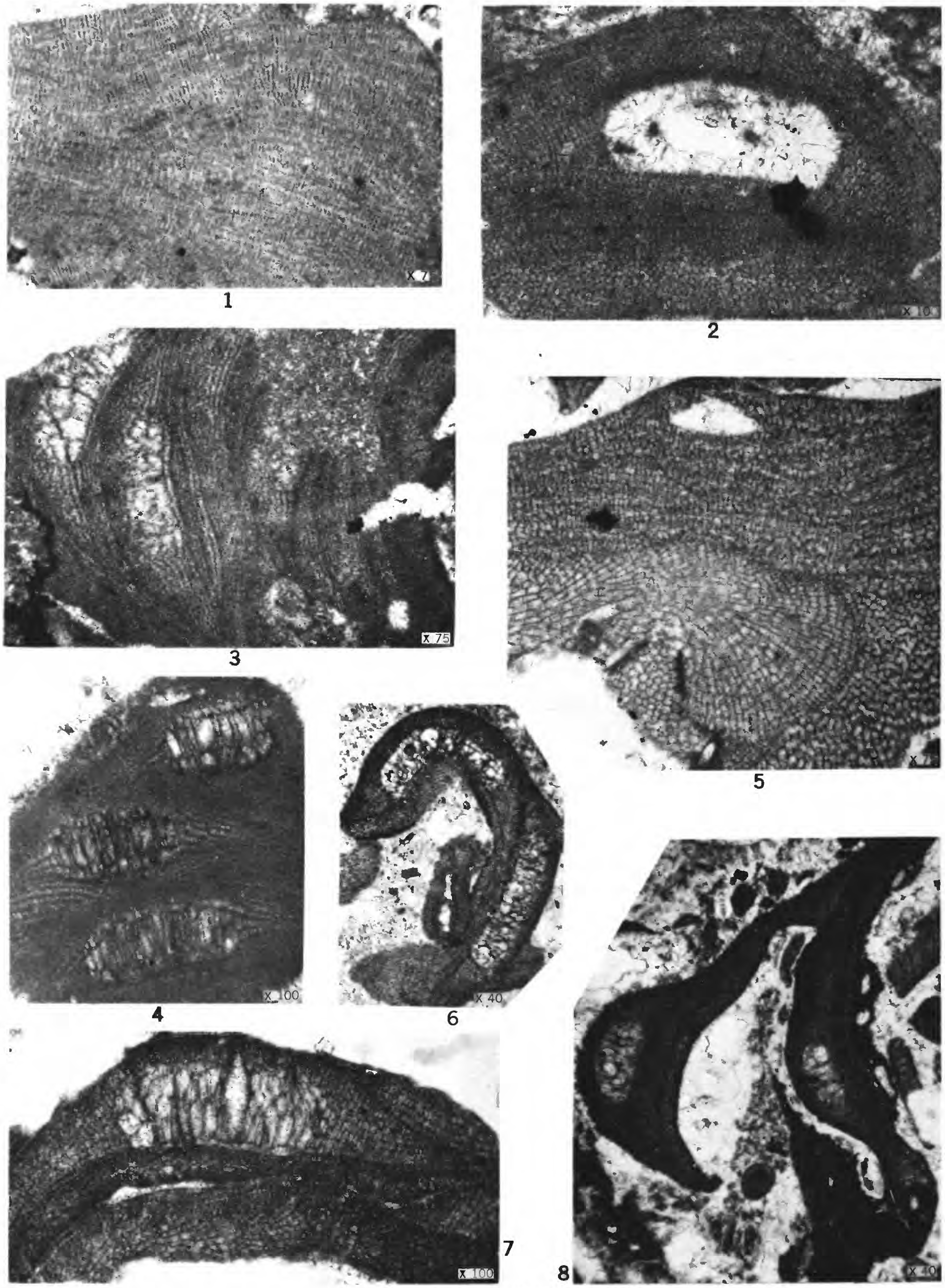
UPPER EOCENE *LITHOTHAMNIUM*



UPPER EOCENE *LITHOTHAMNIUM*

PLATE 42

FIGURES 1, 5. *Lithothamnium* cf. *L. abrardi* Lemoine (p. 221).

1. Detail of the tissue. Matansa limestone, pink facies; loc. D166 (S336); USGS algae a105–1a.
5. Section showing hypothallus, perithallus and the edge of a conceptacle chamber. Densinyama formation, limestone-conglomerate facies; loc. D151 (S170); USNM 624520 (Foraminifera slide).

2. *Lithothamnium* sp. C (p. 225).

Section showing hypothallus, perithallus, and a conceptacle chamber. Matansa limestone, white facies; loc. D124 (C12); USGS algae a44–1a.

3, 4. *Lithothamnium wallisium* Johnson and Tafur (p. 225).

3. Section of tissue and conceptacles. Matansa limestone, pink facies; loc. D203 (C21); USGS algae a134–1a.
4. Detail of tissue and conceptacles containing sporangia. Matansa limestone, white facies; loc. D125 (C13); USGS algae a45–2a.

6–8. *Lithothamnium crispithallus* Johnson, n. sp. (p. 223).

All from Densinyama formation, limestone-conglomerate facies.

6. General view of a small fertile crust. Loc. D152 (S189); USGS algae a89–2a.
7. Detail showing two superimposed thalli. The upper one contains a conceptacle with sporangia. Loc. D217 (S194); USGS algae a41–1a.
8. General view of another fertile specimen. Loc. D143 (S88); holotype, USGS algae a73–1a.

PLATE 43

FIGURES 1, 2. *Lithoporella melobesioides* (Foslie) Foslie (p. 234).

1. A slightly oblique section showing many superimposed thalli and several conceptacles. Matansa limestone, pink facies; loc. D385 (S251); specimen lost or misplaced.
2. Detail of several superimposed thalli. Matansa limestone, pink facies; loc. D233 (S337); USGS algae a82–1a.

3. *Lithophyllum* sp. A (p. 229).

Section through a crust showing the hypothallus and perithallus. Matansa limestone, white facies; loc. D164 (S318); USGS algae a 103–1a.

4, 8. *Lithophyllum ovatum* (Capeder) Lemoine (p. 228).

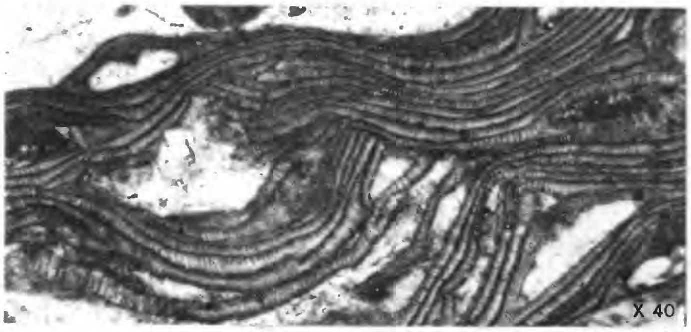
4. A well-developed hypothallus at base, perithallus with several conceptacle scars above. Densinyama formation, limestone-conglomerate facies; loc. D145 (S101); USGS algae a76–1a.
8. Section through a crust showing detail of perithallic tissue and several conceptacle chambers. Matansa limestone, white facies; loc. D97 (B199); USGS algae a11–2b.

5. *Lithophyllum* sp. A (below) and *Dermatolithon?* (above) (p. 229).

The *Lithophyllum* shows a well-developed hypothallus. Tagpochau limestone, inequigranular facies; loc. D170 (S471); USGS algae a109–1a.

6, 7. *Melobesia? cuboides* Johnson, n. sp. (p. 234).

6. Superimposed thalli form a thin crust. Densinyama formation, limestone-conglomerate facies; loc. D146 (S125); holotype, USNM 624732 (Foraminifera slide).
7. A coral at base is coated by an incrusting foraminifer which in turn is covered by superimposed thalli of *Melobesia? cuboides* Johnson, n. sp. Matansa limestone, pink facies; loc. D173 (S604); USGS algae a112–1a.



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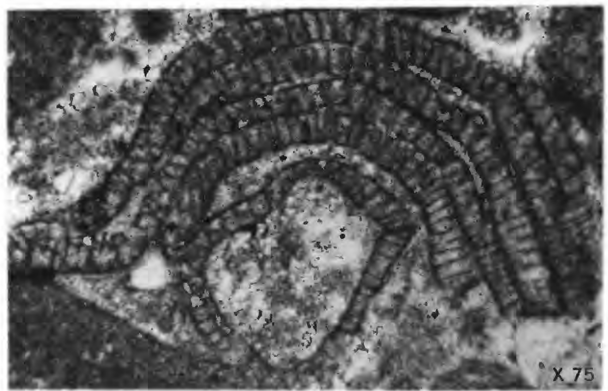

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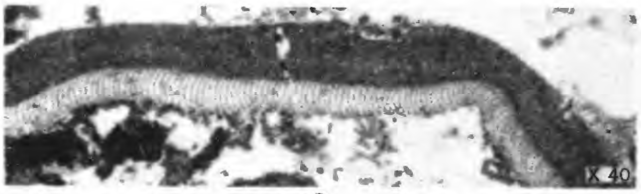

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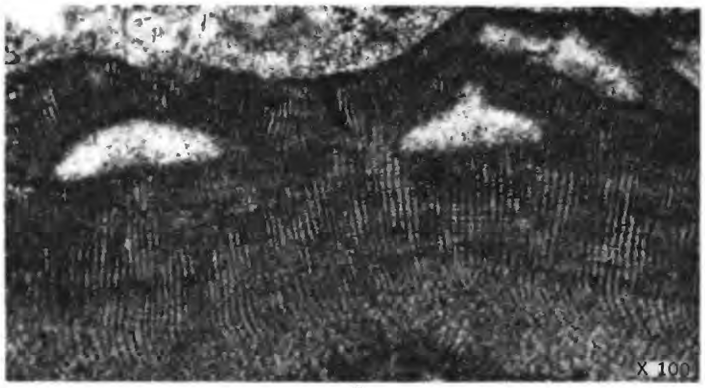

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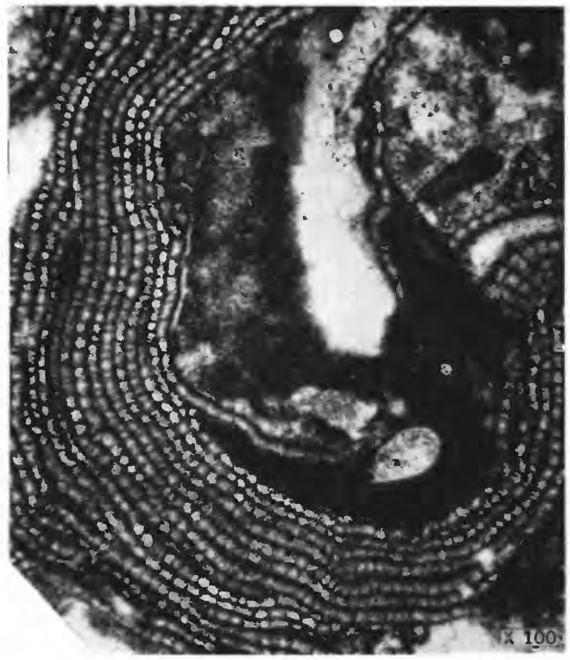

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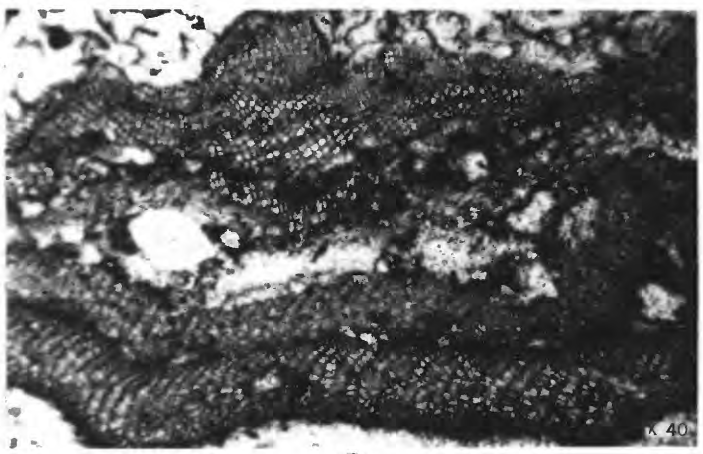

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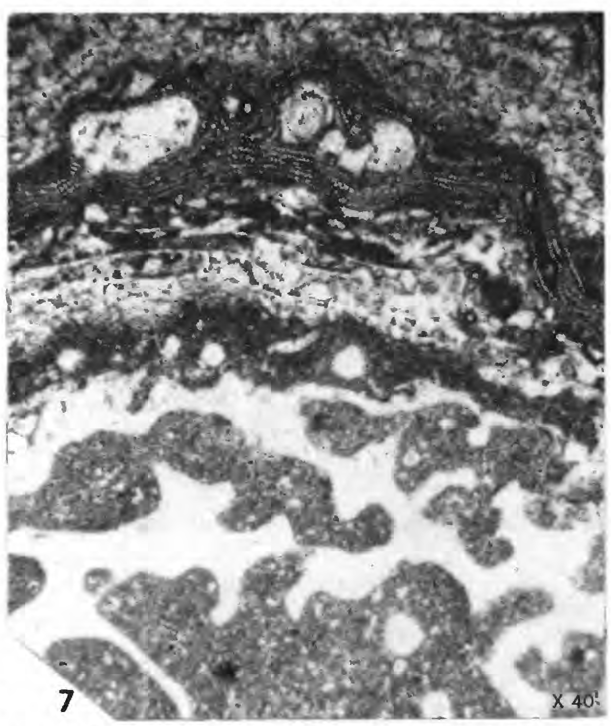

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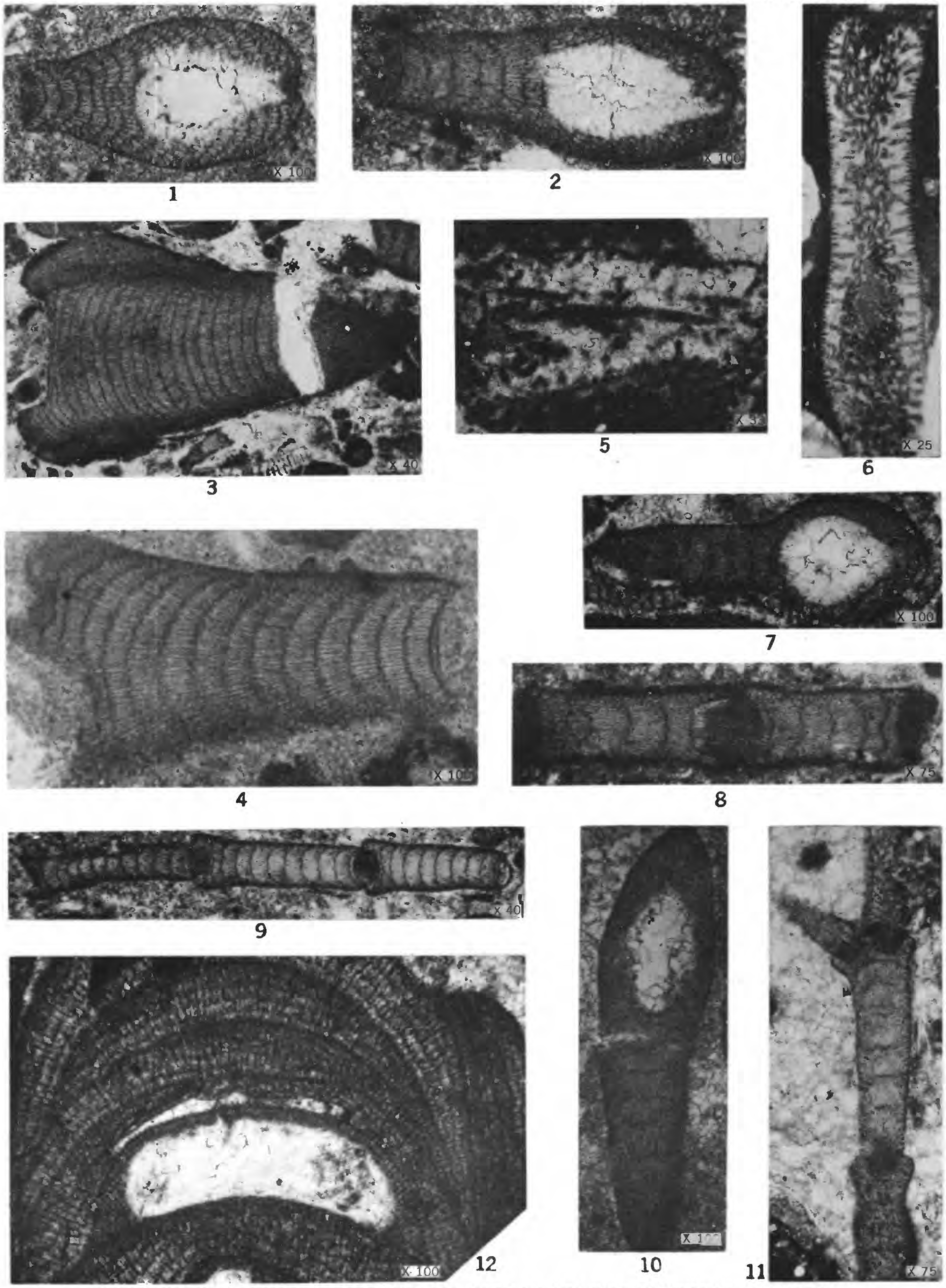
UPPER EOCENE AND LOWER MIOCENE *LITHOPHYLLUM* AND UPPER EOCENE *LITHOPORELLA* AND *MELOBESIA*



UPPER EOCENE *MESOPHYLLUM* AND *CORALLINA* AND LOWER MIOCENE *HALIMEDA*

PLATE 44

FIGURES 1, 2, 7–11. *Corallina prisca* Johnson, n. sp. (p. 239).

1. Sections of terminal segments showing conceptacle chambers. Densinyama formation, limestone-conglomerate facies; loc. D380 (S163); USGS algae a26–1a.
2. Another specimen from same locality showing similar features. USGS algae a26–1b.
7. A terminal segment with well-preserved conceptacle chamber. Densinyama formation, limestone-conglomerate facies; loc. D147 (S133); USNM 624514 (Foraminifera slide).
8. Detail structure of two segments and node. Matansa limestone, pink facies; loc. D165 (S319); USGS algae a104–1a.
9. General view of three segments with connecting nodes. Densinyama formation, limestone-conglomerate facies; loc. D152 (S189); holotype, USGS algae a89–2b.
10. A terminal segment with conceptacle chamber. Matansa limestone, white facies; loc. D221 (S310); USGS algae a90–1a.
11. A worn fragment showing a branch. Matansa limestone, pink facies; loc. D161 (S271); USGS algae a100–1a.

3, 4. *Corallina matansa* Johnson, n. sp. (p. 238).

3. A segment probably from near base of a frond, with unusually well-developed marginal perithallus. Matansa limestone, pink facies; loc. D156 (S241); holotype, USNM 624477 (Foraminifera slide).
4. A segment showing details of the hypothallus. Matansa limestone, pink facies; loc. D158 (S254); USGS algae a96–1a.

5, 6. *Halimeda* sp. (p. 241).

5. Outline of segment and coarse inner tubes shown. The rest of the structure not preserved. Tagpochau limestone, inequigranular facies; loc. D127 (C24); USGS algae a48–1a.
6. Long section of a segment perpendicular to the flat surface showing considerable structural detail. Tagpochau limestone, inequigranular facies; loc. D136 (C103). Specimen lost or misplaced.

12. *Mesophyllum* cf. *M. vaughanii* (Howe) Lemoine (p. 227).

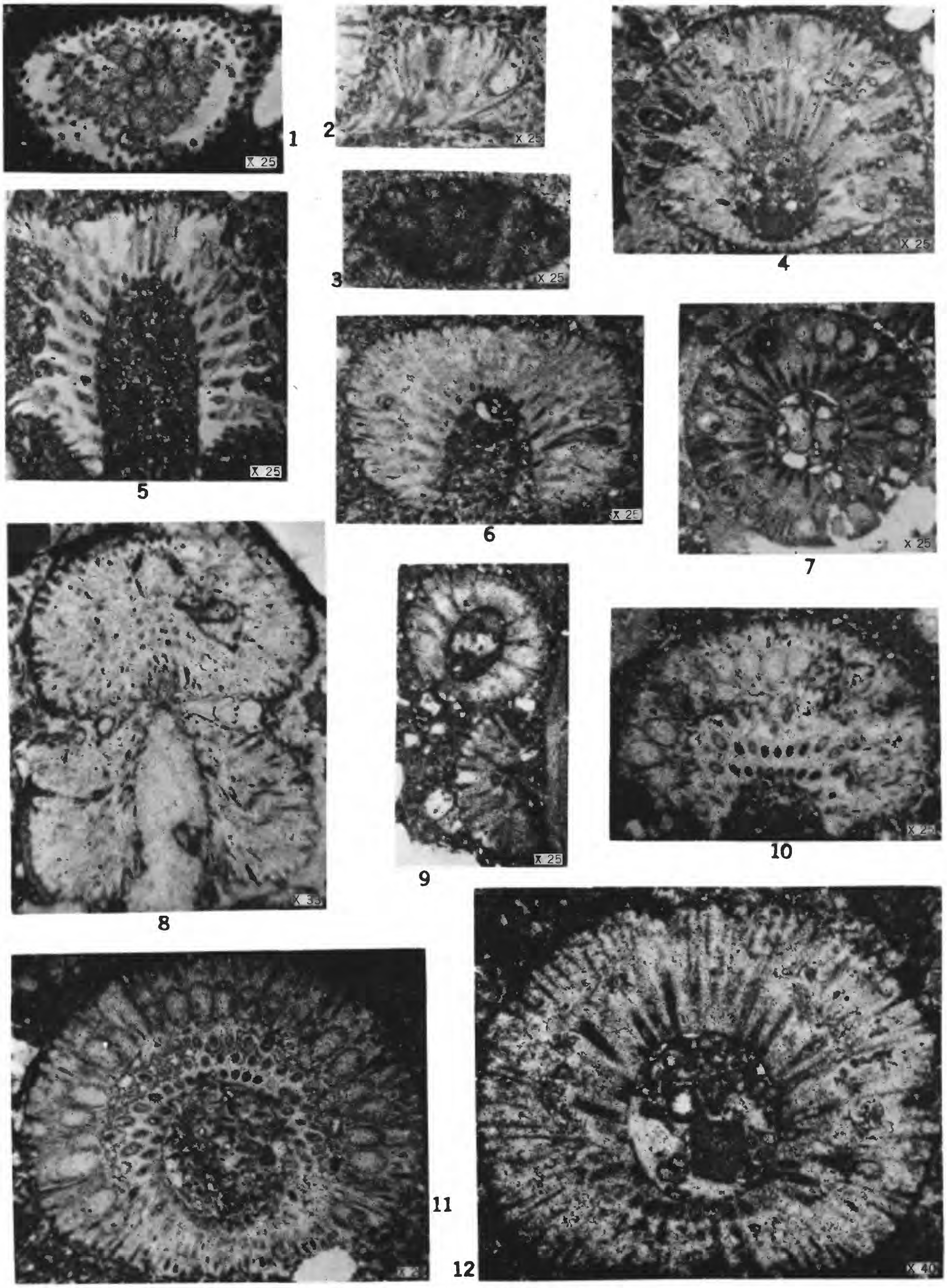
A detail showing pronounced growth zones and a conceptacle chamber. Matansa limestone, transitional facies; loc. D123 (C10); USGS algae a42–2a.

PLATE 45

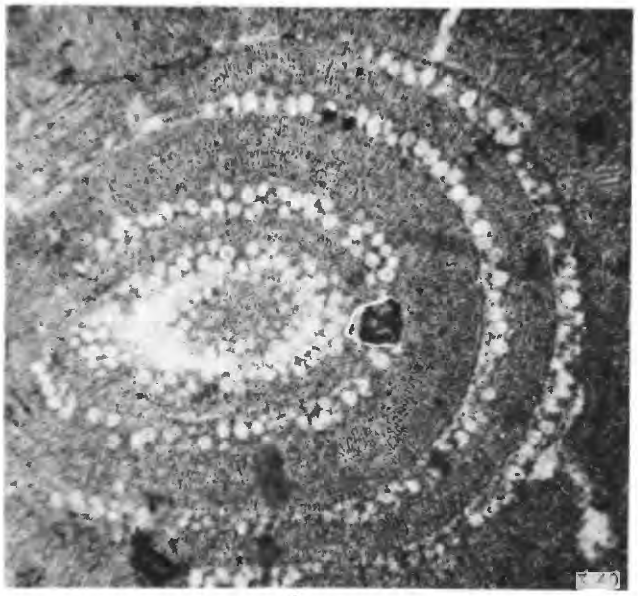
[All except figure 12 from Matansa Limestone, white facies]

FIGURES 1–12. *Cymopolia pacifica* Johnson, n. sp. (p. 240).

1. Perpendicular section near edge of segment showing sporangia and secondary branches (pores). Loc. D97 (B199); USGS algae a27–1a.
2. Detail of a fragment showing branching and sporangia. Loc. D97 (B199); holotype, USGS algae a11–1a.
3. Marginal tangential section showing sporangia. Loc. D97 (B199); USGS algae a11–1b.
4. An oblique section showing central stem, primary branches, sporangia, and a few secondary branches. Loc. D97 (B199); USGS algae a11–2a.
5. A section along axis, showing central stem, pores formed by primary branches, and a few sporangia and secondary branches. Loc. D97 (B199); USGS algae a20–1a.
6. A section close to axis and nearly parallel to it. Loc. D97 (B199); USGS algae a11–1c.
7. A horizontal section perpendicular to axis, showing central stem, a whorl of primary branches, sporangia, and a few secondary branches. Loc. D383 (B330); USGS algae a21–2a.
8. A somewhat oblique section through two segments. Loc. D183 (B67); USGS algae a116–1a.
9. Shows details of the primary and secondary branching. Loc. D383 (B330); USGS algae a21–1a.
10. An oblique section showing pores representing the primary branches and sporangia and suggestions of the secondary branches. Loc. D97 (B199); USGS algae a11–1d.
11. Slightly oblique cross section showing cavity left by the central stem, primary and secondary branching and sporangia. Loc. D97 (B199); USGS algae a11–1e.
12. Another specimen showing similar features. Densinyama formation, limestone-conglomerate facies; loc. D152 (S189); USGS algae a89–1a.



UPPER EOCENE DASYCLADACEAE



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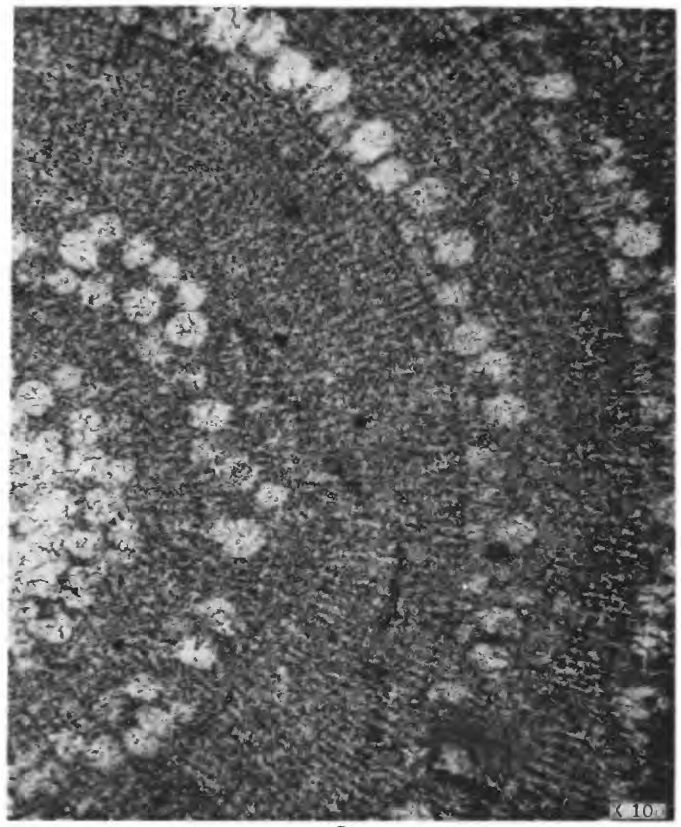

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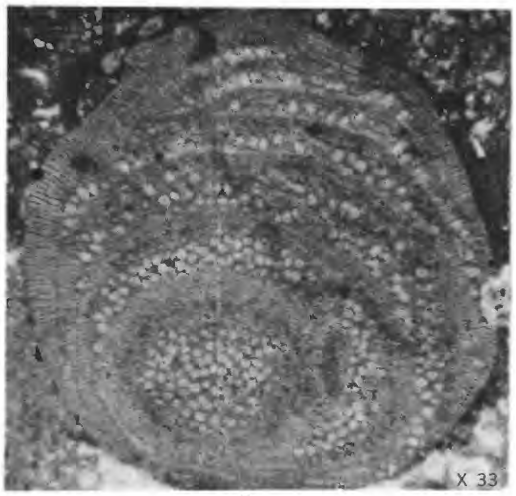

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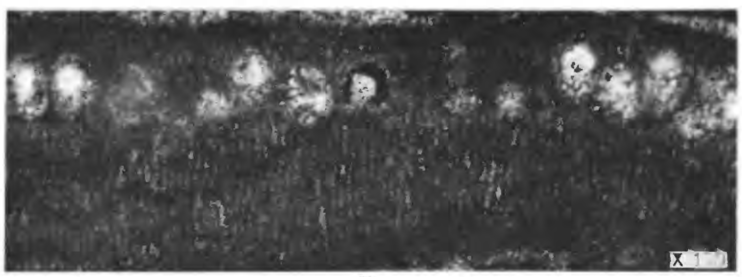

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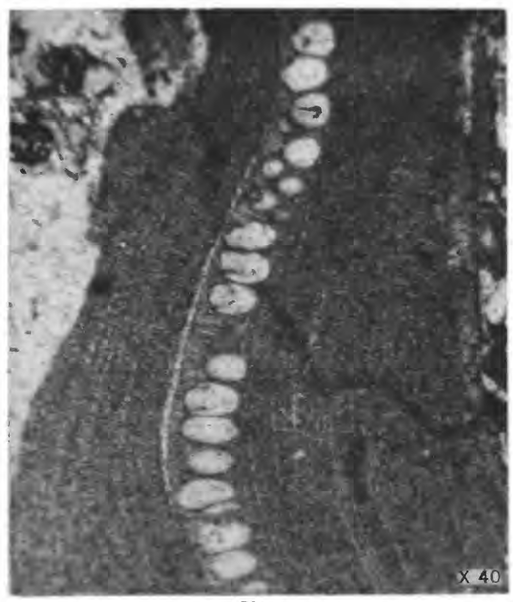

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LOWER MIOCENE *ARCHAEOLITHOTHAMNIUM*

PLATE 46

[All from Tagpochau limestone, inequigranular facies]

FIGURES 1–3. *Archaeolithothamnium myriosporum* Johnson, n. sp. (p. 219).

1. A general section through a nodular mass showing tissue and rows (layers) of sporangia. Loc. D150 (S166); USGS algae a85–2a.
2. A detail of the same specimen.
3. An oblique section across a nodular growth. Loc. D93 (B153); holotype, USGS algae a6–1a.

4–6. *Archaeolithothamnium taiwanensis* Ishijima (p. 218).

4. Sections of a crust showing hypothallus (curved rows at base), perithallus (rest of tissue), and rows of sporangia. Loc. D172 (S585); USNM 624603 (Foraminifera slide).
5. Same features in another specimen. Loc. D118 (B403); USGS algae a24–1a.
6. A section through a thicker crust formed of several superimposed thalli. Loc. D116 (B325); USGS algae a34–1a.
7. *Archaeolithothamnium lauense* Johnson and Ferris (p. 218).
   Detail of perithallic tissue and a row of sporangia. Loc. D112 (B297); USGS algae a28–1a.

PLATE 47

[All from Tagpochau limestone, inequigranular facies]

FIGURES 1–3. *Archaeolithothamnium* cf. *A. lugeoni* Pfender (p. 219).

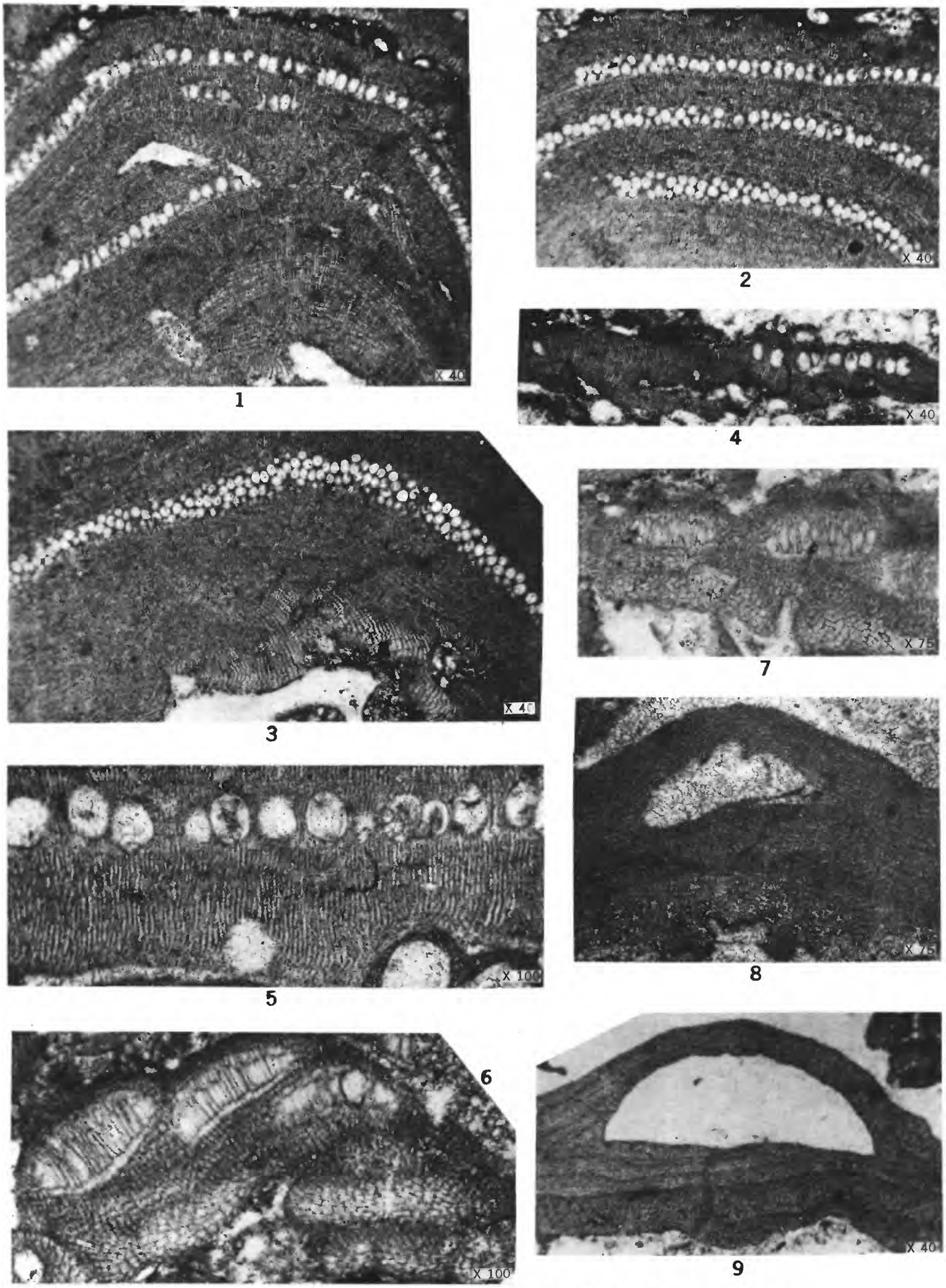
1. Section showing hypothallus (base), secondary hypothallus formed as scar tissue (near center), perithallus, and rows of sporangia. Loc. D220 (S309); USGS algae a102–1a.
2. Oblique section of perithallus and rows of sporangia. Loc. D220 (S309); USGS algae a102–1b.
3. Section largely oblique, showing well-developed hypothallus (middle of base), perithallus and sporangia. Loc. D220 (S309); USGS algae a102–1c.

4, 5. *Archaeolithothamnium* cf. *A. fijiensis* Johnson and Ferris (p. 217).

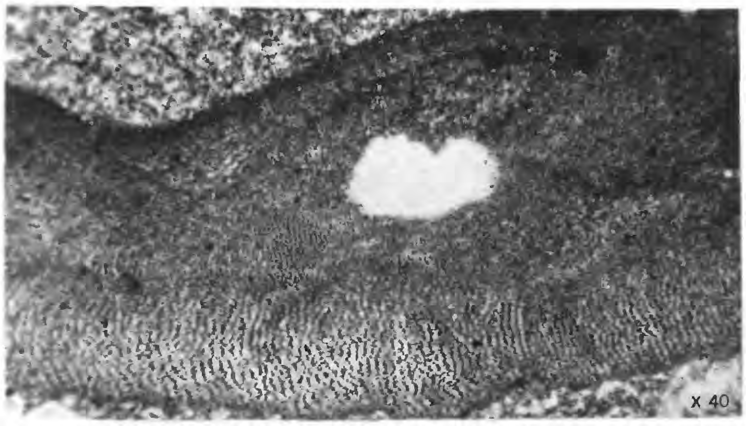
4. Showing poorly developed hypothallus at base, the perithallus and rows of sporangia. Loc. D134 (C93); USGS algae a63–1a.
5. Another specimen from same locality showing similar features. USGS algae a63–2a.

6, 7. *Lithothamnium subtile* Conti (p. 222).

6. A vertical section showing hypothallus, perithallus and several conceptacles with sporangia. Loc. D122 (C4); USGS algae a40–1a.
7. Another section from same locality with a slightly smaller hypothallus, a perithallus and conceptacles showing sporangia. USGS algae a40–1b.
8. *Lithothamnium* cf. *L. fumigatum* Foslie (p. 221).
   A vertical section which shows the poorly developed hypothallus, the relatively thick perithallus, and a conceptacle cavity cut somewhat away from the center. Loc. D153 (S205); USGS algae a91–1a.
9. *Lithothamnium ladronicum* Johnson, n. sp. (p. 222).
   Section with hypothallus, perithallus, and large conceptacle chamber. Loc. D98 (B205); holotype, USGS algae a12–1a.



LOWER MIOCENE *ARCHAEOLITHOTHAMNIUM* AND *LITHOTHAMNIUM*



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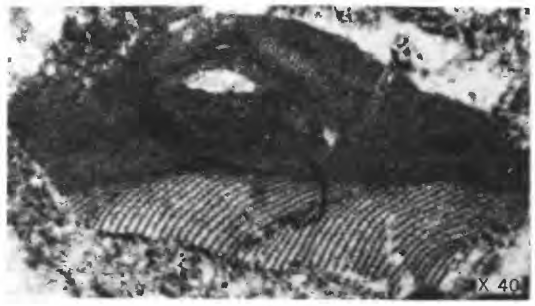

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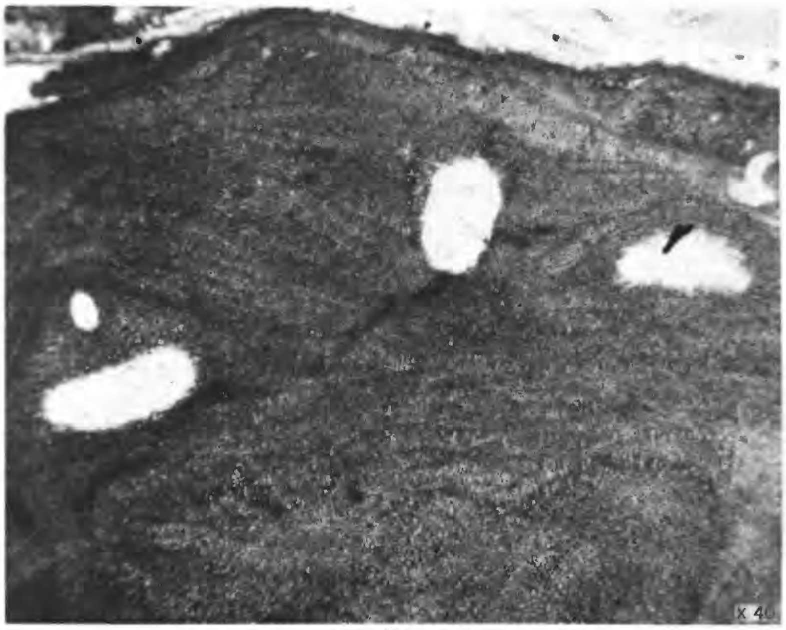

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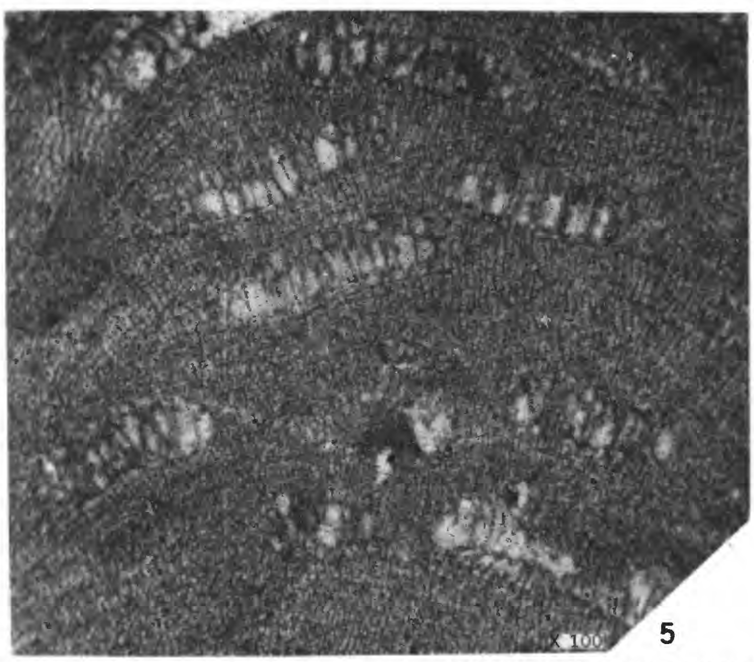

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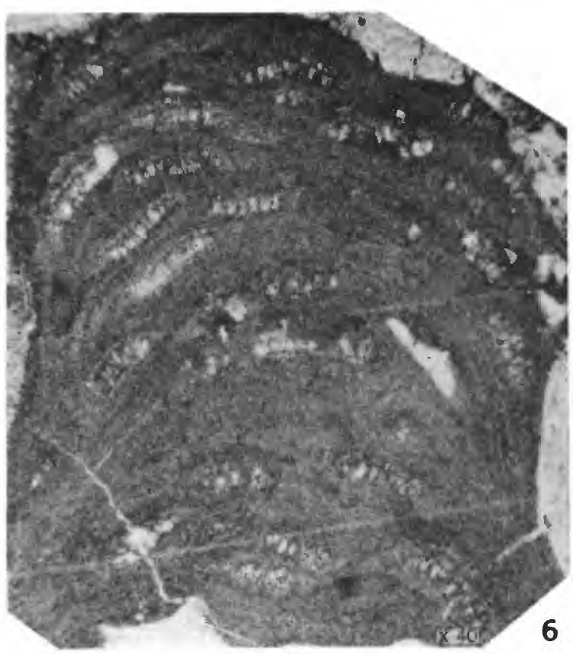

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LOWER MIOCENE *LITHOTHAMNIUM*

PLATE 48

[All from Tagpochau limestone, inequigranular facies]

FIGURE 1. *Lithothamnium* sp. D (p. 223).
Section through a crust showing the hypothallus, perithallus, and a conceptacle chamber. Loc. D147 (S164); USGS algae a84–1a.

2. *Lithothamnium undulatum* Capeder (p. 225).
Section showing the hypothallus, perithallus, and conceptacle chamber. Loc. D135 (C98); USGS algae a64–1a.

3. *Lithothamnium* cf. *L. mirabile* Conti (p. 225).
A somewhat oblique section through an irregular crust showing hypothallus, perithallus, and three conceptacle chambers. Loc. D96 (B197): USGS algae a10–1a.

4. *Lithothamnium* cf. *L. crispatum* Hauck (p. 224).
Shows perithallus and conceptacles containing sporangia. Loc. D122 (C4); USGS algae a40–2a.

5, 6. *Lithothamnium* cf. *L. lecroixi* Lemoine (p. 226).
5. Detail showing tissue and conceptacles with sporangia. Loc. D122 (C4); USGS algae a40–2b.
6. Same specimen. General view of a section through a branch.

PLATE 49

[All except figure 6 from Tagpochau limestone, inequigranular facies]

FIGURES 1, 2. *Lithophyllum prelichenoides* Lemoine (p. 229).

1. General view through a crust showing hypothallus, perithallus, and conceptacle with sporangia. Loc. D91 (B90); USGS algae a4–1a.
2. Detail showing the well-developed coaxial hypothallus and some of the perithallus. Loc. D127 (C24); USGS algae a48–2b.

3. *Lithothamnium saipanense* Johnson, n. sp. (p. 222).
Slightly oblique section with a well-developed hypothallus, the perithallus, and a conceptacle chamber. Loc. D127 (C24); holotype, USGS algae a48–2a.

4. *Lithoporella melobesioides* (Foslie) Foslie (p. 234).
Section through a crust composed of a number of superimposed thalli each consisting of a single row of large cells. One conceptacle chamber and part of another are shown. Loc. D90 (B82); USGS algae a3–1a.

5. *Lithothamnium* cf. *L. bourcarti* Lemoine (p. 221).
Section of a crust showing hypothallus and perithallus. Loc. D122 (C4); USGS algae a39–1a.

6. *Lithothamnium* cf. *L. disarmonicum* Conti (p. 225).
A slightly oblique section of tissue with a conceptacle chamber. Tagpochau limestone, marly facies; loc. D128 (C27); USGS algae a51–1a.

7. *Lithophyllum glangeaudi* Lemoine (p. 230).
Section showing basal hypothallus and a branch. Loc. D150 (S166); USGS algae a85–1a.

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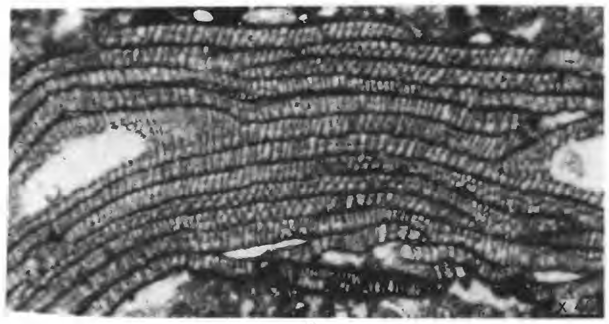

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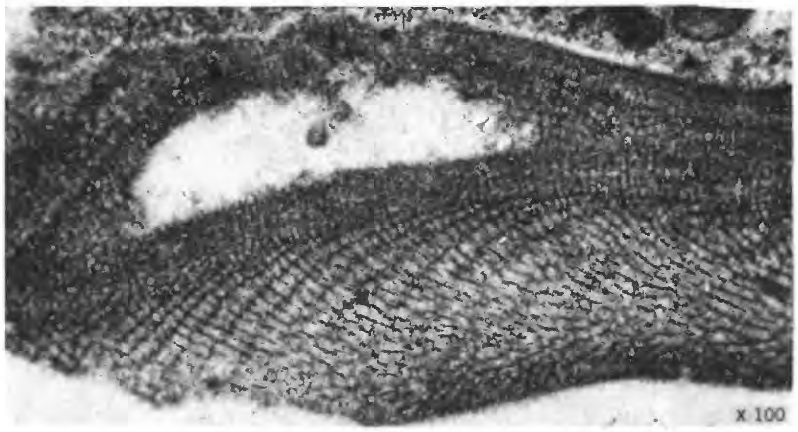

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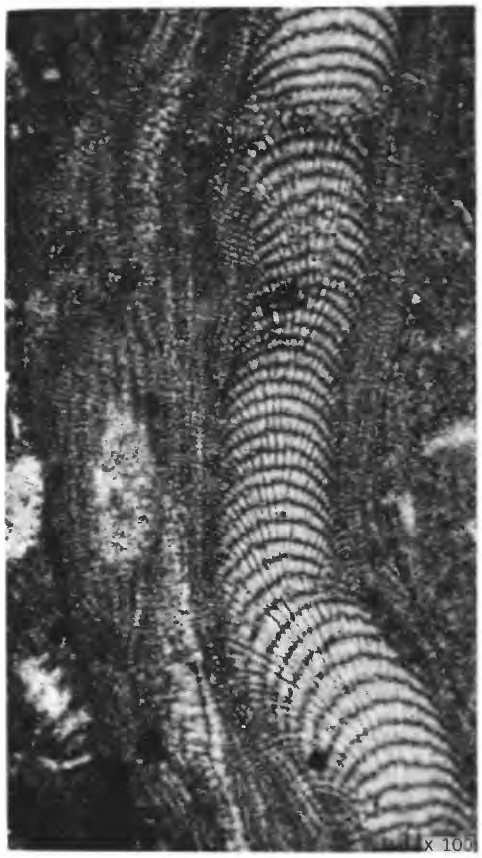

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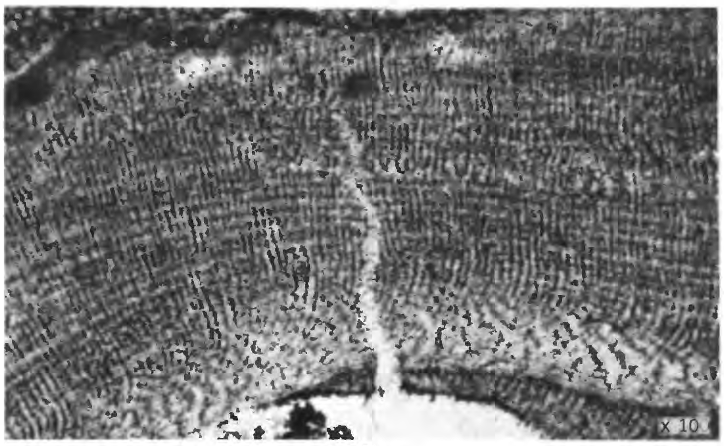

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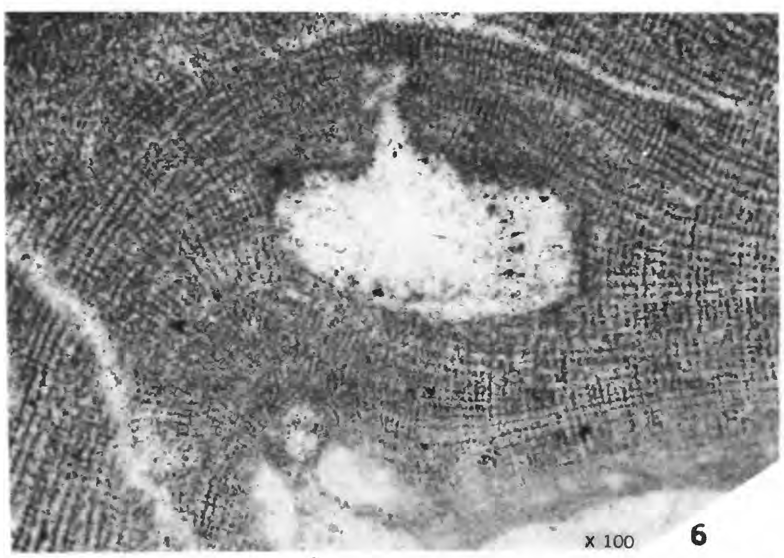

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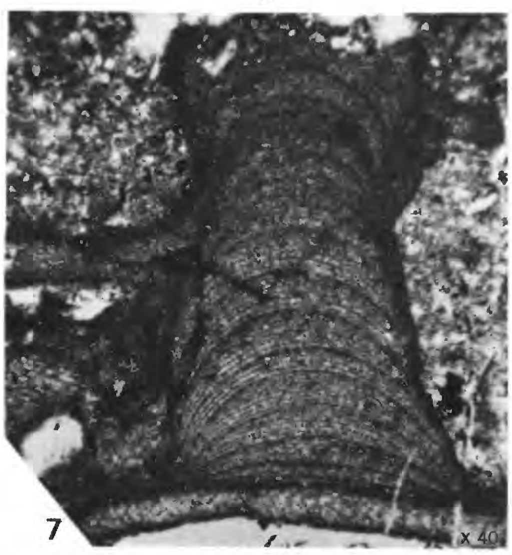

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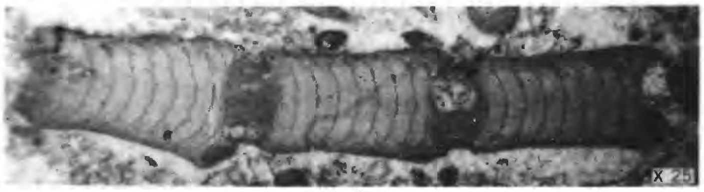
LOWER MIOCENE *LITHOTHAMNIUM*, *LITHOPHYLLUM*, AND *LITHOPORELLA*



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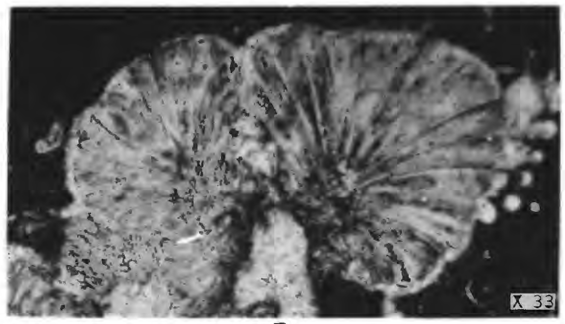

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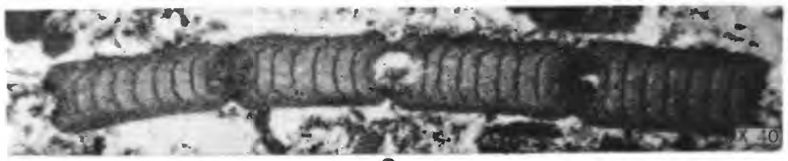

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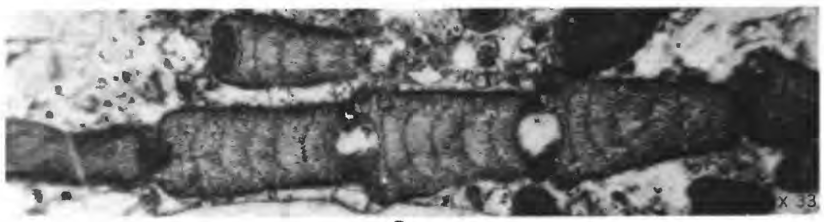

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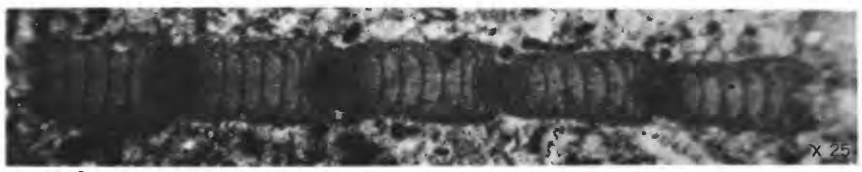

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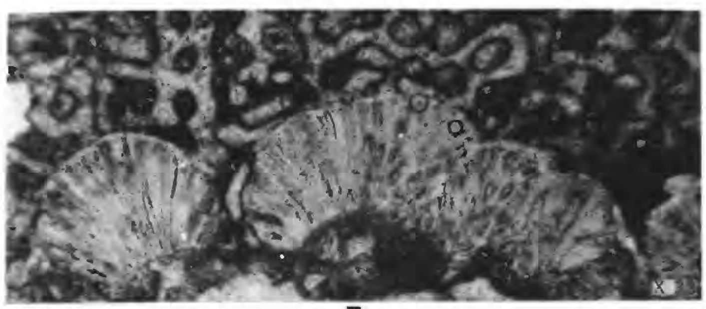

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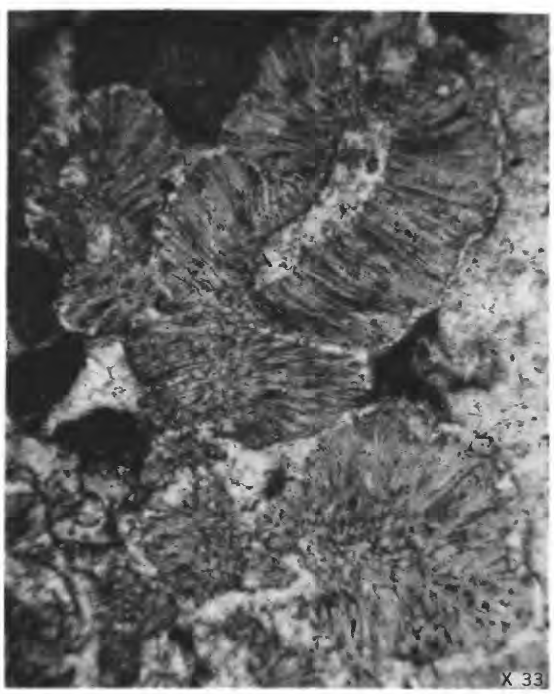

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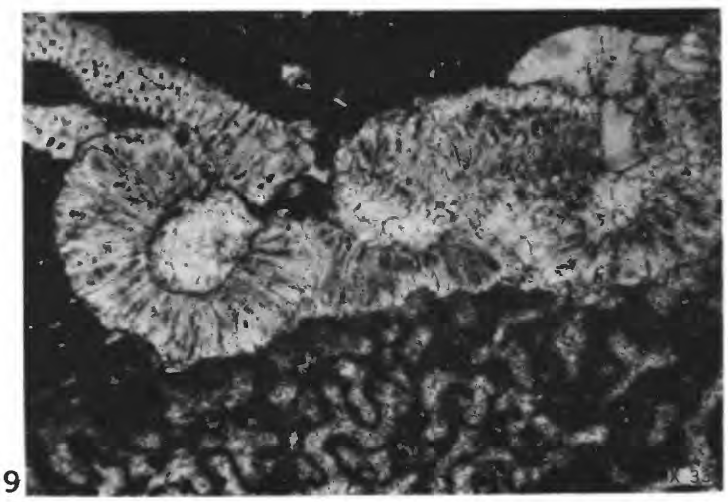

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LOWER MIOCENE *CORALLINA* AND *MICROCODIUM*

PLATE 50

[All from Tagpochau limestone, inequigranular facies]

FIGURES 1–4. *Corallina neuschelorum* Johnson, n. sp. (p. 239).

1. Three segments with nodes. Loc. D120 (B427); USGS algae a38–1a.
2. Fragment of a frond with four segments. Loc. D120 (B427); USGS algae a38–1b.
3. Five segments with nodes. Loc. D171 (S511); USGS algae a110–1a.
4. Five well-preserved segments with nodes. Loc. D113 (B310); holotype, USGS algae a29–1a.

5–9. *Microcodium* sp. (p. 242).

5. A cluster showing clearly the petallike rays. Loc. D94 (B171); USGS algae a7–1a.
6. Associated with fragments of large Foraminifera. Loc. D167 (S339); USGS algae a106–1a.
7. Associated with coral. Loc. D94 (B171); USGS algae a7–1b.
8. Detail of a cluster. Loc. D94 (B171); USGS algae a106–1b.
9. Associated with coral and large Foraminifera. Loc. D94 (B171); USGS algae a7–2a.

PLATE 51

[All from Tagpochau limestone, inequigranular facies]

FIGURES 1–6. *Cymopolia delicata* Johnson, n. sp. (p. 240).

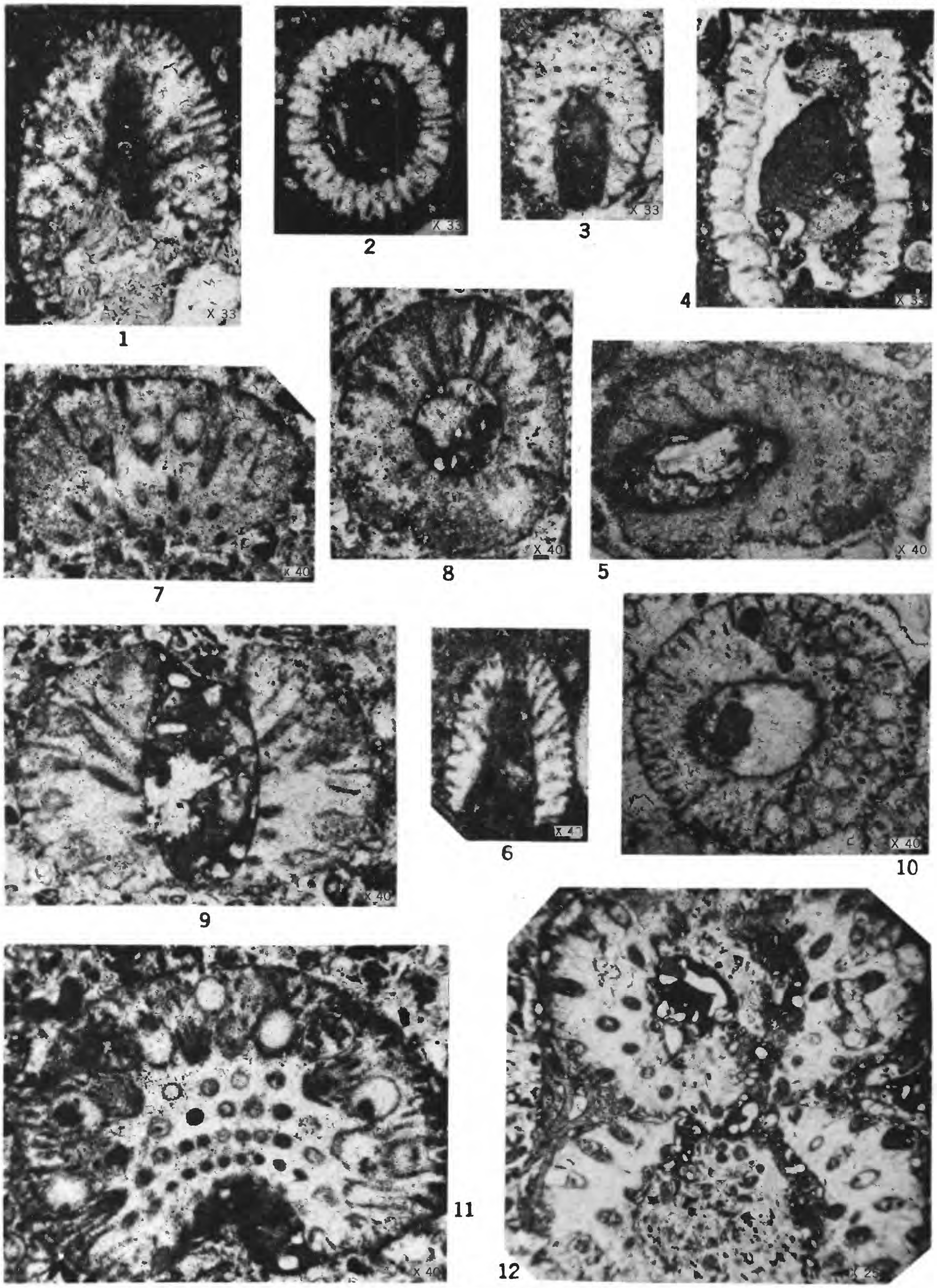
All except figure 5 from loc. D94 (B171).

1. Section nearly parallel to axis. Shows central stem, a few secondary branches. A piece of *Microcodium* is at the base. USGS algae a7–1c.
2. A section perpendicular to axis showing the central stem cavity and pores representing molds of branches. USGS algae a7–2b.
3. A longitudinal section showing central stem and several whorls of branches. Holotype, USGS algae a7–3a.
4. A long section showing central stem cavity and branches. USGS algae a7–1d.
5. A slightly oblique long section with central stem. Some primary branches bearing sporangia are shown. Loc. D189 (B177); USGS algae a7–1e.
6. An axial section showing central stem and primary and seconday branches. USGS algae a7–3b.

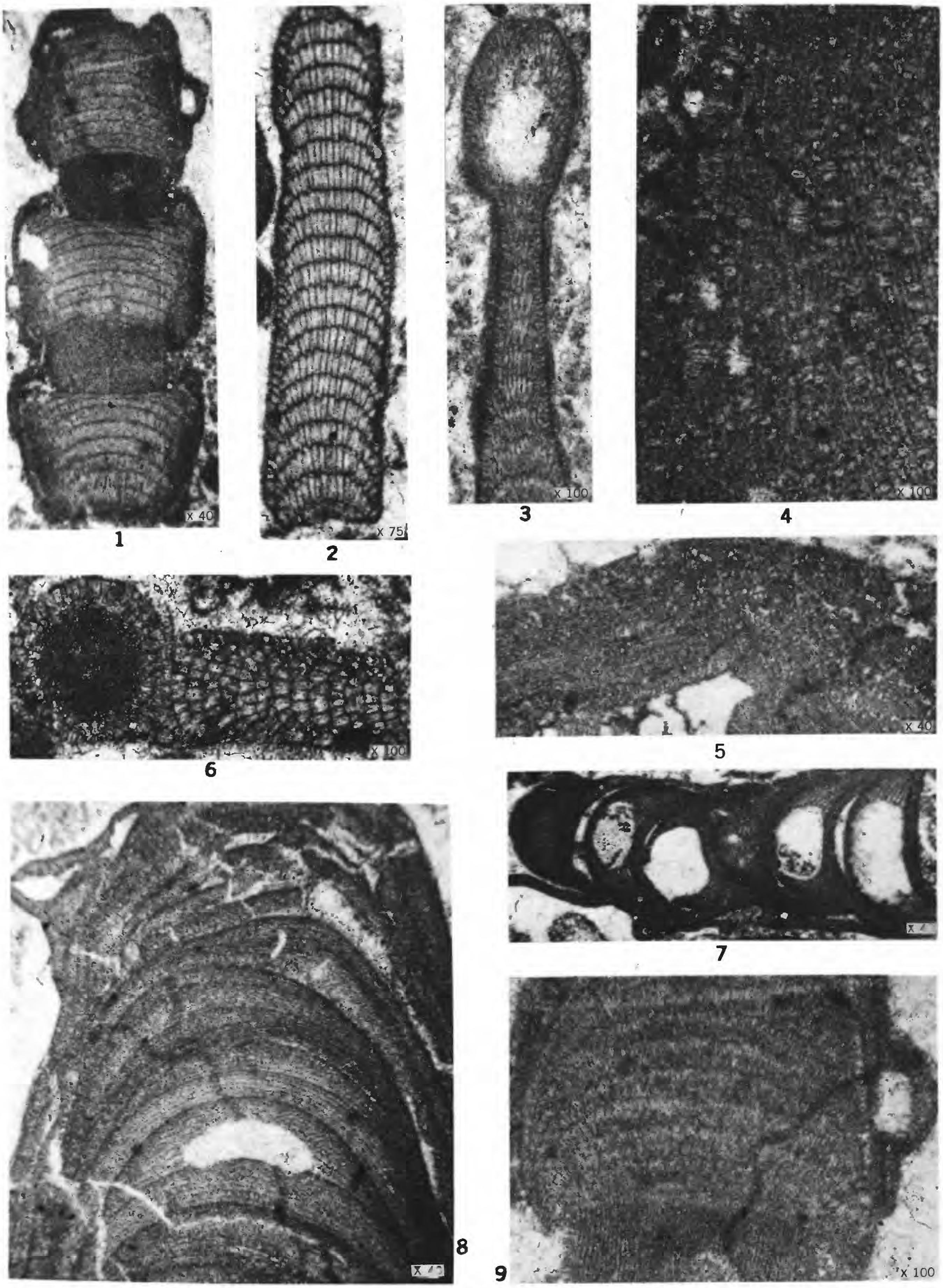
7–12. *Cymopolia saipania* Johnson, n. sp. (p. 241).

All except figure 10 from loc. D92 (B107).

7. A fragment showing detail of sporangia and secondary branches. USGS algae a5–1a.
8. A section perpendicular to axis with central stem and some branches. USGS algae a5–1b.
9. A long section showing central stem cavity and some primary branches bearing sporangia and secondary branches. USGS algae a5–2a.
10. An oblique cross section showing sporangia and branches. Loc. D188 (B172); USGS algae a133–1a.
11. A slightly oblique vertical section with sporangia and tufts of secondary branches. Holotype, USGS algae a5–3a.
12. A long section of two segments. USGS algae a5–2b.



LOWER MIOCENE DASYCLADACEAE



LOWER MIOCENE *CALLIARTHRON*, *JANIA*, *PARAPOROLITHON*, AND *MESOPHYLLUM*

PLATE 52

[All except figures 6 and 7 from Tagpochau limestone, inequigranular facies]

FIGURES 1, 9. *Calliarthron antiquum* Johnson, n. sp. (p. 237).

1. Three segments with nodes between. A conceptacle cavity occurs on right side of upper segment. Loc. D126 (C16); holotype, USGS algae a47–1a.
9. Detail of figure 1 showing contorted arrangement of cells in medullary tissue, and a conceptable chamber on right side.

2. *Jania vetus* Johnson, n. sp. (p. 237).
A nearly complete segment. Loc. D119 (B415); holotype, USGS algae a68–1a.

3, 6. *Jania* sp. B (p. 237).

3. A terminal segment with conceptacle (?) cavity. Loc. D277 (C62); USGS algae a43–1a.
6. A short segment with cross section of a branch at the end. Tagpochau limestone, rubbly facies; loc. D278 (C128); USGS algae a36–1a.

4, 5. *Paraporolithon saipanense* Johnson, n. sp. (p. 233).

4. A detail of the tissue showing the clusters of large megacells (to right) and the scattered, smaller megacells. Top of specimen is to left. Loc. D443 (C133); holotype, USGS algae a66–1a.
5. Same specimen. Section through a crust showing basal hypothallus, and perithallus with the vertical groups of medium megacells and horizontal clusters of large megacells.

7. *Mesophyllum pacificum* Johnson, n. sp. (p. 226).
Section along a branch showing character of the tissue and some conceptacle chambers. Tagpochau limestone, rubbly facies; loc. D138 (S5); holotype, USGS algae a67–1a.

8. *Mesophyllum savornini* Lemoine (p. 227).
Section nearly parallel to axis of a branch showing the strongly zoned tissue and a conceptacle chamber. Loc. D99 (B214); USGS algae a13–1a.

PLATE 53

FIGURES 1, 2. *Archaeolithothamnium megasporum* Johnson, n. sp. (p. 218).

1. Detail showing very thin crust composed essentially of perithallic tissue and large sporangia. Mariana limestone, rubbly facies; loc. D174 (S677); holotype, USGS algae a113–1a.
2. General view of a crust. Above it is a coaxial hypothallus of a *Lithophyllum.* Mariana limestone, rubbly facies; loc. D174 (S677); USGS algae a113–1b.

3, 4. *Archaeolithothamnium puntiense* Airoldi (p. 218).

3. A general view of a section through a crust. The slide is a little too thick to show the tissue very clearly. Mariana limestone, massive facies; loc. D102 (B229); USGS algae a16–1a.
4. A fragment of perithallus showing several layers of sporangia. Mariana limestone, massive facies; loc. D115 (B321); USGS algae a32–1a.

5. *Lithothamnium* cf. *L. madagascariense* Foslie (p. 226).

Detail of tissue and four conceptacle chambers. Mariana limestone, pink massive facies; loc. D131 (C65); USGS algae a55–1a.

6, 7. *Lithothamnium tanapagense* Johnson, n. sp. (p. 223).

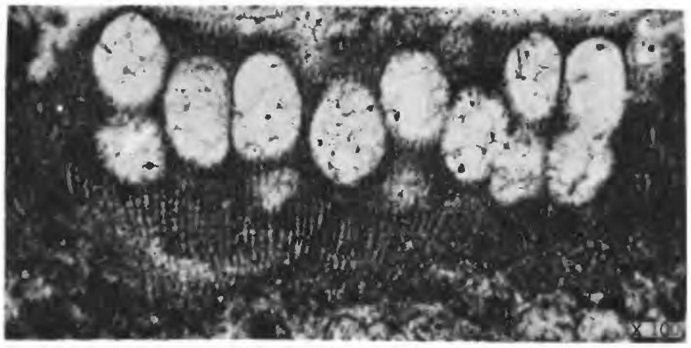
6. Detail of tissue and a conceptacle chamber. Tanapag limestone; loc. D130 (C50); USGS algae a54–1a.
7. Slightly oblique section through a crust. Tanapag limestone; loc. D130 (C50); holotype, USGS algae a54–1b.

8. *Lithothamnium* cf. *L. engelhartii* Foslie (p. 221).

Detail of hypothallus, perithallus, and conceptacles with sporangia. Mariana limestone, massive facies; loc. D133 (C81); USGS algae a60–1a.

9. *Lithothamnium* cf. *L. aucklandicum* Foslie (p. 224).

Section of a fertile crust. Mariana limestone, massive facies; loc. D103 (B232); USGS algae a17–1a.



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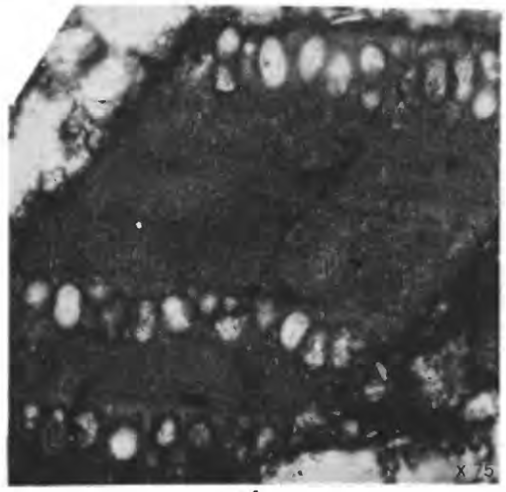

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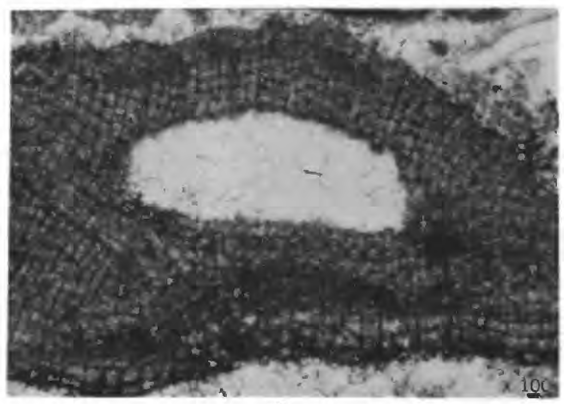

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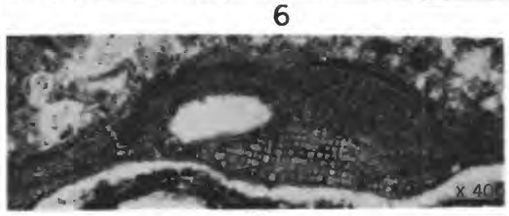

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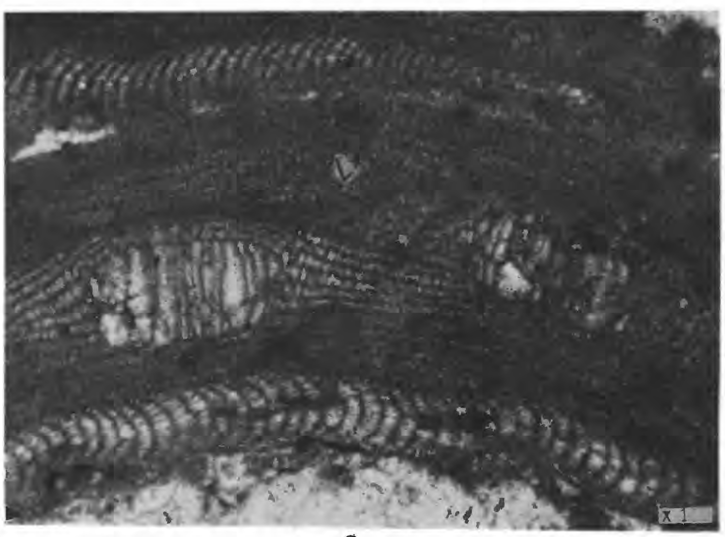

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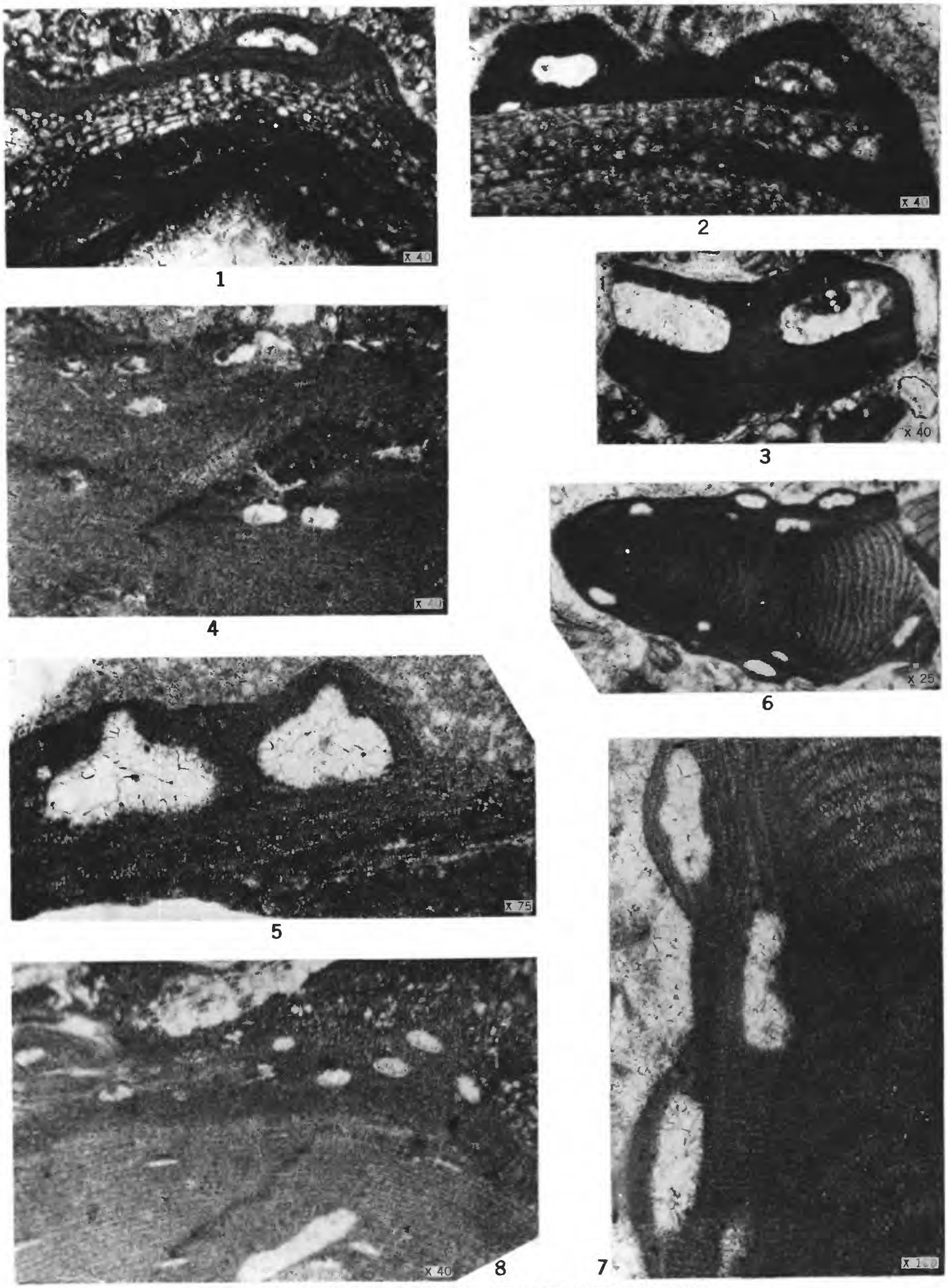
PLEISTOCENE *ARCHAEOLITHOTHAMNIUM* AND *LITHOTHAMNIUM*



PLEISTOCENE *LITHOTHAMNIUM* AND *LITHOPHYLLUM*

PLATE 54

FIGURE 1. *Lithothamnium* cf. *L. lichenoides* (Ellis and Solander) Foslie (p. 222).
A thin crust with a conceptacle chamber on an encrusting foraminifer. Mariana limestone, massive facies; loc. D133 (C81); USGS algae a60–2a.

2. *Lithothamnium tanapagense* Johnson, n. sp. (p. 223).
A thin, fertile crust on a layer of encrusting Foraminifera. Mariana limestone; massive facies; loc. D209 (C80); USGS algae a54–1c.

3. *Lithothamnium funafutiense* Foslie (p. 222).
A fragment with two conceptacle chambers. Mariana limestone, *Halimeda*-rich facies; loc. D129 (C49); USGS algae a53–1b.

4. *Lithophyllum stefaninii* Airoldi (p. 228).
A section showing character of the tissue, several conceptacle chambers and (above center) a secondary hypothallus developed as scar tissue. Mariana limestone, massive facies; loc. D111 (B287); USGS algae a25–1a.

5. *Lithophyllum expansum* Philippi (p. 229).
A worn fragment with two conceptacle chambers. Mariana limestone, massive facies; loc. D109 (B282); USGS algae a23–1a.

6, 7. *Lithophyllum moluccense* Foslie (p. 230).
6. A fragment showing alternating layers of long and short cells and marginal conceptacle chambers. Mariana limestone, pink massive facies; loc. D131 (C65); USGS algae a55–2b.
7. A detail of figure 6, × 100.

8. *Lithophyllum yendoi* Foslie (p. 229).
A thin fertile crust (above) on *Lithophyllum* cf. *L. megacrustum* Johnson and Ferris. Mariana limestone, massive facies; loc. D114 (B319); USGS algae a30–1b.

PLATE 55

FIGURE 1. *Lithophyllum megacrustum* Johnson and Ferris (p. 228).

Part of a crust with many conceptacle chambers. Mariana limestone, massive facies; loc. D114 (B319); USGS algae a30–1a.

2–4. *Amphiroa fragilissima* (Linnaeus) Lamouroux (p. 238).

All from Mariana limestone, pink massive facies.

2. Section across a segment. Loc. D131 (C65); USGS algae a55–1b.
3. Long section of a segment with a well-developed marginal perithallus. The medullary hypothallus shows alternations of long and short tiers of cells. Loc. D131 (C65); USGS algae a55–1c.
4. Detail of a fragment of a segment. Loc. D132 (C67); USGS algae a59–1a.

5. *Halimeda* sp.? (p. 241).

Section of a leaf nearly parallel to the flat surface with characteristic tubular structure. Mariana limestone, massive facies; loc. D95 (B189); USGS algae a9–1a.

6, 7. *Porolithon onkodes* (Heydrich) Foslie (p. 232).

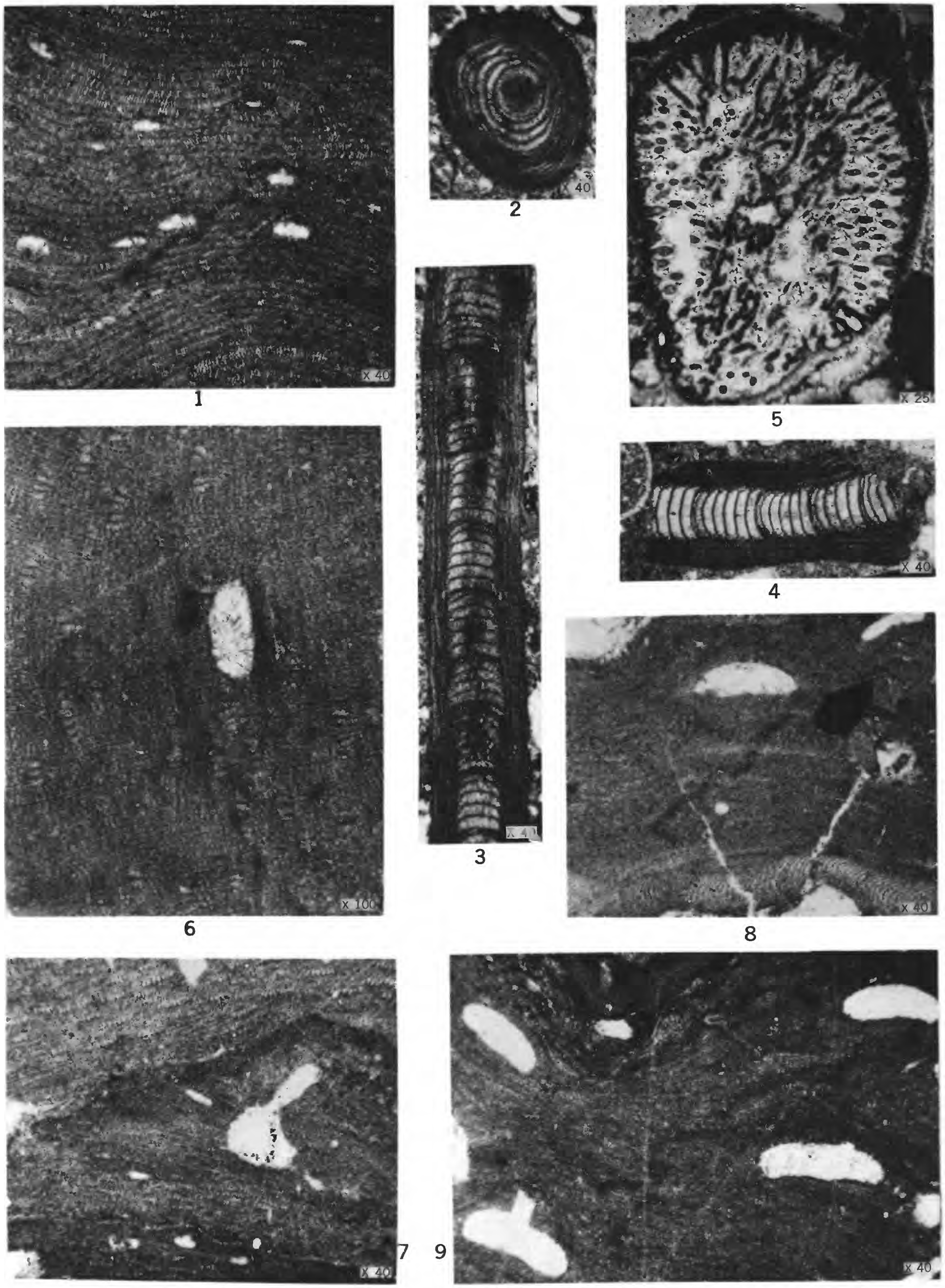
6. Detail of tissue showing clusters of megacells in the perithallic tissue and a conceptacle chamber. Mariana limestone, *Halimeda*-rich facies; loc. D231 (S691). Specimen lost or misplaced.
7. General view of a part of crust. Mariana limestone, *Halimeda*-rich facies; loc. D129 (C49); USGS algae a52–1a.

8. *Lithophyllum* cf. *L. roveretoi* Airoldi (p. 230).

Section of a crust with basal hypothallus, perithallus, and a conceptacle chamber. Mariana limestone, massive facies; loc. D111 (B287); USGS algae a25–1b.

9. *Lithophyllum* cf. *L. racemus* (Lamarck) Foslie (p. 228).

Section of a compound crust with conceptacle chambers. Mariana limestone, massive facies; loc. D101 (B227); USGS algae a15–1a.



PLEISTOCENE *LITHOPHYLLUM*, *POROLITHON*, *AMPHIROA*, AND *HALIMEDA*

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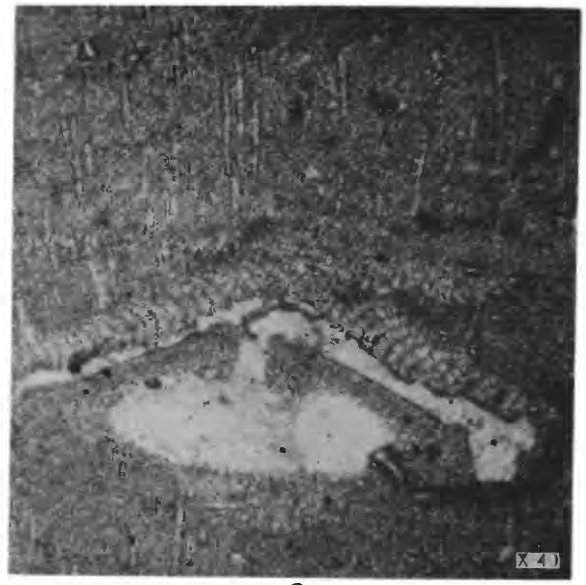

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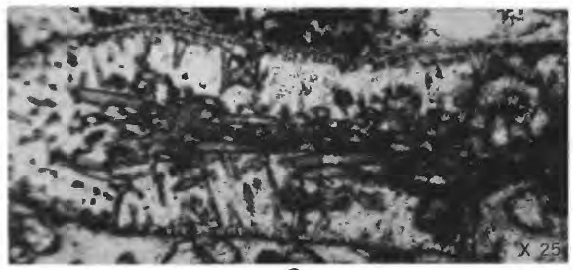

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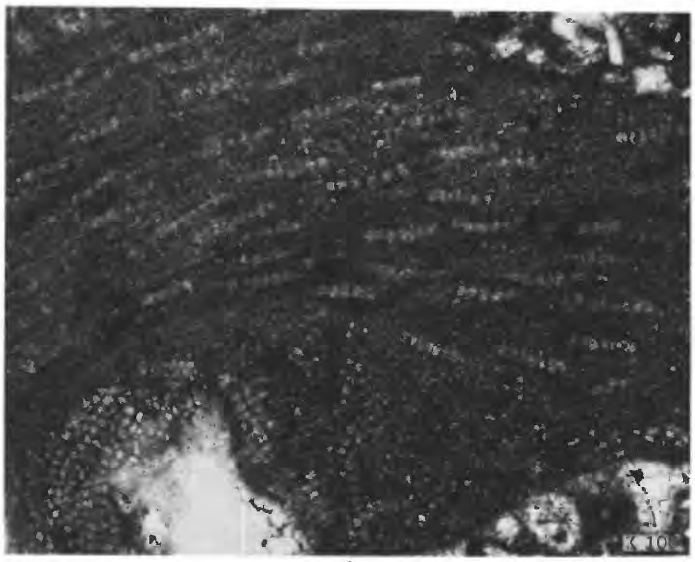

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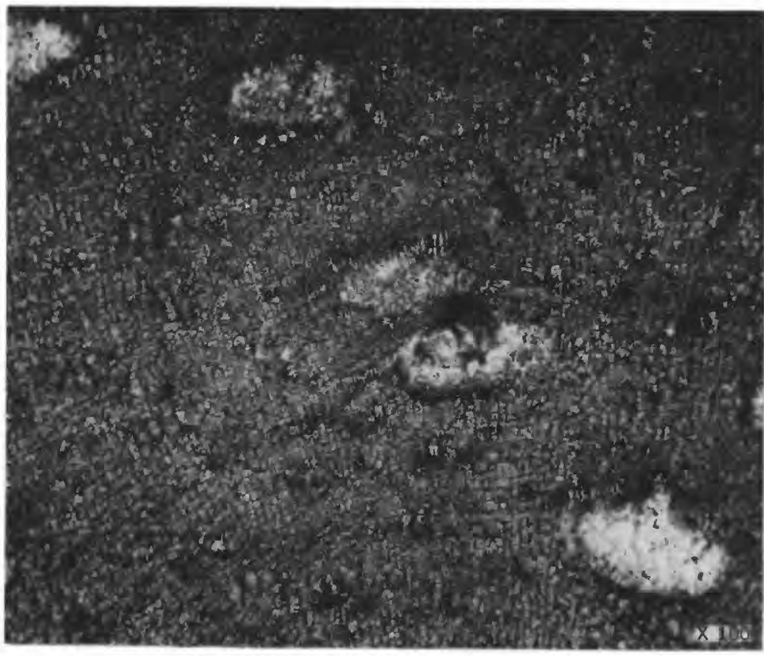

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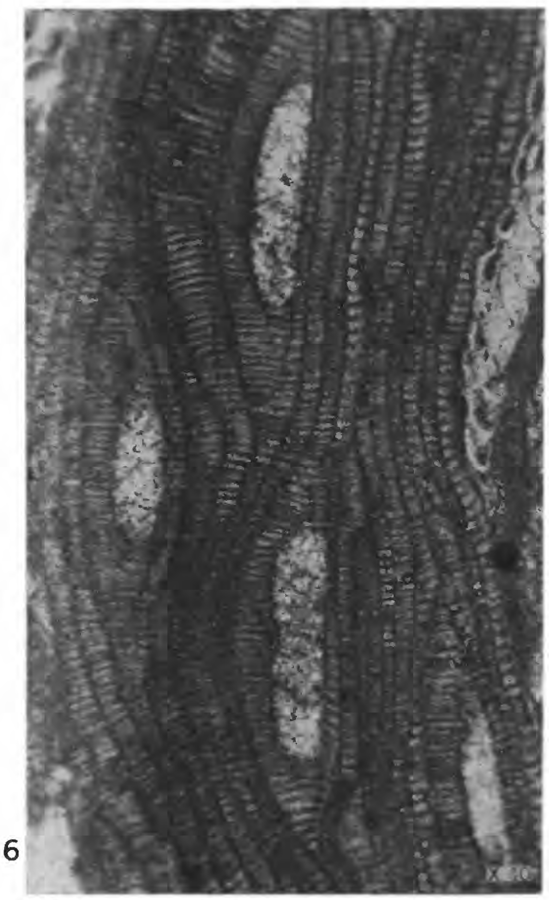

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PLEISTOCENE *GONIOLITHON*, *HALIMEDA*, *POROLITHON*, AND *LITHOPORELLA*

PLATE 56

FIGURE 1. *Goniolithon* sp. B (p. 232).
Section showing hypothallus (lower right) and perithallus with the vertical groups of megacells in the tissue. Mariana limestone, massive facies; loc. D100 (B226); USGS algae a14–1a.

2. *Goniolithon* sp. A (p. 232).
Detail of a crust showing a large conceptacle chamber, above it a secondary hypothallus developed as scar tissue, and perithallic tissue with the typical vertical groups of megacells. Mariana limestone, massive facies; loc. D115 (B321); USGS algae a32–2a.

3. *Halimeda* sp. (p. 241).
Section of a segment with the characteristic internal tubes. Mariana limestone, massive facies; loc. D95 (B189); USGS Algae no. a9–1b.

4, 5. *Porolithon craspedium* (Foslie) Foslie (p. 232).
4. Section with a little of the basal hypothallus. Perithallic tissue contains abundant clusters of megacells. Mariana limestone, massive facies; loc. D104 (B235); USGS algae a18–1a.
5. A slightly oblique section of perithallus with conceptacle chambers and numerous clusters of megacells. Tanapag limestone; loc. D117 (B334); USGS algae a35–1a

6. *Lithoporella melobesioides* (Foslie) Foslie (p. 234).
An array of superimposed thalli. Good detail of several conceptacle chambers. Mariana limestone, massive facies; loc. D133 (C81); USGS algae a60–2b.

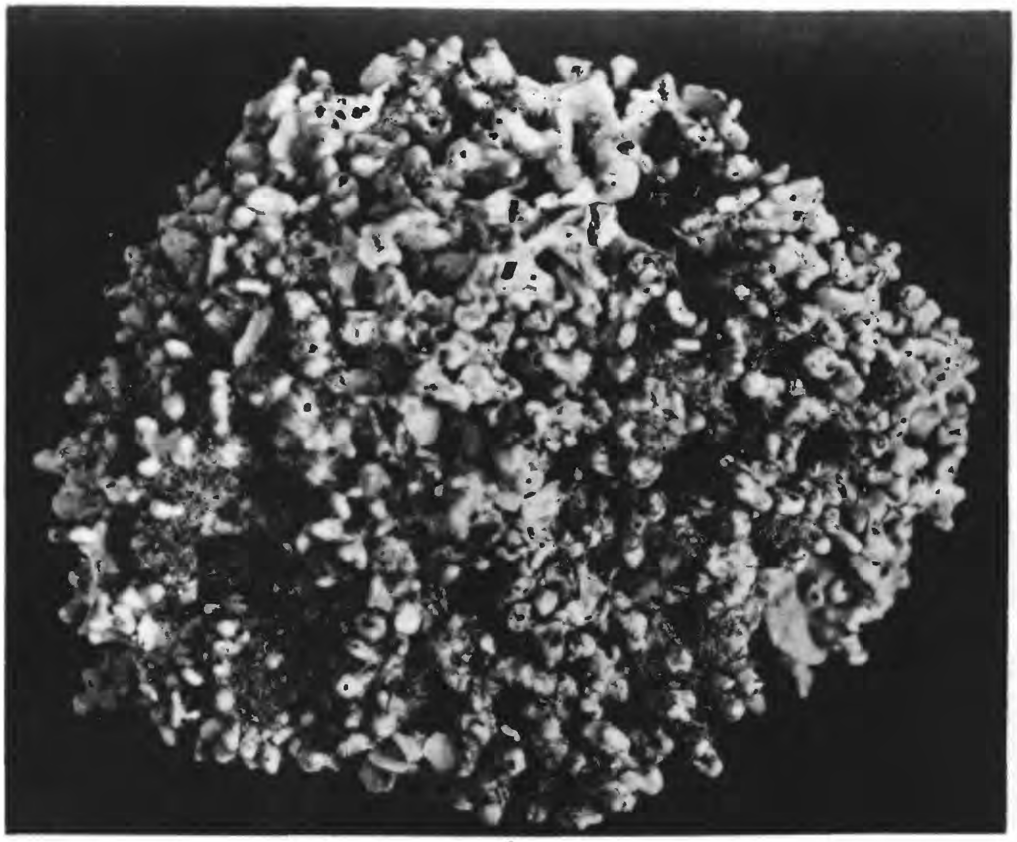
PLATE 57

[All figures are natural size unless otherwise indicated on plate]

FIGURE 1. *Lithophyllum kotschyanum* forma *typica* Foslie (p. 230).
Recent, reef at Obyan Point; loc. D213; USGS algae a98.

2, 3. *Dermatolithon nitida* Johnson, n. sp. (p. 235).
2. Detail of thallus and conceptacle. Densinyama formation, limestone-conglomerate facies; loc. D147 (S133); USNM 624736 (Foraminifera slide).
3. Several thalli, one with two conceptacles. Densinyama formation, limestone-conglomerate facies; loc. D154 (S208); holotype, USGS Algae a92–2a.

4–6. *Dermatolithon saipanense* Johnson, n. sp. (p. 235).
4. Several superimposed thalli. Tagpochau limestone, rubbly facies; loc. D204 (C23); USGS algae a135–1a.
5. Another specimen with several thalli. Tagpochau limestone. inequigranular facies; loc. D105 (B245); USGS algae a19–1a.
6. Several thalli and two conceptacles. Tagpochau limestone, inequigranular facies; loc. D108 (B279); holotype, USGS algae a22–1a.



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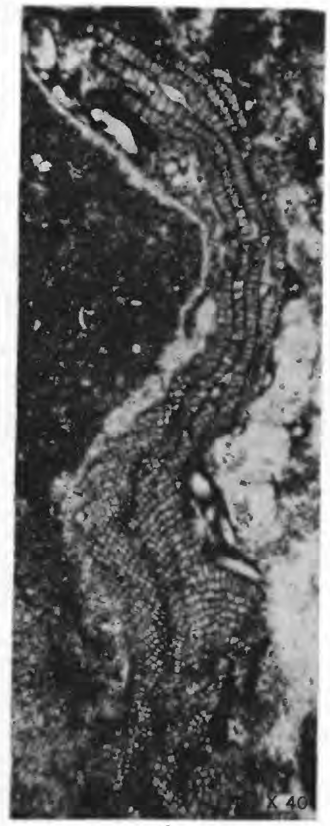

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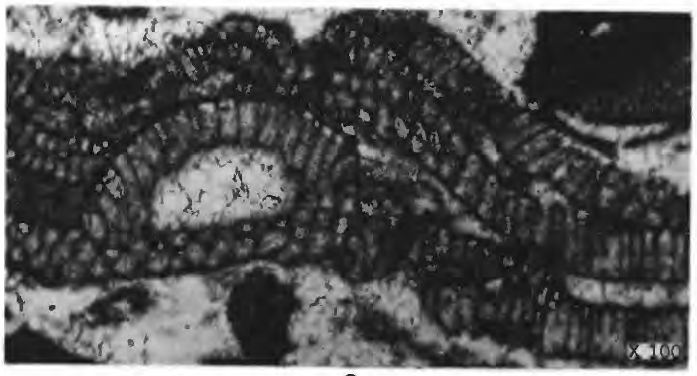

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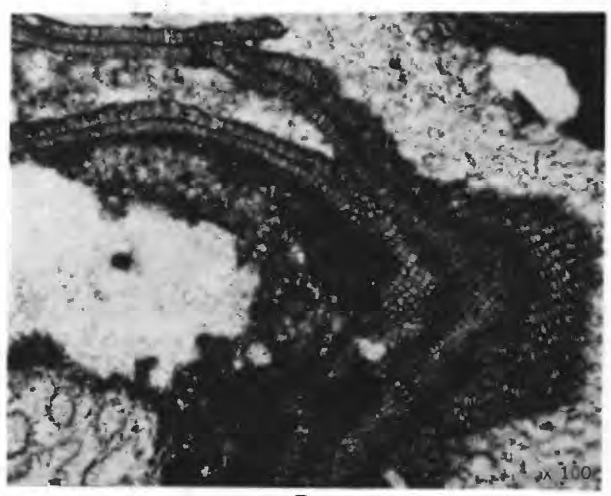

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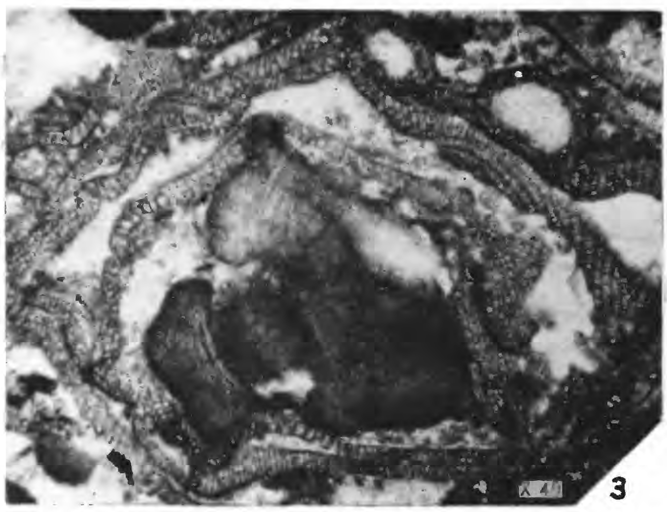

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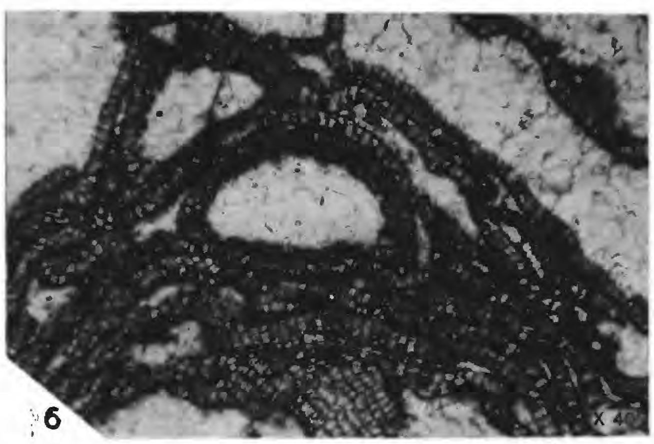

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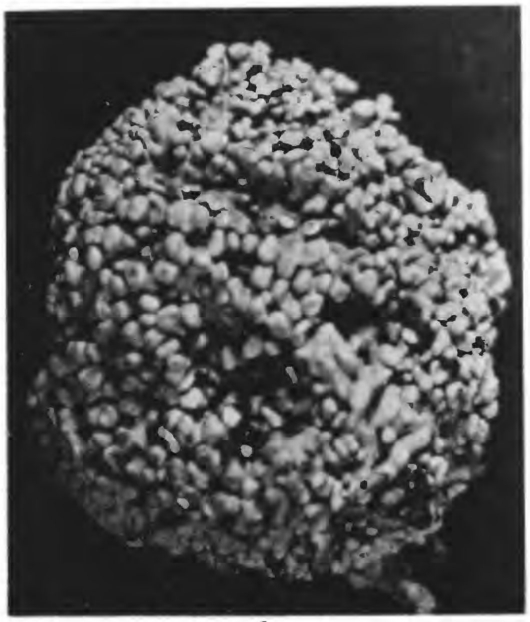
RECENT *LITHOPHYLLUM* AND UPPER EOCENE AND LOWER MIOCENE *DERMATOLITHON*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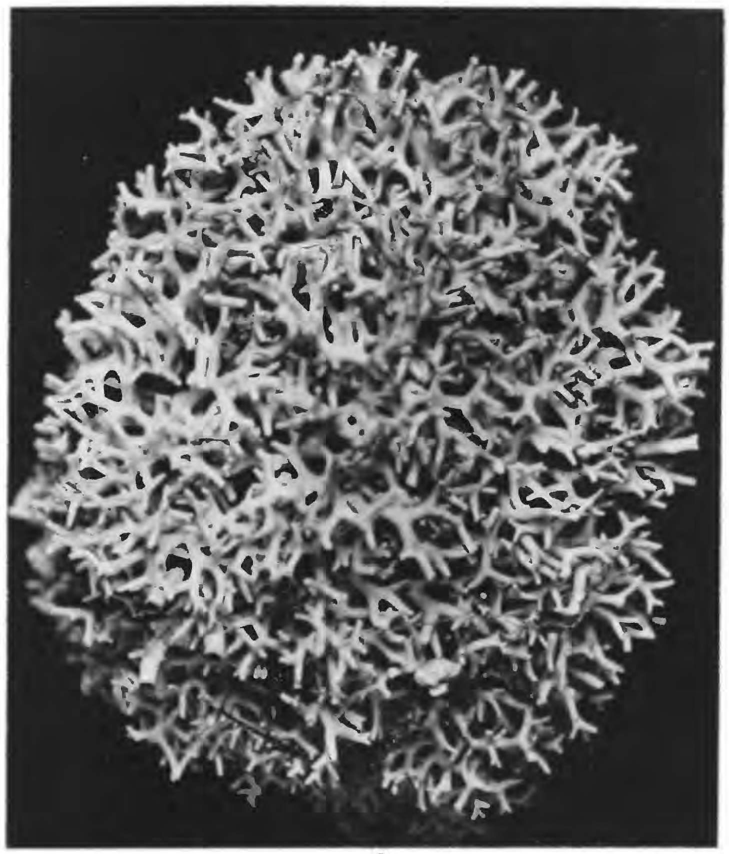
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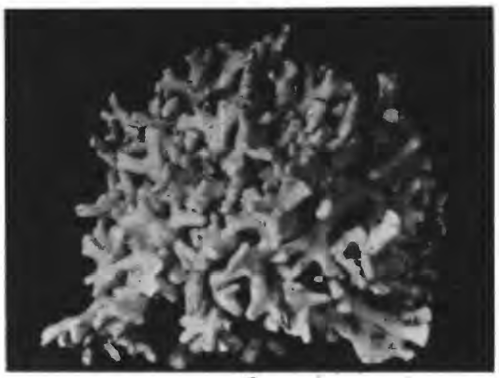
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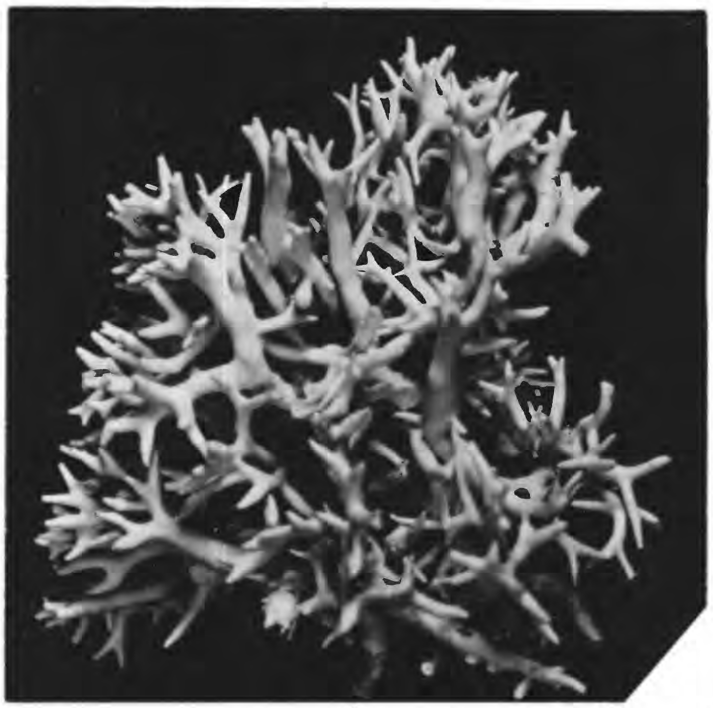
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5

RECENT *LITHOPHYLLUM*

PLATE 58

[All figures natural size unless otherwise indicated on plate]

FIGURE 1. *Lithophyllum kotschyanum* forma *subtilis* Foslie (p. 230). Loc. D176; USGS algae a114.

2–5. *Lithophyllum moluccense* Foslie (p. 230).

2. Forma *pygmaea* Foslie. A ball-like mass. Loc. D260; USGS algae a81.
3. Forma *flabelliformis* Foslie. Loc. D269; USGS algae a62.
4. Forma *typica*. Loc. D261; USGS algae a78.
5. Section of a branch showing the medullary hypothallus with the alternating layers of long and short cells which is characteristic of this species. Loc. D261; USGS algae a78–1a.

PLATE 59

[All figures natural size unless otherwise indicated on plate]

FIGURES 1–3. *Porolithon craspedium* (Foslie) Foslie (p. 232).

1. Side view of a specimen. Reef at Obyan Point; loc. D274; USGS algae a50.
2. Top view of the same specimen.
3. Section of the perithallic tissue of the same specimen, showing several conceptacles and clusters of megacells. USGS algae a50–1a.

4. *Goniolithon frutescens* Foslie (p. 231).
A typical plant from reef at Obyan. Loc. D267; USGS algae a74.

5. *Goniolithon reinboldi* Weber van Bosse and Foslie (p. 231).
A nodular mass. Fañunchuluyan beach; loc. D273; USGS algae a49.

6. *Porolithon onkodes* (Heydrich) Foslie (p. 232).
Knobby crusts on other algae. West coast of Saipan; loc. D272; USGS algae a61.

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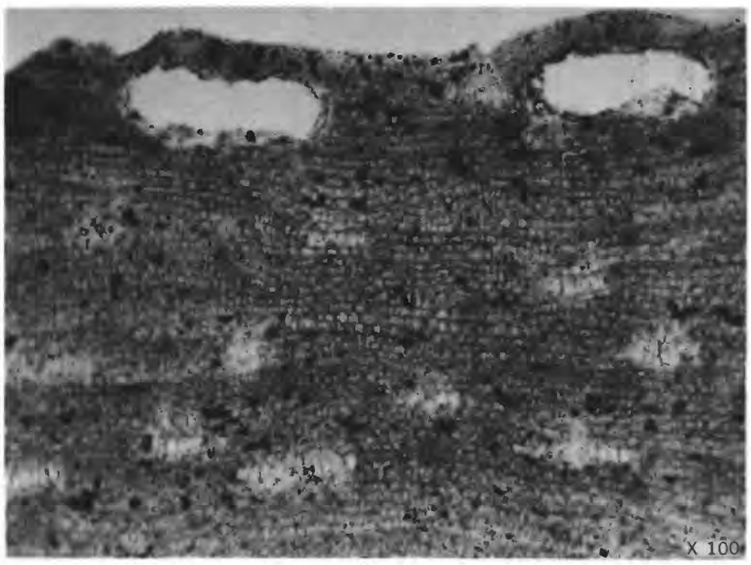

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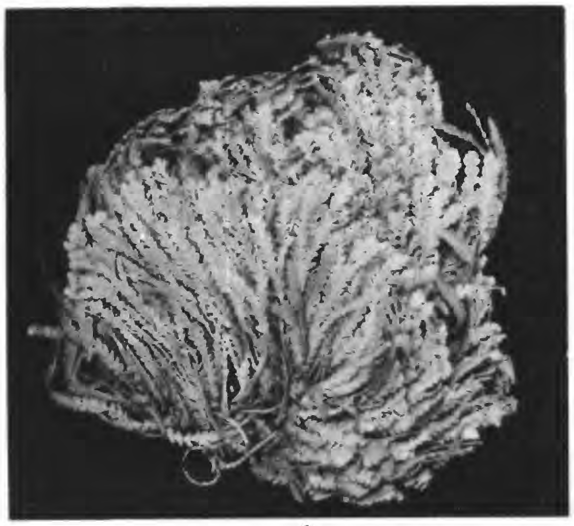
RECENT *POROLITHON* AND *GONIOLITHON*



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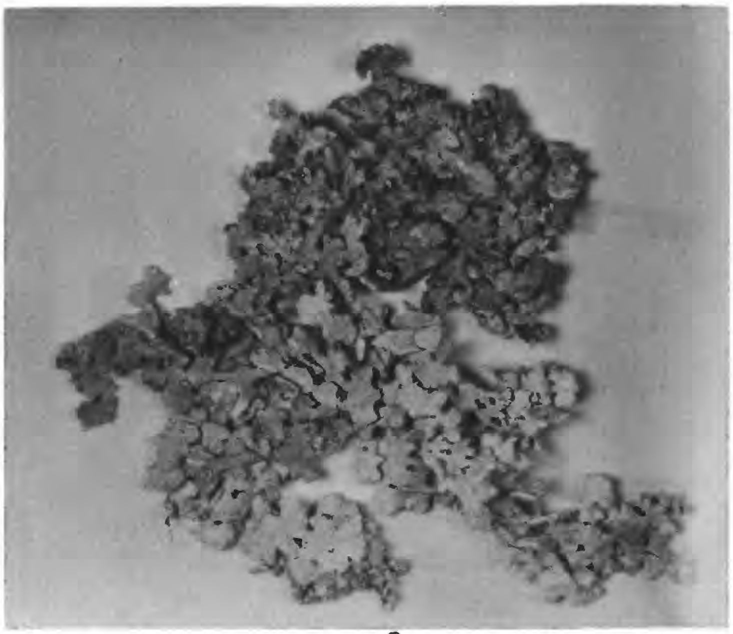

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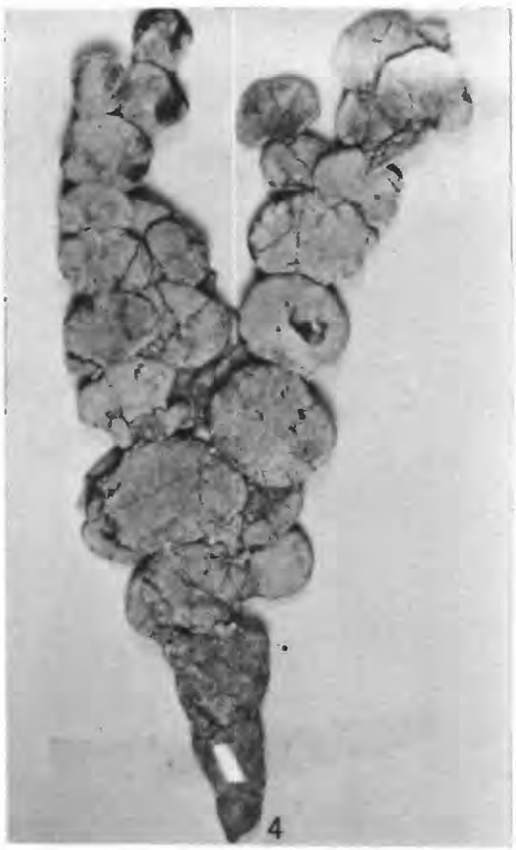

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RECENT *AMPHIROA*, *GONIOLITHON*, AND *HALIMEDA*

PLATE 60

[All natural size]

FIGURE 1. *Amphiroa* sp. (p. 238).
A cluster of this delicate coralline alga from southeast coast of Saipan. Loc. D279; USGS algae a37.

2. *Halimeda opuntia* forma *triloba* Barton (p. 242).
Tanapag Harbor; loc. D270; USGS algae a56.

3. *Goniolithon frutescens* Foslie (p. 231).
A common growth form from west coast of Saipan. Loc. D268; USGS algae a69.

4, 5. *Halimeda gracilis* Harvey (p. 241).
4. Forma *lata* from west coast of Saipan. Loc. D437; USGS algae a57.
5. A variety close to forma *lata* from west coast of Saipan. Loc. D271; USGS algae a58.

Discoaster and Some Related Microfossils

By M. N. BRAMLETTE

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-F

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

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GEOLOGY OF SAIPAN, MARIANA ISLANDS

DISCOASTER AND SOME RELATED MICROFOSSILS

By M. N. Bramlette

ABSTRACT

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

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

INTRODUCTION

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

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

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

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

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

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

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

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

DISCUSSION OF SPECIES IDENTIFIED FROM SAIPAN

DISCOASTERS

Discoaster pentaradiatus Tan Sin Hok, emend. Bramlette and Riedel

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

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

Discoaster brouweri Tan Sin Hok

Plate 61, figure 1

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

Discoaster brouweri Tan Sin Hok var

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

Discoaster challengeri Bramlette and Riedel

Plate 61, figure 2

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

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

Discoaster challengeri Bramlette and Riedel var

Plate 61, figure 3

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

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

Discoaster aster Bramlette and Riedel

Plate 61, figure 4

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

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

Discoaster woodringi Bramlette and Riedel

Plate 61, figure 5

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

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

Discoaster deflandrei Bramlette and Riedel

Plate 61, figure 6

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

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

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

Plate 61, figure 10

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

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

Discoaster saipanensis Bramlette and Riedel

Plate 61, figure 7

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

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

Discoaster tani Bramlette and Riedel

Plate 61, figure 8

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

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

Discoaster tani nodifer Bramlette and Riedel

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

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

COCCOLITHS AND SOME DOUBTFULLY RELATED FORMS

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

Tremalithus eopelagicus Bramlette and Riedel

Plate 61, figure 9

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

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

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

Rhabdoliths and lopadoliths

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

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

Thoracosphaera sp.

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

Ceratolithus sp.

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

Braarudosphaera bigelowi (Gran and Braarud) Deflandre

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

Braarudosphaera discula Bramlette and Riedel

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

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

INTERPRETATIONS OF THE AGE OF STRATA ON SAIPAN

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

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

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

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

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

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

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

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

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

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

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

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

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

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[Italic numbers indicate descriptions]

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

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

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

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

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

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

6. *Discoaster deflandrei* Bramlette and Riedel (p. 249).
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7. *Discoaster saipanensis* Bramlette and Riedel (p. 249).
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8. *Discoaster tani* Bramlette and Riedel (p. 250).
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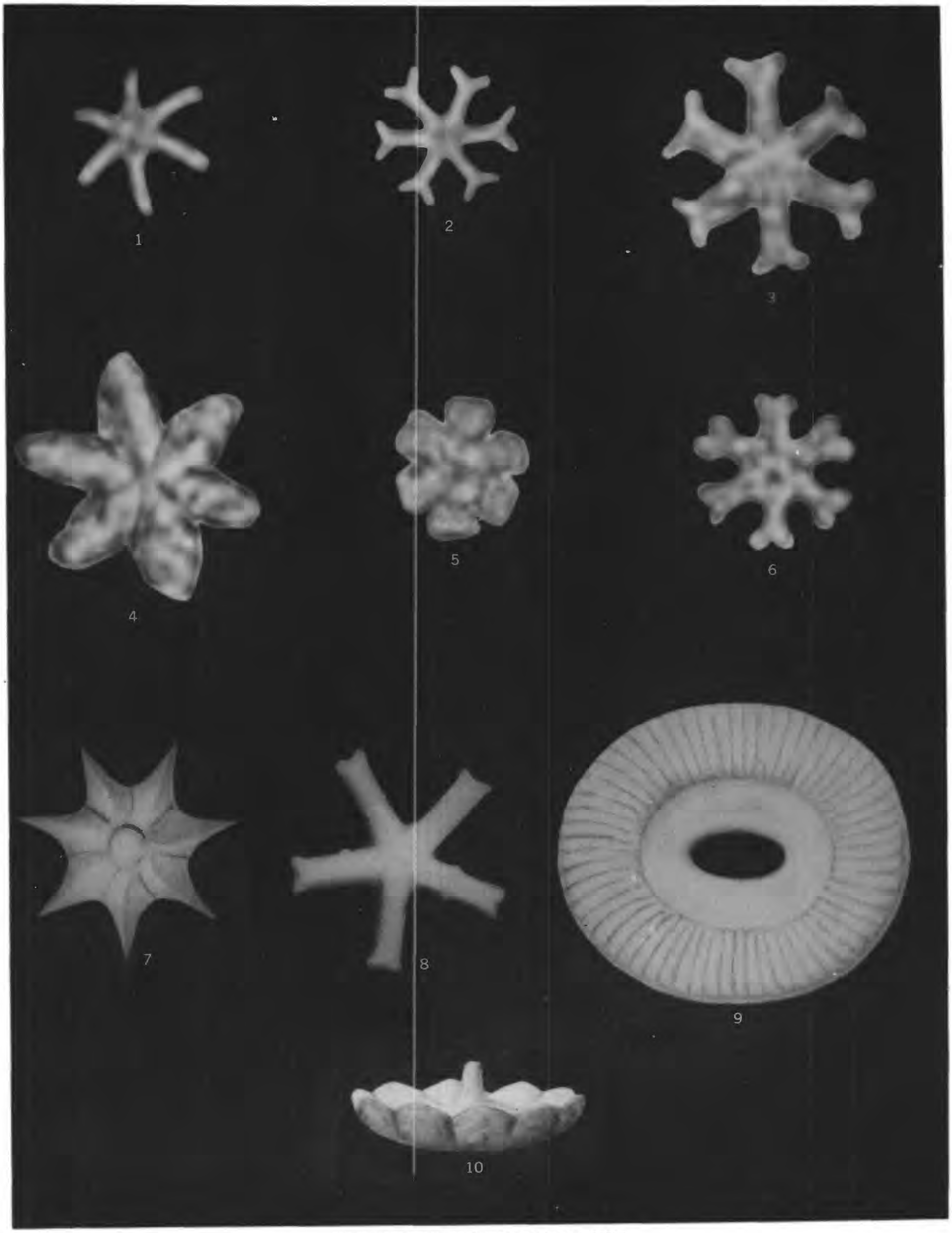

DISCOASTER AND *TREMALITHUS*

Eocene Radiolaria

By WILLIAM R. RIEDEL

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-G

Sixteen species of Radiolaria representing a single faunal zone are recorded from two Eocene formations

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EOCENE RADIOLARIA

By William R. Riedel

ABSTRACT

Sixteen species of Radiolaria, none new, are recorded from two Eocene formations on Saipan. These species apparently represent a single faunal zone and are comparable to early Tertiary forms reported from Barbados, from California, and from modern deep-sea sediments that probably contained reworked older species.

INTRODUCTION

Present knowledge of the Tertiary Radiolaria is so scant that the description of any new assemblage is significant. The only descriptions of early Tertiary radiolarian faunas from the Pacific region are those of Clark and Campbell (1942, 1945) from the Eocene of California. The present paper compares Eocene species from Saipan with those previously described from California and Barbados.

The Radiolaria from Saipan were found in five samples from the Eocene in the north-central part of the island, as follows: Sample S–26, Densinyama formation, conglomerate-sandstone facies, quartz-rich beds; samples S346, S353, S354, S463, Hagman formation, conglomerate-sandstone facies, tuffaceous beds.

The original siliceous material of the radiolarian tests is preserved in samples S26 and S346, but some solution and redeposition of the skeletal material has occurred, obscuring the finer detail of many of the species and thus preventing their identification. The

Table 1.—*Distribution of Radiolaria in upper Eocene of Saipan and the same or similar species in other areas*

Species found in upper Eocene of Saipan

Species	Densinyama formation—conglomerate-sandstone facies	Hagman formation—conglomerate-sandstone facies			
	S26	S346	S353	S354	S463
Anthocyrtium hispidum (Ehrenberg)?			×	×	
Calocyclas turris Ehrenberg	×	×		?	
Ceratospyris aff. *C. echinus* Ehrenberg			×	×	
?*Clathrocyclas* aff. *C. universa* Clark and Campbell	×			×	
Coccodiscus aff. *C. lamarckii* Haeckel					×
?*Eusyringium* aff. *E. fistuligerum* (Ehrenberg)					×
Heliodiscus humboldti (Ehrenberg)	×	×			
Lithochytris aff. *L. cheopsis* Clark and Campbell					×
Lychnocanium sp				×	
Periphaena decora Ehrenberg	×				
Petalospyris platyacantha Ehrenberg?				×	
Podocyrtis aff. *P. argus* Ehrenberg	×	×	×	×	
Podocyrtis triacantha Ehrenberg	×		×	×	
Semantis spinescens (Ehrenberg)			×	×	
Sethamphora mongolfieri (Ehrenberg)	×	×	×	×	
Trigonactura sp				×	

Records of comparable forms from areas other than Saipan

Early Tertiary of Barbados	Eocene of California	Deep-sea sediments (probably reworked)	Species
×		×	*Anthocyrtium hispidum* (Ehrenberg)
×			*Calocyclas turris* Ehrenberg
×			*Ceratospyris echinus* Ehrenberg
	×		*Clathrocyclas universa* Clark and Campbell
×			*Cycladophora spatiosa* Ehrenberg
		×	*Coccodiscus lamarckii* Haeckel
×			*Lithocyclia ocellus* Ehrenberg
×			*Eusyringium fistuligerum* (Ehrenberg)
×			*Eusyringium sipho* (Ehrenberg)
×			*Heliodiscus humboldti* (Ehrenberg)
	×		*Heliodiscus saturnalis* Clark and Campbell
	×		*Lithochytris cheopsis* Clark and Campbell
		×	*Lithochytris lucerna* Haeckel
		×	*Lithochytris pteropus* Haeckel
×			*Lithochytris tripodium* Ehrenberg
×			*Lithochytris vespertilio* Ehrenberg
	×		*Lychnocanium bellum* Clark and Campbell
×			*Periphaena decora* Ehrenberg
		×	*Periphaena cincta* Haeckel
×			*Petalospyris platyacantha* Ehrenberg
×			*Podocyrtis argus* Ehrenberg
×		×	*Podocyrtis triacantha* Ehrenberg
×			*Podocyrtis dipus* Ehrenberg
×			*Podocyrtis princeps* Ehrenberg
×			*Podocyrtis schomburgkii* Ehrenberg
×			*Semantis spinescens* (Ehrenberg)
×			*Sethamphora mongolfieri* (Ehrenberg)
		×	*Sethamphora costata* Haeckel
	×		*Dictyocephalus pulcherrimus* Clark and Campbell
×		×	*Trigonactura* (*Trigonactinium*) spp.

Radiolaria of sample S463 are present only as casts of the interiors of the shells, and it is therefore impossible to recognize most of the forms present. Samples S353 and S354 are tuffs which are difficult to disaggregate but which yield a few well-preserved tests. It must be emphasized that by no means all of the observed Radiolaria are described here. Where the state of preservation is so poor as to prevent generic determination, the forms are usually omitted; and only those species of which a number of examples were obtained, or which seem to be of particular significance in comparing the assemblage with others of a similar age, are recorded. In the study of such a group as the Radiolaria, doubtful determinations of poorly preserved infrequent species are often more confusing than useful.

In the following systematic section, 16 species are described. All of the described forms are identical with, or similar to, species described from the Tertiary (probably upper Eocene or Oligocene) of Barbados, from the Eocene of California, and from deep-sea sediments (mostly from the central Pacific) collected by H. M. S. *Challenger* in 1873–76. With regard to the last-mentioned localities, it appears that many of the species described by Haeckel (1887) are not living at the present day but have been reworked into Recent sediments from submarine Tertiary deposits (Riedel, 1952). Such reworking apparently plays a very important role in sediment formation in the tropical Pacific, with the result that a high proportion of the Recent sediment samples collected from the surface of the sea floor contain reworked Tertiary Radiolaria.

SYSTEMATIC DESCRIPTIONS

Genus PERIPHAENA Ehrenberg

Periphaena decora Ehrenberg

Plate 62, figure 1

Periphaena decora Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 246.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 28, fig. 6.
Haeckel, 1887, *Challenger* Rept., Zoology, v. 18. pt. 1, p. 426.

Examples of this species correspond to the original description except in that they are often somewhat larger (diameter of the disk 300μ).

The species has been recorded only from the early Tertiary of Barbados. The closely related species *P. cincta* Haeckel has been described from the central Pacific *Challenger* station 268 (probably reworked).

Occurrence.—Sample S26 (USNM 548888), Densinyama formation, northern Saipan.

Genus HELIODISCUS Haeckel

Heliodiscus humboldti (Ehrenberg)

Plate 62, figure 2

Haliomma humboldtii Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 235.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 27, fig. 3.
Heliodiscus humboldti (Ehrenberg). Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 1, p. 449.

This species has been recorded only from the early Tertiary of Barbados. It is apparently closely related to *H. saturnalis* Clark and Campbell, from the Eocene of California.

Occurrence.—Samples S26 (USNM 548889), Densinyama formation, northern Saipan; S346, Hagman formation, northeast-central Saipan.

Genus COCCODISCUS Haeckel

Coccodiscus aff. C. lamarckii Haeckel

Plate 62, figure 3

Coccodiscus lamarckii Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 1, p. 461, pl. 36, fig. 1.

Although the outer parts of the skeleton of this species have disappeared during fossilization, the inner structures are well preserved. The form is closer to *C. lamarckii* than to any other described species but differs in that there are 4 or 5 chambered rings surrounding the phacoid shell, the innermost being twice as broad as the others. Also, there are somewhat fewer pores on the phacoid shell.

This form appears to be closely related to *Lithocyclia ocellus* Ehrenberg, from the early Tertiary of Barbados. Although neither Ehrenberg nor Haeckel mention the fact, the innermost chambered ring of specimens from Barbados is often wider than the others, and traces of a second medullary shell can sometimes be found.

Coccodiscus lamarckii has been recorded only from *Challenger* station 220, in the western tropical Pacific (probably reworked).

Occurrence.—Sample S463 (USNM 548892), Hagman formation, northeast-central Saipain.

Genus TRIGONACTURA Haeckel

Trigonactura sp.

Plate 63, figure 1

A single example of this genus was found in sample S–354 (USNM 548896), from the Hagman formation, northeast central Saipan. It does not correspond with the description of any known species but is undoubtedly closely related to the three species described by Haeckel in his subgenus *Trigonactinium*.

The characters of the specimen are as follows: Phacoid shell circular, 2½ times as broad as medullary shell, with 8 circular pores on the radius, and not surrounded by a chambered ring. Arms almost rectangular; their basal breadth a little less than two-thirds diameter of phacoid shell; breadth slightly increasing distally; their length less than diameter of phacoid shell; each armed with a short terminal pyramidal spine. The form of the test without the terminal spines closely resembles that of *Trigonactura pythagorae* (Ehrenberg) Haeckel.

Diameter of phacoid shell 95μ; of medullary shell 40μ. Length of arms 70μ.

The other members of the subgenus *Trigonactinium* have been described from the early Tertiary of Barbados and from the central Pacific *Challenger* stations 265 and 268 (probably reworked).

Genus SEMANTIS Haeckel

Semantis spinescens (Ehrenberg)

Plate 63, figure 2

Stephanolithis spinescens Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, p. 160, pl. 1, fig. 29.
Bütschli, 1882, Zeitschr. wissenschaftliche Zool., Leipzig, v. 36, p. 497, pl. 32, figs. 7a, b.
Semantis spinescens (Ehrenberg). Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 1, p. 958.

Specimens from Saipan are quite typical. This species has been recorded only from the early Tertiary of Barbados. Closely related members of this genus apparently range from the early Tertiary to the Recent.

Occurrence. — Samples S353 and S354 (USNM 548899), Hagman formation, northeast-central Saipan.

Genus PETALOSPYRIS Ehrenberg

Petalospyris platyacantha Ehrenberg?

Plate 63, figure 3

Petalospyris platyacantha Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 247.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 22, fig. 8.
Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1060.

The form from Saipan corresponds well with the original description and figure, except in that the apical spine is conical. *P. platyacantha* has been recorded only from the early Tertiary of Barbados.

Occurrence.—Sample S354 (USNM 548898), Hagman formation, northeast-central Saipan.

Genus CERATOSPYRIS Ehrenberg

Ceratospyris aff. C. echinus Ehrenberg

Plate 63, figure 4

Ceratospyris echinus Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 219.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 20, fig. 12.
Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1068.

The few well-preserved examples of this species found in the Saipan material all are embedded in small lumps of sediment, so that it is impossible to determine some of the important characters such as the number of pores in the basal plate, the exact number of basal spines, and the precise form and length of the accessory spines. In its general features it closely resembles Ehrenberg's species, except in that the basal spines are longer and more delicate and the pores are somewhat smaller in relation to the width of the intervening bars.

C. echinus was originally described from the early Tertiary of Barbados, and Gregory (1895) records a closely related form from the early Tertiary of Cuba.

Occurrence.—Samples S353 and S354 (USNM 548902), Hagman formation, northeast-central Saipan.

Genus LYCHNOCANIUM Ehrenberg

Lychnocanium sp.

Plate 63, figure 5

Shell campanulate, with rough surface and pronounced collar stricture. Cephalis small, hyaline, subspherical, bearing a stout conical horn almost as long as the thorax. Thorax more than hemispherical with numerous subcircular pores with hexagonal or pentagonal frames. Three feet stout, slightly convergent distally, cylindrical, two-thirds as long as the thorax, broadened distally, very similar to those of *Lychnocanium crassipes* Ehrenberg but hollow.

Length of apical horn 80μ, cephalis 20μ, thorax 110μ, basal feet 80μ. Breadth of cephalis 30μ, thorax 135μ.

Hollow cylindrical basal feet are rarely found in *Lychnocanium*, having been described only in *L. bellum* Clark and Campbell (Eocene of the Mount Diablo area, California); as only one specimen of this form was found in the Saipan material, it cannot be determined whether or not the hollowing is a normal character. The thorax of the specimen from Saipan is very similar to that of *L. bellum*,

Occurrence.—Sample S354 (USNM 548900), Hagman formation, northeast-central Saipan.

Genus SETHAMPHORA Haeckel

Sethamphora mongolfieri (Ehrenberg)

Plate 63, figure 6

Eucyrtidium mongolfieri Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 230.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, p. 10, fig. 3.
Sethamphora mongolfieri (Ehrenberg), Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1251.

Forms corresponding well with Ehrenberg's description and figure occur in the Saipan material. It should be pointed out, however, that Haeckel's emended description of this species does not give a true picture of the amount of variation observed. Examination of specimens from several localities of the Oceanic formation of Barbados shows that the number of transverse rows of pores, though usually 8, ranges from 7 to 10; the total length of the shell ranges from 110μ to 170μ, and the maximum breadth, from 70μ to 105μ. The specimens from Saipan have from 7 to 10 transverse rows of pores, a total length of 110μ to 145μ, and a maximum breadth of 80μ to 90μ.

Sethamphora mongolfieri has been recorded only from the early Tertiary of Barbados. Apparently the closest relatives of this species are *S. costata* Haeckel, recorded from the central Pacific *Challenger* stations 265–274, probably reworked, and *Dictyocephalus pulcherrimus* Clark and Campbell, from the Eocene of California.

Occurrence.—Samples S26, Densinyama formation, northern Saipan; S346, S353 (USNM 548894), and S354, Hagman formation, northeast-central Saipan.

Genus ANTHOCYRTIUM Haeckel

Anthocyrtium hispidum (Ehrenberg)?

Plate 63, figure 7

Anthocyrtis hispida Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 216.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 8, fig. 2.
Anthocyrtium hispidum (Ehrenberg), Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1275.

Only broken examples of this form have been observed in the material from Saipan, but it has been possible to establish that it corresponds well with Ehrenberg's species in the nature of the cephalis and apical spine, the shape and size of the thorax and the nature of its pores, and the number and character of the terminal feet. The examples from Saipan have not such pronounced spines on the thorax as in Ehrenberg's figure.

A. hispidum has been recorded from the early Tertiary of Barbados and from the central Pacific *Challenger* stations 263–265 (probably reworked).

Occurrence.—Samples S353 and S354 (USNM 548901), Hagman formation, northeast-central Saipan.

Genus PODOCYRTIS Ehrenberg

Podocrytis aff. P. argus Ehrenberg

Plate 62, figure 4; plate 63, figure 8

Podocyrtis argus Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 248.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, p. 16, fig. 9.
Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1346.

Although the examples from Saipan correspond with the original description and figure in size, general form, and nature and arrangement of the pores, there are several minor differences which render its identification with Ehrenberg's species doubtful. The thorax is relatively shorter in the Saipan examples, the proportions of the lengths of the segments being 1:3:6; the surface of the thorax is somewhat roughened by small protuberances which arise from the hexagonal frames surrounding the circular thoracic pores; and the outer surface of each of the basal feet usually bears a low ridge which terminates distally in a small crest (this condition also occurs frequently in specimens from Barbados).

P. argus has been recorded from the early Tertiary of Barbados and from the surface of the tropical Atlantic at *Challenger* station 347.

Occurrence.—Samples S26 (USNM 548887), Densinyama formation, northern Saipan; S346, S353, and S354 (USNM 548895), Hagman formation, northeast-central Saipan.

Podocyrtis triacantha Ehrenberg

Plate 63, figure 9

Podocyrtis triacantha Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 254.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 13, fig. 4.
Haeckel, 1887, *Challenger* Rept. Zoology, v. 18, pt. 2, p. 1350.

Examples from the Saipan material correspond well with the original description and figure. The species has been recorded from the early Tertiary of Barbados and from the central Pacific *Challenger* station 268 (probably reworked).

Close relatives of this species include *Podocyrtis dipus* Ehrenberg, *P. schomburgkii* Ehrenberg, and *P. princeps* Ehrenberg, all from the early Tertiary of Barbados, the last mentioned also being recorded from the tropical Atlantic *Challenger* station 348.

Occurrence.—Samples S26, Densinyama formation, northern Saipan; S353 and S354 (USNM 548897), Hagman formation, northeast-central Saipan.

Genus LITHOCHYTRIS Ehrenberg

Lithochytris aff. L. cheopsis Clark and Campbell

Plate 62, figure 5

Lithochytris cheopsis Clark and Campbell, Geol. Soc. America Special Paper 39, p. 81, pl. 9, fig. 37.

This form is difficult to identify accurately because of the loss of the apical spine and basal feet. However, in the dimensions and general form of the skeleton and the arrangement of the pores, it is closely similar to Clark and Campbell's species, which has been recorded only from the Eocene of California.

Closely related species of *Lithochytris* have been described from the early Tertiary of Barbados (that is, *L. vespertilio* Ehrenberg and *L. tripodium* Ehrenberg), and from deep-sea sediments collected by the *Challenger* expedition (that is, *L. lucerna* Haeckel and *L. pteropus* Haeckel).

Occurrence.—Sample S463 (USNM 548893), Hagman formation, northeast-central Saipan.

Genus CALOCYCLAS Ehrenberg

Calocyclas turris Ehrenberg

Plate 62, figure 6

Calocyclas turris Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 218.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 18, fig. 7.
Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1383.

Although many of the pores of the thorax are practically obliterated and the lamellar feet broken, little doubt exists that this form is identical with Ehrenberg's species, which has been recorded only from the early Teritiary of Barbados.

Occurrence.—Samples S26 (USNM 54886), Densinyama formation, northern Saipan; S346, Hagman formation, northeast-central Saipan. Fragmentary specimens which can be assigned doubtfully to this species occur also in S354, Hagman formation, northeast-central Saipan.

Genus CLATHROCYCLAS Haeckel

?Clathrocyclas aff. C. universa Clark and Campbell

Plate 62, figure 7

Clathrocyclas universa Clark and Campbell, 1942, Geol. Soc. America Special Paper 39, p. 86, pl. 7, figs. 8–12, 14–21, 25.

The imperfect state of preservation of all observed specimens prevents accurate determination of this species, but the overall form and dimensions, and the nature and disposition of the pores, correspond well with Clark and Campbell's species. If an abdomen was present, it was probably much reduced, as in *C. universa undella* Clark and Campbell.

C. universa has been recorded from several Eocene localities in California (Clark and Campbell, 1942, 1945). This species appears to be closely related to *Cycladophora spatiosa* Ehrenberg, from the early Tertiary of Barbados.

Occurrence.—Samples S26 (USNM 548890), Densinyama formation, northern Saipan; S354, Hagman formation, northeast-central Saipan.

Genus EUSYRINGIUM Haeckel

?Eusyringium aff. E. fistuligerum (Ehrenberg)

Plate 62, figure 8

Eucyrtidium fistuligerum Ehrenberg, 1874, K. preuss. Akad. Wiss. Berlin, Monatsber., 1873, p. 229.
Ehrenberg, 1876, K. preuss. Akad. Wiss. Berlin, Abh., 1875, pl. 9, fig. 3.
Eusyringium fistuligerum (Ehrenberg). Haeckel, 1887, *Challenger* Rept., Zoology, v. 18, pt. 2, p. 1498.

Although the entire test has disappeared, the internal cast indicates that this form closely resembled Ehrenberg's species in general form and in the size and arrangement of the pores. The absence of any indication of the apical spine prevents exact determination.

The closely related *E. fistuligerum* and *E. sipho* (Ehrenberg) have been reported only from the early Tertiary of Barbados.

Occurrence.—Sample S463 (USNM 548891), Hagman formation, northeast-central Saipan.

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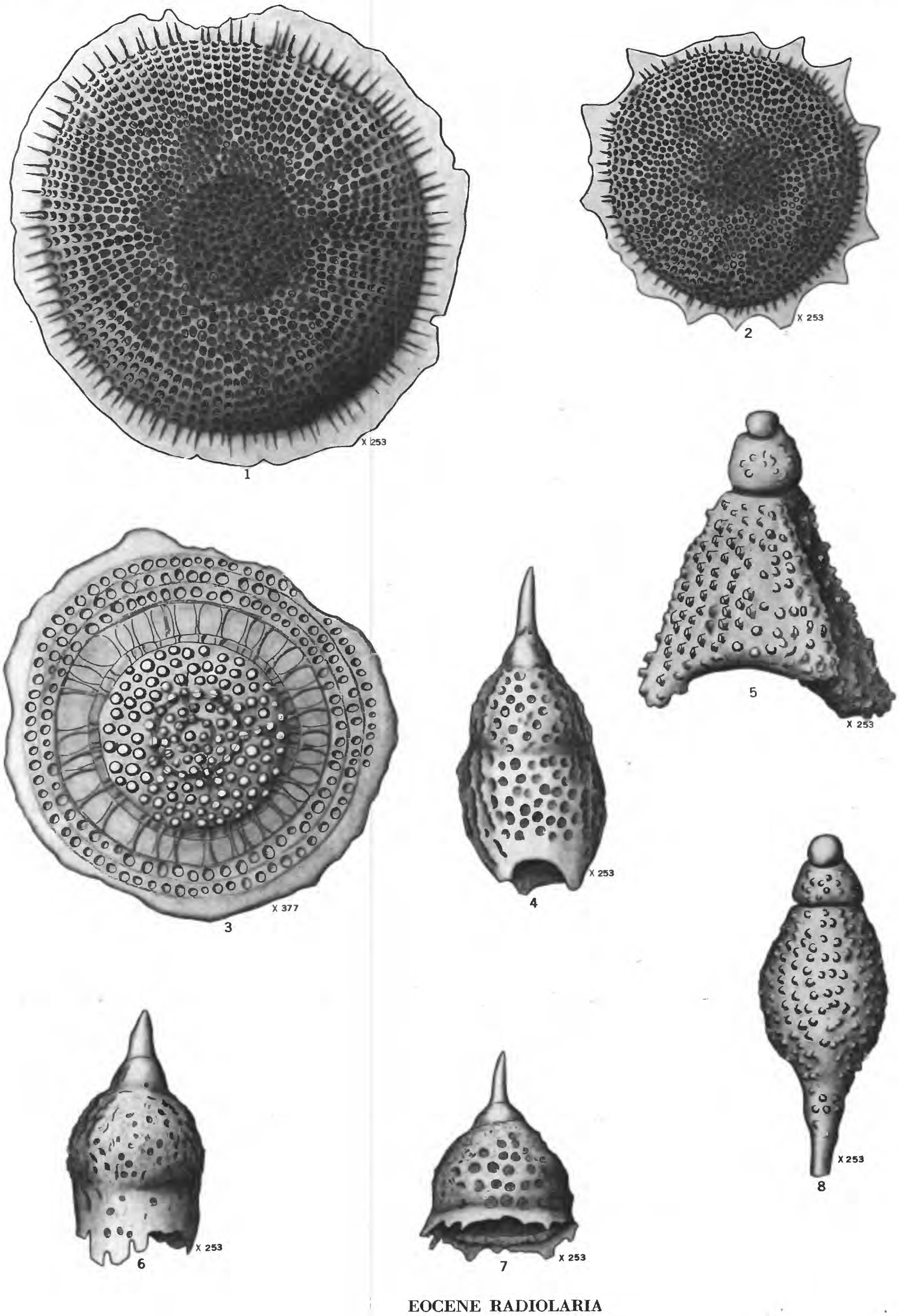
[Italic numbers indicate descriptions]

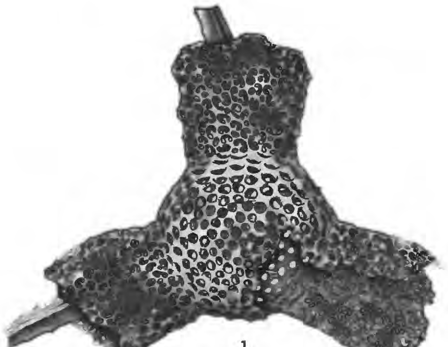
PLATES 62 AND 63

PLATE 62

FIGURE 1. *Periphaena decora* Ehrenberg. USNM 548888. Sample S26 (p. 258).
2. *Heliodiscus humboldti* (Ehrenberg). USNM 548889. Sample S26 (p. 258).
3. *Coccodiscus* aff. *C. lamarckii* Haeckel. USNM 548892. Sample S463. (p. 258).
4. *Podocyrtis* aff. *P. argus* Ehrenberg. USNM 548887. Sample S26 (p. 260).
5. *Lithochytris* aff. *L. cheopsis* Clark and Campbell. USNM 548893. Sample S463 (p. 261).
6. *Calocyclas turris* Ehrenberg. USNM 548886. Sample S26 (p. 261).
7. *?Clathrocyclas* aff. *C. universa* Clark and Campbell. USNM 548890. Sample S26 (p. 261).
8. *?Eusyringium* aff. *E. fistuligerum* (Ehrenberg). USNM 548891. Sample S463 (p. 261).

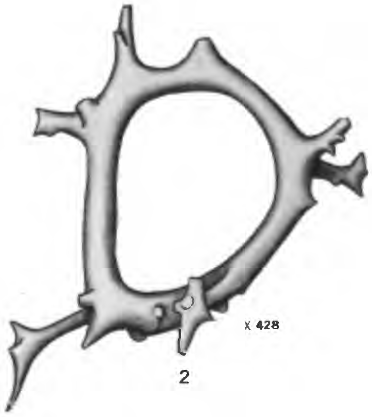


EOCENE RADIOLARIA



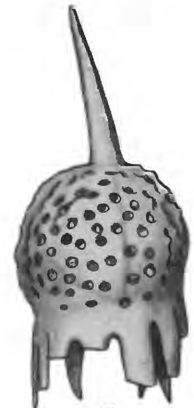
1

X 237



X 428

2



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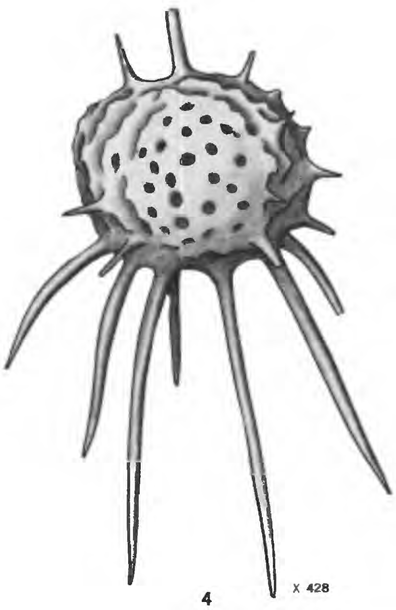
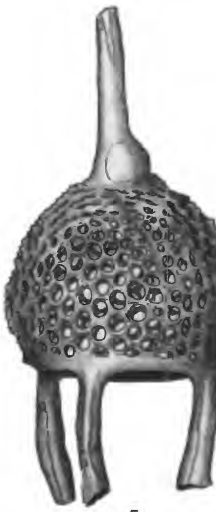


4 X 428

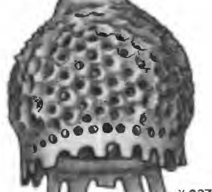


X 237

5

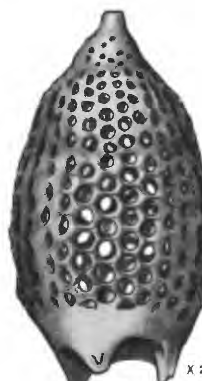
X 428

6



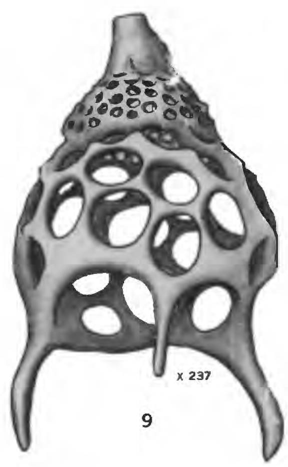
X 237

7



X 237

8



X 237

9

EOCENE RADIOLARIA

PLATE 63

FIGURE 1. *Trigonactura* sp. USNM 548896. Sample S354 (p. 258).
2. *Semantis spinescens* (Ehrenberg). USNM 548899. Sample S354 (p. 259).
3. *Petalospyris platyacantha* Ehrenberg?. USNM 548898. Sample S354. Lateral view. The primary ring is seen through the shell wall (p. 259).
4. *Ceratospyris* aff. *C. echinus* Ehrenberg. USNM 548902. Sample S354 (p. 259).
5. *Lychnocanium* sp. USNM 548900. Sample S354 (p. 259).
6. *Sethamphora mongolfieri* (Ehrenberg). USNM 548894. Sample S353 (p. 260).
7. *Anthocyrtium hispidum* (Ehrenberg)?. USNM 548901. Sample S354 (p. 260).
8. *Podocyrtis* aff. *P. argus* Ehrenberg. USNM 548895. Sample S354 (p. 260).
9. *Podocyrtis triacantha* Ehrenberg. USNM 548897. Sample S354 (p. 260).

Smaller Foraminifera

By RUTH TODD

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-H

Five hundred and forty-one species (thirty-four new), ranging in age from Eocene to Recent, are recorded and most of them illustrated

388273—57——13

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ILLUSTRATIONS

[Plates 64–93 follow index]

TABLES

CHART

GEOLOGY OF SAIPAN, MARIANA ISLANDS

SMALLER FORAMINIFERA

By Ruth Todd

ABSTRACT

The planktonic species of smaller Foraminifera (comprising about 60 percent of the specimens) of the upper Eocene Hagman formation indicate correlation with faunas of similar facies in the upper Eocene (Jackson equivalent) of Mexico, gulf coast of the United States, and West Indian region. The general composition of the rich benthonic population of the Hagman formation (about 130 species), under currently conventional interpretations, would appear to indicate deposition probably between one hundred and several hundred fathoms. About 20 percent of the benthonic population consists of species known from (but not restricted to) the West Indian region and the gulf coast of the United States. A few other species are known from Central Europe and New Zealand. Most of the species are cosmopolitan, new, or unidentifiable.

The upper Eocene Densinyama formation in one part shows no distinction in correlation and ecologic interpretation from the Hagman, but in another part appears to have been deposited under much shallower conditions.

The upper Eocene Matansa limestone yields a meager fauna with a negligible planktonic element. The smaller Foraminifera indicate correlation with the Jackson equivalent of the United States, as do those of the other Eocene formations. The general composition of the population indicates deposition in shallow water.

The Fina-sisu formation is referred to the upper Oligocene. Its correlation with the *Globigerinatella insueta* zone of the Cipero formation of Trinidad is based chiefly on four stratigraphically restricted planktonic species. About 25 percent of the species and about 95 percent of the specimens belong to planktonic genera, and most of the benthonic species belong to genera whose Recent representatives are characteristically found in water of several hundred fathoms. This faunal composition indicates deposition of the Fina-sisu formation in deep water.

The faunas occurring in the lower Miocene Tagpochau limestone fall into two major divisions: that of the Donni sandstone member and that of the other facies of the Tagpochau. The Donni sandstone contains a rich fauna of 95 species. Of these, 25 species (about 75 percent of the total number of specimens) are planktonic, and those remaining are benthonic specimens of typical deep-water species. Other facies of the Tagpochau limestone—transitional, tuffaceous, marly, and inequigranular—contain sparser faunas that are closely related to each other and that, taken as a whole, differ from the Donni fauna in lacking a large planktonic element and in the shallow water rather than deep-water affinities of the benthonic element.

The smaller Foraminifera evidence for correlation of these lower Miocene faunas is based chiefly on the planktonic species *Orbulina universa*, *O. suturalis*, and *Globorotalia menardii*, as they are known to appear and disappear within a sequence of continuously deposited open-sea facies in the Caribbean region. Smaller Foraminifera thus confirm the age determined by field relations and larger Foraminifera.

The Recent fauna from the shallow lagoon on the northwest coast of Saipan and beaches on the northeast coast is rich (containing about 200 species) and similar to other tropical Pacific shallow-water faunas. *Baculogypsina* and *Calcarina* occur together around Saipan, the former somewhat predominating. These two genera and *Marginopora* constitute the bulk of the Recent fauna. Small specimens of planktonic species are present in the lagoon and beach fauna in negligible amounts.

Most of the fossils are preserved as original tests, but in the upper Eocene Hagman formation certain samples contain only internal casts made of the zeolite mineral heulandite.

INTRODUCTION

Smaller Foraminifera have been found on Saipan in three formations of the upper Eocene, one of the upper Oligocene, and one of the lower Miocene and as Recent specimens on the beaches and in the shallow-water sediments surrounding Saipan. The 47 collections of fossils were made by P. E. Cloud, Jr., R. G. Schmidt, and H. W. Burke; and the 60 collections of Recent material, by Cloud. The sedimentary and ecologic associations of this material are separately described by its collectors in other chapters of Professional Paper 280.

A total of 541 species and varieties, many unidentified beyond genus, have been recognized. The richest and most diversified fauna is that of the Recent in which 200 species were separated.

The Eocene yields the richest fossil fauna: 172 species. In the Oligocene 61 species were found; and in the Miocene, 161. There are 53 instances of species occurring in more than one epoch.

In most instances the particular stratigraphic assignment of the sediments was originally based on evidence other than smaller Foraminifera, as summarized in the chapter on General Geology (Cloud and others, 1956), wherein complete stratigraphic detail is given. The strata referred to the upper Oligocene, however, have so far yielded microfossils only and are dated exclusively on the basis of their unusual assemblage of smaller Foraminifera (Todd and others, 1954).

I am indebted for assistance received from many colleagues, chief among whom are H. M. Bolli, Paul Bronnimann, T. F. Grimsdale, R. M. Kleinpell, L. W. LeRoy, Francis Parker, and R. M. Stainforth. The helpful advice and suggestions received from them and others is gratefully acknowledged. I am further indebted to Doris Low, Lynn Glover III, and Rita J. Post for invaluable assistance in the preparation of the fossil material for study and tabulation of the results.

ANALYSES OF FAUNAS

EOCENE

Smaller Foraminifera were found in the Hagman and Densinyama formations and the Matansa limestone. They are abundant both as to species and individuals at three localities in the Hagman and one in the conglomerate-sandstone facies of the Densinyama. At the other localities in the Hagman (see table 1), smaller Foraminifera are rare except for abundant occurrences of a very few of the planktonic species. At the other localities in the Densinyama and in the Matansa limestone, smaller Foraminifera represent a shallower water ecologic province with fewer species, most of which occur in considerable abundance.

In table 1 the smaller Foraminifera of the three formations—Hagman, Densinyama, and Matansa—are combined in one systematic sequence, a total of 172 species and varieties. Of these, only about 40 percent are specifically identifiable with previously known species; about 8 percent are described as new species; and about 52 percent are not specifically identifiable or are questionably referred or compared to known species.

TABLE 1.—*Distribution of smaller Foraminifera in the Eocene of Saipan*

	Hagman formation										Densinyama formation							Matansa limestone			
	Conglomerate-sandstone facies										Conglomerate-sandstone facies				Limestone-conglomerate facies			Transitional facies			
	S273	S344	S346	S348	S361a	S365	S385	S420	S597	S598	S26	S212	S213	S215	S194	S209	S219	S202	S248	S253	S283
Rhizamminidae																					
Rhizammina sp. (pl. 64, fig. 1)			×			×	×				×	×									
Saccamminidae																					
Proteonina? sp.								×													
Technitella archaeonitida Stainforth and Stevenson (pl. 64, fig. 2)			×				×				×										
Ammodiscidae																					
Ammodiscus? sp.							×														
Lituolidae																					
Haplophragmoides spp.								×	×												
Textulariidae																					
Spiroplectammina mississippiensis (Cushman) (pl. 64, fig. 3)																				×	
Textularia recta Cushman (pl. 64, fig. 6)																				×	
sp. A (pl. 64, fig. 4)							×														
sp. B (pl. 64, fig. 5)															×					×	
Verneuilinidae																					
Gaudryina sp. A (pl. 64, fig. 8)															×						
(*Siphogaudryina*) *rugulosa* Cushman (pl. 64, fig. 7)															×						
Pseudoclavulina sp. (pl. 64, fig. 9)	×					×	×				×										
Clavulinoides marielinus Cushman and Bermudez?							×														
szaboi (Hantken) juv.											×										
sp. A (pl. 64, fig. 10)						×															
Valvulinidae																					
Valvulina? sp.																				×	
Eggerella? sp. (pl. 64, fig. 11)																				×	
Dorothia compacta Todd, n. sp. (pl. 64, figs 15, 16)	×						×	×			×										
Karreriella sp. (pl. 64, fig. 12)											×										
Tritaxilina sp. (pl. 64, fig. 13)								×			×										
Liebusella sp. (pl. 64, fig. 14)							×														
Miliolidae																					
Triloculina fusa Todd and Post					×															×	
Massilina placida Todd and Post (pl. 64, fig. 17)										×			×		×						
Spiroloculina sp. (pl. 64, fig. 19)											×										
Pyrgo sp. A (pl. 64, fig. 18)					×						×	×	×	×					×		
Undifferentiated miliolids		×	×	×	×	×	×		×	×		×	×	×	×	×				×	
Lagenidae																					
Robulus alato-limbatus (Gümbel) (pl. 64, fig. 24)	×						×	×			×	×	×	×	×		×		×	×	
arcuato-striatus (Hantken)		×												×							
limbosus (Reuss)?											×		×							×	
texanus (Cushman and Applin) (pl. 64, fig. 20)											×			×	×					×	
sp. A (pl. 64, fig. 25)				×		×	×	×							×						
sp. B (pl. 64, fig. 21)													×								

TABLE 1.—*Distribution of smaller Foraminifera in the Eocene of Saipan*—Continued

	Hagman formation										Densinyama formation							Matansa limestone			
	Conglomerate-sandstone facies										Conglomerate-sandstone facies				Limestone-conglomerate facies			Transitional facies			
	S273	S344	S346	S348	S361a	S365	S385	S420	S597	S598	S26	S212	S213	S215	S194	S209	S219	S202	S248	S253	S283
Lagenidae—Continued																					
Astacolus cf. *A. fragarius* (Gümbel) (pl. 64, fig. 22)							×				×										
sp. A (pl. 64, fig. 23)		×				×	×	×													
Marginulina nuttalli Todd and Kniker (pl. 65, fig. 2)								×			×				×						
Vaginulina cf. *V. mexicana* Nuttall (pl. 65, fig. 1)								×			×	×	×	×						×	
Dentalina communis D'Orbigny (pl. 65, fig. 4)						×															
consobrina D'Orbigny (pl. 65, fig. 9–11)			×	×	×		×	×			×										
cooperensis Cushman (pl. 65, fig. 3)							×	×			×		×	×	×					×	
emaciata Reuss (pl. 65, fig. 12)						×	×				×										
cf. *D. halkyardi* Cushman (pl. 65, fig. 13)						×	×				×										
jacksonensis (Cushman and Applin) (pl. 65, figs. 5–8)								×			×	×	×							×	
obliquestriata Reuss (pl. 65, figs. 17, 18)							×	×			×										
soluta Reuss (pl. 65, fig. 14)								×			×										
Nodosaria longiscata D'Orbigny (pl. 65, figs. 15, 16)								×			×										
Undifferentiated *Dentalina, Nodosaria,* and other calcareous uniserial genera	×	×	×	×	×	×	×	×			×									×	
Lingulina sp. (pl. 65, fig. 19)			×																		
Lagena acuticosta D'Orbigny							×														
Polymorphinidae																					
Globulina? sp. (pl. 65, fig. 20)	×		×																		
Glandulina sp. A (pl. 65, fig. 22)							×														
sp. B (pl. 65, fig. 23)	×																				
Ramulina sp. A (pl. 65, fig. 21)							×														
Nonionidae																					
Nonion cf. *N. graniferum* (Terquem) (pl. 65, fig. 25)											×										
micrum Cole (pl. 65, fig. 26)	×	×					×				×										
planatum Cushman and Thomas (pl. 65, fig. 28)		×	×		×		×	×			×										
rusticum Todd, n. sp. (pl. 65, fig. 24)	×	×		×		×	×				×										
Nonionella jacksonensis Cushman var. *compressa* Cushman and Todd (pl. 65, fig. 29)	×						×				×										
Heterohelicidae																					
Bolivinopsis sp. (pl. 65, fig. 27)								×													
Gümbelina tenuis Todd, n. sp. (pl. 65, fig. 31)	×	×		×		×	×	×		×	×										
Bolivinella sp. A (pl. 65, fig. 30)																				×	
Amphimorphina haueriana Neugeboren (pl. 65, fig. 33)								×													
Nodogenerina rohri Cushman and Stainforth (pl. 65, fig. 32)								×													
Buliminidae																					
Buliminella sp. (pl. 66, fig. 1)								×													
Robertina sp. (pl. 66, fig. 2)					×																
Pseudobulimina sp. (pl. 66, fig. 3)	×		×																		
Bulimina pupoides D'Orbigny (pl. 66, figs. 5, 6)		×	×		×				×		×										
semicostata Nuttall (pl. 66, fig. 7)	×			×		×	×	×			×										
tuxpamensis Cole (pl. 66, fig. 4)						×					×			×							
Fissurina spp							×				×										
Oolina geometrica Todd, n. sp. (pl. 66, fig. 8)								×													
Virgulina cf. *V. cylindrica* Cushman and Bermudez											×										
sp. A (pl. 66, fig. 9)							×														
? sp. B (pl. 66, fig. 10)			×				×				×										
Bolivina arta Macfadyen (pl. 66, fig. 18)		×								×	×										
byramensis Cushman (pl. 66, fig. 11)							×	×			×										
carinata Terquem (pl. 66, fig. 12)						×	×	×			×										
costifera Cushman (pl. 66, fig. 16)							×				×										
cf. *B. gardnerae* Cushman var. *lineata* Cushman and Cederstrom								×			×									×	
jacksonensis Cushman and Applin (pl. 66, fig. 17)							×	×													
marielina Cushman and Bermudez											×										
subrhomboidalis Todd, n. sp. (pl. 66, figs. 13–15)	×	×		×		×	×	×		×	×									?	
sp. A (pl. 66, fig. 19)								×													
sp. B (pl. 66, fig. 20)	×							×													
Loxostomum latum Todd, n. sp. (pl. 66, fig. 21)		×				×	×	×		×	×										
vescum Todd, n. sp. (pl. 66, fig. 22)		×					×														
Reussella exilis Todd, n. sp. (pl. 66, fig. 29–31)	×			×		×	×			×					×						
cf. *R. subrotundata* (Cushman and Thomas) (pl. 66, fig. 28)								×													
Uvigerina spp						×		×													
Angulogerina cooperensis Cushman (pl. 66, figs. 25, 26)		×					×	×			×										
rugoplicata Cushman (pl. 66, fig. 24)		×					×	×			×										
vicksburgensis Cushman (pl. 66, fig. 27)							×	×			×										
Siphogenerina cf. *S. seriata* (Cushman and Jarvis) (pl. 66, fig. 23)								×													

TABLE 1.—*Distribution of smaller Foraminifera in the Eocene of Saipan*—Continued

	Hagman formation										Densinyama formation							Matansa limestone			
	Conglomerate-sandstone facies										Conglomerate-sandstone facies				Limestone-conglomerate facies			Transitional facies			
	S273	S344	S346	S348	S361a	S365	S385	S420	S597	S598	S26	S212	S213	S215	S194	S209	S219	S202	S248	S253	S283
Buliminidae—Continued																					
Siphonodosaria atlantisae var. *hispidula* (Cushman) (pl. 67, fig. 3)											X										
cocoaensis (Cushman) (pl. 67, figs. 1, 2)						X	X	X		X	X				X						
curvatura var. *spinea* (Cushman) (pl. 67, fig. 5)								X			X										
cf. *S. matanzana* (Palmer and Bermudez) (pl. 67, fig. 7)							X	X			X										
nuttalli var. *gracillima* (Cushman and Jarvis) (pl. 67, fig. 4)							X	X			X										
sp. (pl. 67, fig. 6)								X			X										
Ellipsoidinidae																					
Pleurostomella alternans Schwager (pl. 67, figs. 12, 13)							X				X										
brevis Schwager (pl. 67, fig. 10)	X						X				X										
cubensis Cushman and Bermudez (pl. 67, figs. 8, 9)							X	X													
sp. A (pl. 67, fig. 11)											X										
Ellipsopleurostomella sp. (pl. 67, fig. 16)							X	X			X										
Ellipsoglandulina labiata (Schwager) (pl. 67, fig. 15)	X						X				X										
Ellipsonodosaria sp. (pl. 67, fig. 14)							X														
Rotaliidae																					
Discorbis celsa Todd, n. sp. (pl. 67, fig. 20)		X											X	X	X					X	
sp. A (pl. 67, fig. 17)										X	X			X							
sp. B (pl. 68, fig. 1)							X									X					
sp. C (pl. 67, fig. 18)					X					X				X							
? sp. D (pl. 67, fig. 19)					X						X								X		
Heminwayina? sp. (pl. 68, fig. 2)	X						X														
Lamarckina sp. (pl. 68, fig. 7)											X										
Heronallenia? sp											X										
Valvulineria pulchra Todd, n. sp. (pl. 68, fig. 5)			X				X	X			X										
? *scita* Todd, n. sp. (pl. 68, fig. 4)		X		X			X														
scrobiculata (Schwager) (pl. 68, fig. 3)	X	X		X			X	X		X	X			X							
texana Cushman and Ellisor (pl. 68, fig. 6)	X	X					X	X			X										
Eponides umbonatus (Reuss) (pl. 68, fig. 9)						X		X			X										
sp. A (pl. 68, fig. 10)								X													
sp. B (pl. 68, fig. 8)																				X	
Osangularia mexicana (Cole) (pl. 69, fig. 1)						X	X	X			X										
Streblus cf. *S. mexicanus* (Nuttall) (pl. 68, fig. 12)													X	X	X	X		X			X
Höglundina eocenica (Cushman and M. A. Hanna) (pl. 68, fig. 14)	X		X	X							X		X								
Siphonina sp. A (pl. 68, fig. 13)							X														
Baggina sp. (pl. 68, fig. 11)		X									X										
Amphisteginidae																					
Asterigerina cf. *A. bracteata* Cushman (pl. 69, fig. 2)						X	X	X		X											
fimbriata Todd, n. sp. (pl. 69, fig. 3)						X	X				X		X	X						X	
sp. A (pl. 69, fig. 4)							X													X	X
sp. B (pl. 69, fig. 6)																	X				
sp. C (pl. 69, fig. 5)					X						X						X				
sp. D (pl. 69, fig. 7)																				X	
Amphistegina cf. *A. madagascariensis* D'Orbigny (pl. 69, figs. 8–10)	X	X				X	X	X			X	X	X	X	X	X	X			X	
Cassidulinidae																					
Alabamina conica Todd, n. sp. (pl. 69, fig. 11)						X	X	X			X										
Epistominella sp. A (pl. 69, fig. 13)							X				X			X						X	
? sp. B (pl. 69, fig. 14)	X									X											
Cassidulina globosa Hantken (pl. 69, fig. 12)						X	X	X			X										
Chilostomellidae																					
Chilostomella cyclostoma Rzehak (pl. 70, figs. 1, 2)	X		X				X	X	X		X										
Pullenia bulloides (D'Orbigny) (pl. 70, fig. 4)							X														
quadriloba Reuss (pl. 70, fig. 3)							X	X													
Globigerinidae																					
Globigerina bakeri Cole (pl. 70, figs. 8, 9)	X	X	X	X	X	X	X	X		X	X										
pera Todd, n. sp. (pl. 70, figs. 10, 11)	X		X			X	X	X			X										
Globigerinoides index Finlay (pl. 70, figs. 5–7)	X		X	X	X	X	X	X	X		X			X							
cf. *G. rubra* (D'Orbigny) (pl. 70, fig. 12)							X			X	X										
Globigerinita? sp. A (pl. 70, fig. 14)							X			X	X										
? sp. B (pl. 70, fig. 15)							X														
Hantkeninidae																					
Hantkenina bermudezi Thalmann (pl. 70, fig. 13)	X		X	X	X	X	X	X	X		X										
Globorotaliidae																					
Globorotalia centralis Cushman and Bermudez (pl. 71, figs. 1, 3)	X		X	X	X	X	X	X	X	X	X						X				
cerro-azulensis (Cole) (pl. 71, fig. 4)						X	X	X												X	
spinulosa Cushman (pl. 71, fig. 2)							X														
Cycloloculina sp. (pl. 71, fig. 5)							X				X										

TABLE 1.—*Distribution of smaller Foraminifera in the Eocene of Saipan*—Continued

	Hagman formation										Densinyama formation							Matansa limestone			
	Conglomerate-sandstone facies										Conglomerate-sandstone facies				Limestone-conglomerate facies			Transitional facies			
	S273	S344	S346	S348	S361a	S365	S385	S420	S597	S598	S26	S212	S213	S215	S194	S209	S219	S202	S248	S253	S283
Anomalinidae																					
Anomolina alazanensis Nuttall var. *spissiformis* Cushman and Stainforth (pl. 71, fig. 6)						X	X	X			X										
sp. (pl. 71, fig. 7)											X										
Planulina sp. A (pl. 71, fig. 8)							X						X	X	X					X	
Anomalinella? sp											X										
Cibicides cocoaensis (Cushman) (pl. 71, fig. 9)								X													
lobatulus (Walker and Jacob) (pl. 71, figs. 10–12)	X					X	X	X			X			X							
perlucidus Nuttall (pl. 71, fig. 13)							X							X						X	
pseudoungerianus (Cushman) (pl. 71, fig. 14)								X						X							
cf. *C. trinitatensis* (Nuttall) (pl. 72, fig. 2)														?	X					X	
tuxpamensis Cole (pl. 72, fig. 1)				X		X	X	X			X			X						X	
vortex Dorreen (pl. 72, fig. 3)	X	X		X	X	X	X	X		X	X			X		X					
sp. A (pl. 72, fig. 4)						X	X				X										
sp. B (pl. 72, fig. 5)											X										
sp. C (pl. 72, fig. 6)								X			X										
? sp. D (pl. 72, fig. 7)								X			X										
Cibicidina cf. *C. mississippiensis* (Cushman) (pl. 72, fig. 10)		X				X	X	X		X	X			X							
sp. A (pl. 72, fig. 8)	?							X													
? sp. B (pl. 72, fig. 9)						X	X	X			X										
Cibicidella sp. (pl. 72, fig. 11)											X										
Planorbulinidae																					
Planorbulina mediterranensis D'Orbigny (pl. 72, fig. 12)							X	X			X										
Gypsina globula (Reuss) (pl. 72, fig. 13)														X	X						
Homotremidae																					
Homotrema sp																				X	

HAGMAN FORMATION

In the present study the Hagman formation is represented by 10 samples. Three of them, USGS f21122, f21125, and f21126 (S365, S385, and S420), are rich in smaller Foraminifera. A total of about 140 species were found in the Hagman.

CORRELATION

The most useful species for long distance correlation are the planktonic ones, and among the planktonic genera, *Hantkenina* occupies a unique place. The worldwide occurrences of the genus *Hantkenina* seem to be restricted to the Eocene, with the only later records in the lowermost Oligocene open to doubt as to their autochthonous nature or their correct age assignment (Thalmann, 1942b, p. 817–818). A reported use of the genus by W. Mohler as a guide fossil for Tertiary *cd* (Van Bemmelen, 1949, p. 90, text fig. 26) seems doubtful in view of the lack of confirmed post-Eocene occurrences elsewhere.

The genus has been subdivided into 4 morphologic groups (Thalmann, 1942a, p. 7) for which 4 subgenera (Thalmann, 1942b, p. 811–812) and ultimately a fifth (Bronnimann, 1950a, p. 399) have been proposed. This grouping is based on evolutionary trends, such as the trend from loosely coiled compressed tests to closely coiled inflated ones. In this morphologic classification, the species present on Saipan, *H. bermudezi* Thalmann, falls within the group believed to characterize the upper part of the Eocene (Bartonian equivalent) (Thalmann, 1942b, p. 812, table 2 on p. 817).

The genus *Hantkenina* occurs in the upper Eocene of Australia (Parr, 1947), and a zone was briefly described as the *Hantkenina alabamensis* zone by Glaessner (1951, p. 275–276, 280) without a complete description of the accompanying fauna. Though the Australian species of *Hantkenina* does not appear to be identical with the Saipan species, one of the two accompanying species mentioned, *Nonion micrum* Cole, does occur on Saipan. Further study may disclose the specific relationship of the *Hantkenina*-bearing beds of Saipan to this zone in Australia.

Of the important planktonic species, the most significant ones present in the Hagman and Densinyama formations appear in the following table, together with the stratigraphically significant benthonic species. In each instance the commonest, but not necessarily exclusive, stratigraphic and geographic occurrences of each species outside of Saipan also appear in the table.

388273—57——14

Significant planktonic and benthonic species in the Hagman and Densinyama formations

Species	Age	Occurrence
Planktonic Species		
Globigerina bakeri Cole (pl. 70, figs. 8, 9)	Eocene, Guayabal formation	Mexico.
Globigerinoides index Finlay (pl. 70, figs. 5–7)	Middle to upper Eocene (Bortonian to Kaiatan)	New Zealand.
Globorotalia centralis Cushman and Bermudez (pl. 71, figs. 1, 3)	Eocene, Jackson and upper Claiborne groups	Cuba, Louisiana, Mississippi, Dominican Republic.
cerro-azulensis (Cole) (pl. 71, fig. 4)	Eocene, Jackson group	Mexico, Cuba.
spinulosa Cushman (pl. 71, fig. 2)	Eocene and Oligocene	Mexico.
Hantkenina bermudezi Thalmann (pl. 70, fig. 13)	Upper Eocene	Cuba, Trinidad, Barbados.
Benthonic Species		
Angulogerina cooperensis Cushman (pl. 66, figs. 25, 26)	Upper Eocene	Southeast United States.
rugoplicata Cushman (pl. 66, fig. 24)	Lower Oligocene	Mississippi.
vicksburgensis Cushman (pl. 66, fig. 27)	Lower Oligocene	Mississippi.
Anomalina alazanensis Nuttall var. *spissiformis* Cushman and Stainforth (pl. 71, fig. 6).	Eocene, Oligocene	Trinidad and Ecuador.
Bolivina byramensis Cushman (pl. 66, fig. 11)	Lower Oligocene	Mississippi.
carinata Terquem (pl. 66, fig. 12)	Eocene	Paris Basin.
jacksonensis Cushman and Applin (pl. 66, fig. 17)	Eocene, Oligocene	North and South America.
Bulimina semicostata Nuttall (pl. 66, fig. 7)	Eocene	Mexico and Cuba.
tuxpamensis Cole (pl. 66, fig. 4)	Eocene Oligocene Miocene	Mexico, Cuba, Germany, Italy. Trinidad. Spain.
Chilostomella cyclostoma Rzehak (pl. 70, figs. 1, 2)	Oligocene	Austria.
Cibicides cocoaensis (Cushman) (pl. 71, fig. 9)	Eocene	Mississippi, Alabama.
perlucidus Nuttall (pl. 71, fig. 13)	Eocene, Oligocene	Caribbean.
tuxpamensis Cole (pl. 72, fig. 1)	Eocene, lower Oligocene	Caribbean.
vortex Dorreen (pl. 72, fig. 3)	Upper Eocene	New Zealand.
Dentalina cooperensis Cushman (pl. 65, fig. 3)	Upper Eocene, Oligocene	United States.
jacksonensis (Cushman and Applin) (pl. 65, figs. 5–8)	Upper Eocene	United States.
obliquestriata Reuss (pl. 65, figs. 17, 18)	Oligocene	Hermsdorf, Germany.
Höglundina eocenica (Cushman and M. A. Hanna) (pl. 68, fig. 14)	Eocene	West coast and Southeast United States.
Marginulina nuttalli Todd and Kniker (pl. 65, fig 2)	Eocene Oligocene	Chile. Mexico.
Nodogenerina rohri Cushman and Stainforth (pl. 65, fig. 32)	Eocene-Oligocene Eocene	Trinidad. Ecuador.
Nonion micrum Cole (pl. 65, fig. 26)	Middle and upper Eocene	Mexico, United States, Trinidad.
planatum Cushman and Thomas (pl. 65, fig. 28)	Middle Eocene	United States.
Nonionella jacksonensis Cushman var. *compressa* Cushman and Todd (pl. 65, fig. 29).	Upper Eocene	United States.
Osangularia mexicana (Cole) (pl. 69, fig. 1)	Eocene	Mexico, Trinidad.
Robulus alato-limbatus (Gümbel) (pl. 64, fig. 24)	Eocene, Oligocene	Europe and North and South America.
Siphonodosaria cocoaensis (Cushman) (pl. 67, figs. 1, 2)	Upper Eocene	Southeast United States.
Technitella archaeonitida Stainforth and Stevenson (pl. 64, fig. 2)	Lower Oligocene	Ecuador.
Valvulineria scrobiculata (Schwager) (pl. 68, fig. 3)	Eocene	Egypt and United States.
texana Cushman and Ellisor (pl. 68, fig. 6)	Eocene	Texas.

Of the above species, *Bolivina jacksonensis*, *Cibicides cocoaensis*, and *Nodogenerina rohri* were found only in the Hagman formation.

In summary, the smaller Foraminifera of the Hagman and Densinyama formations indicate correlation with the upper Eocene.

ECOLOGIC INTERPRETATION

Quantitatively, the Hagman assemblage of smaller Foraminifera is chiefly composed of planktonic specimens of only 10 species. Of the benthonic forms, species of Lagenidae, Buliminidae, Rotaliidae, Chilostomellidae, and Anomalinidae are most abundant.

If the benthonic species had the same depth ranges as those reported for Recent representatives of the same families and genera, deposition of the Hagman at depths not much less than 100 fathoms would be indicated. However, the benthonic element in the Hagman is relatively rich in species, many of which are indeterminate as to depth significance. In studies of Recent *Globigerina* oozes from around the northern Marshall Islands, those from depths greater than several hundred fathoms do not normally contain as rich and diversified a benthonic element as do *Globigerina* oozes from shallower depths. Hence, I would further interpret the Hagman as having been deposited at depths not exceeding several hundred fathoms. The absence or rarity of species in families and genera known to be from shallow-water habitats, such as Miliolidae, Peneroplidae, Calcarinidae, Amphisteginidae, and *Discorbis* indicates that the parts of the Hagman from which these collections came were not formed in truly shallow waters. Water of moderate depth is indicated, perhaps 100 to several hundred fathoms but possibly shallower.

DENSINYAMA FORMATION

Two facies of the Densinyama formation, the conglomerate-sandstone facies and the impure limestone-calcareous conglomerate facies, yield smaller Foraminifera.

About 117 species were found in the Densinyama formation, as represented by 4 samples from the conglomerate-sandstone facies and 3 samples from the impure limestone-calcareous conglomerate facies. Of these, about 109 species occur in the former facies and 23 in the latter facies. Fifteen species (about 13 percent) occur in both facies.

The conglomerate-sandstone facies, represented by four samples, contains abundant small Foraminifera. One of these samples from USGS f21042 (S26), contains a fauna that is indistinguishable from that of the Hagman formation. Planktonic species constitute the great preponderance of specimens found in S26, although only a small proportion of the species. The remaining three samples are much sparser and differ from S26 in an almost complete lack of planktonic elements. If one should leave S26 from the conglomerate-sandstone facies out of consideration, the two facies of the Densinyama formation would differ only very slightly.

CORRELATION

No separate tabulation is given for the Densinyama species as in each instance, except those previously noted, the species listed for the Hagman occur also in the Densinyama as represented at USGS f21042 (S26).

No age distinction between Hagman and Densinyama can be based on the included smaller Foraminifera.

ECOLOGIC INTERPRETATION

Statements made regarding the ecology of the Hagman formation are also applicable to the conglomerate-sandstone facies of the Densinyama formation as represented by the one rich sample, S26, from that facies.

The other 3 samples from that facies and the 3 samples from the impure limestone-calcareous conglomerate facies represent deposition under very different ecologic conditions. Quantitatively, the meager fauna of these 6 samples, 3 from each facies, consists largely of Amphisteginidae, Rotaliidae, Lagenidae, Miliolidae, and Anomalinidae and is distinguished by an almost total lack of planktonic specimens. The benthonic population, a mixture of shallow-water and deep-water forms, with the shallow-water ones predominating, suggests deposition at depths of probably not much less than 30 fathoms nor much more than 100 fathoms, probably toward the shallower end of this range. The reasons for the scarcity of a planktonic element are obscure.

MATANSA LIMESTONE

In the present study, the Matansa formation is represented by 4 samples in only 1 of which, USGS f21081 (S253), are smaller Foramininifera found commonly.

A total of about 30 species were found in the Matansa; and of these, only about one-fourth are identifiable with already known species. One new species is described from the Matansa. The remaining three-fourths of the species are too rare or poorly preserved for precise identification.

CORRELATION

The following table contains the species most significant for age and correlation, with their major, but not necessarily restricted, stratigraphic and geographic occurrences.

Significant species in the Matansa limestone

Species	Age	Occurrence
Dentalina cooperensis Cushman (pl. 65, fig. 3)	Upper Eocene, Oligocene	United States.
jacksonensis (Cushman and Applin) (pl. 65, figs. 5–8)	Upper Eocene	United States.
Globorotalia cerro-azulensis (Cole) (pl. 71, fig. 4)	Upper Eocene	Mexico, Cuba, United States.
Robulus texanus (Cushman and Applin) (pl. 64, fig. 20)	Upper Eocene, Oligocene	United States.
Spiroplectammina mississippiensis (Cushman) (pl. 64, fig. 3)	Upper Eocene, lower Oligocene	United States.
Textularia recta Cushman (pl. 64, fig. 6)	Upper Eocene, lower Oligocene	United States.

Of the species in the table, *Spiroplectammina mississippiensis* and *Textularia recta* are found in the Matansa limestone only. *Globorotalia cerro-azulensis* and *Spiroplectammina mississippiensis* are represented in the present collections by single specimens only.

The closest age determination of the Matansa formation that can be made on the basis of the included Foraminifera is late Eocene (Jackson equivalent).

ECOLOGIC INTERPRETATION

Quantitatively, the fauna is composed mostly of rather large rotaliform species belonging to the families Amphisteginidae and Rotaliidae, with lesser amounts of species of Lagenidae and Miliolidae. The large, heavy-walled species in the first two families mentioned, together with the miliolids, indicate relatively shallow-water conditions; but this evidence is somewhat outweighed by the presence in moderate abundance of species of Lagenidae, which are not commonly found at depths as shallow as 30 fathoms but at considerably greater depths. The Matansa fauna, in contrast to that of the Hagman formation, is distinguished by general absence of planktonic elements.

OLIGOCENE

FINA-SISU FORMATION

The probably Oligocene Fina-sisu formation contains abundant smaller Foraminifera at one locality, USGS f21133 (C85), and a few specimens at another, USGS f21134 (S662). The Oligocene age assignment is based on the evidence of the planktonic smaller Foraminifera, substantiated by the physical stratigraphy and structure (Todd and others, 1954). About 25 percent of the Fina-sisu species and probably 95 percent or more of the specimens are planktonic. Most of the remaining few benthonic specimens, classified in 45 species, belong to families and genera of known deep-water habitats.

Table 2 systematically presents the complete fauna, 61 species, of the Fina-sisu formation. Of the 61 species in the table, 41 are found on Saipan only in this formation. Of the total 61, 8 species, including 4 planktonic forms, are found in the Cipero formation, Trinidad—7 of the 8 are found on Saipan only in the Fina-sisu formation. Of the 61, 13 species, including 4 planktonic forms, are also found in the Miocene of Saipan; all but 2 of the 13 occur in the Donni sandstone. Of the 61 species 8, including 1 planktonic form, are also found in the Eocene of Saipan.

TABLE 2.—*Species from the Oligocene Fina-sisu formation at USGS f21133 (C85) and their occurrences elsewhere*

[Explanation of box heads: a, occurs also in the Miocene of Saipan; b, occurs also in the Eocene of Saipan, probably includes some reworked forms; c, not known on Saipan outside of the Oligocene; d, occurs also in the Oligocene *Globigerinatella insueta* zone of the Cipero formation, Trinidad; e, common and widespread, of little age significance; f, also known as Recent forms but not necessarily occurring around Saipan]

Fina-sisu species	Occurrences elsewhere					
	a	b	c	d	e	f
Lituolidae:						
Cyclammina sp. A			×			
Textulariidae:						
Textularia sp. A		×				
Valvulinidae:						
Karreriella chilostoma (Reuss) (pl. 73, fig. 1)			×	×	×	
Miliolidae:						
Triloculina trigonula (Lamarck)?	×				×	×
Lagenidae:						
Robulus sp. C			×			
Dentalina spirostriolata (Cushman)	×					
sp. A			×			
Nodosaria sp. A			×			
Lagenonodosaria sp. (pl. 73, fig. 2)			×			
Heterohelicidae:						
Nodogenerina? sp. A (pl. 73, fig. 8)			×			
? sp. B			×			
? sp. C			×			
Buliminidae:						
Buliminella septata Keyzer (pl. 73, fig. 3)	×					
Bulimina sp. (pl. 73, fig. 5)			×			
Fissurina formosa (Schwager) var. *comata* (Brady) (pl. 73, fig. 4)			×			×
sp. A			×			
Bolivina subrhomboidalis Todd, n. sp. (probably reworked)		×				
Reussella sp			×			
Uvigerina nitidula Schwager (pl. 73, fig. 6)			×			
Siphogenerina seriata (Cushman and Jarvis) (pl. 73, fig. 7)			×	×		
Trifarina bradyi Cushman			×	×	×	×
Ellipsoidinidae:						
Pleurostomella cf. P. *acuta* Hantken			×	×		
cf. *P. rimosa* Cushman and Bermudez (pl. 73, fig. 11)			×			
? sp. B (pl. 73, fig. 9)			×			

TABLE 2.—*Species from the Oligocene Fina-sisu formation at USGS f21133 (C85) and their occurrences elsewhere*—Continued

Fina-sisu species	Occurrences elsewhere					
	a	b	c	d	e	f
Rotaliidae:						
Gyroidina nitidula (Schwager) (pl. 73, fig. 12)	X					
Eponides kiliani (Andreae) (pl. 73, fig. 10)			X			
umbonatus (Reuss)		X			X	X
? sp. C (pl. 73, fig. 13)			X			
? sp. D			X			
Osangularia bengalensis (Schwager)	X					
Siphonina sp. B (pl. 73, fig. 14)			X			
Amphisteginidae:						
Amphistegina sp			X			
Cassidulinidae:						
Epistominella tubulifera (Heron-Allen and Earland)	X					X
Cassidulina globosa Hantken (pl. 73, fig. 15)		X				
sp. A (pl. 73, fig. 17)			X			
sp. B (pl. 73, fig. 16)			X			
sp. C (pl. 73, fig. 18)			X			
Ehrenbergina albatrossi Cushman (pl. 74, fig. 2)	X					X
Chilostomellidae:						
Pullenia bulloides (D'Orbigny)		X			X	X
? sp			X			
Sphaeroidina haueri (Czjzek) (pl. 74, fig. 3)			X			
Globigerinidae:						
Globigerina bulloides D'Orbigny	X				X	X
? grata Todd, n. sp. (pl. 74, fig. 4)			X			
pera Todd, n. sp. (probably reworked)		X				
sp. A (pl. 74, fig. 9)			X			
sp. B (pl. 74, fig. 14)			X			
Globigerinoides bispherica Todd [1] (pl. 74, figs. 7, 8)			X	X		
pseudorubra Todd, n. sp.[1] (pl. 74, fig. 10)			X			
subquadrata Bronnimann [2] (pl. 74, fig. 6)			X	X		
triloba (Reuss) (pl. 74, fig. 1)			X		X	X
Globigerinatella insueta Cushman and Stainforth [1] (pl. 74, figs. 12, 13)			X	X		
Orbulina suturalis Bronnimann (pl. 74, fig. 11)	X			X		
Globorotaliidae:						
Globoquadrina altispira (Cushman and Jarvis) (pl. 74, fig. 5)	X					
dehiscens (Chapman, Parr, and Collins)	X					
sp			X			
Anomalinidae:						
Planulina sp. B			X			
Anomalinella rostrata (Brady)	X					X
Cibicides pseudoungerianus (Cushman)	X	X			X	X
sp. E (pl. 74, fig. 15)			X			
sp. F			X			
Cibicidina sp. A		X				

[1] Also from loc. S662, Fina-sisu formation, but questionably assigned to this species.
[2] Also from loc. S662, Fina-sisu formation.

CORRELATION

EVIDENCE FROM PLANKTONIC SPECIES

The separation of planktonic from benthonic forms does not fall necessarily along family or generic lines. The planktonic features of living Foraminifera have not yet been sufficiently investigated to permit one to say categorically that any particular genus or species is or is not planktonic at any particular stage. Lacking such information, it is customarily necessary to rely on (1) resemblance to the few living species that are known to be planktonic, and (2) physical characteristics of the fossil test pointed out by Kemna (1903) as being favorable to flotation, such as: thinness of wall, inflation of chambers, sphericity of the entire test, diameter of wall perforations, and size and multiplicity of apertures.

Planktonic forms are the 14 species listed under the families Globigerinidae and Globorotaliidae in table 2, and probably the 3 additional forms listed under Chilostomellidae should be included. The interpretation of the Oligocene age of the Fina-sisu formation is based almost wholly on 4 planktonic species:

Globigerinatella insueta Cushman and Stainforth
Globigerinoides bispherica Todd
G. subquadrata Bronnimann
Orbulina suturalis Bronnimann

In addition, this interpretation is supported by negative evidence involving the absence from this globigerine facies of species that are abundantly represented in the Miocene and Eocene sediments of identical facies on Saipan.

Common Miocene planktonic species absent from the Fina-sisu formation are as follows:

Globigerinoides conglobata (Brady)
rubra (D'Orbigny)
sacculifera (Brady)
Orbulina universa (D'Orbigny)
Pulleniatina obliquiloculata (Parker and Jones)
Sphaeroidinella dehiscens (Parker and Jones)
kochi (Caudri)
seminulina (Schwager)
Globorotalia menardii (D'Orbigny)
tumida (Brady)

Common Eocene planktonic species absent from the Fina-sisu formation are as follows:

Globigerina bakeri Cole
Globigerinoides index Finlay
Globorotalia centralis Cushman and Bermudez
Hantkenina bermudezi Thalmann

The finding of *Globigerinatella insueta* Cushman and Stainforth in the Fina-sisu formation of Saipan extends the geographic distribution of this zone fossil previously recorded only from Trinidad, Barbados, Ecuador, Venezuela, and Louisiana (Bronnimann, 1950b, p. 80–81, Akers, 1955, p. 656, 658). In the Caribbean region this distinctive species is regarded by local students of the smaller Foraminifera as a marker for the lower part of the upper Oligocene (Stainforth, 1948b; Bronnimann, 1950b; Grimsdale, 1951).

In addition to *G. insueta* the two most abundant forms in the Fina-sisu, *Globigerinoides bispherica* Todd and *Globigerinoides subquadrata* Bronnimann, are also found in the *Globigerinatella insueta* zone of the upper Oligocene in Trinidad. Such presumably planktonic species provide the best kind of tie between lithic and faunal facies similar to that of the Fina-sisu.

A fourth species, *Orbulina suturalis* Bronnimann (formerly *Candorbulina*), occurring rarely in the Fina-sisu formation, first appears in the Trinidad section slightly above the top of the *G. insueta* zone. That *G. insueta* and *O. suturalis* are not contemporaneous within the globigerine sequence in Trinidad (Bronnimann, 1951, p. 131, 134) should not be regarded as proof that they cannot be contemporaneous in other regions. Moreover, this discrepancy may suggest that the material under consideration, in which the two appear to be contemporaneous, should be placed more specifically toward the upper part of the zone of the older species and the lower part of the zone of the younger species.

The middle Tertiary datum plane called the *Orbulina* surface is discussed under the section on the Miocene. It should be pointed out that in defining this surface, *Orbulina* is used in its strict sense, including only *Orbulina universa* D'Orbigny and excluding other species of *Orbulina*, such as *suturalis* and *bilobata*.

As the facies of the Fina-sisu formation in which the fossils occur is closely similar or identical with the facies of the Miocene Donni sandstone member of the Tagpochau limestone, the *Orbulina* surface presumably lies somewhere between the two. It also lies below the main body of the Tagpochau limestone in which *Orbulina universa* is also found, though more rarely.

Another planktonic foraminifer that is missing from the Fina-sisu formation but present in the Donni member is *Globorotalia menardii* (D'Orbigny), which in Trinidad occurs rarely in the uppermost part of the *Globorotalia fohsi* zone (uppermost Oligocene) and more abundantly in the *Globorotalia mayeri* and *G. menardii* zones of the lower Miocene. Thus the absence of this species from a facies in which it would be expected, like the absence of *Orbulina universa*, supports the late Oligocene age of the Fina-sisu formation.

EVIDENCE FROM BENTHONIC SPECIMENS

Little of diagnostic value as to age can be determined from the benthonic specimens present in the Fina-sisu formation.

The following benthonic species of the Fina-sisu have been recorded from Oligocene strata elsewhere:

Cibicides pseudoungerianus (Cushman)	Gulf coast of United States, Mexico, Cuba, Trinidad.
Eponides kiliani (Andreae)	Germany.
E. umbonatus (Reuss)	Washington, Mexico, Cuba, Netherlands, Venezuela, Trinidad, Italy.
Karreriella chilostoma (Reuss)	Central Europe, Trinidad, New Zealand.
Siphogenerina seriata (Cushman and Jarvis)	Trinidad.
Trifarina bradyi Cushman	Cuba, Puerto Rico, Trinidad, New Zealand.

Of the above listed species, *Eponides kiliani* and *Siphogenerina seriata* have not been recorded from strata other than Oligocene.

ECOLOGIC INTERPRETATION

Ecologically, the Fina-sisu formation is similar to the Miocene Donni sandstone. The fauna is more meager and more predominantly planktonic. In the Fina-sisu about 25 percent of the species but 95 percent or more of the specimens are planktonic, whereas in the Donni the ratio is about 25 percent of the species and about 75 percent of the specimens.

The benthonic specimens of the Fina-sisu formation are more specific in their ecologic than in their stratigraphic implications. The probable depth of deposition for the Fina-sisu formation is interpreted from the following evidence: (a) Great predominance of planktonic specimens over benthonic specimens; (b) occurrence records in present oceans of benthonic species common to Oligocene and Recent; (c) composition (expressed in families and genera) of the benthonic population; and (d) average size and shape of specimens of *Amphistegina*, a genus found living both in shallow and deep water.

Predominance of planktonic over benthonic specimens.—The mere presence of planktonic specimens does not, in itself, indicate deposition at great depths (Ladd, 1936). However, the presence of planktonic specimens in greatly predominating quantities, such as 75 percent or more, is believed to be evidence for deposition in the open sea, away from the influence of masking by near-shore benthonic elements.

The instance recorded from Trinidad and cited (Ladd, 1936, p. 301; Crickmay, Ladd, and Hoffmeister, 1941, p. 95) as an example of beach sands composed "almost exclusively [of] *Globigerina* shells" (Twenhofel, 1932, p. 165) fails as evidence for shallow-water accumulation of *Globigerina* oozes as it is a secondary occurrence of the shells washed out from the outcropping *Globigerina*-rich Cipero marls (Bronnimann, 1949, p. 27; Bolli, written communication, Nov. 2, 1953). No verified recorded occurrence of *Globigerina* oozes on beaches or at shallow depths are known to me.

A unique transitory beach occurrence of the planktonic stage of the attached shallow-water genus currently known as *Tretomphalus* was described by E. H. Matthews (Earland, 1902, p. 309–310) and suggests that other planktonic genera (the globigerinids) may suddenly appear in astronomical numbers, like the flowering of diatoms. There must be serious doubt whether such sudden appearances and disappearances would result in a shallow-water *Globigerina* ooze. Nevertheless, if such a shallow-water *Globigerina* ooze should find conditions favorable for its preservation in the fossil record, the associated shallow-water benthonic specimens should render it easily distinguishable from the normal deep-water *Globigerina* oozes.

Recent occurrence records of benthonic species common to Oligocene and Recent.—Nine benthonic species found in the Oligocene are known also from Recent sediments (refer to column f in table 2 of Oligocene species). *Ehrenbergina albatrossi* Cushman was described from 966 fathoms and has not been recorded from shallower depths so far as I know. *Fissurina formosa* (Schwager) var. *comata* (Brady) was described from 1,850 fathoms and has been recorded from numerous samples mostly between 1,000 and 2,500 fathoms, with only 2 shallower records: 891 and 200 fathoms. *Eponides umbonatus* (Reuss) and *Cibicides pseudoungerianus* (Cushman) occur both from shallow (around 20 fathoms) to deep water (around 2,000 fathoms) but are more frequently found in deeper water. *Pullenia bulloides* (D'Orbigny) is a deep-water form, normally occurring at not less than several hundred fathoms. *Anomalinella rostrata* (Brady) is an inhabitant of moderate depths, recorded from 15 to 37 fathoms. *Trifarina bradyi* Cushman is found both shallow and deep, more commonly at depths of around 50 fathoms. *Epistominella tubulifera* (Heron-Allen and Earland) also occurs in shallow and deep waters but is more abundant in waters as deep as several hundred fathoms. *Triloculina trigonula* (Lamarck) is a common inhabitant of very shallow to very deep waters.

The combined evidence from the nine species discussed above is taken to indicate an environment of deep water.

Composition of the benthonic population.—The Fina-sisu formation contains families, such as Lagenidae, Ellipsoidinidae, Cassidulinidae, and Chilostomellidae, and genera, such as *Fissurina, Uvigerina, Trifarina,* and *Gyroidina,* whose living representatives are either predominantly or exclusively found in deep water. It is also marked by the rarity or absence of families, such as Miliolidae, Nonionidae, Peneroplidae, Cymbaloporidae, and Planorbulinidae, and genera, such as *Bolivina, Spirillina, Discorbis,* and *Streblus,* that would be expected in this geographic location and whose living representatives are either predominantly or exclusively found in shallow water.

Average size and shape of Amphistegina *specimens.*—The genus *Amphistegina* is a significant one upon which to base an interpretation of depth, as forms are found from the shallowest lagoon to depths at least as great as 700 or 800 fathoms (Cushman, Todd, and Post, 1954, table 4). In the northern Marshall Islands where both deep-water and shallow-water forms have been studied, two species were recognized, partly on the basis of size and shape. There the shallow-water forms are about 1.5 millimeters in diameter and have a biconical shape, whereas the deep-water forms are about 0.7 millimeter in diameter and have a compressed and more smoothly lenticular shape. Although there are other specific considerations upon which the two species are separated and gradational forms exist between the two extremes of typical deep-water forms and typical shallow-water forms, it is still possible to place some reliance on average size and shape of fossil material of this genus. The rare specimens of *Amphistegina* in the Fina-sisu formation average 0.6 millimeter in diameter and are compressed and smoothly lenticular in shape. I cannot say they are specifically identical with similar ones from deep water around the northern Marshall Islands, but their size and shape do indicate a deep-water habitat.

In the light of the above evidence, the Fina-sisu formation, or at least the facies of it from which the present fauna was obtained is believed to have been deposited at a depth of probably not less than 200 fathoms.

MIOCENE

The Miocene beds on Saipan are only slightly less rich in smaller Foraminifera than the Eocene beds.

TAGPOCHAU LIMESTONE

The Tagpochau limestone is represented by 24 samples, 13 in the Donni sandstone member, 4 in the transitional facies, 1 in the tuffaceous facies, 2 in the marly facies, and 4 in the inequigranular facies.

CORRELATION OF DONNI SANDSTONE MEMBER

The Donni sandstone member contains abundant small Foraminifera, mostly planktonic specimens. Benthonic specimens are relatively rare and most of them belong in genera and families of known deep-water habitats: *Gyroidina*, *Eponides*, Lagenidae, Ellipsoidinidae, Cassidulinidae, Chilostomellidae. A few shallow-water and indeterminate forms are present, but the typically shallow-water species that occur in the four other facies of the Tagpochau are generally absent in the Donni sandstone member.

Of the 161 species found in all the Miocene samples, 95 occur in the Donni sandstone. Seventy-seven of them are restricted to that member, leaving 18 occurring in both the Donni and the other facies of the Tagpochau. Of these 18 species over half are planktonic forms, leaving 8 benthonic species, or only about 5 percent of the Donni fauna, that are also found in the Donni and the shallower water facies of the Tagpochau. The distinctiveness of these two faunas is well displayed in the distribution chart of Miocene species, and on plates 75 to 80 illustrating the Donni and plates 81 to 84, the other facies of the Tagpochau.

TABLE 3.—*Distribution of smaller Foraminifera in the Miocene of Saipan*

	Tagpochau limestone																							
	Donni sandstone member													Transitional facies				Tuffaceous facies	Marly facies		Inequigranular facies			
	B333	B339	C42	C69	C70	S25	S126	S433	S443	S563	S566	S621	S682	C44	C57	S666	S701	S706	C130	C136	B183	B393	S146	S147
Rhizamminidae																								
Bathysiphon? sp.																		×						
Lituolidae																								
Cyclammina sp. B (pl. 75, fig. 1)		×																						
Textulariidae																								
Textularia sp. C (pl. 75, fig. 2)					×																			
sp. D																×								
Vulvulina sp. (pl. 81, fig. 1)																								×
Verneuilinidae																								
Gaudryina sp. B (pl. 81, fig. 2)																×								
? sp. C (pl. 81, fig. 3)																								×
(*Siphogaudryina*) *rugulosa* Cushman (pl. 81, fig. 11)																×				×				
Clavulinoides? sp. B (pl. 81, fig. 4)																								×
Valvulinidae																								
Clavulina angularis D'Orbigny (pl. 81, fig. 5)																						×	×	
multicamerata Chapman (pl. 81, figs. 6, 7)																							×	×
Karreriella bradyi (Cushman) (pl. 75, fig. 3)			×																					
Miliolidae																								
Quinqueloculina sp. A (pl. 81, fig. 8)																×						×		
sp. B (pl. 81, fig. 9)																						×		
sp. C (pl. 81, fig. 10)																×					×			
Triloculina trigonula (Lamarck) (pl. 81, fig. 12)																						×		
sp. (pl. 75, fig. 4)									×															
Austrotrillina sp.																						×		
Sigmoilina tenuis (Czjzek) (pl. 75, fig. 5)									×															
Pyrgo denticulata (Brady) (pl. 75, fig. 7)												×									×		×	×
murrhina (Schwager) (pl. 75, fig. 8)												×												
sp. B (pl. 75, fig. 6)				×				×				×												
Lagenidae																								
Robulus inornatus (D'Orbigny)? (pl. 81, fig. 13)	×											×			×									
limbosus (Reuss)? (pl. 75, fig. 9)							×					×								×			×	
sp. D															×									
Astacolus sp. B															×	×								
Marginulina costata (Batsch) (pl. 75, fig. 11)												×												
Dentalina spirostriolata (Cushman) (pl. 75, fig. 10)					×																			
sp. B (pl. 75, fig. 17)												×												
Nodosaria pauciloculata Cushman (pl. 75, fig. 12)												×												
perversa Schwager (pl. 75, fig. 13)						×																		
tornata Schwager (pl. 75, fig. 16)												×												
sp. B (pl. 75, fig. 14)	×																							
sp. C (pl. 75, fig. 15)												×												
Pseudoglandulina solita (Schwager) (pl. 75, fig. 19)												×												
sp. (pl. 75, fig. 18)												×												
Lagena? exsculpta Brady (pl. 75, fig. 20)												×												
gracilis Williamson (pl. 75, fig. 21)												×												
? sp. (pl. 75, fig. 22)												×												
Nonionidae																								
Nonion grateloupi (D'Orbigny) (pl. 81, fig. 14)																×							×	×
pacificum (Cushman) (pl. 81, fig. 16)																×								
Elphidium advenum (Cushman) (pl. 81, fig. 15)																	×							
sp. (pl. 81, fig. 17)																								×
Heterohelicidae																								
Bolivinella sp. B (pl. 81, fig. 18)																×								
sp. C (pl. 81, fig. 19)																×								
Amphimorphina sp. (pl. 75, fig. 23)												×												

TABLE 3.—*Distribution of smaller Foraminifera in the Miocene of Saipan*—Continued

	Tagpochau limestone																							
	Donni sandstone member													Transitional facies				Tuffaceous facies	Marly facies		Inequigranular facies			
	B333	B339	C42	C69	C70	S25	S126	S433	S443	S563	S566	S621	S682	C44	C57	S666	S701	S706	C130	C136	B183	B393	S146	S147
Buliminidae																								
Buliminella madagascariensis (D'Orbigny)																X								
septata Keyzer (pl. 75, figs. 27–29)	X											X	X											
Bulimina truncana Gümbel (pl. 75, fig. 24)												X												
tuxpamensis Cole (pl. 75, fig. 26)							X			X														
Fissurina auriculata var. *costata* (Brady) (pl. 75, fig. 30)												X												
laevigata Reuss														X										
orbignyana Seguenza (pl. 75, fig. 32)												X												
sp. B (pl. 75, fig. 31)												X												
sp. C (pl. 75, fig. 25)												X												
Oolina lineata (Williamson)												X												
Bolivina densa Todd, n. sp. (pl. 82, fig. 2)																X				X			X	X
tortuosa Brady														X										
sp. C (pl. 82, fig. 3)																							X	X
Loxostomum cf. *L. digitale* (D'Orbigny) (pl. 82, fig. 4)																X				X				
Tubulogenerina tubulifera (Parker and Jones) (pl. 81, fig. 20)															X	X						X		
Uvigerina hispida Schwager juv							X																	
proboscidea Schwager (pl. 76, fig. 1)										X		X		X										
Angulogerina elliptica Dorreen? (pl. 82, fig. 8)																X								
Reussella glabrata (Cushman) (pl. 82, fig. 1)																X				X				
simplex (Cushman)																						X	X	X
Chrysalidinella sp. (pl. 82, fig. 7)																						?	X	
Ellipsoidinidae																								
Pleurostomella alazanensis Cushman (pl. 76, fig. 2)										X														
frons Todd, n. sp. (pl. 76, fig. 4)										X		X												
tenuis Hantken (pl. 76, fig. 3)												X												
Parafissurina ovalis Todd, n. sp. (pl. 76, figs. 5, 6)			X									X												
Rotaliidae																								
Spirillina? sp. (pl. 82, fig. 5)																							X	X
Discorbis mira Cushman (pl. 82, fig. 6)																X							X	X
opima Cushman (pl. 82, fig. 9)																								X
orbicularis (Terquem)																X								
orientalis Cushman (pl. 82, fig. 10)																X								
patelliformis (Brady) (pl. 83, fig. 6)																X	X							
tuberocapitata (Chapman)																X								
sp. E (pl. 82, fig. 11)																							X	X
sp. F (pl. 82, fig. 12)																?							X	X
Gyroidina nitidula (Schwager)					X							X												
sp. (pl. 76, fig. 8)										X														
Eponides cf. *E. conicus* Boomgaart (pl. 76, fig. 7)			X																					
karsteni (Reuss)												X												
repandus (Fichtel and Moll) (pl. 83, fig. 2)												X				X								
cf. *E. umbonatus* (Reuss) (pl. 77, fig. 2)									X	X		X								X				
sp. E (pl. 76, fig. 9)										X														
sp. F (pl. 76, fig. 10)												X							X					
Osangularia bengalensis (Schwager) (pl. 77, fig. 1)												X												
Streblus beccarii (Linné)																						X		
byramensis (Cushman) (pl. 83, fig. 4)																X				X				
mexicanus (Nuttall) (pl. 83, fig. 3)														X		X		X		X			?	
sp. (pl. 83, fig. 5)														X							X			
Rotorbinella sp. (p. 82, fig. 13)																X							X	X
Höglundina elegans (D'Orbigny)?													X											
Mississippina? sp																X								
Siphonina tubulosa Cushman (pl. 83, fig. 1)																X								
Baggina parva Todd, n. sp. (pl. 83, fig. 8)																X								
Amphisteginidae																								
Asterigerina carinata D'Orbigny (pl. 83, fig. 7)																X				X				X
subacuta Cushman (pl. 84, fig. 1)														?		X			X			X		X
venusta Todd, n. sp. (pl. 83, fig. 9)															?									X
Amphistegina lessonii D'Orbigny (pl. 84, fig. 4)															X									
madagascariensis D'Orbigny (pl. 84, figs. 2, 3)														X	X	X				X	X		X	X
Cymbaloporidae																								
Cymbaloporetta squammosa (D'Orbigny)														X										
Cassidulinidae																								
Epistominella tubulifera (Heron-Allen and Earland) (pl. 84, fig. 6)														X										
sp. C (pl. 77, fig. 3)												X							?					
Cassidulina angulosa Cushman										X														
delicata Cushman (pl. 77, fig. 6)	X																							
elegantissima Cushman (pl. 77, fig. 4)												X												
pacifica Cushman (pl. 77, fig. 5)										X	X	X												
subglobosa Brady (pl. 77, fig. 7)	X			X	X	X						X	X											
tricamerata Galloway and Heminway (pl. 77, fig. 8)		X						X				X												
sp. D (pl. 77, fig. 10)												X												
sp. E (pl. 77, fig. 9)				X	X			X					X											
Ehrenbergina albatrossi Cushman (pl. 77, fig. 11)				X								X												
bradyi Cushman (pl. 77, fig. 13)		X																						
serrata Reuss (pl. 77, fig. 12)												X												

TABLE 3.—*Distribution of smaller Foraminifera in the Miocene of Saipan*—Continued

	Tagpochau limestone																							
	Donni sandstone member													Transitional facies				Tuffaceous facies	Marly facies		Inequigranular facies			
	B333	B339	C42	C69	C70	S25	S126	S433	S443	S563	S566	S621	S682	C44	C57	S666	S701	S706	C130	C136	B183	B393	S146	S147
Chilostomellidae																								
Pullenia compressiuscula Reuss (pl. 78, fig. 1)				×																				
quinqueloba (Reuss) (pl. 78, fig. 2)								×				×												
Sphaeroidina cf. *S. nitida* Cushman and Todd					×							×												
Globigerinidae																								
Globigerina bulloides D'Orbigny (pl. 78, fig. 5)							×			×						×			?				×	×
cf. *G. concinna* Reuss												×												
eximia Todd, n. sp. (pl. 78, fig. 8)					×	×		×				×	×			?								
nepenthes Todd, n. sp. (pl. 78, fig. 7)			×	×	×	×		×				×				×								
sp. C (pl. 78, fig. 4)			×	×										×										
Globigerinoides conglobata (Brady) (pl. 78, figs. 10, 11)		×		×	×	×		×				×	×											
elongata (D'Orbigny) (pl. 78, fig. 9)		×			×	×		×				×												
mitra Todd, n. sp. (pl. 78, figs. 3, 6)							×					×												
rubra (D'Orbigny) (pl. 78, fig. 14)	×	×	×			×	×		×															
sacculifera (Brady) (pl. 78, fig. 12)	×	×	×	×	×	×	×	×	×	×		×	×	×		×	×							
Globigerinella aequilateralis (Brady) (pl. 78, fig. 13)	×	×	×			×		×		×		×			?									
Hastigerina pelagica (D'Orbigny) (pl. 79, fig. 1)				×		×						×												
Orbulina bilobata (D'Orbigny) (pl. 79, fig. 5)		×		×	×	×	×			×		×		×										
suturalis Bronnimann (pl. 79, figs. 2–4)			×	×	×							×												
universa D'Orbigny	×	×	×	×	×	×	×	×	×	×		×		×		×								
Pulleniatina obliquiloculata (Parker and Jones) (pl. 79, fig. 9)	×			×								×												
Sphaeroidinella dehiscens (Parker and Jones) (pl. 79, fig. 8)	×	×		×	×	×		×				×	×											
kochi (Caudri) (pl. 79, fig. 6)					×	×		×	×			×	×			×								
seminulina (Schwager) (pl. 79, fig. 7)		×	×	×	×	×	×	×		×		×	×			×								
Candeina nitida D'Orbigny (pl. 79, fig. 10)	×	×	×	×		×			×	×		×	×											
Globorotaliidae																								
Globoquadrina altispira (Cushman and Jarvis) (pl. 79, fig. 11)					×	×	×			×														
dehiscens (Chapman, Parr, and Collins) (pl. 79, fig. 12)	?						×			×														
Globorotalia crassula Cushman and R. E. Stewart (pl. 80, fig. 3)				×		×		×																
hirsuta (D'Orbigny) (pl. 80, fig. 2)	×		×									×	×			×								
menardii (D'Orbigny) (pl. 80, fig. 1)	×		×	×	×	×			×	×		×	×											
tumida (Brady) (pl. 80, fig. 4)	×	×						×								×								
Anomalinidae																								
Anomalina polymorpha Costa (pl. 80, fig. 6)	×																							
Planulina wuellerstorfi (Schwager) (pl. 80, fig. 7)										×		×												
sp. C												×				×								
Laticarinina pauperata (Parker and Jones) (pl. 80, fig. 5)												×												
Anomalinella rostrata (Brady) (pl. 84, fig. 5)															×	×		×	×	×			×	×
Cibicides cicatricosus (Schwager) (pl. 80, fig. 8)					×							×												
lobatulus (Walker and Jacob) (pl. 84, fig. 9)																×			×	×			×	×
pseudoungerianus (Cushman) (pl. 80, figs. 9, 10)	×															×	×			×				
vortex Dorreen (pl. 84, fig. 8)														×		×				×				
Cibicidina mississippiensis (Cushman) (pl. 84, fig. 7)																×				×				
Cibicidella variabilis (D'Orbigny)																								×
Planorbulinidae																								
Planorbulina acervalis Brady (pl. 84, fig. 10)																×				×			×	×
Acervulina inhaerens Schultze																×								
Gypsina globula (Reuss) (pl. 84, fig. 11)																×	×					×		
vesicularis (Parker and Jones)																				×				

EVIDENCE FROM PLANKTONIC SPECIES

The best evidence available from smaller Foraminifera bearing on the age of the Tagpochau limestone is that provided by the planktonic species. The significance of the presence in abundance of *Orbulina* s. s. (that is, *Orbulina universa* D'Orbigny) will be considered first. The first appearance of this species in a sequence of continuously deposited open-sea, deep-water globigerine facies has been suggested by Finlay (1947b, p. 337–340) and LeRoy (1948) as constituting an important datum plane within the middle Tertiary.

If such a datum plane exists, as it well may, its position is yet to be established. Finlay (1947b, p. 339–340) placed the supposed boundary in New Zealand in upper Ihungia time (interpreted as "upper part of the Lower Miocene—probably Burdigalian"). LeRoy (1948, text fig. 3) placed it between Tertiary e_{4-5} and Tertiary *f* in the Kassikan section in Sumatra. The first recorded appearances of *Orbulina* in central Sumatra, southern Turkey, Algeria, north-central Venezuela, Ecuador, Trinidad, and the Pacific coast of the United States were represented by LeRoy (1952, text fig. 4) as being at widely divergent levels from middle Oligocene to upper Miocene. Grimsdale (1951, range chart, text fig. 1) placed the first appearance at the Oligocene-Miocene boundary in the Gulf of Mexico–Caribbean area and somewhere above the base of the Aquitanian in the Middle East. Thus it is clear that the actual position of the *Orbulina*-surface is in question. Presumably *Orbulina* s. s. is nowhere found in pre-Aquitanian rocks.

The lack of agreement between various localities could result from one or more of the following factors: Existence of a land or ecologic barrier to the dispersal of *Orbulina* outward from its original place of evolution; lack of a continuous sequence of the facies in which *Orbulina* occurs; and different placements of epoch boundaries in different geographic provinces.

Appearances and disappearances of planktonic species within a sequence of continuously deposited open-sea facies are boundaries significant for the problem under consideration, regardless of the position of local time divisions.

With this in mind it can only be said that the age of the Donni sandstone is younger than the datum plane marked by the first appearance of *Orbulina universa*, wherever that surface is located in the western north Pacific.

Two other considerations provide further refinement of stratigraphic position: the ranges of the common planktonic species that are associated with *Orbulina universa*, and the quantitative relationships of the species present.

Associated common planktonic species.—The two species most useful for close stratigraphic assignment in the Miocene are *Orbulina suturalis* Bronnimann (*Candorbulina* of some authors) and *Globorotalia menardii* D'Orbigny. In the well-established foraminiferal zonation of Trinidad, *Orbulina suturalis* appears before the first appearance of *O. universa*, and *Globorotalia menardii* appears after *O. universa* (Bronnimann, 1951, text fig. 1, p. 131). Of these three species, only *O. suturalis* does not persist to the Recent. *O. suturalis* is stated to have probably died out in Trinidad by the time of deposition of the "younger Miocene (calcareous clays of the Forest formation)" (Bronnimann, 1951, p. 136). In Ecuador and Colombia the range of this species is reported (Stainforth, 1948a, p. 123) to extend from late Oligocene through the Miocene. Assuming approximate global synchroneity of the times of appearance and disappearance of these common planktonic elements, an undemonstrated but by no means preposterous assumption, *Orbulina suturalis* would be the best available form among the smaller Foraminifera to define the top limit of age of the Donni sandstone member.

As stated above, *Globorotalia menardii* first appears in Trinidad at a higher level than the first appearance of *O. universa;* that is, rarely in the uppermost part of the *Globorotalia fohsi* zone and more abundantly in the *G. mayeri* and *G. menardii* zones of the lower Miocene. On an assumption similar to the foregoing, this species would appear to be the best of the smaller Foraminifera available to define the lower limit of age of the Donni member.

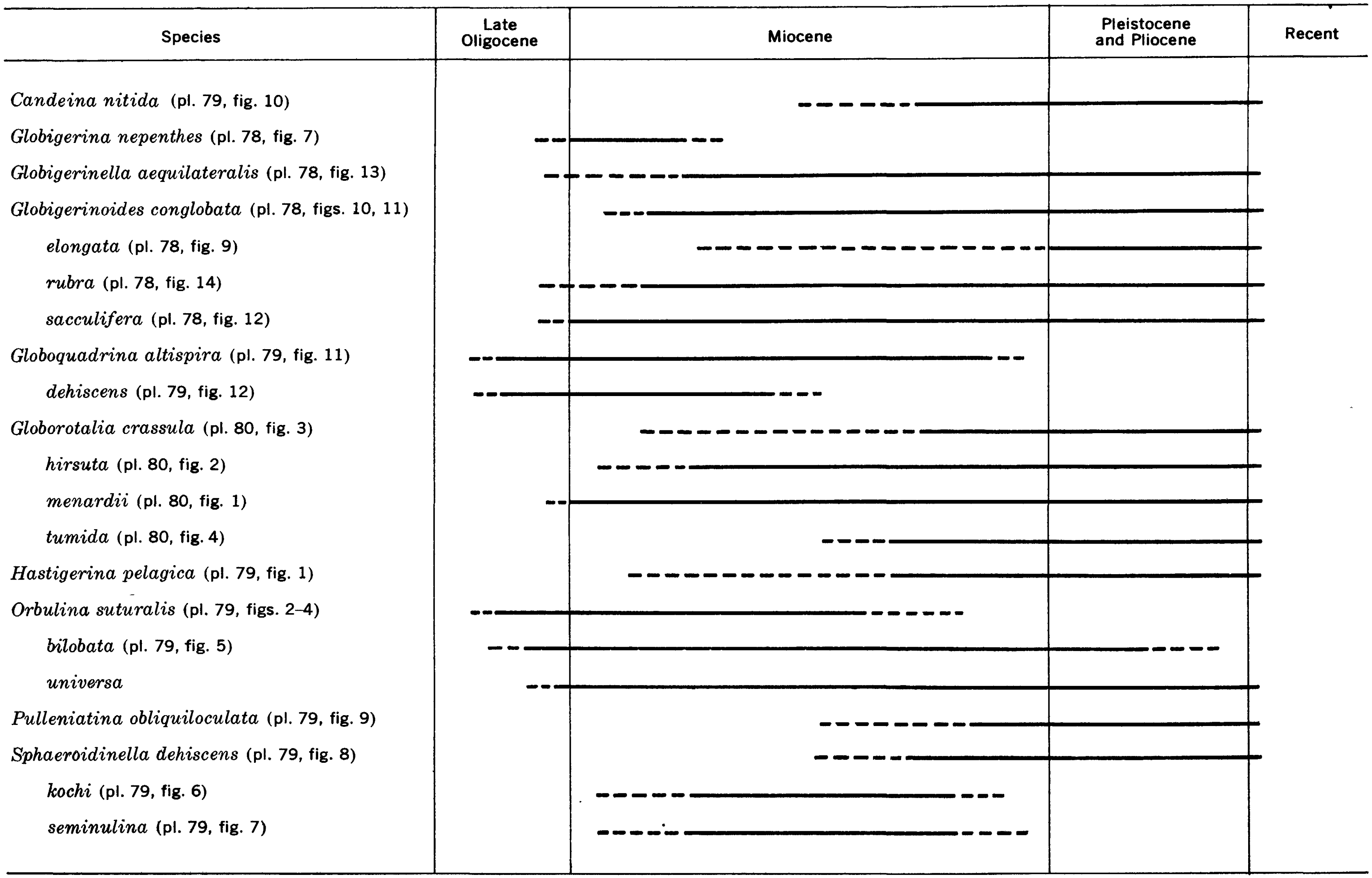
Globigerina nepenthes n. sp. is another well-known species in the Caribbean region, one that until now has remained without a formal name. In Trinidad *G. nepenthes* n. sp. occurs in the *Globorotalia mayeri* and *G. menardii* zones of the lowermost Miocene. It constitutes another tie to a known section; and as its stratigraphic range is rather narrow, it provides additional evidence for the correlation of the Tagpochau limestone with the lower Miocene.

Given the probability of synchronous ranges of common planktonic elements of the fauna as a working hypothesis, the forms named may now be used to suggest the age limits of the Donni beds. On this basis the presence of *Globorotalia menardii* implies that the Donni can be no older than earliest Miocene, whereas *Orbulina suturalis* is presumptive evidence of a pre-latest Miocene age. The independent evidence of the known terminal ranges of the planktonic species thus indicates an early Miocene age for the Donni sandstone member, a conclusion that is consistent with the field relationships and the ages of associated limestones as determined by the larger Foraminifera.

Quantitative relationships.—The great abundance of both *Orbulina universa* and *Globorotalia menardii* indicates that the enclosing beds are at least far enough above the initial appearances of these species to be within the zone of good development of both. Including the four already mentioned, the planktonic species present in great or moderate abundance in the Donni are listed in the accompanying table.

Approximate time spans of planktonic species present in the Donni sandstone member

[Dashed lines indicate doubtful ranges that may extend beyond point where dashed lines end]



There is at present insufficient evidence bearing on the exact stratigraphic ranges of most of these species to permit their use as precise markers. Both *Sphaeroidinella kochi* (Caudri) and *S. seminulina* (Schwager) have been reported to be Miocene index fossils, but no closer restriction has been placed on their ranges (Glaessner, 1943, p. 69). The earliest recorded occurrences for *Candeina nitida* and *Pulleniatina obliquiloculata* are middle Miocene (Bermudez, 1949, p. 284; Crespin, 1943, p. 82 [list]). As both these species are found only rarely in fossil material, restriction of range based on their reported occurrences carries little weight.

The approximate ranges indicated in the table are a composite of published information, chiefly from Grimsdale (1951), Bronnimann (1951), and Stainforth (1948a), and are not meant to include the evidence of probable contemporaneity that is suggested but not proved by the occurrence together of these species in the Donni sandstone. Knowledge of worldwide distribution of planktonic Foraminifera in the Tertiary and the ecologic and other factors that affected their distribution is too incomplete to permit one to do more than guess whether ranges are actually different from place to place or are merely incompletely known.

LeRoy (oral communication, April 6, 1955) suggests that the first appearances of *Globigerinoides rubra*, *Candeina nitida*, and *Pulleniatina obliquiloculata* constitute useful datum planes at levels above the *Orbulina* datum plane. These datum planes have not yet been widely recognized. In Saipan they are all below the Donni sandstone, although the rarity of the latter two species suggests their first appearances are not far below the Donni.

EVIDENCE FROM BENTHONIC SPECIES

Following are tabulated the Donni benthonic species most significant for age correlation with their major, but not necessarily restricted, stratigraphic and geographic occurrences (extremely rare occurrences are omitted).

Significant benthonic species from the Donni sandstone

Species	Age	Occurrence
Bulimina tuxpamensis Cole (pl. 75, fig. 26)	Eocene	Mexico, Cuba, Germany, Italy.
	Oligocene	Trinidad.
	Miocene	Spain.
Cassidulina tricamerata Galloway and Heminway (pl. 77, fig. 8)	Upper Oligocene-lower Miocene	Puerto Rico.
Cibicides cicatricosus (Schwager) (pl. 80, fig. 8)	Miocene	Kar Nicobar.
	Oligocene	Trinidad.
Ehrenbergina serrata Reuss (pl. 77, fig. 12)	Miocene	Vienna Basin.
	Oligocene	Cuba.
Osangularia bengalensis (Schwager) (pl. 77, fig. 1)	Miocene	Kar Nicobar.
Textularia sp. C (="*Vulvulina nicobarica*" of Cushman) (pl. 75, fig. 2)	Miocene	Kar Nicobar.

All of these species are restricted to the Donni beds. Only *Osangularia bengalensis* occurs commonly.

The evidence for age determination provided by the benthonic smaller Foraminifera, so far as it may be interpreted at present, confirms but is less precise than that provided by the planktonic species.

CORRELATION OF THE OTHER FACIES

Of the 161 species found in all the Miocene samples, leaving out of consideration the 77 species restricted to the Donni sandstone member, only 84 species occur in the remaining 4 facies of the Tagpochau. Of these 84 species, only *Anomalinella rostrata* (Brady) is found in all 4 facies of the Tagpochau.

Transitional facies.—The transitional facies, represented by 4 samples, contains about 60 species, 23 of which are restricted to it. Next to the Donni sandstone, this facies has the richest and most diverse fauna. Planktonic species are very sparingly present. Quantitatively, the most abundant forms in this facies are mostly large, heavy-walled specimens in the Amphisteginidae, Rotaliidae, Anomalinidae, and Verneuilinidae. Deepwater species and genera, such as those in the Lagenidae and Chilostomellidae that are well represented in the Donni beds, are almost completely lacking.

Tuffaceous facies.—Only two identified species were found in the single sample representing the tuffaceous facies. They are *Anomalinella rostrata* (Brady) and *Streblus mexicanus* (Nuttall), both of which also occur in the transitional and marly facies.

Marly facies.—In the marly facies, represented by 2 samples, 19 species were found, only 2 of which are not shared with either or both the transitional and inequigranular facies. In general composition the marly facies resembles but is sparser than both the transitional and inequigranular facies, but arenaceous forms and rotalids are rarer, and planktonic species are almost completely lacking.

Inequigranular facies.—The inequigranular facies, represented by 4 samples, contains 38 species, of which 18 are restricted to it. Eighteen of the twenty others are held in common with the transitional facies, and there is a close similarity between the two facies except for the nearly complete lack of planktonic species in the inequigranular facies.

Treating the four above-mentioned facies of the Tagpochau limestone as a unit and omitting extremely rare specimens, the following table gives the species most significant for age correlation with some of their major, but not necessarily restricted, stratigraphic and geographic occurrences.

Species from the Tagpochau limestone significant for age correlation

Species	Age	Occurrence
Anomalinella rostrata (Brady) (pl. 84, fig. 5)	Miocene to Recent	Indo-Pacific.
Asterigerina carinata D'Orbigny (pl. 83, fig. 7)	Miocene to Recent	West Indies.
subacuta Cushman (pl. 84. fig. 1)	Oligocene	United States.
Austrotrillina sp	Miocene	Indo-Pacific.
Cibicidina mississippiensis (Cushman) (pl. 84, fig. 7)	Oligocene and Eocene	United States.
Nonion grateloupi (D'Orbigny) (pl. 81, fig. 14)	Miocene to Recent	Europe, United States, West Indies, South America, Atlantic, Pacific.
Reussella glabrata (Cushman) (pl. 82, fig. 1)	Miocene and Pliocene	United States, West Indies.
Rotorbinella sp. (pl. 82, fig. 13)	Miocene	Bikini.
Streblus byramensis (Cushman) (pl. 83, fig. 4)	Oligocene and upper Eocene	United States, West Indies.
mexicanus (Nuttall) (pl. 83, fig. 3)	Eocene and Oligocene	West Indies.
Tubulogenerina tubulifera (Parker and Jones) (pl. 81, fig. 20)	Eocene Miocene	France. Bikini.

ECOLOGIC INTERPRETATION

The following list contains 27 species found in both the Miocene rocks of Saipan and the Recent sediments around Saipan. Those species represented in the Miocene collection by only a single specimen are marked with an asterisk.

Benthonic species:
- *Acervulina inhaerens* Schultze
- *Amphistegina madagascariensis* D'Orbigny (pl. 84, figs. 2, 3)
- **Bolivina tortuosa* Brady
- *Cibicides lobatulus* (Walker and Jacob) (pl. 84, fig. 9)
- **Cibicidella variabilis* (D'Orbigny)
- **Cymbaloporetta squammosa* (D'Orbigny)
- *Discorbis mira* Cushman (pl. 82, fig. 6)
- *opima* Cushman (pl. 82, fig. 9)
- * *orbicularis* (Terquem)
- *orientalis* Cushman (pl. 82, fig. 10)
- *patelliformis* (Brady) (pl. 83, fig. 6)
- * *tuberocapitata* (Chapman)
- **Elphidium advenum* (Cushman) (pl. 81, fig. 15)
- **Epistominella tubulifera* (Heron-Allen and Earland) (pl. 84, fig. 6)
- *Gaudryina (Siphogaudryina) rugulosa* Cushman (pl. 81, fig. 11)
- *Gypsina globula* (Reuss) (pl. 84, fig. 11)
- * *vesicularis* (Parker and Jones)
- *Nonion pacificum* (Cushman) (pl. 81, fig. 16)
- *Planorbulina acervalis* Brady (pl. 84, fig. 10)
- *Pyrgo denticulata* (Brady) (pl. 75, fig. 7)
- *Reussella simplex* (Cushman)
- *Siphonina tubulosa* Cushman (pl. 83, fig. 1)
- **Streblus beccarii* (Linné)
- *Triloculina trigonula* (Lamarck) (pl. 81, fig. 12)

Planktonic species:
- *Globigerinoides conglobata* (Brady) (pl. 78, figs. 10, 11)
- *rubra* (D'Orbigny) (pl. 78, fig. 14)
- *sacculifera* (Brady) (pl. 78, fig. 12)

Globigerinoides conglobata (Brady) and *G. rubra* (D'Orbigny) are found in the Donni only. *Pyrgo denticulata* (Brady) and *Globigerinoides sacculifera* (Brady) occur in the shallower water facies as well as in the Donni. The remaining species occur only in the shallower water facies.

All the benthonic species in the above list are found in Tanapag Lagoon, and immediately seaward of the reef from the beach to about 6 fathoms, the depth of the deepest sample dredged from the modern sea floor there. The rare representatives of the three planktonic species listed above that are found in Tanapag Lagoon are mostly smaller than typical forms found in the present-day oceanic sediments as well as in the Miocene sediments of Saipan.

In the Miocene the benthonic species listed above are predominantly found in 1 or more of the 4 limestone facies of the Tagpochau from which the samples at hand come, with only 1 individual of *Pyrgo denticulata* (Brady) recorded from the Donni sandstone member. The 3 planktonic species are, by virtue of their floating nature, unaffected by depth and have no particular significance for the ecologic interpretation of these sediments. Although planktonic species are apparently affected by enclosed bodies of water or by nearness to shore, the relationships of size, thickness of wall, nature of perforations, and type of surface of planktonic specimens to the physical and chemical features of their environment have not yet been adequately investigated.

RECENT

Recent Foraminifera were obtained from 60 bottom samples from beaches and shallow water within Tanapag Lagoon and close outside its reef along the northwest and west coasts of Saipan, and Fahang and Nanasu beaches on the northeast coast of Saipan. The occurrence and abundance of 200 species and varieties of Foraminifera found in the lagoon and on the beaches are shown on the distribution chart for the Recent Foraminifera. Most of these bottom samples were taken along Cloud's ecologic traverse lines *C, B, A, D, E,* and *F* (listed in order from northeast to southwest). None of the bottom samples studied came from depths greater than 38 feet; most of them were from shallower depths.

The samples are arranged in groups on table 4 as follows:

- Beach and bar samples
  - Beaches
    - Northeast coast
    - Northwest coast
  - Sandbar adjoining beach
- Lagoonal area
  - Limesand pockets within lagoonal reef patches, depths to 10 feet
  - Areas of seaweed growth on limesand bottom, depths 1 to 18 feet
    - Sparse to moderate seaweed
    - Abundant seaweed
  - Coarse limesand and gravel bottom, depths 1 to 12 feet
  - Dredged areas, depths 18 to 37 feet
  - Mainly limesand bottom, depths 2 to 32 feet
  - Limesand bottom between patch reefs, depths 10 to 36 feet
- Seaward from reef, limesand bottom between patch reefs, depths 10 to 38 feet

COMPOSITION OF FAUNA

The Recent sediments contain abundant and well-preserved specimens of a diversified fauna, closely similar to other well-known shallow-water faunas of the tropical Pacific islands (Cushman, Todd, and Post, 1954). The family Miliolidae is predominant both in number of individuals and diversity of form. The Rotaliidae are next in order of abundance and diversity. When bulk of foraminiferal material is considered, three species, of large size for the smaller Foraminifera, in the Calcarinidae and Peneroplidae are predominant: *Baculogypsina sphaerulata* (Parker and Jones) (pl. 91, fig. 13; pl. 93, fig. 14), *Calcarina spengleri* (Gmelin) (pl. 91, fig. 11), and *Marginopora vertebralis* Blainville (pl. 89, fig. 6; pl. 93, figs. 6–8). These three species are believed to be largely if not exclusively reef dwellers, as evidenced by the natural occurrence of the last two mentioned on the reefs at Onotoa (Cloud, 1952b, p. 65), at Bikini (Cushman, Todd, and Post, 1954, p. 319, 364), and elsewhere (Cloud, 1952a, p. 2144).

Two types of planktonic specimens are found in the Recent lagoon samples: *Tretomphalus*, a common planktonic but nonpelagic genus, or planktonic stage of the genus *Cymbaloporetta*, a common lagoon dweller, and several species of globigerinids, pelagic genera. Planktonic specimens are found in over half the samples examined, but in all instances they occur in negligible amounts. Furthermore, the globigerinids are not large or well developed and may be considered strays from the oceanic currents that flow around Saipan.

The composition of the samples varies considerably, as may be seen in table 4. This variation is probably a result of many factors, including nearness to reefs or reef banks and winnowing effects of currents. The differences seem, however, to follow no particular pattern; and there is little difference, except quantitative relationships and degree of abrasion of species, between beach material and that from the areas farthest removed from beaches and reefs.

Finding list for samples of Recent smaller Foraminifera included in table 4

Traverses	Beaches	Sandbar adjoining beach	Limesand pockets within lagoonal reef patches	Areas of seaweed growth on limesand bottom	Coarse limesand and gravel bottom	Dredged areas	Mainly limesand bottom	Limesand bottom between patch reefs	Seaward from reef
A	*1b*			*1, 1a*		*2, 3, 4*	*5a, 9, 10*	*5, 6, 7, 8, 11*	
B	*1ax*		*10*	*1, 1ay, 1b, 2, 3, 7*			*4, 5, 6, 8, 9*		
C	*1b*		*1, 1a, 6, 7a*	*3, 4, 5*			*2*		
D	*1*	*2, 2a*	*4*	*3*				*5, 7, 7a*	
E	*1*			*1a, 2, 2a, 3*	*4, 5*				*6, 7, 8.*
F X					*1, 2*				
Other localities	Mañagaha Island, Fahang, Nanasu			Loc. *3*					

TABLE 4.—*Distribution of Recent smaller Foraminifera of Saipan*

[A indicates abundant; C, common; R, rare]

	Beach and bar samples										Lagoonal area																						
	Beaches								Sand-bar adjoining beach		Limesand pockets within lagoonal reef patches						Areas of seaweed growth on limesand bottom																
	North-east coast		Northwest coast														Sparse to moderate growth					Abundant growth											
	Fahang	Nanasu	*C15*	*B1ax*	*A1b*	Mañagaha Island	*D1*	*E1*	*D2*	*D2a*	*C1a*	*C1*	*C6*	*C7a*	*B10*	*D4*	*B2*	*C4*	*C5*	*B7*	*D3*	*A1a*	*C3*	*B1ay*	*B1b*	*B1*	*B3*	*A1*	Loc. 3	*E1a*	*E2a*	*E2*	*E3*
Hyperamminidae:																																	
Sagenina frondescens (Brady) (pl. 85, fig. 1)																																	
Textulariidae:																																	
Textularia agglutinans D'Orbigny (pl. 85, fig. 2)	R	C				C	A	C	A	A	R	R	A	A	A	C		C	C	R	A		C	R				R	R	C		R	R
alveata Todd, n. sp. (pl. 85, fig. 12)	R			R		R							R	C	C			A	A	C			R	R		C							
candeiana D'Orbigny (pl. 85, fig. 3)	R											R							R	R													
conica D'Orbigny (pl. 85, fig. 4)	R					R	C		C			A	A	A	A		R	C	R	A			A				R		R				R
foliacea Heron-Allen and Earland (pl. 85, fig. 5)	R																																
kerimbaensis Said (pl. 85, fig. 11)			R									R	R		R					R				R								R	
semialata Cushman			R		R			R		C	C				C	C				R	A				R		R			R			
sp. E (pl. 85, fig. 10)	R	C				R						A		R				R	R				A					R					
Siphotextularia crispata (Brady)																		R															
Verneuilinidae:																																	
Gaudryina cf. *G. pauperata* Earland																			R								R						
(*Siphogaudryina*) *rugulosa* Cushman (pl. 93, fig. 1)	R					C					R				R	R			R									R					
(*Siphogaudryina*) *siphonifera* (Brady) (pl. 93, fig. 2)															R			R					R										
Valvulinidae:																																	
Valvulina davidiana Chapman (pl. 93, fig. 3)	R						R		R			R			R																		
Clavulina difformis Brady (pl. 85, fig. 8)				R			C		R	R	R										R			C					R				
pacifica Cushman (pl. 85, fig. 9)	R						R	R				R	R					R	R	R				R			R			R			
Miliolidae:																																	
Quinqueloculina agglutinans D'Orbigny (pl. 85, fig. 6)				R					R	R	R							R	R	R	R				C	C		C		R			R
anguina Terquem var. *arenata* Said (pl. 85, fig. 7)																										R	R		R				
berthelotiana D'Orbigny											C																						
cf. *Q. berthelotiana* D'Orbigny (pl. 86, fig. 9)								R								R					R												
bidentata D'Orbigny																						R		R								R	R
crassa D'Orbigny var. *subcuneata* Cushman													R					R	R	R			R			R							
distorqueata Cushman (pl. 86, fig. 8)	R		R	R	C		C	C	R	C	R				R		R	R		R	R	R		R	C	R	C	A	A	C	A	A	C
neostriatula Thalmann	R					R			R	R	C	R	R	C	C		R	R	R	R	R		R			R	R	C	R			C	C
neostriatula Thalmann var. (pl. 85, fig. 19)																		R					R			R							
parkeri (Brady) (pl. 85, figs. 13, 14)	R					R							R		R				R									R		R			
cf. *Q. seminulum* (Linné)	R						R																	R			R						
sulcata-Q. ferussaci D'Orbigny (pl. 86, figs. 3–6)		R	A	A		C	C	R	A	R	A	A	R	R	C	R	A	C	R	R	A		R	A	C	A	A	A	A	C	C	C	C
tubus Todd, n. sp. (pl. 85, fig. 18)						R				R			R								R												
Miliolinella australis (Parr) (pl. 87, fig. 15)	R	R												R	R								R										
Triloculinella labiosa (D'Orbigny) (pl. 87, fig. 16)	A	R		R		R				R	C	R	A	R	A	R		C	C	C	R		C	R		R	R		R		R	R	R
oceanica (Cushman)				R						R		R																					R
Massilina cf. *M. durrandi* (Millett) (pl. 87, fig. 2)			R								R					R					R						R	R		R	R	R	
planata Cushman (pl. 87, fig. 1)																																	
pseudoclara Todd, n. sp. (pl. 87, fig. 3)			R	R		R	R		R	R	C	R	R	C	R		R	A	A	C	R		C	C	R	A	C	R	R	R	R	R	
rustica Todd, n. sp. (pl. 87, fig. 4)	R															R	R												R			R	R
Spiroloculina angulata Cushman (pl. 87, fig. 6)	C	R	R	A	R	R	R		R	R	C	R	C	R	R	R	R	R	R	C	C	R	R	C		R	C		C	R	R	R	R
caduca Cushman (pl. 87, fig. 10)											R				R												R				R		
clara var. *lirata* Cushman																																	
communis Cushman and Todd									R			R			R			R		R													
corrugata Cushman and Todd (pl. 87, figs. 7, 8)									R		R																						
eximia Cushman (pl. 87, fig. 12)																											R	R					
folium Todd, n. sp. (pl. 87, fig. 5)																																	
foveolata Egger (pl. 87, fig. 9)							R																										
Articulina pacifica Cushman (pl. 87, fig. 11)	R																														R		R
Nubeculina? sp.	R																																
Hauerina bradyi Cushman (pl. 88, figs. 1, 2)	R									R							R			R						R		R					R
diversa Cushman																																	
involuta Cushman (pl. 88, fig. 5)				R				R		R	R			R	R	R			R		R		R	R			R	R			R		
milletti Cushman (pl. 88, fig. 4)	R										R	R		R					R	R				R			R		R				R
pacifica Cushman (pl. 88, fig. 3)	R	R			R	R	R			C	C	R		R	C	R	R	R	R	R	C	R		R	R	C		C	R		R	R	R
serrata Cushman																																	
cf. *H. speciosa* (Karrer) (pl. 88, fig. 6)																																	
Schlumbergerina alveoliniformis (Brady) (pl. 87, fig. 14)					R																	R					R	R					
Ammomassilina alveoliniformis (Millett) (pl. 87, fig. 13)																																	
Triloculina cf. *T. bassensis* Parr (pl. 86, fig. 1)	R		C						R	R		R					R	R					R					R					R
bicarinata D'Orbigny				R	R													R		R				R				R					
bikiniensis Todd (pl. 86, fig. 14)	R	C	R		R	R		R	R	C	R		C	R	C	C		R	C	C	A									R			

TABLE 4.—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Lagoonal area—Continued																										
	Coarse limesand and gravel bottom				Dredged areas			Mainly limesand bottom									Limesand bottom between patch reefs								Seaward from reef		
	E4	*E5*	*FX1*	*FX2*	*A2*	*A3*	*A4*	*C2*	*B4*	*B5*	*B6*	*B8*	*B9*	*A5a*	*A9*	*A10*	*A5*	*A6*	*A7*	*A8*	*A11*	*D5*	*D7*	*D7a*	*E6*	*E7*	*E8*
Hyperamminidae:																											
Sagenina frondescens (Brady) (pl. 85, fig. 1)					R	R																					
Textulariidae:																											
Textularia agglutinans D'Orbigny (pl. 85, fig. 2)	R	R	C	A	C	A	A	C		R	A	C	R	A	R	C	C	C	A	C	A	A	A	A	A	A	A
alveata Todd, n. sp. (pl. 85, fig. 12)			R		R	C	A			C	A	A	A	R			C	A	C	C	C		C				
candeiana D'Orbigny (pl. 85, fig. 3)		R		R	R		R				R			R			R	R					C		R	R	
conica D'Orbigny (pl. 85, fig. 4)	A	A	C	C	C	A	A	A		C	A	A	A	A		C	A	C	A	R	A	A	C	A	A	A	A
foliacea Heron-Allen and Earland (pl. 85, fig. 5)						R	R																	R	R		
kerimbaensis Said (pl. 85, fig. 11)	R		R	R	R	R	R	R			R	R		R									R	R		R	R
semialata Cushman										C		C		C	R					R				R			
sp. E (pl. 85, fig. 10)		R		R		R		R		R		R											R				
Siphotextularia crispata (Brady)						R		R			R																
Verneuilinidae:																											
Gaudryina cf. *G. pauperata* Earland																											
(*Siphogaudryina*) *rugulosa* Cushman (pl. 93, fig. 1)	R		C		C	A	C				C		R	C			C	R	C	R			R	R			
(*Siphogaudryina*) *siphonifera* (Brady) (pl. 93, fig. 2)				R	R	C					R													R	R	R	
Valvulinidae:																											
Valvulina davidiana Chapman (pl. 93, fig. 3)	R		R	R	R	A	C	R								R	R	R		R				R		R	R
Clavulina difformis Brady (pl. 85, fig. 8)	R				C	A	R								R		R						C	R		R	C
pacifica Cushman (pl. 85, fig. 9)	R				C	R	R	R			R					R	R					R	C	C	R		
Miliolidae:																											
Quinqueloculina agglutinans D'Orbigny (pl. 85, fig. 6)	R				C	C	R				R			R			R	R	R			R	R	R	R	R	
anguina Terquem var. *arenata* Said (pl. 85, fig. 7)					R		R			R	R			R						R						R	
berthelotiana D'Orbigny				C						R	R																
cf. *Q. berthelotiana* D'Orbigny (pl. 86, fig. 9)		R																							R		
bidentata D'Orbigny					C	A	R											R						R			
crassa D'Orbigny var. *subcuneata* Cushman		R			R	R		R			C	R	R							R			R				
distorqueata Cushman (pl. 86, fig. 8)	A		R	C	A	A	A							C		R	C	R	R	R	R	C	C	C	C	A	A
neostriatula Thalmann	R	C	R	A	A	R	R	C		R	C	C	R	C		R	R	R	C	R	R		R		R	R	R
neostriatula Thalmann var. (pl. 85, fig. 19)						R				R								R	R								
parkeri (Brady) (pl. 85, figs. 13, 14)			C	R	A	A	A				R			R		R	R	R	C		R		R			R	
cf. *Q. seminulum* (Linné)			R		R	R			R	R	R										R						
sulcata-ferussaci D'Orbigny (pl. 86, figs. 3–6)	C		C	A	A	A	A	A		R	C	R	C	A		A	C	R	A	A	A	C	A	A	C	C	C
tubus Todd, n. sp. (pl. 85, fig. 18)			R																		R				R		
Miliolinella australis (Parr) (pl. 87, fig. 15)								R				R							R						?		
Triloculinella labiosa (D'Orbigny) (pl. 87, fig 16)	R	R	R	C	R	R	R	C			C	C		C	R		R			C	R		R			R	R
oceanica (Cushman)																						R					
Massilina cf. *M. durrandi* (Millett) (pl. 87, fig. 2)	R	R	R							R				R	R						R	R				R	
planata Cushman (pl. 87, fig. 1)					R	R																					
pseudoclara Todd, n. sp. (pl. 87, fig. 3)		C	R	R		C	R	A	R	R	C	A	C	C	R	C		R	C	R			R		R		R
rustica Todd, n. sp. (pl. 87, fig. 4)		R	R				R	R				R					R			C		R	C		R	R	
Spiroloculina angulata Cushman (pl. 87, fig. 6)	R	R	R	C	A	A	C	R		R	C	R	R	C	R	R	R		R	R	C	C	C	R	C	C	R
caduca Cushman (pl. 87, fig. 10)					R							R		R													
clara var. *lirata* Cushman					R	C		R												R							
communis Cushman and Todd						R	R					R															
corrugata Cushman and Todd (pl. 87, figs. 7, 8)					R	C										R											
eximia Cushman (pl. 87, fig. 12)					R							R	R										R				
folium Todd, n. sp. (pl. 87, fig. 5)			R	R																		R	R	R			
foveolata Egger (pl. 87, fig. 9)																					R						
Articulina pacifica Cushman (pl. 87, fig. 11)		R		R	R	R						R															R
Nubeculina? sp					R																						
Hauerina bradyi Cushman (pl.88, figs. 1, 2)		R	R	R	R		R	R			R	R		R		R		R						R	R	R	
diversa Cushman		R																									
involuta Cushman (pl. 88, fig. 5)		C		C	C	A	R	R			R	R	R	R			R		R		R	R	R		R	C	R
milletti Cushman (pl. 88, fig. 4)	R	R			C	R	R	R				R	R	R		R		R	R	R				R	R		
pacifica Cushman (pl. 88, fig. 3)	R	R	R	C	R	R	R	R	R	R	R		R	R		C			C		R	R	R	R	R	A	A
serrata Cushman			R	R																							
cf. *H. speciosa* (Karrer) (pl. 88, fig. 6)																	R										
Schlumbergerina alveoliniformis (Brady) (pl. 87, fig. 14)					A	A	R										R					R		R		R	
Ammomassilina alveoliniformis (Millett) (pl. 87, fig. 13)						R																					
Triloculina cf. *T. bassensis* Parr (pl. 86, fig. 1)					C	C	C	R		R	R						R	R	R				R				R
bicarinata D'Orbigny	R	R					R	R	R		R	R	R														
bikiniensis Todd (pl. 86, fig. 14)	R		R	R	R	R	R	R		R	R	C	C							R	C	R	R	C	A	C	C

TABLE 4—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Beach and bar samples										Lagoonal area																						
	Beaches								Sand-bar adjoining beach		Limesand pockets within lagoonal reef patches						Areas of seaweed growth on limesand bottom																
	North-east-coast		Northwest coast														Sparse to moderate growth					Abundant growth											
	Fahang	Nanasu	*C1b*	*B1ax*	*A1b*	Managaha Island	*D1*	*E1*	*D2*	*D2a*	*C1a*	*C1*	*C6*	*C7a*	*B10*	*D4*	*B2*	*C4*	*C5*	*B7*	*D3*	*A1a*	*C3*	*B1ay*	*B1b*	*B1*	*B3*	*A1*	Loc. 3	*E1a*	*E2a*	*E2*	*E3*
Miliolidae—Continued																																	
Triloculina cuneata Karrer (pl. 86, fig. 11)	R		C	A		C			R		A	C	A	R	C	C	R	A	C	A	C	C	C	A	C	A	A	C	C		A	A	C
earlandi Cushman (pl. 85, fig. 17)			R	R						R	R				R					R		R	R	R	R	C	C	R	R		R	R	
incisura Todd, n. sp. (pl. 86, fig. 18)				R		R						R												R									
involuta Todd																																	
irregularis (D'Orbigny) (pl. 86, fig. 2)	C	R	A	A		C	R		R	C	A	A	A	C	A	A		A	A	A	A	R	A	A		A	A	A		R		R	R
irregularis (D'Orbigny) var.																											R		R				
kerimbatica (Heron-Allen and Earland) (pl. 86, fig. 7)	R	R	R				R	C	C	C	R		R	R	C			R	R	C	R	R			R		C	R		R	R		
marshallana Todd (pl. 86, fig. 10)				R							R	R			R	R			R		R						C	R					
cf. *T. oblonga* (Montagu) (pl. 86, figs. 12, 13)	R		R	R	C	R	R	C		R	C				R		R	R	R	C	R		R	R	R	R	R	R	A	A		C	R
terquemiana (Brady) (pl. 85, fig. 15)	R	R					R	R	R	R				R	R			R	R	R			R	R						R			
transversestriata (Brady) (pl. 85, fig. 16)									R			R						R	R	R				R		R	R	R	C			R	R
tricarinata D'Orbigny (pl. 86, fig. 15)																												R	C				
tricarinata D'Orbigny var.																						R											
trigonula (Lamarck) (pl. 86, fig. 16)			R	C		R	R		R		C	R	R	R	C	R	R	R	R	R	R	C	R	A	A	A	A	R	C	C	A	A	A
trigonula (Lamarck) var. (pl. 86, fig. 17)	R						R		R		R																						
Pyrgo denticulata (Brady) (pl. 88, figs. 7, 8)	R			R	R				R			R	C	R	R		R	C	R	R	R		R						R			R	R
Biloculinella globula (Bornemann)																																	
Ophthalmidiidae:																																	
Cornuspira planorbis Schultze (pl. 88, fig. 9)	R								R		R	R	R		R		R	R	R	R					R	R	R		R	R			R
Vertebralina striata D'Orbigny (pl. 88, fig. 11)				R		R					R	R	C	R		R		C	C	R	R	R	C	R	R	R	C	R	R		C	C	R
Planispirina exigua (Brady)																																	
Wiesnerella auriculata (Egger) (pl. 88, fig. 10)									R						R					R													
Nubecularia lacunensis Chapman																																	
Parrina bradyi (Millett) (pl. 88, fig. 12)	R						R																			R	R						
Trochamminidae:																																	
Trochammina inflata (Montagu)																								R									
cf. *T. vesicularis* Goës																				R													
sp.																																	
Rotaliammina mayori Cushman					R		R				R		R			R																	R
Carterina spiculotesta (Carter)																			R														
Placopsilinidae:																																	
Haddonia torresiensis Chapman (pl. 88, figs. 13–15)		R			R																												
Lagenidae:																																	
Robulus sp. E (pl. 88, fig. 16)		R																	R														
Lagena spiralis Brady																																	
Polymorphinidae:																																	
Sigmomorphina semitecta (Reuss) var. *terquemiana* (Fornasini)																																	
Ramulina? sp. B																																	
Nonionidae:																																	
Nonion pacificum (Cushman)																													R			R	
Nonionella sp. (pl. 88, fig. 17)																																	
Elphidium advenum (Cushman) (pl. 88, fig. 20)					R		R			R							R	C	R				R				R	R				R	
crispum (Linné) (pl. 88, fig. 18)	R	C	R	R	R	R	R	R	C	C	R		R	C	R	R		R	R	R	C	R	R	R			R			R			
formosum Todd, n. sp. (pl. 88, fig. 22)				C	R														R			R		C	R	R	C			R		R	
hyalocostatum Todd, n. sp. (pl. 88, fig. 19)	R		R	A	A	R	R		C	C	C	R			R	R	R			R	A	R	R	A	R	C	R	A	C	R	C	R	R
simplex Cushman				R	R						R	R	R		R			R		C		R	R		R	R	C			R			R
striato-punctatum (Fichtel and Moll) (pl. 88, fig. 21)				R			C		A													A			A	C	A	C	R	R	C	R	
Camerinidae:																																	
Operculina sp.	R												R																				
Heterostegina suborbicularis D'Orbigny (pl. 93, fig. 5)	C	R				R	R	R	R	C					R			R		R	R							R					R
Peneroplidae:																																	
Peneroplis ellipticus D'Orbigny (pl. 89, fig. 1)				R			R		R	R	R				R		R	R	R	R	R		R	R	R	R	C	R		R	R		
proteus D'Orbigny (pl. 93, fig. 4)						R																											
Spirolina acicularis (Batsch)																	R			R						R						R	
arietina (Batsch) (pl. 89, figs. 2–4)	C	R	R	R		R		R	R	C			R	R	R		R	C	C	C	A	R	R	R		C	C	C	A	R	R	C	R
Monalysidium politum Chapman																																	
Sorites marginalis (Lamarck) (pl. 89, fig. 5)	R								R	R			R		R			A	A	C			R				R				R	R	R
Marginopora vertebralis Blainville (pl. 89, fig. 6; pl. 93, figs. 6–8)	C	C	C	C	R	C	C	C	C	C	C	A	C	A	C	R	R	C	A	C	A	A	C	C	C	C	C	A	A	C	A	A	A
Alveolinellidae:																																	
Borelis pulchrus (D'Orbigny)																																	

TABLE 4.—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Lagoonal area—Continued																										
	Coarse limesand and gravel bottom				Dredged areas			Mainly limesand bottom									Limesand bottom between patch reefs								Seaward from reef		
	E4	*E5*	*FX1*	*FX2*	*A2*	*A3*	*A4*	*C2*	*B4*	*B5*	*B6*	*B8*	*B9*	*A5a*	*A9*	*A10*	*A5*	*A6*	*A7*	*A8*	*A11*	*D5*	*D7*	*D7a*	*E6*	*E7*	*E8*
Miliolidae—Continued																											
Triloculina cuneata Karrer (pl. 86, fig. 11)	R	R	R	C	A	A	R	A			R	A	A	C	C	C		R	C	C	A		R	R	R	R	R
earlandi Cushman (pl. 85, fig. 17)	R			R	C	A	C	R		R	A	R		A	R		R	C	C	R							
incisura Todd, n. sp. (pl. 86, fig. 18)		R	R																						R		R
involuta Todd																							R				
irregularis (D'Orbigny) (pl. 86, fig. 2)	A	R	A	A	A	A		A	R	R	C	A	C	A	C	C	R	R	C	C	A		A	C	C	C	C
irregularis (D'Orbigny) var.		R					C	R											R			R	R				
kerimbatica (Heron-Allen and Earland) (pl. 86, fig. 7)		R	R	R	C	C	C	R			C	C	R	R	R	R	R			C	R	R	R	C	C	R	
marshallana Todd (pl. 86, fig. 10)	R	R		R	R	C	R			R	R		R		R					R	R		R	R	R	R	
cf. *T. oblonga* (Montagu) (pl. 86, figs. 12, 13)	C	R	R	A	C	C	R	R	R	R	A	C	R	C				R		R		R			R	R	
terquemiana (Brady) (pl. 85, fig. 15)				R								R								R			R	R	R	R	R
transversestriata (Brady) (pl. 85, fig. 16)					R		R	R		R	C	C	R	R												R	
tricarinata D'Orbigny (pl. 86, fig. 15)							R			R							R					R				R	
tricarinata D'Orbigny var.	R			R		R	R																			R	R
trigonula (Lamarck) (pl. 86, fig. 16)	C	R		C	A	A	A	C			C	R	R	A	R	R	R		R	R	R	R	C	C		R	R
trigonula (Lamarck) var. (pl. 86, fig. 17)					C	C								R							R						
Pyrgo denticulata (Brady) (pl. 88, figs. 7, 8)	R	R	R	C	C	R	R	R			R	R	R	R					R		C	R	R	R	R	R	C
Biloculinella globula (Bornemann)																									R		
Ophthalmidiidae:																											
Cornuspira planorbis Schultze (pl. 88, fig. 9)	R		R	C	R		R			R	C	R		R					R	R							R
Vertebralina striata D'Orbigny (pl. 88, fig. 11)	R	R	R	A	C	A	R	R		R	C	C	R	R		R		R	R	R	C	R	R	R	C	R	R
Planispirina exigua (Brady)												R															
Wiesnerella auriculata (Egger) (pl. 88, fig. 10)									R						R					R							R
Nubecularia lacunensis Chapman						R																					
Parrina bradyi (Millett) (pl. 88, fig. 12)					R	R		R										R			R						
Trochamminidae:																											
Trochammina inflata (Montagu)																											
cf. *T. vesicularis* Goës																											
sp.															R												
Rotaliammina mayori Cushman	R														R												R
Carterina spiculotesta (Carter)																											
Placopsilinidae:																											
Haddonia torresiensis Chapman (pl. 88, figs. 13–15)			R		R	R								R					R		R					R	
Lagenidae:																											
Robulus sp. E (pl. 88, fig. 16)																									R		
Lagena spiralis Brady											R																
Polymorphinidae:																											
Sigmomorphina semitecta (Reuss) var. *terquemiana* (Fornasini)						R																					
Ramulina? sp. B						R																					
Nonionidae:																											
Nonion pacificum (Cushman)	R			R	R			R														R					R
Nonionella sp. (pl. 88, fig. 17)																				R							
Elphidium advenum (Cushman) (pl. 88, fig. 20)	R					R	R	R		R	C		R	C				R									
crispum (Linné) (pl. 88, fig. 18)			R	R	R	A	C	R			R	C	R		R	R			R	R	R	C	C	C	A	C	R
formosum Todd, n. sp. (pl. 88, fig. 22)						R	R									R	R	R									
hyalocostatum Todd, n. sp. (pl. 88, fig. 19)	R	R	R	A	R			R			R				R	C	R		R		R	C	C	R	R	R	
simplex Cushman		R		R		R	R	R	R	R	C	R	R	R						C	R						R
striato-punctatum (Fichtel and Moll) (pl. 88, fig. 21)					A	A	C							C			R										
Camerinidae:																											
Operculina sp.				R				R																			
Heterostegina suborbicularis D'Orbigny (pl. 93, fig. 5)	R	R	C	C	A	A	C		C		C	R	R	C	R	R	R	C	R	R	R	R	R	C	R	C	R
Peneroplidae:																											
Peneroplis ellipticus D'Orbigny (pl. 89, fig. 1)	R	R		R		C	C	R			A	A	C	C			R	R	R	R		R		R	R		
proteus D'Orbigny (pl. 93, fig. 4)						C																					
Spirolina acicularis (Batsch)					R		R			R	R			R													
arietina (Batsch) (pl. 89, figs. 2–4)	R	R	C	A	A	A	R	R		C	C	R	R	R	R	R	R			R	R	R	R	R	R	C	R
Monalysidium politum Chapman										R	R		R														
Sorites marginalis (Lamarck) (pl. 89, fig. 5)	R	C			R		C	R		C	C	A	R	R	R		R	R	R	R			R				
Marginopora vertebralis Blainville (pl. 89, fig. 6; pl. 93, figs. 6–8)	C	A	A	A	A	A	A	C	C	R	C	C	C	C	R	C	C	C	C	A	C	R	C	C	C	C	R
Alveolinellidae:																											
Borelis pulchrus (D'Orbigny)		R			R																				R		R

TABLE. 4—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Beach and bar samples										Lagoonal area																						
	Beaches								Sand-bar adjoining beach		Limesand pockets within lagoonal reef patches						Areas of seaweed growth on limesand bottom																
	North-east coast		Northwest coast														Sparse to moderate growth					Abundant growth											
	Fahang	Nanasu	*C1b*	*B1ax*	*A1b*	Mañagaha Island	*D1*	*E1*	*D2*	*D2a*	*C1a*	*C1*	*C6*	*C7a*	*B10*	*D4*	*B2*	*C4*	*C5*	*B7*	*D3*	*A1a*	*C3*	*B1ay*	*B1b*	*B1*	*B3*	*A1*	Loc. 3	*E1a*	*E2a*	*E2*	*E3*
Heterohelicidae:																																	
Bolivinella folium (Parker and Jones) (pl. 89, fig. 7)	R														R				R	R							R	R	R				
Buliminidae:																																	
Buliminella milletti Cushman (pl. 89, fig. 8)	R														R		R	R		R													
Buliminoides williamsoniana (Brady) (pl. 89, fig. 9)	R												R		R				R										R				
Fissurina lagenoides (Williamson) (pl. 89, fig. 10)											R		R		R																		
cf. *F. marginata* (Montagu)															R																		
wrightiana (Brady) (pl. 89, fig. 11)																																	
Bolivina compacta Sidebottom (pl. 89, fig. 13)	R			C		R					C		R	R	C		R	R	R	C		R	R	C		C	C	R	A			C	R
ligularia Schwager (pl. 89, fig. 17)	R								R								R		R	R						C			R			R	R
pseudopygmaea Cushman (pl. 89, figs. 15, 16)	R			R		R							C	C	C			R	C	R	R		R						R				R
rhomboidalis (Millett) (pl. 89, fig. 18)				R							C				R		R	C	R	R		R		R		R	R		R			R	
cf. *B. semicostata* Cushman	R																																
spinea Cushman (pl. 89, fig. 20)	C			R	R						R		C		C			C	R	C			R	R		R	C					R	
striatula Cushman (pl. 89, fig. 14)					R				C		R		R				C	R	R	R		C		C	C	C	C		A			C	
tortuosa Brady (pl. 89, fig. 19)	C			A	R	R	R		R	R	A	R	C	C	A		R	A	C	C	C	R	C	A	R	A	A	C	A		R	R	R
sp. D (pl. 89, fig. 21)																																	
Loxostomum limbatum (Brady) (pl. 89, fig. 22)	R			C		R		R	R	R	R				R	R	R			R	C			R		R	C	R	C			R	R
Rectobolivina sp.											R																R						
Reussella simplex (Cushman) (pl. 89, fig. 23)	R	R	R	C	R	C	R	R	R	C	C	C	C	C	R	R	R	C	C	C	C		C	C	R	R	A	C	R	R	R	R	
Mimosina pacifica Cushman																				R													
Chrysalidinella fijiensis Cushman							R																										
Uvigerina porrecta Brady (pl. 89, fig. 24)				R									R							R			R	R			R		R				
Siphogenerina raphana (Parker and Jones) (pl. 89, fig. 12)	R	R	R	R			R	R	R	R			R	R	C			R	R		C		R		R	C		R	R	R			
Rotaliidae:																																	
Spirillina decorata Brady (pl. 90, fig. 1)	R					R			R				R							C			R										
inaequalis Brady																			R														
tuberculato-limbata Chapman (pl. 90, fig. 4)															R																		
vivipara Ehrenberg var. *densepunctata* Cushman																																	R
vivipara Ehrenberg var. *revertens* Rhumbler (pl. 90, fig. 2)	R																									R							
Conicospirillina semi-involuta Cushman																																	
trochoidea Cushman															R																		
Patellina advena Cushman																																	
Patellinella inconspicua (Brady) (pl. 90, fig. 3)																																	
jugosa (Brady)																																	
Discorbis candeiana (D'Orbigny) (pl. 90, fig. 9)									R		R						R	R					R						C			R	R
crustata Cushman											R																						R
fulva Todd, n. sp. (pl. 90, fig. 8)											R			R					R	R							R		R				
micens Cushman (pl. 90, fig. 7)																				R		R											
mira Cushman (pl. 90, fig. 5)																											R	R	R				R
opima Cushman (pl. 90, fig. 11)	R	R	R	R	R	R	R				R		A	R	C			R	C	C		R	R	R		R	C	R	R		R	R	
orbicularis (Terquem) (pl. 90, fig. 12)							R		R		R	R	R	R	R	R		C	C	R			R			R			R				
orientalis Cushman (pl. 90, fig. 13)				R		R						R		R			R				R		R			R	R						
patelliformis (Brady) (pl. 91, fig. 1)	R			R			R				R		R		R				R	R			R				R	R					
rugosa (D'Orbigny) (pl. 90, fig. 10)												R	R	R	R				R	R		C				C					R	C	C
tuberocapitata (Chapman) (pl. 91, fig. 2)																											R						
valvulata (D'Orbigny) var. *granulosa* (Heron-Allen and Earland) (pl. 90, fig. 6)				R	C		R	A	R															R						C		R	
Poroeponides cribrorepandus Asano and Uchio (pl. 93, fig. 9)							R		R	R									R	R	R							R					
Streblus beccarii (Linné) (pl. 91, fig. 3)			R	A			R	R	C	R						R	R		R		R	R		C	C	R	R	R	R	R	R	R	
beccarii (Linné) var. *tepida* (Cushman) (pl. 91, fig. 5)				A	A		R	C	R	R			R		R	R		R	R	R	R		R	A						C			
beccarii (Linné) var. (pl. 91, fig. 4)					C			R																	R					R			
Discorinopsis aguayoi (Bermudez)							R																										
Epistomaroides polystomelloides (Parker and Jones) (pl. 93, fig. 10)	R	R		R		R		R		R							R				R		R				R	R				R	R
Siphonina tubulosa Cushman (pl. 91, fig. 6)							R		R	R	R		R	R				R			R			R			R						
Siphoninoides echinata (Brady) (pl. 91, fig. 7)	R		R	C	C		C	C	A	A	A				R	R	R		R	R	C	C		R	A	R	R	C	R	R			R
glabra (Heron-Allen and Earland) (pl. 91, fig. 8)			R	R	R		R	R			R		R								R								R				
Cancris sagra (D'Orbigny)									R																								
Pegidiidae:																																	
Pegidia dubia (D'Orbigny) (pl. 93, fig. 11)	R	R																		R								R	R				
Sphaeridia papillata Heron-Allen and Earland (pl. 93, fig. 12)						R													R														
rugata Heron-Allen and Earland (pl. 91, fig. 9)										R			R							R			R										
Rugidia corticata (Heron-Allen and Earland)						R		R			R																						

TABLE 4.—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Lagoonal area—Continued																										
	Coarse limesand and gravel bottom				Dredged areas			Mainly limesand bottom									Limesand bottom between patch reefs								Seaward from reef		
	E4	*E5*	*FX1*	*FX2*	*A2*	*A3*	*A4*	*C2*	*B4*	*B5*	*B6*	*B8*	*B9*	*A5a*	*A9*	*A10*	*A5*	*A6*	*A7*	*A8*	*A11*	*D5*	*D7*	*D7a*	*E6*	*E7*	*E8*
Heterohelicidae:																											
Bolivinella folium (Parker and Jones) (pl. 89, fig. 7)					C		C			R	R	C	R	R			R			R			R			C	C
Buliminidae:																											
Buliminella milletti Cushman (pl. 89, fig. 8)					R			R	R		R	R	R	R						R							R
Buliminoides williamsoniana (Brady) (pl. 89, fig. 9)			R	R							R	R	R						R	R							R
Fissurina lagenoides (Williamson) (pl. 89, fig. 10)							R				R									R							R
cf. *F. marginata* (Montagu)																											
wrightiana (Brady) (pl. 89, fig. 11)																					R						
Bolivina compacta Sidebottom (pl. 89, fig. 13)	R		R	A	R		C	R		R	A	C	R	R	R	R			R	C	R					C	C
ligularia Schwager (pl. 89, fig. 17)							R	R		R	C			R					R	R	R						
pseudopygmaea Cushman (pl. 89, figs. 15, 16)	R		R	A			C	C			R	A	R	R		R	R	R	R	R	C	R	C			C	A
rhomboidalis (Millett) (pl. 89, fig. 18)	R			R			R	R		R	R	R	R	R			R	R		C	R					R	
cf. *B. semicostata* Cushman																											
spinea Cushman (pl. 89, fig. 20)	R			A	R	R	C	C		C	A	C	C	C		R		R	R	R	C		R			R	R
striatula Cushman (pl. 89, fig. 14)	R			R	R	R	R			R	R	R		R				R		R			R				
tortuosa Brady (pl. 89, fig. 19)	C	R	C	A	A	C	A	A		A	A	C	C	A	R	C	R	A	C	A	C	R	C		R	A	A
sp. D (pl. 89, fig. 21)																			R								
Loxostomum limbatum (Brady) (pl. 89, fig. 22)	R			R	A	R	R				R			R		R		R		R	R	R			R		R
Rectobolivina sp.				R	R																R	R					R
Reussella simplex (Cushman) (pl. 89, fig. 23)	R	R	C	A	A	A	A	R		R	A	A	R	C	R	R	R	R	C	C	C	C	C	C	A	C	C
Mimosina pacifica Cushman										R	R									R							
Chrysalidinella fijiensis Cushman																											
Uvigerina porrecta Brady (pl. 89, fig. 24)				R			R			R	R	R	R	R				R	R	R	R						
Siphogenerina raphana (Parker and Jones) (pl. 89, fig. 12)			R	C	C	C		R			C	C	R			R			R	R	C	R	C	C	R	R	R
Rotaliidae:																											
Spirillina decorata Brady (pl. 90, fig. 1)							R	R			R	R												R		R	R
inaequalis Brady												R															
tuberculato-limbata Chapman (pl. 90, fig. 4)																					R						
vivipara Ehrenberg var. *densepunctata* Cushman	R			R																							R
vivipara Ehrenberg var. *revertens* Rhumbler (pl. 90, fig. 2)	R			R																R							
Conicospirillina semi-involuta Cushman												R															
trochoidea Cushman																											
Patellina advena Cushman	R																										
Patellinella inconspicua (Brady) (pl. 90, fig. 3)																			R								
jugosa (Brady)											R																
Discorbis candeiana (D'Orbigny) (pl. 90, fig. 9)				R	R		R	R							R						R						
crustata Cushman		R								R																R	
fulva Todd, n. sp. (pl. 90, fig. 8)			R				R				R	R						R		R							
micens Cushman (pl. 90, fig. 7)				R			R																				
mira Cushman (pl. 90, fig. 5)				R	C	R								R													
opima Cushman (pl. 90, fig. 11)	R		R	C	C	A	R	C			C	C	R	R	R	R			R	C	A				R	C	A
orbicularis (Terquem) (pl. 90, fig. 12)				C	R	R	R	R	R	R	R	C	R	R	R	R			R		R						C
orientalis Cushman (pl. 90, fig. 13)		R	R	R		R				R	R	R						R			R	R			R		
patelliformis (Brady) (pl. 91, fig. 1)				C	C	R	C	R			C	C	R	R			R	R	R	C	R		R		R	R	R
rugosa (D'Orbigny) (pl. 90, fig. 10)		R		R	R	R		R		R	R		R							R	R	R					
tuberocapitata (Chapman) (pl. 91, fig. 2)					R	R		R																			
valvulata (D'Orbigny) var. *granulosa* (Heron-Allen and Earland) (pl. 90, fig. 6)																C										R	
Poroeponides cribrorepandus Asano and Uchio (pl. 93, fig. 9)		R	R	R	R	C	R		R		R			R			R	R			R		R	C	R	R	R
Streblus beccarii (Linné) (pl. 91, fig. 3)					R	C	C		R		C		R	C		R	R					R			R		
beccarii (Linné) var. *tepida* (Cushman) (pl. 91, fig. 5)	R	R		R	R			R		R	R	C	R		R		R	R	R	R	R	R			R	R	C
beccarii (Linné) var. (pl. 91, fig. 4)																											
Discorinopsis aguayoi (Bermudez)																											
Epistomaroides polystomelloides (Parker and Jones) (pl. 93, fig. 10)	R				C	C	C	R	R			R	R				R	R		R	R	R	R	R		R	
Siphonina tubulosa Cushman (pl. 91, fig. 6)				R	R	R															R	R	R	R	R	R	R
Siphoninoides echniata (Brady) (pl. 91, fig. 7)	R		R	R	A	A	C	R			R	R		C	R	R	C	R	R	R	R	R	R	C	C	R	R
glabra (Heron-Allen and Earland) (pl. 91, fig. 8)				R		R	R															R			R		
Cancris sagra (D'Orbigny)																											R
Pegidiidae:																											
Pegidia dubia (D'Orbigny) (pl. 93, fig. 11)			R	R	R	R	R												R	R					R		
Sphaeridia papillata Heron-Allen and Earland (pl. 93, fig. 12)				R														R	R	R				R			
rugata Heron-Allen and Earland (pl. 91, fig. 9)					R	R					R											R	R	R	R		
Rugidia corticata (Heron-Allen and Earland)				R							R	R		R				R									

TABLE 4.—*Distribution of Recent smaller Foraminifera of Saipan*—Continued

[A indicates abundant; C, common; R, rare]

	Beach and bar samples										Lagoonal area																						
	Beaches								Sand-bar adjoining beach		Limesand pockets within lagoonal reef patches						Areas of seaweed growth on limesand bottom																
	North-east-coast		Northwest coast														Sparse to moderate growth					Abundant growth											
	Fahang	*Nanasu*	*C1b*	*B1ax*	*A1b*	*Managaha Island*	*D1*	*E1*	*D2*	*D2a*	*C1a*	*C1*	*C6*	*C7a*	*B10*	*D4*	*B2*	*C4*	*C5*	*B7*	*D3*	*A1a*	*C3*	*B1ay*	*B1b*	*B1*	*B3*	*A1*	*Loc. 3*	*E1a*	*E2a*	*E2*	*E3*
Amphisteginidae:																																	
Amphistegina madagascariensis D'Orbigny (pl. 93, fig. 13)	A	C	R			R		C	R	R		R	R	R	C			C	C	C			C					R		R			
Calcarinidae:																																	
Calcarina spengleri (Gmelin) (pl. 91, fig. 11)			R	R	R	R	C	R	R	C							R				R	R			R	R	C	C		R		R	C
Baculogypsina sphaerulata (Parker and Jones) (pl. 91, fig. 13; pl. 93, fig. 14)	R		A	A	A	R	A	A	A	A	C	R	R			C	C	R	R	R	A	A	R	A	R	R	R	A	C	A		R	
Cymbaloporidae:																																	
Cymbaloporetta bradyi (Cushman) (pl. 91, fig. 12)			C	A		R					A	R	A	C	R	R	R	A	A	R	R	R	A	A	R	A	A	C	R		R	R	R
squammosa (D'Orbigny) (pl. 91, fig. 10)	R	C	R	A		C	R	R		R	C	C	C	C	A		R	A	A	A	C		A	C	R	A	A	R	R	R	R	R	C
Cymbaloporella tabellaeformis (Brady)												R																					
Tretomphalus concinnus (Brady) (pl. 92, fig. 4)	R													R				R		R						R			R			R	
planus Cushman (pl. 92, fig. 3)										C					R				R					R			R						
Cassidulinidae:																																	
Epistominella tubulifera (Heron-Allen and Earland) (pl. 92, fig. 1)	R									R			R	R	R			R			R						R						
sp. D (pl. 92, fig. 2)																																	
Cassidulina minuta Cushman	R																																
Robertinidae:																																	
Alliatina translucens (Cushman)	R								R				R					R												R			R
Cushmanella sp.																			R														
Globigerinidae:																																	
Globigerina sp. D (pl. 92, fig. 6)													R		R									R			R						
Globigerinoides conglobata (Brady) (pl. 92, fig. 8)			R															R	R	R			R	R									
rubra (D'Orbigny) (pl. 92, fig. 9)	R												R					C	R		R		R										
sacculifera (Brady) (pl. 92, fig. 7)	R		R	R		R		R			R		R	R	R		R	R	R	R	R		R	R		R	R						
Orbulina? sp. (pl. 92, fig. 5)															R								R										
Anomalinidae:																																	
Anomalina glabrata Cushman																R																	
? maculosa Todd, n. sp. (pl. 92, fig. 12)						R			R		R	R			R				R				R	R		R	R	R					
Cibicides cf. *C. cicatricosus* (Schwager) (pl. 92, fig. 11)		R				R	R			R		R	R	R	C				R	R	R		R	R		R		R	R				
lobatulus (Walker and Jacob)	R				R	R				R	R				R			R	R	R	R	R	R				R		R		R		R
mayori (Cushman) (pl. 92, fig. 10)		R									R				R								R			R	R					R	R
cf. *C. pseudoungerianus* (Cushman)				R			R							R	R			R			R			R					R		R	R	
Cibicidella variabilis (D'Orbigny)	R						R		R		C			R	R			R								R	R	R	C				
Planorbulinidae:																																	
Planorbulina acervalis Brady (pl. 92, fig. 13)	R	C	C			C	R		R		R	C	C	C	C	R		R	C	R	R	R	R	C		R	C	C	R		R	R	C
? rubra D'Orbigny (pl. 92, fig. 14)													R	R	R			R	R				R										
Acervulina inhaerens Schultze (pl. 93, fig. 15)		R									R	R		R	R			R		R	R		R				C		R				
sp. (pl. 92, fig. 15)		R	R											R	R			R															
Gypsina globula (Reuss)	R		R	C		R	R	R			R	R	R	R	R		R	R	R				R	R	R	R	R		R	R	R	R	
vesicularis (Parker and Jones) (pl. 93, figs. 16, 17)																																	
Rupertiidae:																																	
Carpenteria proteiformis Goës (pl. 93, fig. 18)	R													R																			
Homotremidae:																																	
Homotrema rubrum (Lamarck)	R	R	R	R		R	R		R		R	C	R	R	C		R	R	R		R		R		R		R						

TABLE 4—*Distribution of Recent smaller Foraminifera of Siapan*—Continued

[A indicates abundant; C, common; R, rare]

	Lagoonal area—Continued																										
	Coarse limesand and gravel bottom				Dredged areas			Mainly limesand bottom									Limesand bottom between patch reefs								Seaward from reef		
	E4	*E5*	*FX1*	*FX2*	*A2*	*A3*	*A4*	*C2*	*B4*	*B5*	*B6*	*B8*	*B9*	*A5a*	*A9*	*A10*	*A5*	*A6*	*A7*	*A8*	*A11*	*D5*	*D7*	*D7a*	*E6*	*E7*	*E8*
Amphisteginidae:																											
Amphistegina madagascariensis D'Orbigny (pl. 93, fig. 13)			C	C		A	A	R	R	R	C	A	C			R	C	C	C	R	R		R	C	C	C	C
Calcarinidae:																											
Calcarina spengleri (Gmelin) (pl. 91, fig. 11)		R			C	C			R			R					R					R	C	C	R		
Baculogypsina sphaerulata (Parker and Jones) (pl. 91, fig. 13; pl. 93, fig. 14)	R	A	C	C	A	C		R	A		R	R	R	R	C	A	C	R		C	A	A	A	A	A	A	
Cymbaloporidae:																											
Cymbaloporetta bradyi (Cushman) (pl. 91, fig. 12)	R		R	R	A	A	R	A				A	C	C	R		R	R	R	R	A	R	R	R	R	R	
squammosa (D'Orbigny) (pl. 91, fig. 10)	R	R	C	A	A	A	C	A		R	A	A	R	C	C	C	R		C	C	A	R	R	R	R	R	R
Cymbaloporella tabellaeformis (Brady)						R							R								R						
Tretomphalus concinnus (Brady) (pl. 92, fig. 4)	R					R					R									R		R	R				
planus Cushman (pl. 92, fig. 3)											R			R													
Cassidulinidae:																											
Epistominella tubulifera (Heron-Allen and Earland) (pl. 92, fig. 1)			R	R	R						R	R	R	R						R	R	R	R	R	R	R	R
sp. D (pl. 92, fig. 2)									R			R	R								R		R				
Cassidulina minuta Cushman							R				R			R													
Robertinidae:																											
Alliatina translucens (Cushman)										R	R		R	R													R
Cushmanella sp.												R															
Globigerinidae:																											
Globigerina sp. D (pl. 92, fig. 6)								R			R	R		R					R	R	R						
Globigerinoides conglobata (Brady) (pl. 92, fig. 8)							R							R		R		R								R	
rubra (D'Orbigny) (pl. 92, fig. 9)				R				R			R		R	R						R							
sacculifera (Brady) (pl. 92, fig. 7)	R		R	R	R	R	R	R			C	R	R	R		R				R	R	R	R		R	R	R
Orbulina? sp. (pl. 92, fig. 5)											R	R															
Anomalinidae:																											
Anomalina glabrata Cushman				R		R																					
? maculosa Todd, n. sp. (pl. 92, fig. 12)		R			C	R		R			R		R						R		R	R			R		
Cibicides cf. *C. cicatricosus* (Schwager) (pl. 92, fig. 11)	R		R	R	R	R				R	R	R						R			R	R	R		R	R	R
lobatulus (Walker and Jacob)			R	R	R	R	R	R			C	R	R				R		R	R	R		R			R	R
mayori (Cushman) (pl. 92, fig. 10)				R	R	C	R	R													R					R	
cf. *C. pseudoungerianus* (Cushman)			R	R	R	R	R					R		R			R			R							R
Cibicidella variabilis (D'Orbigny)			R	C	R	R		R					R	R				R		R							
Planorbulinidae:																											
Planorbulina acervalis Brady (pl. 92, fig. 13)	R	R	R	C	A	A	C	C		R	C	R	R	R	R	R	R	R	R	R	A	R	R	R	R	R	R
? rubra D'Orbigny (pl. 92, fig. 14)								R			R	R	R	R							R						
Acervulina inhaerens Schultze (pl. 93, fig. 15)				R	R	R	R	R			R	R			R				R		C						R
sp. (pl. 92, fig. 15)													R			R		R									
Gypsina globula (Reuss)	R	R	R	R	R	C	R	R		R	R	R	R	R	R	C	R	R	R	R	R	R	R	R	R	R	R
vesicularis (Parker and Jones) (pl. 93, figs. 16, 17)						R	R												R						R		
Rupertiidae:																											
Carpenteria proteiformis Goës (pl. 93, fig. 18)					R	R	R														R					R	
Homotremidae:																											
Homotrema rubrum (Lamarck)		R	R	R				R	R		R	C	C	R	C	C	R	R	R	C	C	R	R	R	R	R	R

DIFFERENCES FROM MARSHALL ISLANDS FAUNA

Two instances were noted in which this fauna is different from that of similar environments in the Marshall Islands. The more striking of these is the presence in abundance of *Baculogypsina sphaerulata* (Parker and Jones) around Saipan. This species was not found in the Recent sediments examined from four atolls of the northern Marshall Islands, and only very rarely in fossil material from drill holes on Bikini in the Marshall Islands. Its comparable position as a major component of beach sands is occupied in the Marshall Islands by *Calcarina spengleri* (Gmelin). *Calcarina spengleri* is also present with *Baculogypsina sphaerulata* around Saipan but invariably has a subordinate position.

The second distinctive feature of Saipan's Recent fauna is the presence of *Streblus beccarii* (Linné) and its varieties. These also, like *Baculogypsina*, were not found in the surface sediments of the Marshall Islands but only in the wells drilled on Bikini. Unlike *Baculogypsina*, *Streblus beccarii* has a worldwide distribution. Therefore, its apparently very recent disappearance from the Marshall Islands is probably not accidental, but significant of some change in environment which reacted unfavorably on that species.

A unique occurrence in one of the beach samples USGS f11381 *(D1)* is worthy of note. If we can assume the single specimen did not enter in by contamination, *Discorinopsis aguayoi* (Bermudez) is present in Tanapag Lagoon. The species is otherwise known only from coastal and brackish environments in Cuba (Bermudez, 1935, p. 204, pl. 15, figs. 10–14) and the Gulf of Paria, Trinidad (Cushman and Brönnimann, 1948, p. 20, pl. 4, figs. 9, 10, *"Discorinopsis vadescens,"* a synonym). The environment on Saipan in which the specimen was found is probably not unsuitable for such a form, but the means by which it got to Saipan, if it did, across totally unsuitable environments are open to question. It may be mentioned, however, that living specimens have been introduced by marine equipment, but over much shorter distances, into Salton Sea (Rogers, 1949, p. 24).

CALCARINA-BACULOGYPSINA DISTRIBUTION PROBLEM

The distribution of the two closely related genera, *Calcarina* and *Baculogypsina*, presents a unique problem. Both genera are restricted to the Indo-Pacific area both as living species and as fossils. Furthermore, within the Indo-Pacific area, they may occur together, as around Saipan, or singly as in the case of *Calcarina* in the Marshall Islands. Both are believed to be mainly, if not wholly, inhabitants of the surfaces of reefs that are awash at low tide. Because of their very coarse spines, they are well adapted to being enmeshed in the algal mats that are present on such reef surfaces. The problem of their distribution is a part of the general problem of distribution of all benthonic Foraminifera.

It appears probable that such benthonic forms as *Calcarina* and *Baculogypsina* with both general (Indo-Pacific) and specific (reef) restrictions on their occurrences have a planktonic stage during which dissemination is effected. If this is so, then currents probably play a major part in their distribution. If the two genera originated in two areas, remote from each other, or became diversified from an ancestral root and spread to remote areas, then oceanic currents may explain in part the peculiar occurrence pattern of *Calcarina* and *Baculogypsina*. Conversely, the occurrence pattern of the two genera in the fossil record, when more completely known, may shed some light on the ocean currents of past geologic epochs.

RELATIONSHIPS TO OTHER FAUNAS

Faunal affinities are more easily recognized in the planktonic element of a fauna than in the benthonic element. Most benthonic species give more significant information about their habitats than their geologic age.

The Eocene and Oligocene Saipan faunas appear to show a closer affinity to those of equivalent age to the east (America and Europe) than to the west and south (Asia and Indonesia). Previous notable instances in which strong affinities with American faunas have appeared in foraminiferal faunas of the Pacific are those of the Upper Cretaceous and Tertiary planktonic faunas obtained from the mid-Pacific flat-topped seamounts (Hamilton, 1953).

The apparent affinity between American and Saipan faunas may be biased by more complete knowledge of the American faunas of equivalent facies, and my better acquaintance with American than with Asian and Indonesian faunas. Estimates of faunal affinities are further affected by the possibility of certain widespread species having both an eastern (American) and a western (Asian) name, for example: *Globigerinoides index* Finlay vs. *Globigerinoides semiinvolutus* Keijzer, *Sphaeroidinella kochi* (Caudri) vs. *Globigerina grimsdalei* Keijzer, and *Poroeponides cribrorepandus* Asano and Uchio vs. *Eponides repandus* (Montfort).

Few of the published Eocene and Oligocene foraminiferal faunas of the regions to the west and south of Saipan (Asia and Indonesia) are comparable in facies to those of Saipan, and thus little can be determined about their relative ages.

Of the Miocene faunas from the west and south, some described by LeRoy (1939, 1941, 1944) and Keyzer (1953) are generally similar in facies to the Miocene strata of Saipan, particularly to the Donni beds. Although the ages are not equivalent (older on

Saipan), the faunal affinities are closer to the west than to the east in these beds.

PRESERVATION OF MATERIAL

The Recent sediments surrounding Saipan yield beautifully preserved, mostly unworn and empty, tests of Foraminifera. The Miocene Foraminifera are moderately well preserved. Most of the Oligocene Foraminifera are not well preserved and are obscured by adhering matrix. The Eocene Foraminifera occur in two forms: original shell material usually rather well preserved and showing the surface ornamentation, and replacements and internal casts composed of the zeolite mineral heulandite (Switzer and Boucot, 1955). The internal casts, when complete and not eroded, preserve even the perforations through the shell wall as fine spines on the surface of the cast. (See pl. 71, fig. 3.) So far as can be determined, no different species are represented by internal casts than are present as original tests.

The fauna of the Hagman formation at USGS f21090, f21115, f21116, f21120, and f21128 (S273, S346, S348, S361a, and S597) is represented wholly by these replaced specimens and internal casts. The remaining five Hagman samples contain original shells. The fauna of the Hagman formation thus exists as original shells in one part of the formation and as replaced specimens only in another part of the formation. This suggests the possibility of differential solution in the part of the Hagman where no original shells were found.

The fauna of the Densinyama formation at USGS f21042 (S26), on the other hand, contains both original and a few replaced shells and suggests the possibility of the following sequence of stages: *a*, Deposition of Foraminifera under marine conditions; *b*, filling of interiors of tests with heulandite; *c*, solution of original calcareous shell material; *d*, erosion of the original sediments (either subaerial or submarine erosion); and *e*, redeposition of the heulandite casts under marine conditions together with original tests of the same species still living under marine conditions similar to *a*.

The conditions under which foraminiferal tests may be filled with heulandite have not been conclusively determined, but Switzer and Boucot (1955, p. 531) suggest a low-temperature hydrothermal process which presumably does not require elevation above sea level. Evidence from the present series of samples as well as evidence from occurrence of heulandite fillings and replacements in America (Switzer and Boucot, 1955, p. 529–531) indicates that it may happen nearly simultaneously with deposition.

DESCRIPTIONS OF NEW SPECIES AND NOTES ON OTHER SPECIES

INTRODUCTORY STATEMENT

Following are descriptions of the 34 species here described as new: 14 from the Eocene, 2 from the Oligocene, 8 from the Miocene, and 10 from the Recent. Included alphabetically with these 34 descriptions are incomplete descriptions of and notes on 25 selected additional species, mostly indeterminate. These 25 selected species do not include all the indeterminate species noted on the distribution charts. The remaining approximately 480 species and varieties are not described here. Hence, arrangement of species in the following pages is not systematic but alphabetical for ease in finding.

Four tables list completely the identified species found in the Eocene, Oligocene, and Miocene strata and the Recent beach and lagoon sediments. In these tables the species are arranged systematically following in general the classification of J. A. Cushman (1948). Included in the Selected bibliography are references wherein the identified species are described or restudied.

TAXONOMIC INCONSISTENCIES

In the light of new knowledge of Recent smaller Foraminifera it appears that some minor revisions are needed in the Cushman classification: particularly the bases for generic separations. The separations most in question in this study are those between *Quinqueloculina* and *Triloculina*, *Spiroloculina* and *Massilina*, *Bolivina* and *Loxostomum*, *Bulimina* and *Buliminella*, and *Uvigerina* and *Angulogerina*. The recognition of these as apparent form genera leads one to regard other generic separations with misgivings. Nevertheless, pending further firsthand experience and additional evidence from other sources, I prefer to follow the current usage. As a matter of convenience, I am also following current usage in separating such apparent form species as *Quinqueloculina sulcata* and *Q. ferussaci* (pl. 86, figs. 3–6) and *Sphaeroidinella dehiscens*, *S. seminulina*, and *S. kochi* (pl. 79, figs. 6–8).

SYSTEMATIC DESCRIPTIONS

Alabamina conica Todd, n. sp.

Plate 69, figure 11

Test large for the genus, planoconvex with a tendency toward flanging on the highly convex ventral side; periphery acute but not keeled. Chambers indistinct, not inflated, 5 constituting the last whorl, rapidly increasing in size and particularly in thickness as added. Sutures indistinct, flush; dorsal ones tangential and slightly curved; ventral ones nearly radial but sharply curved at their inner ends. Wall calcareous, finely perforate, smooth. Aperture elongate, rather widely open, under the ventral edge of the last-formed chamber. extending from the umbilical region to the infolded portion of the wall just ventral to and parallel with the periphery. Diameter 0.35–0.55 mm; thickness 0.25–0.30 mm.

Holotype (USNM 623894) from the upper Eocene, Densinyama formation, northern Saipan, USGS f21042 (S26).

This species differs from *Alabamina wilcoxensis* Toulmin in having a larger and more distinctly flanged test and a wider aperture.

Amphistegina madagascariensis D'Orbigny and related species

Plate 69, figures 8–10; plate 84, figures 2, 3; plate 93, figure 13

Specimens belonging to the genus *Amphistegina* constitute large proportions of the smaller Foraminifera populations found in the relatively shallow-water sediments of the upper Eocene, Miocene (exclusive of Donni sandstone), and Recent of Saipan.

The Recent specimens occur abundantly in most of the bottom samples from Tanapag Lagoon. They exhibit a wide range in size, relative thickness, translucency of the test, and limbation of sutures. In general, the specimens are relatively thick, have about 10 chambers per adult whorl, and appear to belong to a single species. This same species, including similar wide variations, is abundant in the Miocene Tagpochau limestone. The genus *Amphistegina* is abundant in the Eocene Densinyama formation and also occurs, mostly as worn and broken specimens, in the Hagman formation and the Matansa limestone. In these Eocene strata, two rather distinct forms are present: a smoothly lenticular form with indistinct sutures (see pl. 69, fig. 9) and a form with dark, limbate, but not raised, sutures and a test that is thick in the central part leaving the outer edge as a peripheral flange (see pl. 69, fig. 8). These two forms are found together and are gradational to one another. This suggests that ecologic control rather than specific difference is the explanation for these two forms. It is not possible to say specifically whether variation in depth, agitation of the bottom, turbidity, or other conditions are responsible for these differences.

Further study of additional suites of better preserved material may permit the recognition of specific differences between the fossil and the Recent Amphisteginas. For the present, the Miocene and Recent ones are regarded as a single species, with the Eocene ones as a closely related ancestral form of the same species.

Judging from the abundance of *Amphistegina madagascariensis* in the lagoon at Saipan, the species is regarded as indicative of shallow water, or of the nearness upslope of shallow water. In the northern Marshall Islands this species was found in abundance throughout the lagoons and on the outer slopes of the atolls down to several hundred fathoms.

Anomalina? maculosa Todd, n. sp.

Plate 92, figure 12

Test nearly globular, rotaliform, slightly evolute on the dorsal side; ventral umbilicus closed and very slightly depressed. Chambers indistinct; probably 6 or 7 constituting the adult whorl. Sutures only faintly discernible. Wall calcareous, thick, translucent, polished, smooth surfaced, pitted with large, closely and irregularly spaced perforations, with an unperforated glassy area over the umbilicus and on the last chamber just above the aperture. Aperture a very low elongate opening under the sharp edge of the last chamber extending from the umbilicus to the peripheral plane. Diameter 0.35–0.55 mm; thickness 0.25–0.35 mm.

Holotype (USNM 624126) from the Recent, western Saipan, Tanapag Lagoon, USGS f11348, about one-third of a mile directly northwest off beach at Puerto Rico. Cloud's (1957) traverse *A*, station *2*. Hummocky limesand bottom with abundant growth of *Halimeda* at depth of 18 feet in dredged harbor area.

This species is distinctive in the closely spaced coarse perforations that give the otherwise smooth and glassy surface a mottled appearance. The openings of the perforations appear as white dots in the dark transparent wall, and the tubes viewed obliquely within the thick wall appear as irregular white lines. The very compact, nearly involute structure of the test together with the coarse perforations suggest Anomalinidae rather than Rotaliidae, and the species is questionably placed in *Anomalina*.

Asterigerina fimbriata Todd, n. sp.

Plate 69, figure 3

Test planoconvex; dorsal side flat; ventral side smoothly conical; periphery entire, acute with a translucent fimbriate keel. Chambers indistinct, not inflated, about 8 in the last-formed whorl, very gradually increasing in size as added, so that the outline of the test remains nearly circular. Sutures limbate but neither raised nor depressed; spiral suture outlining at least two whorls on the dorsal side; dorsal sutures straight and tangential; ventral sutures radial, outlining the elongate supplementary chambers. Wall calcareous, perforate, smooth or finely granular, with a small papillate area just in front of the aperture. Aperture low, under the ventral edge of the last-formed chamber. Diameter 0.50–0.60 mm; thickness 0.22–0.28 mm.

Holotype (USNM 623799) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species resembles *Asterigerina alabamensis* Cushman and McGlamery in having a fimbriate peripheral keel but differs in being a more tightly coiled form (thus more steeply conical) and in the earlier whorls occupying a larger area on the dorsal side.

Asterigerina venusta Todd, n. sp.

Plate 83, figure 9

Test compressed, about equally biconvex; the umbilicus filled by a prominent knob of clear shell material; periphery entire, acute but not keeled. Chambers indistinct, about 10 in the last-formed whorl, very gradually increasing in size as added, not inflated; secondary ventral chambers large, narrow, elongate, and extending nearly to the periphery at their outer ends. Sutures indistinct, curved and strongly oblique on the dorsal side with only those of the last whorl and one volution of the spiral suture visible, radial but strongly curved at their outer ends on the ventral side. Wall unornamented except for a papillate area on the ventral side in front of the aperture. Aperture a low arched opening near the periphery, in a reentrant of the apertural face. Greatest diameter 0.75–1.00 mm; thickness 0.33–0.43 mm.

Holotype (USNM 624105) from the Miocene, Tagpochau limestone, northwest Saipan, USGS f21525 (S147). The species occurs in great abundance at locality S147 but was not found elsewhere on Saipan.

This species differs from *Asterigerina subacuta* Cushman, with which it occurs, in having a compressed biconvex test and more numerous chambers.

Baggina parva Todd, n. sp.

Plate 83, figure 8

Test small for the genus, compressed; periphery not indented. Chambers indistinct, not inflated, 5 constituting the last whorl, very rapidly increasing in size as added, the last-formed chamber making up about one-third the test. Sutures indistinct, limbate, flush with the surface, straight with a slight curve at their outer ends. Wall smooth; large clear lunate area on ventral face of the last chamber. Aperture ventral, under the umbilical edge of the last chamber. Length 0.35–0.43 mm; breadth about 0.30 mm; greatest thickness about 0.22 mm.

Holotype (USNM 624074) from the Miocene, Tagpochau limestone, east-central Saipan, USGS f21582 (S666).

This species differs from *Baggina gibba* Cushman and Todd from the Miocene of Europe in having a much smaller and more compressed test and a lack of inflation of the chambers.

Bolivina densa Todd, n. sp.

Plate 82, figure 2

Test short, broad, thick; initial end pointed; periphery acute (even around the apertural end), irregular, not keeled; the plane of the test slightly twisted. Chambers few, indistinct, rapidly increasing in size and especially in breadth as added, not inflated. Sutures indistinct, strongly curved, limbate but neither raised nor depressed. Wall calcareous, covered throughout by a fine roughness with the addition of numerous faint costae over the initial part. Aperture indistinct, a very narrow elongate slit extending into the apertural face about as far as half the breadth of the chamber. Length about 0.37 mm; breadth across apertural end about 0.30 mm; thickness about 0.15 mm.

Holotype (USNM 624063) from the Miocene, Tagpochau limestone, east-central Saipan, USGS f21582 (S666).

This species differs from *Bolivina tortuosa* Brady in having a thicker test with irregular periphery, very strongly curved sutures, a rough surface (although this might be a result of its fossilization), and a less strongly twisted test.

Bolivina subrhomboidalis Todd, n. sp.

Plate 66, figures 13–15

Test small for the genus, short and tapering, broad and thick at the apertural end; some specimens rhomboid in section with the plane of the test slightly twisted and a thick truncate apertural end; other specimens with only a faintly rhomboid character and a compressed apertural end; periphery rounded to acute, irregularly lobulated. Chambers few, strongly overlapping, not very distinct, not inflated, very rapidly increasing in size as added. Sutures rather indistinct except when moistened, flush, strongly curved. Wall calcareous, finely perforate; surface rather rough and granular. Some specimens ornamented by longitudinal costae that are most prominent over the initial end and the peripheries of the test. A few backward-projecting peripheral spines are rarely present on the more strongly rhomboid individuals. Aperture large, elongate in the plane of the test, slightly rimmed. Length 0.30–0.37 mm; breadth 0.20–0.22 mm; thickness 0.12 mm.

Holotype (USNM 623780) from the upper Eocene, Hagman formation, northeast-central Saipan USGS f21125 (S385).

This species differs from *Bolivina rhomboidalis* (Millett) in the rhomboid character of the test being much less strongly developed; in the wall being finely, not coarsely, perforate; and in the occasional presence of longitudinal costae.

This species is abundant in the Hagman formation and, as interpreted here, includes a rather wide range of variation as described above. In most of the specimens the rhomboid character is faint or not recognizable. Of 85 individuals examined from the type locality, only 3 had peripheral spines.

Bolivina spp. A and B

Plate 66, figures 19, 20

A variety of unnamed and probably undescribed Bolivinas are found in the upper Eocene sediments. Two forms are illustrated: one a compressed, nearly parallel-sided form with straight oblique sutures (pl. 66, fig. 19) and the other a more tapering form, slightly thicker in the middle, with curved sutures (pl. 66, fig. 20).

Buliminella septata Keyzer

Plate 73, figure 3; plate 75, figures 27–29

Buliminella septata Keyzer, 1953, Leidse Geol. Mededel., v. 17, p. 276, pl. 1, figs. 26–29.

Test nearly globular. Chambers strongly embracing. Sutures indistinct, flush, limbate, scalloped on the part of test opposite to the aperture. Wall thick, ornamented by rough irregular translucent costae over the lower part of the test that are rarely extended into basal spines, the costae coinciding in position and accentuating the scallops, and by fine lines and costae radiating out from the aperture. Aperture small, circular, in a deep depression at the base of the apertural face, surrounded by a very low collar present only on the three sides that are bordered by the final chamber. Length 0.85–1.25 mm; diameter 0.65–0.80 mm.

This species was described from the Miopliocene of Buton in the Malay Archipelago. Found in association with it there was another species, *B. sculpturata* Keyzer (1953, p. 276, pl. 1, figs. 20–22), that seems to be represented in the Saipan material by immature individuals. Although these two species are clearly distinct in the Buton material, the present suite of specimens from Saipan includes gradational forms between immature individuals (see pl. 75, figs. 28, 29), comparable to *B. sculpturata*, and adult individuals (see pl. 73, fig. 3; pl. 75, fig. 27), comparable to *B. septata.*

The scalloped sutures characterize this species and seem to relate it to *Buliminella grata* var. *spinosa* Parker and Bermudez (1937, p. 516, pl. 59, fig. 7) described from the Eocene of Cuba.

The species occurs in the upper Oligocene, Fina-sisu formation, southern Saipan, USGS f21133 (C85) and at three Miocene localities, USGS f21578, f21588, and f21345 (S621, S682, and B333). The Miocene specimens are somewhat larger and have a lesser development of basal spines.

Cassidulina sp. D

Plate 77, figure 10

Test compact, slightly flattened; periphery broad, rounded. Chambers distinct; 5 pairs constituting the last whorl. Sutures distinct, incised, very strongly curved, especially at their inner ends. Wall smooth, polished. Aperture large, a broad loop-shaped opening into the apertural face, curved nearly at right angles to the plane of the test. Diameter 0.50 mm; thickness 0.35 mm.

A single specimen was found in the Miocene, Donni sandstone, at USGS f21578 (S621).

Cassidulina sp. E

Plate 77, figure 9

Test flattened; periphery subacute, serrate. Chambers distinct, narrow, slightly inflated at their umbilical ends, 5 pairs constituting last whorl. Sutures distinct, straight, angled at the point of contact with the previous chamber from the opposite side. Wall covered by a rather coarse roughness, resulting in a sugary texture. Aperture a large broad loop-shaped opening on the periphery parallel with the plane of the test, extending well into the last chamber. Diameter 0.65–0.87 mm; thickness 0.40–0.50 mm.

Single specimens were found at four localities in the Miocene, Donni sandstone.

Cibicides vortex Dorreen

Plate 72, figure 3; plate 84, figure 8

Cibicides vortex Dorreen, 1948, Jour. Paleontology, v. 22, p. 299, pl. 41, fig. 5.

This species is abundant and quite typical in the Eocene of Saipan. A closely related form is found in the Miocene Tagpochau limestone, abundantly at USGS f21582 (S666), and rarely at two other localities. The Miocene form differs from the typical form in being slightly more involute, with a lower apertural face to the last chamber and without the depressed ventral umbilicus, and in having one or two chambers less per adult whorl. It is regarded as an evolutionary descendant of *Cibicides vortex,* but not specifically separable from it.

Cibicides sp. E

Plate 74, figure 15

Test close coiled, thickest at the periphery, depressed at both umbilici, more so dorsally than ventrally; periphery rounded, indented, especially over the later chambers. Chambers distinct; later ones inflated; about 8 in the adult whorl. Sutures distinct, very slightly curved; later ones somewhat incised. Wall calcareous, smooth, distinctly and coarsely perforate on both dorsal and ventral sides. Aperture not observed. Diameter about 0.70 mm; thickness 0.36 mm.

This species is distinctive in its closely coiled, nearly involute test, with a depressed dorsal umbilicus, and in its wall being coarsely perforate on both dorsal and ventral sides. It shows no evidence of having been attached, as most species of this genus are.

It was found only in the upper Oligocene, Fina-sisu formation.

Clavulinoides sp. A

Plate 64, figure 10

Test small for the genus, triangular in section with slightly concave faces; breadth about equal throughout; angles acute; carinate. Chambers and sutures indistinct. Wall very finely arenaceous, smooth surfaced. Aperture circular, terminal, not protruding. Length 0.85 mm; breadth 0.43 mm.

Two specimens were found in the upper Eocene, Hagman formation, at USGS f21122 (S365).

Discorbis celsa Todd, n. sp.

Plate 67, figure 20

Test of medium size for the genus, high, conical; periphery entire. Chambers indistinct, not inflated, 6 constituting the final whorl. Dorsal sutures very indistinct, tangential and strongly curved; ventral sutures radial, limbate, and slightly depressed. Wall calcareous, finely perforate, thick. Aperture low, under the edge of the ventral chamber wall in a reentrant about midway from the umbilicus to the periphery. Diameter 0.70–0.75 mm; height about 0.55 mm.

Holotype (USNM 623925) from the upper Eocene, Matansa limestone, northeast-central Saipan, USGS f21081 (S253).

This species resembles *Discorbis alveata* Cushman in shape but is much larger and more heavily built, has a more steeply conical test, and lacks radial ornamentation on the ventral side.

Discorbis fulva Todd, n. sp.

Plate 90, figure 8

Test very small for the genus, compressed, circular in outline; dorsal side slightly convex; ventral side slightly concave; periphery subacute, entire. Chambers distinct, strongly curved, not inflated, regular in shape, 6 to 8 constituting the adult whorl. Sutures distinct, strongly curved, limbate on the dorsal side. Wall calcareous; dorsal surface densely covered by fine perforations with coarser ones along the sutures and periphery; the earliest part usually but not always brown, grading outward to clear. Aperture very low, elongate, under the ventral edge of the last chamber. Diameter 0.25–0.33 mm; thickness 0.07 mm.

Holotype (USNM 624186) from the Recent, western Saipan, Tanapag Lagoon, USGS f11350, about three-quarters of a mile directly northwest off beach at Puerto Rico. Cloud's (1957) traverse *A*, station *4*. Slightly uneven limesand bottom strewn with small scattered masses of dead coral, at depth of 33 feet in dredged harbor area.

This minute species, usually clear brown in the earliest part, is easily overlooked. In addition to the size difference, it differs from *Discorbis candeiana* (D'Orbigny) in having a more acute and nonindented periphery, limbate dorsal sutures, and regular chambers.

Dorothia compacta Todd, n. sp.

Plate 64, figures 15, 16

Test elongate; initial end bulbous; later part slightly compressed; apertural end bluntly conical. Chambers indistinct, numerous; later ones slightly inflated and overhanging the earlier ones. Sutures very indistinct; later ones indented. Wall arenaceous but with a very smooth surface. Aperture large, broad, arched, at the base of the apertural face in adult forms, high and narrow in juvenile specimens. Length 0.60–0.90 mm; breadth 0.35–0.40 mm.

Holotype (USNM 623858) from the upper Eocene, Densinyama formation, northern Saipan, USGS f21042 (S26).

This species differs from *Dorothia hayi* (Karrer) from Motatura, New Zealand, in having a smaller and more compact form, using finer grains in constructing its test, and having a smoother surface.

Elphidium formosum Todd, n. sp.

Plate 88, figure 22

Test compressed; periphery subacute, entire; umbilicus flush, filled by a mass of clear shell material. Chambers distinct, narrow, curved, not inflated; about 13 in the adult whorl; each chamber marked by the clear glassy surface that appears as a limbate line between adjacent sets of retral processes. Sutures distinct, slightly curved; each suture bridged by about 8 distinct, short retral processes between the periphery and the umbilicus on each side; the pits between the retral processes giving a beaded appearance to the sutures. Wall calcareous, thin, translucent, finely and distinctly perforate. Aperture a very low elongate opening or a series of pores at the base of the apertural face. Diameter 0.30–0.40 mm; thickness 0.20–0.25 mm.

Holotype (USNM 624226) from the Recent, western Saipan, USGS f11359. Beach at Tanapag. Cloud's (1957) traverse *B*, station *1ax*. Limesand in intertidal zone.

This species differs from *Elphidium advenum* (Cushman) in being less strongly compresssed and lacking the peripheral keel and in its "beaded" sutures.

Elphidium hyalocostatum Todd, n. sp.

Plate 88, figure 19

Test compressed, very slightly depressed at the umbilicus; periphery rounded, not indented. Chambers narrow, not inflated; about 13 in the adult whorl. Sutures indistinct, very slightly curved; each suture bridged by about 8 distinct, elongate retral processes between the periphery and the umbilicus on each side; retral processes over adjacent sutures crudely aligned in concentric spirals, not confluent, leaving virtually no intervening smooth chamber surface but only a narrow limbate ridge marking the position of the chamber. Wall calcareous, thin, translucent when moistened, densely perforated by distinct fine pores. Aperture very low, elongate, at the base of the slightly bulging apertural face. Diameter 0.45–0.50 mm; thickness about 0.22 mm.

Holotype (USNM 624228) from the Recent, western Saipan, USGS f11360. Just offshore from beach at Tanapag. Cloud's (1957) traverse *B*, station *1ay*. Organically rich limesand just below low tide level.

This species resembles *Elphidium indicum* Cushman in the retral processes forming a reticulation of limbate lines with a crudely spiral pattern. It differs from *E. indicum* in having a depressed, not raised or filled, umbilicus and in its more rapidly expanding coil and much smaller size.

Eponides sp. B

Plate 68, figure 8

Test large for the genus, biconvex or nearly planoconvex with the ventral side flattened; periphery blunt, entire. Chambers indistinct, not inflated; about 10 in the last whorl. Sutures indistinct; radial on the ventral side, becoming slightly incised at their inner ends toward the large umbilical boss; slightly tangential on the dorsal side. Wall calcareous, thick, smooth; areas between suture lines thickly covered with rather coarse perforations. Aperture low, elongate, under the ventral edge of the last-formed chamber. Diameter up to 2.3 mm; thickness up to 1.4 mm.

This species was found only in the upper Eocene, Matansa limestone, and at only one locality, USGS f21081 (S253), in northeast-central Saipan. Although it occurs abundantly, the available material is too fragmentary and poorly preserved to permit adequate description and naming. The form is distinctive in its large size. From its association with species of the Amphisteginidae and from its heavy, robust test, I should judge it to have been an inhabitant of rather shallow waters.

Gaudryina sp. B

Plate 81, figure 2

Test elongate, triangular in the early part, quadrangular in the later part; angles rounded. Chambers numerous, distinct, low, and broad, gradually increasing in size as added, slightly inflated. Sutures distinct, incised, nearly horizontal. Wall very finely agglutinated, smoothly finished. Length about 1.5 mm; breadth across last-formed chambers about 0.75 mm.

The species is common at USGS f21582 (S666) in the Tagpochau limestone, but no complete specimens were obtained, and the material is inadequate for erection of a new species. It is distinctive in its low distinct chambers and incised sutures. It differs from *Gaudryina lapugyensis* Cushman in having a very fine-grained and smoothly finished surface and a smoothly rounded, not angular, periphery.

Globigerina eximia Todd, n. sp.

Plate 78, figure 8

Test large, compact, low spired; umbilicus narrow and deep. Chambers few, large, inflated toward their dorsal and peripheral parts, becoming constricted toward the umbilicus, strongly embracing dorsally and overhanging the umbilicus ventrally, last 3 constituting most of the test. Sutures distinctly indented. Wall calcareous, perforate, coarsely cancellated. Aperture small, narrow, at the junction of the ventral sutures. Greatest dimension of test 0.75–0.85 mm, thickness 0.55–0.70 mm.

Holotype (USNM 623978) from the Miocene, Donni sandstone member of the Tagpochau limestone, southeast Saipan, USGS f21450 (C70).

This species seems related to *Globigerina venezuelana* Hedberg from the Oligocene of Venezuela, but in *G. eximia* the chambers are more inflated and more rapidly increasing in size as added, resulting in 3 instead of 4 chambers constituting the last whorl and in the last chamber making up a larger proportion of the test.

Globigerina? grata Todd, n. sp.

Plate 74, figure 4

Test small for the genus, complanate; spire depressed; periphery indented. Chambers distinct, inflated; 5 or 6, usually of about equal size, constituting the last whorl. Sutures distinct, straight, deeply indented. Wall calcareous, finely perforate, smooth, polished, lacking both cancellations and spines. Aperture obscure, a very narrow slit extending from the umbilicus to the periphery under the edge of the last-formed chamber. Diameter 0.30–0.45 mm; thickness 0.26–0.35 mm.

Holotype (USNM 623949) from the upper Oligocene, Fina-sisu formation, southern Saipan, USGS f21133 (C85).

This small species was only observed in the type sample. It is unique in its low-spired form with numerous inflated chambers and in its smooth and polished wall lacking any surface ornamentation. In this feature it is distinct from most of the globigerinids, and because of this lack, its generic placement is questioned.

This species appears to be closer to *Globorotalia mayeri* Cushman and Ellisor than to any described species of *Globigerina*. Comparison with *G. mayeri* shows clear distinctions in that the present species lacks any suggestion of cancellation or spinosity. Furthermore, it has more distinctly inflated chambers and a very obscure aperture without an apertural lip as is present in *G. mayeri*.

Globigerina nepenthes Todd, n. sp.

Plate 78, figure 7

Test small, compactly coiled except for the last-formed protruding chamber; height of spire ranges between three-quarters of and equal to diameter of spire. Chambers indistinct, slightly inflated; 4 chambers constituting the last whorl, with a fifth elongate chamber extending downward and at an angle to the axis of coiling. Sutures indistinct, except the last few which are indented. Wall thin, calcareous, perforate, ornamented by a rather coarse cancellation. Aperture large and semicircular or broad and arched at the umbilical edge of the protruding chamber, bordered by a thickened and slightly upturned lip of clear shell material. Diameter exclusive of protruding chamber 0.30–0.37 mm; greatest dimension of test 0.42–0.58 mm.

Holotype (USNM 624037) from the Miocene, Donni sandstone member of the Tagpochau limestone, northeast-central Saipan, USGS f21578 (S621). The species occurs very abundantly here and at several other Donni localities.

The species is distinctive in its protruding final chamber, and this character is quite uniform so cannot be regarded as an abnormality. The species shows a wall ornamentation somewhat similar to that of *Globigerinoides sacculifera*, and both species have distinctively shaped final chambers. The adult test of *Globigerina nepenthes* is much smaller, however, and the widely open aperture, as well as the protruding thumblike final chamber, serves to distinguish it easily. The specific name, by which this species has been informally known, was suggested by Thomas F. Grimsdale from a resemblance of the last chamber to the pitcher plant flower, *Nepenthes*.

I am indebted to Thomas F. Grimsdale, B. B. Hart, and H. M. Bolli for information regarding other occurrences of this species and its stratigraphic range in the Caribbean region. It has been found in Cuba, the Dominican Republic, Trinidad, Morocco, and Kabu, East Java. In the Caribbean it occurs in the *Globorotalia menardii* and *G. mayeri* zones of the lower Miocene and is a marker for the Lengua formation in Trinidad. Mr. Grimsdale (written communication, Jan. 11, 1955) reports that in Cuba the same species, or perhaps a variety, is found rarely in what seems to be an older horizon, in association with *Globoquadrina quadraria* (Cushman and Ellisor), *Globorotalia fohsi barissanensis* LeRoy, and *Globigerina grimsdalei* Keijzer (which in the present work is called *Sphaeroidinella kochi* (Caudri)).

Globigerina pera Todd, n. sp.

Plate 70, figures 10, 11

Test somewhat compressed, low spired. Chambers few, rapidly increasing in size as added; 3½ to 4 constituting the adult whorl, with a smaller and smoother supplementary chamber extending from the periphery downward over the umbilicus. Sutures deeply incised. Wall calcareous, perforate, covered by a fine-grain pattern of round pits (possibly the basis for delicate spines during life of the animal) and stubby irregular spines. Aperture a single opening under the lip at the inner edge of the supplementary chamber that covers the umbilicus. Length 0.55–0.65 mm; width 0.48–0.55 mm; thickness 0.35–0.48 mm.

Holotype (USNM 623805) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species is easily confused with the Oligocene species *Globigerina dissimilis* Cushman and Bermudez, which it superficially resembles. The distinction between the two species, pointed out to me by Paul Bronnimann, lies in the supplementary chamber, which in *G. dissimilis* is like a bridge open at both ends, over the umbilicus, but in the present species is like a pocket, open only at one end. In addition, this species is more compressed than *G. dissimilis*. In the pocketlike supplementary chamber, *G. pera* resembles *G. turgida* Finlay as illustrated and described by Bronnimann (1952, p. 19, pl. 3, figs. 1–3) but is a more elongate and more strongly compressed form. *Globigerina bakeri* Cole, which occurs with the present species, also usually has a pocketlike supplementary chamber present, but *G. bakeri* is a larger, high-spired form with the last several chambers of nearly equal size.

Globigerina sp. C

Plate 78, figure 4

Test compressed, low spired, loosely coiled; umbilicus small, depressed; periphery lobulate. Chambers globular, 4 constituting the last whorl. Sutures indented. Wall calcareous, perforate, ornamented by uniform distribution of coarse tubercles. Aperture not observed. Maximum dimension of figured specimen 0.60 mm; thickness 0.35 mm.

This distinctive rugose species appears to be undescribed, but insufficient material was obtained to permit complete description and naming. It occurs rarely at 3 localities in the Miocene Tagpochau limestone, 2 of which are in the Donni sandstone member.

Globigerinita? sp. A

Plate 70, figure 14

Only rare specimens were found of a small, globular, spinose form, the umbilicus of which is filled in by an irregular supplementary chamber having a smoother surface than the remainder of the test. This smooth chamber has armlike projections with slight lips at their ends, usually along the sutural depressions, at the ends of which the apertures are situated.

So far as I am aware, this particular modification of the globigerinids has not previously been noted in beds earlier than the upper Oligocene. At three localities in the upper Eocene Hagman and Densinyama formations, this minute species occurs fairly commonly.

Globigerinita? sp. B

Plate 70, figure 15

A single specimen from the upper Eocene Hagman formation, here figured, is probably either an abnormal specimen or a rare example of an undescribed species in which the supplementary chamber is in the shape of a large elongate mound wrapped spirally about half way around the test. This chamber has no projecting arms, and the apertures are high-arched openings along the straight-sided mound.

Globigerinoides bispherica Todd

Plate 74, figures 7, 8

Globigerinoides bispherica Todd, 1954, *in* Todd, Cloud, Low, and Schmidt, Am. Jour. Sci., v. 252, p. 681, pl. 1, figs. 1, 4.
Globigerinoides conglobata Cushman and Stainforth [not Brady], 1945, Cushman Lab. Foram. Research Special Pub. 14, p. 68, pl. 13, fig. 6.
Globigerinoides cf. *G. conglobata* Cushman and Renz [in part] [not Brady], 1947, idem, Special Pub. 22, p. 41.
Globigerinoides conglobata Stainforth [not Brady], 1948, Jour. Paleontology, v. 22, p. 121, pl. 26, fig. 4.

Test consists of two spheres of equal or nearly equal size, confluent in greater or less degree. one sphere consisting of the last-formed chamber, the other sphere consisting of the penultimate chamber strongly embracing all the previous ones, coiling dextral and sinistral. Sutures distinct and incised in individuals where the chambers are less embracing, indistinct in individuals where the chambers are more embracing. Wall calcareous, perforate, ornamented by a dense pattern of small, delicate round cancellations. Apertures two or more; in the case of individuals where the chambers are more embracing the apertures are irregular, narrow fissures appearing to result from the breaking apart of the test wall at the suture lines or suture junctions and usually bordered with irregular knobs of clear shell material; in the case of individuals where the chambers are less embracing the apertures are more distinct, low-arched openings into the final chamber, overhung by the rough, knobby edge of the chamber. Length 0.55–0.65 mm, greater diameter 0.45–0.50 mm.—Todd, *in* Todd and others, 1954.

Holotype (USNM 548876) from the upper Oligocene, Fina-sisu formation, southern Saipan, USGS f21133 (C85).

This is the most abundant species in the upper Oligocene of Saipan. As described, it includes a rather wide range of shapes but is characterized by its bispherical form. Further studies of early Tertiary globigerinids are needed to determine the evolutionary relatives of this species.

This species differs from *Globigerinoides subquadrata* Bronnimann, with which it occurs, in its circular, not compressed test, its less widely open apertures, and its finely cancellated wall. The individuals with strongly embracing chambers when poorly preserved may be confused with *Orbulina suturalis* Bronnimann and with *Globigerinatella insueta* Cushman and Stainforth but are distinguished by the faint trace of an equatorial suture line.—Todd, *in* Todd and others, 1954.

Globigerinoides mitra Todd, n. sp.

Plate 78, figures 3, 6

Test large, high spired. Chambers numerous, higher than broad, inflated; 3 or 4 (exceptionally as many as 6) constituting the final whorl. Sutures indented. Wall thin, calcareous, perforate, finely spinose. Apertures several; the main one a large semicircular opening occupying most of the umbilical edge of the last-formed chamber; supplementary apertures small, at the junctions of the vertical sutures with the spiral suture, not observed in the early part of the spire. Height 1.00–1.40 mm; diameter 0.85–1.00 mm.

Holotype (USNM 624038) from the Miocene, Donni sandstone member of the Tagpochau limestone, northeast-central Saipan, USGS f21578 (S621).

This species is distinctive in its very high, sharp spire, and high, narrow chambers. It resembles *Globigerina subcretacea* Lomnicki in number of chambers in the final whorl but differs in its high spire and dorsal supplementary apertures.

LeRoy reported (oral communication, April 4, 1955) that *G. mitra* occurs in the Miocene strata on Okinawa.

Globigerinoides pseudorubra Todd, n. sp.

Plate 74, figure 10

Test large for the genus, loosely coiled, very high spired, triserial. Chambers large, inflated. Sutures distinctly incised. Wall calcareous, perforate, ornamented with closely spaced, blunt spines. Apertures several; the main one a large high-arched opening into the last chamber at the junction between that chamber and the suture separating the two preceding chambers; supplementary apertures much smaller arched openings, situated in the incised areas of suture junctions. Maximum dimension of test 0.60–0.80 mm.

Holotype (USNM 623954) from the upper Oligocene, Fina-sisu formation, southern Saipan, USGS f21133 (C85).

Except for the final chamber, this species resembles a giant *Globigerinoides rubra* in its chamber arrangement, but the supplementary apertures are much smaller. None of the chambers show any peripheral flattening nor does the final chamber appear to balance the rest of the test, as it does in *G. rubra.* This species differs from the Miocene form *Globigerinoides mitra* n. sp. from the Donni sandstone in having a more inflated and loosely coiled test and fewer chambers per whorl (3 instead of as many as 6). That *G. pseudorubra* may be an advanced stage of *Globigerinoides subquadrata* Bronnimann is a possibility, though I think rather a remote one because of the prominent spire in *G. pseudorubra.*

Globigerinoides rubra (D'Orbigny) and related forms

Plate 70, figure 12; plate 78, figure 14; plate 92, figure 9

This widespread planktonic species was found rarely in a few of the lagoon samples of Recent sediments and more abundantly in the deep-water Miocene Donni sandstone. In the Eocene Hagman formation there are rare specimens of a small high-spired species like *Globigerinoides rubra,* having the characteristic ornamentation of closely spaced pits but lacking the numerous large apertural openings. Instead, the Eocene forms have several small, inconspicuous openings usually at the junctures between the later suture lines and only very narrowly open. These Eocene forms probably are specifically distinct, but for the present, lacking sufficient well-preserved material, they are considered ancestral forms of *G. rubra.*

Globigerinoides subquadrata Bronnimann

Plate 74, figure 6

Globigerinoides subquadrata Bronnimann, 1954, *in* Todd, Cloud, Low, and Schmidt, Am. Jour. Sci., v. 252, p. 680, pl. 1, figs. 5, 8.

The general outline of the test is subquadrate. The major portion of the test is represented by the three-chambered final volution. The early portion of the test is distinctly trochoid. It is only slightly smaller than the antipenultimate chamber. The subglobular and appressed chambers of the final volution increase rapidly in size, and the end-chamber is equal to or only slightly smaller than the preceding part of the test. The ultimate and penultimate chambers are added perpendicularly to the preceding oral face. The initial spiral is indistinct and the spiral side is much like the umbilical side. The umbilicus is very shallow. The arcuate main aperture is situated at the intersection of the umbilical sutures; the smaller, also arcuate, accessory aperture is opposite the main aperture on the spiral side. Additional accessory apertures of the early spiral are visible only in large and well-preserved specimens. The main aperture is bordered by large pustules. The well-defined sutures of the end-stage are straight. Those of the initial stage are slightly curved. The walls are finely perforate and the surface is covered with strong and rather uniform pustules. The species coils to the right and to the left. The length of the test ranges from 0.35 mm to 0.6 mm.

Dimensions of the holotype: length, 0.58 mm; diameter of end-chamber, 0.4 mm; diameter of the two preceding chambers, 0.47 mm; diameter of main aperture, ±0.11 mm; diameter of accessory aperture of end-chamber, ±0.07 mm.—Bronnimann, *in* Todd and others, 1954.

Holotype (USNM 548881) from the upper Oligocene, Fina-sisu formation, southern Saipan, USGS f21133 (C85).

The species is distinguished by its symmetrical, subquadrate test and indistinct initial spiral, and by the main aperture being situated directly opposite the suture line.

This species occurs very abundantly in the upper Oligocene of Saipan. The same form is known as an undescribed index fossil for the Oligocene of Trinidad and eastern Venezuela—Bronnimann, *in* Todd and others, 1954.

Gümbelina tenuis Todd, n. sp.

Plate 65, figure 31

Test small, elongate, compressed; periphery rounded, only very slightly indented. Chambers numerous, distinct, not much inflated, later ones strongly overlapping; 6 or 7 pairs constituting the adult test. Sutures distinct, incised. Wall calcareous, perforate, smooth, polished. Aperture an elongate slit extending from the base of the apertural face well into the last-formed chamber. Length up to 0.40 mm; breadth up to 0.20 mm; thickness about 0.10 mm.

Holotype (USNM 623873) from the upper Eocene, Densinyama formation, northern Saipan, USGS f21042 (S26).

This species differs from *Gümbelina goodwini* Cushman and Jarvis in having a slenderer test with more distinct chambers and sutures and a more elongate aperture.

Hantkenina bermudezi Thalmann

Plate 70, figure 13

Hantkenina (*Sporohantkenina*) *brevispina* Bermudez [not Cushman, 1924], 1937, Soc. cubana hist. nat. Mem., v. 11, no. 3, p. 151, pl. 19, figs. 7–10.

Hantkenina (*Cribrohantkenina*) *bermudezi* Thalmann, 1942. Am. Jour. Sci., v. 240, p. 814, pl. 1, figs. 5, 6.

Bronnimann, 1950, Jour. Paleontology, v. 24, no. 4, p. 417, pl. 56, figs. 6–9, 24, 25.

Abundant specimens are found in the Hagman formation and one sample, USGS f21042 (S26), of the Densinyama formation.

Although no evidence of the cribrate apertural area presumed to be one of the diagnostic features of Bermudez' species (renamed by Thalmann) have been observed in the Saipan Hantkeninas, I have identified them as *H. bermudezi*. In the light of what is generally known regarding differences between the aperture of the final chamber and that of the penultimate or earlier chambers in other genera, it seems doubtful that the basis on which the subgenus *Cribrohantkenina* was established is a firm one. Accordingly, the apparent absence of a cribrate aperture in the Saipan specimens fails as a distinguishing feature of *Hantkenina bermudezi*. The remaining diagnostic features (shape of chambers; length, place of insertion, and position of spines; and nature of sutures) reveal no major differences between the present specimens and *H. bermudezi* of the Eocene of Cuba, Mexico, Trinidad, and Barbados.

This species falls into group IV of Thalmann's (1942a, p. 7) classification of the species of *Hantkenina*. The ranges of species in this group are reported to be within the Bartonian, and questionably into Lattorfian.

Heminwayina? sp.

Plate 68, figure 2

Test small, planoconvex, compressed; periphery slightly lobulated, acute, surrounded by a smooth, limbate keel. Chambers few, indistinct, not inflated on the dorsal side, discernible only as prominent knobs near the umbilicus on the ventral side; about 6 constituting the last whorl. Dorsal sutures strongly curved, tangential, limbate; ventral sutures radial, indistinct. Wall calcareous, finely perforate. Aperture low, under the edge of a deep reentrant of the ventral face of the last chamber. Diameter 0.25 mm; thickness 0.12 mm.

Only rare specimens from the upper Eocene Hagman formation were found of this small form that is distinctive in the prominent ventral knobs nearly surrounding the umbilicus. In this feature, they resemble species placed in the recently erected genus *Heminwayina* Bermudez (1951). I cannot determine positively whether this resemblance is a superficial one or whether the structure is the same. Hence, the genus is questioned for the present.

Loxostomum latum Todd, n. sp.

Plate 66, figure 21

Test elongate, broad, strongly compressed, rapidly tapering at the initial end, then of nearly equal breadth throughout; periphery subacute, not lobulated. Chambers distinct, not inflated; early ones low and broad; later ones more rapidly increasing in height as added and tending to become uniserial. Sutures distinct, very slightly incised; early ones straight and oblique; later ones curved. Wall calcareous, finely perforate, ornamented by faint and fine longitudinal costae over the initial quarter or third of the test. Aperture elongate, very narrow, extending in the plane of the test from the suture line up toward the apex. Length 0.42–0.55 mm; breadth 0.17–0.25 mm; thickness 0.07–0.10 mm.

Holotype (USNM 623784) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species differs from *Loxostomum vicksburgense* (Howe) in the nature of its wall, which is finely instead of coarsely perforate and faintly costate over the early part of the test, and in lacking the collapsed area of the last-formed chamber that is so characteristic of *L. vicksburgense*.

Loxostomum vescum Todd, n. sp.

Plate 66, figure 22

Test small for the genus, slender, compressed; periphery rounded, slightly lobulated toward the apertural end. Chambers distinct, rather high, very gradually increasing in size as added, not inflated. Sutures distinct, slightly depressed; early ones straight and oblique; later ones slightly curved. Wall calcareous, finely perforate, smooth. Aperture elongate, narrow, extending in the plane of the test from the suture line up to the apex. Length of the holotype 0.62 mm; breadth 0.17 mm; thickness 0.10 mm. Length of other specimens 0.28–0.38 mm; breadth 0.10–0.12 mm; thickness 0.05 mm.

Holotype (USNM 623783) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species differs from *Loxostomum wilcoxense* Cushman and Ponton in having higher chambers and a more strongly compressed test.

Massilina pseudoclara Todd, n. sp.

Plate 87, figure 3

Test small for the genus; early part quinqueloculine; later chambers planispiral; periphery truncate. Chambers distinct, angular, thickest at the truncate periphery, much embracing. Sutures indistinct. Wall calcareous, imperforate, smooth with a fine matte surface, thickened and limbate at the peripheral angles, in some specimens translucent over the central part of the chamber. Aperture rectangular, at the end of a very short neck, without a lip, with a short, T-shaped, bifid tooth at the base of the aperture, and a very short simple tooth at the top. Length 0.50–0.65 mm; breadth 0.27–0.43 mm; thickness 0.10–0.18 mm.

Holotype (USNM 624174) from the Recent, western Saipan, Tanapag Lagoon, USGS f11350. About three-quarters of a mile directly northwest off beach at Puerto Rico. Cloud's (1957) traverse *A*, station *4*. Slightly uneven limesand bottom strewn with small scattered masses of dead coral, at depth of 33 feet in dredged harbor area.

This species is one of the most abundant miliolids of Tanapag Lagoon. In the elongate dark bands of translucent shell material that mark the central part of the later chambers, this species resembles *Spiroloculina clara* Cushman. In fact, its distinction from that species is the degree of development of the quinqueloculine stage, before the spiroloculine stage is assumed. Inasmuch as the generic distinction between *Spiroloculina* and *Massilina* consists of this same distinction, that is, degree of development of the quinqueloculine stage, it appears that here is an example of the same "species" in two different "genera." It, therefore, follows that the generic distinction between these two "genera" is not valid.

Pending further study, especially of living material, of the two genera *Spiroloculina* and *Massilina* and conforming with current practice, the present material is being separated as a distinct species.

Massilina rustica Todd, n. sp.

Plate 87, figure 4

Test large, compressed, but with a well-developed quinqueloculine stage which prevents the test from being strictly planispiral in all instances; periphery rounded. Chambers curved, much embracing. Sutures indistinct, slightly incised. Wall calcareous, imperforate, ornamented by numerous heavy, irregular, longitudinal costae, ranging from rounded to sharp in profile. Aperture large, nearly circular, rimless, with a bifid tooth extending about halfway into the opening. Length 1.00–1.15 mm; breadth 0.44–0.55 mm; thickness about 0.25 mm.

Holotype (USNM 624209) from the Recent, western Saipan, Tanapag Lagoon, USGS f11355. About 1½ miles directly northwest off beach at Puerto Rico. Cloud's (1957) traverse *A*, station *8*. Limesand bottom at depth of 17 feet at base of patch reef that rises within 8 feet of surface.

In ornamentation this species resembles the longitudinally costate species of *Spiroloculina*, such as *S. corrugata* Cushman and Todd, but is a much more robust and irregular form with chambers more strongly embracing.

Nonion rusticum Todd, n. sp.

Plate 65, figure 24

Test compressed; umbilici small but deep and surrounded by a smooth polished rim that extends spirally outward along the base of the chambers; periphery rounded, very slightly indented over the last several chambers. Chambers indistinct, about 8 per whorl; early ones not inflated; later ones very slightly inflated. Sutures limbate, slightly curved; early ones flush, later ones slightly indented. Wall calcareous, rather coarsely perforate, smooth. Aperture elongate, low, between the base of the last chamber and the previous whorl, beneath a slight projecting lip. Diameter about 0.45 mm; thickness about 0.22 mm. Holotype (USNM 623872) from the upper Eocene, Densinyama formation, northern Saipan, USGS f21042 (S26).

This species resembles *Nonion pompilioides* (Fichtel and Moll) in the deep umbilicus within the limbate ring of fused sutures. It differs from *N. pompilioides* in being more strongly compressed throughout, with rhe later chambers showing a slight inflation, and in having a higher apertural face.

Oolina geometrica Todd, n. sp.

Plate 66, figure 8

Test nearly spherical, slightly elongated from base to top. Wall ornamented with 2 sets of longitudinal costae, the major set consisting of 7 to 9 high, sharp, regular costae, fused at both poles of the test and the costae ornamented by numerous transverse tubules resulting in a ladder appearance in side view; the minor set, not always present, consisting of an equal number of unornamented and less prominent costae interspaced between the major ones, visible only in end view. Aperture very small, at the end of a short slender tube which projects out of the area of the fused costae. Nature of internal tube undetermined. Length 0.35 mm; diameter 0.28 mm.

Holotype (USNM 623829) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21126 (S420).

This species is distinct from *Oolina williamsoni* (Alcock) (see Wright, 1877, p. 104. pl. 4, fig. 14) in having transversely ornamented but fewer costae and in the costae being fused simply (without the collar of pits) around the apertural end. The transverse tubules in the longitudinal costae of *O. geometrica* are similar to those in the peripheral flanges of various species of *Fissurina*, such as *F. formosa* (Schwager).

Parafissurina ovalis Todd, n. sp.

Plate 76, figures 5, 6

Test compressed, oval, slightly pointed at the apertural end; periphery acute but not keeled. Wall thick, smooth, translucent, so that the lighter chamber area is surrounded by a darker peripheral band. Aperture an elongate narrow slit parallel to but slightly in front of the plane of the test, consequently visible from the front of the test but not the back. Internal tube present, extending about half the length of the chamber, curved or enlarged at its outer end, nearer the back chamber wall through which it is faintly visible. Length about 0.60 mm; breadth about 0.55 mm; thickness about 0.30 mm.

Holotype (USNM 624025) from the Miocene, Donni sandstone member of the Tagpochau limestone, north-east-central Saipan, USGS f21578 (S621).

This species differs from *Parafissurina barri* (Cushman and Stainforth) from the Oligocene of Trinidad in having a smaller and more nearly circular test and lacking an apical spine.

Pleurostomella frons Todd, n. sp.

Plate 76, figure 4

Test strongly compressed, broad, tapering evenly toward both ends and sloping evenly outward toward the periphery; periphery smooth, not lobulated, acute but not keeled; initial end sharply pointed, with a very small apical spine; apertural end about equally protruding. Chambers numerous, distinct, rapidly increasing in size as added, not inflated, thicker toward the middle of the test, thinner toward the periphery. Sutures limbate, distinct but neither raised nor depressed, straight and oblique. Wall calcareous, thick, ornamented by numerous low faint longitudinal costae, more prominent over the central part of the test. Aperture small, semicircular, just under the protruding top of the last-formed chamber. Length of holotype 0.62 mm; breadth 0.32 mm. Largest specimen found (incomplete) measures 1.10 mm in length and 0.52 mm in breadth.

Holotype (USNM 624023) from the Miocene, Donni sandstone member of the Tagpochau limestone, north-east-central Saipan, USGS f21578 (S621).

This species with its compressed test and numerous oblique chambers appears at first glance to belong in *Bolivina*, but the nature of its aperture indicates its placement in *Pleurostomella*. It may be related to *P. sapperi* Schubert (1911, p. 56, text figs. 3a, b) from fossil material from the Bismarck Archipelago, from which it differs in having a much broader test and more numerous chambers. The variety *Pleurostomella bolivinoides* var. *lata* Keyzer (1953, p. 279, pl. 2, figs. 14, 15) described as rare from the Miopliocene of Buton appears to be a very similar form, but the present species differs in having lower, broader, and more numerous chambers and a thicker test.

Pseudoclavulina sp.

Plate 64, figure 9

Test elongate, slender; initial part compact, conical; later uniserial chambers separated by incised sutures. Wall finely arenaceous. Aperture terminal, slightly protruding. Length up to 1.35 mm; diameter about 0.30 mm.

This species occurs rarely in the upper Eocene, Hagman and Densinyama formations.

Pyrgo sp. B

Plate 75, figure 6

This Recent deep-water species is widely known in the Pacific and has been recorded as *Biloculina depressa* D'Orbigny (Cushman, 1917, p. 74, pl. 28, figs. 1, 2). It is not, however, identical with *Pyrgo depressa* (D'Orbigny) as represented by Recent material from off the British Isles. The present species, including the Recent form mentioned above, needs describing; but the fossil material is inadequate for erection of a new species.

The species is distinctive in its circular, evenly biconvex and flanged test and the narrow aperture that does not protrude from the circular periphery. It was found only in the Miocene Donni sandstone.

Quinqueloculina tubus Todd, n. sp.

Plate 85, figure 18

Test small for the genus, nearly as broad as long; peripheries subacute. Chambers curved, not inflated. Sutures indistinct, incised. Wall calcareous, imperforate, ornamented with fine but distinct longitudinal costae more prominent over the peripheral parts of each chamber. Aperture circular, rimless, at the end of a prominent though short and slender neck, with a slight trace of a bifid tooth at the base of the aperture. Length 0.40–0.50 mm; breadth 0.30–0.40 mm.

Holotype (USNM 624247) from the Recent, western Saipan, USGS f11379. Zone of massive *Porites* and *Acropora palifera* at inner edge of barrier reef, 1.8 miles northeast from Mañagaha Islet. Cloud's (1957) traverse *C*, station *6*. Limesand bottom at depth of 10 feet between coral masses.

This species resembles *Quinqueloculina neostriatula* Thalmann in ornamentation but differs in its tubular aperture and generally more compact test.

Reussella exilis Todd, n. sp.

Plate 66, figures 29–31

Test small for the genus, slender, tapering toward both ends; axis of test usually slightly twisted; sides distinctly concave; peripheral angles blunt, not serrate. Chambers few, indistinct except when test is moistened; later ones rather high. Sutures limbate, oblique, gently curved. Wall calcareous, finely perforate; some specimens with crude longitudinal costae over the initial part. Aperture large, loop-shaped, extending from the last suture line up to the apex of the test. Length 0.25–0.33 mm; width 0.13–0.17 mm.

Holotype (USNM 623914) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species differs from *Reussella ensiformis* (Chapman) in having a smaller, slenderer test and fewer and higher chambers.

Genus ROBULUS Montfort, 1808

This genus is only rarely found in the Miocene samples. Apparently at least three species are represented. The poor preservation of the specimens, together with the extreme variability of this genus, makes identification uncertain. The presence of the genus suggests moderately deep water, although rare specimens were found in Tanapag Lagoon.

Robulus sp. A

Plate 64, figure 25

Test small for the genus, close coiled, compressed; periphery acute, keeled, irregularly serrate owing to breakage. Chambers about 10 in the last whorl, not inflated, not much increasing in size as added. Sutures distinct, limbate but not raised, straight and tangential to the broad umbo. Wall smooth, unornamented. Aperture slightly protruding. Diameter 0.70–0.95 mm; thickness 0.25–0.40 mm.

This species occurs rarely at several localities in the upper Eocene Hagman and Densinyama formations.

Spiroloculina folium Todd, n. sp.

Plate 87, figure 5

Spiroloculina sp. A, Cushman, Todd, and Post, 1954, U. S. Geol. Survey Prof. Paper 260–H, p. 336, pl. 84, figs. 21, 22.

Test compressed; both ends projecting outward from the otherwise oval outline of the test; periphery bluntly acute in the adult stage, truncate and broad in the immature stage. Chambers large, broad, curved, very strongly embracing leaving an elongate, small, deep, depressed area under overhanging edges at the middle of each side; basal part of the final chamber extending well beyond the penultimate chamber. Sutures very indistinct. Wall calcareous, imperforate, smooth, polished, opaque. Aperture very small, circular, at the end of an elongate slender neck, without a lip; no tooth observed. Length 0.90–1.10 mm; breadth 0.58–0.65 mm.

Holotype (USNM 624249) from the Recent, western Saipan, USGS f11388. A little less than 1 mile directly west-northwest off from Muchot Point and about 900 feet offshore from largest patch reef beyond the point. Cloud's (1957) traverse *D*, station *7a*. Limesand bottom about 22 feet deep between 2 small patch reefs that rise within 9 feet of the surface.

This species has not been found abundantly either on Saipan or in the Marshall Islands (see synonymy above) but is a distinctive form in its very strongly embracing chambers and its slender and elongate apertural neck. It seems to be unique in frequently combining in one specimen, the early truncate periphery on one side and the later acute periphery on the other side.

Streblus sp.

Plate 83, figure 5

Test thick, complanate, close-coiled; periphery slightly indented; dorsal surface flat. Chambers and sutures largely obscured by ornamentation consisting of 6 to 10 or more prominently raised rounded knobs over the closed ventral umbilicus, with smaller and lower, thickly set papillae completely covering the remainder of the test. Aperture not observed. Diameter 0.90–1.00 mm; thickness 0.45–0.60 mm.

This species appears to be related to *S. saipanensis* Cole described from the Miocene "Laulau limestone" of Saipan (Cole and Bridge, 1953, p. 27, pl. 5, figs. 8, 9). Present material from 2 localities, USGS f21444 and f21259 (C44 and B183), in the Tagpochau limestone is inadequate for complete description.

Textularia alveata Todd, n. sp.

Plate 85, figure 12

Test compressed, rapidly tapering in the initial part only; later part of about equal breadth; apertural face depressed and channelled; periphery indented by the sutures, acute in the early part, becoming rounded in the later part. Chambers numerous, very low and broad, slightly inflated. Sutures incised, horizontal. Wall agglutinated, composed of mostly rounded calcareous grains in a fine calcareous groundmass; inner surface of wall and the apertural faces smooth and polished; outer surface roughened by the projecting grains of the wall, with a tendency toward increasing coarseness over the later chambers. Aperture a short, low, horizontal opening occupying the middle third of the apertural face and situated at the base of the distinct troughlike depression that indents the central part of the apertural face from the aperture to the periphery. Length 0.65–0.80 mm; breadth 0.55–0.65 mm; thickness about 0.45 mm.

Holotype (USNM 624133) from the Recent, western Saipan, Tanapag Lagoon, USGS f11349. About one-half a mile directly northwest offshore from beach at Puerto Rico. Cloud's (1957) traverse *A*, station *3*. Nearly barren limesand bottom at depth of 36 feet in dredged harbor area.

This species differs from *Textularia conica* D'Orbigny in its compressed test and depressed apertural face with a distinct channel extending from the aperture outward toward the periphery.

Textularia sp. E

Plate 85, figure 10

Recent specimens similar to that figured are distinguishable from *Textularia candeiana* D'Orbigny in that the last pair of chambers are not flattened nor so strongly overhanging as in that species but are more distinctly separated and inflated throughout the test.

This form was found in scattered samples from Tanapag Lagoon.

Triloculina incisura Todd, n. sp.

Plate 86, figure 18

Test small for the genus, compressed, rounded at base and at apertural end and on peripheries. Chambers triloculine, indistinct except when moistened. Sutures indistinct, slightly curved, not incised. Wall calcareous, imperforate, smooth, polished throughout, slightly translucent, especially when moistened. Aperture a large elongate loop-shaped opening, rimless and not projecting beyond the smooth oval outline of the test; the opening almost completely occupied by a similar-shaped tooth. Length of holotype 0.48 mm; breadth 0.42 mm; thickness 0.28 mm. Other specimens slightly smaller, about 0.35 mm long.

Holotype (USNM 624255) from the Recent, western Saipan, USGS f11396. About two-thirds of a mile directly west off Garapan Beach opposite Schildkrote Rock. Cloud's (1957) traverse *E*, station *6*. Clean limesand bottom at depth of about 10 feet in area of intermingled limesand and gravel in shallow pass through barrier reef.

This species resembles *Triloculina oblonga* (Montagu) in general shape and texture of wall but is distinctive in its apertural tooth resulting in the appearance of a peg neatly fitting into a slot.

Valvulineria pulchra Todd, n. sp.

Plate 68, figure 5

Test compact, compressed; umbilicus open and depressed, covered by a large ventral extension from the last-formed chamber; periphery entire, rounded. Chambers distinct, not inflated, rapidly increasing in size as added; 7 or 8 constituting the adult whorl. Sutures distinct, dorsal ones curved, flush, limbate at their inner ends; ventral ones radial, incised at their inner ends. Wall calcareous, thick, translucent, smooth, thickly covered with fine perforations; the perforations when viewed obliquely appearing as delicate, light markings in the dark translucent wall. Aperture under the ventral umbilical flap. Length 0.50–0.70 mm; breadth 0.45–0.55 mm, thickness about 0.25 mm.

Holotype (USNM 623888) from the upper Eocene, Densinyama formation, northern Saipan, USGS f21042 (S26).

This species differs from *Valvulineria samanica* (Berry) in having a thicker and more compact test, with entire periphery and flush sutures, and a distinctly perforate wall.

Valvulineria? scita Todd, n. sp.

Plate 68, figure 4

Test very small for the genus; dorsal side flat; ventral side conical; periphery bluntly angled, very slightly indented by the sutures. Chambers few, very rapidly increasing in size and especially in depth as added, not inflated; 5 constituting the adult whorl. Sutures distinct, limbate, very slightly indented, straight and tangential on the dorsal side, radial and slightly curved on the ventral side. Wall calcareous, smooth, finely perforate. Aperture a low elongate arched opening under a projecting lip on the ventral edge of the last-formed chamber, near the umbilical end of the ventral face. Length 0.20–0.25 mm; thickness 0.15 mm.

Holotype (USNM 623797) from the upper Eocene, Hagman formation, northeast-central Saipan, USGS f21125 (S385).

This species is questionably placed in *Valvulineria* because I am unable to determine whether or not the ventral part of the chamber is actually a projecting lobe over the umbilicus or a fundamental part of an extraordinarily thick chamber. The species is unique in its small thick test and few chambers.

Virgulina? sp. B

Plate 66, figure 10

Specimens similar to that illustrated may belong in this genus but seem to be indeterminable on the basis of present material. If the species is a *Virgulina*, it is a strongly involute and somewhat compressed form. I do not know any comparable species. The compression of the present specimens seems to be in part, at least, of secondary origin.

This species was found in the upper Eocene, abundantly at USGS f21042 (S26) in the Densinyama formation and at USGS f21125 (S385) in the Hagman formation, and rarely at USGS f21115 (S346) in the Hagman.

LOCALITIES AND TYPE NUMBERS

Localities and USNM Nos. of type and figured specimens found there

[USGS loc. nos. marked with asterisk (*) indicate localities where larger Foraminifera are also found (see Cole, 1957)]

USGS loc. nos.	Field nos. (See pl. 4.)	USNM type nos.
Hagman formation—Eocene		
f21090	S273	623751, 623752
f21113	S344	623753
f21115	S346	623754–623757
f21116	S348	
f21120	S361a	623758
f21122	S365	623759–623764
f21125	S385	623765–623814
f21126	S420	623815–623851
f21128	S597	
f21129	S598	623852–623856
Densinyama formation—Eocene		
f21042	S26	623857–623909
*f21067	S212	
f21068	S213	623910–623912
f21070	S215	
*f21062	S194	623913–623918, 624263
f21066	S209	
*f21072	S219	623919
Matansa limestone—Eocene		
*f21064	S202	
*f21079	S248	
*f21081	S253	623920–623928
f21092	S283	
Fina-sisu formation—Oligocene		
f21133	C85	548876, 548881, 623929–623961
f21134	S662	
Tagpochau limestone—Miocene		
f21345	B333	623962–623966
f21346	B339	623967, 623968
f21443	C42	623969, 623970
f21449	C69	623971–623975
f21450	C70	623976–623980
f21514	S25	623981, 623982
*f21521	S126	623983, 623984
f21563	S433	623985–623987
f21564	S443	623988, 623989
f21572	S563	623990–623997
f21573	S566	
f21578	S621	623998–624050
f21588	S682	624051, 624052
f21444	C44	624053, 624054
f21447	C57	624055, 624056
f21582	S666	624057–624083
*f21594	S701	624084
f21596	S706	

Localities and USNM Nos. of type and figured specimens found there—Continued

USGS loc. nos.	Field nos. (See pl. 4.)	USNM type nos.
Tagpochau limestone—Miocene—Continued		
*f21492	C130	624085
f21497	C136	
*f21259	B183	
f21395	B393	624086–624088
f21524	S146	624089–624095
f21525	S147	624096–624105
Recent		
f11345	*A1b*	
f11346	*A1a*	
f11347	*A1*	624106, 624107
f11348	*A2*	624108–624127
f11349	*A3*	624128–624167
f11350	*A4*	624168–624190
f11351	*A5*	624191
f11352	*A5a*	624192–624197
f11353	*A6*	624198
f11354	*A7*	624199–624208
f11355	*A8*	624209–624214
f11356	*A9*	
f11357	*A10*	
f11358	*A11*	624215–624225
f11359	*B1ax*	624226, 624227
f11360	*B1ay*	624228, 624229
f11361	*B1b*	
f11362	*B1*	
f11363	*B2*	
f11364	*B3*	624230–624233
f11365	*B4*	
f11366	*B5*	
f11367	*B6*	624234–624240
f11368	*B7*	
f11369	*B8*	
f11370	*B9*	
f11371	*B10*	624241–624243
f11372	*C1b*	
f11373	*C1a*	624244
f11374	*C1*	
f11375	*C2*	
f11376	*C3*	624245, 624246
f11377	*C4*	
f11378	*C5*	
f11379	*C6*	624247
f11380	*C7a*	
f11381	*D1*	
f11382	*D2*	
f11383	*D2a*	
f11384	*D3*	
f11385	*D4*	
f11386	*D5*	624248
f11387	*D7*	
f11388	*D7a*	624249
f11389	*E1*	624250, 624251
f11390	*E1a*	
f11391	*E2a*	
f11392	*E2*	
f11393	*E3*	624252
f11394	*E4*	
f11395	*E5*	
f11396	*E6*	624253–624258
f11397	*E7*	624259
f11398	*E8*	624260–624262
f11399	*FX1*	
f11400	*FX2*	
f11401	Loc. *3*	
f11402	Mañagaha Island	
f11403	Fahang Beach	
f11404	Nanasu Beach	

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[Italic numbers indicate descriptions]

PLATES 64–93

PLATE LABELING

Labeling of the plates follows a conventional system of each number applying to a different specimen and each letter applying to different views of the same specimen. Where two views of one specimen are given, *a* designates the major view and *b*, the peripheral or end view. Where three views are given of a rotaliform species, *a* designates the dorsal; *b*, the ventral; and *c*, the peripheral view. In the case of three views of nonrotaliform species, the views may differ but are specified in the plate explanation. In all instances the views are arranged on the plate in orthographic projection with rotation 90° (sometimes 180°) to the right, left, up, or down from the major view. Thus, in the case of the three conventional views of a dextrally coiled specimen, the views read (from left to right) *a*, *c*, and *b*, and in the case of a sinistrally coiled one, they read *b*, *c*, and *a*. Magnifications are approximate.

PLATE 64

FIGURE 1. *Rhizammina* sp. (p. 266 tab.).
USNM 623857, × 45; USGS f21042 (S26).

2. *Technitella archaeonitida* Stainforth and Stevenson (p. 266 tab.).
USNM 623765, × 28; USGS f21125 (S385).

3. *Spiroplectammina mississippiensis* (Cushman) (p. 266 tab.).
USNM 623920, × 45; USGS f21081 (S253); *a*, front view; *b*, side view.

4. *Textularia* sp. A (p. 266 tab.).
USNM 623766, × 55; USGS f21125 (S385); *a*, front view; *b*, top view.

5. *Textularia* sp. B (p. 266 tab.).
USNM 623922, × 28; USGS f21081 (S253); *a*, front view; *b*, top view.

6. *Textularia recta* Cushman (p. 266 tab.).
USNM 623921, × 28; USGS f21081 (S253); *a*, front view; *b*, top view.

7. *Gaudryina (Siphogaudryina) rugulosa* Cushman (p. 266 tab.).
USNM 623913, × 28; USGS f21062 (S194); *a*, front view; *b*, top view.

8. *Gaudryina* sp. A (p. 266 tab.).
USNM 624263, × 28; USGS f21062 (S194).

9. *Pseudoclavulina* sp. (p. 306).
USNM 623760, × 45; USGS f21122 (S365).

10. *Clavulinoides* sp. A (p. 299).
USNM 623759, × 45; USGS f21122 (S365).

11. *Eggerella?* sp. (p. 266 tab.).
USNM 623923, × 28; USGS f21081 (S253); *a*, front view; *b*, top view.

12. *Karreriella* sp. (p. 266 tab.).
USNM 623859, × 45; USGS f21042 (S26); *a*, front view; *b*, side view.

13. *Tritaxilina* sp. (p. 266 tab.).
USNM 623816, × 28; USGS f21126 (S420).

14. *Liebusella* sp. (p. 266 tab.).
USNM 623767, × 28; USGS f21125 (S385); *a*, front view; *b*, top view.

15, 16. *Dorothia compacta* Todd, n. sp. (p. 299).
15. Young specimen, USNM 623815, × 55; USGS f21126 (S420).
16. Holotype, USNM 623858, × 45; USGS f21042 (S26).

17. *Massilina placida* Todd and Post (p. 266 tab.).
USNM 623852, × 55; USGS f21129 (S598); *a*, side view; *b*, apertural view.

18. *Pyrgo* sp. A (p. 266 tab.).
USNM 623861, × 55; USGS f21042 (S26); *a*, side view; *b*, apertural view.

19. *Spiroloculina* sp. (p. 266 tab.).
USNM 623860, × 55; USGS f21042 (S26).

20. *Robulus texanus* (Cushman and Applin) (p. 266 tab.).
USNM 623863, × 45; USGS f21042 (S26).

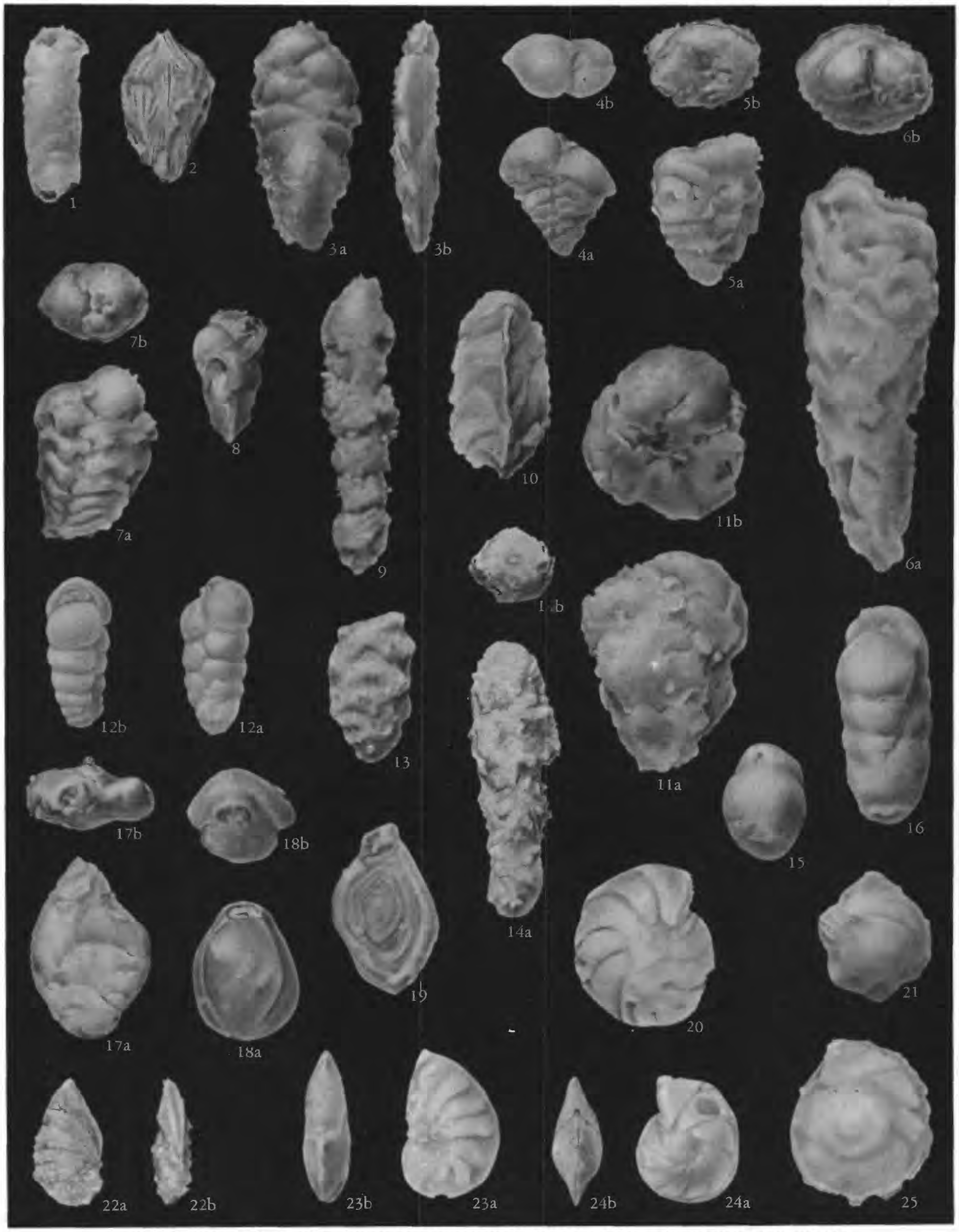
21. *Robulus* sp. B (p. 266 tab.).
USNM 623910, × 28; USGS f21068 (S213).

22. *Astacolus* cf. *A. fragarius* (Gümbel) (p. 267 tab.).
USNM 623864, × 28; USGS f21042 (S26); *a*, side view; *b*, peripheral view.

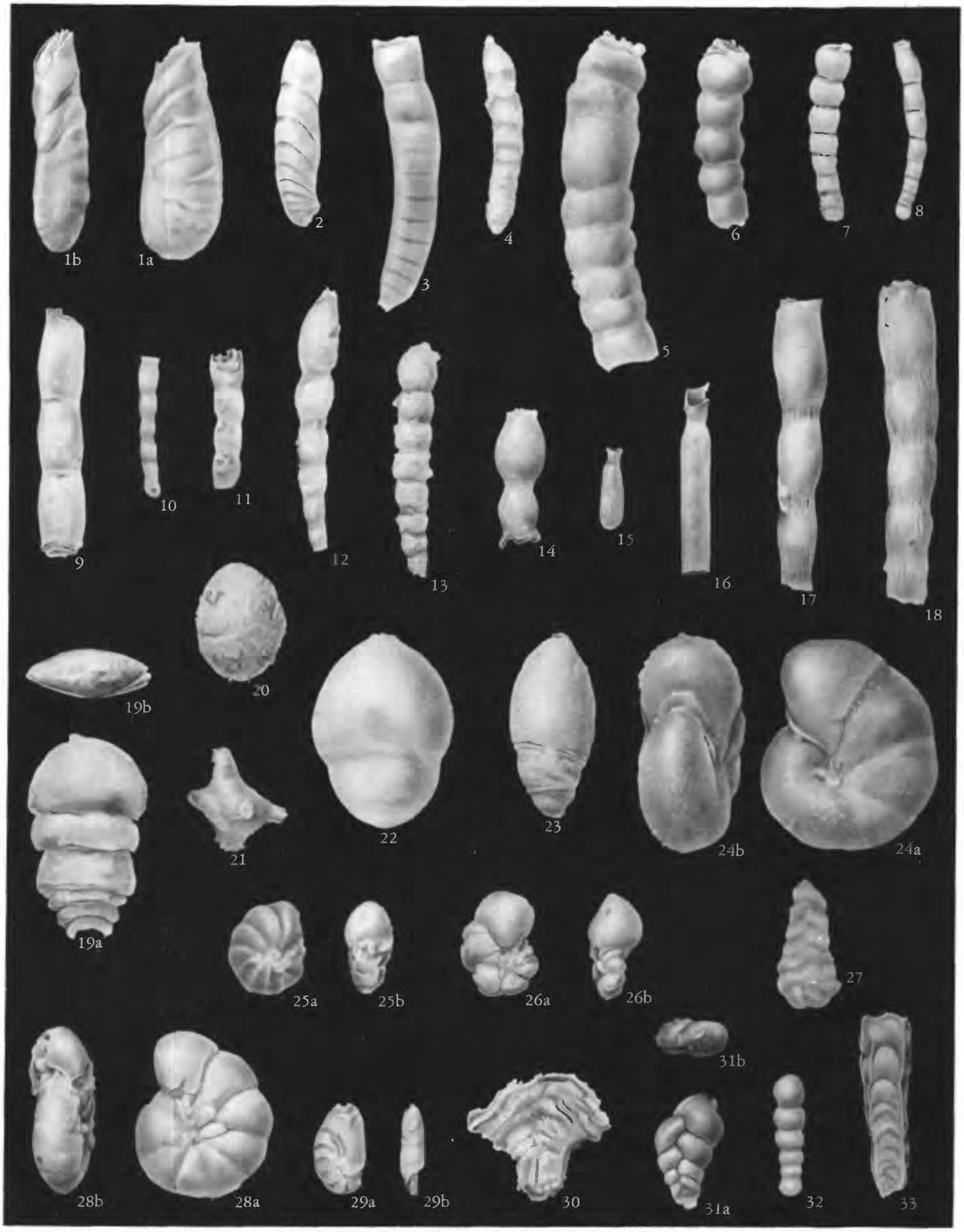
23. *Astacolus* sp. A (p. 267 tab.).
USNM 623768, × 28; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

24. *Robulus alato-limbatus* (Gümbel) (p. 266 tab.).
USNM 623862, × 17; USGS f21042 (S26); *a*, side view; *b*, peripheral view.

25. *Robulus* sp. A (p. 307).
USNM 623817, × 45; USGS f21126 (S420).



REPRESENTATIVES OF SEVEN FAMILIES (RHIZAMMINIDAE TO LAGENIDAE) FROM THE UPPER EOCENE FORMATIONS



LAGENIDAE, POLYMORPHINIDAE, NONIONIDAE, AND HETEROHELICIDAE FROM THE UPPER EOCENE FORMATIONS

PLATE 65

[All figures × 28, except as indicated]

FIGURE 1. *Vaginulina* cf. *V. mexicana* Nuttall (p. 267 tab.).
USNM 623865; USGS f21042 (S26); *a*, side view; *b*, oblique peripheral view.

2. *Marginulina nuttalli* Todd and Kniker (p. 267 tab.).
USNM 623818, × 45; USGS f21126 (S420).

3. *Dentalina cooperensis* Cushman (p. 267 tab.).
USNM 623869; USGS f21042 (S26).

4. *Dentalina communis* D'Orbigny (p. 267 tab.).
USNM 623761; USGS f21122 (S365).

5–8. *Dentalina jacksonensis* (Cushman and Applin) (p. 267 tab.).
5. USNM 623911; USGS f21068 (S213).
6. USNM 623912; USGS f21068 (S213).
7. USNM 623820; USGS f21126 (S420).
8. USNM 623819; USGS f21126 (S420).

9–11. *Dentalina consobrina* D'Orbigny (p. 267 tab.).
9. USNM 623868; USGS f21042 (S26).
10. USNM 623866; USGS f21042 (S26).
11. USNM 623867; USGS f21042 (S26).

12. *Dentalina emaciata* Reuss (p. 267 tab.).
USNM 623769; USGS f21125 (S385).

13. *Dentalina* cf. *D. halkyardi* Cushman (p. 267 tab.).
USNM 623762; USGS f21122 (S365).

14. *Dentalina soluta* Reuss (p. 267 tab.).
USNM 623821; USGS f21126 (S420).

15, 16. *Nodosaria longiscata* D'Orbigny (p. 267 tab.).
15. Initial end, USNM 623822; USGS f21126 (S420).
16. USNM 623823; USGS f21126 (S420).

17, 18. *Dentalina obliquestriata* Reuss (p. 267 tab.).
17. USNM 623770; USGS f21125 (S385).
18. USNM 623870; USGS f21042 (S26).

19. *Lingulina* sp. (p. 267 tab.).
Internal cast, USNM 623754; USGS f21115 (S346); *a*, front view; *b*, top view.

20. *Globulina?* sp. (p. 267 tab.).
Internal cast, USNM 623755; USGS f21115 (S346).

21. *Ramulina* sp. A (p. 267 tab.).
USNM 623772, × 45; USGS f21125 (S385).

22. *Glandulina* sp. A (p. 267 tab.).
USNM 623771; USGS f21125 (S385).

23. *Glandulina* sp. B (p. 267 tab.).
USNM 623751; USGS f21090 (S273).

24. *Nonion rusticum* Todd, n. sp. (p. 305).
Holotype, USNM 623872, × 95; USGS f21042 (S26); *a*, side view; *b*, peripheral view.

25. *Nonion* cf. *N. graniferum* (Terquem) (p. 267 tab.).
USNM 623871, × 55; USGS f21042 (S26); *a*, side view; *b*, peripheral view.

26. *Nonion micrum* Cole. (p. 267 tab.).
USNM 623773, × 55; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

27. *Bolivinopsis* sp. (p. 267 tab.).
USNM 623825, × 55; USGS f21126 (S420).

28. *Nonion planatum* Cushman and Thomas (p. 267 tab.).
USNM 623824, × 55; USGS f21126 (S420); *a*, side view; *b*, peripheral view.

29. *Nonionella jacksonensis* Cushman var. *compressa* Cushman and Todd (p. 267 tab.).
USNM 623774, × 55; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

30. *Bolivinella* sp. A (p. 267 tab.).
USNM 623924, × 95; USGS f21081 (S253).

31. *Gümbelina tenuis* Todd, n. sp. (p. 303).
Holotype, USNM 623873, × 95; USGS f21042 (S26); *a*, front view; *b*, top view.

32. *Nodogenerina rohri* Cushman and Stainforth (p. 267 tab.).
USNM 623827; USGS f21126 (S420).

33. *Amphimorphina haueriana* Neugeboren (p. 267 tab.).
USNM 623826, × 45; USGS f21126 (S420).

PLATE 66

[All figures × 95, except as indicated]

FIGURE 1. *Buliminella* sp. (p. 267 tab.).
USNM 623828, × 45; USGS f21126 (S420).

2. *Robertina* sp. (p. 267 tab.).
USNM 623758, × 55; USGS f21120 (S361a); *a*, dorsal view; *b*, ventral view.

3. *Pseudobulimina* sp. (p. 267 tab.).
USNM 623756, × 45; USGS f21115 (S346); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Bulimina tuxpamensis* Cole (p. 267 tab.).
USNM 623763, × 55; USGS f21122 (S365); *a*, front view; *b*, top view.

5, 6. *Bulimina pupoides* D'Orbigny, × 45 (p. 267 tab.).
5. USNM 623874; USGS f21042 (S26).
6. USNM 623875; USGS f21042 (S26).

7. *Bulimina semicostata* Nuttall (p. 267 tab.).
USNM 623775, × 55; USGS f21125 (S385); *a*, front view; *b*, top view.

8. *Oolina geometrica* Todd, n. sp. (p. 305).
Holotype, USNM 623829, × 55; USGS f21126 (S420); *a*, side view; *b*, top view.

9. *Virgulina* sp. A (p. 267 tab.).
USNM 623776; USGS f21125 (S385).

10. *Virgulina?* sp. B (p. 309).
USNM 623876, × 45; USGS f21042 (S26).

11. *Bolivina byramensis* Cushman (p. 267 tab.).
USNM 623777; USGS f21125 (S385); *a*, front view; *b*, apertural view.

12. *Bolivina carinata* Terquem (p. 267 tab.).
USNM 623778; USGS f21125 (S385); *a*, front view; *b*, apertural view.

13–15. *Bolivina subrhomboidalis* Todd, n. sp. (p. 297).
13. Paratype, USNM 623781; USGS f21125 (S385); *a*, front view; *b*, apertural view.
14. Holotype, USNM 623780; USGS f21125 (S385); *a*, front view; *b*, apertural view.
15. Paratype, USNM 623782; USGS f21125 (S385). *a*, front view; *b*, apertural view.

16. *Bolivina costifera* Cushman (p. 267 tab.).
USNM 623779; USGS f21125 (S385); *a*, front view; *b*, apertural view.

17. *Bolivina jacksonensis* Cushman and Applin (p. 267 tab.).
USNM 623830; USGS f21126 (S420).

18. *Bolivina arta* Macfadyen (p. 267 tab.).
USNM 623877; USGS f21042 (S26).

19. *Bolivina* sp. A (p. 298).
USNM 623831; USGS f21126 (S420).

20. *Bolivina* sp. B (p. 298).
USNM 623752; USGS f21090 (S273).

21. *Loxostomum latum* Todd, n. sp. (p. 304).
Holotype, USNM 623784, × 55; USGS f21125 (S385); *a*, front view; *b*, top view.

22. *Loxostomum vescum* Todd, n. sp. (p. 304).
Holotype, USNM 623783, × 55; USGS f21125 (S385); *a*, front view; *b*, top view.

23. *Siphogenerina* cf. *S. seriata* (Cushman and Jarvis) (p. 267 tab.).
USNM 623834, × 55; USGS f21126 (S420).

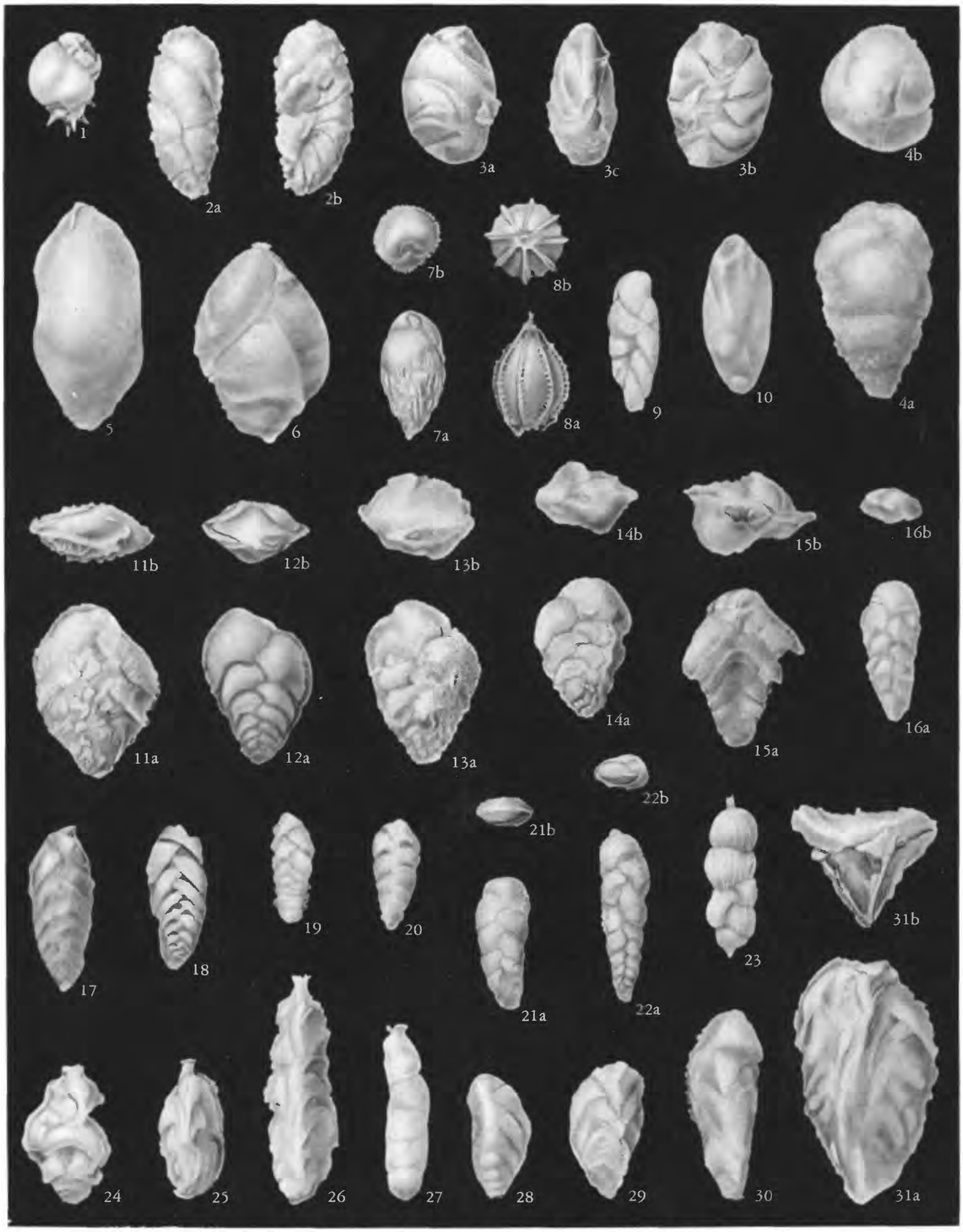
24. *Angulogerina rugoplicata* Cushman (p. 267 tab.).
USNM 623880; USGS f21042 (S26).

25, 26. *Angulogerina cooperensis* Cushman (p. 267 tab.).
25. USNM 623878; USGS f21042 (S26).
26. USNM 623879; USGS f21042 (S26).

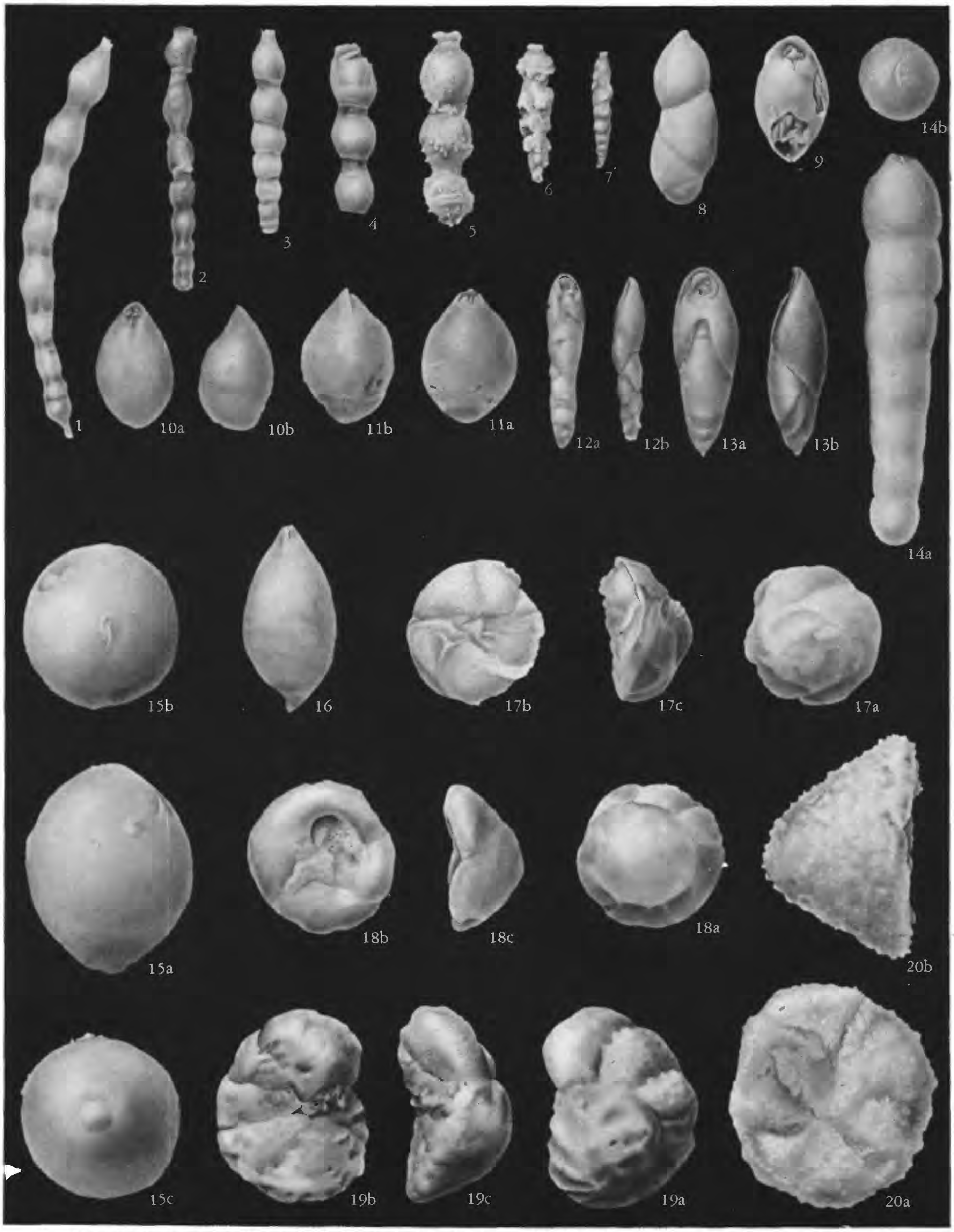
27. *Angulogerina vicksburgensis* Cushman (p. 267 tab.).
USNM 623833, × 55; USGS f21126 (S420).

28. *Reussella* cf. *R. subrotundata* (Cushman and Thomas) (p. 267 tab.).
USNM 623832; USGS f21126 (S420).

29–31. *Reussella exilis* Todd, n. sp. (p. 307).
29. USNM 623785; USGS f21125 (S385).
30. USNM 623786; USGS f21125 (S385).
31. Holotype, USNM 623914; USGS f21062 (S194); *a*, side view; *b*, top view.



BULIMINIDAE FROM THE UPPER EOCENE FORMATIONS



BULIMINIDAE, ELLIPSOIDINIDAE, AND ROTALIIDAE FROM THE UPPER EOCENE FORMATIONS

PLATE 67

[All figures × 45, except as indicated]

FIGURES 1, 2. *Siphonodosaria cocoaensis* (Cushman) (p. 268 tab.).
1. USNM 623788; USGS f21125 (S385).
2. USNM 623764; USGS f21122 (S365).

3. *Siphonodosaria atlantisae* var. *hispidula* (Cushman) (p. 268 tab.).
USNM 623881; USGS f21042 (S26).

4. *Siphonodosaria nuttalli* var. *gracillima* (Cushman and Jarvis) (p. 268 tab.).
USNM 623835; USGS f21126 (S420).

5. *Siphonodosaria curvatura* var. *spinea* (Cushman) (p. 268 tab.).
USNM 623882; USGS f21042 (S26).

6. *Siphonodosaria* sp. (p. 268 tab).
USNM 623836; USGS f21126 (S420).

7. *Siphonodosaria* cf. *S. matanzana* (Palmer and Bermudez) (p. 268 tab.).
USNM 623787; USGS f21125 (S385).

8, 9. *Pleurostomella cubensis* Cushman and Bermudez, × 28 (p. 268 tab.).
8. USNM 623838; USGS f21126 (S420).
9. USNM 623837; USGS f21126 (S420).

10. *Pleurostomella brevis* Schwager (p. 268 tab.).
USNM 623791, × 28; USGS f21125 (S385); *a*, apertural view; *b*, side view.

11. *Pleurostomella* sp. A (p. 268 tab).
USNM 623883; USGS f21042 (S26); *a*, apertural view; *b*, side view.

12, 13. *Pleurostomella alternans* Schwager (p. 268 tab.).
12. USNM 623789, × 55; USGS f21125 (S385). *a*, apertural view; *b*, side view.
13. USNM 623790; USGS f21125 (S385). *a*, apertural view; *b*, side view.

14. *Ellipsonodosaria* sp. (p. 268 tab.).
USNM 623792, × 28; USGS f21125 (S385); *a*, side view; *b*, apertural view.

15. *Ellipsoglandulina labiata* (Schwager) (p. 268 tab.).
USNM 623793; USGS f21125 (S385); *a*, side view; *b*, apertural view; *c*, basal view.

16. *Ellipsopleurostomella* sp. (p. 268 tab.).
USNM 623884; USGS f21042 (S26).

17. *Discorbis* sp. A (p. 268 tab.).
USNM 623853, × 95; USGS f21129 (S598); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

18. *Discorbis* sp. C (p. 268 tab.).
USNM 623854, × 95; USGS f21129 (S598); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

19. *Discorbis?* sp. D (p. 268 tab.).
USNM 623885; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

20. *Discorbis celsa* Todd, n. sp. (p. 299).
Holotype, USNM 623925, × 55; USGS f21081 (S253); *a*, ventral view; *b*, peripheral view.

PLATE 68

[All figures × 55, except as indicated]

FIGURE 1. *Discorbis* sp. B (p. 268 tab.).
USNM 623794, × 95; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Heminwayina?* sp. (p. 304).
USNM 623795, × 95; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Valvulineria scrobiculata* (Schwager) (p. 268 tab.).
USNM 623887; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Valvulineria? scita* Todd, n. sp. (p. 308).
Holotype, USNM 623797; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Valvulineria pulchra* Todd, n. sp. (p. 308).
Holotype, USNM 623888, × 45; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6. *Valvulineria texana* Cushman and Ellisor (p. 268 tab.).
USNM 623796, × 95; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Lamarckina* sp. (p. 268 tab.).
USNM 623886; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view.

8. *Eponides* sp. B (p. 300).
USNM 623926, × 17; USGS f21081 (S253); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9. *Eponides umbonatus* (Reuss) (p. 268 tab.).
USNM 623839; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view.

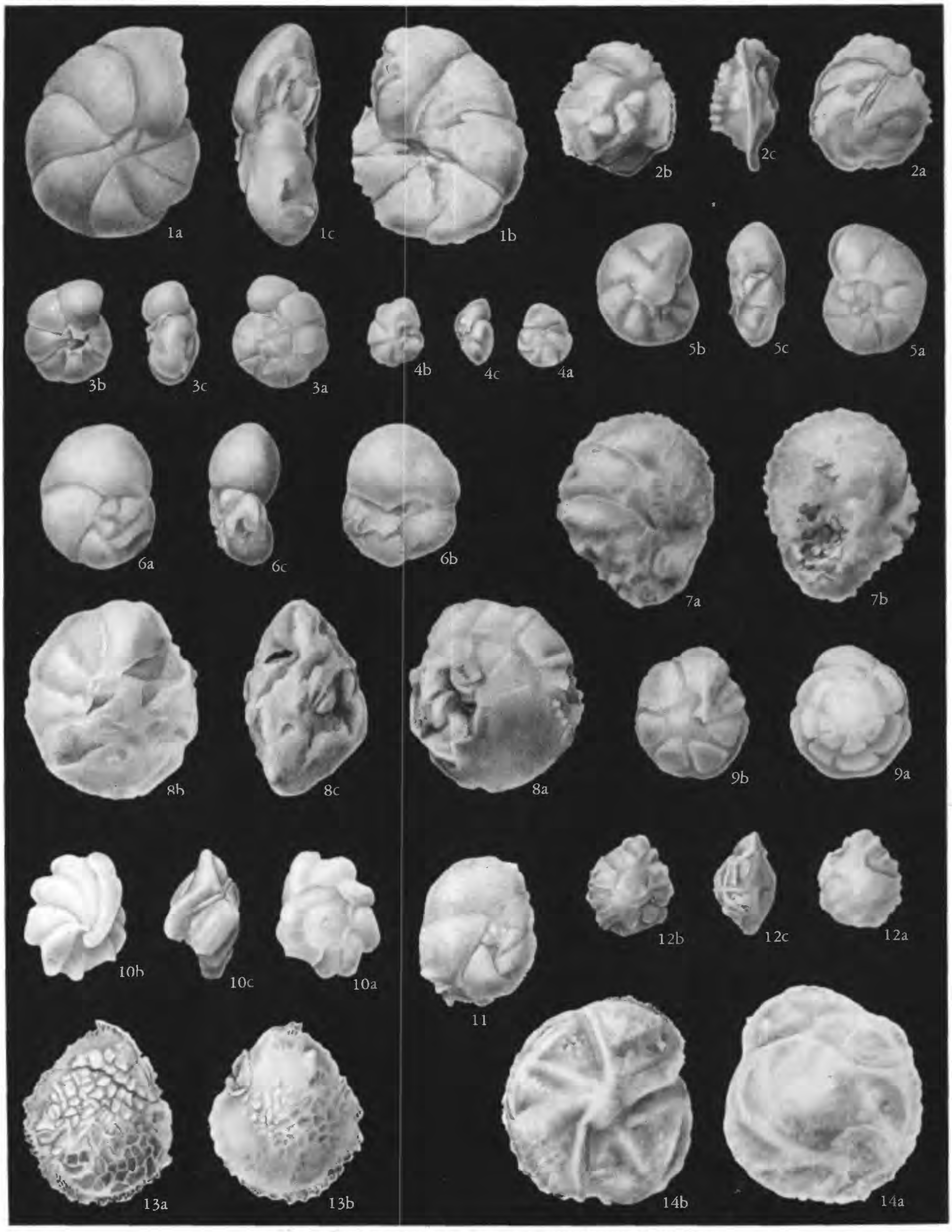
10. *Eponides* sp. A (p. 268 tab.).
USNM 623840; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

11. *Baggina* sp. (p. 268 tab.).
USNM 623753, × 45; USGS f21113 (S344).

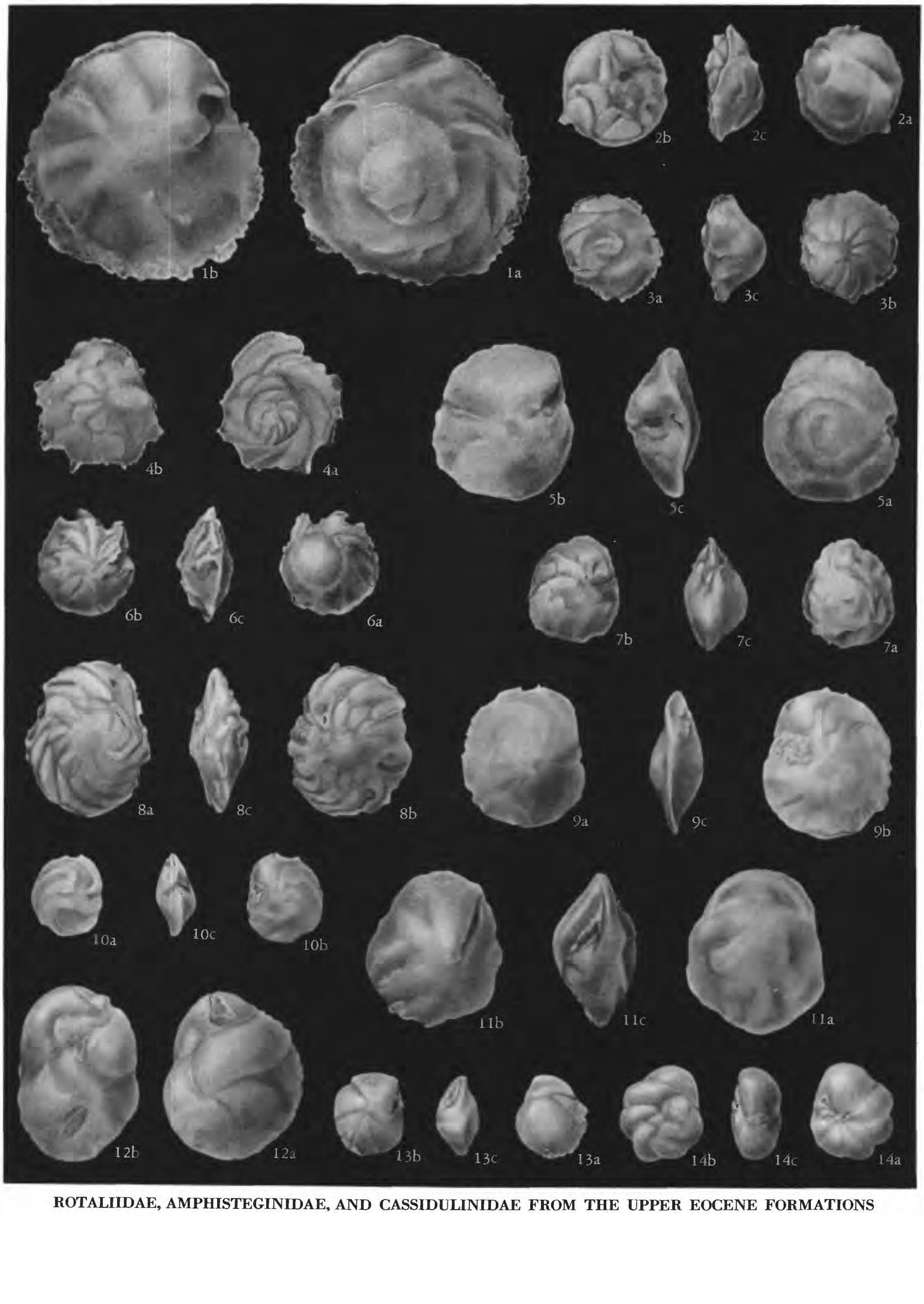
12. *Streblus* cf. *S. mexicanus* (Nuttall) (p. 268 tab.).
USNM 623915, × 28; USGS f21062 (S194); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

13. *Siphonina* sp. A (p. 268 tab.).
USNM 623798; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view.

14. *Höglundina eocenica* (Cushman and M. A. Hanna) (p. 268 tab.).
USNM 623890; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view.



ROTALIIDAE FROM THE UPPER EOCENE FORMATIONS



ROTALIIDAE, AMPHISTEGINIDAE, AND CASSIDULINIDAE FROM THE UPPER EOCENE FORMATIONS

PLATE 69

[All figures × 28, except as indicated]

FIGURE 1. *Osangularia mexicana* (Cole) (p. 268 tab.).
USNM 623889, × 55; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view.

2. *Asterigerina* cf. *A. bracteata* Cushman (p. 268 tab.).
USNM 623855, × 95; USGS f21129 (S598); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Asterigerina fimbriata* Todd, n. sp. (p. 296).
Holotype, USNM 623799, × 45; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Asterigerina* sp. A (p. 268 tab.).
USNM 623800, × 95; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view.

5. *Asterigerina* sp. C (p. 268 tab.).
USNM 623891; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6. *Asterigerina* sp. B (p. 268 tab.).
USNM 623919; USGS f21072 (S219); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Asterigerina* sp. D (p. 268 tab.).
USNM 623927; USGS f21081 (S253); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

8–10. *Amphistegina* cf. *A. madagascariensis* D'Orbigny (p. 296).
8. USNM 623916; USGS f21062 (S194); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
9. USNM 623892; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
10. USNM 623893; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

11. *Alabamina conica* Todd, n. sp. (p. 295).
Holotype, USNM 623894, × 55; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

12. *Cassidulina globosa* Hantken (p. 268 tab.).
USNM 623896, × 95; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view.

13. *Epistominella* sp. A (p. 268 tab.).
USNM 623895; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

14. *Epistominella?* sp. B (p. 268 tab.).
USNM 623856, × 55; USGS f21129 (S598); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

PLATE 70

FIGURES 1, 2. *Chilostomella cyclostoma* Rzehak, × 28 (p. 268 tab.).
1. USNM 623897, front view; USGS f21042 (S26).
2. USNM 623898, side view; USGS f21042 (S26).

3. *Pullenia quadriloba* Reuss (p. 268 tab.).
USNM 623802, × 55; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

4. *Pullenia bulloides* (D'Orbigny) (p. 268 tab.).
USNM 623801, × 55; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

5–7. *Globigerinoides index* Finlay, × 45 (p. 268 tab.).
5. USNM 623841; USGS f21126 (S420).
6. USNM 623842; USGS f21126 (S420).
7. USNM 623843; USGS f21126 (S420).

8, 9. *Globigerina bakeri* Cole (p. 268 tab.).
8. Dextral specimen, USNM 623803, × 55; USGS f21125 (S385).
9. Sinistral specimen, USNM 623804, × 28; USGS f21125 (S385).
a, *a*, dorsal views; *b*, *b*, ventral views; *c*, *c*, peripheral views.

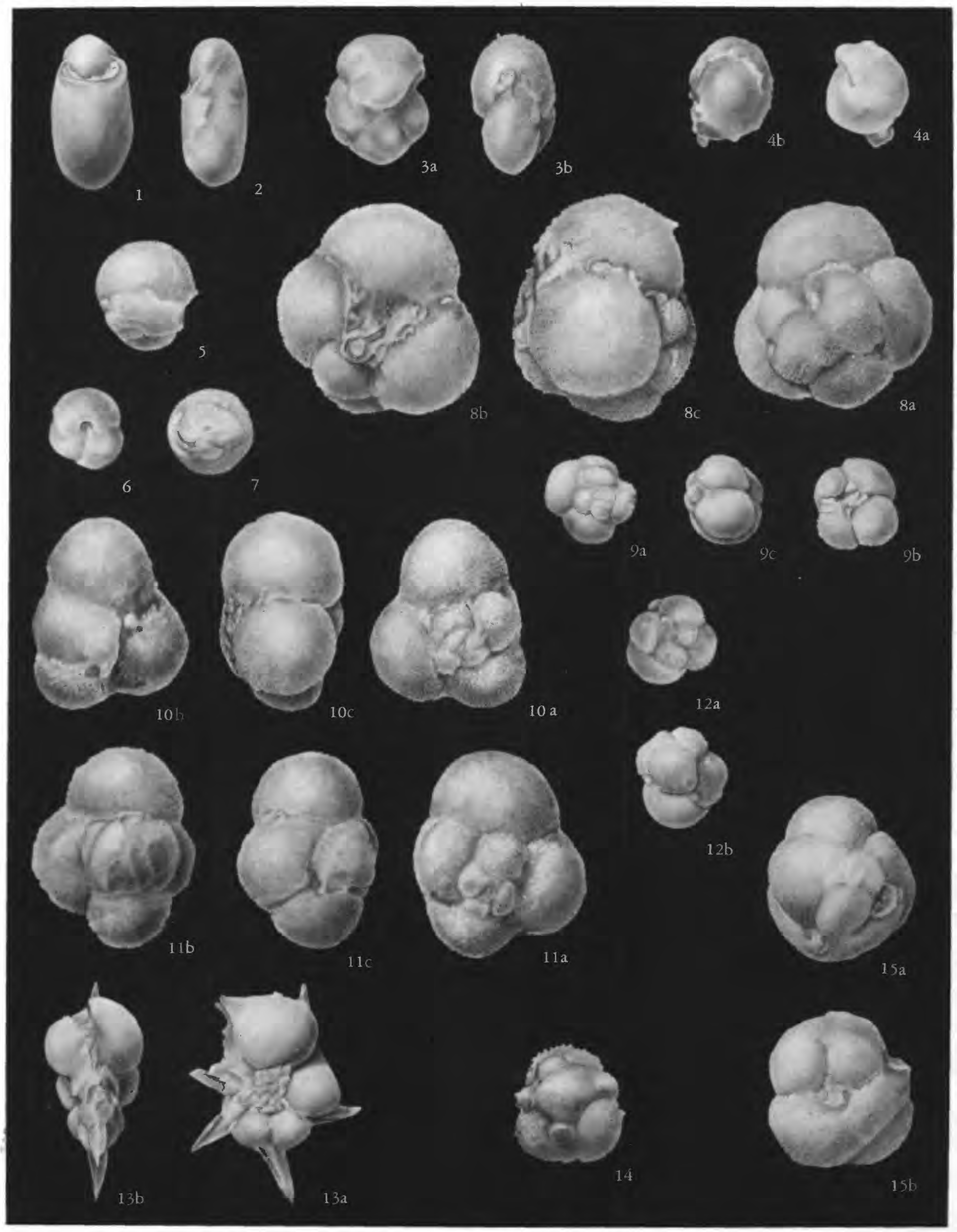
10, 11. *Globigerina pera* Todd, n. sp., × 55 (p. 301).
10. Holotype, USNM 623805; USGS f21125 (S385).
11. Paratype, USNM 623806; USGS f21125 (S385). Ventral view shows the final pocketlike chamber, open toward the left. *a*, *a*, dorsal views; *b*, *b*, ventral views; *c*, *c*, peripheral views.

12. *Globigerinoides* cf *G. rubra* (D'Orbigny) (p. 303).
USNM 623807, × 45; USGS f21125 (S385); *a*, dorsal view; *b*, side view.

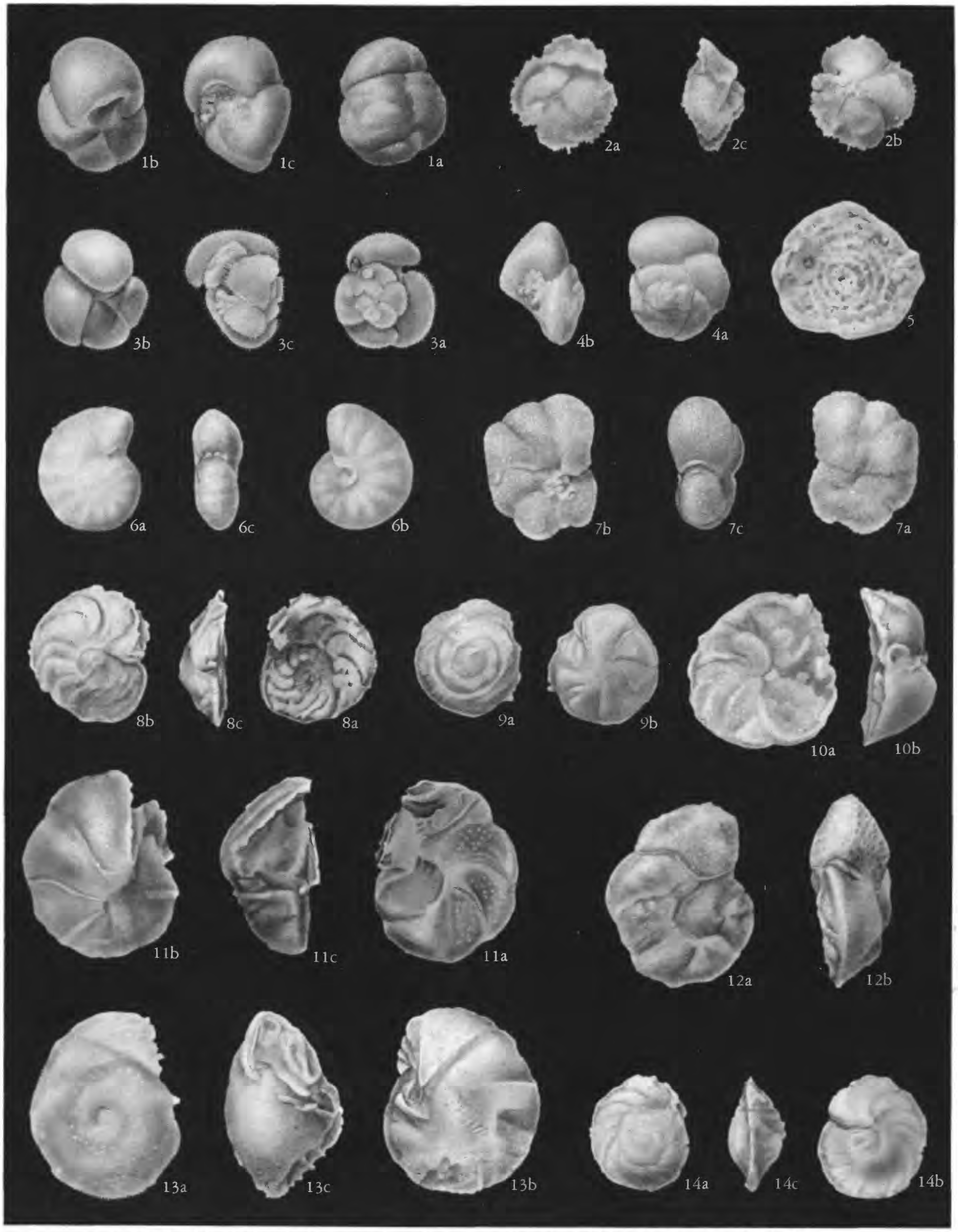
13. *Hantkenina bermudezi* Thalmann (p. 304).
USNM 623810, × 45; USGS f21125 (S385); *a*, side view; *b*, peripheral view.

14. *Globigerinita?* sp. A (p. 302).
USNM 623809, × 55; USGS f21125 (S385).

15. *Globigerinita?* sp. B (p. 302).
USNM 623808, × 55; USGS f21125 (S385); *a*, dorsal view; *b*, side view.



CHILOSTOMELLIDAE, GLOBIGERINIDAE, AND HANTKENINIDAE FROM THE UPPER EOCENE FORMATIONS



GLOBOROTALIIDAE AND ANOMALINIDAE FROM THE UPPER EOCENE FORMATIONS

PLATE 71

FIGURES 1, 3. *Globorotalia centralis* Cushman and Bermudez (p. 268 tab.).
1. USNM 623844, × 45; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
3. USNM 623757, × 45; USGS f21115 (S346); heulandite internal cast. The spiny surface represents the perforations of the test wall. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Globorotalia spinulosa* Cushman (p. 268 tab.).
USNM 623811, × 55; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Globorotalia cerro-azulensis* (Cole) (p. 268 tab.).
USNM 623845, × 45; USGS f21126 (S420); *a*, dorsal view; *b*, peripheral view.

5. *Cycloloculina* sp. (p. 268 tab.).
USNM 623899, × 28; USGS f21042 (S26).

6. *Anomalina alazanensis* Nuttall var. *spissiformis* Cushman and Stainforth (p. 269 tab.).
USNM 623812, × 45; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Anomalina* sp. (p. 269 tab.).
USNM 623900, × 45; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

8. *Planulina* sp. A (p. 269 tab.).
USNM 623928, × 28; USGS f21081 (S253); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9. *Cibicides cocoaensis* (Cushman) (p. 269 tab.).
USNM 623846, × 55; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view.

10–12. *Cibicides lobatulus* (Walker and Jacob), × 95 (p. 269 tab.).
10. USNM 623848; USGS f21126 (S420); *a*, dorsal view; *b*, peripheral view.
11. USNM 623847; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
12. USNM 623901; USGS f21042 (S26); *a*, dorsal view; *b*, peripheral view.

13. *Cibicides perlucidus* Nuttall (p. 269 tab.).
USNM 623813, × 55; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

14. *Cibicides pseudoungerianus* (Cushman) (p. 269 tab.).
USNM 623849, × 28; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

PLATE 72

FIGURE 1. *Cibicides tuxpamensis* Cole (p. 269 tab.).
USNM 623850, × 28; USGS f21126 (S420); *a*, dorsal view; *b*. ventral view; c, peripheral view.

2. *Cibicides* cf. *C. trinitatensis* (Nuttall) (p. 269 tab.).
USNM 623917, × 28; USGS f21062 (S194); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Cibicides vortex* Dorreen (p. 298).
USNM 623902, × 45; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Cibicides* sp. A (p. 269 tab.).
USNM 623903, × 55; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Cibicides* sp. B (p. 269 tab.).
USNM 623904, × 95; USGS f21042 (S26); *a*, dorsal view; *b*, peripheral view.

6. *Cibicides* sp. C (p. 269 tab.).
USNM 623905, × 55; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Cibicides?* sp. D (p. 269 tab.).
USNM 623906, × 55; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

8. *Cibicidina* sp. A (p. 269 tab.).
USNM 623851, × 95; USGS f21126 (S420); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

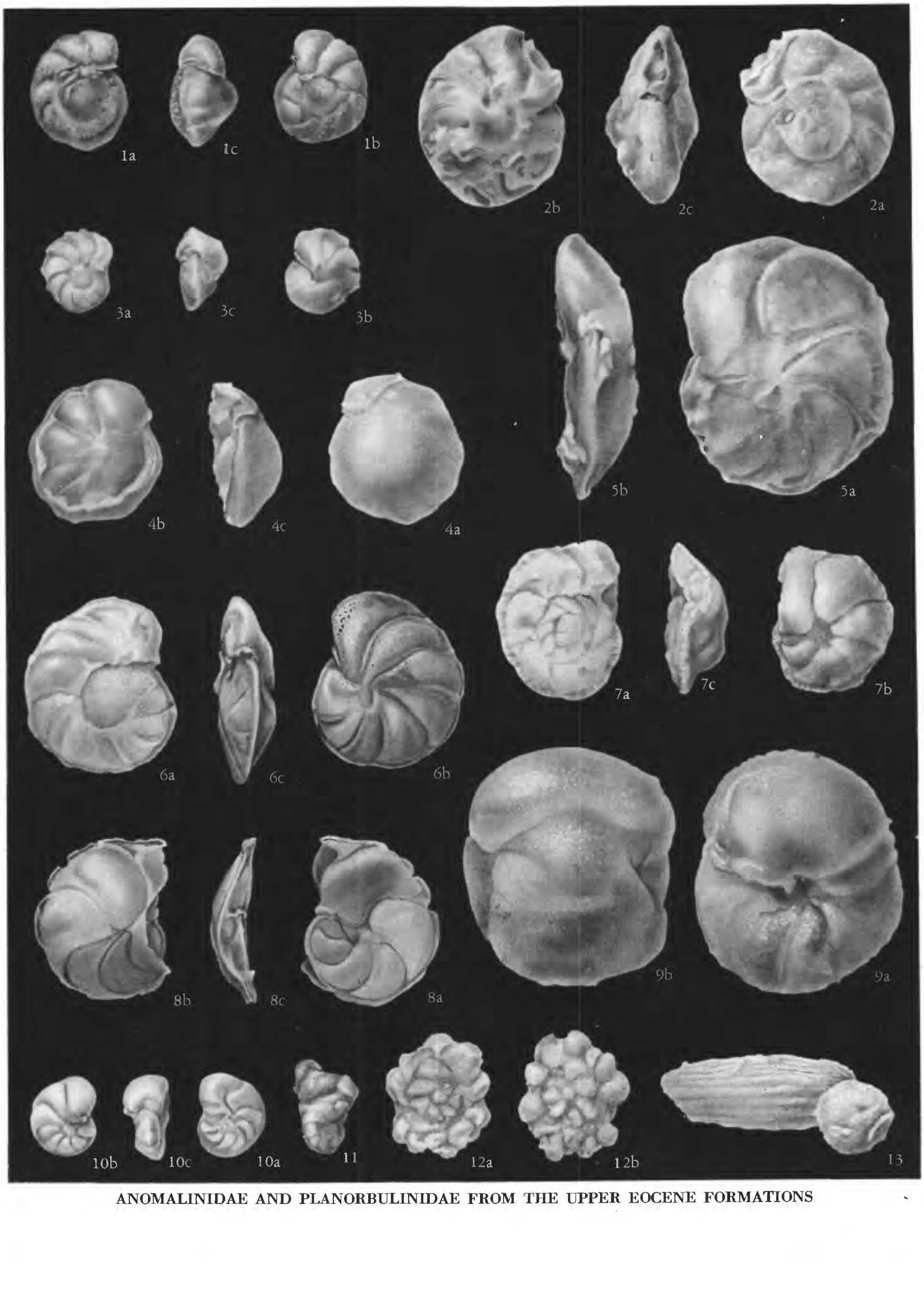
9. *Cibicidina?* sp. B (p. 269 tab.).
USNM 623908, × 95; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view.

10. *Cibicidina* cf. *C. mississippiensis* (Cushman) (p. 269 tab.).
USNM 623907, × 45; USGS f21042 (S26); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

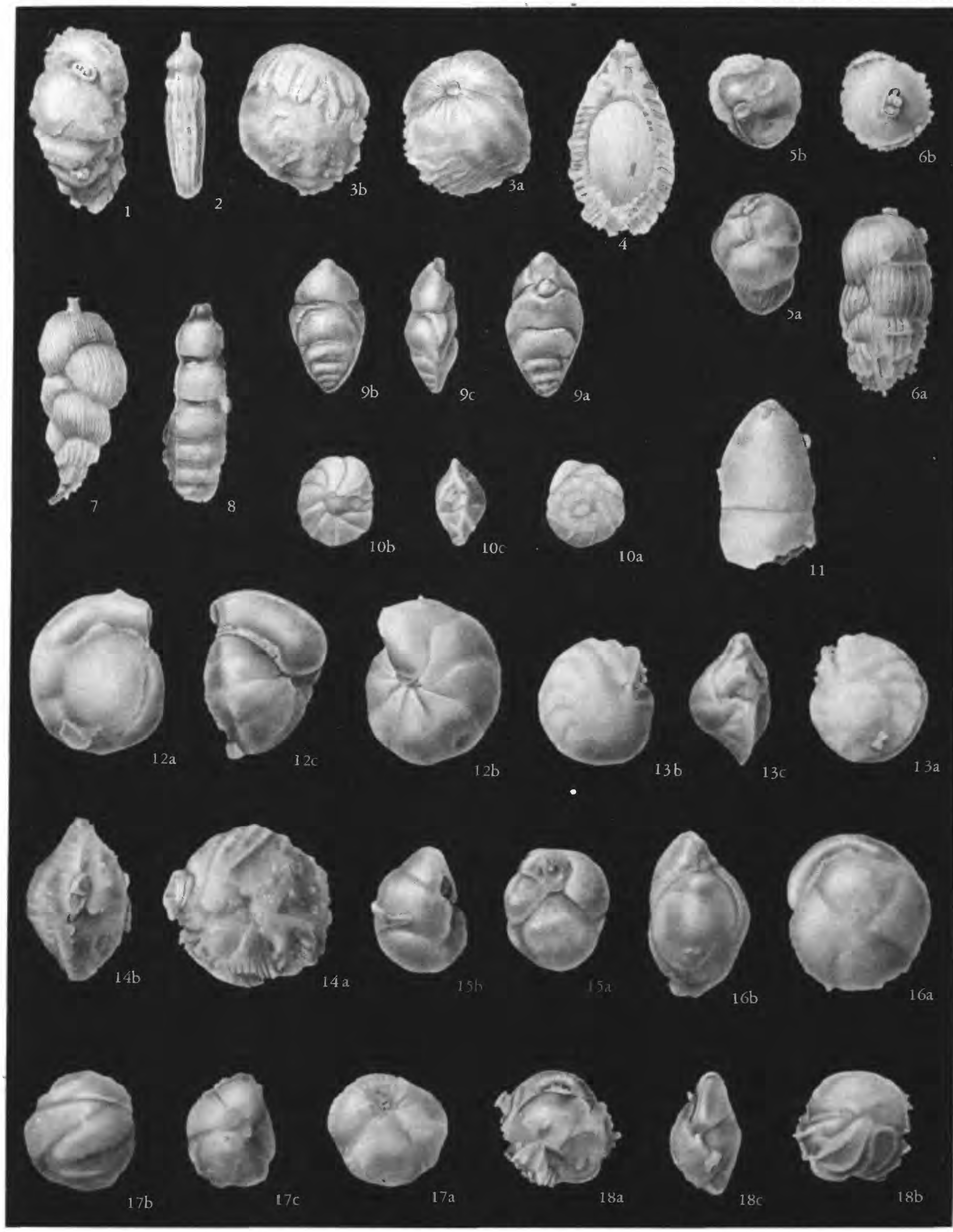
11. *Cibicidella* sp. (p. 269 tab.).
USNM 623909, × 45; USGS f21042 (S26).

12. *Planorbulina mediterranensis* D'Orbigny (p. 269 tab.).
USNM 623814, × 55; USGS f21125 (S385); *a*, dorsal view; *b*, ventral view.

13. *Gypsina globula* (Reuss) (p. 269 tab.).
USNM 623918, × 28; USGS f21062 (S194).



ANOMALINIDAE AND PLANORBULINIDAE FROM THE UPPER EOCENE FORMATIONS



REPRESENTATIVES OF SEVEN FAMILIES (VALVULINIDAE TO CASSIDULINIDAE) FROM THE UPPER OLIGOCENE FINA-SISU FORMATION

PLATE 73

[All specimens from USGS f21133 (C85)]

FIGURE 1. *Karreriella chilostoma* (Reuss) (p. 273 tab.).
USNM 623929, × 45.
2. *Lagenonodosaria* sp. (p. 273 tab).
USNM 623930, × 28.
3. *Buliminella septata* Keyzer (p. 298).
USNM 623932, × 55; *a*, front view showing aperture; *b*, rear view.
4. *Fissurina formosa* (Schwager) var. *comata* (Brady) (p. 273 tab.).
USNM 623934, × 45.
5. *Bulimina* sp. (p. 273 tab.).
USNM 623933, × 55; *a*, top view; *b*, side view.
6. *Uvigerina nitidula* Schwager (p. 273 tab.).
USNM 623935, × 55; *a*, side view; *b*, top view.
7. *Siphogenerina seriata* (Cushman and Jarvis) (p. 273 tab.).
USNM 623936, × 45.
8. *Nodogenerina?* sp. A (p. 273 tab.).
USNM 623931, × 95.
9. *Pleurostomella?* sp. B (p. 273 tab.).
USNM 623938, × 95; *a*, *b*, opposite sides; *c*, peripheral view.
10. *Eponides kiliani* (Andreae) (p. 274 tab.).
USNM 623940, × 55; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
11. *Pleurostomella* cf. *P. rimosa* Cushman and Bermudez (p. 273 tab.).
USNM 623937, × 28; fragment of an apertural end.
12. *Gyroidina nitidula* (Schwager) (p. 274 tab.).
USNM 623939, × 45; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
13. *Eponides?* sp. C (p. 274 tab.).
USNM 623941, × 55; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
14. *Siphonina* sp. B (p. 274 tab.).
USNM 623942, × 55; *a*, side view; *b*, peripheral view.
15. *Cassidulina globosa* Hantken (p. 274 tab.).
USNM 623943, × 95; *a*, front view; *b*, side view.
16. *Cassidulina* sp. B (p. 274 tab.).
USNM 623945, × 55; *a*, front view; *b*, side view.
17. *Cassidulina* sp. A (p. 274 tab.).
USNM 623944, × 45; *a*, front view; *b*, rear view.
18. *Cassidulina* sp. C (p. 274 tab.).
USNM 623946, × 95; *a*, front view; *b*, rear view; *c*, side view.

PLATE 74

[All specimens from USGS f21133 (C85)]

FIGURE 1. *Globigerinoides triloba* (Reuss) (p. 274 tab.).
USNM 623956, × 55.

2. *Ehrenbergina albatrossi* Cushman (p. 274 tab.).
USNM 623947, × 28.

3. *Sphaeroidina haueri* (Czjzek) (p. 274 tab.).
USNM 623948, × 28.

4. *Globigerina? grata* Todd, n. sp. (p. 300).
Holotype, USNM 623949, × 45; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Globoquadrina altispira* (Cushman and Jarvis) (p. 274 tab.).
USNM 623960, × 55; *a*, dorsal view; *b*, side view.

6. *Globigerinoides subquadrata* Bronnimann (p. 303).
Holotype, USNM 548881, × 80; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7, 8. *Globigerinoides bispherica* Todd (p. 302).
7. Holotype, USNM 548876, × 80; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
8. Paratype, USNM 623952, × 60; view indeterminate.

9. *Globigerina* sp. A (p. 274 tab.).
USNM 623950, × 95; *a*, dorsal view; *b*, side view.

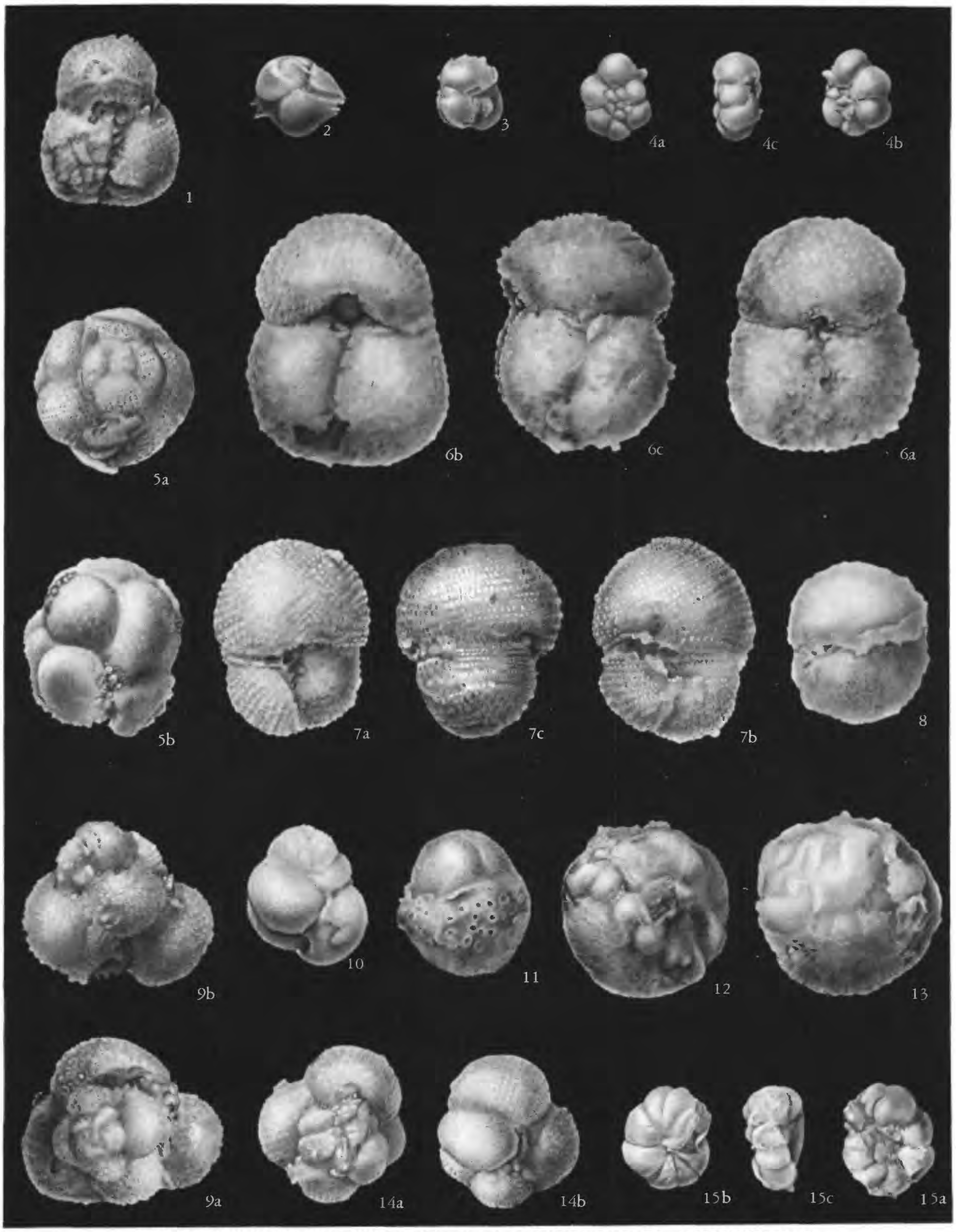
10. *Globigerinoides pseudorubra* Todd, n. sp. (p. 303).
Holotype, USNM 623954, × 45.

11. *Orbulina suturalis* Bronnimann (p. 274 tab.).
USNM 623959, × 55.

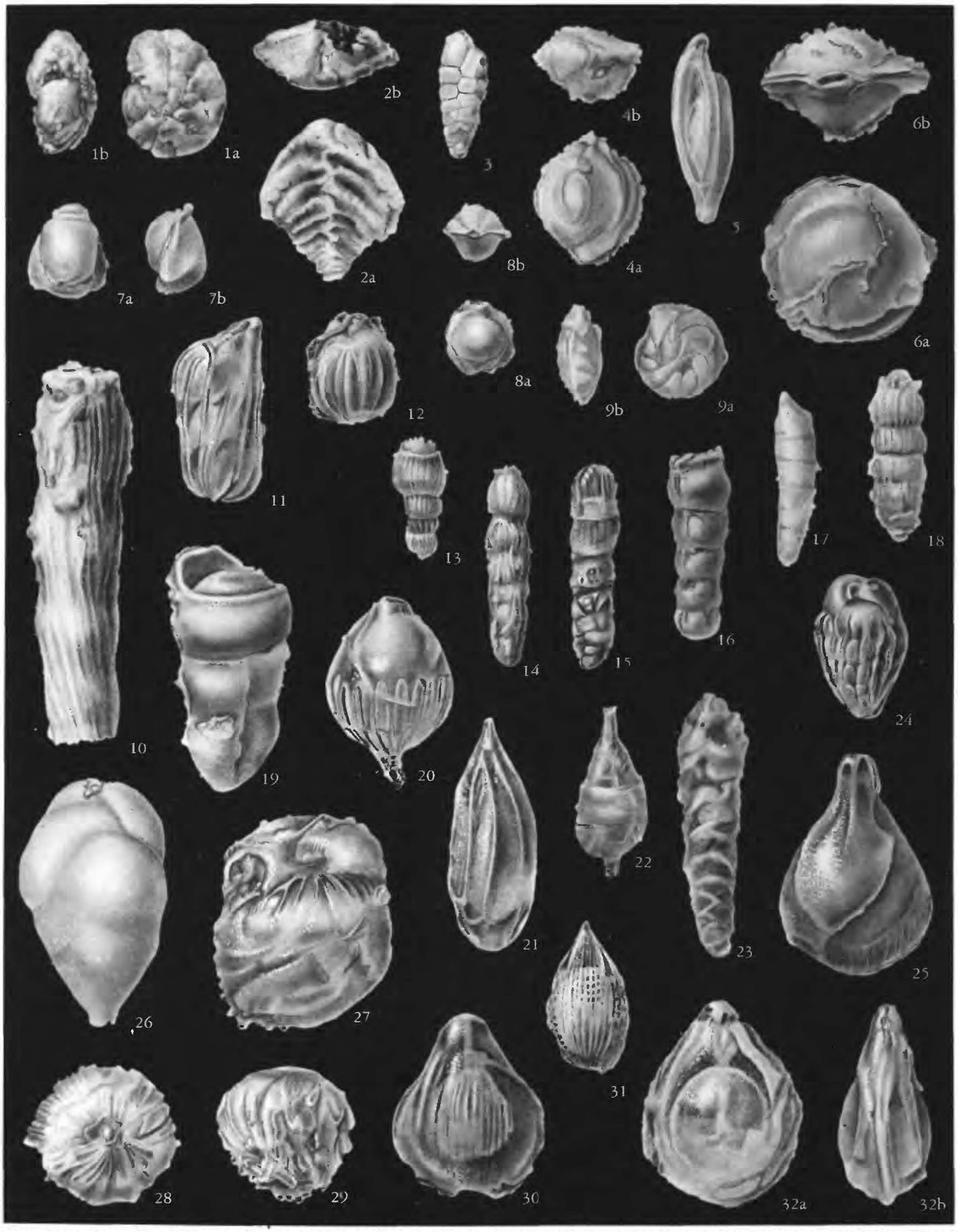
12, 13. *Globigerinatella insueta* Cushman and Stainforth, × 85 (p. 274 tab.).
12. USNM 623957.
13. USNM 623958.

14. *Globigerina* sp. B (p. 274 tab.).
USNM 623951, × 95; *a*, dorsal view; *b*, ventral view.

15. *Cibicides* sp. E (p. 298).
USNM 623961, × 28; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.



REPRESENTATIVES OF FIVE FAMILIES (CASSIDULINIDAE TO ANOMALINIDAE) FROM THE UPPER OLIGOCENE FINA-SISU FORMATION



REPRESENTATIVES OF SEVEN FAMILIES (LITUOLIDAE TO BULIMINIDAE) FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE

PLATE 75

FIGURE 1. *Cyclammina* sp. B (p. 277 tab.).
USNM 623967, × 45; USGS f21346 (B339); *a*, side view; *b*, peripheral view.

2. *Textularia* sp. C (p. 277 tab.).
USNM 623976, × 28; USGS f21450 (C70); *a*, front view; *b*, end view.

3. *Karreriella bradyi* (Cushman) (p. 277 tab.).
USNM 623969, × 28; USGS f21443 (C42).

4. *Triloculina* sp. (p. 277 tab.).
USNM 623988, × 45; USGS f21564 (S443); *a*, side view; *b*, top view.

5. *Sigmoilina tenuis* (Czjzek) (p. 277 tab.).
USNM 623989, × 95; USGS f21564 (S443).

6. *Pyrgo* sp. B (p. 306).
USNM 623998, × 28; USGS f21578 (S621); *a*, front view; *b*, top view.

7. *Pyrgo denticulata* (Brady) (p. 277 tab.).
USNM 623999, × 28; USGS f21578 (S621); *a*, front view; *b*, side view.

8. *Pyrgo murrhina* (Schwager) (p. 277 tab.).
USNM 624000, × 28; USGS f21578 (S621); *a*, front view; *b*, top view.

9. *Robulus limbosus* (Reuss)? (p. 277 tab.).
USNM 624001, × 28; USGS f21578 (S621); *a*, side view, *b*, peripheral view.

10. *Dentalina spirostriolata* (Cushman) (p. 277 tab.).
USNM 623977, × 28; USGS f21450 (C70).

11. *Marginulina costata* (Batsch) (p. 277 tab.).
USNM 624002, × 45; USGS f21578 (S621).

12. *Nodosaria pauciloculata* Cushman (p. 277 tab.).
USNM 624004, × 55; USGS f21578 (S621).

13. *Nodosaria perversa* Schwager (p. 277 tab.).
USNM 623981, × 45; USGS f21514 (S25).

14. *Nodosaria* sp. B (p. 277 tab.).
USNM 623962, × 55; USGS f21345 (B333).

15. *Nodosaria* sp. C (p. 277 tab.).
USNM 624006, × 55; USGS f21578 (S621).

16. *Nodosaria tornata* Schwager (p. 277 tab.).
USNM 624005, × 45; USGS f21578 (S621).

17. *Dentalina* sp. B (p. 277 tab.).
USNM 624003, × 28; USGS f21578 (S621).

18. *Pseudoglandulina* sp. (p. 277 tab.).
USNM 624008, × 55; USGS f21578 (S621).

19. *Pseudoglandulina solita* (Schwager) (p. 277 tab.).
USNM 624007, × 28; USGS f21578 (S621).

20. *Lagena? exsculpta* Brady (p. 277 tab.).
USNM 624009, × 55; USGS f21578 (S621).

21. *Lagena gracilis* Williamson (p. 277 tab.).
USNM 624010, × 95; USGS f21578 (S621).

22. *Lagena?* sp. (p. 277 tab.).
USNM 624011, × 28; USGS f21578 (S621).

23. *Amphimorphina* sp. (p. 277 tab.).
USNM 624012, × 95; USGS f21578 (S621).

24. *Bulimina truncana* Gümbel (p. 278 tab.).
USNM 624013, × 95; USGS f21578 (S621).

25. *Fissurina* sp. C (p. 278 tab.).
USNM 624020, × 95; USGS f21578 (S621).

26. *Bulimina tuxpamensis* Cole (p. 278 tab.).
USNM 623990, × 45; USGS f21572 (S563).

27–29. *Buliminella septata* Keyzer, × 55 (p. 298).
27. USNM 624014; USGS f21578 (S621); front view.
28. USNM 624015; USGS f21578 (S621); top view.
29. USNM 624016; USGS f21578 (S621); rear view.

30. *Fissurina auriculata* var. *costata* (Brady) (p. 278 tab.).
USNM 624017, × 55; USGS f21578 (S621).

31. *Fissurina* sp. B (p. 278 tab.).
USNM 624019, × 95; USGS f21578 (S621).

32. *Fissurina orbignyana* Seguenza (p. 278 tab.).
USNM 624018, × 95; USGS f21578 (S621); *a*, front view; *b*, peripheral view.

PLATE 76

FIGURE 1. *Uvigerina proboscidea* Schwager (p. 278 tab.).
USNM 624021, × 55; USGS f21578 (S621).

2. *Pleurostomella alazanensis* Cushman (p. 278 tab.).
USNM 623991, × 55; USGS f21572 (S563); *a*, apertural view; *b*, side view.

3. *Pleurostomella tenuis* Hantken (p. 278 tab.).
USNM 624022, × 95; USGS f21578 (S621); *a*, apertural view; *b*, side view.

4. *Pleurostomella frons* Todd, n. sp. (p. 306).
Holotype, USNM 624023, × 95; USGS f21578 (S621); *a*, side view; *b*, apertural view.

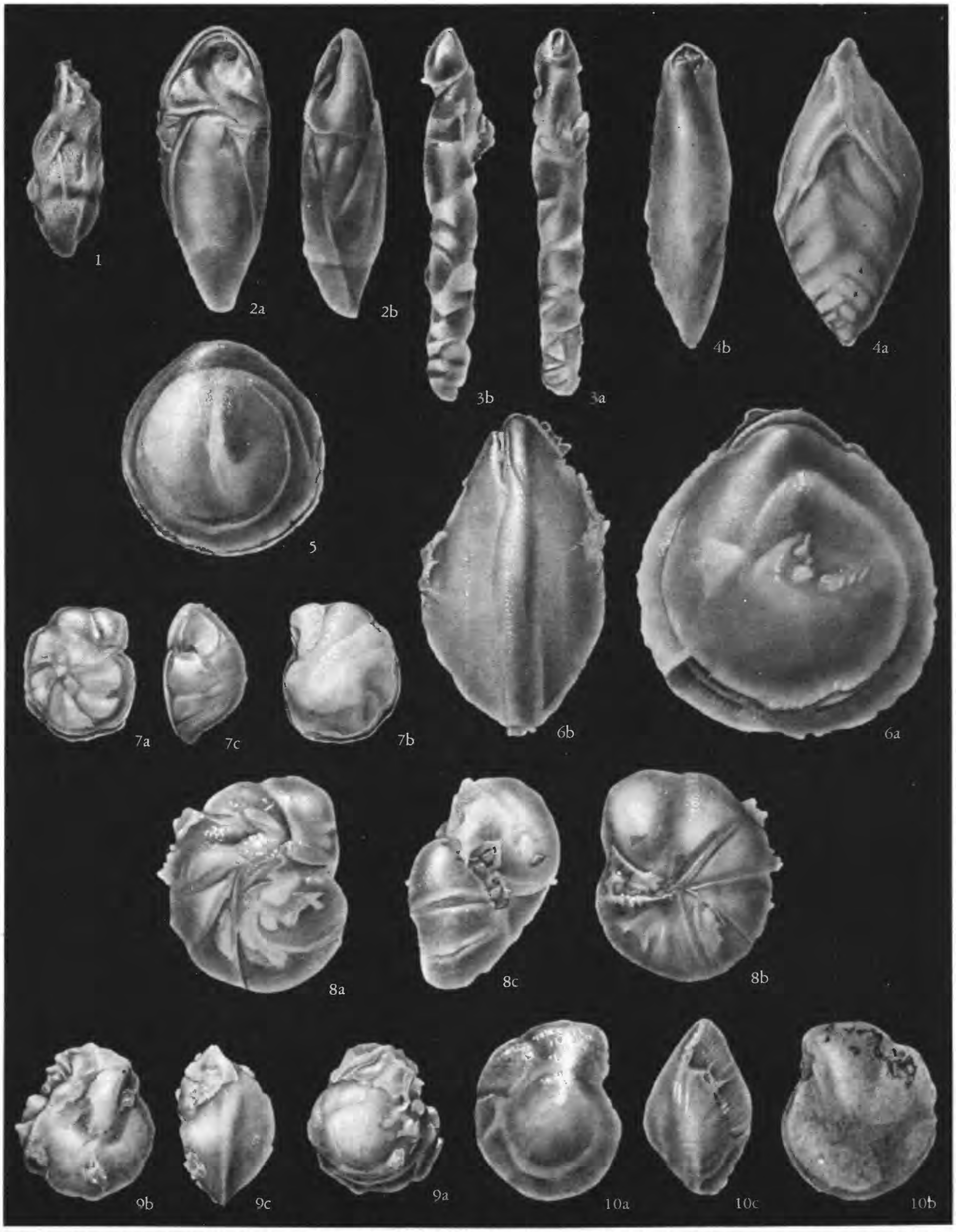
5, 6. *Parafissurina ovalis* Todd, n. sp., × 95 (p. 306).
5. Paratype, USNM 624025; USGS f21578 (S621), front view.
6. Holotype, USNM 624024, USGS f21578 (S621); *a*, front view; *b*, peripheral view.

7. *Eponides* cf. *E. conicus* Boomgaart (p. 278 tab.).
USNM 623970, × 55; USGS f21443 (C42); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

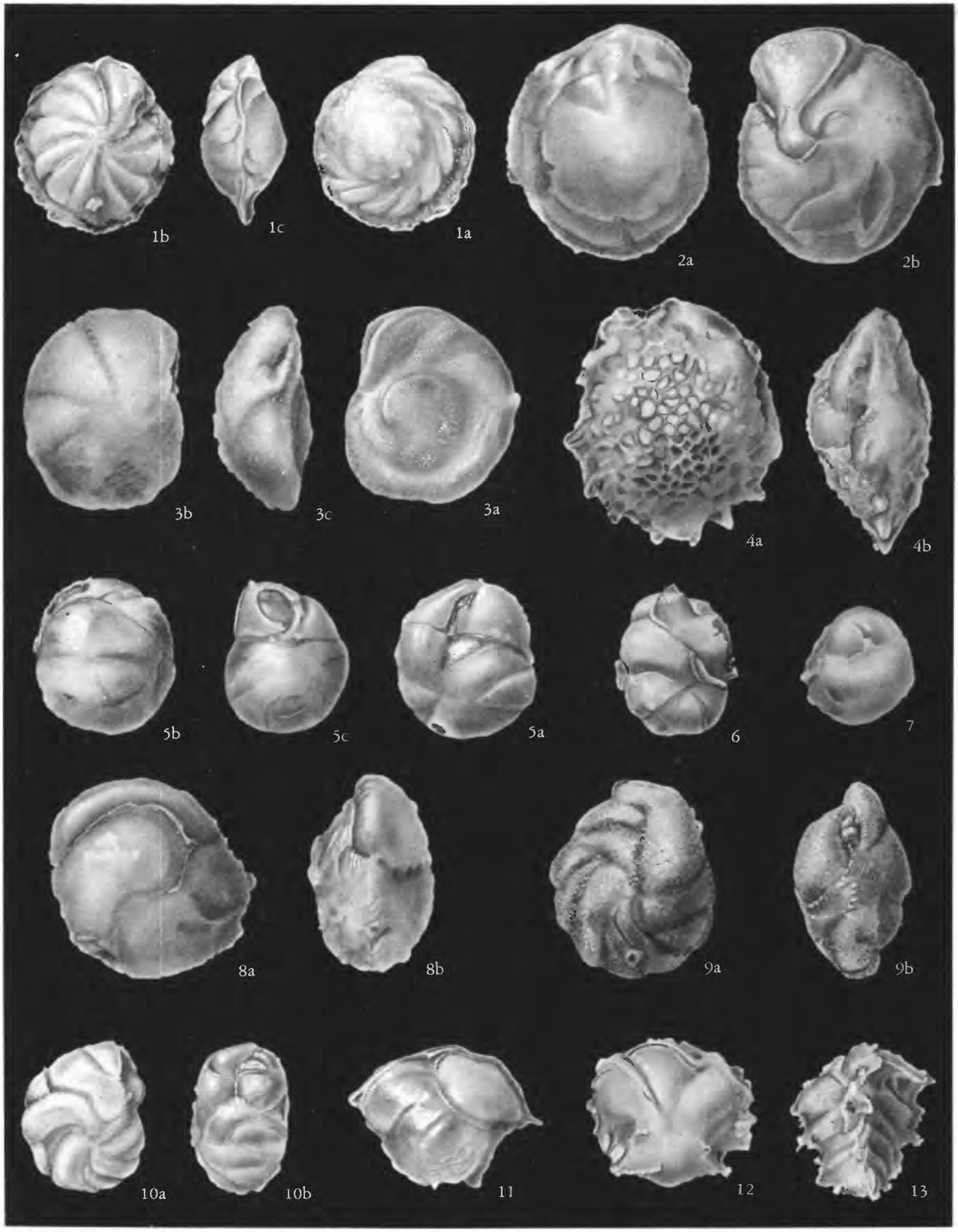
8. *Gyroidina* sp. (p. 278 tab.).
USNM 623992, × 95; USGS f21572 (S563); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9. *Eponides* sp. E. (p. 278 tab.).
USNM 623993, × 28; USGS f21572 (S563); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

10. *Eponides* sp. F. (p. 278 tab.).
USNM 624027, × 95; USGS f21578 (S621); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.



BULIMINIDAE, ELLIPSOIDINIDAE, AND ROTALIIDAE FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE



ROTALIIDAE AND CASSIDULINIDAE FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE

PLATE 77

FIGURE 1. *Osangularia bengalensis* (Schwager) (p. 278 tab.).
USNM 624028, × 55; USGS f21578 (S621); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Eponides* cf. *E. umbonatus* (Reuss) (p. 278 tab.).
USNM 624026, × 95; USGS f21578 (S621); *a*, dorsal view; *b*, ventral view.

3. *Epistominella* sp. C (p. 278 tab.).
USNM 624029, × 45; USGS f21578 (S621); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Cassidulina elegantissima* Cushman (p. 278 tab.).
USNM 624030, × 45; USGS f21578 (S621); *a*, side view; *b*, peripheral view.

5. *Cassidulina pacifica* Cushman (p. 278 tab.).
USNM 624031, × 55; USGS f21578 (S621); *a*, front view; *b*, rear view; *c*, side view.

6. *Cassidulina delicata* Cushman (p. 278 tab.).
USNM 623963, × 55; USGS f21345 (B333).

7. *Cassidulina subglobosa* Brady (p. 278 tab.).
USNM 624032, × 28; USGS f21578 (S621).

8. *Cassidulina tricamerata* Galloway and Heminway (p. 278 tab.).
USNM 624033, × 95; USGS f21578 (S621); *a*, side view; *b*, peripheral view.

9. *Cassidulina* sp. E (p. 298).
USNM 623971, × 55; USGS f21449 (C69); *a*, side view; *b*, peripheral view.

10. *Cassidulina* sp. D (p. 298).
USNM 624034, × 55; USGS f21578 (S621); *a*, side view; *b*, peripheral view.

11. *Ehrenbergina albatrossi* Cushman (p. 278 tab.).
USNM 624035, × 55; USGS f21578 (S621).

12. *Ehrenbergina serrata* Reuss (p. 278 tab.).
USNM 624036, × 28; USGS f21578 (S621).

13. *Ehrenbergina bradyi* Cushman (p. 278 tab.).
USNM 623968 × 55; USGS f21346 (B339).

PLATE 78

[All figures × 55, except as indicated]

FIGURE 1. *Pullenia compressiuscula* Reuss (p. 279 tab.).
USNM 623972, × 95; USGS f21449 (C69); *a*, side view; *b*, peripheral view.

2. *Pullenia quinqueloba* (Reuss) (p. 279 tab.).
USNM 623985, × 95; USGS f21563 (S433); *a*, side view; *b*, peripheral view.

3, 6. *Globigerinoides mitra* Todd, n. sp., × 28 (p. 302).
3. Holotype, USNM 624038; USGS f21578 (S621); rear view.
6. Paratype, USNM 624039; USGS f21578 (S621); front view.

4. *Globigerina* sp. C (p. 302).
USNM 623973; USGS f21449 (C69).

5. *Globigerina bulloides* D'Orbigny (p. 279 tab.).
USNM 623994; USGS f21572 (S563); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Globigerina nepenthes* Todd, n. sp. (p. 301).
Holotype, USNM 624037; USGS f21578 (S621); *a*, side view; *b*, ventral view.

8. *Globigerina eximia* Todd, n. sp. (p. 300).
Holotype, USNM 623978, × 45; USGS f21450 (C70); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

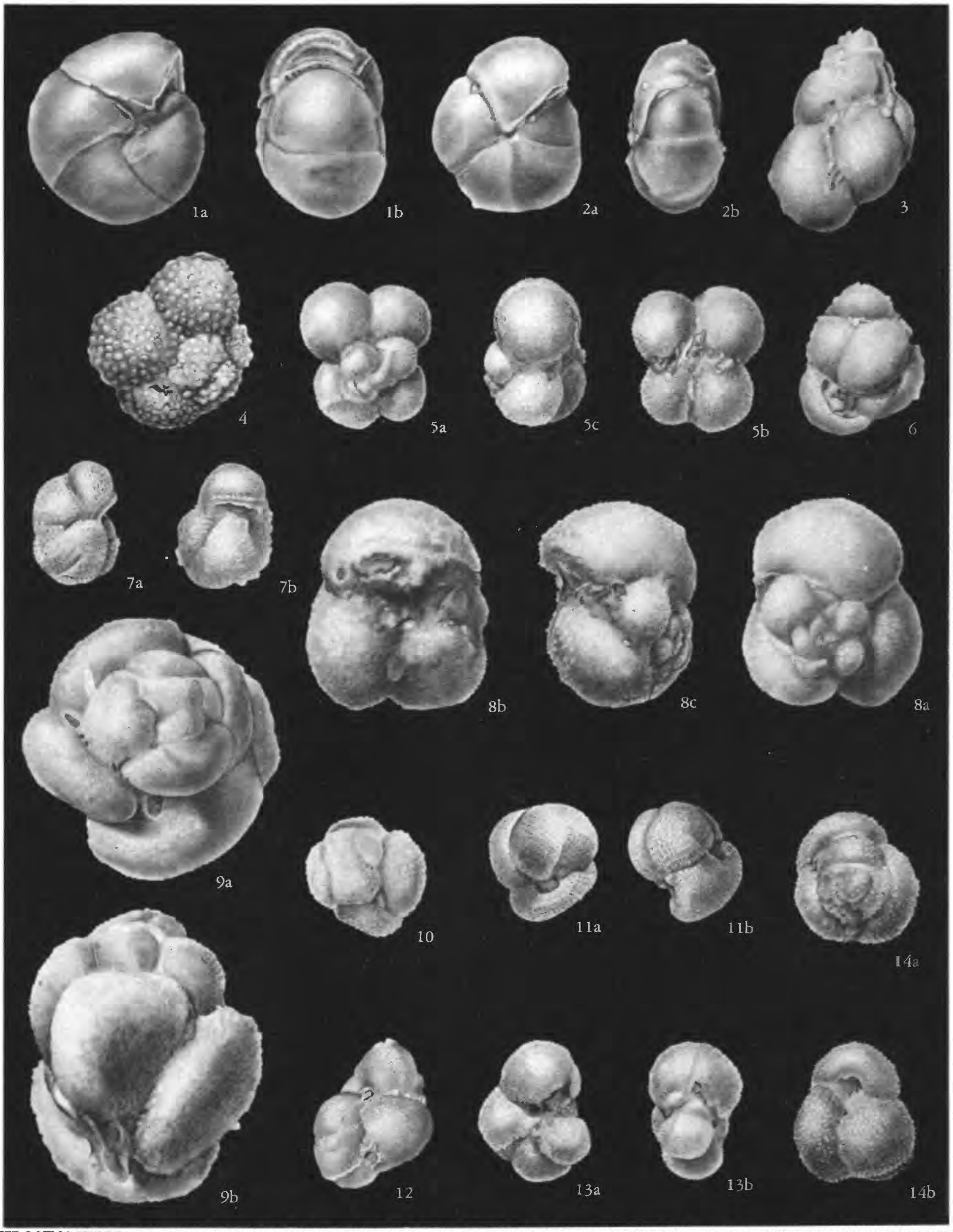
9. *Globigerinoides elongata* (D'Orbigny) (p. 279 tab.).
USNM 623979; USGS f21450 (C70); *a*, dorsal view; *b*, side view.

10, 11. *Globigerinoides* cf. *G. conglobata* (Brady) (p. 279 tab.).
10. USNM 623986; USGS f21563 (S433).
11. USNM 624040; USGS f21578 (S621); *a*, *b*, side views about 90° apart.

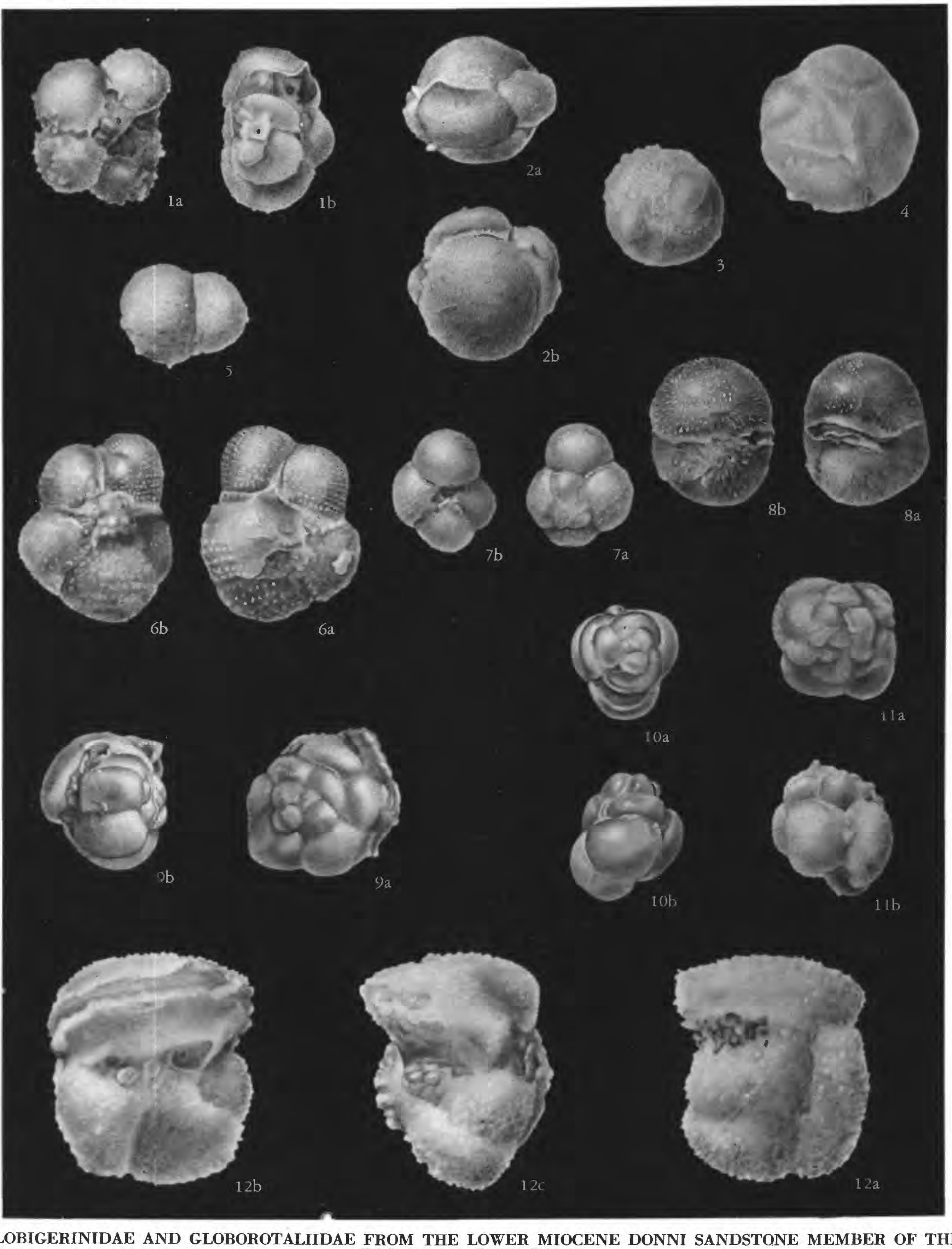
12. *Globigerinoides sacculifera* (Brady) (p. 279 tab.).
USNM 624041, × 28; USGS f21578 (S621).

13. *Globigerinella aequilateralis* (Brady) (p. 279 tab.).
USNM 623982; USGS f21514 (S25); *a*, side view; *b*, peripheral view.

14. *Globigerinoides rubra* (D'Orbigny) (p. 303).
USNM 623983; USGS f21521 (S126); *a*, dorsal view; *b*, ventral view.



CHILOSTOMELLIDAE AND GLOBIGERINIDAE FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE



GLOBIGERINIDAE AND GLOBOROTALIIDAE FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE

PLATE 79

[All figures × 45, except as indicated]

FIGURE 1. *Hastigerina pelagica* (D'Orbigny) (p. 279 tab.).
USNM 624042; USGS f21578 (S621); *a*, side view; *b*, peripheral view.

2–4. *Orbulina suturalis* Bronnimann, × 28 (p. 279 tab.).
2. USNM 624044; USGS f21578 (S621); *a*, *b*, views 90° apart.
3. USNM 624045; USGS f21578 (S621).
4. USNM 624046; USGS f21578 (S621).

5. *Orbulina bilobata* (D'Orbigny) (p. 279 tab.).
USNM 624043, × 28; USGS f21578 (S621).

6. *Sphaeroidinella kochi* (Caudri) (p. 279 tab.).
USNM 624048; USGS f21578 (S621); *a*, ventral view; *b*, peripheral view.

7. *Sphaeroidinella seminulina* (Schwager) (p. 279 tab.).
USNM 623984; USGS f21521 (S126); *a*, dorsal view; *b*, ventral view.

8. *Sphaeroidinella dehiscens* (Parker and Jones) (p. 279 tab.).
USNM 623974; USGS f21449 (C69); *a*, dorsal view; *b*, ventral view.

9. *Pulleniatina obliquiloculata* (Parker and Jones) (p. 279 tab.).
USNM 624047; USGS f21578 (S621); *a*, dorsal view; *b*, peripheral view.

10. *Candeina nitida* D'Orbigny (p. 279 tab.).
USNM 624051; USGS f21588 (S682); *a*, dorsal view; *b*, side view.

11. *Globoquadrina altispira* (Cushman and Jarvis) (p. 279 tab.).
USNM 623995; USGS f21572 (S563); *a*, dorsal view; *b*, side view.

12. *Globoquadrina dehiscens* (Chapman, Parr, and Collins) (p. 279 tab.).
USNM 623996. × 95; USGS f21572 (S563); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

PLATE 80

[All figures × 55, except as indicated]

FIGURE 1. *Globorotalia menardii* (D'Orbigny) (p. 279 tab.).
USNM 624052, × 45; USGS f21588 (S682); *a*, dorsal view; *b*, ventral view.

2. *Globorotalia hirsuta* (D'Orbigny) (p. 279 tab.).
USNM 624049; USGS f21578 (S621); *a*, dorsal view; *b*, ventral view.

3. *Globorotalia crassula* Cushman and R. E. Stewart (p. 279 tab.).
USNM 623975; USGS f21449 (C69); *a*, dorsal view; *b*, ventral view.

4. *Globorotalia tumida* (Brady) (p. 279 tab.).
USNM 623987, × 45; USGS f21563 (S433); *a*, dorsal view; *b*, ventral view.

5. *Laticarinina pauperata* (Parker and Jones) (p. 279 tab.).
USNM 624050, × 28; USGS f21578 (S621).

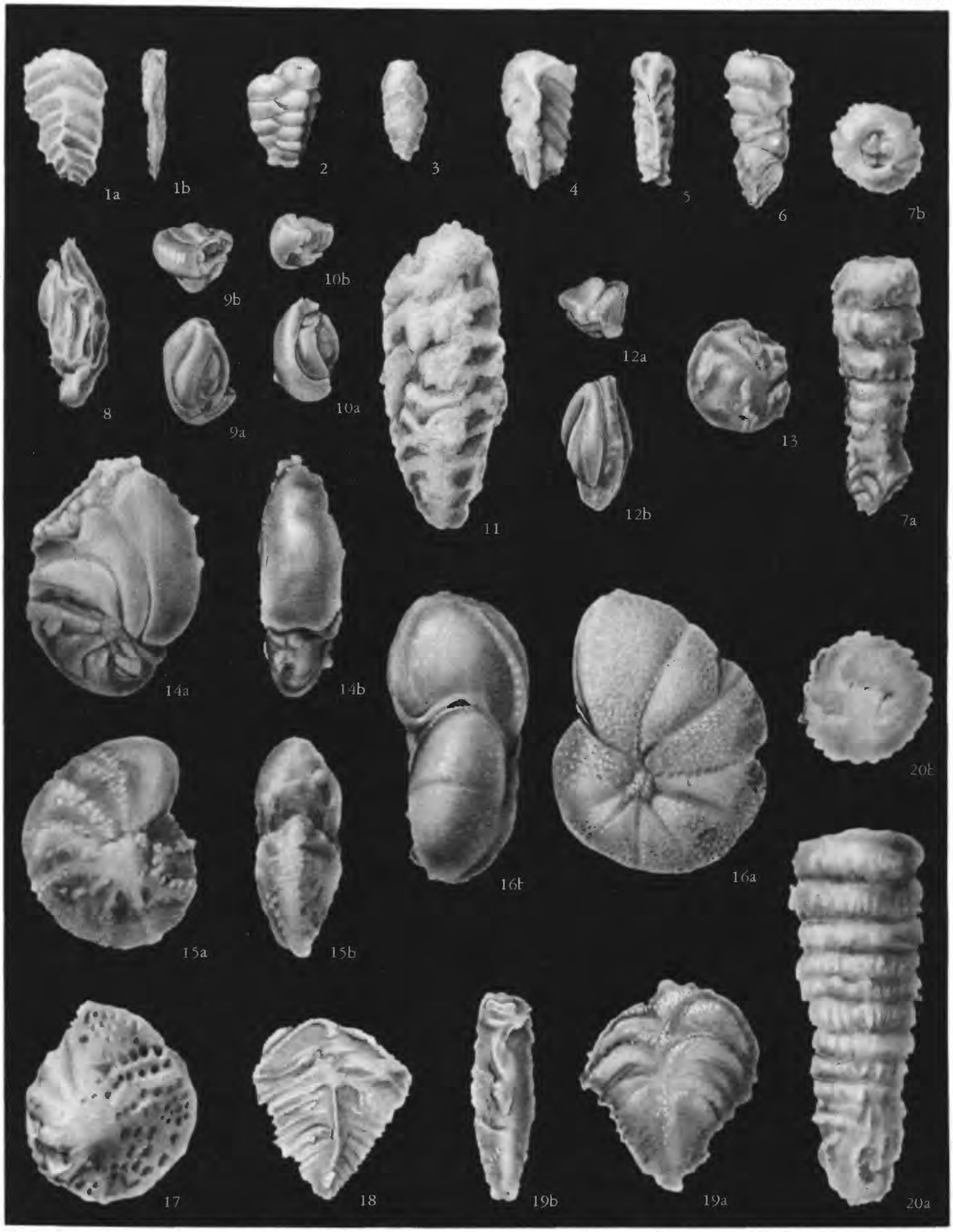
6. *Anomalina polymorpha* Costa (p. 279 tab.).
USNM 623964; USGS f21345 (B333); *a*, ventral view; *b*, peripheral view.

7. *Planulina wuellerstorfi* (Schwager) (p. 279 tab.).
USNM 623997; USGS f21572 (S563); *a*, dorsal view; *b*, peripheral view.

8. *Cibicides cicatricosus* (Schwager) (p. 279 tab.).
USNM 623980, × 45; USGS f21450 (C70); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9, 10. *Cibicides pseudoungerianus* (Cushman) (p. 279 tab.).
9. USNM 623966; USGS f21345 (B333); *a*, dorsal view, *b*, ventral view.
10. USNM 623965, × 95; USGS f21345 (B333); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

GLOBOROTALIIDAE AND ANOMALINIDAE FROM THE LOWER MIOCENE DONNI SANDSTONE MEMBER OF THE TAGPOCHAU LIMESTONE



REPRESENTATIVES OF EIGHT FAMILIES (TEXTULARIIDAE TO BULIMINIDAE) FROM THE SHALLOW-WATER FACIES OF THE LOWER MIOCENE TAGPOCHAU LIMESTONE

PLATE 81

FIGURE 1. *Vulvulina* sp. (p. 277 tab.).
USNM 624096, × 28; USGS f21525 (S147); *a*, side view; *b*, peripheral view

2. *Gaudryina* sp. B (p. 300).
USNM 624057, × 28; USGS f21582 (S666).

3. *Gaudryina?* sp. C (p. 277 tab.).
USNM 624097, × 55; USGS f21525 (S147).

4. *Clavulinoides?* sp. B (p. 277 tab.).
USNM 624098, × 28; USGS f21525 (S147).

5. *Clavulina angularis* D'Orbigny (p. 277 tab.).
USNM 624089, × 28; USGS f21524 (S146).

6, 7. *Clavulina multicamerata* Chapman, ×45 (p. 277 tab.).
6. USNM 624099; USGS f21525 (S147), side view.
7. USNM 624100; USGS f21525 (S147); *a*, side view; *b*, top view.

8. *Quinqueloculina* sp. A (p. 277 tab.).
USNM 624086, × 55; USGS f21395 (B393).

9. *Quinqueloculina* sp. B (p. 277 tab.).
USNM 624087, × 45; USGS f21395 (B393); *a*, side view; *b*, top view.

10. *Quinqueloculina* sp. C (p. 277 tab.).
USNM 624059, × 45; USGS f21582 (S666); *a*, side view; *b*, top view.

11. *Gaudryina* (*Siphogaudryina*) *rugulosa* Cushman (p. 277 tab.).
USNM 624058, × 28; USGS f21582 (S666).

12. *Triloculina trigonula* (Lamarck) (p. 277 tab.).
USNM 624088, × 55; USGS f21395 (B393); *a*, side view; *b*, top view.

13. *Robulus inornatus* (D'Orbigny)? (p. 277 tab.).
USNM 624055, × 28; USGS f21447 (C57).

14. *Nonion grateloupi* (D'Orbigny) (p. 277 tab.).
USNM 624101, × 95; USGS f21525 (S147); *a*, side view; *b*, peripheral view.

15. *Elphidium advenum* (Cushman) (p. 277 tab.).
USNM 624084, × 95; USGS f21594 (S701); *a*, side view; *b*, peripheral view.

16. *Nonion pacificum* (Cushman) (p. 277 tab.).
USNM 624060, × 95; USGS f21582 (S666); *a*, side view; *b*, peripheral view.

17. *Elphidium* sp. (p. 277 tab.).
USNM 624102, × 55; USGS f21525 (S147).

18. *Bolivinella* sp. B (p. 277 tab.).
USNM 624061, × 95; USGS f21582 (S666).

19. *Bolivinella* sp. C (p. 277 tab.).
USNM 624062, × 95; USGS f21582 (S666); *a*, side view; *b*, peripheral view.

20. *Tubulogenerina tubulifera* (Parker and Jones) (p. 278 tab.).
USNM 624066, × 95; USGS f21582 (S666); *a*, side view; *b*, top view.

PLATE 82

[All figures × 95, except as indicated]

FIGURE 1. *Reussella glabrata* (Cushman) (p. 278 tab.).
USNM 624065; USGS f21582 (S666); *a*, side view; *b*, top view.

2. *Bolivina densa* Todd, n. sp. (p. 297).
Holotype, USNM 624063; USGS f21582 (S666); *a*, side view; *b*, top view.

3. *Bolivina* sp. C (p. 278 tab.).
USNM 624090; USGS f21524 (S146).

4. *Loxostomum* cf. *L. digitale* (D'Orbigny) (p. 278 tab.).
USNM 624064, × 55; USGS f21582 (S666).

5. *Spirillina?* sp. (p. 278 tab.).
USNM 624092; USGS f21524 (S146).

6. *Discorbis mira* Cushman (p. 278 tab.).
USNM 624093; USGS f21524 (S146); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Chrysalidinella* sp. (p. 278 tab.).
USNM 624091, × 45; USGS f21524 (S146).

8. *Angulogerina elliptica* Dorreen? (p. 278 tab.).
USNM 624067, × 55; USGS f21582 (S666).

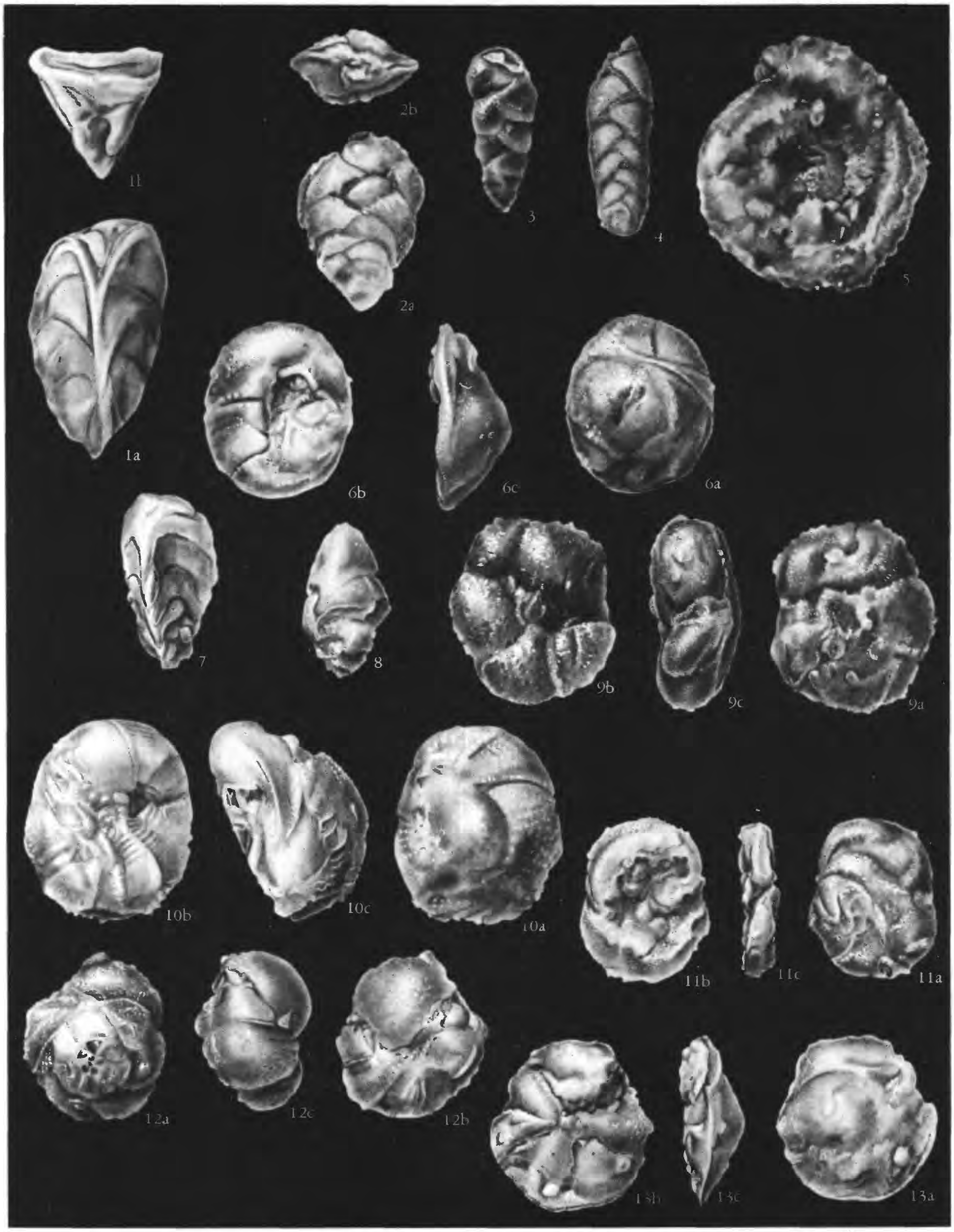
9. *Discorbis opima* Cushman (p. 278 tab.).
USNM 624103; USGS f21525 (S147); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

10. *Discorbis orientalis* Cushman (p. 278 tab.).
USNM 624068; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

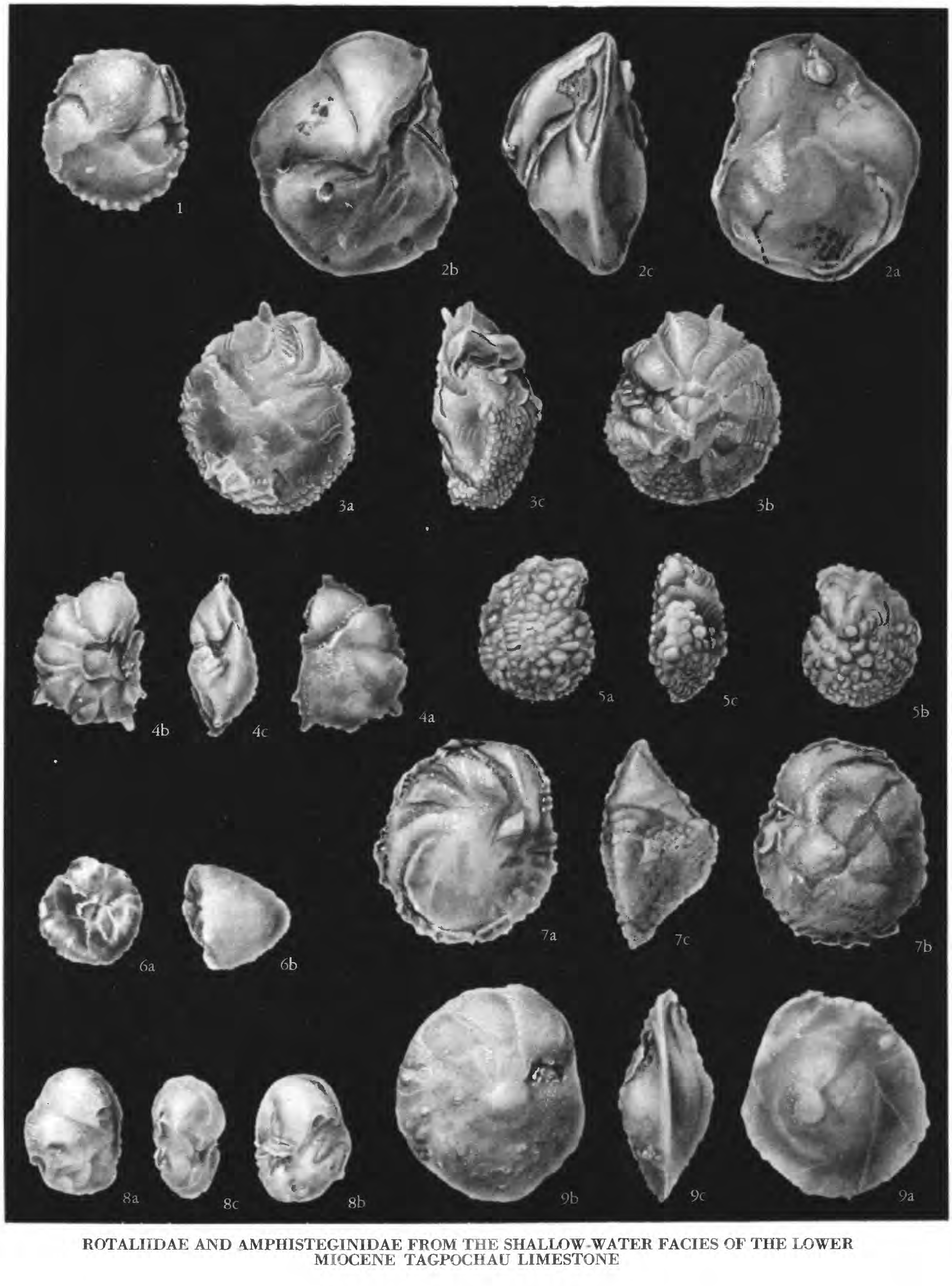
11. *Discorbis* sp. E (p. 278 tab.).
USNM 624104, × 55; USGS f21525 (S147); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

12. *Discorbis* sp. F (p. 278 tab.).
USNM 624094; USGS f21524 (S146); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

13. *Rotorbinella* sp. (p. 278 tab.).
USNM 624095, × 55; USGS f21524 (S146); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.



BULIMINIDAE AND ROTALIIDAE FROM THE SHALLOW-WATER FACIES OF THE LOWER MIOCENE TAGPOCHAU LIMESTONE



ROTALIIDAE AND AMPHISTEGINIDAE FROM THE SHALLOW-WATER FACIES OF THE LOWER MIOCENE TAGPOCHAU LIMESTONE

PLATE 83

FIGURE 1. *Siphonina tubulosa* Cushman (p. 278 tab.).
USNM 624073, × 95; USGS f21582 (S666).

2. *Eponides repandus* (Fichtel and Moll) (p. 278 tab.).
USNM 624070, × 45; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Streblus mexicanus* (Nuttall) (p. 278 tab.).
USNM 624072, × 28; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Streblus byramensis* (Cushman) (p. 278 tab.).
USNM 624071, × 55; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Streblus* sp. (p. 307).
USNM 624053, × 28; USGS f21444 (C44); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6. *Discorbis patelliformis* (Brady) (p. 278 tab.).
USNM 624069, × 95; USGS f21582 (S666); *a*, ventral view; *b*, peripheral view.

7. *Asterigerina carinata* D'Orbigny (p. 278 tab.)
USNM 624075, × 95; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

8. *Baggina parva* Todd, n. sp. (p. 297).
Holotype, USNM 624074, × 55; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9. *Asterigerina venusta* Todd, n. sp. (p. 297).
Holotype, USNM 624105, × 45; USGS f21525 (S147); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

PLATE 84

FIGURE 1. *Asterigerina subacuta* Cushman (p. 278 tab.).
USNM 624085, × 45; USGS f21492 (C130); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2, 3. *Amphistegina madagascariensis* D'Orbigny (p. 296).
2. USNM 624076, × 28; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
3. USNM 624077, × 45; USGS f21582 (S666): *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Amphistegina lessonii* D'Orbigny (p. 278 tab.).
USNM 624056, × 28; USGS f21447 (C57); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Anomalinella rostrata* (Brady) (p. 279 tab.).
USNM 624078, × 28; USGS f21582 (S666).

6. *Epistominella tubulifera* (Heron-Allen and Earland) (p. 278 tab.).
USNM 624054, × 95; USGS f21444 (C44); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

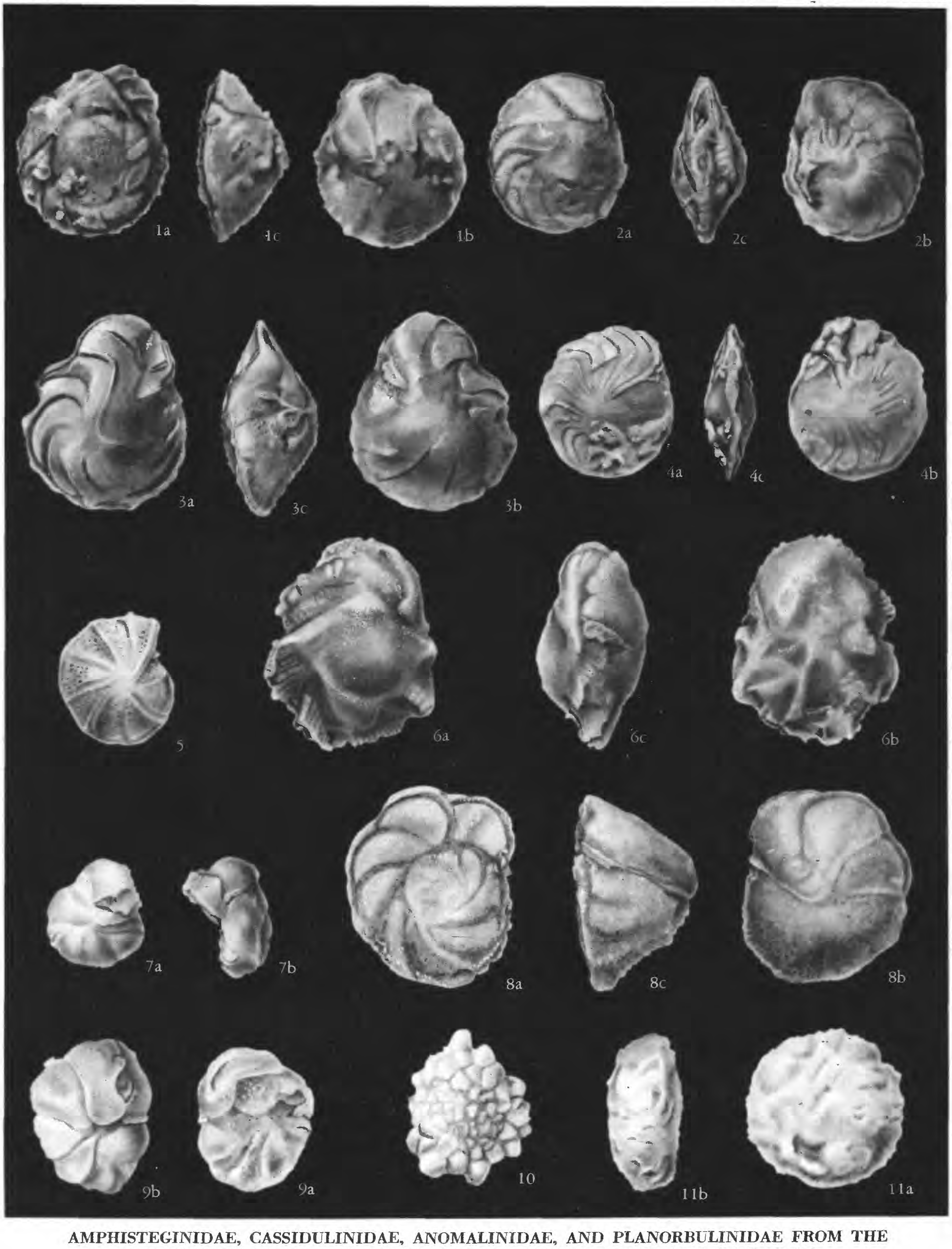
7. *Cibicidina mississippiensis* (Cushman) (p. 279 tab.).
USNM 624081, × 55; USGS f21582 (S666); *a*, ventral view; *b*, peripheral view.

8. *Cibicides vortex* Dorreen (p. 298).
USNM 624080, × 95; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

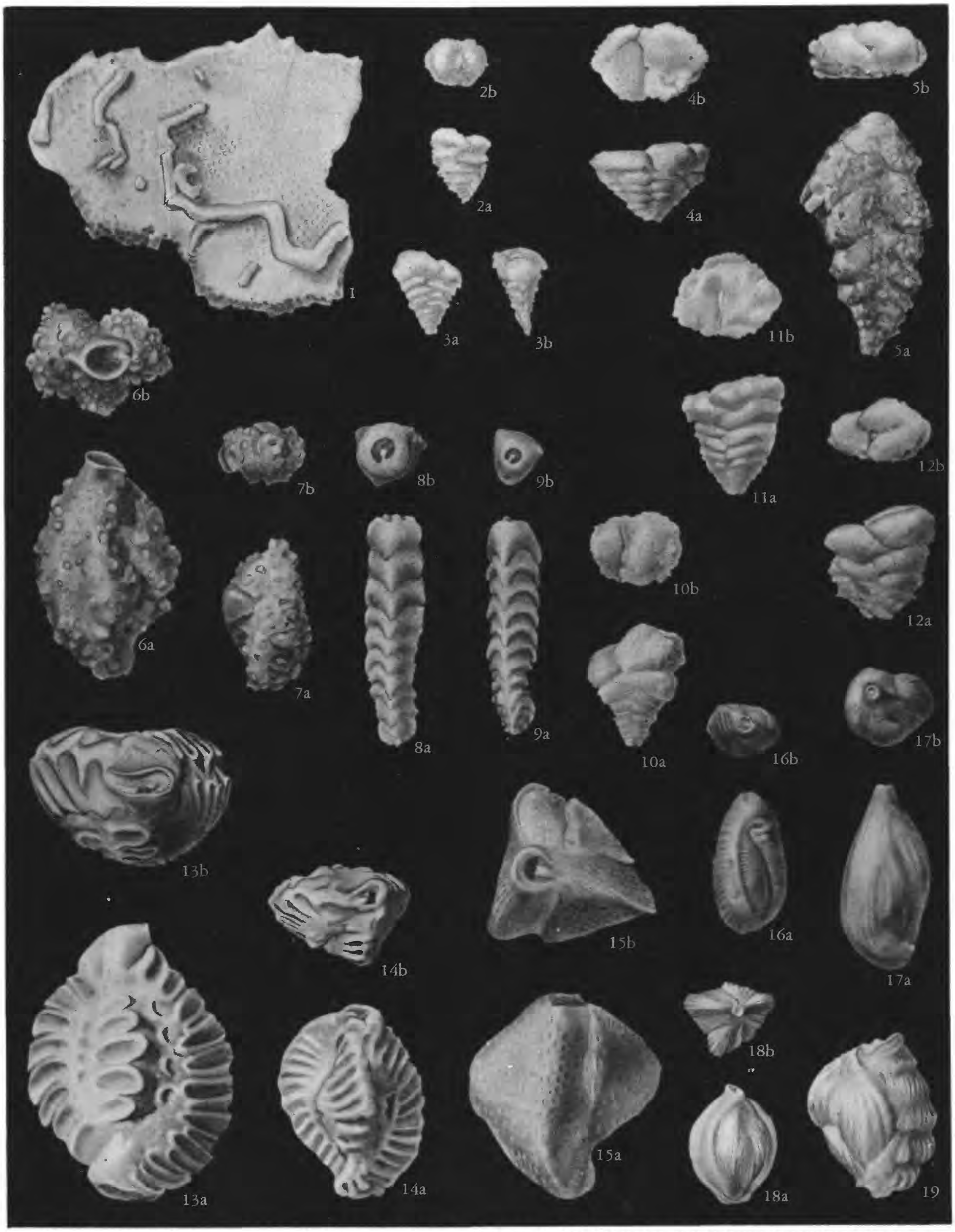
9. *Cibicides lobatulus* (Walker and Jacob) (p. 279 tab.).
USNM 624079, × 55; USGS f21582 (S666); *a*, dorsal view; *b*, ventral view.

10. *Planorbulina acervalis* Brady (p. 279 tab.).
USNM 624082, × 28; USGS f21582 (S666).

11. *Gypsina globula* (Reuss) (p. 279 tab.).
USNM 624083, × 28; USGS f21582 (S666); *a*, side view; *b*, edge view.



AMPHISTEGINIDAE, CASSIDULINIDAE, ANOMALINIDAE, AND PLANORBULINIDAE FROM THE SHALLOW-WATER FACIES OF THE LOWER MIOCENE TAGPOCHAU LIMESTONE



HYPERAMMINIDAE, TEXTULARIIDAE, VALVULINIDAE, AND MILIOLIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON

PLATE 85

FIGURE 1. *Sagenina frondescens* (Brady) (p. 286 tab.).
USNM 624128, × 28; USGS f11349 (*A3*).

2. *Textularia agglutinans* D'Orbigny (p. 286 tab.).
USNM 624129, × 28; USGS f11349 (*A3*); *a*, front view; *b*, top view.

3. *Textularia candeiana* D'Orbigny (p. 286 tab.).
USNM 624253, × 28; USGS f11396 (*E6*); *a*, front view; *b*, side view.

4. *Textularia conica* D'Orbigny (p. 286 tab.).
USNM 624131, × 28; USGS f11349 (*A3*); *a*, front view; *b*, top view.

5. *Textularia foliacea* Heron-Allen and Earland (p. 286 tab.).
USNM 624168, × 28; USGS f11350 (*A4*); *a*, front view; *b*, top view.

6. *Quinqueloculina agglutinans* D'Orbigny (p. 286 tab.).
USNM 624136, × 55; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

7. *Quinqueloculina anguina* Terquem var. *arenata* Said (p. 286 tab.).
USNM 624169, × 55; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.

8. *Clavulina difformis* Brady (p. 286 tab.).
USNM 624108, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

9. *Clavulina pacifica* Cushman (p. 286 tab.).
USNM 624109, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

10. *Textularia* sp. E (p. 308).
USNM 624130, × 28; USGS f11349 (*A3*); *a*, front view; *b*, top view.

11. *Textularia kerimbaensis* Said (p. 286 tab.).
USNM 624132, × 28; USGS f11349 (*A3*); *a*, front view; *b*, top view.

12. *Textularia alveata* Todd, n. sp. (p. 307).
Holotype, USNM 624133, × 28; USGS f11349 (*A3*); *a*, front view; *b*, top view.

13, 14. *Quinqueloculina parkeri* (Brady) (p. 286 tab.).
13. USNM 624138, × 55; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.
14. USNM 624110, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

15. *Triloculina terquemiana* (Brady) (p. 288 tab.).
USNM 624200, × 55; USGS f11354 (*A7*); *a*, side view; *b*, apertural view.

16. *Triloculina transversestriata* (Brady) (p. 288 tab.).
USNM 624194, × 55; USGS f11352 (*A5a*); *a*, side view; *b*, apertural view.

17. *Triloculina earlandi* Cushman (p. 288 tab.).
USNM 624148, × 55; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

18. *Quinqueloculina tubus* Todd, n. sp. (p. 306).
Holotype, USNM 624247, × 55; USGS f11379 (*C6*); *a*, side view; *b*, apertural view.

19. *Quinqueloculina neostriatula* Thalmann, variant (p. 286 tab.).
USNM 624245, × 55; USGS f11376 (*C3*).

PLATE 86

[All figures × 55, except as indicated]

FIGURE 1. *Triloculina* cf. *T. bassensis* Parr (p. 286 tab.).
USNM 624146; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

2. *Triloculina irregularis* (D'Orbigny) (p. 288 tab.).
USNM 624216; USGS f11358 (*A11*); *a*, side view; *b*, apertural view.

3–6. *Quinqueloculina sulcata-Q. ferussaci* gradational series (p. 286 tab.).
3. Young specimen, USNM 624141; USGS f11349 (*A3*).
4, 5. *Quinqueloculina sulcata* D'Orbigny. 4, USNM 624139; 5, USNM 624140, × 28; USGS f11349 (*A3*).
6. *Quinqueloculina ferussaci* D'Orbigny. USNM 624111, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

7. *Triloculina kerimbatica* (Heron-Allen and Earland) (p. 288 tab.).
USNM 624217; USGS f11358 (*A11*); *a*, side view; *b*, apertural view.

8. *Quinqueloculina distorqueata* Cushman (p. 286 tab.).
USNM 624137, × 28; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

9. *Quinqueloculina* cf. *Q. berthelotiana* D'Orbigny (p. 286 tab.).
USNM 624254; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

10. *Triloculina marshallana* Todd (p. 288 tab.).
USNM 624234; USGS f11396 (*E6*); *a*, side view; *b*, apertural view.

11. *Triloculina cuneata* Karrer (p. 288 tab.).
USNM 624147; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

12, 13. *Triloculina* cf. *T. oblonga* (Montagu) (p. 288 tab.).
12. USNM 624116; USGS f11348 (*A2*);
13. USNM 624172; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.

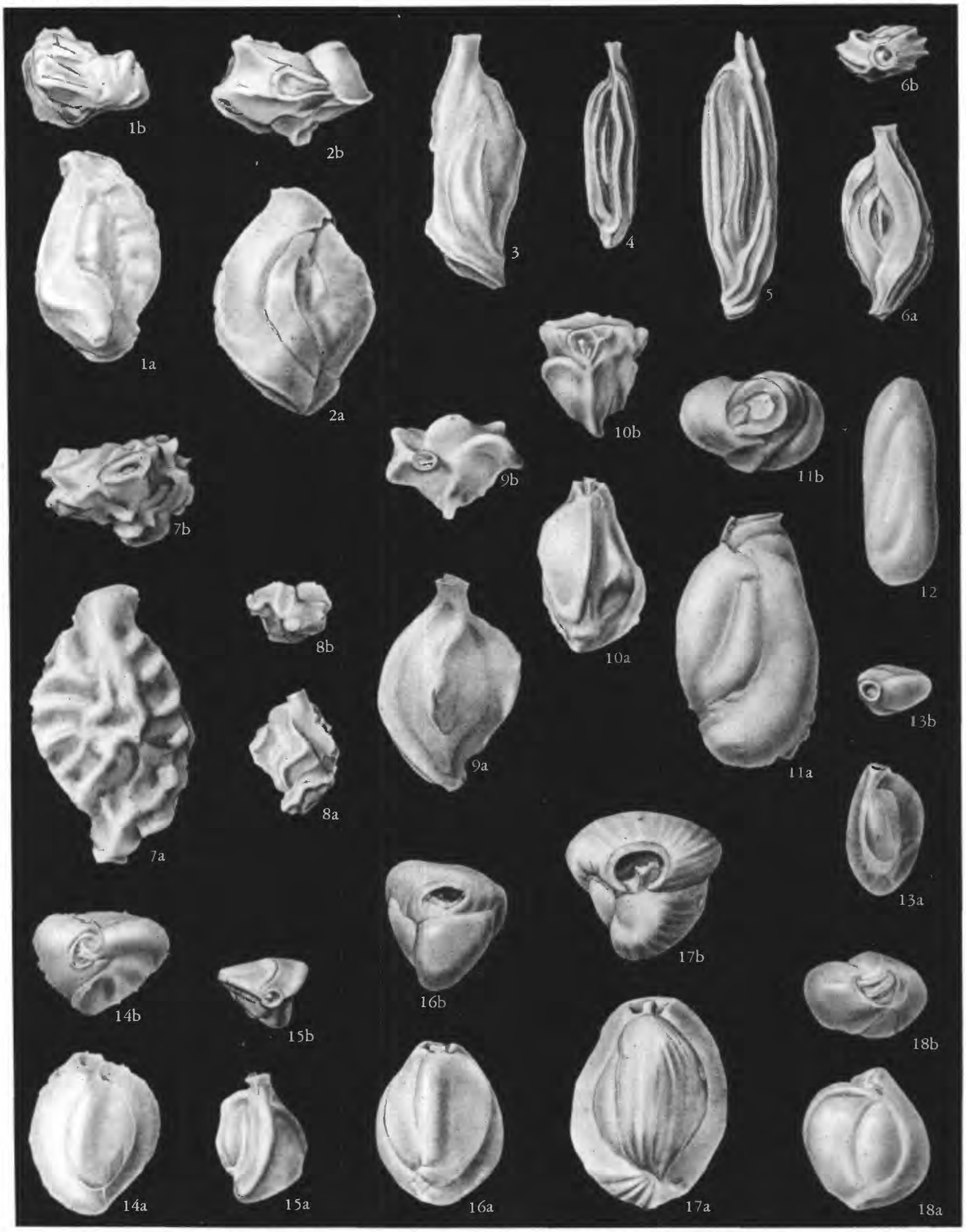
14. *Triloculina bikiniensis* Todd (p. 286 tab.).
USNM 624215; USGS f11358 (*A11*); *a*, side view; *b*, apertural view.

15. *Triloculina tricarinata* D'Orbigny (p. 288 tab.).
USNM 624173; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.

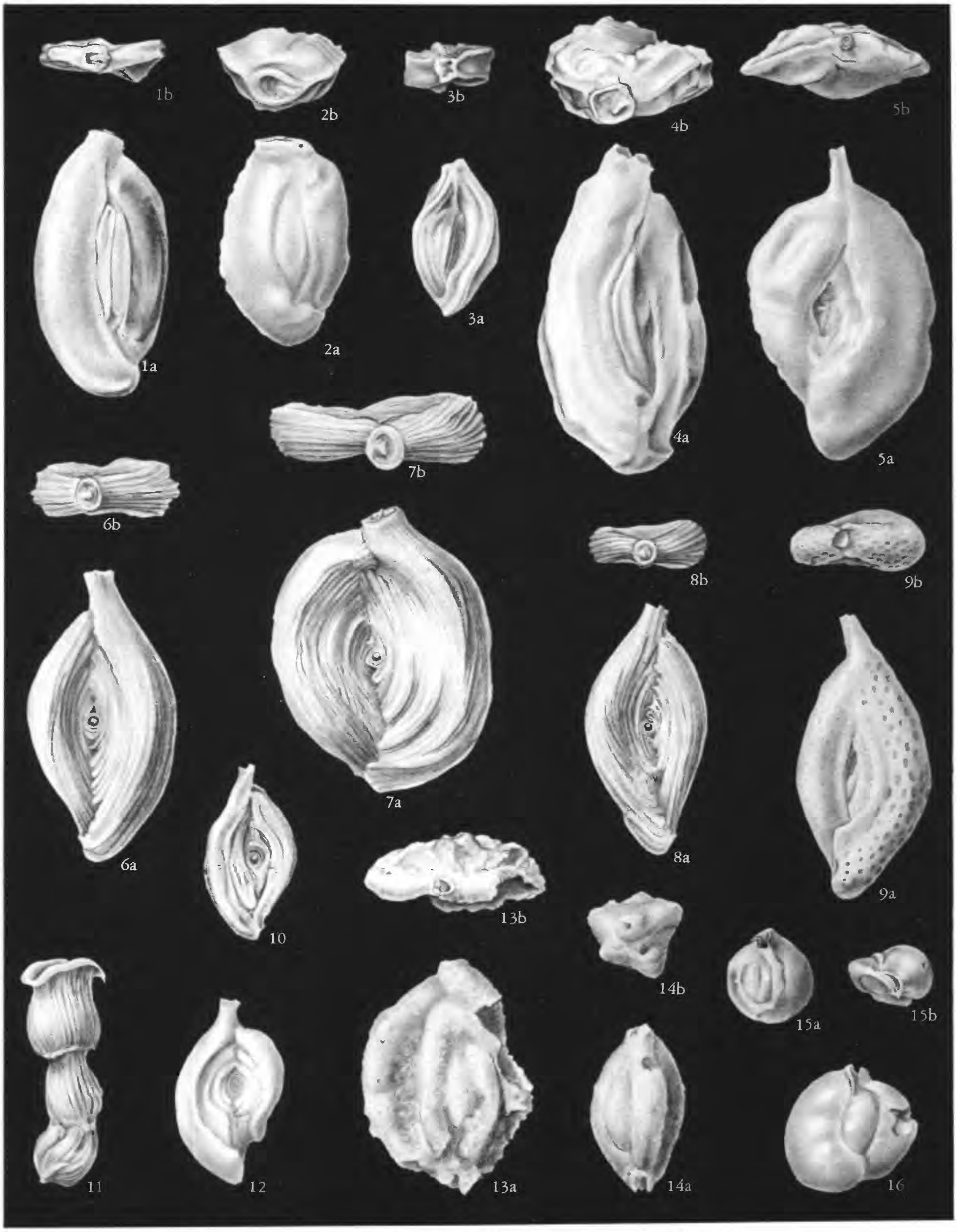
16. *Triloculina trigonula* (Lamarck) (p. 288 tab.).
USNM 624149; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

17. *Triloculina trigonula* (Lamarck), costate variety (p. 288 tab.).
USNM 624150; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

18. *Triloculina incisura* Todd, n. sp. (p. 308).
Holotype, USNM 624255; USGS f11396 (*E6*); *a*, side view; *b*, apertural view.



MILIOLIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON



MILIOLIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON

PLATE 87

[All figures × 55, except as indicated]

FIGURE 1. *Massilina planata* Cushman (p. 286 tab.).
USNM 624112, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

2. *Massilina* cf. *M. durrandi* (Millett) (p. 286 tab.).
USNM 624230; USGS f11364 (*B3*); *a*, side view; *b*, apertural view.

3. *Massilina pseudoclara* Todd, n. sp. (p. 304).
Holotype, USNM 624174; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.

4. *Massilina rustica* Todd, n. sp. (p. 305).
Holotype, USNM 624209; USGS f11355 (*A8*); *a*, side view; *b*, apertural view.

5. *Spiroloculina folium* Todd, n. sp. (p. 307).
Holotype, USNM 624249; USGS f11388 (*D7a*); *a*, side view; *b*, apertural view.

6. *Spiroloculina angulata* Cushman (p. 286 tab.).
USNM 624113; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

7, 8. *Spiroloculina corrugata* Cushman and Todd (p. 286 tab.).
7. USNM 624114; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.
8. USNM 624143; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

9. *Spiroloculina foveolata* Egger (p. 286 tab.).
USNM 624218; USGS f11358 (*A11*); *a*, side view; *b*, apertural view.

10. *Spiroloculina caduca* Cushman (p. 286 tab.).
USNM 624193; USGS f11352 (*A5a*).

11. *Articulina pacifica* Cushman (p. 286 tab.).
USNM 624260; USGS f11398 (*E8*).

12. *Spiroloculina eximia* Cushman (p. 286 tab.).
USNM 624231; USGS f11364 (*B3*).

13. *Ammomassilina alveoliniformis* (Millett) (p. 286 tab.).
USNM 624145, × 28; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

14. *Schlumbergerina alveoliniformis* (Brady) (p. 286 tab.).
USNM 624115, × 28; USGS f11348 (*A2*); *a*, side view; *b*, apertural view.

15. *Miliolinella australis* (Parr) (p. 286 tab.).
USNM 624199; USGS f11354 (*A7*); *a*, side view; *b*, apertural view.

16. *Triloculinella labiosa* (D'Orbigny) (p. 286 tab.).
USNM 624142; USGS f11349 (*A3*).

PLATE 88

[All figures × 55, except as indicated]

FIGURES 1, 2. *Hauerina bradyi* Cushman (p. 286 tab.).
1. USNM 624170; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.
2. USNM 624256; USGS f11396 (*E6*); *a*, side view; *b*, apertural view.

3. *Hauerina pacifica* Cushman (p. 286 tab.).
USNM 624171; USGS f11350 (*A4*); *a*, side view; *b*, apertural view.

4. *Hauerina milletti* Cushman (p. 286 tab.).
USNM 624192; USGS f11352 (*A5a*); *a*, side view; *b*, apertural view.

5. *Hauerina involuta* Cushman (p. 286 tab.).
USNM 624144; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

6. *Hauerina* cf. *H. speciosa* (Karrer) (p. 286 tab.).
USNM 624191; USGS f11351 (*A5*); *a*, side view; *b*, apertural view.

7, 8. *Pyrgo denticulata* (Brady) (p. 288 tab.).
7. USNM 624151; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.
8. USNM 624195; USGS f11352 (*A5a*); *a*, side view; *b*, apertural view.

9. *Cornuspira planorbis* Schultze (p. 288 tab.).
USNM 624201, × 95; USGS f11354 (*A7*).

10. *Wiesnerella auriculata* (Egger) (p. 288 tab.).
USNM 624261; USGS f11398 (*E8*); *a*, front view; *b*, side view.

11. *Vertebralina striata* D'Orbigny (p. 288 tab.).
USNM 624152; USGS f11349 (*A3*); *a*, ventral view; *b*, peripheral view.

12. *Parrina bradyi* (Millett) (p. 288 tab.).
USNM 624219, × 28; USGS f11358 (*A11*); *a*, front view; *b*, peripheral view.

13–15. *Haddonia torresiensis* Chapman, × 28 (p. 288 tab.).
13. USNM 624202; USGS f11354 (*A7*); *a*, side view; *b*, peripheral view.
14. USNM 624203; USGS f11354 (*A7*); *a*, side view; *b*, top view.
15. USNM 624117; USGS f11348 (*A2*); *a*, side view; *b*, peripheral view; *c*, top view.

16. *Robulus* sp. E (p. 288 tab.).
USNM 624257; USGS f11396 (*E6*); *a*, side view; *b*, peripheral view.

17. *Nonionella* sp. (p. 288 tab.).
USNM 624210, × 95; USGS f11355 (*A8*).

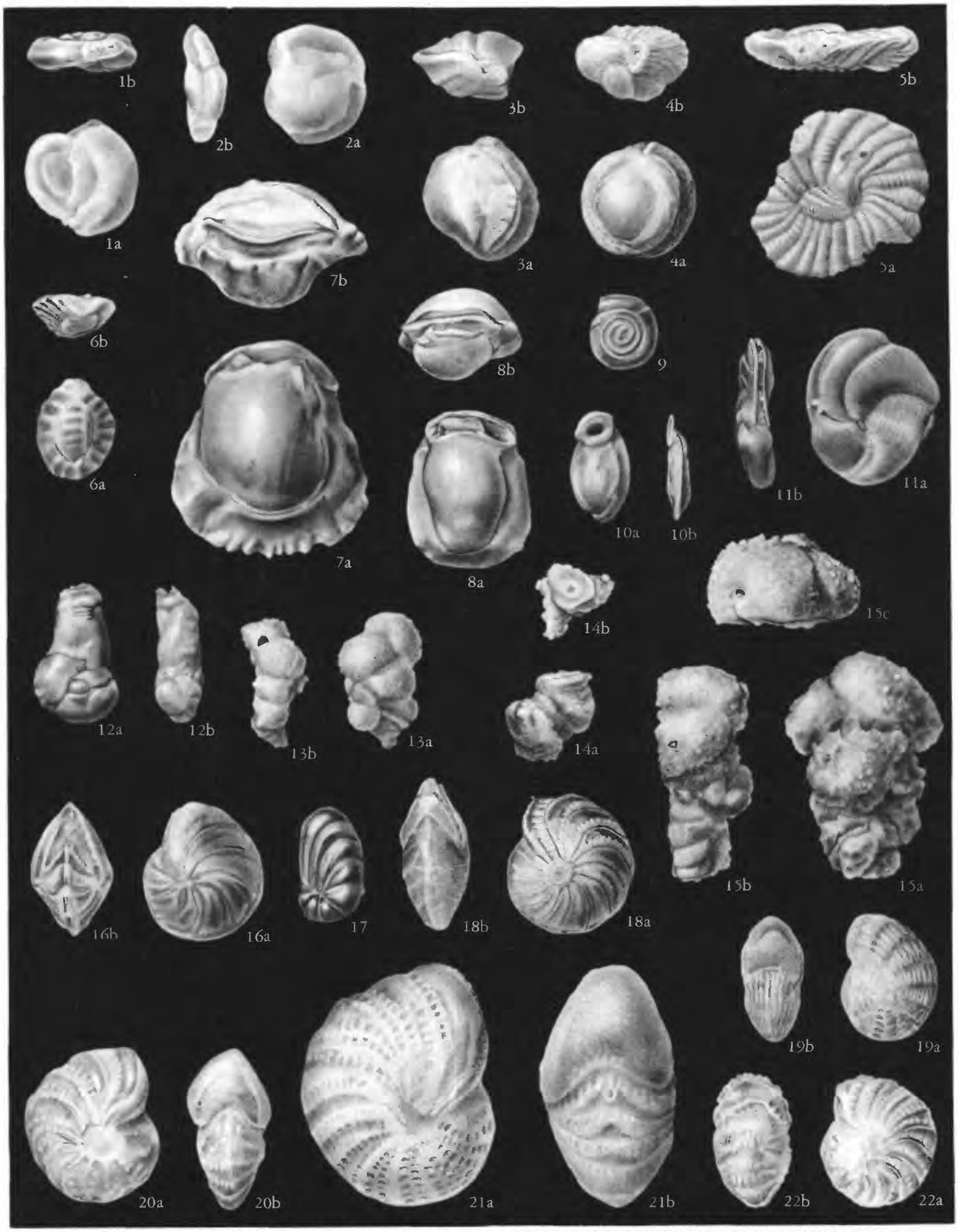
18. *Elphidium crispum* (Linné) (p. 288 tab.).
USNM 624153; USGS f11349 (*A3*); *a*, side view; *b*, peripheral view.

19. *Elphidium hyalocostatum* Todd, n. sp. (p. 300).
Holotype, USNM 624228; USGS f11360 (*B1ay*); *a*, side view; *b*, peripheral view.

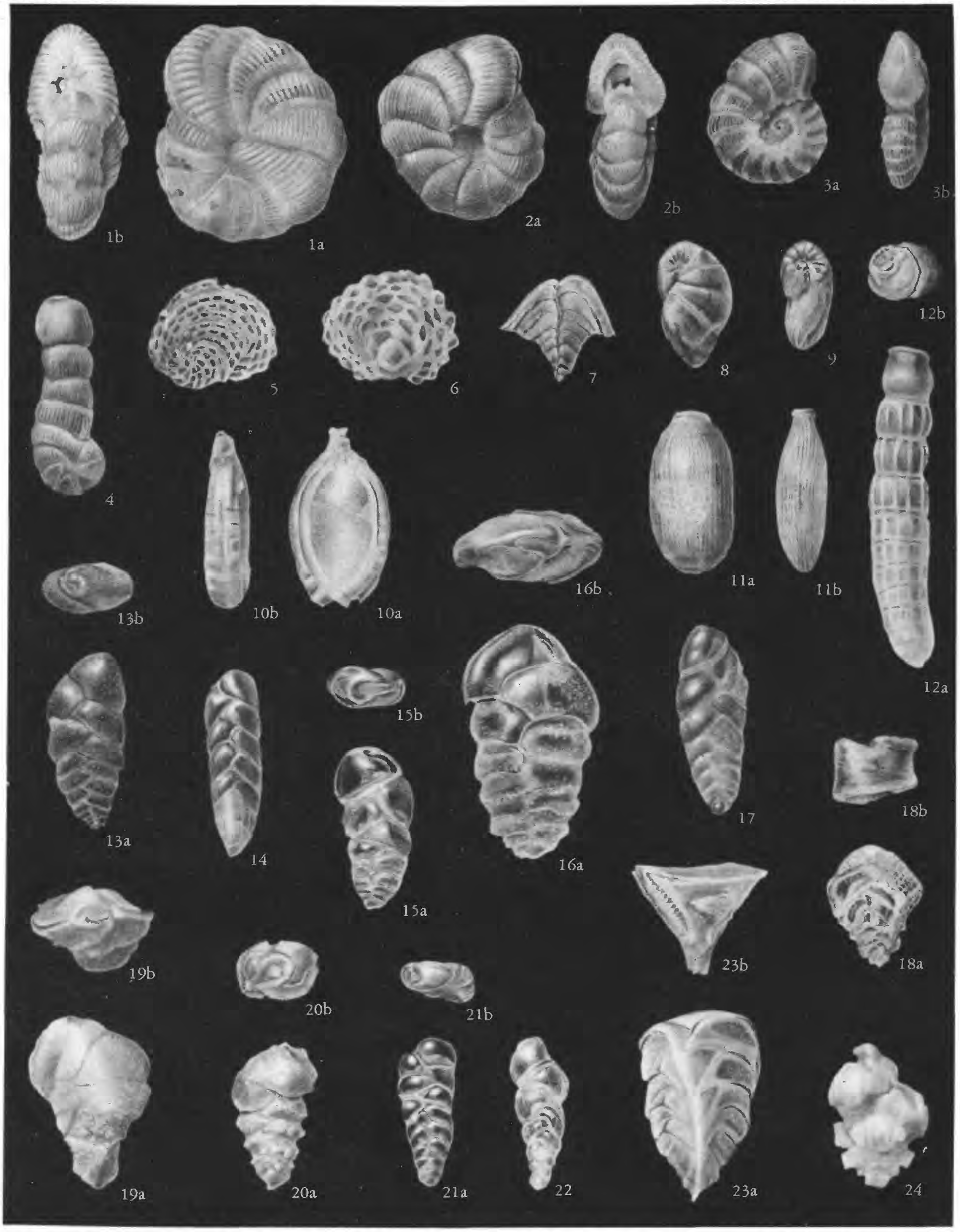
20. *Elphidium advenum* (Cushman) (p. 288 tab.).
USNM 624175; USGS f11350 (*A4*); *a*, side view; *b*, peripheral view.

21. *Elphidium striato-punctatum* (Fichtel and Moll) (p. 288 tab.).
USNM 624118; USGS f11348 (*A2*); *a*, side view; *b*, peripheral view.

22. *Elphidium formosum* Todd, n. sp. (p. 299).
Holotype, USNM 624226; USGS f11359 (*B1ax*); *a*, side view; *b*, peripheral view.



REPRESENTATIVES OF FIVE FAMILIES (MILIOLIDAE TO NONIONIDAE) FROM RECENT SEDIMENTS OF TANAPAG LAGOON



PENEROPLIDAE, HETEROHELICIDAE, AND BULIMINIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON

PLATE 89

[All figures × 95, except as indicated]

FIGURE 1. *Peneroplis ellipticus* D'Orbigny (p. 288 tab.).
USNM 624232, × 55; USGS f11364 (*B3*); *a*, side view; *b*, peripheral view.

2–4. *Spirolina arietina* (Batsch), × 55 (p. 288 tab.).
2. USNM 624233; USGS f11364 (*B3*); *a*, side view; *b*, peripheral view.
3. USNM 624196; USGS f11352 (*A5a*); *a*, side view; *b*, peripheral view.
4. USNM 624176, × 55; USGS f11350 (*A4*).

5. *Sorites marginalis* (Lamarck) (p. 288 tab.).
USNM 624177, × 55; USGS f11350 (*A4*).

6. *Marginopora vertebralis* Blainville (p. 288 tab.).
USNM 624178, × 55; USGS f11350 (*A4*).

7. *Bolivinella folium* (Parker and Jones) (p. 290 tab.).
USNM 624179, × 55; USGS f11350 (*A4*).

8. *Buliminella milletti* Cushman (p. 290 tab.).
USNM 624197; USGS f11352 (*A5a*).

9. *Buliminoides williamsoniana* (Brady) (p. 290 tab.).
USNM 624204; USGS f11354 (*A7*).

10. *Fissurina lagenoides* (Williamson) (p. 290 tab.).
USNM 624262; USGS f11398 (*E8*); *a*, front view; *b*, peripheral view.

11. *Fissurina wrightiana* (Brady) (p. 290 tab.).
USNM 624220; USGS f11358 (*A11*); *a*, front view; *b*, peripheral view.

12. *Siphogenerina raphana* (Parker and Jones) (p. 290 tab.).
USNM 624158, × 55; USGS f11349 (*A3*); *a*, side view; *b*, apertural view.

13. *Bolivina compacta* Sidebottom (p. 290 tab.).
USNM 624180; USGS f11350 (*A4*); *a*, front view; *b*, apertural view.

14. *Bolivina striatula* Cushman (p. 290 tab.).
USNM 624236; USGS f11367 (*B6*).

15, 16. *Bolivina pseudopygmaea* Cushman (p. 290 tab.).
15. USNM 624205; USGS f11354 (*A7*); *a*, front view; *b*, apertural view.
16. USNM 624221; USGS f11358 (*A11*); *a*, front view; *b*, apertural view.

17. *Bolivina ligularia* Schwager (p. 290 tab.).
USNM 624235; USGS f11367 (*B6*).

18. *Bolivina rhomboidalis* Millett) (p. 290 tab.).
USNM 624181; USGS f11350 (*A4*); *a*, front view; *b*, apertural view.

19. *Bolivina tortuosa* Brady (p. 290 tab.).
USNM 624156; USGS f11349 (*A3*); *a*, front view; *b*, apertural view.

20. *Bolivina spinea* Cushman (p. 290 tab.).
USNM 624155; USGS f11349 (*A3*); *a*, front view; *b*, apertural view.

21. *Bolivina* sp. D (p. 290 tab).
USNM 624206; USGS f11354 (*A7*); *a*, front view; *b*, apertural view.

22. *Loxostomum limbatum* (Brady) (p. 290 tab.).
USNM 624198, × 45; USGS f11353 (*A6*).

23. *Reussella simplex* (Cushman) (p. 290 tab.).
USNM 624157, × 55; USGS f11349 (*A3*); *a*, front view; *b*, apertural view.

24. *Uvigerina porrecta* Brady (p. 290 tab.).
USNM 624182; USGS f11350 (*A4*).

PLATE 90

[All figures × 95, except as indicated

FIGURE 1. *Spirillina decorata* Brady (p. 290 tab.).
USNM 624183; USGS f11350 (*A4*); *a*, *b*, opposite sides; *c*, peripheral view.

2. *Spirillina vivipara* Ehrenberg var. *revertens* Rhumbler (p. 290 tab.).
USNM 624211; USGS f11355 (*A8*); *a*, *b*, opposite sides.

3. *Patellinella inconspicua* (Brady) (p. 290 tab.).
USNM 624207; USGS f11354 (*A7*); *a*, front view; *b*, apertural view.

4. *Spirillina tuberculato-limbata* Chapman (p. 290 tab.).
USNM 624242; USGS f11371 (*B10*); *a*, *b*, opposite sides.

5. *Discorbis mira* Cushman (p. 290 tab.).
USNM 624252, × 45; USGS f11393 (*E3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6. *Discorbis valvulata* (D'Orbigny) var. *granulosa* (Heron-Allen and Earland) (p. 290 tab.).
USNM 624250, × 45; USGS f11389 (*E1*); *a*, dorsal view, *b*, ventral view; *c*, peripheral view.

7. *Discorbis micens* Cushman (p. 290 tab.).
USNM 624184; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

8. *Discorbis fulva* Todd, n. sp. (p. 299).
Holotype, USNM 624186; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

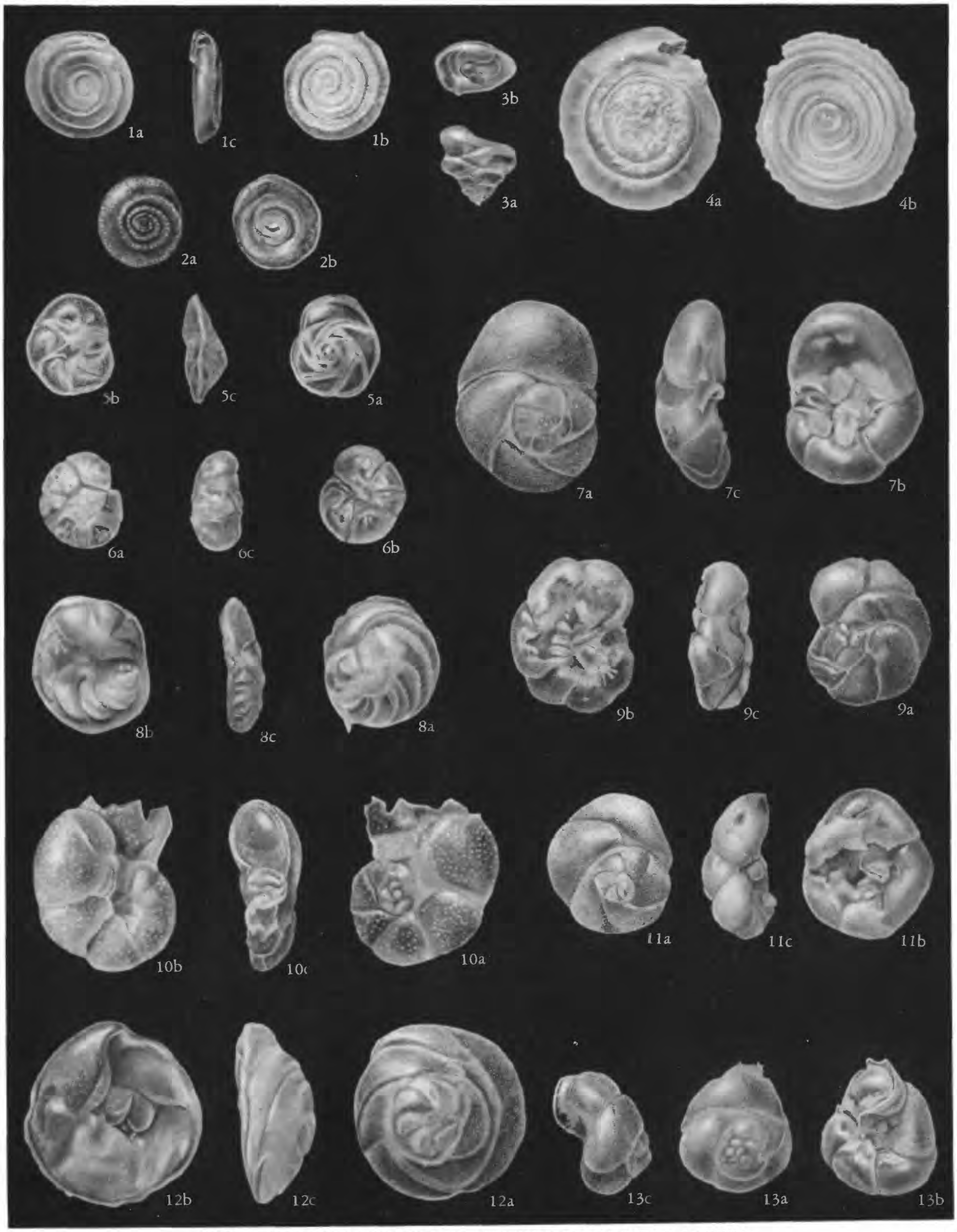
9. *Discorbis candeiana* (D'Orbigny) (p. 290 tab.).
USNM 624244, × 55; USGS f11373 (*C1a*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

10. *Discorbis rugosa* (D'Orbigny) (p. 290 tab.).
USNM 624212; USGS f11355 (*A8*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

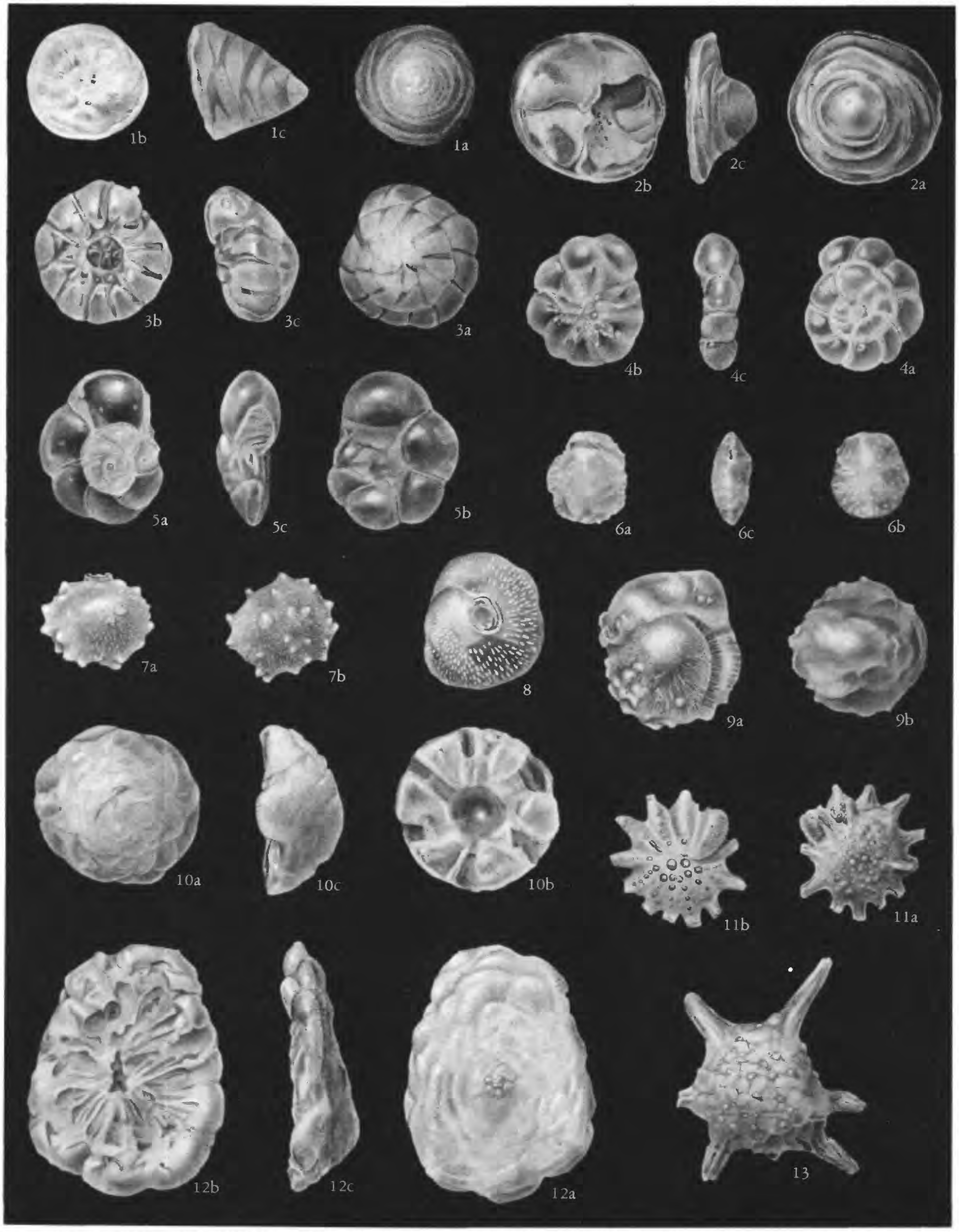
11. *Discorbis opima* Cushman (p. 290 tab.).
USNM 624159, × 55; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

12. *Discorbis orbicularis* (Terquem) (p. 290 tab.).
USNM 624208; USGS f11354 (*A7*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

13. *Discorbis orientalis* Cushman (p. 290 tab.).
USNM 624227, × 55; USGS f11359 (*B1ax*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view from side opposite aperture.



ROTALIIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON



ROTALIIDAE, PEGIDIIDAE, CALCARINIDAE, AND CYMBALOPORIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON

PLATE 91

FIGURE 1. *Discorbis patelliformis* (Brady) (p. 290 tab.).
USNM 624185, × 95; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Discorbis tuberocapitata* (Chapman) (p. 290 tab.).
USNM 624160, × 55; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Streblus beccarii* (Linné) (p. 290 tab.).
USNM 624161, × 45; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Streblus beccarii* (Linné) var. (p. 290 tab.).
USNM 624251, × 45; USGS f11389 (*E1*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Streblus beccarii* (Linné) var. *tepida* (Cushman) (p. 290 tab.).
USNM 624213, × 95; USGS f11355 (*A8*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6. *Siphonina tubulosa* Cushman (p. 290 tab.).
USNM 624222, × 45; USGS f11358 (*A11*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7. *Siphoninoides echinata* (Brady) (p. 290 tab.).
USNM 624162, × 55; USGS f11349 (*A3*); *a*, side view; *b*, top view.

8. *Siphoninoides glabra* (Heron-Allen and Earland) (p. 290 tab.).
USNM 624248, × 95; USGS f11386 (*D5*).

9. *Sphaeridia rugata* Heron-Allen and Earland (p. 290 tab.).
USNM 624237, × 95; USGS f11367 (*B6*); *a*, side view; *b*, top view.

10. *Cymbaloporetta squammosa* (D'Orbigny) (p. 292 tab.).
USNM 624164, × 55; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

11. *Calcarina spengleri* (Gmelin) (p. 292 tab.).
USNM 624163, × 28; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view.

12. *Cymbaloporetta bradyi* (Cushman) (p. 292 tab.).
USNM 624125, × 55; USGS f11348 (*A2*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

13. *Baculogypsina sphaerulata* (Parker and Jones) (p. 292 tab.).
USNM 624107, × 55; USGS f11347 (*A1*).

PLATE 92

[All figures × 55, except as indicated]

FIGURE 1. *Epistominella tubulifera* (Heron-Allen and Earland) (p. 292 tab.).
USNM 624259; USGS f11397 (*E7*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Epistominella* sp. D (p. 292 tab.).
USNM 624223, × 95; USGS f11358 (*A11*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Tretomphalus planus* Cushman (p. 292 tab.).
USNM 624229; USGS f11360 (*B1ay*); *a*, side view; *b*, top view.

4. *Tretomphalus concinnus* (Brady) (p. 292 tab.).
USNM 624238, × 95; USGS f11367 (*B6*).

5. *Orbulina?* sp. (p. 292 tab.).
USNM 624165, × 95; USGS f11349 (*A3*).

6. *Globigerina* sp. D (p. 292 tab.).
USNM 624239; USGS f11367 (*B6*); dorsal view.

7. *Globigerinoides sacculifera* (Brady) (p. 292 tab.).
USNM 624188; USGS f11350 (*A4*); *a*, dorsal view; *b*, peripheral view.

8 *Globigerinoides conglobata* (Brady) (p. 292 tab.).
USNM 624246; USGS f11376 (*C3*).

9. *Globigerinoides rubra* (D'Orbigny) (p. 303).
USNM 624240, × 95; USGS f11367 (*B6*).

10. *Cibicides mayori* (Cushman) (p. 292 tab.).
USNM 624189; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

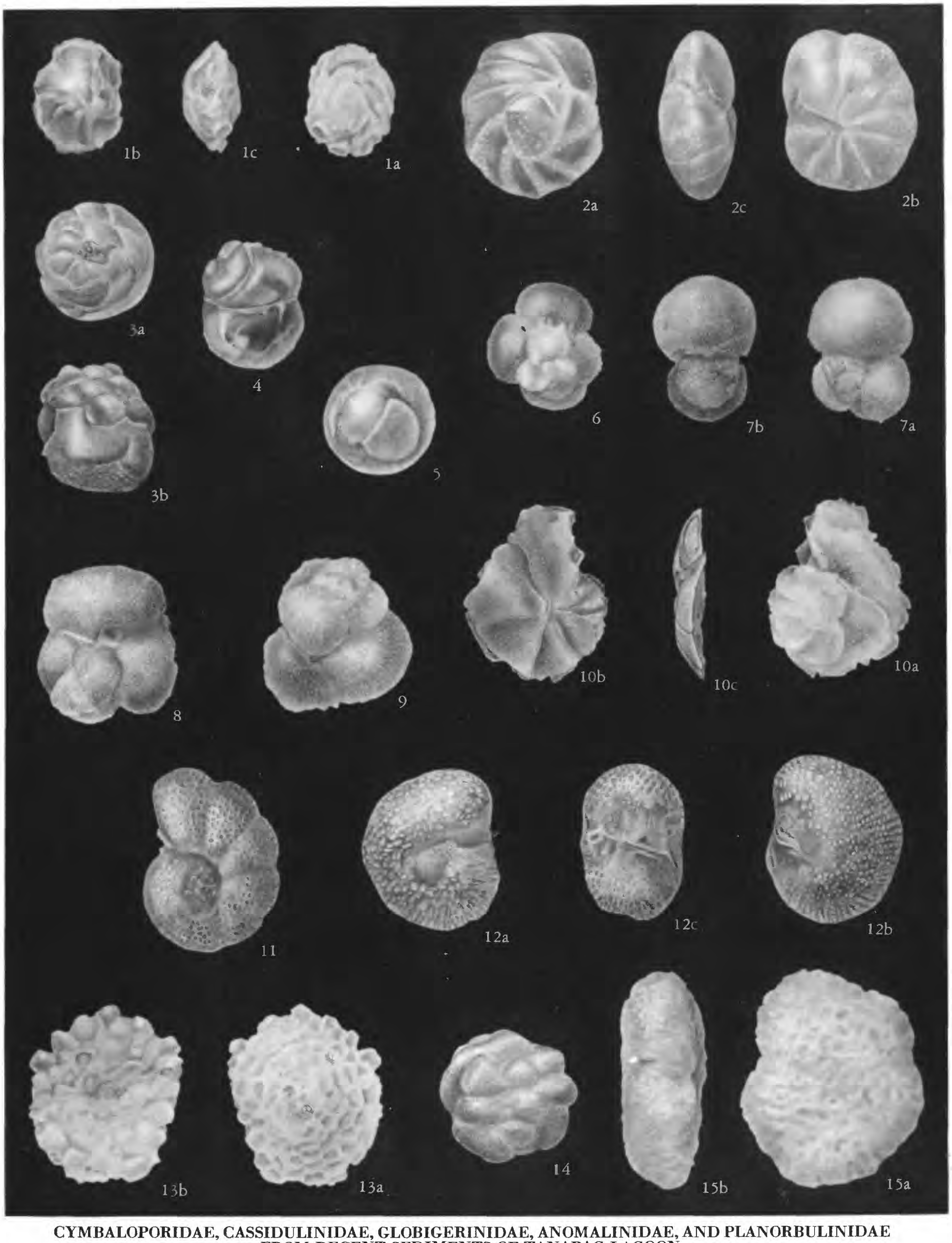
11. *Cibicides* cf. *C. cicatricosus* (Schwager) (p. 292 tab.).
USNM 624224; USGS f11358 (*A11*).

12. *Anomalina? maculosa* Todd, n. sp. (p. 296).
Holotype, USNM 624126; USGS f11348 (*A2*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

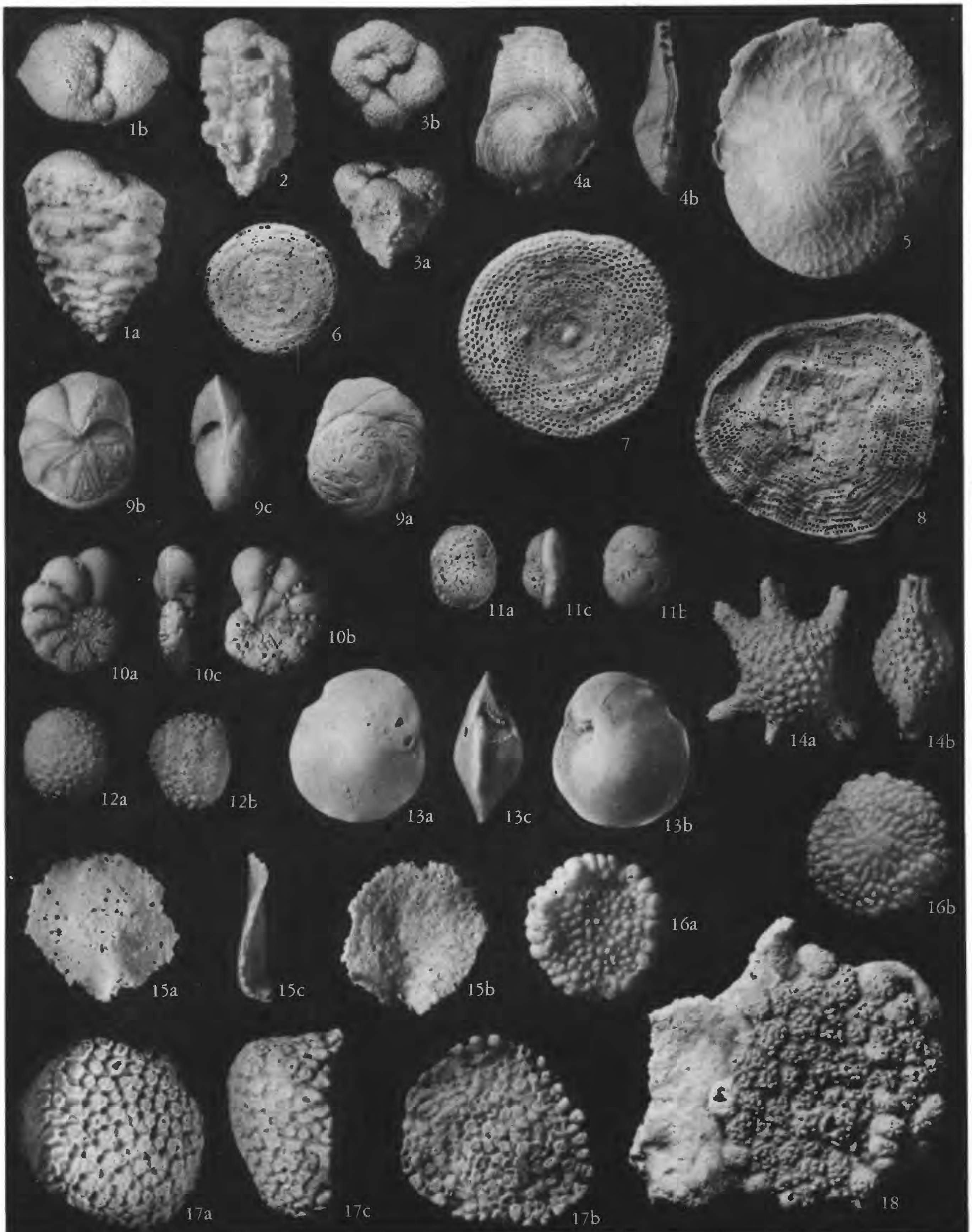
13. *Planorbulina acervalis* Brady (p. 292 tab.).
USNM 624166, × 28; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view.

14. *Planorbulina? rubra* D'Orbigny (p. 292 tab.).
USNM 624225; USGS f11358 (*A11*).

15. *Acervulina* sp. (p. 292 tab.).
USNM 624243; USGS f11371 (*B10*); *a*, top view; *b*, peripheral view.



CYMBALOPORIDAE, CASSIDULINIDAE, GLOBIGERINIDAE, ANOMALINIDAE, AND PLANORBULINIDAE FROM RECENT SEDIMENTS OF TANAPAG LAGOON



MISCELLANEOUS LARGE SPECIMENS REPRESENTING 10 FAMILIES (VERNEUILINIDAE TO RUPERTIIDAE) FROM RECENT SEDIMENTS OF TANAPAG LAGOON

PLATE 93

[All figures × 17, except as indicated]

FIGURE 1. *Gaudryina* (*Siphogaudryina*) *rugulosa* Cushman (p. 286 tab.).
USNM 624134; USGS f11349 (*A3*); *a*, front view; *b*, top view.

2. *Gaudryina* (*Siphogaudryina*) *siphonifera* (Brady) (p. 286 tab.).
USNM 624241, × 25; USGS f11371 (*B10*).

3. *Valvulina davidiana* Chapman (p. 286 tab.).
USNM 624135; USGS f11349 (*A3*); *a*, front view; *b*, top view.

4. *Peneroplis proteus* D'Orbigny (p. 288 tab.).
USNM 624154; USGS f11349 (*A3*); *a*, front view; *b*, peripheral view.

5. *Heterostegina suborbicularis* D'Orbigny (p. 288 tab.).
USNM 624119; USGS f11348 (*A2*).

6–8. *Marginopora vertebralis* Blainville (p. 288 tab.).
6, 7. USNM 624120; USGS f11348 (*A2*).
8. USNM 624121; USGS f11348 (*A2*).

9. *Poroeponides cribrorepandus* Asano and Uchio (p. 290 tab.).
USNM 624122; USGS f11348 (*A2*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

10. *Epistomaroides polystomelloides* (Parker and Jones) (p. 290 tab.).
USNM 624123; USGS f11348 (*A2*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

11. *Pegidia dubia* (D'Orbigny) (p. 290 tab.).
USNM 624124; USGS f11348 (*A2*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

12. *Sphaeridia papillata* Heron-Allen and Earland (p. 290 tab.).
USNM 624214; USGS f11355 (*A8*); *a*, dorsal view; *b*, peripheral view.

13. *Amphistegina madagascariensis* D'Orbigny (p. 296).
USNM 624187; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

14. *Baculogypsina sphaerulata* (Parker and Jones) (p. 292 tab.).
USNM 624106; USGS f11347 (*A1*); *a*, front view; *b*, peripheral view.

15. *Acervulina inhaerens* Schultze (p. 292 tab.).
USNM 624167; USGS f11349 (*A3*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

16, 17. *Gypsina vesicularis* (Parker and Jones) (p. 292 tab.).
16. USNM 624258; USGS f11396 (*E6*); *a*, dorsal view; *b*, ventral view.
17. USNM 624190; USGS f11350 (*A4*); *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

18. *Carpenteria proteiformis* Goës (p. 292 tab.).
USNM 624127; USGS f11348 (*A2*).

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Larger Foraminifera

By W. STORRS COLE

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-I

Describes and discusses range and associations of 20 species from the upper Eocene, 35 from the Miocene, and 7 from the Pleistocene; most are illustrated

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ILLUSTRATIONS

[Plates 94-118 follow index]

TABLES

CHART

GEOLOGY OF SAIPAN, MARIANA ISLANDS

LARGER FORAMINIFERA

By W. Storrs Cole

ABSTRACT

Sixty-two species of larger Foraminifera from the Eocene, Miocene, and Pleistocene of Saipan are discussed, and most of them are illustrated. Twenty species occur in the upper Eocene, Tertiary *b*; 35 in the Miocene, Tertiary *e*; and 7 in the Pleistocene.

The Eocene and the Pleistocene faunas are not subdivided, but the Miocene includes two faunal zones. Of the 33 Miocene species, 14 range throughout the Miocene, 6 are restricted to a lower zone, and 13 occur only in an upper zone. In the East Indies *Heterostegina borneensis* is believed to mark lower Tertiary *e*, whereas such species as *Flosculinella globulosa* and *Miogypsinoides dehaartii* (Van der Vlerk) are restricted to upper Tertiary *e*. As the ranges of these and associated species on Saipan are stratigraphically segregated in the same order of superposition, their stratigraphic distribution is assumed to be approximately that found in the East Indies, and the Miocene of Saipan is divided into upper and lower Tertiary *e*.

The range of *Cycloclypeus* (*Katacycloclypeus*) *transiens* Tan is extended downward into upper Tertiary *e*. Elsewhere, species of this subgenus are thought to be restricted to Tertiary *f*.

INTRODUCTION

In a preliminary report (Cole and Bridge, 1953) describing the results of reconnaissance studies on Saipan, larger Foraminifera from 25 localities were recorded. After the manuscript for this preliminary report had been prepared, samples from an additional 650 localities were received in documentation of detailed mapping by Cloud, Schmidt, and Burke (1956). In most instances the study material consisted of three large random thin sections from hand specimens, but matrix-free specimens were utilized whenever available.

The distribution of the larger Foraminifera at 591 localities studied in detail is shown on tables 1–4. The Eocene is represented by 98 localities, the Miocene by 426, and the Pleistocene by 67. The Eocene and Pleistocene are not subdivided paleontologically, but the Miocene is divided into 2 faunal zones. Approximately 50 localities are without recognizable Foraminifera.

In the zonation of the Miocene, 170 localities represent lower Tertiary *e*, the stratigraphically lower zone of the Miocene, and 256 localities are assigned to upper Tertiary *e*.

The ranges of the genera of larger Foraminifera in the East Indies have been compiled by numerous workers. Glaessner (1943), Van der Vlerk (1948), and M. G. Rutten (*in* Bemmelen, 1949, p. 87) have published the most recent range charts. The genera of larger Foraminifera from Saipan are believed to have the same stratigraphic ranges as they do in the East Indies with the exception of *Cycloclypeus* (*Katacycloclypeus*), which occurs in association with distinctive Tertiary *e* species. Elsewhere this subgenus has heretofore been recorded only from Tertiary *f*.

The genera of larger Foraminifera are so distinctive that the field party was able to use accidental sections of them observed on the broken surfaces of the rocks to locate themselves stratigraphically. Very few changes of ages assigned in the field had to be made as a result of the detailed examination of the samples. However, the zonation of the Miocene was the result of the laboratory study.

The Eocene of Saipan is correlated with the upper Eocene, Tertiary *b*, of the East Indies time scale, and the Miocene is correlated with the lower Miocene, Tertiary *e*, of this same scale. Except for the Pleistocene, these are the only major divisions recognized by means of larger Foraminifera on Saipan, although an Oligocene age has been proposed for certain restricted deposits on the basis of smaller Foraminifera.

During the final stages of the preparation of this report, I had access to a manuscript titled "Cenozoic Foraminifera of Micronesia," by Dr. Shoshiro Hanzawa (1956).

It was expected at that time that the excellent report by Dr. Hanzawa would be published first and that my work would be published at a later date. In order to avoid confusion I have used wherever possible the new generic and specific names proposed by Hanzawa, and a summary is given on the points on which disagreement occurred. The localities are indexed and their positions shown on plate 4.

TABLE 1.—*Distribution of Eocene Tertiary* b *species of larger Foraminifera on Saipan*

[See pl. 4 for localities]

Species	64, The	33, The	103, The	592, The	631, The	9, Tdeq	212, Tdeq	214, Tdq	335, Tdeq	79, Tdm	88, Tdm	90, Tdm	100, Tdm	101, Tdm	125, Tdm	132, Tdm	133, Tdm	134, Tdm	150, Tdm	163, Tdm	170, Tdm	188, Tdm	189, Tdm	190, Tdm	191, Tdm	194, Tdm	201, Tdm	217, Tdm	208, Tdm	219, Tdm	222, Tdm	223, Tdm	227, Tdm	258, Tdm	259, Tdm	10, Tmt	202, Tmt	247, Tmt	248, Tmt	253, Tmt	282, Tmt	286, Tmt	287, Tmt	288, Tmt	349, Tmt	211, Tmp	221, Tmp	251, Tmp
Localities	C	S				C	S			S																									C	S									B		
Asterocyclina incisuricamerata Cole, n. sp.																																			X													
matanzensis Cole, n. sp.		X					X	X		X		X		X	X	X	X	X			X			X		X		X		X	X					X	X		X	X	X	X	X	X	X	X		
penuria Cole, nom. nov.										X	X		X	X				X				X						X			X				X	X									X			
Biplanispira fulgeria (Whipple)									X											X	X		X										X			X				X				X		X		X
hoffmeisteri (Whipple)		X											X					X											X						X													
mirabilis (Umbgrove)								X	X												X												X			X	X	X				X	X	X		X		X
Borelis pygmaeus Hanzawa											X																																					
Camerina djokdjokarta (Martin)																																																
saipanensis Cole								X	X	X	X	X		X	X	X	X		X		X			X				X								X				X		X	X	X				
Dictyoconus saipanensis Cole, n. sp.																																																
Discocyclina omphala (Fritsch)	X						X			X	X		X	X	X	X	X	X	X		X							X							X	X						X	X	X	X	X		
Eorupertia plecte (Chapman)		X						X													X		X										X			X		X			X				X			
Fabiania saipanensis Cole		X			X		X			X	X	X					X				X		X			X		X	X	X	X	X	X			X	X	X		X		X		X	X	X	X	X
Halkyardia bikiniensis Cole																																																
Heterostegina saipanensis Cole		X	X				X			X		X		X	X		X		X					X											X	X	X			X		X	X			X		X
Operculinoides saipanensis Cole, n. sp.							X			X																														X							
Pellatispira orbitoidea (Provale)		X		X			X					X	X					X	X	X		X			X			X	X	X	X				X								X		X			
provaleae Yabe		X	X	X	X	X	X			X	X			X			X	X	X	X	X			X	X	X	X	X	X					X	X	X					X			X		X		
Planorbulinella larvata (Parker and Jones)										X																							X					X			X							
Spiroclypeus vermicularis Tan																X					X												X										X			X		X

Species	21, Tmp	22, Tmp	241, Tmp	242, Tmp	251, Tmp	254, Tmp	256, Tmp	262, Tmp	270, Tmp	271, Tmp	290, Tmp	291, Tmp	292, Tmp	315, Tmp	319, Tmp	321, Tmp	336, Tmp	338, Tmp	341, Tmp	342, Tmp	345, Tmp	351, Tmp	364, Tmp	369, Tmp	381, Tmp	603, Tmp	604, Tmp	19, Tmw	20, Tmw	22, Tmw	23, Tmw	51, Tmw	56, Tmw	65, Tmw	69, Tmw	77, Tmw	78, Tmw	80, Tmw	85, Tmw	110, Tmw	111, Tmw	176, Tmw	268, Tmw	307, Tmw	308, Tmw	310, Tmw	311, Tmw	318, Tmw	340, Tmw	359, Tmw
Localities—Continued	C		S																									B															S							
Asterocyclina incisuricamerata Cole, n. sp.																																																		
matanzensis Cole, n. sp.		X		X	X	X	X	X	X	X	X	X	X	X		X	X	X				X		X	X		X																X	X	X			X		X
penuria Cole, nom. nov.		X		X									X	X				X			X	X	X																											
Biplanispira fulgeria (Whipple)		X	X		X	X	X		X	X						X	X	X							X	X																						X		
hoffmeisteri (Whipple)																																																		
mirabilis (Umbgrove)	X	X	X		X	X	X	X					X		X		X		X		X				X																		X	X	X		X	X		
Borelis pygmaeus Hanzawa																																																		
Camerina djokdjokarta (Martin)																			X																															
saipanensis Cole	X	X		X		X		X	X	X			X	X		X	X		X	X	X	X	X		X			X	X	X	X	X	X		X	X	X	X	X	X	X			X						
Dictyoconus saipanensis Cole, n. sp.																																		X								X								
Discocyclina omphala (Fritsch)	X	X	X		X		X	X		X	X		X	X	X	X		X	X		X	X	X		X	X																	X	X	X	X		X		
Eorupertia plecte (Chapman)			X		X	X		X		X				X	X	X		X				X	X					X		X	X	X	X								X			X	X	X	X		X		
Fabiania saipanensis Cole		X	X	X	X	X		X	X		X		X		X		X	X	X	X	X			X	X							X								X				X		X		X	X	X
Halkyardia bikiniensis Cole		X																X																X														X		
Heterostegina saipanensis Cole								X		X										X	X																													
Operculinoides saipanensis Cole, n. sp.		X								X								X																																
Pellatispira orbitoidea (Provale)		X			X					X									X	X							X																							
provaleae Yabe				X												X			X		X				X	X	X																							
Planorbulinella larvata (Parker and Jones)					X	X	X						X																			X															X			
Spiroclypeus vermicularis Tan	X	X								X	X			X					X		X																						X	X	X			X		

STRATIGRAPHIC PALEONTOLOGY

EOCENE

Although the three Eocene formations, the Hagman and Densinyama formations and the Matansa limestone, have slightly variant assemblages of larger Foraminifera, they are here regarded as constituting a single faunal unit. The number of localities in each facies of the Eocene which contained larger Foraminifera is shown in the following table. Five samples were studied from the Hagman formation, 30 from the Densinyama formation, and 63 from the Matansa limestone. The distribution of the Eocene species is shown on table 1.

The samples from the five localities which represent the Hagman formation were not very fossiliferous with the exception of the one from locality S33, which had larger Foraminifera in moderate abundance. Therefore, many of the genera and species which occur in the Densinyama formation and Matansa limestone were not found in the Hagman formation.

Number of localities in each Eocene facies that contained larger Foraminifera

Formation	Facies	Localities			Total
		B	C	S	
Matansa limestone	White	15		8	23
	Pink	3	2	25	30
	Transitional		1	9	10
Densinyama	Limestone-conglomerate			26	26
	Conglomerate-sandstone		1	3	4
Hagman	Conglomerate-sandstone		1	4	5
Total		18	5	75	98

The number of occurrences of each species in each facies of the Eocene is shown in the following table.

Number of occurrences of each species in each Eocene facies

Species	Matansa limestone			Densinyama formation		Hagman formation	Total
	White	Pink	Transitional	Limestone-conglomerate	Conglomerate-sandstone	Conglomerate-sandstone	
Asterocyclina incisuricamerata Cole, n. sp				1			1
A. matanzensis Cole, n. sp	5	20	9	13	2	1	50
A. penuria Cole, nom. nov		9	2	9			20
Biplanispira fulgeria (Whipple)	1	14	3	4	1		23
B. hoffmeisteri (Whipple)				4		1	5
B. mirabilis (Umbgrove)	5	15	6	2	2		30
Borelis pygmaeus Hanzawa				1			1
Camerina djokdjokarta (Martin)		1					1
C. saipanensis Cole	14	17	5	11	2		49
Dictyoconus saipanensis Cole, n. sp	2						2
Discocyclina omphala (Fritsch)	5	20	5	12	1	1	44
Eorupertia plecte (Chapman)	11	11	4	3	1	1	31
Fabiania saipanensis Cole	7	20	7	13	1	2	50
Halkyardia bikiniensis Cole	2	2					4
Heterostegina saipanensis Cole		6	5	8	1	2	22
Operculinoides saipanensis Cole, n. sp		3	1	1	1		6
Pellatispira orbitoidea (Provale)		6	2	12	1	2	23
P. provaleae Yabe		8	3	16	2	4	33
Planorbulinella larvata (Parker and Jones)	2	4	2	2			10
Spiroclypeus vermicularis Tan	4	8	1	3			16

Four species were found in all of the fossiliferous facies of the Eocene: *Asterocyclina matanzensis*, *Discocyclina omphala*, *Eorupertia plecte*, and *Fabiania saipanensis*. Three species were found in the three formations, but not in all the facies: *Heterostegina saipanensis*, *Pellatispira orbitoidea*, and *P. provaleae*. Seven species were found in the Densinyama formation and the Matansa limestone: *Asterocyclina penuria*, *Biplanispira fulgeria*, *B. mirabilis*, *Camerina saipanensis*, *Operculinoides saipanensis*, *Planorbulinella larvata*, and *Spiroclypeus vermicularis*. Three species were found only in the Matansa limestone: *Camerina djokdjokarta*, *Dictyoconus saipanensis*, and *Halkyardia bikiniensis*. Two species were found only in the Densinyama formation: *Asterocyclina incisuricamerata* and *Borelis pygmaeus*. And one species, *Biplanispira hoffmeisteri*, was found in the Densinyama and Hagman formations.

No species occurred at all of the 98 Tertiary *b* localities. *Fabiania saipanensis* was found at the greatest number of localities (50), whereas *Asterocyclina incisuricamerata*, *Camerina djokdjokarta*, and *Borelis pygmaeus* were found at single localities. Species which occurred either at single or few localities were represented by few specimens. There is only 1 specimen of *Borelis pygmaeus* and *Camerina djokdjokarta*, 2 of *Dictyoconus saipanensis*, 4 of *Halkyardia bikiniensis*, and 6 of *Operculinoides saipanensis*. Thus, 5 of the 20 Tertiary *b* species are extremely rare.

These rare species which appear to be restricted to a given formation or facies occur so infrequently that little stratigraphic importance is given them. The more abundantly occurring species are well distributed through the localities assigned to the three formations. Therefore, no species or group of species can be designated as stratigraphic markers for any of the Eocene formations, and the fauna is considered to be a unit.

Van der Vlerk (1948, p. 61, 62) concluded that the presence of *Biplanispira* and *Spiroclypeus* indicates a

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Tertiary *b* (upper Eocene) age. M. G. Rutten (*in* Bemmelen, 1949, p. 87) concluded that in most areas in the East Indies it was not possible to separate the Eocene into Tertiary *a* and *b*. However, Mohler (*in* Bemmelen, 1949, p. 86) postulated that this division could be made in southeast Borneo on the presence of *Biplanispira mirabilis* (Umbgrove) and a saddle-shaped *Discocyclina* which was named *D. omphala* "*selliformis*." This variety is here referred to typical *D. omphala*.

As the Saipan fauna contains abundant *Biplanispira*, *Discocyclina omphala*, and frequent specimens of *Spiroclypeus vermicularis* Tan, it is correlated with Tertiary *b* of the East Indies.

MIOCENE

In a preliminary report on Saipan, Cole and Bridge (1953, p. 8–11) recognized four units in the Miocene: the Densinyama beds, Laulau limestone, and Donni beds of Miocene, Tertiary *e* (Aquitanian) age and the Tagpochau limestone of probable high Tertiary *e* or possible low Tertiary *f* (Burdigalian) age. Detailed mapping by Cloud, Schmidt, and Burke (1956) indicates that only one Miocene formation, the Tagpochau limestone, can be recognized in the field. This formation is subdivided by them into 8 facies, two of which, the Donni sandstone member and the Machegit conglomerate member, have been given geographic names.

Although material from only 16 localities was available in the preliminary study, these localities were separated into two ages, one of which was assigned definitely to Tertiary *e* on the presence of *Lepidocyclina* (*Eulepidina*) and *Spiroclypeus* and the other either to high *e* or low *f* on the presence of *Miogypsina* (*Miogypsina*) and *Miogypsinoides*.

The present study is based on samples from 426 localities from the Tagpochau limestone. From these localities 33 species of larger Foraminifera were recognized, of which 14 species appear to range throughout the formation. Six species are confined to the lower part of the formation, and 13 species occur in the upper part.

In the analysis of the abundant material in the present collection, which represents a very comprehensive sampling of the Miocene of Saipan, the twofold faunal division proposed in the preliminary report is substantiated. However, the possibility that the upper stratigraphic zone might be Tertiary *f* had to be abandoned.

The critical species for the recognition of the stratigraphically lower part of the Tagpochau limestone are *Heterostegina borneensis* Van der Vlerk, *Lepidocyclina* (*Nephrolepidina*) *brouweri* L. Rutten, and *Spiroclypeus tidoenganensis* Van der Vlerk. The upper part has the following diagnostic species: *Flosculinella globulosa* L. Rutten, *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton and Holland, *L.* (*N.*) *verrucosa* Scheffen, *Miogypsina* (*Miogypsina*) *thecideaeformis* (L. Rutten), *Miogypsinoides dehaartii* (Van der Vlerk), and *Spiroclypeus higginsi* Cole.

Van der Vlerk (1948, p. 61) stated that *Heterostegina borneensis* in the East Indies is confined to lower Tertiary *e* and that upper Tertiary *e* has "the same assemblage without *Heterostegina borneensis* but with *Flosculinella* and *Lepidocyclina* (*Multilepidina* and *Trybliolepidina*)." M. G. Rutten (*in* Bemmelen, 1949, p. 87) accepted these ranges. Hanzawa (1940, p. 776) placed *Miogypsinoides dehaartii* in the Aquitanian, whereas Mohler (1949, p. 526) considered that this species in Borneo ranged from upper Tertiary *e* into Tertiary *f*.

On Saipan, samples from 83 localities contained *Heterostegina borneensis*, and those from 113 localities contained *Miogypsinoides dehaartii*. Before any critical check was made of the known stratigraphic position of these localities, they were separated into two faunal groups. Subsequent check against the known field relationship demonstrated that the grouping and assumed stratigraphic relationship was correct.

Localities at which neither *Heterostegina borneensis* nor *Miogypsinoides dehaartii* occurred were assigned either to lower *e* or upper *e* on the species which did occur at these localities. In this preliminary assignment of such localities, those with *Lepidocyclina* (*Nephrolepidina*) *brouweri* and *Spiroclypeus tidoenganensis* were placed in lower *e*. This association proved to be correct when it was checked against the known stratigraphic position of the localities. A small number of localities which did not have any of these species were assigned to lower *e* on their general appearance. This group includes the only localities about whose correlation there was question when the paleontologic determinations were checked against the field relationships. The localities assigned to upper *e* were handled in a similar manner. Again, the difference between the paleontologic determination and the known stratigraphic relationships occurred only with those localities at which the critical species did not occur. The range charts (tables 2, 3) of the Miocene species have been prepared to show the various grouping of the diagnostic species which were used. Lower *e* (table 2) is divided first into localities at which *Heterostegina borneensis* was present, then those at which *Spiroclypeus tidoenganensis* was recognized, and finally those which were without either of these species. The localities assigned to upper *e* (table 3), which have *Miogypsinoides dehaartii*, are listed first, followed by those which have *Miogypsina* (*Miogypsina*) *thecideaeformis* and then by those without these species.

For a time it seemed that localities at which *Miogypsinoides bantamensis* occurred could be grouped together and placed either in lower *e* or upper *e*. Detailed study, however, proved that this species is associated with the critical species both of lower *e* and upper *e*. On the distribution chart of lower Tertiary *e* species, it was not practical to group together the localities at which *M. bantamensis* is found, because it occurred with *Heterostegina borneensis* and *Spiroclypeus tidoenganensis* as well as at localities where these species were not found. However, on the chart (table 3) of upper *e* associations, the localities at which *M. bantamensis* occurred are grouped together.

The only species which did not fit the known range of the species in the East Indies was *Cycloclypeus* (*Katacycloclypeus*) *transiens* Tan, which was found at two localities (B701, B704) in association with typical upper Tertiary *e* species. In the East Indies this subgenus has not been found in Tertiary *e* and is supposed to be restriced to Tertiary *f*.

Mohler (1949, p. 526) recently has suggested that upper Tertiary *e* should be removed from the Aquitanian and placed with Tertiary f_1, in the Burdigalian, largely on the discovery of *Flosculinella* in beds of Tertiary *e* age on Borneo.

Glaessner (1953, p. 654) disagreed with this separation of Tertiary *e* and wrote concerning the presence of *Flosculinella* in beds of upper Tertiary *e* age, "Its discovery in earlier beds containing the *Eulepidina-Spiroclypeus* fauna means only that *Flosculinella* existed elsewhere somewhat earlier than previously known, but not that the Burdigalian must now be extended downward." The same reasoning applies to the discovery of infrequent specimens of *Katacycloclypeus* on Saipan.

Inasmuch as lower Tertiary *e* and upper Tertiary *e* on Saipan contain *Eulepidina* and *Spiroclypeus*, it would appear that only one stage is represented. The infrequent occurrence of *Flosculinella* and *Katacycloclypeus* is not as important as the occurrence of *Eulepidina* and *Spiroclypeus* whose ranges are considered more reliably established on abundant and widely distributed material.

Glaessner (1953, p. 656) rejected the letter classification because it has "become defective and no improvement can be expected in the near future. . . ." He considered (p. 655) that there is "no evidence at present to show which part of the e-Stage is Chattian and which is Aquitanian. . . ."

Although it appears that the Aquitanian as a definite world stage cannot be recognized yet in the East Indies, the letter classification still serves a useful purpose. It has been possible in terms of this classification to correlate the faunas of Saipan with those of the East Indies. However, it is preferable to refer to the subdivisions of *e* in the general terms lower *e* and upper *e* rather than use the numerical subscripts which were proposed originally.

The question of whether this Tertiary *e* fauna on Saipan is Oligocene or Miocene cannot be decided with evidence available. However, because of its general unity it seems preferable to consider it either all Oligocene or all Miocene. For the present, Tertiary *e* on Saipan is considered to be lower Miocene.

The possibility was entertained that the various faunal associations at the localities within the Miocene could be explained by facies. The following table was prepared showing the number of localities at which the different specific associations were found are shown with the facies recognized in the field.

Number of localities in each lower Miocene paleontologic association and facies

Facies or member of Tagpochau limestone	Lower Tertiary *e*										Upper Tertiary *e*												
	Heterostegina borneensis from localities—			*Spiroclypeus tidoenganensis* from localities—			Others from localities—			Totals	*Miogypsinoides dehaartii* from localities—			*Miogypsina thecideaeformis* from localities—			*Miogypsinoides bantamensis* from localities—			Others from localities—			Totals
	B	C	S	B	C	S	B	C	S		B	C	S	B	C	S	B	C	S	B	C	S	
Inequigranular	38	6	27	30	5	14	16	3	3	142	74	16	7	32	2	4	24	5		41	2	1	208
Equigranular				2						2				7			1			3			11
Rubbly		1		6						7		3		4						1			8
Marly			4		1		1	1	1	8		1	1	1	3						2		8
Tuffaceous		1	1					1		3	2	2		1	1	1	1						8
Transitional		1	4						1	6			1		1								2
Machegit conglomerate																							
Donni sandstone						1				1	1								1				2
Undifferentiated					1					1		5			3						1		9
Totals	83			60			27			170	113			60			32			51			256

TABLE 4.—*Distribution of Pleistocene species of larger Foraminifera on Saipan*

[See pl. 4 for localities]

B localities

Species	28, Qmm	38, Qta	64, Qmm	179, Qmm	181, Qmm	188, Qmm	192, Qmm	193, Qmm	215, Qmm	226, Qmm	227, Qmm	229, Qmm	230, Qmm [1]	231, Qmm	232, Qmm	233, Qmm	234, Qmm	235, Qmm	282, Qmm	286, Qmm	287, Qmm	293, Qmm	294, Qmm	299, Qmm	300, Qta	317, Qmm	318, Qmm	321, Qmm	324, Qmm	328, Qmm	331, Qmm	334, Qta	338, Qmr	340, Qmm	406, Qta
Amphistegina madagascariensis D'Orbigny	X	X		X	X	X		X		X	X		X									X	X		X					X	X		X	X	X
Baculogypsina sphaerulata (Parker and Jones)	X	X	X			X	X			X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X				X	X
Calcarina spengleri (Gmelin)	X	X					X							X	X		X	X		X	X			X	X	X	X	X		X		X			X
Cycloclypeus (*Cycloclypeus*) *carpenteri* Brady				X																		X	X								X				
Heterostegina suborbicularis D'Orbigny						X		X										X															X		
Marginopora vertebralis Quay and Gaimard									X		X				X								X	X	X			X			X				
Operculinoides venosus (Fichtel and Moll)				X																															

C localities

Species	49, Qmh	50, Qta	52, Qmh	54, Qmh	59, Qmm	61, Qmm	65, Qmm	66, Qrb	67, Qmm	68, Qmm	76, Qmm	77, Qmm	78, Qmm	80, Qmm
Amphistegina madagascariensis D'Orbigny	X	X	X	X					X	X				
Baculogypsina sphaerulata (Parker and Jones)								X						
Calcarina spengleri (Gmelin)				X										
Cycloclypeus (*Cycloclypeus*) *carpenteri* Brady					X							X	X	X
Heterostegina suborbicularis D'Orbigny		X												
Marginopora vertebralis Quay and Gaimard				X		X	X				X			X
Operculinoides venosus (Fichtel and Moll)			X											

S localities

Species	417, Qta	430, Qmr	452, Qmb	564, Qmr	568, Qmr	611, Qta	613, Qmm	622, Qmm [1]	630, Qmm	670, Qmr [1]	676, Qmr	677, Qmr [1]	678, Qmr [1]	681, Qmr	690, Qmm	691, Qmh	697, Qmr	699, Qmh
Amphistegina madagascariensis D'Orbigny	X	X			X		X	X	X	X						X		
Baculogypsina sphaerulata (Parker and Jones)																		
Calcarina spengleri (Gmelin)						X						X						
Cycloclypeus (*Cycloclypeus*) *carpenteri* Brady	X	X	X		X		X	X	X	X	X	X	X	X	X			X
Heterostegina suborbicularis D'Orbigny		X																
Marginopora vertebralis Quay and Gaimard				X							X		X				X	
Operculinoides venosus (Fichtel and Moll)												X				X		

[1] Locality at which reworked specimens were found (see text p. 327).

Of the 426 Miocene localities studied, 351 represent the inequigranular facies of the Tagpochau formation. As all of the paleontological associations of lower and upper Tertiary *e* are represented, there is apparently no correlation between the species of larger Foraminifera and the several limestone facies. No larger Foraminifera were found in the tuffaceous beds of the Donni member; however, at one Donni locality (B186) larger Foraminifera were obtained from limestone presumed to be in place; at the other two localities (S126 and S127) the Foraminifera were in erratic limestone blocks.

The echinoid *Sismondia* was collected at 18 localities. Eight of these localities were examined for larger Foraminifera. Seven of the localities represent lower Tertiary *e* and one (C122) upper Tertiary *e*. All of the lower Tertiary *e* localities (C109, C130, C141, S145, S536, S540 and S541) have *Spiroclypeus tidoenganensis* as the diagnostic Foraminifera. Although *Sismondia* was found most commonly with a lower Tertiary *e* foraminiferal assemblage, its occurrence at an unquestioned upper Tertiary *e* locality seriously qualifies its use as an index fossil.

The fauna of 16 Miocene localities is known from one small thin section only from each of the localities given below. As these small thin sections are not as representative as the large ones used for the localities on the distribution charts, these localities were not plotted there. They are as follows: Localities representing lower Tertiary *e* with *Heterostegina borneensis*, B47, B52, C18, C19, S12; with *Spiroclypeus tidoenganensis*, S8, S76; without either of these species, but with associated species, S11. Localities representing upper Tertiary *e* either with *Myogypsinoides dehaartii* or *Miogypsina thecideaeformis* or both, B24a, B34, B44, B46, C30, C32; without either of these species, but with associated species, B37, B40.

PLEISTOCENE

In the younger formations the genera *Baculogypsina* and *Calcarina* occur frequently. At some stations there are abundant specimens of *Cycloclypeus* (*Cycloclypeus*) *carpenteri* Brady and occasionally specimens of *Heterostegina suborbicularis* D'Orbigny. Most of the stations have *Amphistegina madagascariensis* D'Orbigny.

All of the species recognized are still living. No larger Foraminifera were found which would be satisfactory to separate these formations. The concensus of evidence, summarized under the discussion of the Marina limestone by Cloud, Schmidt, and Burke (1956), appears to favor a Pleistocene age, and the evidence of the Foraminifera is consistent with this conclusion.

The distribution of the Pleistocene species is shown on table 4.

REWORKED SPECIMENS

At a few localities the presence of reworked specimens from older deposits was established with certainty. This is particularly true in the case of certain Pleistocene localities. Sections of small pebbles were found in the thin sections from locality B230 in which there were abundant specimens of *Miogypsinoides bantamensis* Tan, a Miocene species, whereas in the surrounding limestone Pleistocene species occur.

At locality S622 a single specimen of *Miogypsinoides dehaartii* (Van der Vlerk) was found; at S670 four specimens of *Miogypsina* (*Miogypsina*) *thecideaeformis* (L. Rutten) and several specimens of *Austrotrillina howchini* (Schlumberger) occur; at S677 one specimen of *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth, another of *L.* (*N.*) *verbeeki* Newton and Holland, and several specimens of *A. howchini* were observed; and at S678 two specimens of *Miogypsina* (*Miogypsina*) *thecideaeformis* (L. Rutten) and one specimen of *A. howchini* occur. At all of these localities the abundant species in the thin sections were Pleistocene ones.

In the Miocene samples the evidence of reworking is not as good as it is for the Pleistocene. At three localities, C131, C140, and S239, rare specimens of *Spiroclypeus tidoenganensis* occur. This species is assumed to be restricted to lower Tertiary *e*. These three stations are placed in upper Tertiary *e* because of the other species found in the thin sections. As these are the only localities at which this species appears without its associated species and as the specimens are rare and somewhat abraded, it is believed that they probably represent reworked specimens.

At S667 specimens of *Fabiania saipanensis* Cole occur with specimens identified as *Eorupertia semiornata* (Howchin) and *Streblus saipanensis* Cole. As the latter species are assumed to be confined to the Miocene, the specimens of the Eocene genus *Fabiania* may be reworked. The species which are believed to be reworked are not plotted in the distribution charts, but all of the important instances of reworking are noted above.

COMPARISON WITH IDENTIFICATIONS BY HANZAWA

A summary of the differences between my identifications and those made by Hanzawa is given. These differences are more apparent than real inasmuch as Hanzawa subdivided many of the species, whereas the writer prefers to group them.

Species upon which there is agreement

Amphistegina radiata (Fichtel and Moll)
Austrotrillina howchini (Schlumberger)
Baculogypsina sphaerulata (Parker and Jones)
Biplanispira mirabilis (Umbgrove)
Borelis pygmaeus Hanzawa
Calcarina spengleri (Linné)
Fabiania saipanensis Cole
Flosculinella globulosa L. Rutten
Gypsina disca Göes
  marianensis Hanzawa
Heterostegina borneensis Van der Vlerk
Lepidocyclina (*Nephrolepidina*) *parva* Oppenoorth
Marginopora vertebralis Quoy and Gaimard
Miogypsinoides bantamensis Tan
  dehaartii (Van der Vlerk)
Operculinoides ammonoides (Gronovius)
Pellatispira orbitoidea (Provale)
Planorbulinella larvata (Parker and Jones)
Sorites martini (Verbeek)
Spiroclypeus higginsi Cole
  tidoenganensis Van der Vlerk
  vermicularis Tan

Species upon which different names are used

Hanzawa's determinations	*Names used in this report*
Archaias angulatus (Fichtel and Moll)	*A. vandervlerki* De Neve
Biplanispira absurda Umbgrove	*B. fulgeria* (Whipple)
inflata Hanzawa	*mirabilis* (Umbgrove)
mirabilis depressa Hanzawa	*hoffmeisteri* (Whipple)
elliptica Hanzawa	*mirabilis* (Umbgrove)
Borelis parvulus Hanzawa	*B. pygmaeus* Hanzawa (part)
Carpenteria proteiformis Goës	*Eorupertia plecte* (Chapman)
Cycloclypeus guembelianus H. B. Brady	*C. carpenteri* H. B. Brady
neglectus eidae Tan	*C. eidae* Tan
Discocyclina (*Asterocyclina*) *stellaris* (Brunner)	*Asterocyclina matanzensis* Cole
Discocyclina (*Discocyclina*) *dispansa* (Sowerby)	*Asterocyclina penuria* Cole
(*D.*) *indopacifica* Hanzawa	*D.* (*D.*) *omphala* (Fritsch)
(*D.*) cf. *D. molengraeffi* Henrici	*Asterocyclina penuria* Cole
Halkyardia minima (Liebus)	*Halkyardia bikiniensis* Cole
Lepidocyclina (*Eulepidina*) *bridgei* Cole	*L.* (*E.*) *badjirraensis* Crespin
(*Eulepidina*) *formosa* Schlumberger	(*E.*) *ephippioides* Jones and Chapman
gibbosa Yabe	*ephippioides* Jones and Chapman
monstrosa Yabe	*ephippioides* Jones and Chapman
rotaensis Hanzawa	*ephippioides* Jones and Chapman
(*Nephrolepidina*) *angulosa* Provale (part)	(*N.*) *angularis* Newton and Holland
angulosa Provale (part)	*brouweri* L. Rutten
dekroesi Van der Vlerk	*verbeeki* Newton and Holland
ferreroi Provale	*brouweri* L. Rutten
flexuosa L. Rutten	*verbeeki* Newton and Holland
morgani Lem. and R. Douvillé	*verrucosa* Scheffen
nipponica Hanzawa	*verbeeki* Newton and Holland
inornata L. Rutten	*sumatrensis* (Brady)
Miogypsina (*Mogypsina*) sp	*M. thecideaeformis* (L. Rutten)
Miogypsinoides borodinensis (Hanzawa)	*Miogypsinoides bantamensis* Tan
complanatus (Schlumberger)	*bantamensis* Tan
formosensis Yabe and Hanzawa	*dehaartii* Van der Vlerk
lateralis Hanzawa	*bantamensis* Tan
mauretanicus Bronnemann	*bantamensis* Tan
saipanensis Hanzawa	*bantamensis* Tan
Nummulites striata d'Archiac and Haime	*Camerina saipanensis* Cole
Pellatispira crassicolumnata (Umbgrove)	*P. provaleae* Yabe
rutteni Umbgrove	*orbitoidea* (Provale)
Rotalia mecatepecensis Nuttall	*Streblus saipanensis* Cole
Spiroclypeus leupoldi Van der Vlerk	*orbitoideus* H. Douvillé
Sporadotrema cylindricum Carter	*Eorupertia semiornata* (Howchin)

Species not found by Hanzawa

Asterocyclina incisuricamerata Cole
Camerina djokdjokarta (Martin)
Cycloclypeus (*Cycloclypeus*) *indopacifica* Tan
(*Cycloclypeus*) *posteidae* Tan
(*Katacycloclypeus*) *transiens* Tan
Dictyoconus saipanensis Cole
Heterostegina saipanensis Cole
Operculina bartschi Cushman
complanata (Defrance)
victoriensis Chapman and Parr
Operculinoides saipanensis Cole
venosus (Fichtel and Moll)

Species discussed by Hanzawa, but not described in this report

Acervulina inhaerens plana Carter
linearis Hanzawa
(*Ladoronia*) *vermicularis* Hanzawa
Alveolinella quoii (D'Orbigny)
Borelis vanderschmitti (Schweighauser)?
Borodina septentrionalis Hanzawa
Gypsina globulus Reuss
saipanensis Hanzawa
vesicularis (Parker and Jones)
Homotrema rubrum (Lamarck)
Kanakaia marianensis Hanzawa
Miniacina miniacea (Pallas)
Nummulites bagelensis Verbeek
pengaronensis Verbeek
Orbulina universa D'Orbigny

Fundamentally, Hanzawa and the writer are in agreement concerning the correlation of the sediments. He recognized Tertiary *b*, *e*, and Pleistocene. However, he did not attempt a subdivision of Tertiary *e* as he considered that the fauna of Tertiary *e* was a unit. In this report Tertiary *e* is divided into two faunal zones.

SYSTEMATIC DESCRIPTIONS

Family VALVULINIDAE

Genus DICTYOCONUS Blanckenhorn, 1900

Dictyoconus saipanensis Cole, n. sp.

Plate 101, figure 3

The test is low conical with a flat base. The diameter at the base is 1.41 mm, and the height is 0.71 mm. The marginal chambers are large, about 200μ wide and 100μ high, with a single plate which has a thickness of about 20μ and projects about 50μ into the chamber. The outer wall of the test has a thickness of about 25μ. The interior of the test is irregularly labyrinthic. The wall structure appears to be very finely arenaceous with an abundance of cement.

Type material.—Holotype: axial section from locality B176, USNM 624496.

Remarks.—This one accidental axial section at locality B176 was the best specimen found. The single projecting plate suggests that it is a very primitive type of *Dictyoconus* related to *D. cookei* (Moberg). *D. saipanensis* has fewer and much larger marginal chambers, and the interior is less complicated.

Family MILIOLIDAE

Genus AUSTROTRILLINA Parr, 1942

Austrotrillina howchini (Schlumberger)

Plate 101, figures 4–6

1953. *Austrotrillina howchini* (Schlumberger). Cole, U. S. Geol. Survey Prof. Paper 253, p. 20, pl. 14, fig. 12.

Although Glaessner (1943, chart) gives the range of this species as *e* and f_{1-2}, Van der Vlerk (1948, fig. 1) believed it to be *e* and f_1. Miss Crespin (1948, p. 139) wrote concerning *A. howchini*, "The species has been recorded from '*e* stage' but has its greatest development in '*f* stage'. . . . Records indicate that *A. howchini* has not been found in the Indo-Pacific Region outside Australia in rocks younger than f_2."

The Indo-Pacific specimens have all been identified as *A. howchini*. There is some possibility that more than one species is present and that these species may have restricted ranges. However, the specimens commonly illustrated are from random thin sections of matrix material. It would be difficult to distinguish species with slight differences from this type of material.

Family CAMERINIDAE

Genus CAMERINA Bruguière, 1792

Camerina djokdjokarta (Martin)

Plate 102, figure 21

1881. *Nummulina djokdjokartae* Martin, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 1, p. 109, 110, pl. 5, figs. 8–11.
1934. *Camerina djokdjokartae* (Martin). Caudri, Tertiary Deposits of Soemba, Amsterdam, p. 67–72, text fig. 19 [references].

This species is known in the present collection from a single transverse section. This section has a diameter of 4.15 mm and a thickness at the center of 2.2 mm. The surface would be ornamented by papillae with diameters of 180μ to 300μ.

The embryonic chambers have a diameter of 500μ and a height of 450μ.

There would be about six volutions if an oriented median section were available for study. Pillars are strongly developed and irregularly distributed. Two major pillars occur, one on either side of the embryonic apparatus.

Remarks.—The large size of the embryonic chambers and the form of the pillars are similar to illustrations given of this species (Verbeek and Fennema, 1896, pl. 8, fig. 119; Caudri, 1934, text fig. 19). However, without the median section, there must always be some doubt concerning the correct identification of the Saipan specimen.

Camerina saipanensis Cole

Plate 102, figure 20

1953. *Camerina saipanensis* Cole, U. S. Geol. Survey Prof. Paper 253, p. 20–21, pl. 2, figs. 7–19.

This species was completely described from matrix-free specimens in the preliminary report on Saipan. One transverse section is illustrated for comparison with *C. djokdjokarta* (pl. 102, fig. 21).

Genus OPERCULINA D'Orbigny, 1826

Operculina ammonoides (Gronovius)

Plate 94, figures 12–14

1937. *Operculina ammonoides* (Gronovius) Chapman and Parr, Royal Soc. Victoria Proc., v. 50, pt. 1, n. ser., p. 290–292, pl. 17, figs. 12–16, text fig. 5 [references].

The test is thin, compressed, evolute, and the spiral suture is in a marked depression with the radial sutures raised and beaded at their proximal ends. Measurements of the four specimens which illustrate the external appearance follow:

	1	2	3	4
Height (mm)	1. 96	2. 3	1. 7	1. 7
Width (mm)	1. 53	1. 9	1. 3	1. 27

The embryonic chambers are small, bilocular. The initial chamber has an internal diameter of about 30μ; the second chamber has internal diameters of about 25μ by 30μ.

A specimen with a height of 1.9 mm and a width 1.6 mm has 3½ coils with 46 chambers. There are 7 chambers in the first volution and 18 chambers in the final volution.

The chambers increase regularly in height as they are added. Chambers in the final volution near the apertural end have a height of about 500μ. The chamber walls are straight and radial for about one-third their length and then recurved.

In transverse section the thickness through the center is about 0.25 mm. At either end of the nearly straight-sided central part, there are inflated areas representing the final volution.

Remarks.—Through the courtesy of the late Dr. Vaughan, the writer has abundant specimens described by Yabe and Hanzawa (1925, p. 49) from Nakôshi, Haneji-mura, Okinawa-jima. Yabe and Hanzawa have given excellent illustrations of these specimens which they identified as *Operculina venosa* (Fichtel and Moll).

Later Hanzawa (1939, p. 229) reclassified these specimens, placing them in the species *O. ammonoides* (Gronovius) a revision which had been made earlier by Chapman and Parr (1938, p. 290). Hanzawa (1939, p. 225) believed that *Nautilus venosus* Fichtel and Moll, 1798, was a synonym of *Operculina ammonoides* (Gronovius), but Chapman and Parr recognized separate species.

In the collection from Saipan certain specimens are similar to the ones from the Ryukyu Islands and are identified as *O. ammonoides*. Other specimens are similar to *O. venosus*. *O. ammonoides* is always evolute to some degree and, therefore, belongs in the genus *Operculina*, whereas *O. venosus* is always involute and should be placed in the genus *Operculinoides*.

Operculina bartschi Cushman

Plate 94, figures 16–21

1950. *Operculina bartschi* Cushman. Cole, U. S. Geol. Survey Prof. Paper 221–B, p. 22–23, pl. 5, figs. 3–5 [references].

The test is evolute, thin, and compressed with a very slightly elevated central part which is surrounded by the thinner peripheral part. There is either a single, very slightly raised, papilla or a group of smaller papillae over the embryonic chambers. The diameter of this central ornamentation is from 200μ to 400μ. The spiral suture is depressed and more strongly so as the periphery is approached. The radial sutures are very slightly raised and normally not beaded except those of the initial coils which may have faint beading. The following are measurements of the two specimens which illustrate the external appearance:

	1	2
Height mm	3. 05	3. 2
Width mm	2. 8	2. 6

The embryonic chambers are bilocular. The initial chamber has an internal diameter of about 80μ; the second chamber has internal diameters of about 25μ by 75μ.

A specimen with a height of 2.4 mm and a width of 2.3 mm has 3¾ coils with 60 chambers. There are 8 chambers in the first volution and 23 chambers in the final volution.

The chamber walls normally are straight, radial, except a few have a slight recurvature at their distal ends.

The thickness at the center in transverse section is about 0.75 mm. Marked axial plugs occur on either side of the embryonic apparatus. The surface diameter of these plugs is from 400μ to 500μ. The marginal cord is well developed and prominent.

Remarks.—This species is normally larger than *O. ammonoides*, the ornamentation is less pronounced, and the transverse shape is different. The axial plugs are well developed and large.

Operculina complanata (Defrance)

Plate 94, figure 15; plate 118, figures 19, 20

1822. *Lenticulites complanata* Defrance, Dict. Sci. Nat., v. 5, p. 453.

Abundant specimens of a thin, fragile *Operculina* are found in the thin sections from a few localities.

As these specimens are present as transverse sections only, it was impossible to study all the features necessary for exact identification. As the transverse sections are similar to those of this species from localities elsewhere, they are assigned to this species.

Operculina victoriensis Chapman and Parr

Plate 94, figures 1–3

1953. *Operculina victoriensis* Chapman and Parr. Cole, U. S. Geol. Survey Prof. Paper 253, p. 21, pl. 5, figs. 1–7 [references].

Measurements of median and transverse sections from locality C145 follow.

	Specimen, from loc. C145, shown on pl. 94—		
	Fig. 2	Fig. 3	Fig. 1
Height ... mm	1.5	1.95	2.05
Width ... mm	1.23		
Thickness ... mm			0.40
Embryonic chambers:			
Diameter of initial chamber ... μ	60 x 70	50 x 40	
Diameter of second chamber ... μ	50 x 80	40 x 70	
Number of coils	2½	3½	
Chambers in first volution	7	7	
Chambers in final volution	15	19	
Total number of chambers	31	47	

Genus OPERCULINOIDES Hanzawa, 1935

Operculinoides saipanensis Cole, n. sp.

Plate 102, figures 15, 16

Very infrequent specimens of this species are found in the Eocene thin sections. The best median and transverse sections are described.

Test is small, compressed, and slightly umbonate with a fairly broad rim.

The median section which is incomplete has a height of 1.64 mm and a width of 1.25 mm. The initial chamber with an internal diameter of 30μ is small. The second chamber has internal diameters of 30μ by 50μ. The distance across both chambers is 65μ. There are 3½ coils with 7 chambers in the first volution, 23 in the last, and 56 in all.

An incomplete transverse section has a height of 1.92 mm and a thickness of 0.54 mm. One axial plug shows and has a surface diameter of 120μ.

Type material.—Holotype: median section from locality S271, USNM 624521; paratype: transverse section from locality S79*b*, USNM 624522.

Remarks.—The specimens which most nearly resemble this new species are described by Provale (1908, p. 71) from Borneo under the name *Operculina pyramidum* Ehrenberg. As she figures only a median section, it is impossible to decide whether this specimen belongs to *Operculina* or *Operculinoides*. The Borneo specimen is slightly larger, has fewer chambers in the final volution, and the chamber walls are straighter.

Operculinoides venosus (Fichtel and Moll)

Plate 94, figures 4–11

1937. *Operculinella venosa* (Fichtel and Moll.) Chapman and Parr, Royal Soc. Victoria Proc., v. 50 pt. 1, new ser., p. 293, pl. 17, figs. 21, 22, text fig. 7 [references].

1950. *Operculina ammonoides* Cole [not Gronovius], U. S. Geol. Survey Prof. Paper 221–B, p. 22, pl. 5, figs. 6, 7.

The test is small and completely involute with a diameter of 1.3 to 1.9 mm and a thickness of about 0.9 mm.

There are about 3⅛ coils with 20 chambers in the final volution. The first volution has about 7 chambers, and the total number of chambers in all the volutions is about 40.

The chamber walls are nearly straight except at their distal ends where they recurve slightly.

Remarks.—Hanzawa (1939, p. 226) combined *O. venosa* and *O. ammonoides*, but study of the Saipan and other specimens demonstrates that not only are there two species, but they belong to different genera. *O. ammonoides* is evolute and belongs to the genus *Operculina* (Cole, 1953, p. 28), whereas the involute *O. venosus* should be assigned to the genus *Operculinoides*.

Genus HETEROSTEGINA D'Orbigny, 1826

Heterostegina borneensis Van der Vlerk

Plate 95, figures 16–20

1953. *Heterostegina borneensis* Van der Vlerk. Cole, U. S. Geol. Survey Prof. Paper 253, p. 23, pl. 2, figs. 1–3, 5; pl. 4, figs. 16–18 [synonymy].

Several additional illustrations are given to supplement those previously published.

Heterostegina saipanensis Cole

Plate 102, figures 17–19

1953. *Heterostegina saipanensis* Cole, U. S. Geol. Survey Prof. Paper 253, p. 23, 24, pl. 2, figs. 4, 6.

This species was described from two median sections. Three additional matrix-free specimens were found in the present collection, of which two were made into median sections and one into a transverse section. Measurements are given of the best median section and the transverse section in the following table.

	Specimen, from loc. S259, shown on pl. 102—	
	Fig. 18	Fig. 19
Height ... mm	3.0	2.9
Width ... mm	2.75	
Thickness ... mm		1.08
Diameter of umbo ... mm		1.9
Width of flange ... mm		1.0
Thickness of flange ... mm		0.17
Embryonic chambers:		
Diameters of initial chamber ... μ	80 x 85	
Diameters of second chamber ... μ	40 x 140	
Distance across both chambers ... μ	150	
Number of operculine chambers	4	
Number of coils	2½	
Surface diameter of axial plug ... μ		500

Genus SPIROCLYPEUS H. Douvillé, 1905

Spiroclypeus higginsi Cole

Plate 95, figures 1–5; plate 109, figure 16

1939. *Spiroclypeus higginsi* Cole, Jour. Paleontology, v. 13, p. 185, 186, pl. 23, figs. 10–15; pl. 24, fig. 13.

1953. *Spiroclypeus higginsi* Cole, U. S. Geol. Survey Prof. Paper 253, p. 24–25, pl. 4, figs. 1–3, 13, 14, 19; pl. 5, figs 10–12; pl. 8, figs. 16, 17.

Typical specimens (pl. 95, figs. 3, 5) have lateral chambers with slitlike openings between thick roofs and floors. Other specimens (pl. 95, figs. 1, 2) have lateral chambers with open cavities between thin roofs and floors. These specimens superficially resemble *S. leupoldi* Van der Vlerk.

The typical specimens are the kind most frequently found in the samples from Saipan. The other type occurs in only a few samples, and in these they are always in association with the typical form with which there is complete intergradation.

Only one microspheric specimen (pl. 109, fig. 16) was found.

Remarks.—Cole (1939, p. 186) stated in the original description of *S. higginsi* that it resembled *S. leupoldi* in size and shape but it differed in possessing thick roofs and floors of the lateral chambers and pillars. These may not be valid criteria for the separation of these species. Therefore, eventually it may be proved that *S. higginsi* is a synonym of *S. leupoldi*.

Spiroclypeus orbitoideus H. Douvillé

Plate 95, figures 6–12

1905. *Spiroclypeus orbitoideus* H. Douvillé, Soc. géol. France Bull., sér. 4, v. 5, p. 460–462, pl. 14, figs. 1–6.

1953. *Spiroclypeus orbitoideus* H. Douvillé. Cole, U. S. Geol. Survey Prof. Paper 253, p. 26, pl. 4, figs. 4, 5 [references].

Measurements of transverse sections from four localities follow.

Remarks.—This species is characterized in transverse section by having long open rectangular lateral chambers with thin floors and roofs which are arranged in regular tiers. It is always associated on Saipan with *S. tidoenganensis* Van der Vlerk. Although it is not as abundant as that species, it occurs commonly at certain localities.

Measurements of transverse sections of Spiroclypeus orbitoideus

	Specimen from locality—					
	B429, shown on—	B392, shown on—		B354, shown on—	B355, shown on—	
	Pl. 95, fig. 10	Pl. 95, fig. 7	Pl. 95, fig. 6	Pl. 95, fig. 8	Pl. 95, fig. 11	Pl. 95, fig. 12
Diameter mm	4. 8	3. 5+	2. 2+	5. 8+	4. 6+	8. 3
Thickness mm	1. 81	1. 78	1. 5	1. 65	1. 66	2. 3
Diameter of umbo mm	2. 3	2. 3	2. 0	2. 6	2. 8	2. 7
Width of flange mm	1. 3	----------	----------	2. 0	1. 0+	4. 2
Thickness of flange mm	0. 13	----------	----------	0. 12	0. 14	0. 27
Embryonic chambers:						
Length μ	380	420	290	390	320	500
Height μ	190	240	240	410	320	340
Median layer:						
Height at center μ	130	140	190	110	100	150
Height at periphery μ	130	----------	----------	110	140	210
Lateral chambers:						
Number	13	14	12	11	12	10
Length μ	140–440	100–200	180–240	170–350	200–240	140–400
Height μ	40	20–30	15	20–30	40	40–60
Thickness of floors and roofs μ	10	20	20	10	20–40	20–50

Spiroclypeus tidoenganensis Van der Vlerk

Plate 95, figures 13–15

1925. *Spiroclypeus tidoenganensis* Van der Vlerk, Nederlandsche Akad. Wetensch. Meded., no. 3, p. 16, pl. 1, fig. 12; pl. 5, figs. 42, 47.

1953. *Spiroclypeus tidoenganensis* Cole, U. S. Geol. Survey Prof. Paper 253, p. 25–26, pl. 3, figs. 1–12; pl. 4, figs. 6–12; pl. 7, figs. 7–11 [references].

This species, of which a complete description and numerous illustrations were given in the preliminary report on Saipan, is abundant at many of the localities. Its comparatively large size, slitlike lateral chambers between thick roofs and floors, and the heavy pillars of the transverse section made it easy to recognize.

Remarks.—Certain large thin specimens with a small umbo, from station B435, are assigned to this species because of the shape of the lateral chambers and the presence of pillars. These specimens somewhat resemble the illustration of *S. tidoenganensis* given by Tan (1937b, pl. 4, fig. 5) although his specimen was much smaller. A description of these specimens is given:

The test is large with a diameter from 9.0 to 10.0 mm. The umbo is small with diameter from 1.0 to 1.7 mm, and a thickness of 1.0 to 1.7 mm, and is surrounded by a wide, fragile rim with a thickness near the umbo of about 0.4 mm and a thickness at the periphery of 0.15 mm.

The embryonic chambers are large with a diameter of 460μ to 480μ and a height of 210μ to 300μ.

The lateral chambers are arranged in moderately regular tiers with some overlapping with 4 to 6 chambers in each tier on either side of the embryonic chambers. They are long and low with a length of 150μ to 270μ, a height of 20μ to 30μ, and floors and roofs 20μ to 40μ thick. Small but distinct pillars with surface diameters of 150μ to 180μ are distributed irregularly throughout the umbo.

Spiroclypeus vermicularis Tan

Plate 102, figures 12–14

1937. *Spiroclypeus vermicularis* Tan, De Ingenieur in Nederlandsch—Indië—IV Mijnbouw en Geologie, Jaarg. 4, no. 10, p. 187–190, pl. 1, figs. 7, 8; pl. 2, figs. 6–10; pl. 3, figs. 13–23; pl. 4, figs. 11–18.
1953. *Spiroclypeus* sp. Cole, U. S. Geol. Survey Prof. Paper 253, p. 18, pl. 14, fig. 7.

Matrix-free specimens of this species were not available. Several transverse sections of specimens from the limestone thin sections are illustrated. These sections show all the features which characterize this species in transverse section.

The floors and roofs of the lateral chambers are thick. The chamber openings are slitlike and irregular in development. Strong pillars are present and irregularly scattered throughout the inflated part of the test.

The median section is similar to that of *Heterostegina*. In the material available it was impossible to distinguish median sections of this species from those of *Heterostegina saipanensis*, therefore this type of section is not illustrated.

Distribution elsewhere.—Koetai, East Borneo.

Genus PALLATISPIRA Boussac, 1906

Pellatispira orbitoidea (Provale)

Plate 96, figures 3–5, 7–9; plate 97, figures 1–12; plate 99, figures 7–11

1908. *Assilina madaraszi orbitoidea* Provale, Riv. italiana paleont., v. 14, p. 71, pl. 5, fig. 5.
1928. *Pellatispira orbitoidea* (Provale). Umbgrove, Nederlandsche Akad. Wetensch. Meded., no. 10, p. 18, 19, figs. 2, 3, 5, 7, 9, 11–26, 34–41.
1928. *Pellatispira rutteni* Umbgrove, idem, p. 20, 21, figs. 57 -61.
1928. *Pellatispira inflata* Umbgrove, idem, p. 21, figs. 42–56.
1953. *Pellatispira rutteni* Umbgrove. Cole, U. S. Geol. Survey Prof. Paper 253, p. 22, pl. 6, figs. 1–8.

Examination of several hundred specimens in the present collection proves that the external shape of the test and the size of the individuals is extremely variable. In the preliminary inspection several species were recognized, but detailed study of thin sections demonstrates that the internal structure in all of these specimens is the same.

The name *P. orbitoidea* has been given to compressed lenticular individuals. More inflated individuals have been called *P. inflata*, and larger individuals with an umbonate central area which is surrounded by a rim have been termed *P. rutteni*. All of these form an integrated series and are grouped together.

Distribution elsewhere.—Borneo and Eua, Tonga.

Pellatispira provaleae Yabe

Plate 96, figures 1, 2, 6; plate 98, figures 1–12

1908. *Assilina madaraszi* Provale, Riv. italiana paleont., v. 14, p. 66–70, pl. 4, figs. 21–24; pl. 5, figs. 1–4. [*Not Nummulites madaraszi* von Hankten, 1875.]
1928. *Pellatispira madaraszi provalei* Yabe. Umbgrove, Nederlandsche Akad. Wetetnsch. Meded., no. 10, p. 17, 18, figs. 27–33 [synonymy].
1941. *Pellatispira madaraszi provalei* Yabe. Heinrici, Palaeontographica, supp.; v. 4, p. 33, 34, pl. 2, figs. 10, 11.
1941. *Pellatispira crassicolumnata* Umbgrove. Heinrici, idem, p. 35, pl. 2, fig. 8.
1953. *Pellatispira crassicolumnata* Umbgrove. Cole, U. S. Geol. Survey Prof. Paper 253, p. 21–22, pl. 15, figs. 3–7.

The only observable distinction between *P. provaleae* and *P. crassicolumnata* is the development in the latter species of a thin fibrous keel beyond the main part of the test. This fragile structure is easily broken and, therefore, is not present in most matrix-free specimens or specimens that were slightly abraided before fossilization.

P. provaleae differs from *P. orbitoidea* in possessing pillars of two different sizes, the larger of which project irregularly above the surface of the test.

Distribution elsewhere.—Bonin Islands; Ryukyu Islands; Japan; Borneo; Timor.

Genus BIPLANISPIRA UMBGROVE, 1937

Biplanispira fulgeria (Whipple)

Plate 98, figures 13–18

1932. *Pellatispira fulgeria* Whipple, Bernice P. Bishop Mus. Bull. 96, p. 82, pl. 20, figs. 2, 3, 5, 6, 7.
1938. *Biplanispira absurda* Umbgrove, Leidsche geol. Meded., v. 10, p. 82–89, text figs. 1–17.

Comparison of Umbgrove's illustrations of *B. absurda* with those given by Whipple of *P. fulgeria* indicate that only one species is represented. The specimens in this collection are similar in all respects to those previously illustrated.

Distribution elsewhere.—Borneo and Eua, Tonga.

Remarks.—The degree of development of the marginal cord in this species is extremely variable. The other features are constant.

Biplanispira hoffmeisteri (Whipple)

Plate 100, figures 4–11

1932. *Pellatispira hoffmeisteri* Whipple, Bernice P. Bishop Mus. Bull. 96, p. 82, pl. 20, fig. 4; pl. 21, figs. 4, 5.
1956. *Biplanispira mirabilis* (Umbgrove) var. *depressa* Hanzawa, Geol. Soc. America Mem. 66 (in press).

The transverse sections show a single layer of equatorial chambers except near the periphery where subdivision into chamberlets occurs. Median sections have a bilocular embryonic apparatus. In one section the initial chamber has internal diameters of 240μ by 260μ, and the second chamber has internal diameters of 190μ by 260μ. The distance across both chambers is 440μ. There are about 2½ coils of *Pellatispira*-like chambers after which the equatorial chambers are subdivided into chamberlets. The following table gives the measurements of four transverse sections.

	Specimens from locality—			
	S100, shown on—	S259, shown on—	S134, shown on—	
	Pl. 100, fig. 8	Pl. 100, fig. 9	Pl. 100, fig. 10	Pl. 100, fig. 11
Height mm	7.8	4.7	8.55	8.6
Thickness mm	1.4	1.0	1.07	1.4
Embryonic chambers:				
Length μ	490	300	480	420
Height μ	490	220	300	290
Surface diameter of pillars μ	160–200	150–200	120–180	150–250
Diameter of vertical canals μ	5–30	5–20	10–20	5–30

Distribution elsewhere.—Eua, Tonga.

Remarks.—At the time this specific name was given, the genus *Biplanispira* was not recognized. Through the courtesy of Dr. Evitt, of the University of Rochester, the writer was able to examine the types of *P. hoffmeisteri*. There is no question that this species is *Biplanispira*, not *Pellatispira*.

B. hoffmeisteri is not only much larger and more compressed than *B. mirabilis* but also has more *Pellatispira*-like chambers surrounding the embryonic apparatus.

Hanzawa gives a varietal name, *B. mirabilis depressa*, to specimens which resemble *B. hoffmeisteri*. He apparently overlooked Whipple's species. Although *B. hoffmeisteri* has many of the features of *B. mirabilis*, there are sufficient differences to retain the specific name *B. hoffmeisteri*.

Biplanispira mirabilis (Umbgrove)

Plate 99, figures 1–6; plate 100, figures 1–3

1953. *Biplanispira mirabilis* (Umbgrove). Cole, U. S. Geol. Survey Prof. Paper 253, p. 22–23, pl. 6, figs. 9–19 [synonymy].
1956. *Biplanispira mirabilis* (Umbgrove) var. *elliptica* Hanzawa, Geol. Soc. America Mem. 66 (in press).
1955. *Biplanispira inflata* Hanzawa, idem.

The illustrations of the type (Umbgrove, 1936, figs. 1–11) are drawings, but two distinct transverse sections are shown, compressed lenticular and umbonate with a pronounced rim. These two forms of test are associated on Saipan. There are other specimens which have thick lenticular tests with or without a rim. As there is complete gradation, only one species is recognized.

Distribution elsewhere.—Borneo and New Guinea.

Remarks.—Specimens that would be included as Hanzawa's *B. mirabilis elliptica* are illustrated as figures 2, 3, plate 100, and one that would be included as his *B. inflata* is shown as figure 6, plate 99.

Genus CYCLOCLYPEUS W. B. Carpenter, 1856

Subgenus CYCLOCLYPEUS W. B. Carpenter, 1856

Cycloclypeus (Cycloclypeus) carpenteri Brady

Plate 101, figures 1, 2

1953. *Cycloclypeus* (*Cycloclypeus*) *carpenteri* Brady. Cole, U. S. Geol. Survey Prof. Paper 253, p. 26–27, pl. 14, figs. 5, 6.

This species is a common form at many of the localities of Pleistocene age. It is still living in the Indo-Pacific region.

Cycloclypeus (Cycloclypeus) eidae Tan

Plate 101, figure 15

1953. *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan. Cole, U. S. Geol. Survey Prof. Paper 253, p. 27, pl. 5, figs. 13–19 [references].

The equatorial section illustrated has an initial chamber with internal diameters of 55μ by 60μ and a second chamber with internal measurements of 40μ by 120μ. There are 19 nepionic chambers arranged in 2 volutions.

Cycloclypeus (Cycloclypeus) indopacificus Tan

Plate 101, figures 7, 8

1932. *Cycloclypeus indopacificus* Tan, Nederlandsche Akad. Wetensch. Meded., no. 19, p. 65–67, pl. 15, fig. 7; pl. 18, fig. 3; pl. 19, fig. 1; pl. 22, fig. 10; pl. 23, figs. 1, 2.

As the material on which this determination is based was not sufficiently abundant for a complete analysis, the assignment of these specimens to this species is tentative.

Cycloclypeus (Cyclocylpeus) posteidae Tan

Plate 101, figures 9–11

1932. *Cycloclypeus posteidae* Tan, Nederlandsche Akad. Wetensch. Meded., no. 19, p. 59–62, pl. 13, fig. 3; pl. 14, figs. 1–6; pl. 15, figs. 1–4; pl. 17, figs. 2, 7; pl. 22, figs. 3, 4, 8.

The test is small with a slightly raised umbo surrounded by a thinner rim. Papillae with a diameter of about 120μ are irregularly scattered over the umbo. Smaller papillae with a diameter of about 60μ are arranged in concentric circles on the rim. The diameter is from 1.8 to 2.5 mm; thickness at the center, about 0.6 mm.

The initial chamber has internal diameters of 70μ by 100μ, and the second chamber has internal measurements of 50μ by 130μ. The distance across both chambers is 130μ. The thickness of the outer wall is about 30μ.

There are about 11 nepionic chambers arranged in 1⅛ volutions.

The vertical section has laminar walls on either side of the equatorial layer.

Remarks.—The Saipan specimens resemble the variety which Tan named *C. posteidae dodekasepta* (compare Tan's fig. 5, pl. 14 with pl. 10, fig. 11). It is doubtful if the varieties which Tan recognized serve any useful purpose inasmuch as all larger Foraminifera show considerable variation between individuals.

Subgenus KATACYCLOCLYPEUS Tan, 1932

Cycloclypeus (Katacycloclypeus) transiens Tan

Plate 101, figures 12–14

1950. *Cycloclypeus* (*Katacycloclypeus*) *transiens* Tan. Cole, U. S. Geol. Survey Prof. Paper 221–B, p. 23–24, pl. 5, figs. 9–11 [synonymy].

The test has a lenticular central area with a diameter of about 1.6 mm around which there is a depressed zone which in turn is followed by an inflated annulus. The diameter of the entire specimens is from 3.3 to 3.8 mm. The entire surface has small indistinct papillae arranged in concentric circles. The thickness at the center is about 0.75 mm, at the depressed zone about 0.25 mm, and at the inflated annulus about 0.5 mm.

In the one median section available the initial chamber has an internal diameter of 90μ, and the second chamber has internal diameters of 60μ by 160μ. The distance across both chambers is 160μ. The embryonic chambers are followed by one operculinelike chamber and 13 partial rings of heterosteginelike chambers before the annular rings of chamberlets are developed.

Distribution elsewhere.—Java; Lau, Fiji; Palau Islands.

Family PENEROPLIDAE

Genus ARCHAIAS Montfort, 1808

Archaias vandervlerki De Neve

Plate 103, figures 5–9

1947. *Archaias vandervlerki* De Neve, Bull. Bureau Mines and Geol. Survey in Indonesia, v. 1, no. 1, p. 14–16, text figs. 1–4.

The earliest record of *Archaias* in the Miocene of the Malay Archipelago is that of Rutten (1917, pl. 5, fig. 142) from the Miocene of Java. He compared these specimens with *A. aduncus* (Fichtel and Moll). Later, Van der Vlerk (1924, pl. 5, fig. 25) figured a specimen from the Njalindoeng beds of Java without specific designation.

De Neve described and illustrated the external appearance of specimens from East Borneo to which he gave the name *A. vandervlerki*. These specimens of *Archaias* were found with *Flosculinella globulosa* L. Rutten, *Miogypsina*, and species of *Lepidocyclina*. This association is similar to the one on Saipan in which *Archaias* occurs.

Although De Neve did not publish sections, it would appear from his description that the Saipan specimens represent the same species and, therefore, are assigned to De Neve's species.

It should be noted, however, that Drooger (1951, text fig. 1) illustrates by a drawing a transverse section of *A. angulatus* (Fichtel and Moll), from the Leeward Islands, which is similar to certain transverse sections (pl. 103, fig. 8) of *Archaias* from Saipan. It may be that all of these specimens represent only one species, the recent *A. angulatus*.

Occurrence elsewhere.—Java; East Borneo.

Genus SORITES Ehrenberg, 1840

Sorites martini (Verbeek)

1953. *Sorites martini* (Verbeek). Cole, U. S. Geol. Survey Prof. Paper 253, p. 27, pl. 12, fig. 11; pl. 14, figs. 1, 2.

This species is known in the present collection only from random thin sections of the matrix material.

Genus MARGINOPORA Quoy and Gaimard, in Blainville, 1830

Marginopora vertebralis Quoy and Gaimard

Plate 103, figures 19, 20

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.

1954. *Marginopora vertebralis* Quoy and Gaimard. Cole, U. S. Geol. Survey Prof. Paper 260–O, p. 582–583, pl. 210, figs. 10–13; pl. 211, figs. 3–29.

Rare specimens of this species were found. The writer has discussed this genus and species in the report on the Bikini test holes. Similar specimens occurred abundantly in the Miocene of these holes.

Remarks.—In accidental sections it is very easy to confuse this species with *Sorites martini* (Verbeek), particularly when only a part of the equatorial plane is exposed.

Family ALVEOLINELLIDAE

Genus BORELIS Montfort, 1808

Borelis pygmaeus Hanzawa, 1930

Plate 102, figure 1; plate 110, figures 5–7

1953. *Borelis pygmaeus* Hanzawa. Cole, U. S. Geol. Survey Prof. Paper 253, p. 27, pl. 12, fig. 16; pl. 13, figs. 4–7 [synonymy].
1951. *Alveolina pygmaea* (Hanzawa). Ritsema, K. Nederlandse Akad. Wetensch. Proc., ser. B, v. 54, no. 2, p. 179, figs. 2D, 3D.
1956. *Borelis parvulus* Hanzawa, Geo. Soc. America Mem. 66 (in press).

Hanzawa (1947a) has given a complete description of this species based on specimens from Saipan.

Remarks.—Hanzawa named certain small specimens *B. parvulus* and compared this new species with *B. melo* (Fichtel and Moll). Similar specimens in the present collection are considered to be small *B. pygmaeus.*

One specimen (pl. 102, fig. 1) which appears to be this species was found at locality S88 with an undoubted Eocene fauna. Bakx (1932, p. 254) gave the range of *B. pygmaeus* from upper Tertiary *a* through *b*, *c*, and *e*. Reichel (1937, p. 130) stated that its presence in the Eocene of the Sunda Islands needs confirmation. Caudri (1934, p. 134) stated, "This species could be identified on Soemba in Tertiary-*a* . . . and further in a number of later rocks from Tertiary-*c* age."

Genus FLOSCULINELLA Schubert, 1910

Flosculinella globulosa L. Rutten

Plate 110, figures 1–4

1917. *Alveolinella (Flosculinella) globulosa* L. Rutten, Geol. Reichs-Mus. Leiden Samml., Neue Folge, v. 2, pt. 7, p. 277, pl. 5, figs. 140–141.
1922. *Alveolinella globulosa* L. Rutten. Van der Vlerk, Geol.–mijnb. genootsch. Nederland en Kolonien, Verh., Geol. ser., v. 5, p. 395, pl. 2, figs 12, 12a.
1937. *Flosculinella globulosa* L. Rutten. Reichel, Soc. Paléont. Suisse, Mém., v. 59, p. 113.

The test is small, globular to subspherical with a diameter of about 1.1 mm.

The embryonic chambers in axial sections are bilocular, the initial chamber with internal diameters of about 100μ and the second chamber with internal diameters of about 25μ by 110μ.

There are about 3 undivided coils of chambers around the embryonic chambers beyond which occur about 6 subdivided annuli, each consisting of a row of major openings on the distal side of which are a row of minor openings. A typical annulus near the periphery of the test has a height of 210μ. The major openings have internal diameters of about 100μ by 120μ, and the secondary openings have internal diameters of about 20μ by 20μ.

Remarks.—The specimens in the present collection are somewhat larger than the types whose diameter was given as 0.5 to 0.9 mm. Otherwise they are similar. Mohler (1949, p. 521) has named small specimens from the Tertiary e_5 of Borneo *F. reicheli.* Specimens from Saipan identified by Hanzawa (1942, figs. 1–3) as *F. globulosa* are referred by Mohler to *F. reicheli.*

The Saipan specimens are larger than those named *F. reicheli* and have a greater number of coils and a larger number of primary chambers in the final volution. In all respects, however, the two species are similar. It is entirely possible that the name *F. reicheli* was applied to specimens from a population of small individuals of *F. globulosa.*

Family CALCARINIDAE

Genus CALCARINA D'Orbigny, 1826

Calcarina spengleri (Gmelin)

Plate 118, figures 1, 2

This species occurs in great abundance on the shallow-water reef flats in the present seas. The fossils are morphologically the same as the living ones, and presumably lived under similar conditions.

Genus BACULOGYPSINA Sacco, 1893

Baculogypsina sphaerulata (Parker and Jones)

Plate 118, figures 3–7

1952. *Baculogypsina sphaerulata* (Parker and Jones). Hanzawa, Short papers, Inst. Geol. and Paleont., Tōhoku Imp. Univ., Sendai, Japan, no. 4, p. 1–22, 2 pls., 3 text figs. [references].

The habitat of this species is similar to that of *Calcarina spengleri,* described above, and on Saipan they are commonly associated.

Family CYMBALOPORIDAE

Genus HALKYARDIA Heron-Allen and Earland, 1919

Halkyardia bikiniensis Cole

Plate 102, figures 10, 11

1954. *Halkyardia bikiniensis* Cole, U. S. Geol. Survey Prof. Paper 260–0, p. 584–585, pl. 210, figs. 1–5.

Three axial sections, one of which exposes the embryonic chambers, were found. The best section represents a specimen with a diameter of 0.95 mm and a total height of 0.4 mm. The thickness of the test at the center is 0.31 mm, and the height of the umbilicus is 0.09 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 which start at the embryonic chambers and expand slowly as they approach the base of the test.

The upper tubulated zone has a thickness of 60μ above the embryonic chambers and thins progressively toward the base of the test. The lower tubulated zone has a thickness of 180μ below the embryonic chambers, and it thins toward the periphery of the test.

Only one of the embryonic chambers is exposed. This chamber has internal diameters of 60μ by 80μ. The wall of this embryonic chamber is about 8μ thick.

The chambers of the middle zone expand from the embryonic chambers and appear in 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 at the base of the test have a length of about 180μ and a height of about 60μ. There are about 12 chambers on each side of the embryonic chambers.

The other sections were not centered, and therefore measurements were not made.

Remarks.—These specimens are very similar to those recovered from the Bikini test wells and represent the same species.

Genus FABIANIA A. Silvestri, 1926

Fabiania saipanensis Cole

Plate 102, figures 7–9; plate 118, figure 8

1953. *Fabiania saipanensis* Cole, U. S. Geol. Survey Prof. Paper 253, p. 28, pl. 15, figs. 1, 2.

The illustration of the type is a transverse section. Three additional illustrations are given: one (pl. 102, fig. 8) is similar to the type; a second (pl. 102, fig. 9) is a transverse section which shows the form of the major chambers; and the third (pl. 102, fig. 7) is a tangential section which parallels the surface of the test, so that the chamberlets into which the chambers near the surface of the test are divided are exposed.

A few specimens from locality S253 appear to have the form of *Gunteria*. A part of one of these specimens is illustrated (pl. 118, fig. 8). It may be that *Gunteria* is only compressed *Fabiania*. Unfortunately, there were not enough well-preserved specimens available to prove this relationship, but the structural details of the two genera are remarkably similar.

Family PLANORBULINIDAE

Genus PLANORBULINELLA Cushman, 1927

Planorbulinella larvata (Parker and Jones)

Plate 102, figures 2, 3

In the matrix of both the Eocene and Miocene rocks, specimens similar to those illustrated are commonly found. They may represent the Recent species to which most fossil specimens of this type have been referred, or they may be new species. From the material available, it is impossible to state.

Genus GYPSINA Carter, 1877

Gypsina disca Goës

1947. *Gypsina disca* Goës. Bursch, Schweizer. Palaeont. Gesell Abh., v. 65, p. 40–42, pl. 3, figs. 2, 4, 13, 17, 22; pl. 5, figs. 6, 7; text figs: 15, 20 [references].

Infrequent specimens which are similar to descriptions and illustrations of this species occur rarely in lower and upper Tertiary *e*.

The localities for this species are S687, B145, B152, B168, B303, B432.

Gypsina marianensis Hanzawa

Plate 103, figures 1–4

1956. *Gypsina marianensis* Hanzawa, Geol. Soc. America Mem. 66 (in press).

As this species is described completely by Hanzawa, it is necessary only to give illustrations of the specimens in this collection. They are in every respect identical with the types.

Family EORUPERTIIDAE, n. family name [1]

Genus EORUPERTIA Yabe and Hanzawa, 1925

1914. *Carpenteria* L. Rutten [not Gray, 1858], Nova Guinea, Géol., v. 6, p. 47, pl. 7, figs. 6–9.
1930. *Victoriella* Chapman and Crespin, Royal Soc. Victoria Proc., v. 42, pt. 2, p. 110–112, pl. 7, figs. 1–4.
1931. *Hofkerina* Chapman and Parr, Royal Soc. Victoria Proc., v. 50, pt. 2, p. 237, 238, pl. 9, figs. 1–5.

Eorupertia plecte (Chapman)

Plate 102, figures 4–6

1921. *Carpenteria proteiformis* var. *plecte* Chapman, Reconn. Geol. Survey Victoria, v. 4, p. 320, pl. 51, fig. 3.
1930. *Victoriella plecte* (Chapman). Chapman and Crespin, Royal Soc. Victoria Proc., v. 42, p. 110–112, pl. 7, figs. 1–4.

A new illustration (pl. 103, fig. 10) of a topotype of *Eorupertia boninensis* Yabe and Hanzawa, made available through the courtesy of Dr. S. Hanzawa, is given to demonstrate the similarities between it and specimens from Saipan.

The Saipan specimens have slightly thicker walls, and the structure of the walls is much coarser. In these respects the Saipan specimens resemble *E. plecte*

[1] Under article 5, of the presently effective International Rules of Zoological Nomenclature, a change in family name is mandatory with this suppression of the generic name *Victoriella*. It is a recommendation of the Copenhagen Decisions on Zoological Nomenclature that this rule be reversed, but this recommendation is not a rule, and the author prefers to follow the practice called for by article 5.

(Chapman) and, therefore, are referred to that species. However, thickness and coarseness of wall structure may be the result of differences in individuals or environment rather than specific differences. At some future time it may be found that *E. boninensis* and *E. plecte* represent only one species, but this decision will depend upon study of more specimens.

Remarks.—According to Chapman and Crespin (1930, p. 112), *Victoriella* differs from *Eorupertia* "in having larger and fewer chambers, a much thicker shell wall and less pronounced hollow center." These differences are specific rather than generic, therefore the two genera are combined.

At the time the genus *Victoriella* was proposed, it was assumed to be restricted to the Miocene, whereas *Eorupertia* was known to occur only in the Eocene. Recently, Raggatt and Crespin (1952, p. 145, 146) have stated that *V. plecte* is restricted to the Jan Juc formation of the Janjukian stage (upper Eocene). Glaessner (1951, p. 274) placed the *V. plecte* zone in the Chattian, an opinion which is not accepted by Crespin (1952b, p. 225, 226), who maintained it is Eocene in age.

Eorupertia semiornata (Howchin)

Plate 103, figures 11–16

1899. *Pulvinulina semiornata* Howchin, Royal Soc. South Australia, Trans., v. 12, p. 14, pl. 1, figs. 12a–c.
1930. *Hofkerina semiornata* (Howchin). Chapman and Parr, Proc. Royal Soc. Victoria, v. 43, pt. 2, new ser., p. 237 238, pl. 9, figs. 1–5.
1953. *Victoriella plecte* Cole [not Chapman 1921], U. S. Geol. Survey Prof. Paper 253, p. 28, pl. 14, fig. 4.

The original illustrations of this species are drawings which show only the external appearance. Chapman and Parr presented photomicrographs of the external appearance and one thin section. This illustration (Chapman and Parr, 1931, pl. 9, fig. 5) should be compared with plate 103, figure 12.

Remarks.—Chapman and Parr stated, "*Hofkerina* differs from *Victoriella* in the rotaline form of the test and the cribrate apertures." Chapman and Crespin (1930, p. 111) in the description of *Victoriella* wrote, "It is distinguished by the great development of the earlier series of chambers, plaited together and forming almost a rotaline coil. . . ." Finally, Yabe and Hanzawa (1922, p. 72) stated in their description of *Eorupertia* that "the chambers are arranged spirally in some two convolutions. . . ." From these statements it would appear that the initial development at least is the same in *Hofkerina*, *Victoriella*, and *Eorupertia*.

Although there is supposed to be apertural differences in the three genera, the general plan of the test and the structure of the walls is so similar that it is doubtful if they can be separated.

E. semiornata has thicker walls with a coarser structure than does *E. plecte*. The initial chambers of *E. semiornata* are larger, and the final chambers are smaller and more numerous.

Specimens from New Guinea described by L. Rutten (1914. p. 47) as *Carpenteria conoidea* probably are *E. semiornata*, but the illustrations are too poor for exact comparison. Hanzawa (1930, p. 94) has presented excellent illustrations of *E. semiornata* from the Miocene of Pabeasan, Java, under the name *Sporadotrema cylindricum* Carter.

Family ROTALIIDAE

Genus STREBLUS Fischer, 1817

Streblus saipanensis Cole

Plate 103, figures 17, 18

1953. *Streblus saipanensis* Cole, U. S. Geol. Survey Prof. Paper 253, p. 27–28, pl. 5, figs. 8, 9.

The internal features of this species were illustrated in the preliminary report on Saipan by a median section. Another median and transverse section are illustrated.

Remarks.—The specimens illustrated by Cole (1939, pl. 24, figs. 10–12) and Hanzawa (1931, pl. 26, figs. 6–8) as *Rotalia schroeteriana* Parker and Jones are not that species. Although there is a superficial resemblance to *S. saipanensis*, the specimens from Guam are larger, much coarser, and more strongly papillate.

Family MIOGYPSINIDAE

Genus MIOGYPSINOIDES Yabe and Hanzawa, 1928

Miogypsinoides bantamensis Tan

Plate 110, figures 8–18; plate 111, figures 1–4

1936. *Miogypsinoides complanata* forma *bantamensis* Tan, De Ingenieur in Nederlandsch-Indië—IV Mijnbouw en Geologie, de Jaarg. 3, no. 3, p. 48–50, pl. 1, fig. 13.
1940. *Miogypsinoides bantamensis* Tan. Hanzawa, Jubilee Pub. in Commemoration of Prof. H. Yabe's 60th Birthday, p. 782–783, pl. 39, figs. 15–19; pl. 41, figs. 24–26.
1940. *Miogypsinoides lateralis* Hanzawa, idem, p. 783, pl. 39, figs. 10–14.

These small *Miogypsinoides* were observed only in thin section. Well-oriented equatorial sections were scarce, but a sufficient number were found to give the statistics of this species. The following table presents measurements of 5 equatorial sections.

Measurements of equatorial sections of Miogypsinoides bantamensis *Tan*

	Specimens from locality—				
	B391, shown on—				B316, shown on—
	Pl. 110, fig. 12	Pl. 111, fig. 2	Pl. 111, fig. 3	Pl. 110, fig. 15	Pl. 110, fig. 13
Length mm	1.26	1.5	1.56	1.9	1.55
Width mm	0.86	1.68	1.62	1.95	1.5
Embryonic chambers:					
Diameters of initial chamber μ	120 x 110	90 x 90	80 x 80	140 x 130	120 x 100
Diameters of second chamber μ	105 x 80	90 x 60	95 x 60	150 x 110	100 x 60
Distance across both chambers μ	195	160	150	250	190
Periembryonic chambers:					
Number of whorls	1⅛	1¼	1¼	1	1⅛
Number of chambers	13	13	14	11	12
Number of chambers in first volution	10	10	10	11	10
Equatorial chambers:					
Radial diameter μ	110	130	110	100	130
Tangential diameter μ	130	140	140	110	120

Well-oriented vertical sections which cut the embryonic chambers were extremely rare; therefore, measurement of only two of these are given in the following table.

Measurements of vertical sections of Miogypsinoides bantamensis *Tan*

	Specimens from locality—	
	B316, shown on pl. 110, fig. 8	B395
Length mm	1.75	2.15
Thickness mm	0.75	0.72
Embryonic chambers:		
Length μ	230	160
Height μ	150	130
Thickness of outer wall μ	30	10
Equatorial layer:		
Height near embryonic chambers μ	150	130
Height at periphery μ	150	130
Surface diameter of pillars μ	100–200	80–150

The walls over the equatorial layer are composed of pillarlike structures between which are small vertical pores that extend from the equatorial layer to the surface of the test.

Remarks.—Hanzawa (1940, p. 773) considered that the position of the periembryonic chambers in the coils of these chambers, with respect to the apical part of the test, is a constant character in the miogypsinoids. It is in this character that he distinguished *M. lateralis* from *M. bantamensis* Tan. He states, "In its external form and transverse section alone, the present form is almost indistinguishable from *Miogypsinoides bantamensis* Tan Sin Hok . . . . But, the former is easily distinguishable from the latter by the characteristics of its juvenarium."

Although the number of coils and the number of periembryonic chambers are significant in specific identification, it does not appear that the position of the periembryonic chambers, with regard to the apical part of the test, has any special significance. Therefore, *M. lateralis* Hanzawa is combined with *M. bantamensis* Tan.

The illustration of the type of *M. bantamensis* is an equatorial section. No illustration of the vertical section is given. The equatorial sections of specimens from Saipan are identical with the type, and the vertical sections of these specimens are very similar to those identified as *M. bantamensis* by Hanzawa in the North Borodino Island test hole.

Miogypsinoides dehaartii (Van der Vlerk)

Plate 111, figures 5–16

1924. *Miogypsina dehaartii* Van der Vlerk, Eclogae geol. Helvetiae, v. 18, no. 3, p. 429–432, text figs. 1–3.

1927. *Miogypsina abunensis* Tobler, idem, v. 20, no. 2, p. 323–330, text figs. 3, 5.

1928. *Miogypsina (Miogypsinoides) dehaartii* Van der Vlerk var. *formosensis* Yabe and Hanzawa, Imp. Acad. Japan Proc., v. 4, no. 9, p. 535–536, text fig. 1.

1928. *Miogypsina verrucosa* Zuffardi-Comerci, Soc. geol. italiana Boll., v. 47, no. 2, p. 143, pl. 9, figs. 8–10, 14, 15.

1930. *Miogypsina (Miogypsinoides) dehaartii* Van der Vlerk var. *formosensis* Yabe and Hanzawa, Tōhoku Imp. Univ., Sci. Repts., 2d ser. (Geol.), v. 14, no. 1, p. 32–33, pl. 3, figs. 4, 5; pl. 4, figs. 3, 4; pl. 7, fig. 12; pl. 9, fig. 9; pl. 11, figs. 1–6, 12.

1936. *Conomiogypsinoides* cf. *C. abunensis* Tobler. Tan, De Ingenieur in Nederlandsch-Indië—IV Mijnbouw en Geologie, de Jaarg. 3, no. 3, p. 51–52, pl. 1, figs. 8–10.

1939. *Miogypsinoides dehaartii* Van der Vlerk, var. *formosensis* Yabe and Hanzawa. Cole, Jour. Paleontology, v. 13, no. 2, p. 187, pl. 24, figs. 1–7.

1940. *Miogypsinoides formosensis* Yabe and Hanzawa. Hanzawa, Jubilee Pub. in Commemoration of Prof. H. Yabe's 60th Birthday, p. 773.

1940. *Miogypsinoides dehaartii* (Van der Vlerk) var. *pustulosa* Hanzawa, idem, p. 780–782, pl. 40, figs. 9–29; pl. 42, fig. 13.

1953. *Miogypsinoides abunensis* (Tobler). Cole, U. S. Geol. Survey Prof. Paper 253, p. 38, pl. 13, figs. 8, 9; pl. 14, figs. 9, 10 [additional references].

1953. *Miogypsinoides formosensis* Yabe and Hanzawa. Cole, idem, p. 38, 39, pl. 8, figs. 18, 19; pl. 13, figs. 1–3, 10, 11, 15, 16; pl. 14, fig. 8.

1953. *Miogypsina dehaartii* Van der Vlerk. Drooger, K. Nederlandse Akad. Wetensch. Proc., ser. B, v. 56, no. 1, p. 110–114, pl. 1, figs. 15–19.

1953. *Miogypsina verrucosa* Zuffardi-Comerci. Drooger, idem, p. 116, pl. 1, figs. 24–26.

1953. *Miogypsina abunensis* Tobler. Drooger, idem, p. 116–117.

Two circumstances have caused the tangled nomenclature of this species: (1) poor, incomplete, inadequate descriptions and illustrations and (2) doubt concerning the value and stability of certain of the characters used to distinguish the various species.

Certain authors have believed that the presence or absence of pillars was a specific feature, whereas others have placed considerable reliance on the position of the periembryonic chambers with respect to the apical part of the test. Still others have used the shape of the test as a means of defining not only species but also subgenera.

Van der Vlerk adequately described and illustrated "*Miogypsina*" *dehaartii*, but Tobler illustrated "*Miogypsina*" *abunensis* by a drawing of an unoriented vertical section and a poor photograph of numerous sections surrounded by matrix material. Yabe and Hanzawa distinguished *Miogypsinoides formosensis* from *M. dehaartii* "by the features of the juvenarium, namely the apical part of the test is occupied by the 8th chamber, and not by the second." (Hanzawa, 1940, p. 773.)

The writer (Cole and Bridge, 1953, p. 38, 39) in a previous discussion of Saipan specimens of *Miogypsinoides*, identified *M. abunensis* and *M. formosensis*. He believed that specimens with large distinct pillars with fibrous intervening zones could be separated from specimens with lamellar structure in which small pillars might or might not occur.

However, the examination of a large number of thin sections since that time has demonstrated that such separation is impossible. It has been discovered that certain specimens are devoid of pillars but others have strong pillars. In every other respect, however, these specimens are identical. Moreover, the thickness of the thin section plays an important role. In very thick sections the lamellar structure is pronounced, whereas in thinner sections the pillars and the fibrous intervening zones show clearly.

The position of the periembryonic chambers is variable. In one of the specimens illustrated (pl. 111, fig. 7), there are no periembryonic chambers between the embryonic chambers and the apex of the test; in another (pl. 111, fig. 6) there is one; and in a third (pl. 111, fig. 8) there are several.

Three topotypes of *M. formosensis* Yabe and Hanzawa are illustrated. One of the vertical sections (pl. 111, fig. 16) shows marked lamellar structure, a second (pl. 111, fig. 14) has small pillars, and the third (pl. 111, fig. 15) has neither pillars nor lamellar structure. All of these types are duplicated in specimens which occur together in samples from Saipan.

Drooger (1953, p. 115) believed that *Miogypsina cupulaeformis* Zuffardi-Comerci (1929, p. 142) is a conical variety of *M. dehaartii* (Van der Vlerk). Although he may be correct, there is not sufficient evidence at this time for this conclusion. Cole (1954, p. 601) referred certain specimens from the Bikini test holes to *Miogypsinoides cupulaeformis* because of their very coarse papillae and size. Equatorial sections of these Bikini specimens compare favorably with the equatorial section illustrated by Zuffardi-Comerci.

As Hanzawa (1940, p. 772) has demonstrated in his criticism of Tan's subgenus *Conomiogypsinoides*, a low conical shape with the embryonic chambers situated at the apex of the cone is not a distinguishing feature either for subgeneric or specific purposes. Many of the random thin sections have individuals with this shape in association with the normal type, and all gradations occur. One of the low conical individuals is illustrated (pl. 111, fig. 9) for comparison with the normal types.

Genus MIOGYPSINA Sacco, 1893

Miogypsina (Miogypsina) thecideaeformis (L. Rutten)

Plate 112; plate 113; plate 114

1911. *Lepidosemicyclina thecideaeformis* L. Rutten, K. Akad. Wetensch. Amsterdam Proc., p. 1135, 1136.

1912. *Miogypsina thecideaeformis* (L. Rutten). Rutten, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 9, p. 204–207, pl. 12, figs. 1–5.

1927. *Miogypsina tuberosa* Tobler, Eclogae geol. Helvetiae, v. 20, no. 2, p. 323–330, text figs. 1, 2, 4.

1930. *Miogypsina* (s. s.) *inflata* Yabe and Hanzawa, Tōhoku Imp. Univ., Sci. Repts., 2d ser. (Geol.), v. 14, p. 33, pl. 3, fig. 6; pl. 10, fig. 7?; pl. 12, figs. 6, 7; pl. 14, fig. 6; pl. 16, fig. 9.

1930. *Miogypsina* (s. s.) *irregularis* Yabe and Hanzawa [not Michelotti, 1841], idem, p. 35, pl. 11, fig. 11; pl. 12, figs. 2–5.

1930. *Miogypsina* (s. s.) *mamillata* Yabe and Hanzawa, idem, p. 34, pl. 1, fig. 11; pl. 3, figs. 7, 8; pl. 4, fig. 6; pl. 6, fig. 13; pl. 11, figs. 7, 8; pl. 12, fig. 1; pl. 13, fig. 8.

1931. *Miogypsina kotoi* Hanzawa, idem, v. 12, no. 2 A, p. 154, pl. 25, figs. 14–18.

1931. *Miogypsina ozawai* Hanzawa, idem, p. 155, pl. 24, fig. 12; pl. 25, figs. 10–13; pl. 26, fig. 3.

1935. *Miogypsina kotoi* Hanzawa, idem, v. 18, no. 1, p. 23–25, pl. 3.

1937. *Miogypsina kotoi* Hanzawa. Tan, De Ingenieur in Nederlandsch-Indië—IV Mijnbouw en geologie, Jaarg. 4, no. 2, p. 31, 32, 6 figs.

1953. *Miogypsina thecidaeformis* (L. Rutten). Drooger, K. Nederlandse Akad. Wetensch. Proc., ser. B, v. 56, no. 1, p. 109, 110, pl. 1, figs. 10–14, 32.

1953. *Miogypsina* (*Miogypsina*) *inflata* Yabe and Hanzawa. Cole, U. S. Geol. Survey Prof. Paper 253, p. 37, 38, pl. 13, figs. 12–14.

1953. *Miogypsina* (*Miogypsina*) *irregularis* (Michelotti) [teste Yabe and Hanzawa]. Cole, idem, p. 38, pl. 14, fig. 11.

1953. *Miogypsina* (*Miogypsina*) *mamillata* Yabe and Hanzawa. Cole, idem, p. 38, pl. 13, fig. 16.

The external views and equatorial and vertical sections show most of the characteristics of this species. To supplement the illustrations measurements of equatorial and vertical sections are given in the following two tables.

Measurements of equatorial sections of Miogypsina thecideaeformis

	Specimens from locality—					
	Balik Papan, East Borneo, shown on pl. 112, fig. 10	Inokosi, Japan, shown on—		S701, shown on—		B413, shown on pl. 112, fig. 4
		Not illustrated	Pl. 112, fig. 11	Pl. 112, fig. 2	Pl. 112, fig. 3	
Length mm	1. 7	2. 3	2. 65	2. 4	2. 85	2. 2
Width mm	1. 7	2. 1	2. 43	2. 7	2. 9	1. 9
Embryonic chambers:						
Diameters initial chamber μ	140 x 140	180 x 185	180 x 160	130 x 145	120 x 120	100 x 100
Diameters second chamber μ	90 x 170	100 x 160	90 x 200	110 x 180	110 x 180	85 x 130
Distance across both μ	240	290	290	260	250	190
Thickness of outer wall μ	20–30	10–20	10–25	10–40	20–40	20
Equatorial chambers:						
Radial diameter μ	80–120	80–190	100–160	70–110	100–180	80–140
Tangential diameter μ	90–120	60–120	80–140	60–100	70–130	60–140

Measurements of vertical sections of Miogypsina thecideaeformis

	Specimens from locality—									
	Balik Papan, East Borneo, shown on—			Inokosi, Japan, shown on—			S701, shown on—			B413, shown on pl. 114, fig. 1
	Pl. 114, fig. 13	Pl. 114, fig. 14	Pl. 114, fig. 12	Pl. 114, fig. 17	Pl. 114, fig. 11	Pl. 114, fig. 10	Pl. 114, fig. 3	Pl. 114, fig. 20	Pl. 114, fig. 5	
Diameter mm	1. 87	1. 88	1. 92	2. 35	2. 8	2. 15	2. 3+	2. 25	2. 35	2. 5
Thickness mm	0. 55	0. 65	0. 66	0. 75	1. 0	0. 95	0. 83	1. 06	1. 05	0. 54
Embryonic chambers:										
Diameter μ	230	220	240	225	320	270	250	260	210	190
Height μ	115	120	150	130	210	150	150	150	150	130
Thickness of outer wall μ	50	40–60	30–70	20–50	20–50	35–50	30	30	15–50	20
Equatorial layer:										
Height near embryonic chambers μ	140	120	140	150	180	160	140	140	140	100
Height near periphery μ	130	120	130	150	150	150	140	100	130	150
Lateral chambers:										
Number	4	5	5	4	6	5	5	8	9	5
Length μ	50–110	50–120	40–150	40–90	50–210	60–130	40–200	50–140	50–130	50–70
Height μ	20–50	20–50	20–40	20–40	20–50	10–40	30–60	15–40	20–40	20–30
Thickness of floors and roofs μ	10–25	10–40	10–30	10–40	10–40	10–40	20–40	10–20	10–50	10–35
Surface diameter of pillars μ	30–60	50–150	30–50	50–90	70–110	60–100	50	50–90	80–150	20–50

Remarks.—The late Helen Jeanne Plummer gave the writer specimens which are labeled *Miogypsina thecideaeformis* (L. Rutten) from Balik-Papan Bay, east coast of Borneo. This is the type locality of the species, but Rutten also described *M. polymorpha* from this general locality from beds which were supposed to be stratigraphically higher. Drooger (1953, p. 53) recently has restudied Rutten's specimens. From his description and figures the conclusion was reached that the specimens are *M. thecideaeformis*. Thin sections of these specimens are illustrated on plate 112, figure 10, and plate 114, figures 12–14.

Dr. Hanzawa kindly supplied me with abundant specimens of *M. kotoi*, from Inokosi, Koyamaiti, Koyama-mura, Kawakanir-gun, Okayama Prefecture, Japan. Although this is not the type locality of the species, Hanzawa (1935, p. 23) has discussed specimens from this locality and presented an excellent series of illustrations. Later, Tan (1937a, p. 31) restudied specimens from this locality and gave more details concerning the embryonic apparatus.

Tan (1936, p. 58; 1937a, p. 32) stated both of these species have "*bifida*-type" nepionic chambers. Rutten (1912, pl. 12, figs. 2–4) demonstrated that the distal equatorial chambers of *M. thecideaeformis* are hexagonal, a fact which Drooger (1953, p. 110) substantiated. Although Hanzawa did not mention that *M. kotoi* possessed any hexagonal equatorial chambers, Tan (1937a, p. 32) wrote, "Hexagonal shapes are very exceptional." Thus, it would appear that *M. thecideaeformis* and *M. kotoi* may develop hexagonal equatorial chambers, but chambers of this shape are more commonly found in *M. thecideaeformis.*

In the thin sections of these species available for this study, there does not appear to be sufficient differences in either equatorial or vertical section to separate them.

Hanzawa (1947b, p. 569) stated that strata in Japan containing "*Nephrolepidina* and/or *Miogypsina* . . . can certainly be regarded as belonging to stage *f* of the Netherlands East Indies Tertiary sequence." Van Bemmelen (1949, p. 134) wrote concerning the age of Pulubalang beds from which *M. thecideaeformis* came: "The age of the Pulubalang Stage is generally accepted as T. f_1. Beets . . . remarked on the age of the type locality of Pulu Balang, an island in the northwestern part of Balikpapan Bay, that the range of the concerning molluscan species does not justify to say any more about its age than that for the moment it may be correlated with the T. f_1 or f_2 until more complementary material has been collected." It would appear, therefore, that these two species occur in strata which have approximately the same age.

Van der Vlerk (1948, p. 61, 62) gave the range of *Miogypsina* (*Miogypsina*) as *e* through f_3, a vertical distribution which is generally accepted in the East Indies. *Miogypsinoides dehaartii* (Van der Vlerk) is assigned to Tertiary *e*, but *Cycloclypeus* (*Katacycloclypeus*) is restricted to Tertiary *f. Lepidocyclina* (*Eulepidina*) ranges through *d* and *e*. Thus, *Miogypsina thecideaeformis* on Saipan is associated with subgenera and species which elsewhere in the East Indies occur only in upper Tertiary *e* or *f*.

If the rare specimens of *Katacycloclypeus* are discounted, *M. thecideaeformis* would be associated on Saipan with subgenera and species which would indicate an e_5 age. Tan (1937a, p. 32) has reported previously that specimens he identified as *M. kotoi* occur in Java in association with *Eulepidina*, which would place these beds in Tertiary *e*. Therefore, *M. thecideaeformis* would appear to be a Tertiary *e* species, but it may extend into Tertiary f_1.

Certain specimens (pl. 114, fig. 15) have very strong pillars. These specimens resemble *M.* (*M.*) *tuberosa* Tobler (1927, p. 323). However, they occur with and appear to intergrade with specimens which are identified as *M.* (*M.*) *thecideaeformis;* therefore, they are considered one of the possible variants.

Family ORBITOIDIDAE

Genus LEPIDOCYCLINA Gümbel, 1870

Subgenus NEPHROLEPIDINA H. Douvillé, 1911

Lepidocylina (Nephrolepidina) angularis Newton and Holland

Plate 107, figures 13, 14

1902. *Orbitoides* (*Lepidocyclina*) *angularis* Newton and Holland, Jour. College of Sci., Tokyo Imp. Univ., v. 17, pt. 3, p. 10, 11, pl. 1, figs. 1, 6; pl. 3, fig. 7.

1930. *Lepidocyclina* (*Nephrolepidina*) *angularis* Newton and Holland. Yabe and Hanzawa, Tōhoku Imp. Univ., Sci. Repts., 2d ser. (Geol.), v. 14, no. 1, p. 27, 28, pl. 10, fig. 7; pl. 11, figs. 2, 4.

Rare vertical sections appear to represent this species. A specimen (pl. 107, fig. 13) from Sekihekiryô in Daianryo, Taihoku Prefecture, Formosa, given me by the late Dr. T. Wayland Vaughn is illustrated for comparison with the Saipan specimens.

It is possible that specimens similar to plate 107, figure 12, identified as small specimens of *L.* (*N.*) *verbeeki*, may be *L.* (*N.*) *angularis.*

Lepidocyclina (Nephrolepidina) brouweri L. Rutten

Plate 105, figures 1–10

1924. *Lepidocyclina brouweri* L. Rutten, Jaar. Mijnwezen in Nederlandsch Oost-Indië, p. 182, figs. 22–29.

The test has an inflated central part bounded by a narrow flat rim. There is an apical crown of large, prominent papillae.

The embryonic chambers (pl. 105, fig. 9) are nephrolepidine. The initial chamber is subspherical with internal diameters of 180μ by 210μ. The second chamber, with internal diameters of 100μ by 360μ, embraces about half of the periphery of the initial chamber. The internal distance across both chambers is 290μ. The thickness of the outer wall is about 50μ.

In another specimen (pl. 105, fig. 8) the initial chamber has internal diameters of 120μ by 160μ. The second chamber, with internal diameters of 140μ by 260μ does not embrace the initial chamber. The internal distance across both chambers is 270μ. The thickness of the outer wall is about 40μ.

The equatorial chambers are rhombic to short spatulate. Those near the periphery have radial diameters from 40μ to 70μ. The tangential diameter is from 60μ to 70μ. Measurements of the vertical sections are given in the following table.

Measurements of vertical sections of Lepidocyclina (Nephrolepidina) brouweri

	Specimens from locality—					
	B361, not illustrated	C102b, shown on—		B420, shown on pl. 105, fig. 7	B357, shown on pl. 105, fig. 4	B419, shown on pl. 105, fig. 2
		Pl. 105, fig. 1	Pl. 105. fig. 6			
Diameter mm	3. 2	3. 9	3. 14	----------	3. 1	3. 5
Thickness mm	1. 8	1. 46	1. 65	1. 34	1. 75	1. 37
Embryonic chambers:						
Length μ	200	270	340	320	280	250
Height μ	110	170	210	190	190	150
Thickness of outer wall μ	50	25	40	40	50	30
Equatorial layer:						
Height at center μ	80	75	80	120	80	80
Height at periphery μ	130	150	150	160	180	160
Lateral chambers:						
Number	15	12	12	9	12	11
Length μ	110–260	130–150	140–210	110–200	100–140	130–170
Height μ	40	20–40	40	20–35	10–40	20–40
Thickness of floors and roofs μ	20	10–20	10–20	10–25	15–25	10–20
Surface diameter of pillars μ	130–340	230–480	180–300	170–450	200–400	700

The lateral chambers are arranged in regular tiers except near the periphery of the test where overlapping occurs. The chamber cavities are open, long, and rather high. The floors and roofs are moderately thick and slightly arched.

The pillars are heavy, prominent, and irregularly scattered.

Remarks.—Specimens of this type have been identified commonly as *L.* (*N.*) *angulosa* Provale. *L.* (*N.*) *angulosa* has elongate hexagonal equatorial chambers; the floors and roofs of the lateral chambers are straight; and the chamber cavity is very long. The specimens from Saipan typically have rhombic to short spatulate equatorial chambers; the floors and roofs of the lateral chambers are arched; and the chamber cavities are not as long as those of *L.* (*N.*) *angulosa.*

Although the type figures of *L.* (*N.*) *brouweri* are drawings, the internal structure of the species is shown clearly. The specimens from Saipan have the same internal structure as that illustrated for *L.* (*N.*) *brouweri.*

At its type locality near Patoenoeang Asoe (Maros, Celebes), *L.* (*N.*) *brouweri* occurs in association with *Spiroclypeus orbitoideus* H. Douvillé and *Heterostegina* sp., an association similar to that on Saipan.

Lepidocyclina (Nephrolepidina) parva Oppenoorth

Plate 104, figures 10–17; plate 107, figure 17

1953. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth. Cole, U. S. Geol. Survey Prof. Paper 253, p. 30–32, pl. 7, fig. 6; pl. 9, figs. 5–12, 15–18; pl. 10, figs. 11–18; pl. 11, figs. 1, 2; pl. 12, fig. 6 [references].

1953. *Lepidocyclina* (*Nephrolepidina*) *brouweri* L. Rutten. Cole, idem, p. 28–29, pl. 8, fig. 1; pl. 9, fig. 1; pl. 11, fig. 3, pl. 12, figs. 5, 14.

Additional illustrations are given to supplement those previously published. These illustrations demonstrate that the size of the pillars differs between specimens.

Remarks.—*L. parva* is very similar to the American species *L. yurnagunensis* Cushman. At some future time and with more study, it may be found that these two species can be combined. For the present, however, this is not done (see remarks under *L. ephippioides*) for the same reasons that *L. favosa* and *L. ephippioides* are not combined.

Microspheric specimens with heavy pillars and rhombic equatorial chambers similar to plate 107, figure 17, are referred commonly to *L. morgani* Lemoine and R. Douvillé. As this type of microspheric specimen is always associated with megalospheric specimens of *L. parva,* the two generations are associated under this specific name.

Lepidocyclina (Nephrolepidina) sumatrensis (Brady)

Plate 104, figures 1–9; plate 105, figure 18; plate 106, figure 5; plate 109, figures 1–3

1953. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (Brady). Cole, U. S. Geol. Survey Prof. Paper 253, p. 32–33, pl. 10, figs. 7–10; pl. 11, figs. 4, 5 [references].

This is a variable species as shown by the illustrations. Some specimens have lateral chambers with thick roofs and floors; others have thin roofs and floors. Three varietal names have been proposed: *L. sumatrensis minor* L. Rutten (1911), *L. sumatrensis inornata* L. Rutten (1913), and *L. sumatrensis umbilicata* L. Rutten (1913). As there is complete intergradation, these subspecies designations are without value.

Basically, this species consists of specimens with short spatulate equatorial chambers and lateral chambers with arched roofs and floors arranged in regular tiers. The presence or absence of pillars and the degree of thickness of the roofs and floors of the lateral chambers are individual rather than specific differences.

Lepidocyclina (Nephrolepidina) verbeeki Newton and Holland

Plate 106, figures 1–3, 6, 7, 9, 10; plate 107, figures 1–12, 16; plate 109, figures 7, 8

1899. *Orbitoides* (*Lepidocyclina*) *verbeeki* Newton and Holland, Annals and Mag. Nat. History, ser. 7, v. 3, p. 257–259, pl. 9, figs. 7–11; pl. 10, fig. 1.

1953. *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton and Holland. Cole, U. S. Geol. Survey Prof. Paper 253, p. 33–34, pl. 11, figs. 6–14; pl. 12, figs. 7, 12, 13.

The test has an umbonate central part which is surrounded by a relatively wide, fragile rim. Moderately heavy papillae are irregularly scattered over the umbonate part. The rim shows the equatorial chambers because it is not covered by lateral chambers.

The embryonic chambers are nephrolepidine, rather large, and bounded by a moderately thick outer wall. Several large periembryonic chambers occur irregularly spaced on the periphery of the embryonic chambers. These are shown clearly in plate 106, figure 9.

Measurements of three equatorial sections appear in the following table.

Measurements of equatorial sections of Lepidocyclina (Nephrolepidina) verbeeki

	Specimen from locality—		
	B138, shown on pl. 106, figs. 6, 9	B136, shown on pl. 106, fig. 1	B373, shown on pl. 106, fig. 2
Diameter mm	2. 5	1. 75	1. 9
Embryonic chambers:			
Diameters of initial chamber μ	160 x 240	120 x 200	210 x 300
Diameters of second chamber μ	140 x 350	150 x 320	200 x 440
Distance across both chambers μ	310	280	420
Thickness of outer wall μ	30	30	35
Equatorial chambers:			
Radial diameter μ	60–80	50–70	50–60
Tangential diameter μ	40	30–50	40

The equatorial chambers are either rhombic or short spatulate. The radial diameter is always greater than the tangential diameter. The chambers are arranged in rather regular, concentric circles.

The following table contains measurements of five vertical sections.

Measurements of vertical sections of Lepidocyclina (Nephrolepidina) verbeeki

	Specimens from locality—				
	B135, shown on pl. 107, fig. 4	B161, shown on pl. 107, fig. 5	B131, shown on pl. 107, fig. 1	B138, shown on—	
				Pl. 107, fig. 7	Pl. 107, fig. 9
Diameter mm	4. 55	5. 65	2. 9+	2. 92+	2. 95+
Thickness mm	1. 4	1. 45	1. 4	1. 0	0. 82
Diameter of umbo mm	2. 8	2. 4	2. 1	2. 2	2. 4
Width of rim mm	0. 8	2. 1	----------	----------	0. 3
Thickness of rim mm	0. 2	0. 21	----------	----------	0. 11
Embryonic chambers:					
Length μ	400	200	310	160	190
Height μ	260	110	190	120	110
Thickness of outer wall μ	30	25	30	20	25
Equatorial layer:					
Height at center μ	100	80	80	60	60
Height at periphery μ	220	210	120	110	110
Lateral chambers:					
Number	11	10	12	11	11
Length μ	140–300	100–320	70–120	100–140	90–140
Height μ	30–50	30–50	25–30	20–30	20
Thickness of floors and roofs μ	10	10–25	10–15	10	10
Surface diameter of pillars μ	60–140	80–200	120–200	40–90	40

The lateral chambers are arranged in regular tiers. In some specimens the lateral chambers near the periphery overlap, but this is the exceptional rather than normal condition. The cavities of the lateral chambers are open, rectangular in shape. The floors and roofs are straight and thin.

Moderately heavy pillars are irregularly scattered throughout the umbonal part of the test. The number of the pillars differ from specimen to specimen.

Remarks.—In the Vaughan collection of larger Foraminifera in the U. S. National Museum, there are matrix-free specimens of this species from Sumatra which apparently are topotypes from the "coral-limestone, Padang Highlands, West-Coast District, Sumatra" (Brady, 1875, p. 536). A vertical section (pl. 107, fig. 11) and an equatorial section (pl. 106, fig. 7) are illustrated for comparison with the specimens from Saipan.

Dr. S. Hanzawa generously had sent me specimens from Pinaiko, Taihoku Prefecture, Formosa which he (1943, p. 129) had identified as *L.* (*N.*) *verbeeki.* Sections (pl. 106, fig. 10; pl. 107, fig. 8) were prepared from these specimens for comparison with the specimens in the present collection.

As Hanzawa (1943, p. 129) stated, *L.* (*N.*) *verbeeki* is similar to his *L.* (*N.*) *nipponica.* Dr. H. G. Schenck had sent me abundant specimens of this species from Shimo-shiroiwa, Shizuoka Prefecture, Japan. Sections (pl. 106, figs. 4, 8; pl. 107, fig. 15) are illustrated for comparison with the Saipan specimens assigned to *L.* (*N.*) *verbeeki.*

Although the vertical sections of *L.* (*N.*) *nipponica* and *L.* (*N.*) *verbeeki* are similar, the equatorial chambers are different. These chambers are elongate hexagonal to elongate spatulate in *L.* (*N.*) *nipponica,* but rhombic to short spatulate in *L.* (*N.*) *verbeeki.*

Lepidocyclina (Nephrolepidina) verrucosa Scheffen

Plate 105, figures 11–17; plate 109, figures 4–6

1932. *Lepidocyclina verrucosa* Scheffen, Nederlandsche Akad. Wetensch. Meded., no. 21, p. 33, 34, pl. 7, figs. 2–4.
1939. *Lepidocyclina verrucosa* Scheffen. Caudri, Geol.-Mijnb. genootsch. v. Nederland en Kolonien, Verh., Geol. ser., v. 12, p. 179–185, figs. 26–30, 42, 46.
1954. *Lepidocyclina* (*Nephrolepidina*) *verrucosa* Scheffen. Cole, U. S. Geol. Survey Prof. Paper 260–0, p. 593–594, pl. 213, figs. 1–9.

The embryonic chambers are nephrolepidine. The initial chamber is subspherical with internal diameters of 180μ by 240μ. The second chamber, with internal diameters of 110μ by 380μ, very slightly embraces the initial chamber. The internal distance across both chambers is 320μ. The thickness of the outer wall is 20μ.

Two distinct periembryonic chambers are present, lying at either end of the dividing partition between the embryonic chambers. These chambers have internal diameters of about 35μ by 100μ.

The equatorial chambers were not satisfactorily exposed in any of the thin sections available. Some that could be seen indistinctly appear to be small and rhombic in shape. Measurements of vertical sections from four localities are given below.

Measurements of vertical sections of Lepidocyclina (Nephrolepidina) verrucosa

	Specimens from locality—			
	B177, shown on pl. 105, fig. 16	C132, shown on pl. 105, fig. 15	C140, shown on pl. 105, fig. 13	B320, shown on pl. 105, fig. 14
Diameter mm	1. 75	2. 36	3. 2	2. 85
Thickness mm	1. 22	1. 18	1. 9	1. 53
Embryonic chambers:				
Length μ	310	330	400	240
Height μ	210	210	270	165
Thickness of outer wall μ	40	40	20	40
Equatorial layer:				
Thickness at center μ	100	120	90	90
Thickness at periphery μ	100	130	115	130
Lateral chambers:				
Number	11	10	15	11
Length μ	100–130	100–140	110–220	120–160
Height μ	20–30	40	30–40	30–40
Thickness of floors and roofs μ	10–20	10	20	20–30
Surface diameter of pillars μ	100–250	150–300	200–450	150–180

The lateral chambers are arranged in rather regular tiers. The floors and roofs of the lateral chambers either are straight or slightly arched. The chamber cavity is open, nearly rectangular.

The pillars are strong, rather numerous, and irregularly scattered throughout the central part of the test.

Subgenus EULEPIDINA H. Douvillé, 1911

Lepidocyclina (Eulepidina) badjirraensis Crespin

Plate 108, figures 1–3; plate 109, figures 9, 10

1952. *Lepidocyclina* (*Eulepidina*) *badjirraensis* Crespin, Contr. Cushman Found. Foram. Research, v. 3, pt. 1, p. 29, 30, pl. 6, figs. 1, 2, 5; pl. 7, figs. 1, 2; pl. 8, figs. 1–5.
1952. *Lepidocyclina* (*Eulepidina*) *manduensis* Crespin, idem, p. 30, 31, pl. 6, figs. 3, 4; pl. 7, figs. 3, 5, 6; pl. 8, figs. 6, 7.
1953. *Lepidocyclina* (*Eulepidina*) *bridgei* Cole, U. S. Geol. Survey Prof. Paper 253, p. 34, pl. 9, figs. 2–4, 13, 14, 19–21.
1953. *Lepidocyclina* (*Eulepidina*) *saipanensis* Cole, idem, p. 37, pl. 8, figs. 8–15.
1953. *Lepidocyclina* (*Eulepidina*) *badjirraensis* Crespin. Crespin, Australia, Bur. Mineral Res., Geol. and Geophysics Bull. 21, p. 61, pl. 7, figs. 2, 3; pl. 8, fig. 4; pl. 10, fig. 3.
1953. *Lepidocyclina* (*Eulepidina*) *manduensis* Crespin, idem, p. 63, pl. 8, figs. 2, 3.

Matrix-free specimens of *Lepidocyclina badjirraensis* were not found on Saipan, but both equatorial and vertical cuts were observed in mislabeled sections whose exact locality on the island is unknown. Measurements of vertical sections of selected specimens follow.

Measurements of vertical sections of Lepidocyclina badjirraensis

	Pl. 108, fig. 2	Pl. 108, fig. 1	Not illustrated	Pl. 109, fig. 10	Pl. 109, fig. 9
Diameter ... mm	7. 2	9. 7	6. 15	2. 55+	3. 1
Diameter of umbo ... mm	2. 0	1. 8	2. 0	1. 6	2. 1
Thickness of umbo ... mm	0. 92	0. 76	0. 86	0. 72	1. 13
Thickness of rim near umbo ... mm	0. 46	0. 42	0. 40	0. 25	0. 45
Thickness of rim at periphery ... mm	0. 25	0. 13	0. 14	----------	----------
Embryonic chambers:					
Diameter ... μ	430	390	360	350	320
Height ... μ	140	140	150	120	160
Thickness of outer wall ... μ	30	30	40	50	30
Equatorial layer:					
Height at center ... μ	50	40	50	30	35
Height at periphery ... μ	60	60	60	----------	----------
Lateral chambers:					
Number ... no	7	7	7	6	9
Length ... μ	90–150	70–120	50–120	100–120	90–140
Height ... μ	10–20	10	10	10	10–25
Thickness of floors and roofs ... μ	30	20	20–30	30	20–30
Surface diameter of pillars ... μ	150	60–150	60–150	80–110	140–250

Remarks.—*L.* (*E.*) *bridgei* and *L.* (*E.*) *saipanensis* were described as new species in the preliminary report on Saipan (Cole and Bridge, 1953, p. 34, 37) where they were found associated at a single locality. After the manuscript of that report was in press, Crespin (1952a, p. 28) published two new species, *L.* (*E.*) *badjirraensis* and *L.* (*E.*) *manduensis*, which occur together in the Miocene, Tertiary *e*, of Australia. As *L.* (*E.*) *bridgei* appeared to be similar to, if not identical with *L.* (*E.*) *badjirraensis*, a footnote to this effect was inserted in the preliminary report.

L. (*E.*) *bridgei* and *L.* (*E.*) *saipanensis* differed from each other largely in the size and thickness of the wall of the embryonic chambers. These same differences occur between the two Australian species.

The measurements of the maximum diameters of the embryonic chambers of these four species follow:

Species	Locality	Maximum diameter of embryonic chambers
Lepidocyclina (*Eulepidina*) *saipanensis*	Saipan	200μ–250μ
(*Eulepidina*) *bridgei*	Saipan	720μ–1, 480μ
manduensis	Australia	500μ–800μ
badjirraensis	Australia	1, 200μ–1, 300μ

Specimens in the present collection which were identified first as *L.* (*E.*) *saipanensis* have embryonic chambers with a diameter of 360μ to 430μ. Thus, these specimens are intermediate between *L.* (*E.*) *bridgei* and *L.* (*E.*) *saipanensis*.

In a study of the American species, *L.* (*N.*) *chaperi* Cole (1953, p. 25) demonstrated that the range in diameter of the embryonic chambers of this species is 640μ to 1,420μ. The size and thickness of the wall of the embryonic chambers is apparently not a specific character.

As the Saipan specimens and the Australian ones have essentially the same form and internal structure, they are all combined under the name *L.* (*E.*) *badjirraensis*.

Unfortunately, the most complete vertical sections occur on slides mislabeled as coming from a known Eocene locality. However, illustrations are used from these slides, because they include the most complete vertical sections available.

Lepidocyclina (Eulepidina) ephippioides Jones and Chapman

Plate 108, figures 4–13; plate 109, figures 11–15

1900. *Orbitoides* (*Lepidocyclina*) *ephippioides* Jones and Chapman, *in* C. W. Andrews, A monograph of Christmas Island (Indian Ocean), British Mus. (Nat. History), London, p. 251, 252, 256, pl. 20, fig. 9; pl. 21, fig. 15.

1952. *Lepidocyclina ephippioides* Jones and Chapman. Grimsdale, Bull. British Mus. (Nat. History) Geol., London, v. 1, no. 8, p. 240–244, pl. 23, figs. 8, 17, 18 [references].

1953. *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger. Cole, U. S. Geol. Survey Prof. Paper 253, p. 34–35, pl. 7, figs. 4, 5; pl. 10, figs. 1–6.

1953. *Lepidocyclina* (*Eulepidina*) *gibbosa* Yabe. Cole, idem, p. 35–36, pl. 8, figs. 2–7.

1953. *Lepidocyclina* (*Eulepidina*) *planata* Oppenoorth. Cole, idem, p. 36, pl. 7, figs. 1–3 [references].

1953. *Lepidocyclina* (*Nephrolepidina*) *newtoni* Yabe and Hanzawa. Cole, idem, p. 29–30, pl. 12, figs. 8–10, 15; pl. 14, fig. 3.

The various species *L. formosa*, *L. gibbosa*, *L. planata*, and *L. newtoni*, here considered variants of *L. ephippioides*, were described and illustrated in the preliminary report on Saipan. Additional illustrations are given which in conjunction with the illustrations previously published show the variation which may occur within this species and prove the interconnection of all these individuals.

Remarks.—Grimsdale (1952, p. 240–244) has made a study recently of the species most commonly called *L.* (*E.*) *formosa* Schlumberger. He believed that the earliest name given to this species was *Orbitoides* (*Lepidocyclina*) *ephippioides* Jones and Chapman and that this specific name should have priority. He placed in the synonymy of *L.* (*E.*) *ephippioides* numerous Indo-Pacific species, all of which have "hexagonal or spatulate equatorial chambers, eulepidine nucleoconch, lack of pillars, but thickening of the lateral chamber walls visible in varying degree." He believed, also, that the American Oligocene species *L.* (*E.*) *favosa* Cushman should be a synonym of *L. ephippioides*.

Earlier, Hanzawa and Asano (1942, p. 121), after a comparative study of *L. favosa* and *L. formosa*, decided that the species were closely related but could be separated. Grimsdale (1952, p. 244) in commenting on the opinion of Hanzawa and Asano stated: "From this I would infer that the distinction between these species is not proven and is better not maintained. There remains, however, the possibility that geographical or stratigraphical races may eventually be found to merit recognition in a varietal status only."

Although there is parallel development in *L. formosa* and *L. favosa* and it is possible that only one species is represented, the author agrees with a statement made by Vaughan (1933, p. 4): " . . . I wish to say that I sympathize with Douvillé's comparison of American with European species. I feel, however, that the time is not quite ripe for extensive critical comparisons."

Eventually, a worldwide comparison of the species of larger Foraminifera must be made, but the information on most of the species is still too fragmental. In the case of the species under consideration, it is believed that they can be separated, admittedly with difficulty, but if this be true it appears that the separate specific names should be retained because of stratigraphical and geographical implications.

It is certain, however, that Grimsdale is correct in placing in synonymy most of the names which have been given to various specimens of *L. formosa* within the Indo-Pacific province and that the first name used was *L. ephippioides* Jones and Chapman. This name is accepted for the Saipan specimens.

In the preliminary report (Cole and Bridge, 1953, p. 35, 36) the name *L. gibbosa* Yabe (1919, p. 46) was retained for certain specimens associated with *L. ephippioides* (*L. formosa*) because "The specimens from Saipan have the thickened wall surrounding the lateral chambers which is the outstanding characteristic of *L. gibbosa*. . . ." After studying the abundant material from Saipan which is available at present, this position can not be maintained. There is complete gradation between specimens of the *L. ephippioides* and the *L. gibbosa* type.

Certain aberrant specimens (pl. 109, figs. 12–15) which have a depressed central part surrounded by an inflated ring were found in the thin sections from a few localities. The specimens have all the internal features of *L. ephippioides* except the cross section shape. They are found only rarely and always in association with normal specimens of *L. ephippioides*. Therefore, these specimens are believed to be an unusual, perhaps pathological, form of this species.

L. monstrosa Yabe (1919, p. 42), a variant of *L. ephippioides*, which is found at certain of the stations on Saipan combines the characters of "*L. gibbosa*" and "*L. formosa*" types.

Previously, Cole (Cole and Bridge, 1953, p. 29, 36) recognized the species *L.* (*N.*) *newtoni* Yabe and Hanzawa and *L.* (*E.*) *planata* Oppenoorth on Saipan. He wrote concerning *L. planata*, "The relationship and association of *L. formosa* and *L. planata* is the same as that of *L. favosa* and *L. undosa* from the American Oligocene." Since that time, Cole (1952, p. 23) studied abundant and well-preserved material of *L.* (*N.*) *chaperi* Lemoine and R. Douvillé from Panama. In this species he proved the wide variation which may occur in a given species.

Inasmuch as the variation between individuals in a single population of *L. chaperi* is no greater than that between *L. planata* and *L. ephippioides*, these two species are combined. As the illustrations (pl. 108, figs. 5–13) demonstrate, the thin specimens of the *L. planata* type merge with thicker specimens which are called "*L. ephippioides*.

Although certain Saipan specimens (Cole and Bridge, 1953, pl. 12, fig. 8) appeared to have nephrolepidine embryonic chambers and therefore were assigned to *L.* (*N.*) *newtoni* Yabe and Hanzawa, it is doubtful if this assignment was correct. Cole (1945, p. 43) among others has long recognized that in *L. favosa* and *L. undosa* (probably comprising a single gradational species) the embryonic chambers grade from nephrolepidine to eulepidine. The same gradation occurs in *L. ephippioides*.

Family DISCOCYCLINIDAE

Genus DISCOCYCLINA Gümbel, 1870

Subgenus DISCOCYCLINA Gümbel, 1870

Discocyclina (Discocyclina) omphala (Fritsch)

Plate 115, figures 1–12

1875. *Orbitoides omphalus* Fritsch, Palaeontographica, supp. 3, p. 142, 143, pl. 18, fig. 13; pl. 19, fig. 5.

1905. *Orthophragmina umbilicata* Deprat, Soc. géol. France, Bull., sér. 4, v. 5, p. 497–501, pl. 16, figs. 2–11.

1905. *Orthophragmina umbilicata* Deprat, var. *fournieri* Deprat, idem, p. 501, 502, pl. 17, fig. 12.

1905. *Orthophragmina javana* Verbeek var. *minor* Verbeek, idem, p. 502, 503, pl. 17, figs. 13, 14. [Not *Orbitoides papyracea* var. *javana minor* Verbeek, 1896.]

1905. *Orthophragmina* cf. *O. stella* D'Archiac. Deprat, idem, p. 504, 505, pl. 17, figs. 15–18. [Not *Orbitolites stella* D'Archiac, 1848.]

1905. *Orthophragmina* cf. *O. dispansa* Sowerby. Deprat, idem, p. 505, pl. 17, fig. 19. [Not *Lycophris dispansus* Sowerby, 1837.]

1905. *Orthophragmina* cf. *varians* Kaufmann. Deprat, idem, p. 505, 506, pl. 18, figs. 20–22. [Not *Orbitoides varians* Kaufmann, 1867.]

1905. *Orthophragmina omphala* (Fritsch). Douvillé, Soc. géol. France Bull., sér. 4, v. 5, p. 440, 441, text figs. 1, 2.

1914. *Orthophragmina umbilicata* Deprat. L. Rutten, Nova Guinea, v. 6, géol. 2, Leiden, p. 49, pl. 9, figs. 4–7.

1947. *Discocyclina umbilicata* Deprat. Bursch, Schweizer. palaeont. Gesell. Abh., v. 65, p. 57–59, pl. 3, figs. 18, 21, 24.

1953. *Discocyclina* sp. A, Cole, U. S. Geol. Survey Prof. Paper 253, p. 37, pl. 12, fig. 3.

1956. *Discocyclina* (*Discocyclina*) *indopacifica* Hanzawa, Geol. Soc. America Mem. 66 (in press).

The test is moderate size with or without a central umbo. The umbonate forms have the inflated central area bordered by a wide rim. The umbo is either gently arched, flat-topped, or slightly depressed in the center. The nonumbonate forms are lenticular. The surface is covered with small, very slightly raised papillae.

The embryonic chambers are bilocular with the larger chamber embracing the initial chamber except for a distance of about 100μ along their common boundary. The initial chamber is subspherical with an internal diameter of about 180μ. The second chamber is large with diameters of 680μ by 530μ. The outer wall of the embryonic chamber is 15μ thick. Distinct periembryonic chambers do not appear, and the embryonic chambers are followed by the normal rectangular equatorial chambers.

The equatorial chambers are radially elongated with radial diameters of 50μ to 70μ and tangential diameters of 20μ to 25μ. The annular stolon is situated on the proximal side of the radial chamber walls. The radial chamber walls are well developed and straight, and those of one annulus alternate in position with those of the next adjacent annuli.

The following table contains measurements of five vertical sections.

Measurements of vertical sections of Discocyclina omphala

	Specimens from locality—				
	S100, shown on—			S259, shown on—	
	Pl. 115, fig. 3	Pl. 115, fig. 9	Pl. 115, fig. 5	Pl. 115, fig. 8	Pl. 115, fig. 6
Diameter mm	8. 3	5. 2+	5. 1+	3. 8+	5. 3+
Thickness mm	1. 45	1. 75	1. 1	1. 1	1. 8
Diameter of umbo mm	3. 0	2. 8	2. 6	2. 3	3. 0
Width of flange mm	3. 0	1. 8+	1. 5+	1. 0+	1. 8+
Thickness of flange mm	0. 55	0. 65	0. 35	0. 35	0. 65
Equatorial chambers:					
Length μ	380	510	380	730	470
Height μ	140	160	120	180	200
Thickness of outer wall μ	10	10	10	5	10
Equatorial layer:					
Height at center μ	50	60	50	40	60
Height at periphery μ	70	60	40	40	60
Lateral chambers:					
Number	26	28	22	17	33
Length μ	50–80	50–90	60–100	40–100	80–120
Height μ	10	10	10	10	10
Thickness of floors and roofs μ	10	10	20	10	10
Surface diameter of pillars μ	150	100	120–150	100	50–140

The lateral chambers are not arranged in regular tiers, but irregularly overlap. The chamber cavities are low, slitlike between relatively thick floors and roofs.

Heavy pillars are irregularly scattered throughout the vertical sections with the greatest concentration of pillars in the umbo.

Occurrence elsewhere.—Borneo; New Caledonia; New Guinea; Gross Kei, Moluccas.

Remarks.—The type description and illustrations are inadequate. However, the external view shows a depressed area within the umbo although the internal features are not clearly characterized. Later, Douvillé (1905, p. 440) gave better illustrations of the external view. Fortunately, Dr. A. Tobler had sent Vaughan specimens from Douvillé's Borneo locality; therefore, the internal structure of the species could be investigated. These specimens have the same internal structure as that of the Saipan specimens.

Deprat (1905, p. 497) described a new species from New Caledonia to which he gave the name *Orthophragmina umbilicata*. He illustrated this species with photomicrographs showing the internal structure. As the internal features of the specimens identified by Douvillé with *D. omphala* (Fritsch) appear to be the same as those of Deprat's *D. umbilicata*, these species are combined.

The external shape of *D. omphala* is similar to that of *Pseudophragmina* (*Proporocyclina*) *peñonensis* Cole and Gravell (1952, p. 723). Examination of many matrix-free specimens of this species showed that there is great variation in external shape. Although some specimens have a marked central depression, others are without this feature. This same variation occurs in *P.* (*P.*) *advena* (Cushman), another American species in which certain individuals have a marked central depression and others do not.

External shape is not a criterion upon which a species may be based, as this character is variable. Internal structure is constant, and the main reliance for the definition of species of larger Foraminifera should be based on the internal structures.

Although most of the Saipan specimens do not have a depressed center, certain individuals (pl. 115, fig. 4) do. The internal structure of the Saipan specimens, however, compares favorably with that of the East Indies specimens.

Bemmelen (1949, fig. 40) figures specimens to which the name *Discocyclina omphalus* (v. Fritsch) var. "*selliformis*" is given. Although only the external appearance is shown, these specimens appear to be the same as those from Saipan.

Genus ASTEROCYCLINA Gümbel, 1870

Asterocyclina incisuricamerata Cole, n. sp.

Plate 117, figures 1–5

The test is small, with the central part inflated. There are 4 rays which are short with blunted rounded ends and merge imperceptibly into the central part. Small papillae, slightly raised, occur on the inflated part.

The embryonic chambers are bilocular. The initial chamber is subspherical slightly embraced by a reniform second chamber. The dividing partition between the two chambers is curved.

There appear to be four principal periembryonic chambers, one lying at each end of the dividing partition between the embryonic chambers. The other two are situated so that one is on the outer edge of the initial chamber and the other is on the outer edge of the second chamber. These chambers have diameters of about 25μ by 60μ. Measurements of horizontal sections are given below.

	Specimen shown on—	
	Pl. 117, fig. 3	Pl. 117, fig. 4
Diameter mm	2.1	2.0
Embryonic chambers:		
Diameter of initial chamber μ	50 x 50	45 x 40
Diameter of second chamber μ	80 x 40	50 x 40
Distance across both chambers μ	95	90
Thickness of outer wall μ	10	10
Equatorial chambers:		
In rays:		
Radial diameter μ	50	55
Tangential diameter μ	20	20
In interrays:		
Radial diameter μ	35	20–35
Tangential diameter μ	35	30

The four rays show prominently in all of the equatorial sections. The chambers in the rays are tangentially elongate, whereas the interray chambers are nearly square. Measurements of vertical sections are given below.

	Specimens from locality S259, shown on—	
	Pl. 117, fig. 1	Pl. 117, fig. 2
Diameter mm	2.2+	2.35
Thickness mm	0.77	0.65
Embryonic chambers:		
Diameter μ	60	80
Height μ	30	50
Thickness of outer wall μ	5	20
Equatorial layer:		
Height at center μ	50	50
Height at periphery μ	60	60
Lateral chambers:		
Number	10	11
Length μ	50–60	50
Height μ	5–10	10
Thickness of floors and roofs μ	10–25	20–25
Surface diameter of pillars μ	60–160	60–130

The lateral chambers are not arranged in regular tiers. The chamber cavities are low, slitlike between thick floors and roofs.

Heavy pillars are irregularly scattered throughout the test, with the greatest concentration in the central area.

Type material.—Holotype, USNM 624717; paratype, USNM 624719, from locality S–259.

Remarks.—The small embryonic chambers, the slitlike lateral chambers with thick floors and roofs, and their overlapping arrangement distinguish this species from the others found on Saipan.

The equatorial chambers are nearly square, but some of them have a faint hexagonal shape. This type of equatorial chamber was found in *Orthocyclina soeroeanensis* Van der Vlerk (1923, p. 93). Although Van der Vlerk based the genus *Orthocyclina* on the shape of the equatorial chambers, it is doubtful if this is a sufficiently well-defined characteristic on which to base a genus.

Many of the discocyclinids have certain of the chambers in the equatorial section with a faint hexagonal shape, but other chambers in the same section are square or rectangular.

A. soeroeanensis (Van der Vlerk) is incompletely described, as the only illustration given is the one of the equatorial section. The embryonic chambers are very different from those of *A. incisuricamerata*.

Asterocyclina matanzensis Cole, n. sp.

Plate 117, figures 6–10; plate 118, figures 9–18

The test is small, compressed, consisting of a central umbonate area from which radiate four slightly elevated rays; interray areas are thin, flat; the surface is covered by small, projecting papillae.

In all of the specimens available the embryonic apparatus has been destroyed by replacement with calcite. Typical equatorial sections are illustrated (pl. 117, figs. 6, 7) but not described.

The following table contains measurements of four vertical sections made from matrix-free specimens.

	Specimens from locality—			
	S259, shown on—			S134, shown on pl. 118, fig. 16
	Pl. 117, fig. 9	Pl. 117, fig. 8	Pl. 118, fig. 17	
Diameter mm	2. 65+	2. 25+	2. 1+	2. 55+
Thickness mm	0. 88	0. 85	1. 03	1. 18
Embryonic chambers:				
Diameter μ	160	140	150	150
Height μ	120	70	60	90
Thickness of outer wall μ	10	5	5	----------
Equatorial layer:				
Height at center μ	35	30	35	40
Height at periphery μ	30	20	30	40
Lateral chambers:				
Number	17	20	20	24
Length μ	70	50	70	50–70
Height μ	10	5	10	10
Thickness of floors and roofs μ	10	10	10	10
Surface diameter of thickened areas between lateral chambers μ	80–100	50–70	50–90	80

The lateral chambers are in regular tiers. The chamber cavities are low, slitlike between floors and roofs which are about as thick as the height of the chamber cavity. Thickened areas occur between the tiers of lateral chambers which resemble pillars.

Type material.—Holotype, vertical section from locality S259, USNM 624723; paratype, median section from locality S259, USNM 624721.

Remarks.—Although the matrix-free specimens are small and apparently represent only the central portion, vertical sections in the thin sections made from the limestone are much larger because of the preservation of a wide but very fragile rim. Several of these are illustrated (pl. 118, figs. 9–18), and the measurements of the best one are listed below.

Diameter	mm	6. 41+
Thickness at center	mm	1. 12
Diameter of umbo	mm	1. 1
Rim:		
Width	mm	3. 65
Thickness near the umbo	mm	0. 5
Thickness at the periphery	mm	0. 21
Embryonic chambers:		
Diameter	μ	150
Height	μ	120
Height of equatorial layer:		
Near center	μ	40
Near periphery	μ	35
Lateral chambers:		
Length	μ	50
Height	μ	10
Thickness of roofs and floors	μ	10
Number		21
Surface diameter of pillars	μ	50

The features of these specimens compare favorably with specimens from the East Indies which have been commonly referred to *Asterocyclina lanceolata* (Schlumberger). Deprat (1905, p. 509) referred certain specimens from New Caledonia to this species, but his specimens appear to be similar to those of the present collection.

All of the specimens, however, differ from the types of *A. lanceolata* and should be given a new name.

Asterocyclina penuria Cole, nom. nov.

Plate 116, figures 1–10

1905. *Orthophragmina pentagonalis* Deprat, Soc. géol. France Bull., ser. 4, v. 5, p. 507, 508, pl. 18, figs. 24, 25; pl. 19, fig. 27. [Not *Asterodiscus pentagonalis* Schafhäult, 1863, Sud-Bayerns Lethaea Geog., p. 107, pl. 15, fig. 2.]

1905. *Orthophragmina nummulitica* (Gümbel) (?). Deprat, idem, p. 506, pl. 18, fig. 23. [Not *Orbitoides* (*Rhipidocyclina*) *nummulitica* Gümbel, 1868.]

1934. *Asterocyclina* aff. *A. pentagonalis* Deprat. Caudri, Tertiary Deposits of Soemba, Amsterdam, p. 97–99, pl. 3, figs. 1, 9.

1953. *Discocyclina* sp. B. Cole, U. S. Geo. Survey Prof. Paper 253, p. 37, pl. 12, fig. 4.

The test is moderate size with an inflated central area surrounded by a narrow brim on which there are 4 slightly elevated areas at right angles to each other representing rays. The rays are not at all distinct. The surface of the test is covered by shallow polygonal pits which are bounded by elevated walls of clear shell material. The largest specimen has a diameter of more than 5 mm.

The embryonic chambers are bilocular consisting of an initial chamber with diameters of 220μ by 140μ and a second chamber with diameters of 310μ by 160μ. The distance across both chambers is 300μ. The outer wall of the embryonic chambers is 18μ thick. The dividing partition between the chambers is gently curved.

There are 4 large, prominent periembryonic chambers which completely surround the embryonic chambers. The 2 larger chambers are situated so that their point of juncture is at the apex of the initial chamber from which they extend on either side of the initial chamber to a point on the second embryonic chamber about 80μ beyond the dividing partition between the chambers. The 2 smaller chambers extend from their juncture with the larger chambers around the second embryonic chamber and meet at the apical point. The larger chambers have diameters of about 300μ by 50μ, and the smaller chambers have diameters of about 240μ by 50μ.

The equatorial chambers are radially elongate. The chambers in the interray areas have radial diameters of 70μ to 90μ and tangential ones of 20μ to 30μ. The chambers which compose the 4 rays have radial diameters of 120μ and tangential diameters of 15μ to 20μ.

Measurements of vertical sections of Asterocyclina penuria

	Specimens from locality—					
	S259, shown on—			S188, shown on pl. 116, fig. 5	S259, shown on pl. 116, fig. 2	S134, not illustrated
	Pl. 116, fig. 1	Pl. 116, fig. 3	Pl. 116, fig. 4			
Diameter mm	3. 4	3. 55	3. 6+	3. 7+	1. 9	5. 4
Thickness mm	1. 36	2. 2	1. 8	3. 15	0. 85	2. 5
Embryonic chambers:						
Length μ	260	270	320	270	210	340
Height μ	160	180	130	190	170	190
Thickness of outer wall μ	10	10	15	10	20	15
Equatorial layer:						
Height at center μ	60	40	80	60	70	60
Height at periphery μ	50	50	60	60	40	60
Lateral chambers:						
Number	20	22	20	44	16	28
Length μ	50–150	200–260	70–200	150	70	100–200
Height μ	10–20	25–40	20–30	20–30	10	10–30
Thickness of floors and roofs μ	10–25	20	10	10	10	10–25
Surface diameter of thickened areas between the lateral chambers μ	50–150	200–300	100–200	100–170	40–140	140–300

The lateral chambers are in regular tiers. The lateral chambers over the embryonic apparatus have slitlike openings between thick floors and roofs. Those toward the periphery have open rectangular cavities between straight moderately thick floors and roofs.

Between the tiers of lateral chambers, there are thickened areas which resemble pillars.

Occurrence elsewhere.—New Caledonia; Soemba.

Remarks.—Although the types are smaller than the average Saipan specimen, certain specimens compare favorably in size with the types. The internal features of the New Caledonian and the Saipan specimens are similar.

The figures demonstrate that in vertical section there is considerable variation between individuals in the degree of inflation, number of lateral chambers, and thickness of floors and roofs. However, all the specimens have the lateral chambers arranged in regular tiers. The chambers over the embryonic apparatus have low slitlike cavities, whereas those near the periphery have open rectangular cavities.

Miss Caudri (1934, p. 97) compared specimens from Soemba with *A. pentagonalis* Deprat. The description which she gave of these specimens demonstrates that they are similar to the Saipan specimens. Although she hesitated to assign her specimens to Deprat's species, it appears from the variation shown by the Saipan specimens that they should be.

Hanzawa refers similar Saipan specimens to *Discocyclina* cf. *D. molengraaffi* Henrici.

LOCALITIES AND TYPE NUMBERS

Localities and type numbers

[See pl. 4 for locality data]

USGS permanent locality numbers	Field locality numbers	USNM type numbers
Eocene		
f11471	B19	
f11472	B20	
f21021	B22	
f21022	B23	
f21023	B51	
f21024	B56	
f21025	B65	
f21026	B69	
f21027	B77	
f21028	B78	
f21029	B80	
f21030	B85	
f21031	B110	
f21032	B111	
f21033	B176	624496
f21034	B211	
f21035	B221	
f21036	B251	
f21037	C9	624466, 624468
f21038	C10	
f21039	C21	
f21040	C22	624476
f21041	C64	
f21043	S33	624454, 624470
f21044	S74	
f21045	S79	624522
f21046	S88	624464, 624508
f21047	S90	
f21048	S100	624449, 624458, 624459, 624483, 624491, 624698 to 624702, 624706, 624707, 624709
f21049	S101	
f21050	S103	
f21051	S125	624732, 624734
f21052	S132	624525
f21053	S133	624514, 624736
f21054	S134	624452, 624455, 624461, 624489, 624490, 624493, 624739
f21055	S150	
f21056	S163	
f21057	S170	624511, 624520
f21058	S188	624448, 624450, 624453, 624456, 624482, 624485, 624712, 624714
f21059	S189	624746
f21060	S190	
f21061	S191	624445, 624446, 624460, 624467, 624469
f21062	S194	
f21063	S201	
f21064	S202	624741
f21065	S208	
f21067	S212	
f21069	S214	624513
f21071	S217	
f21072	S219	
f21073	S222	
f21074	S223	624515
f21075	S227	624480, 624509
f21076	S241	624477
f21077	S242	
f21078	S247	
f21079	S248	
f21080	S251	624471, 624475, 624478
f21081	S253	624731
f21082	S254	624479, 624487, 624512
f21083	S256	
f21084	S258	
f21085	S259	624447, 624451, 624457, 624463, 624484, 624492, 624523, 624524, 624703–624705, 624708, 624710, 624711, 624713, 624715–624724, 624740, 624745
f21086	S262	
f21087	S268	
f21088	S270	624474, 624488
f21089	S271	624518, 624521
f21091	S282	
f21093	S286	624737
f21094	S287	
f21095	S288	624465, 624472
f21096	S290	624519
f21097	S291	
f21098	S292	624733
f21099	S307	
f21100	S308	
f21101	S310	
f21102	S311	624510
f21103	S315	
f21104	S318	624517
f21105	S319	624481
f21106	S321	624473
f21107	S335	
f21108	S336	624486
f21109	S338	624516
f21110	S340	
f21111	S341	624462, 624526
f21112	S342	
f21114	S345	
f21117	S349	
f21118	S351	
f21119	S359	
f21121	S364	
f21123	S369	
f21124	S381	
f21127	S592	
f21130	S603	
f21131	S604	624735, 624738
f21132	S631	
Miocene		
f21135	B1	624616
f21136	B2	624649
f21137	B3	624592, 624615
f21138	B4	
f21139	B5	
f21140	B6	
f21141	B7	
f21142	B8	
f21143	B9	
f21144	B10	
f21145	B11	
f21146	B12	
f21147	B13	
f21148	B14	
f21149	B15	624648
f21150	B16	
f21151	B24a	
f21152	B27	
f21153	B29	624591
f21154	B34	
f21155	B35	
f21156	B37	
f21157	B40	
f21158	B42	
f21159	B44	
f21160	B46	
f21161	B47	
f21162	B49	
f21163	B50	624538
f21164	B52	
f21165	B55	624620
f21166	B57	
f21167	B59	
f21168	B60	
f21169	B61	
f21170	B66	
f21171	B73	
f21172	B76	
f21173	B79	624540
f21174	B82	
f21175	B84	
f21176	B86	
f21177	B88	
f21178	B89	
f21179	B90	
f21180	B91	
f21181	B92	
f21182	B93	
f21183	B94	
f21184	B95	
f21185	B96	
f21186	B98	
f21187	B99	
f21188	B101	624550
f21189	B103	624555
f21190	B104	
f21191	B016	
f21192	B108	
f21193	B109	
f21194	B112	
f21195	B113	
f21196	B114	
f21197	B115	
f21198	B116	
f21199	B117	
f21200	B118	
f21201	B119	
f21202	B120	
f21203	B121	
f21204	B122	
f21205	B123	
f21206	B124	
f21207	B125	

Localities and type numbers—Continued

USGS permanent locality numbers	Field locality numbers	USNM Type numbers
Miocene—Continued		
f21208	B126	624556
f21209	B127	
f21210	B128	
f21211	B129	
f21212	B130	
f21213	B131	
f21214	B132	
f21215	B133	
f21216	B134	
f21217	B135	624585
f21218	B136	624577, 624623
f21219	B137	
f21220	B138	624558, 624579, 624588, 624590, 624593
f21221	B139	
f21222	B140	
f21223	B141	
f21224	B143	
f21225	B144	
f21226	B145	
f21227	B146	
f21228	B147	
f21229	B148	
f21230	B149	
f21231	B150	
f21232	B151	
f21233	B152	
f21234	B153	
f21235	B154	
f21236	B155	624619
f21237	B156	
f21238	B157	624432
f21239	B158	
f21240	B159	
f21241	B160	
f21242	B161	624586
f21243	B162	624416, 624595
f21244	B163	
f21245	B164	
f21246	B165	
f21247	B166	624600, 624601
f21248	B167	
f21249	B168	
f21250	B169	
f21251	B170	624497, 624628
f21252	B171	
f21253	B172	
f21254	B173	
f21255	B174	
f21256	B175	
f21257	B177	624574
f21258	B178	
f21259	B183	
f21260	B186	
f21261	B187	624670, 624688
f21262	B195	
f21263	B197	
f21264	B198	
f21265	B200	
f21266	B201	
f21267	B202	
f21268	B203	
f21269	B204	
f21270	B205	
f21271	B206	
f21272	B207	
f21273	B208	
f21274	B209	
f21275	B210	
f21276	B212	
f21277	B213	
f21278	B214	624546
f21279	B216	
f21280	B217	
f21281	B218	
f21282	B219	
f21283	B220	
f21284	B222	
f21285	B223	
f21286	B224	624536, 624633, 624637, 624640, 624642
f21287	B225	624644
f21288	B228	
f21289	B236	
f21290	B237	624527
f21291	B238	624530
f21292	B239	
f21293	B240	
f21294	B241	
f21295	B242	
f21296	B243	
f21297	B244	624529
f21298	B245	
f21299	B246	624547
f21300	B247	624548, 624552
f21301	B248	
f21302	B249	
f21303	B252	
f21304	B254	624528, 624682, 624689
f21305	B255	
f21306	B258	
f21307	B260	
f21308	B261	624569, 624611
f21309	B262	
f21310	B264	
f21311	B265	
f21312	B270	
f21313	B276	
f21314	B277	
f21315	B278	
f21316	B279	624554
f21317	B281	624606, 624621
f21318	B283	
f21319	B284	624617
f21320	B290	624622
f21321	B291	624433
f21322	B295	
f21323	B296	
f21324	B298	
f21325	B301	624632, 624634
f21326	B302	
f21327	B303	624597, 624604
f21328	B304	
f21329	B305	
f21330	B306	
f21331	B307	
f21332	B308	
f21333	B309	
f21334	B310	624549
f21335	B311	
f21336	B312	624584, 624630
f21337	B313	
f21338	B314	
f21339	B315	624412, 624418, 624561
f21340	B316	624631, 624636
f21341	B320	624572, 624576
f21342	B322	
f21343	B323	624499
f21344	B325	
f21347	B341	624553
f21348	B342	624623
f21349	B343	
f21350	B344	
f21351	B345	
f21352	B346	
f21353	B347	
f21354	B348	
f21355	B349	
f21356	B350	
f21357	B351	
f21358	B352	
f21359	B353	
f21360	B354	624436
f21361	B355	624437–624440
f21362	B356	
f21363	B357	624562
f21364	B358	
f21365	B359	
f21366	B360	
f21367	B361	
f21368	B362	624567
f21369	B363	
f21370	B364	624419
f21371	B365	
f21372	B366	
f21373	B367	
f21374	B368	
f21375	B369	
f21376	B370	
f21377	B371	
f21378	B372	
f21379	B373	624578, 624587
f21380	B375	
f21381	B376	
f21382	B377	
f21383	B378	
f21384	B380	
f21385	B382	
f21386	B383	
f21387	B385	
f21388	B386	
f21389	B387	
f21390	B388	
f21391	B389	
f21392	B390	
f21393	B391	624612, 624613, 624635, 624638, 624639, 624643
f21394	B392	624435
f21396	B394	624570
f21397	B395	624614, 624641
f21398	B396	

Localities and type numbers—Continued

USGS permanent locality numbers	Field locality numbers	USNM type numbers
Miocene—Continued		
f21399	B397	
f21400	B398	
f21401	B399	
f21402	B400	b24500, 624557
f21403	B402	
f21404	B403	
f21405	B404	
f21406	B408	
f21407	B410	
f21408	B411	
f21409	B412	
f21410	B413	624424–624426, 624582, 624626, 624627, 624657, 624662, 624663, 624673–624675, 624681, 624695
f21411	B414	
f21412	B415	
f21413	B416	
f21414	B417	
f21415	B418	
f21416	B419	624560
f21417	B420	624563, 624565
f21418	B421	
f21419	B422	
f21420	B423	624629
f21421	B424	
f21422	B425	
f21423	B426	
f21424	B427	
f21425	B428	
f21426	B429	624744
f21427	B431	
f21428	B432	
f21429	B433	624423, 624742, 624743
f21430	B434	
f21431	B435	624441
f21432	C1	
f21433	C14	
f21434	C16	624430, 624431, 624539
f21435	C18	
f21436	C19	
f21437	C23	
f21438	C24	
f21439	C27	
f21440	C30	
f21441	C32	
f21442	C36	
f21445	C55	
f21446	C56	
f21448	C62	
f21451	C71	
f21452	C72	
f21453	C73	
f21454	C74	
f21455	C76	
f21456	C82	
f21457	C87	
f21458	C88	
f21459	C89	624625
f21460	C90	
f21461	C91	
f21462	C92	
f21463	C93	
f21464	C95	
f21465	C96	
f21466	C97	
f21467	C98	
f21468	C100	
f21469	C102b	624559, 624564, 624566, 624568
f21470	C103	
f21471	C104	
f21472	C105	
f21473	C106	
f21474	C107	
f21475	C109	
f21476	C111	
f21477	C112	
f21478	C113	624544, 624545
f21479	C115	
f21480	C117	624434
f21481	C118	
f21482	C119	
f21483	C120	
f21484	C121	624427–624429, 624671
f21485	C122	
f21486	C123	
f21487	C125	
f21488	C126	
f21489	C127	
f21490	C128	
f21491	C129	
f21492	C130	
f21493	C131	624583
f21494	C132	624573
f21495	C133	

Localities and type numbers—Continued

USGS permanent locality numbers	Field locality numbers	USNM type numbers
Miocene—Continued		
f21496	C135	
f21498	C137	
f21499	C138	
f21500	C139	
f21501	C140	624542, 624571
f21502	C141	
f21503	C142	
f21504	C143	
f21505	C144	
f21506	C145	624410, 624411
f21507	C146	
f21508	C147	
f21509	C148	
f21510	S6	
f21511	S8	
f21512	S11	
f21513	S12	
f21515	S61	
f21516	S62	
f21517	S64	
f21518	S65	
f21520	S85	624531, 624532
f21521	S126	
f21522	S127	
f21523	S145	
f21526	S149	
f21527	S164	624602
f21528	S165	624413, 624415, 624533, 624534
f21529	S166	
f21530	S168	
f21531	S203	624605
f21532	S204	
f21533	S205	
f21534	S206	
f21535	S224	
f21536	S228	
f21537	S239	
f21538	S240	
f21539	S243	
f21540	S244	
f21541	S246	
f21542	S249	
f21543	S250	
f21544	S255	
f21545	S257	
f21546	S260	
f21547	S263	
f21548	S264	624414, 624417
f21549	S289	
f21550	S309	
f21551	S312	624498
f21552	S320	
f21553	S323	
f21554	S328	
f21555	S339	
f21556	S360	
f21557	S371	
f21558	S378	
f21559	S386	
f21560	S416	
f21561	S421	
f21562	S422	
f21565	S470	
f21566	S471	
f21567	S478	
f21568	S511	
f21569	S536	
f21570	S540	624420–624422
f21571	S541	
f21574	S585	524603
f21575	S589	
f21576	S616	
f21577	S619	
f21579	S651	
f21580	S656	
f21581	S664	
f11473	S667	624537, 624541, 624543
f21583	S668	
f21584	S669	
f21585	S671	
f21586	S672	624442–624444, 624507, 624608, 624618
f21587	S674	624607
f21589	S683	
f21590	S684	
f21591	S685	
f21592	S686	
f21593	S687	
f21594	S701	624501–624504, 624506, 624551, 624575, 624609, 624610, 624645–624647, 624651, 624652, 624654–624656, 624658, 624659, 624, 664 to 624669, 624672, 624676–624679, 624683–624687, 624697
f21595	S704	624505

Localities and type numbers—Continued

USGS permanent locality numbers	Field locality numbers	USNM type numbers
Pleistocene		
f21597	B28	
f21598	B38	624726, 624729
f21599	B64	
f21600	B179	
f21601	B181	
f21602	B188	
f21603	B192	
f21604	B193	
f21605	B215	
f21606	B226	
f21607	B227	624730
f21608	B229	
f21609	B230	
f21610	B231	624725, 624727
f21611	B232	
f21612	B233	
f21613	B234	
f21614	B235	624728
f21615	B282	
f21616	B286	
f21617	B287	
f21618	B293	
f21619	B294	624494, 624495
f21620	B299	
f21621	B300	
f21622	B317	
f21623	B318	
f21624	B321	
f21625	B324	
f21626	B328	
f21627	B331	
f21628	B334	
f21629	B338	
f21630	B340	
f21631	B406	
f21632	C49	
f21633	C50	
f21634	C52	
f21635	C54	
f21636	C59	
f21637	C61	
f21638	C65	
f21639	C66	
f21640	C67	
f21641	C68	
f21642	C75	
f21643	C77	
f21644	C78	
f21645	C80	
f21646	S417	
f21647	S430	
f21648	S452b	
f21649	S564	
f21650	S568	
f21651	S611	
f21652	S613	
f21653	S622	
f21654	S630	
f21655	S670	
f21656	S676	
f21657	S677	
f21658	S678	
f21659	S681	
f21660	S690	
f21661	S691	
f21662	S697	
f21663	S699	

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PLATE 94

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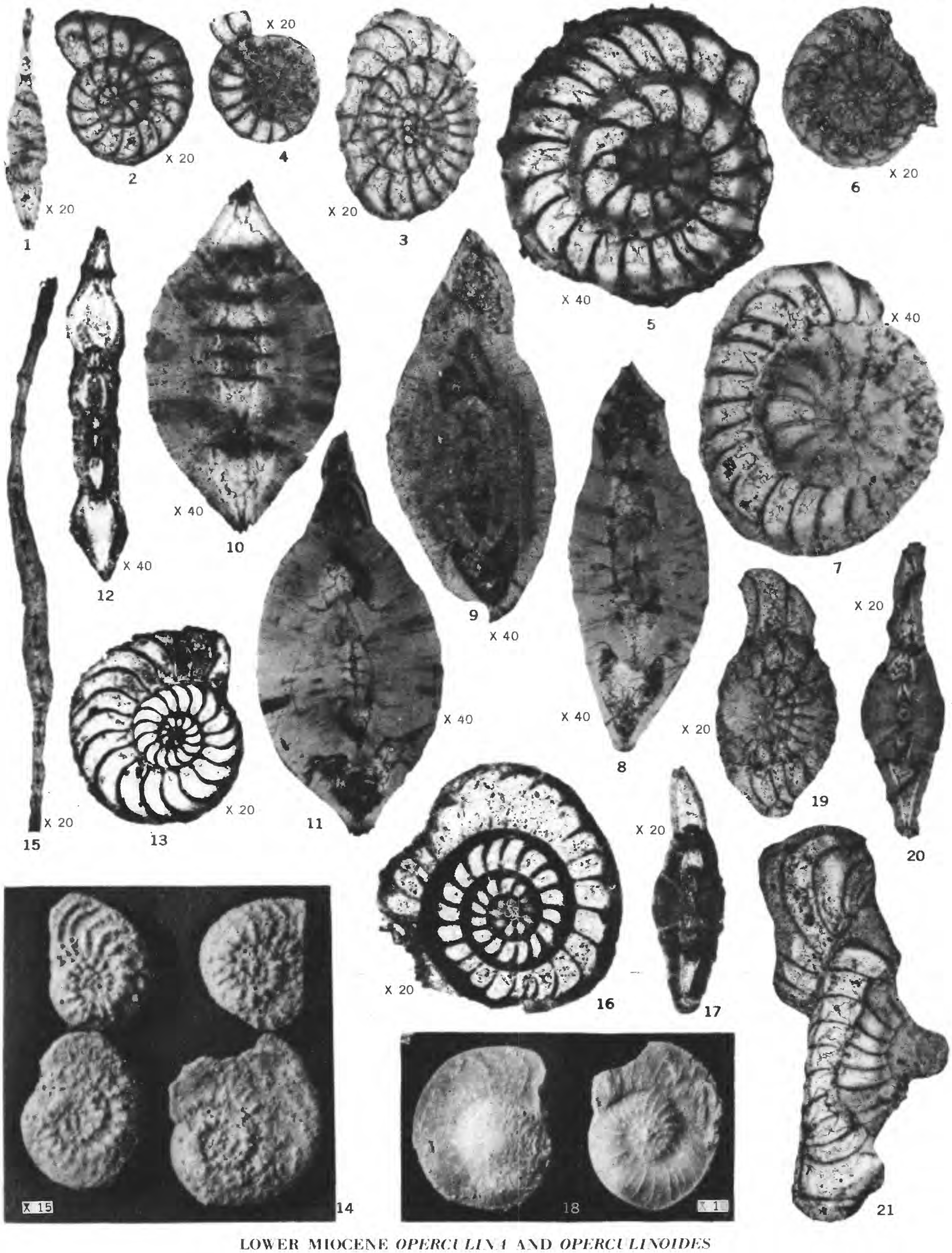
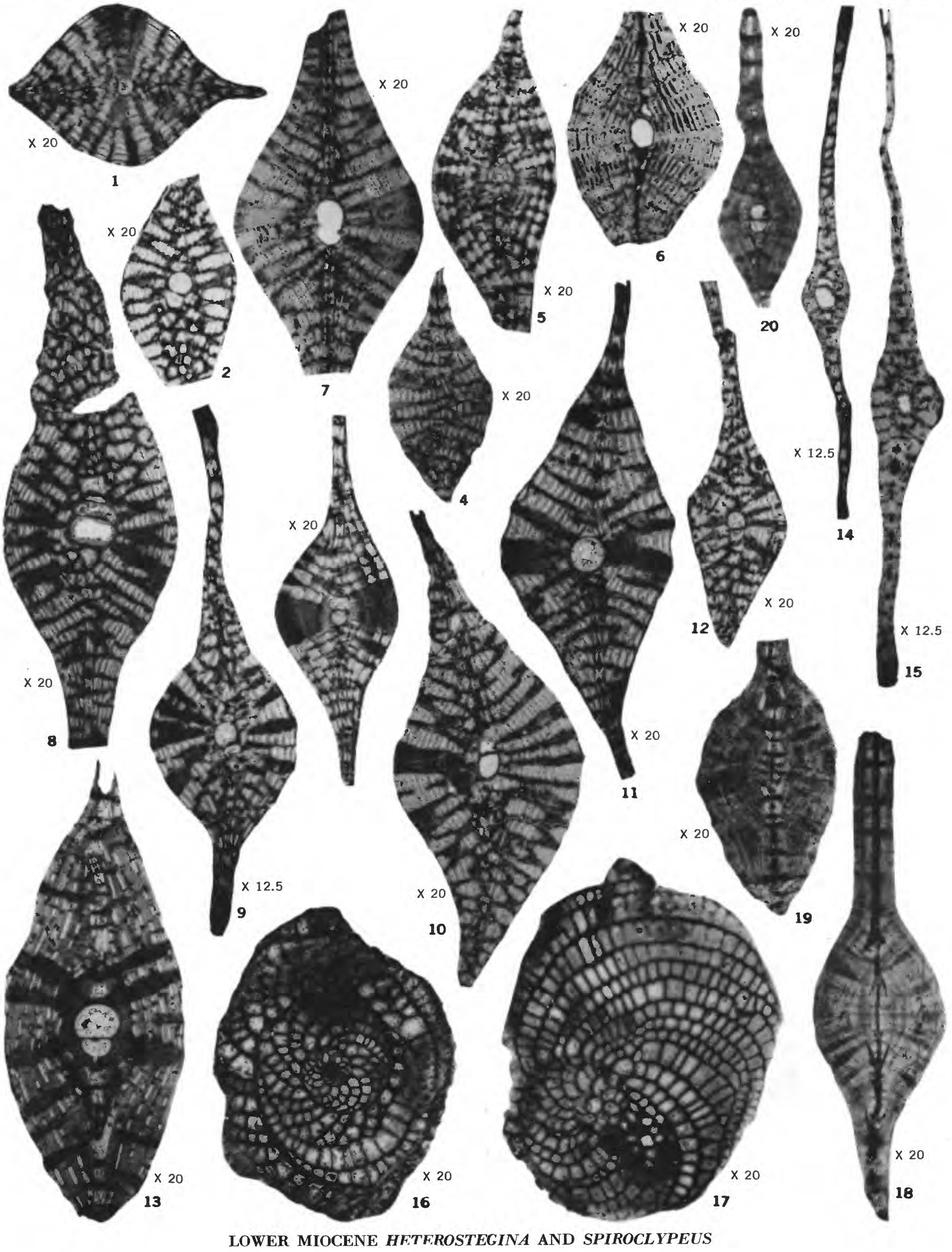


LOWER MIOCENE *OPERCULINA* AND *OPERCULINOIDES*



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3. Transverse section of an umbonate specimen with strong central pillars; locality B157. USNM 624432.
4. Transverse section not centered; locality B291. USNM 624433.
5. Transverse section of a typical specimen; locality C117. USNM 624434.

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8. Transverse section of a large specimen; locality B354. USNM 624436.
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10. Transverse section; locality B429. USNM 624744.
11. Transverse section; locality B355. USNM 624438.
12. Transverse section of a compressed specimen; locality B355. USNM 624439.

13–15. *Spiroclypeus tidoenganesis* Van der Vlerk (p. 332).

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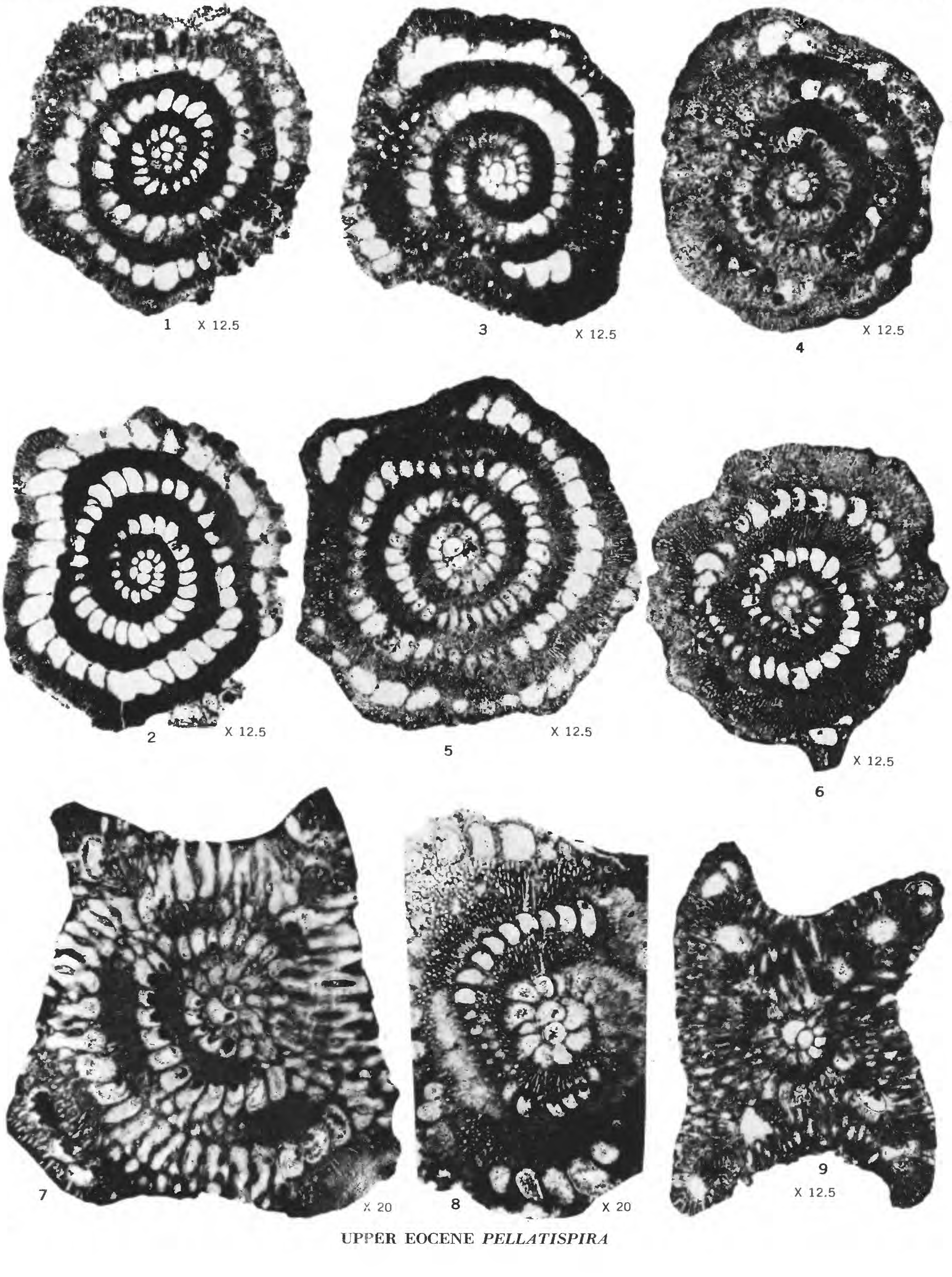


UPPER EOCENE *PELLATISPIRA*

UPPER EOCENE *PELLATISPIRA*

PLATE 97

FIGURES 1–12. *Pellatispira orbitoidea* (Provale) (p. 333).

Vertical sections to show individual variation and progressive gradation from flat, compressed, lenticular to thick, selliform individuals.

1. Locality S33. USNM 624454.
2. Locality S134. USNM 624455.
3, 7, 11. Locality S188. USNM 624456.
4–6, 8, 10. Locality S259. USNM 624457.
9. Locality S100. USNM 624458.
12. Locality S100. USNM 624459.

PLATE 98

FIGURES 1–12. *Pellatispira provaleae* Yabe (p. 333).

1–3. External views to show differences in shape and the prominent papillae.

1, 3. Locality S191. USNM 624460.

2. Locality S134. USNM 624461.

4–12. Transverse sections

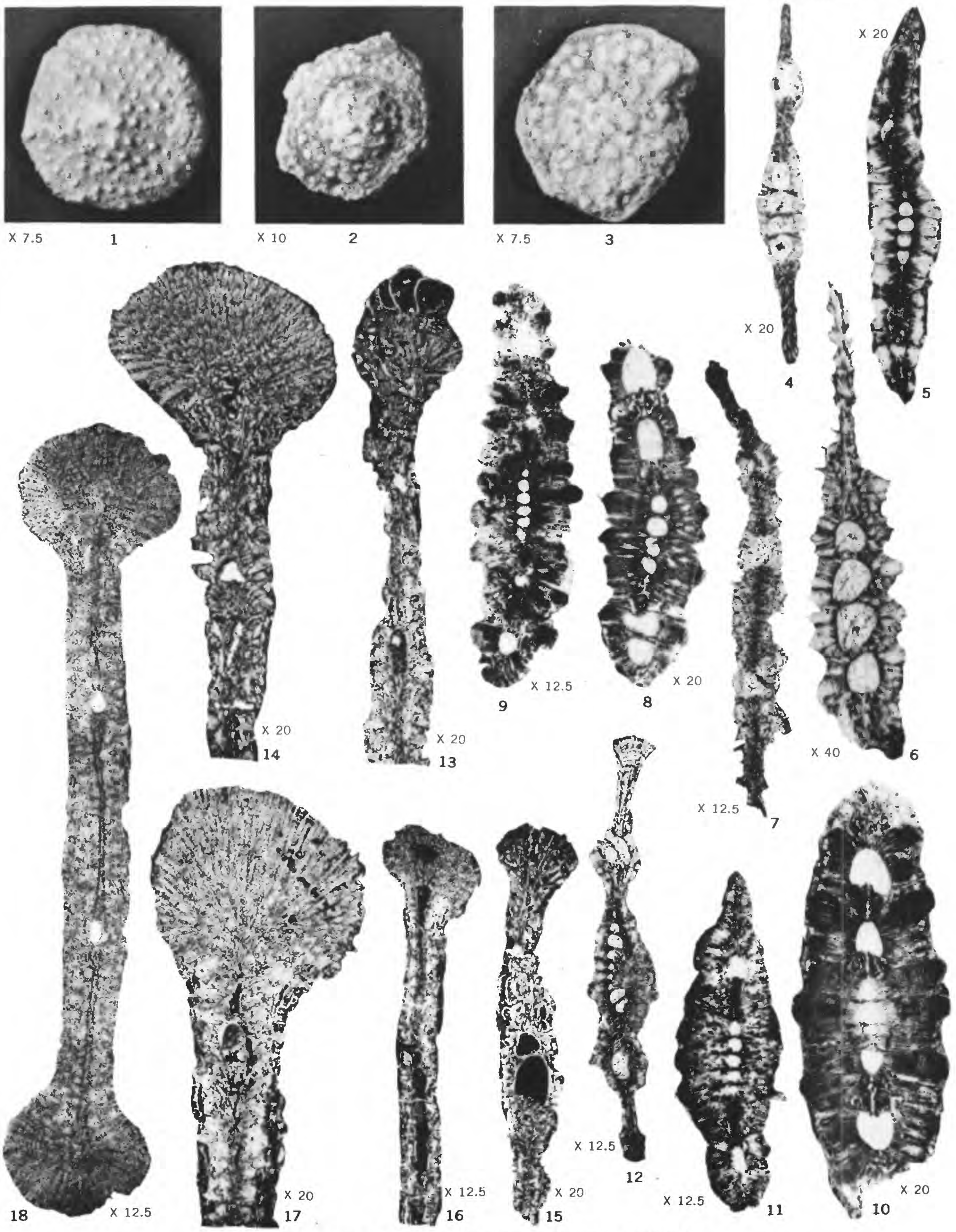
4. Locality S341. USNM 624462.
5. Locality S259. USNM 624463.
6. Locality S88. USNM 624464.
7. Locality S288. USNM 624465.
8. Locality C9*a*. USNM 624466.
9. Locality S191. USNM 624467.
10. Locality C9*a*. USNM 624468.
11. Locality S191. USNM 624469.
12. Locality S33. USNM 624470.

13–18. *Biplanispira fulgeria* (Whipple) (p. 333).

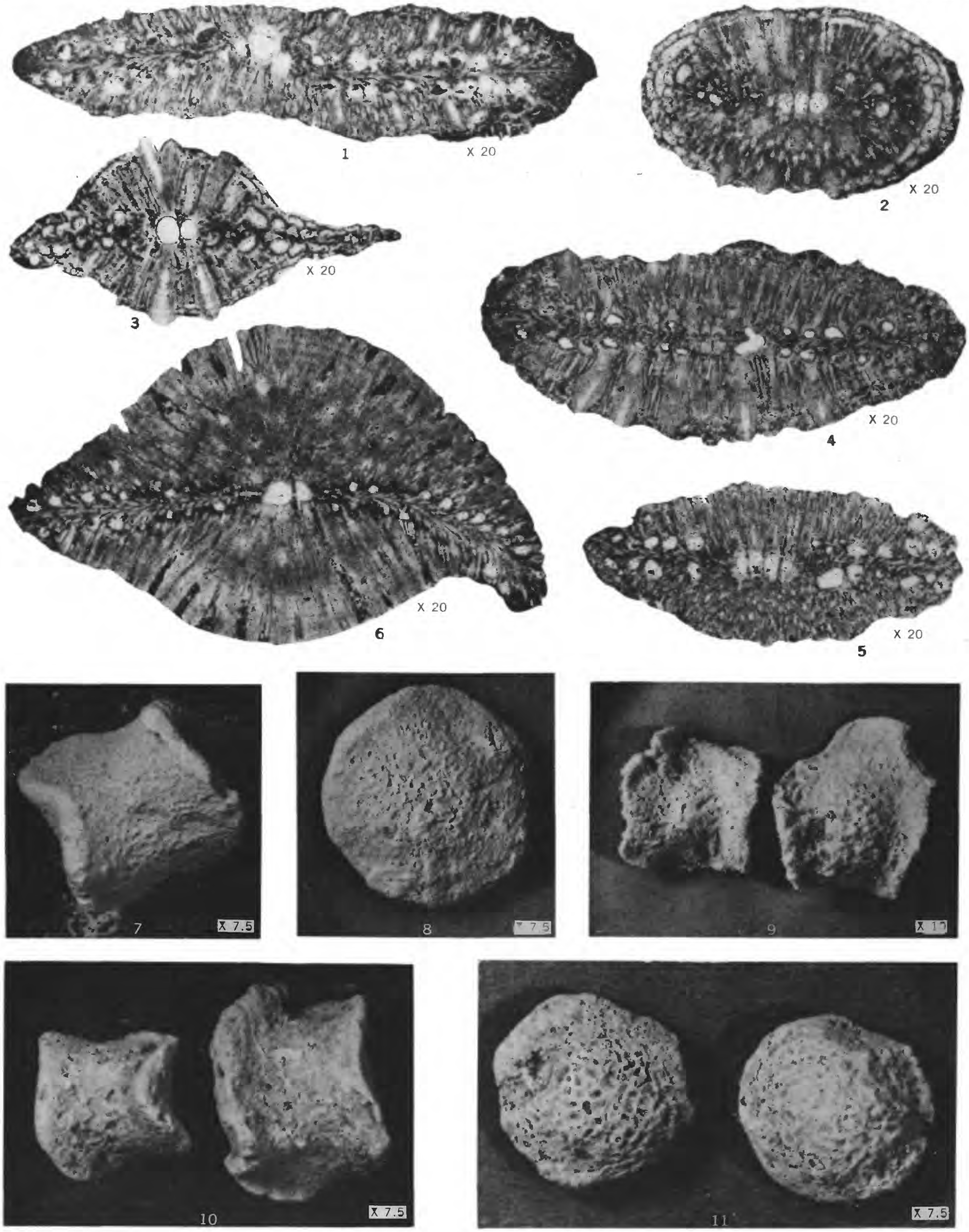
Parts of transverse sections to show the variable development of the marginal cord.

13, 14. Locality S251. USNM 624471.

15. Locality S288. USNM 624472.
16. Locality S321. USNM 624473.
17. Locality S270. USNM 624474.
18. Locality S251. USNM 624475.



UPPER EOCENE *BIPLANISPIRA* AND *PELLATISPIRA*



UPPER EOCENE *BIPLANISPIRA* AND *PELLATISPIRA*

PLATE 99

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1. Transverse section of a compressed specimen; locality C22. USNM 624476.
2. Transverse section of an inflated specimen; locality S241. USNM 624477.
3. Transverse section of an umbonate specimen; locality B251. USNM 624478.
4. Transverse section of a moderately inflated specimen; locality S254. USNM 624479.
5. Transverse section of a moderately inflated specimen; locality S227. USNM 624480.
6. Transverse section of a highly inflated specimen; locality S319. USNM 624481.

7–11. *Pellatispira orbitoidea* (Provale) (p. 333).

7. External view of a selliform specimen; locality S188. USNM 624482.
8. External view of a flat, moderately inflated specimen; locality S100. USNM 624483.
9. External views of umbonate, selliform specimens; locality S259. USNM 624745.
10. External views of selliform specimens; locality S259. USNM 624484.
11. External views of highly inflated specimens; locality S188. USNM 624485.

PLATE 100

FIGURES 1–3. *Biplanispira mirabilis* (Umbgrove) (p. 334).

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2. Transverse section of a thick lenticular specimen; locality S254. USNM 624487.
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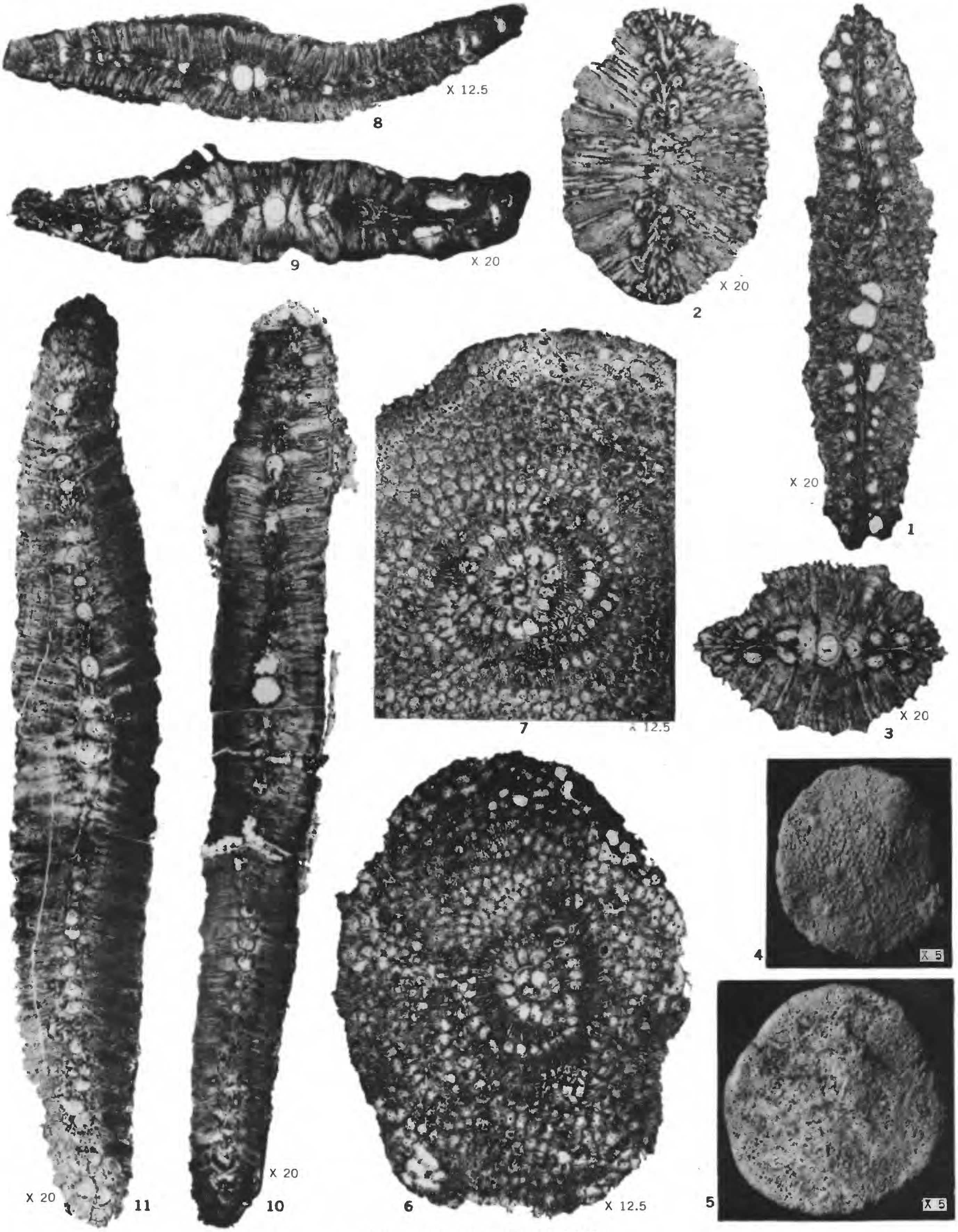
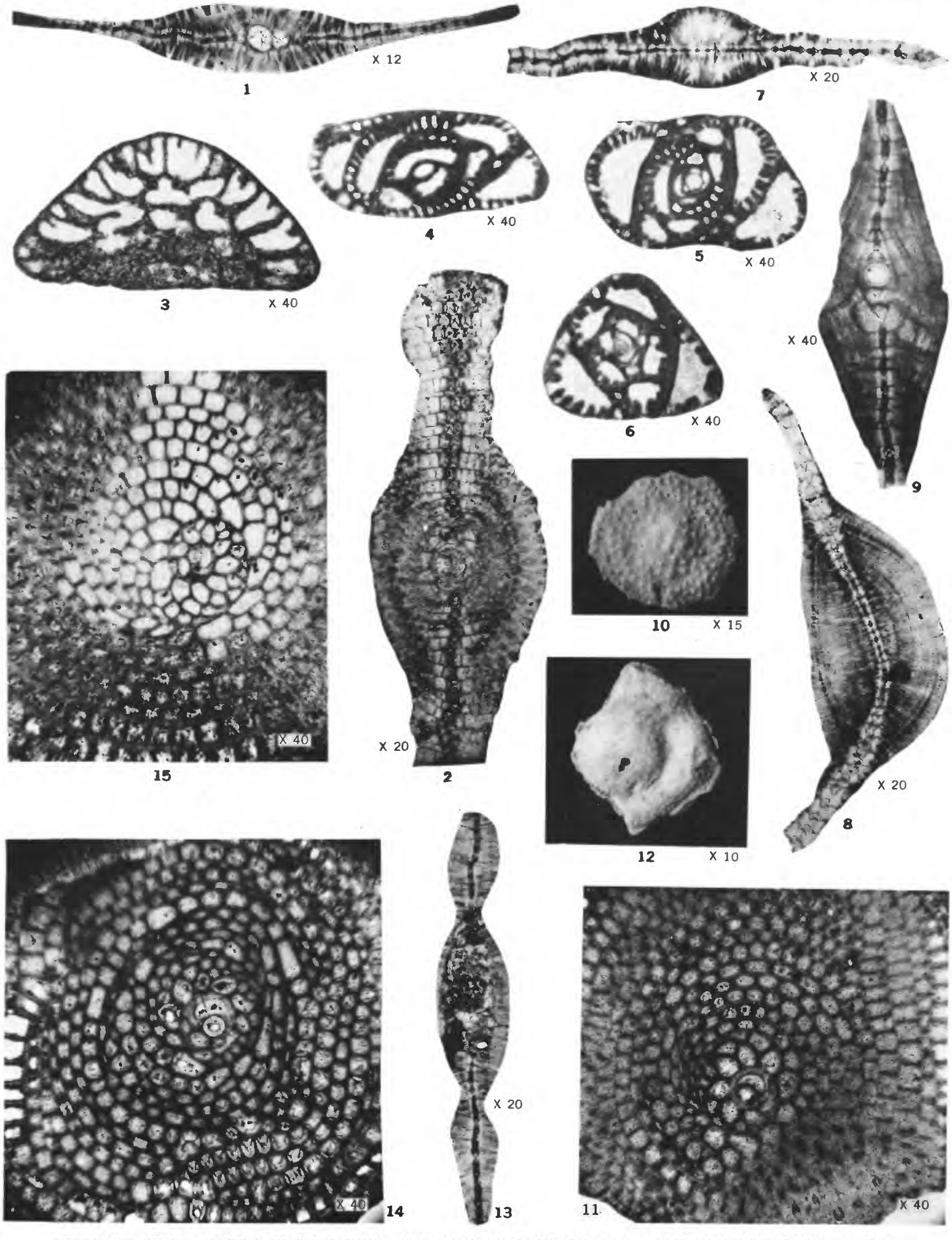
4, 5. External views; locality S134. USNM 624489.
6, 7. Equatorial sections; locality S134. USNM 624490.
8–11. Transverse sections.
8. Locality S100. USNM 624491.
9. Locality S259. USNM 624492.
10, 11. Locality S134. USNM 624493.



UPPER EOCENE *BIPLANISPIRA*



UPPER EOCENE *DICTYOCONUS*, LOWER MIOCENE *AUSTROTRILLINA*, AND LOWER MIOCENE AND PLEISTOCENE *CYCLOCLYPEUS*

PLATE 101

FIGURES 1, 2. *Cycloclypeus* (*Cycloclypeus*) *carpenteri* Brady (p. 334).
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2. Oblique equatorial section; locality B294. USNM 624495.

3. *Dictyoconus saipanensis* Cole, n. sp. (p. 329).
Axial section of the holotype; locality B176. USNM 624496.

4–6. *Austrotrillina howchini* (Schlumberger) (p. 329).
4, 5. Locality B170. USNM 624497.
6. Locality S312. USNM 624498.

7, 8. *Cycloclypeus* (*Cycloclypeus*) *indopacificus* Tan (p. 334).
7. Vertical section nearly centered; locality B323. USNM 624499.
8. Oblique equatorial section; locality B400. USNM 624500.

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9. Vertical section; locality S701. USNM 624501.
10. External view; locality S701. USNM 624502.
11. Part of an equatorial section to show the embryonic and periembryonic chambers; locality S701. USNM 624503.

12–14. *Cycloclypeus* (*Katacycloclypeus*) *transiens* Tan (p. 335).
12. External view; locality S701. USNM 624504.
13. Vertical section; locality S704. USNM 624505.
14. Part of an equatorial section to show the embryonic and periembryonic chambers; locality S701. USNM 624506.

15. *Cycloclypeus* (*Cycloclypeus*) *eidae* Tan (p. 334).
Part of an equatorial section; locality S672. USNM 624507.

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Longitudinal section; locality S88. USNM 624508.

2, 3. *Planorbulinella larvata* (Parker and Jones) (p. 337).
2. Transverse section; locality S227. USNM 624509.
3. Transverse section; locality S311. USNM 624510.

4–6. *Eorupertia plecte* (Chapman) (p. 337).
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5. Longitudinal section of a specimen with inflated terminal chambers; locality S254. USNM 624512.
6. Part of a specimen to show the wall structure; locality S214. USNM 624513.

7–9. *Fabiania saipanensis* Cole (p. 337).
7. Section parallel to the outer surface to show the chamberlets; locality S133. USNM 624514.
8. Transverse section through the embryonic chambers; locality S223. USNM 624515.
9. Transverse section not centered; locality S189. USNM 624746.

10, 11. *Halkyardia bikiniensis* Cole (p. 336).
10. Transverse section not centered; locality S338. USNM 624516.
11. Transverse section through the embryonic chambers; locality S318. USNM 624517.

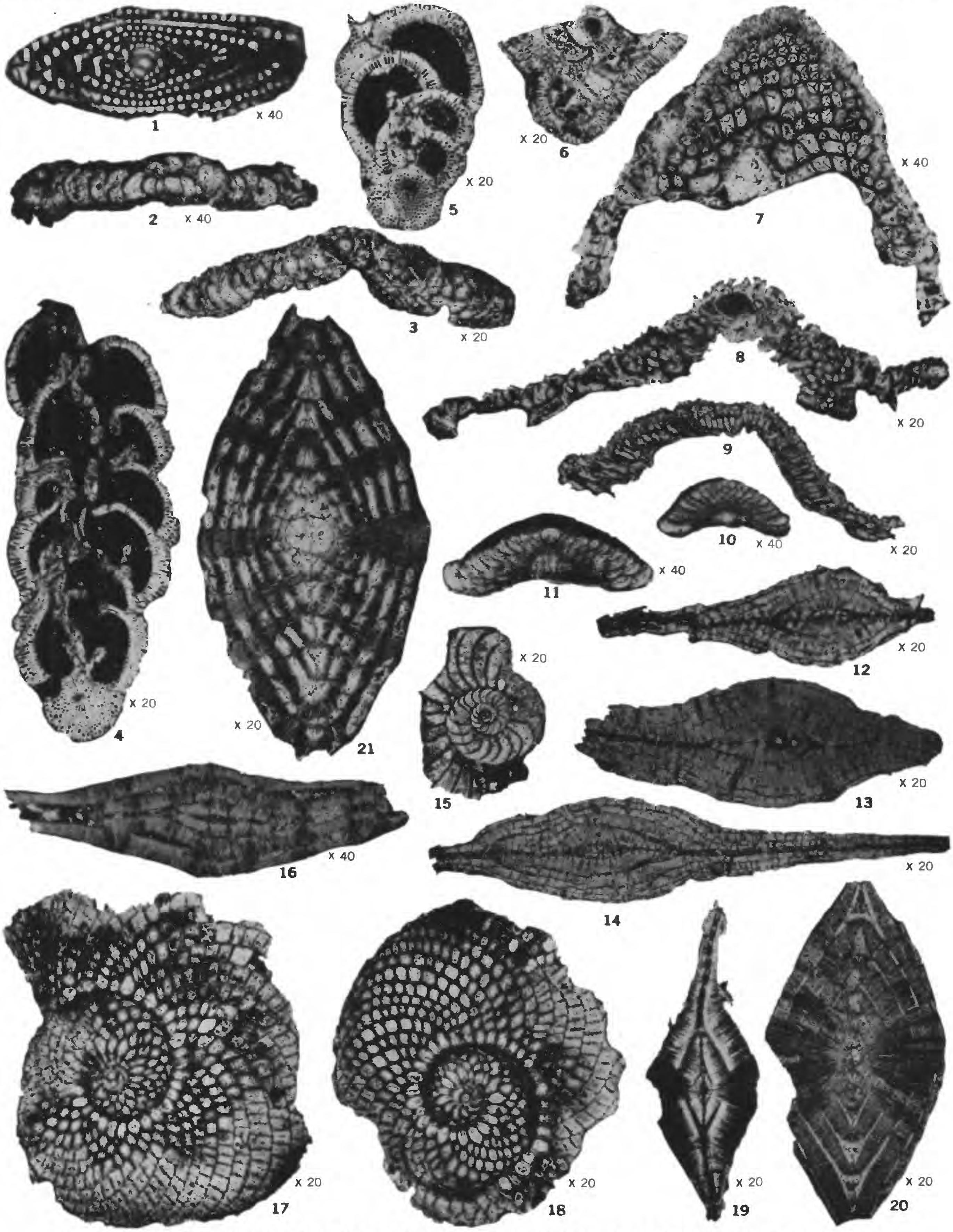
12–14. *Spiroclypeus vermicularis* Tan (p. 333).
12. Transverse section; locality S271. USNM 624518.
13. Transverse section; locality S290. USNM 624519.
14. Transverse section; locality S170. USNM 624520.

15, 16. *Operculinoides saipanensis* Cole, n. sp. (p. 331).
15. Median section of the holotype; locality S271. USNM 624521.
16. Transverse section of a paratype; locality S79*b*. USNM 624522.

17–19. *Heterostegina saipanensis* Cole (p. 331).
17, 18. Median sections; locality S259. USNM 624523.
19. Transverse section; locality S259. USNM 624524.

20. *Camerina saipanensis* Cole (p. 330).
Transverse section; locality S132. USNM 624525.

21. *Camerina djokdjokarta* (Martin) (p. 329).
Transverse section; locality S341. USNM 624526.



UPPER EOCENE *BORELIS, CAMERINA, EORUPERTIA, FABIANIA, HALKYARDIA, HETEROSTEGINA, OPERCULINOIDES, PLANORBULINELLA*, AND *SPIROCLYPEUS*

UPPER EOCENE AND LOWER MIOCENE *EORUPERTIA* AND LOWER MIOCENE *ARCHAIAS*, *MARGINOPORA*, *STREBLUS*, AND *GYPSINA*

PLATE 103

FIGURES 1–4. *Gypsina marianensis* Hanzawa (p. 337).

All transverse sections.

1. Locality B237. USNM 624527.
2. Locality B254. USNM 624528.
3. Locality B244. USNM 624529.
4. Locality B238. USNM 624530.

5–9. *Archaias vandervlerki* De Neve (p. 335).

5. Embryonic chambers; locality S85. USNM 624531.
6, 7. Median section; locality S85. USNM 624532.
8. Transverse section; locality S165. USNM 624533.
9. Transverse section; locality S165. USNM 624534.

10. *Eorupertia boninensis* (Yabe and Hanzawa) (p. 337).

Longitudinal section of a topotype specimen from Oki-mura, Haha-jima (Hillsborough island), Bonin group, introduced for comparison with the Saipan specimens; gift of Dr. S. Hanzawa. USNM 624535.

11–16. *Eorupertia semiornata* (Howchin) (p. 338).

11. Locality B224. USNM 624536.
12. Locality S667. USNM 624537.
13. Locality B50. USNM 624538.
14. Locality C16. USNM 624539.
15. Locality B79. USNM 624540.
16. Locality S667. USNM 624541.

17, 18. *Streblus saipanensis* Cole (p. 338).

17. Transverse section; locality C140. USNM 624542.
18. Median section; locality S667. USNM 624543.

19, 20. *Marginopora vertebralis* Quoy and Gaimard (p. 335).

19. Transverse section; locality C113. USNM 624544.
20. Part of a median section; locality C113. USNM 624545.

PLATE 104

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1, 2. Vertical sections of microspheric individuals; locality B214. USNM 624546.

3. Vertical section of a small, nearly globular megalospheric individual; locality B246. USNM 624547.

4. Oblique vertical section; locality B247. USNM 624548.

5. Vertical section of a specimen with a wide rim; locality B310. USNM 624549.

6. Vertical section to show pillars which are present in some specimens; locality B101. USNM 624550.

7. Vertical section of a specimen with thin floor and roofs to the lateral chambers; locality S701. USNM 624551.

8. Vertical section of a compressed specimen; locality B247. USNM 624552.

9. Vertical section of a specimen with thin, strongly arched roofs and floors to the lateral chambers; locality B341. USNM 624553.

10–17. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth (p. 343).

Vertical sections of megalospheric individuals showing the different degrees that pillars are developed.

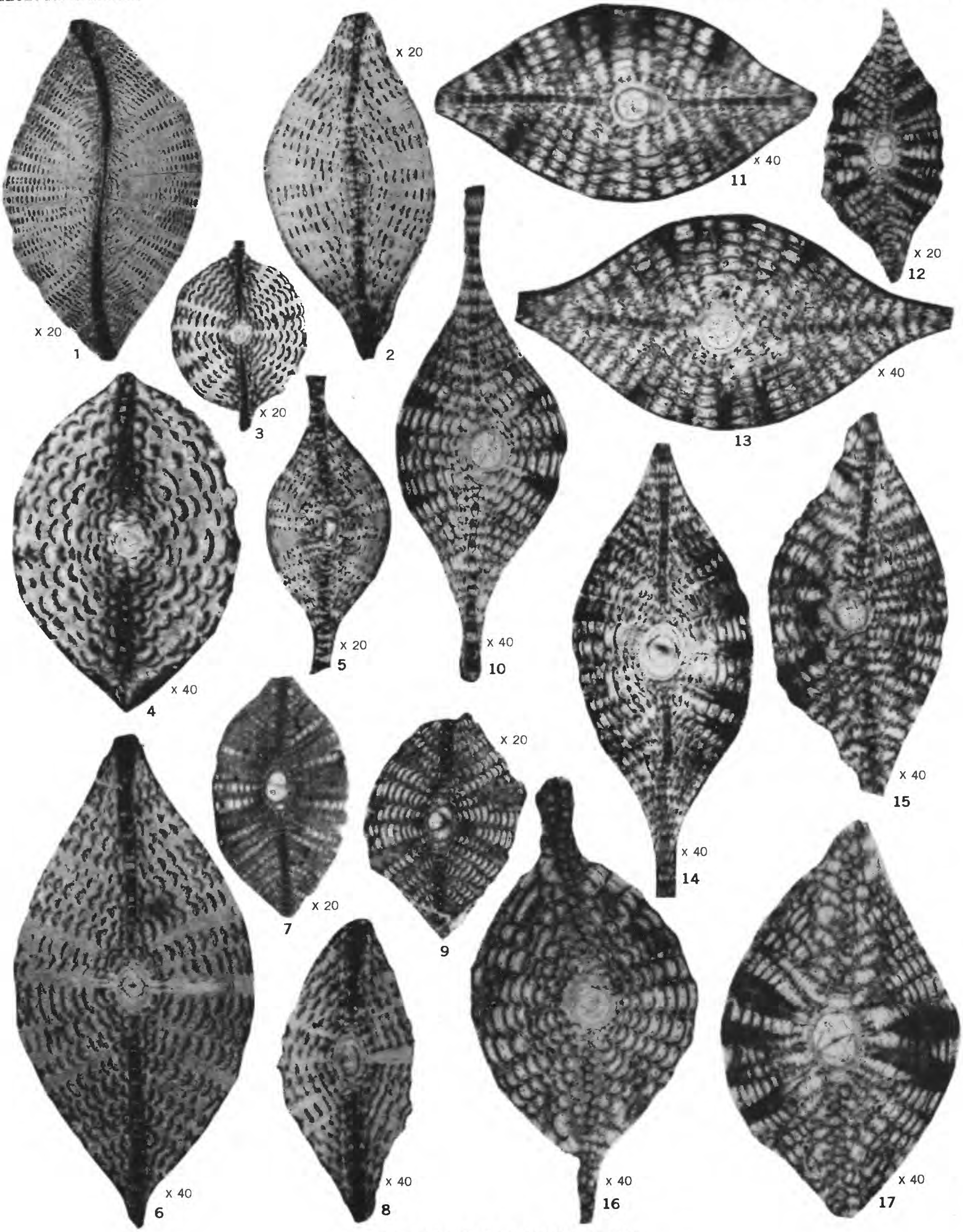
10. Locality B279. USNM 624554.

11, 13–15. Locality B103. USNM 624555.

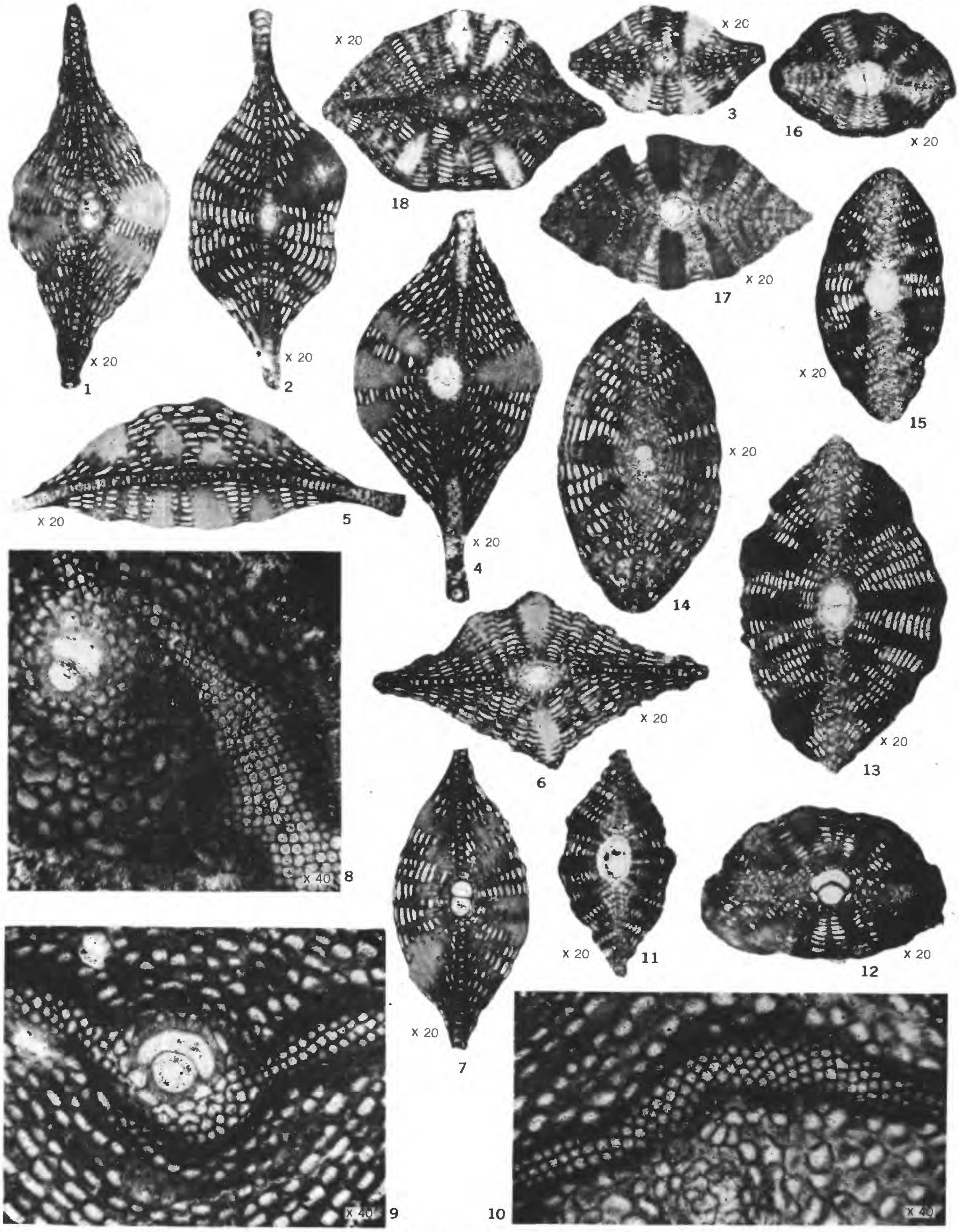
12. Locality B126. USNM 624556.

16. Locality B400. USNM 624557.

17. Locality B138. USNM 624558.



LOWER MIOCENE *LEPIDOCYCLINA*



LOWER MIOCENE *LEPIDOCYCLINA*

PLATE 105

FIGURES 1–10. *Lepidocyclina* (*Nephrolepidina*) *brouweri* L. Rutten (p. 342).

1–7. Vertical sections of megalospheric specimens showing the variation which occurs in this species.

1. Locality C102. USNM 624559.
2. Locality B419. USNM 624560.
3. Locality B315. USNM 624561.
4. Locality B357. USNM 624562.
5. Locality B420. USNM 624563.
6. Locality C102. USNM 624564.
7. Locality B420. USNM 624565.

8–10. Parts of slightly oblique equatorial sections to show the embryonic and equatorial chambers.

8. Locality C102. USNM 624566.
9. Locality B362. USNM 624567.
10. Locality C102. USNM 624568.

11–17. *Lepidocyclina* (*Nephrolepidina*) *verrucosa* Scheffen (p. 345).

11–17. Vertical sections of megalospheric specimens showing the variation which occurs in this species.

11. Locality B261. USNM 624569.
12. Locality B394. USNM 624570.
13. Locality C140. USNM 624571.
14. Locality B320. USNM 624572.
15. Locality C132. USNM 624573.
16. Locality B177. USNM 624574.
17. Locality S701. USNM 624575.

18. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (Brady) (p. 343).

Vertical section of specimen introduced for comparison with the other species; locality B320. USNM 624576.

PLATE 106

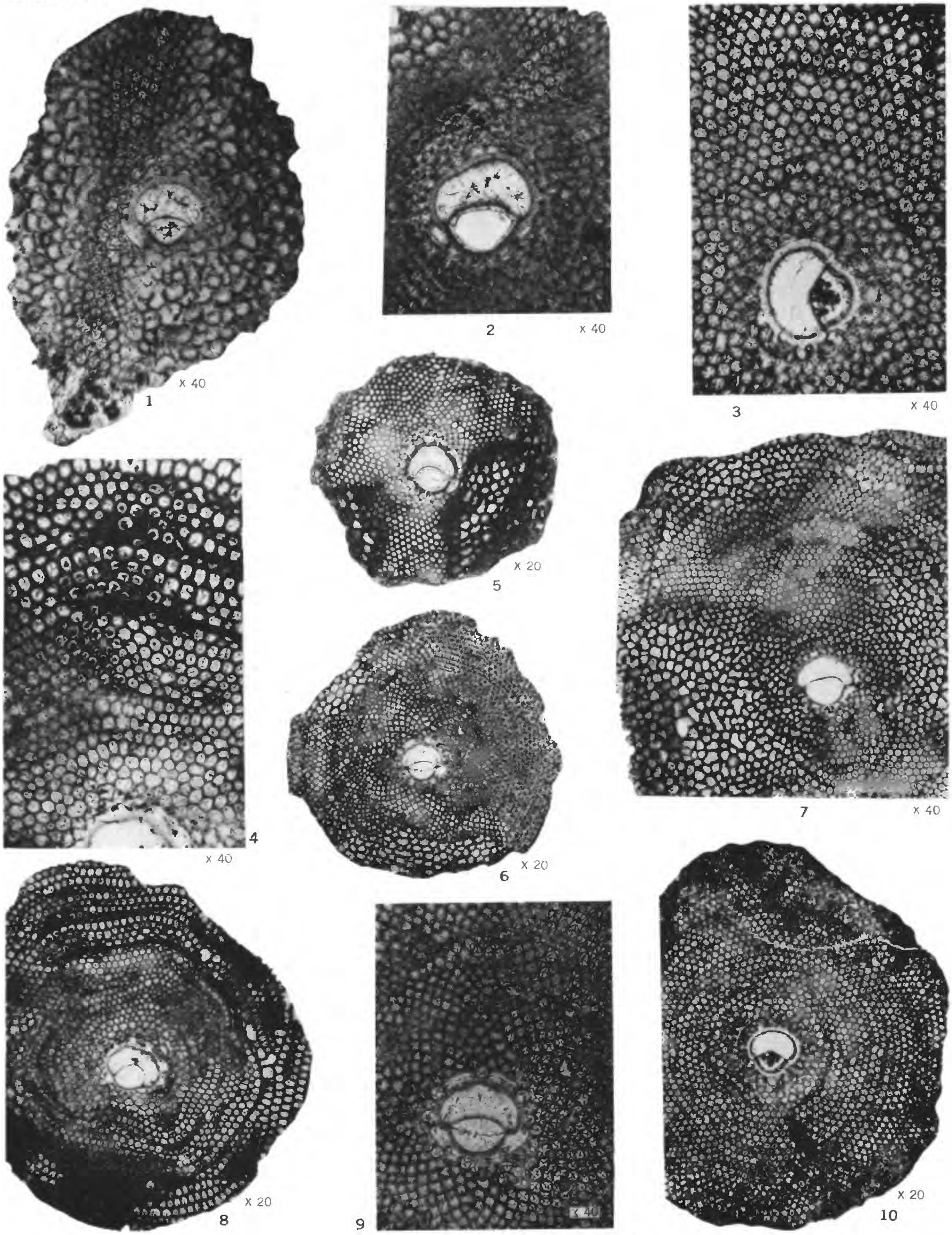
FIGURES 1–3, 6, 7, 9, 10. *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton and Holland (p. 344).

1. Slightly oblique equatorial section; locality B136. USNM 624577.
2. Part of an equatorial section showing the embryonic and equatorial chambers; locality B373. USNM 624578.
3. Enlargement of the central part of the equatorial section, figure 10, to show the embryonic and equatorial chambers, introduced for comparison with the Saipan specimens; same locality as figure 10. USNM 624580.
6. Equatorial section; locality B138. USNM 624579.
7. Part of an equatorial section of a topotype specimen from the U. S. National Museum collection from the "coral-limestone, Padang Highlands, West-Coast District, Sumatra" introduced for comparison. USNM 544990.
9. Enlargement of the central portion of the specimen illustrated as figure 6. USNM 624579.
10. Part of an equatorial section of a specimen identified by Dr. S. Hanzawa and presented by him to the writer; Kaizan beds, Pinaikô, Sansikyaku, Ôka-syô, Kaizan-gun, Taihoku Prefecture, Formosa. USNM 624580.

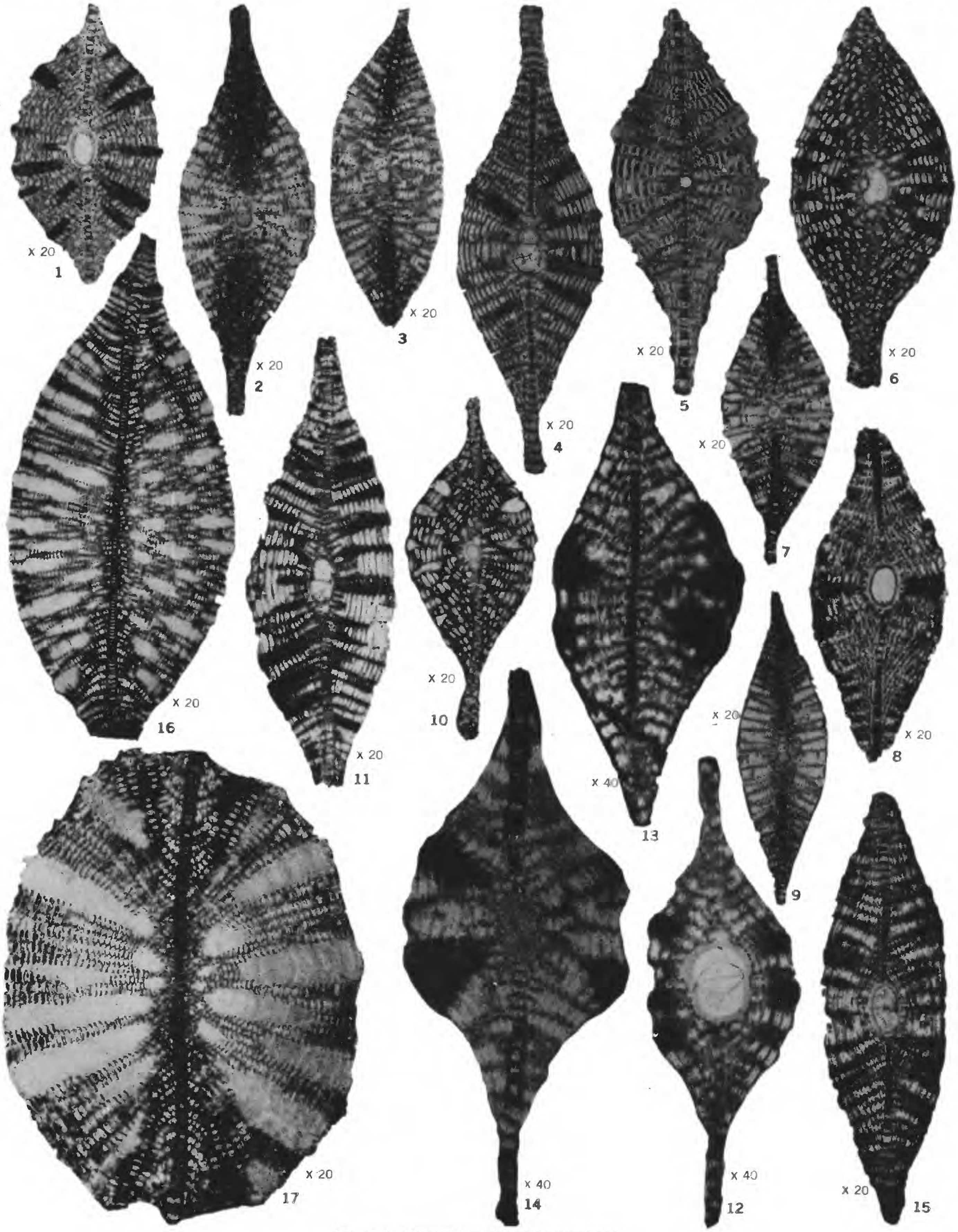
4, 8. *Lepidocyclina* (*Nephrolepidina*) *nipponica* Hanzawa (p. 345).

4. Enlargement of a part of the equatorial section, figure 8, showing the shape of the equatorial chambers, introduced for comparison with *L. verbeeki*. USNM 624581.
8. Part of an equatorial section collected and presented by Dr. H. Schenck; Shimo-shiraiwa, Shimo-omimura, Takota-gun, Shizuoka Prefecture, Japan. USNM 624581.

5. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (Brady) (p. 343).
Equatorial section; locality B413. USNM 624582.



LOWER MIOCENE *LEPIDOCYCLINA*



LOWER MIOCENE *LEPIDOCYCLINA*

PLATE 107

FIGURES 1–12, 16. *Lepidocyclina* (*Nephrolepidina*) *verbeeki* Newton and Holland p. 344).

1. Vertical section; locality C131. USNM 624583.
2, 3. Vertical sections; locality B312. USNM 624584.
4. Vertical section; locality B135. USNM 624585.
5. Vertical section; locality B161. USNM 624586.
6. Slightly oblique vertical section; locality B373. USNM 624587.
7. Vertical section; locality B138. USNM 624588.
8. Vertical section of a specimen identified by Dr. S. Hanzawa and presented to the writer, introduced for comparison; Kaizan beds, Pinaikô, Sansikyaku, Ôka-syô, Kaizan-gun, Taihoku Prefecture, Formosa. USNM 624589.
9. Vertical section; locality B138. USNM 624590.
10. Vertical section of a specimen with extremely thin floors and roofs to the lateral chambers; locality B29*a*. USNM 624591.
11. Vertical section of a topotype specimen from "coral-limestone, Padang Highlands, West-Coast District, Sumatra," introduced for comparison. USNM 544990.
12. Vertical section of small, not fully developed specimen; locality B3. USNM 624592.
16. Vertical section of a microspheric specimen with numerous, rather strong pillars; locality B138. USNM 624593.

13, 14. *Lepidocyclina* (*Nephrolepidina*) *angularis* Newton and Holland (p. 342).

13. Vertical section of specimen presented to the writer by the late Dr. Vaughan, introduced for comparison; Sekihekiryô in Daiamryô, Dojô-shô, Kaizan-gun, Taihoku Prefecture, Formosa. USNM 624594.
14. Vertical section; locality B162. USNM 624595.

15. *Lepidocyclina* (*Nephrolepidina*) *nipponica* Hanzawa (p. 345).

Vertical section introduced for comparison with *L. verbeeki*, collected and presented by Dr. H. Schenck; Shimo- shiroiwa, Shimo-ômi-mura, Tagata-gun, Shizuoka Prefecture, Japan. USNM 624596.

17. *Lepidocyclina* (*Nephrolepidina*) *parva* Oppenoorth (p. 343).

Vertical section of a microspheric individual; locality B303. USNM 624597.

PLATE 108

FIGURES 1–3. *Lepidocyclina* (*Eulepidina*) *badjirraensis* Crespin (p. 345).

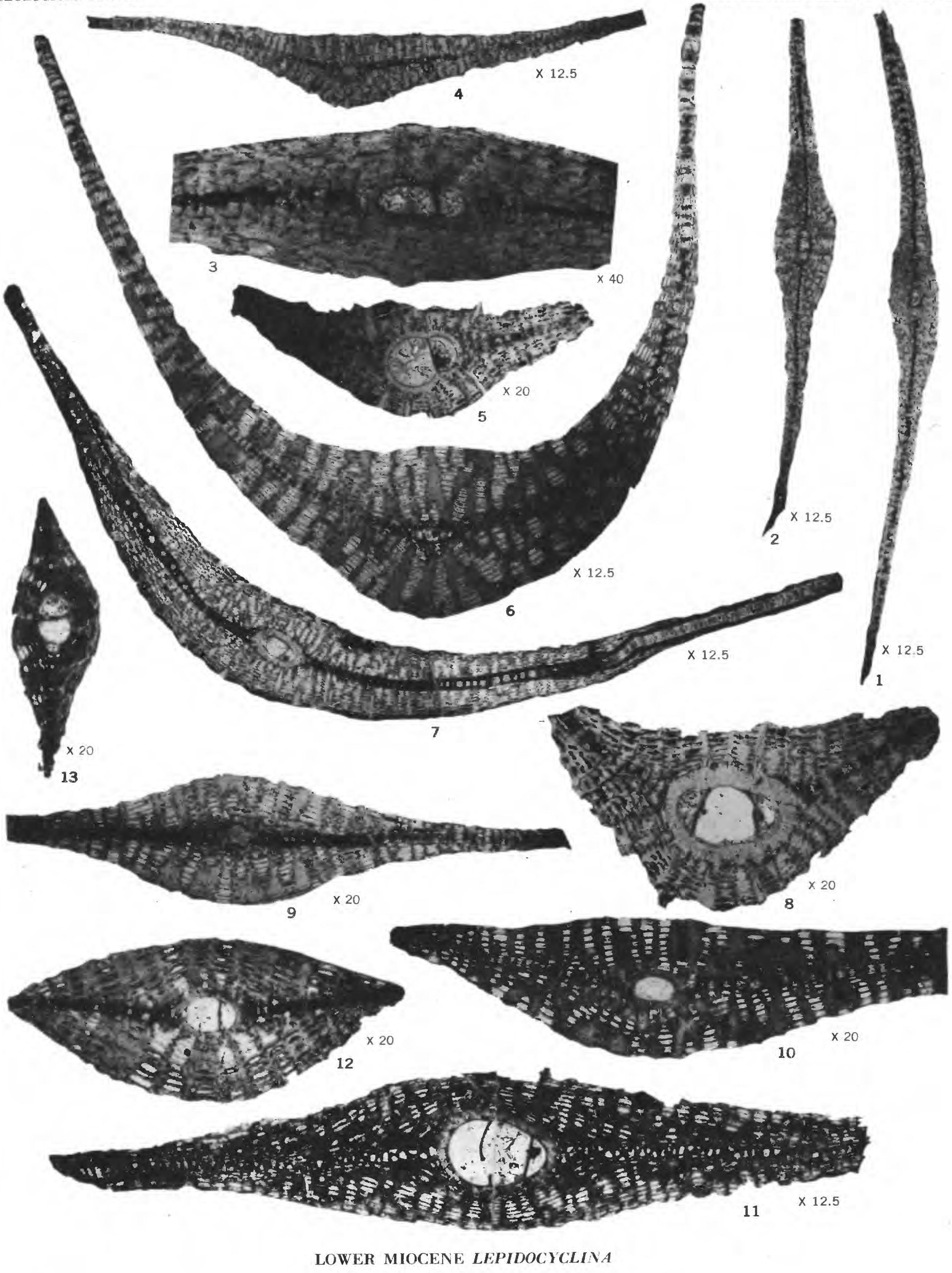
1, 2. Vertical sections; Saipan, locality unknown. USNM 624598.

3. Part of a vertical section showing the embryonic chambers and the low oppressed lateral chambers; Saipan, locality unknown. USNM 624599.

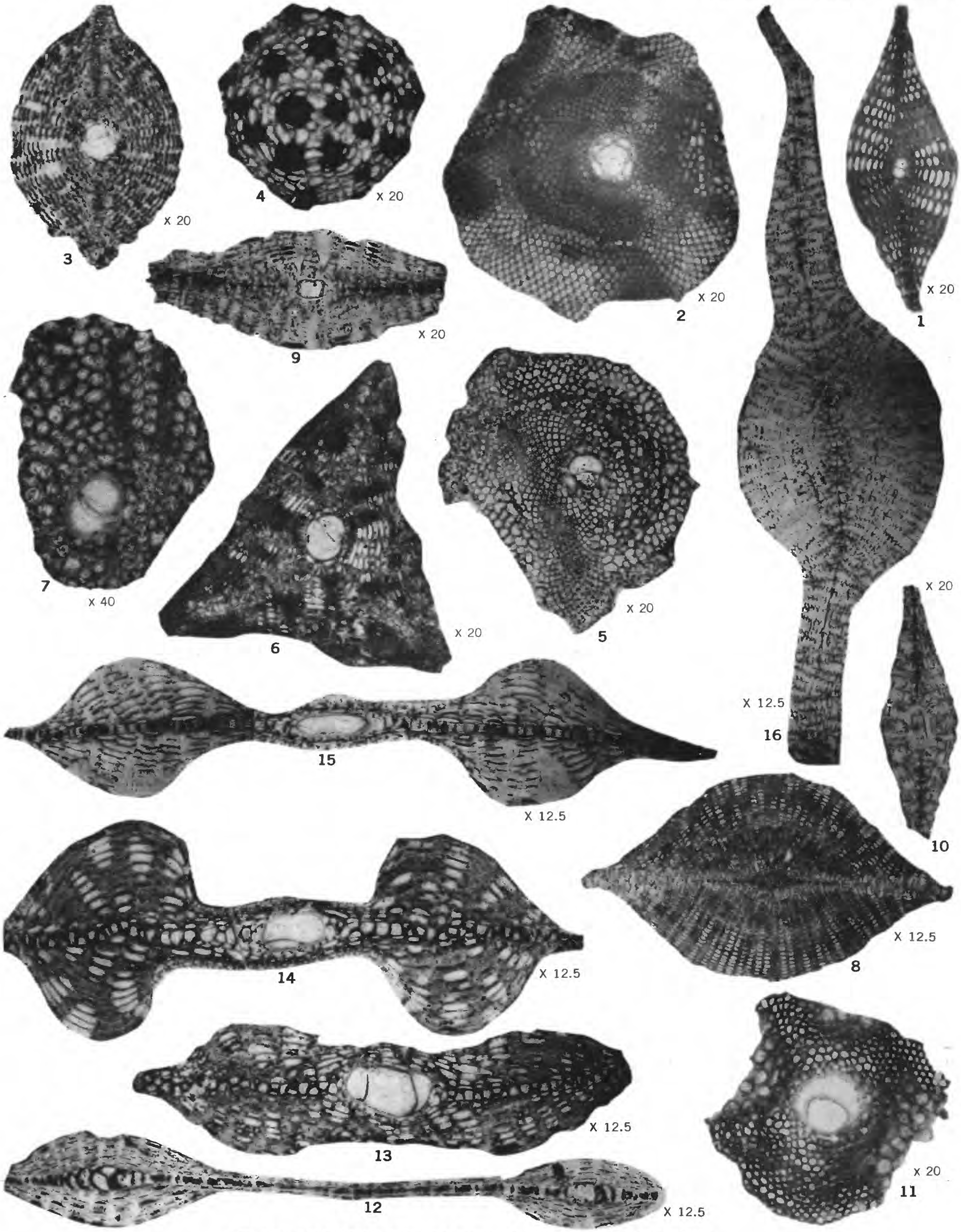
4–13. *Lepidocyclina* (*Eulepidina*) *ephippioides* Jones and Chapman (p. 346).

Vertical sections to show the great variation in size and shape.

4. Locality B166. USNM 624600.
5. Locality B166. USNM 624601.
6. Locality S164. USNM 624602.
7. Locality S585. USNM 624603.
8. Locality B303. USNM 624604.
9. Locality S203. USNM 624605.
10. Locality B281. USNM 624606.
11. Locality S674. USNM 624607.
12, 13. Locality S672. USNM 624608.



LOWER MIOCENE *LEPIDOCYCLINA*



LOWER MIOCENE *LEPIDOCYCLINA* AND *SPIROCLYPEUS*

PLATE 109

FIGURES 1–3. *Lepidocyclina (Nephrolepidina) sumatrensis* (Brady) (p. 343).

1. Vertical section of a compressed specimen with open lateral chambers; locality S701. USNM 624609.
2. Equatorial section; locality S701. USNM 624610.
3. Vertical section of an inflated specimen with low lateral chambers; locality B261. USNM 624611.

4–6. *Lepidocyclina (Nephrolepidina) verrucosa* Scheffen (p. 345).

4. Section parallel to the equatorial plane showing distribution of the pillars; locality B391. USNM 624612.
5. Equatorial section slightly oblique; locality B391. USNM 624613.
6. Vertical section of a trigonal specimen; locality B395. USNM 624614.

7, 8. *Lepidocyclina (Nephrolepidina) verbeeki* Newton and Holland (p. 344).

7. Equatorial section of a specimen of the type illustrated by figure 12, plate 107; locality B3. USNM 624615.
8. Vertical section of a microspheric specimen; locality B1. USNM 624616.

9, 10. *Lepidocyclina (Eulepidina) badjirraensis* Crespin (p. 345).

Vertical sections; locality B284. USNM 624617.

11–15. *Lepidocyclina (Eulepidina) ephippioides* Jones and Chapman (p. 346).

11. Equatorial section of a small specimen; locality S672. USNM 624618.

12–15. Vertical sections of irregularly developed specimens.

12. Locality B155. USNM 624619.
13. Locality B55. USNM 624620.
14. Locality B281. USNM 624621.
15. Locality B290. USNM 624622.

16. *Spiroclypeus higginsi* Cole (p. 332).

Transverse section of a microspheric specimen; locality B136. USNM 624623.

PLATE 110

FIGURES 1–4. *Flosculinella globulosa* L. Rutten (p. 336).

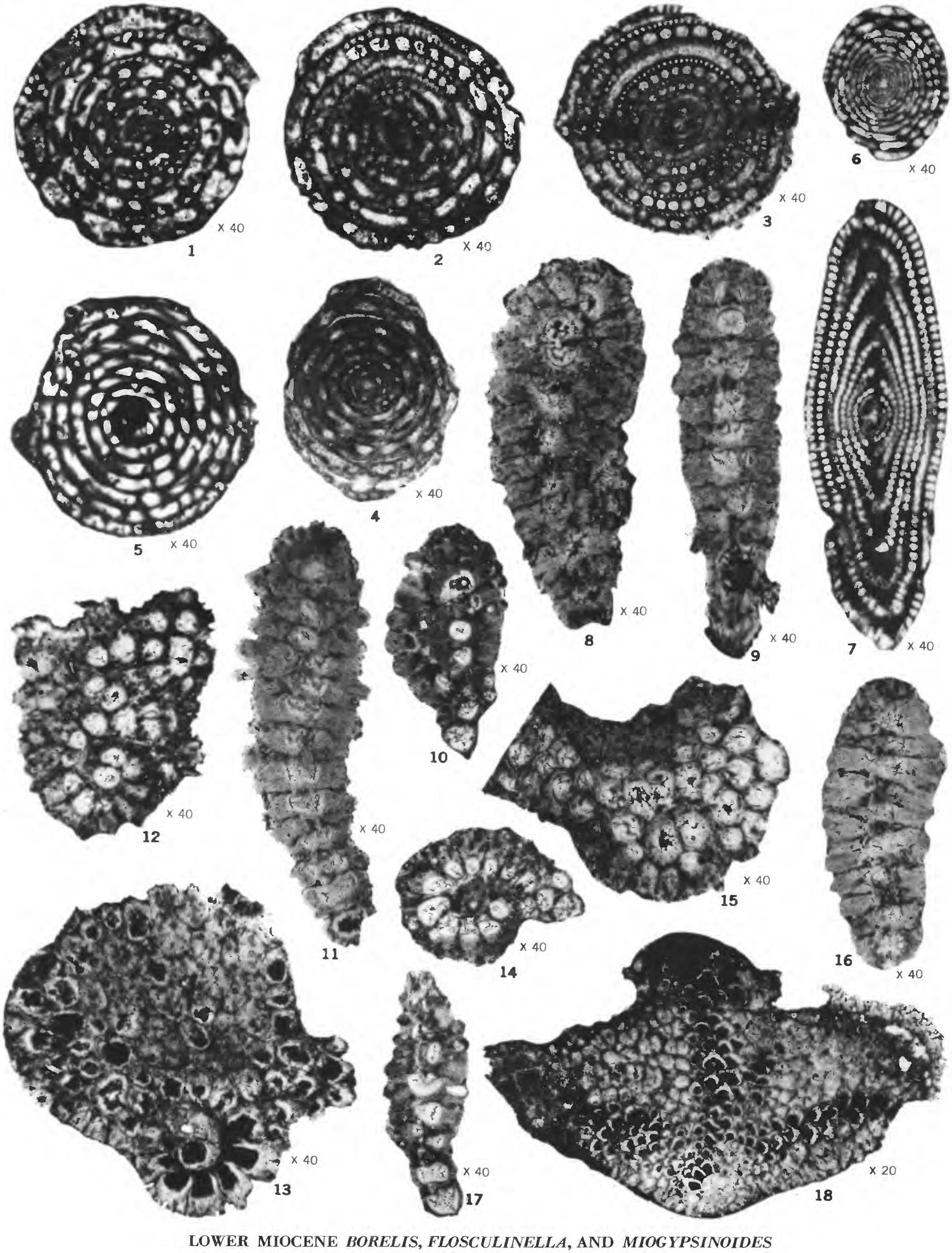
1. Transverse section; locality B342. USNM 624624.
2. Axial section; locality C89. USNM 624625.
3. Axial section; locality B413. USNM 624626.
4. Transverse section; locality B413. USNM 624627.

5–7. *Borelis pygmaeus* Hanzawa (p. 336).

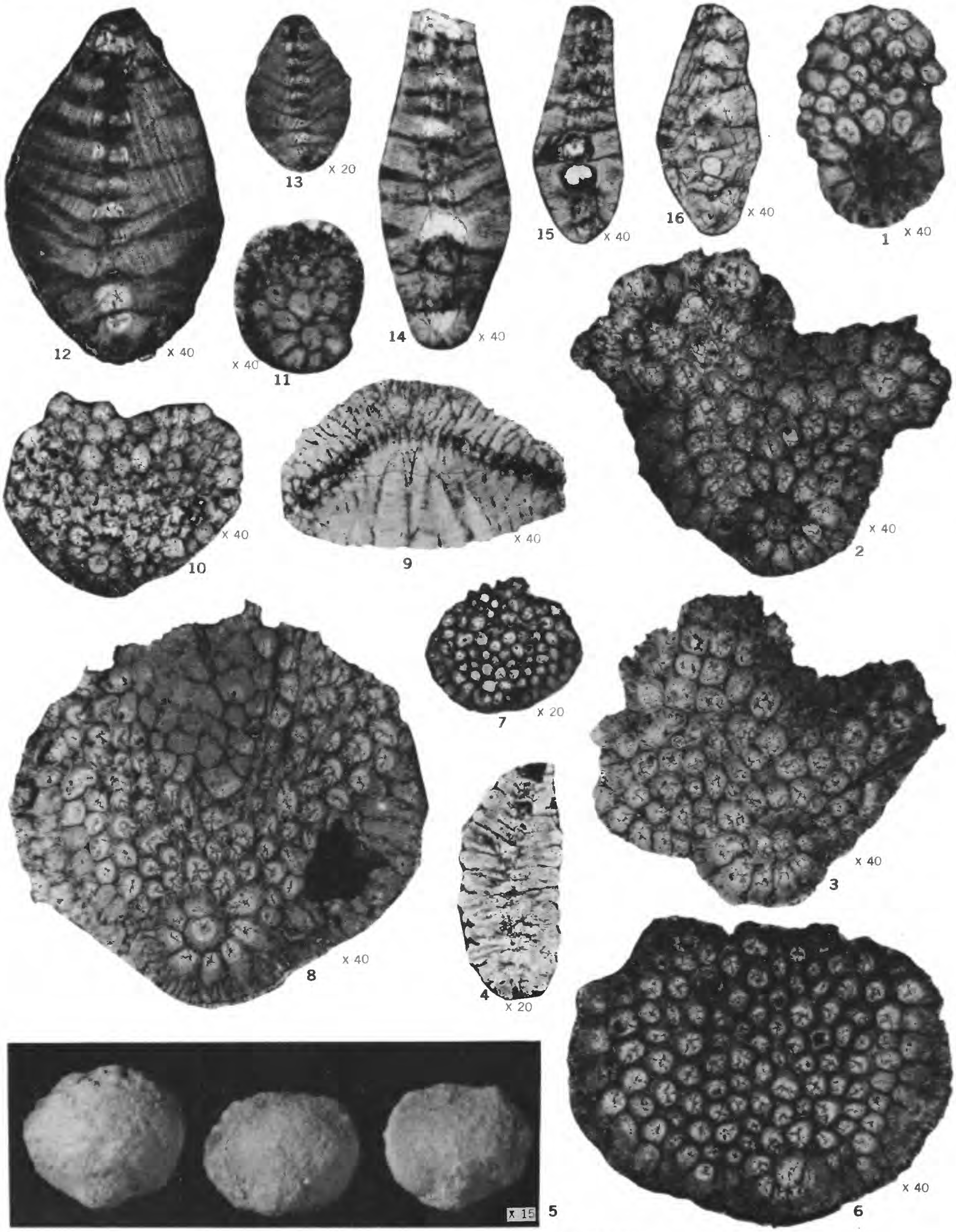
5. Transverse section; locality B170. USNM 624628.
6. Transverse section; locality B423. USNM 624629.
7. Axial section; locality B312. USNM 624630.

8–18. *Miogypsinoides bantamensis* Tan (p. 338).

8. Vertical section; locality B316. USNM 624631.
9. Vertical section; locality B301. USNM 624632.
10. Vertical section; locality B224. USNM 624633.
11. Vertical section; locality B301. USNM 624634.
12. Equatorial section to show the embryonic, periembryonic and equatorial chambers; locality B391. USNM 624635.
13. Equatorial section; locality B316. USNM 624636.
14. Equatorial section; locality B224. USNM 624637.
15. Equatorial section; locality B391. USNM 624638.
16. Vertical section; locality B391. USNM 624639.
17. Vertical section; locality B224. USNM 624640.
18. Equatorial section of a microspheric specimen; locality B395. USNM 624641.



LOWER MIOCENE *BORELIS*, *FLOSCULINELLA*, AND *MIOGYPSINOIDES*



LOWER MIOCENE *MIOGYPSINOIDES*

PLATE 111

FIGURES 1–4. *Miogypsinoides bantamensis* Tan (p. 338).

1. Equatorial section of a microspheric specimen; locality B224. USNM 624642.

2, 3. Equatorial sections of megalospheric specimens to illustrate the embryonic, periembryonic, and equatorial chambers; locality B391. USNM 624643.

4. Vertical section, not centered, to illustrate the pillars; locality B225. USNM 624644.

5–16. *Miogypsinoides dehaartii* (Van der Vlerk) (p. 339).

5. External views of three megalospheric specimens; locality S701. USNM 624645.

6. Equatorial section of a megalospheric specimen; locality S701. USNM 624646.

7. Equatorial section of a megalospheric specimen; locality S701. USNM 624647.

8. Equatorial section of a megalospheric specimen; locality B15. USNM 624648.

9. Oblique vertical section of a probable microspheric specimen to illustrate strong pillars; locality B2. USNM 624649.

10, 11. Equatorial sections of topotype specimens of *Miogypsinoides formosensis* Yabe and Hanzawa illustrating embryonic and equatorial chambers; Sekihekiryo in Taihoku Prefecture, Formosa. USNM 624650.

12. Vertical section of a megalospheric specimen; locality S701. USNM 624651.

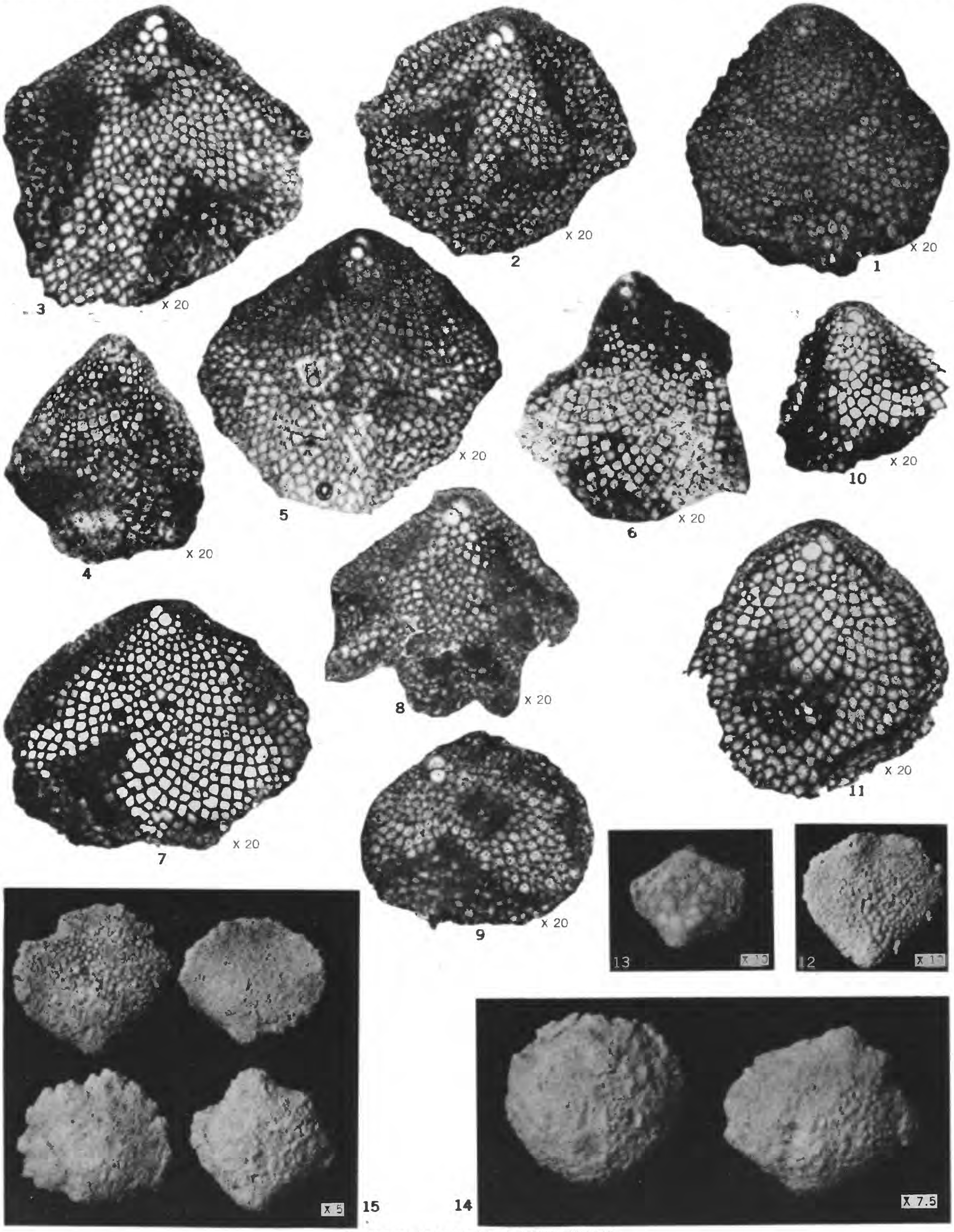
13. Vertical section of a megalospheric specimen; locality S701. USNM 624652.

14–16. Vertical sections of topotype specimens of *Miogypsinoides formosensis* Yabe and Hanzawa; same locality as figures 10, 11. USNM 624653.

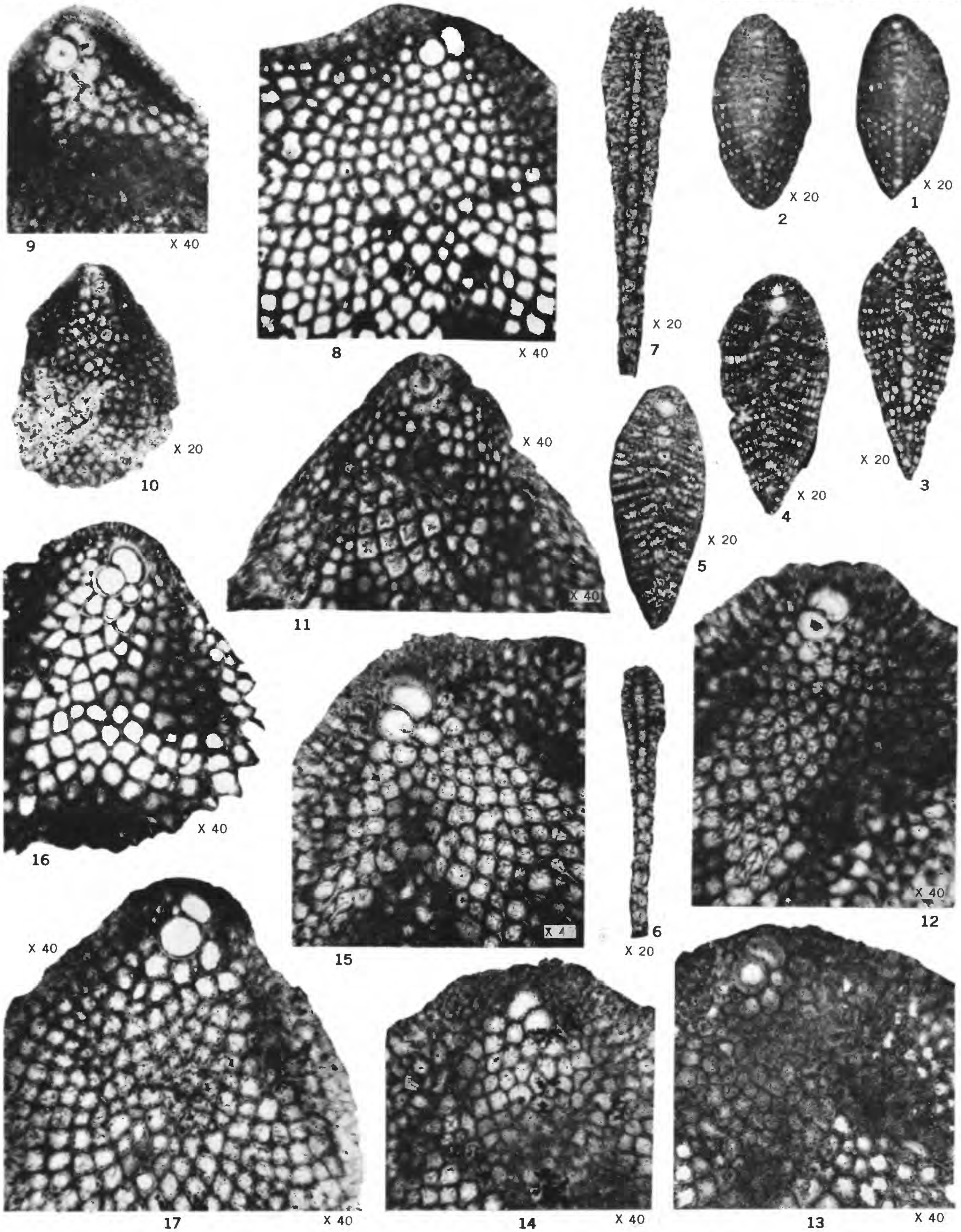
PLATE 112

FIGURES 1–15. *Miogypsina* (*Miogypsina*) *thecideaeformis* (L. Rutten) (p. 340).

1. Equatorial section of a specimen with rudely hexagonal equatorial chambers near the distal margin; locality S701. USNM 624654.
2. Equatorial section, an enlargement of part of which is illustrated as figure 15, plate 113; locality S701. USNM 624679.
3. Equatorial section illustrating the shape of the equatorial chambers; locality S701. USNM 624655.
4. Equatorial section, an enlargement of part of which is illustrated as figure 11, plate 113; locality B413. USNM 624675.
5. Equatorial section; locality S701. USNM 624656.
6. Equatorial section to illustrate the shape of the distal equatorial chambers; locality B413. USNM 624657.
7. Equatorial section, an enlargement of part of which is illustrated as figure 8, plate 113; locality S701. USNM 624672.
8. Equatorial section of a specimen with a digitate distal margin; locality S701. USNM 624658.
9. Equatorial section of a specimen with a rounded proximal margin; locality S701. USNM 624659.
10. Equatorial section of a probable topotype specimen of *M.* (*M.*) *thecideaeformis*, an enlargement of part of which is illustrated as figure 16, plate 113; Balik-Papan, East Borneo. USNM 624660.
11. Equatorial section of a specimen called *M.* (*M.*) *kotoi* Hanzawa for comparison; Inokosi, Kayamaiti, Koyamamur, Kawakanir-gun, Okayama Prefecture, Japan. USNM 624661.
12. External view of a specimen with small pillars; locality B413. USNM 624662.
13. External view of a specimen with few, large pillars; locality B413. USNM 624663.
14. External view of two weathered, rather thick specimens; locality S701. USNM 624664.
15. External view of four thin specimens; locality S701. USNM 624665.



LOWER MIOCENE *MIOGYPSINA*



LOWER MIOCENE *MIOGYPSINA*

PLATE 113

FIGURES 1–17. *Miogypsina (Miogypsina) thecideaeformis* (L. Rutten) (p. 340).

1–5. Vertical sections of megalospheric specimens.

1, 2, 4, 5. Locality S701. USNM 624666–624669.

3. Locality B187. USNM 624670.

6, 7. Vertical sections not centered, of probable microspheric specimens; locality C121. USNM 624671.

8. Part of an equatorial section illustrating the embryonic, periembryonic, and equatorial chambers; locality S701. USNM 624672.

9. Part of an equatorial section of a specimen similar to the one whose vertical section is illustrated as figure 1, plate 114; locality B413. USNM 624673.

10. Part of an equatorial section of a specimen similar to the one whose vertical section is illustrated as figure 15, plate 114; locality B413. USNM 624674.

11. Part of an equatorial section; locality B413. USNM 624675.

12–15. Parts of equatorial sections; locality S701. USNM 624676–624679.

16. Part of an equatorial section of a probable topotype specimen of *M.* (*M.*) *thecideaeformis* for comparison with the Saipan specimens; Balik-Papan, East Borneo. USNM 624660.

17. Part of an equatorial section of a specimen called *M.* (*M.*) *kotoi* Hanzawa for comparison; Inokosi, Kayamaiti, Koyama-mur, Kawakanir-gun, Okayama Prefecture, Japan. USNM 624680.

PLATE 114

FIGURES 1–20. *Miogypsina* (*Miogypsina*) *thecideaeformis* (L. Rutten) (p. 340).

1. Vertical section of a compressed specimen; locality B413. USNM 624681.
2. Slightly oblique vertical section of a specimen similar to those previously identified with *M.* (*M.*) *inflata* Yabe and Hanzawa (see Cole and Bridge, 1953, pl. 13, figs. 12–14); locality B254. USNM 624682.
3. Vertical section of a specimen with intermediate thickness; locality S701. USNM 624683.

4–9. Vertical sections of thick specimens.

4, 5, 7, 9. Locality S701. USNM 624684–624687.

6. Locality B187. USNM 624688.

8. Locality B254. USNM 624689.

10, 11. Vertical sections of specimens called *M.* (*M.*) *kotoi* Hanzawa; Inokosi, Kayamaiti, Koyama-mur, Kawakanir-gun, Okayama Prefecture, Japan. USNM 624690, 624691.

12–14. Vertical sections of probable topotype specimens of *M.* (*M.*) *thecideaeformis* illustrating the variable development of pillars; Balik-Papan, East Borneo. USNM 624692–624694.

15. Vertical section of a specimen with strong pillars similar to specimens called *M. tuberosa* Tobler; locality B413. USNM 624695.

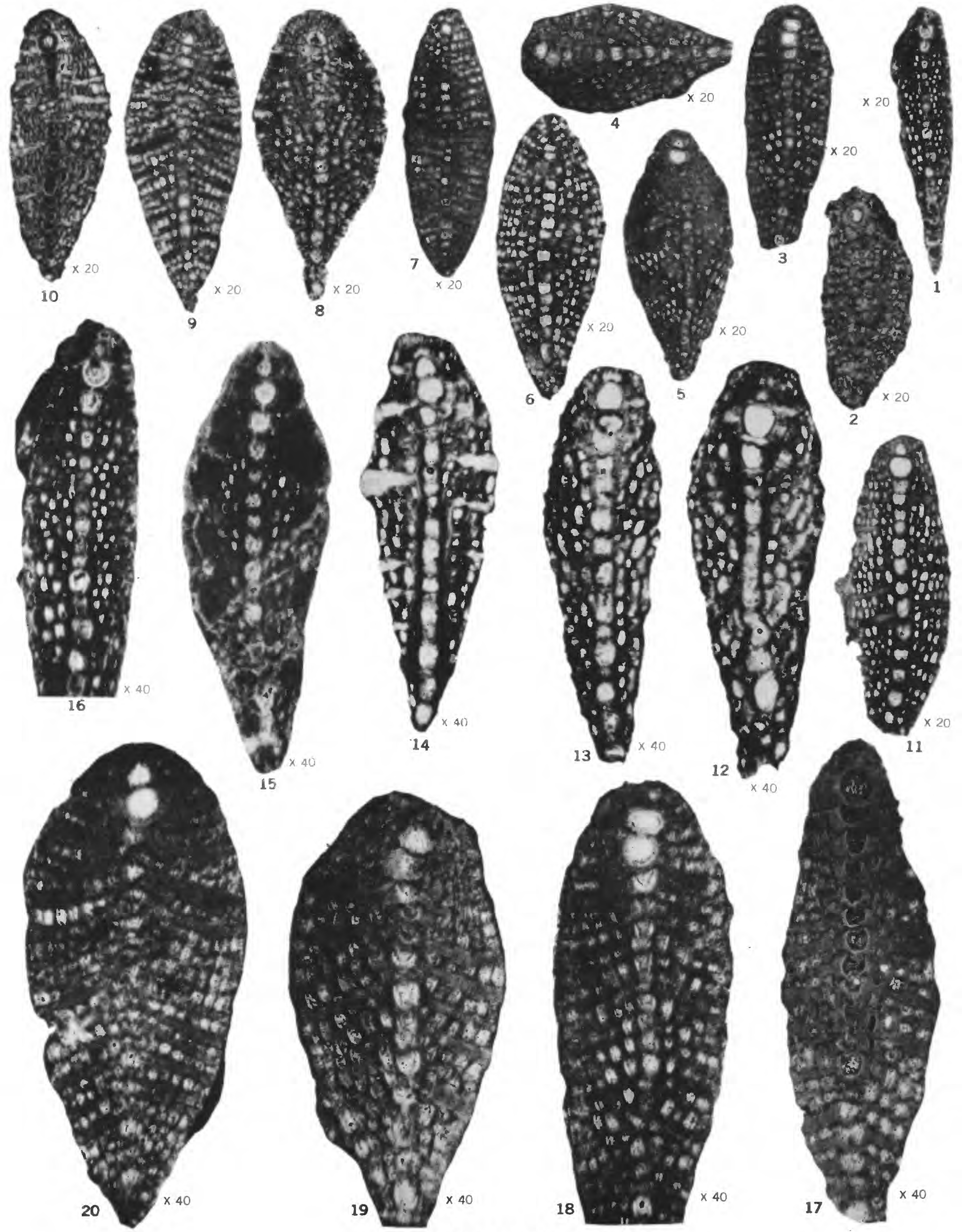
16. Part of the vertical section of the specimen illustrated as figure 1 for comparison with figure 13. USNM 624681.

17. Vertical section of a specimen called *M.* (*M.*) *kotoi* Hanzawa; same locality as figures 10, 11. USNM 624696.

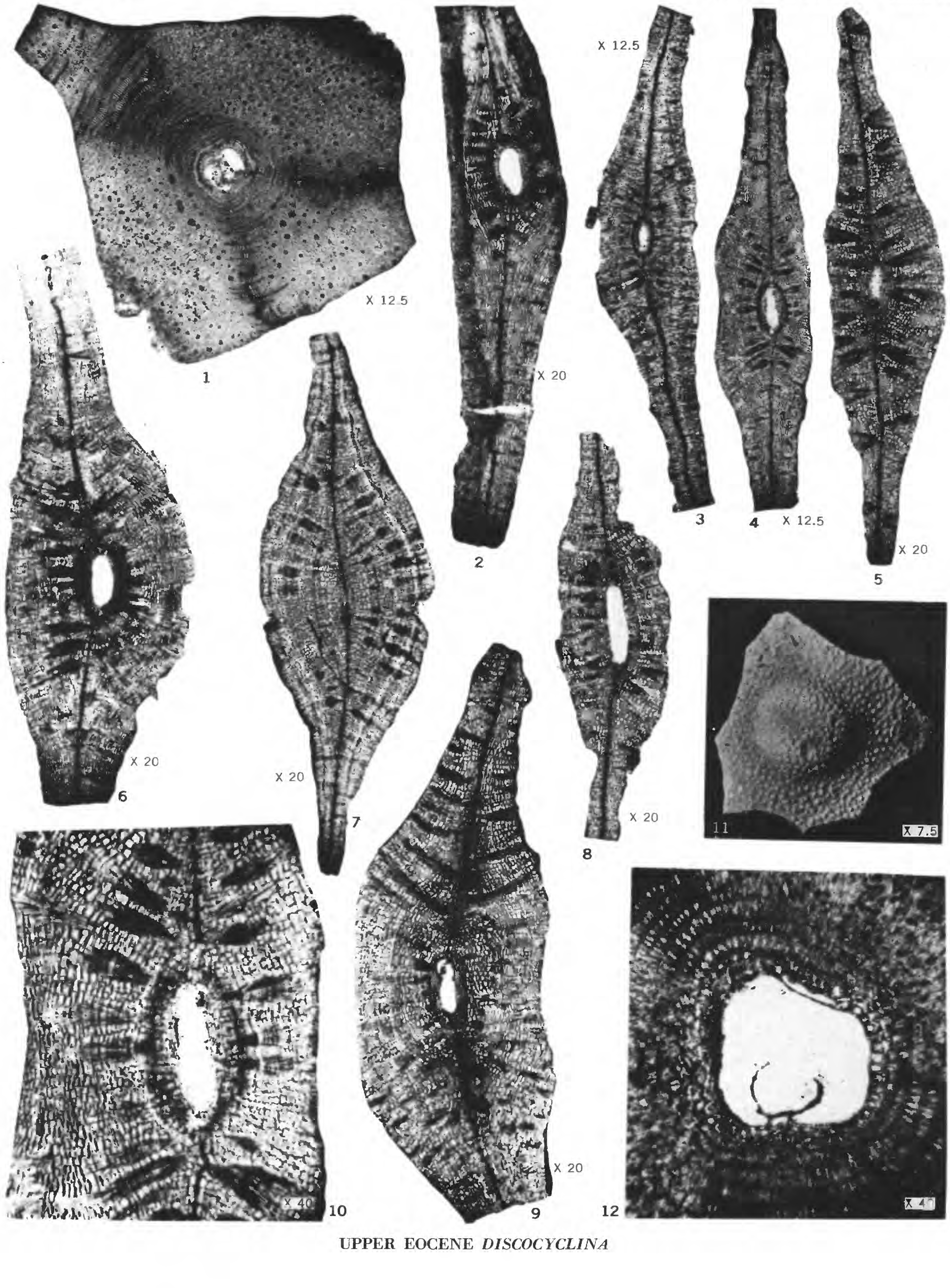
18. Part of the vertical section of the specimen illustrated as figure 3 for comparison with figure 17. USNM 624683.

19. Part of the vertical section of the specimen illustrated as figure 4 for comparison with figures 12, 17, 18. USNM 624684.

20. Vertical section to illustrate the structures developed by another specimen; locality S701. USNM 624697.



LOWER MIOCENE *MIOGYPSINA*



UPPER EOCENE *DISCOCYCLINA*

PLATE 115

FIGURES 1–12. *Discocyclina* (*Discocyclina*) *omphala* (Fritsch) (p. 347).

1. Equatorial section of a megalospheric specimen illustrating embryonic and equatorial chambers; locality S100. USNM 624698.
2. Vertical section of a megalospheric specimen; locality S100. USNM 624699.
3. Vertical section of a megalospheric specimen showing a well-developed umbo; locality S100. USNM 624700.
4. Vertical section of a megalospheric specimen showing a marked umbonal depression; locality S100. USNM 624701.
5. Vertical section of a megalospheric specimen with a pronounced umbo; locality S100. USNM 624702.
6. Vertical section of a megalospheric specimen with the umbonal area distinctly separated from the rim; locality S259. USNM 624703.
7. Vertical section of a microspheric specimen; locality S259. USNM 624704.
8. Vertical section of a megalospheric specimen with very large embryonic chambers; locality S259. USNM 624705.
9. Vertical section of a megalospheric specimen showing a marked umbonal depression; locality S100. USN 624706.
10. Part of the vertical section illustrated in figure 4 illustrating the embryonic chambers, lateral chambers and pillars; locality S100. USNM 624707.
11. External view of a specimen with a slightly depressed umbonal area; locality S259. USNM 624708.
12. Central part of an equatorial section illustrating the embryonic and periembryonic chambers; locality S100. USNM 624709.

PLATE 116

FIGURES 1–10. *Asterocyclina penuria* Cole, nom. nov. (p. 350).

1–5. Vertical sections.

1, 3, 4. Locality S259. USNM 624710.

2. Locality S259. USNM 624711.

5. Locality S188. USNM 624712.

6–9. Equatorial sections.

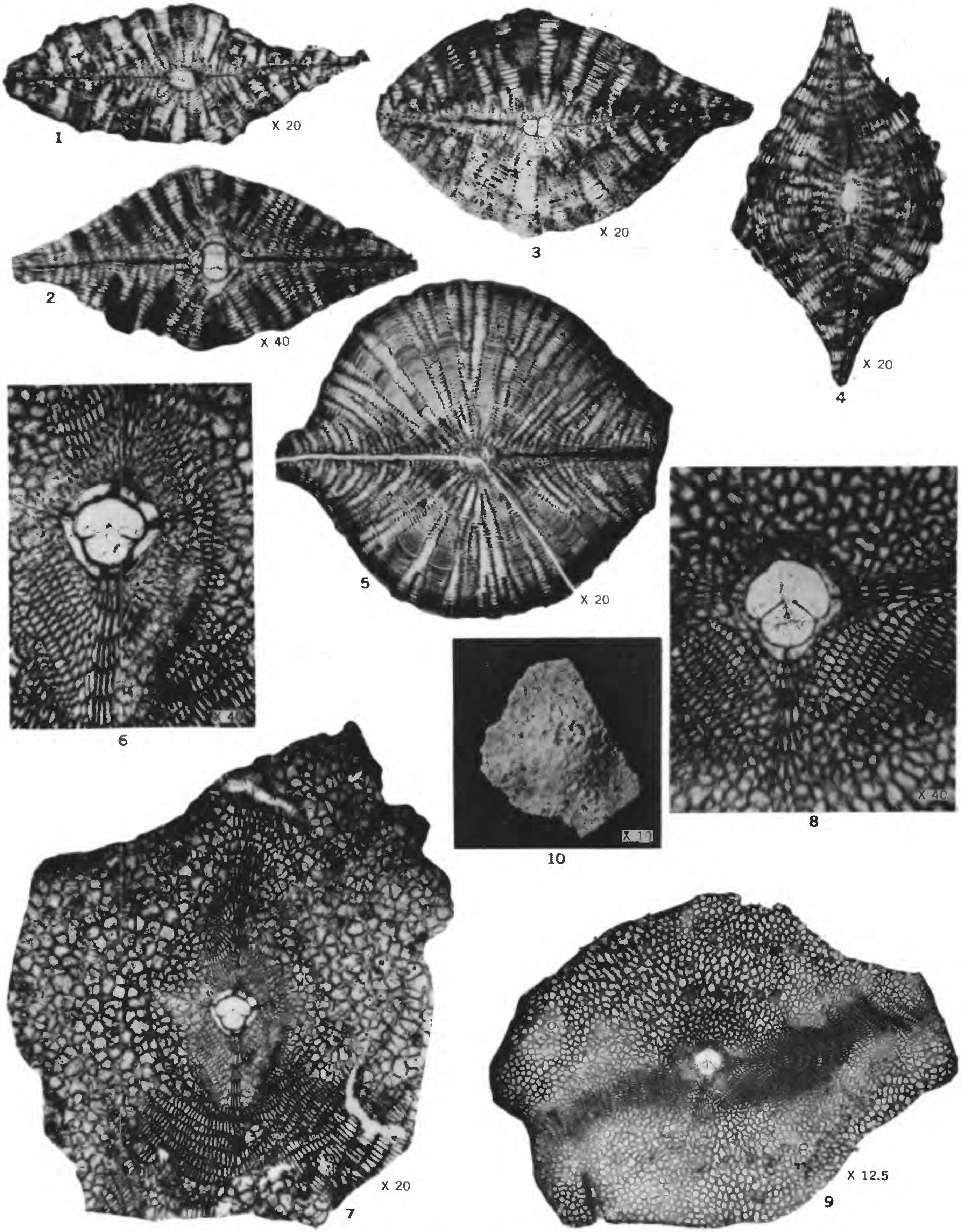
6. Enlargement of the embryonic chambers of figure 7; locality S259. USNM 624713.

7. Entire equatorial section; locality S259. USNM 624713.

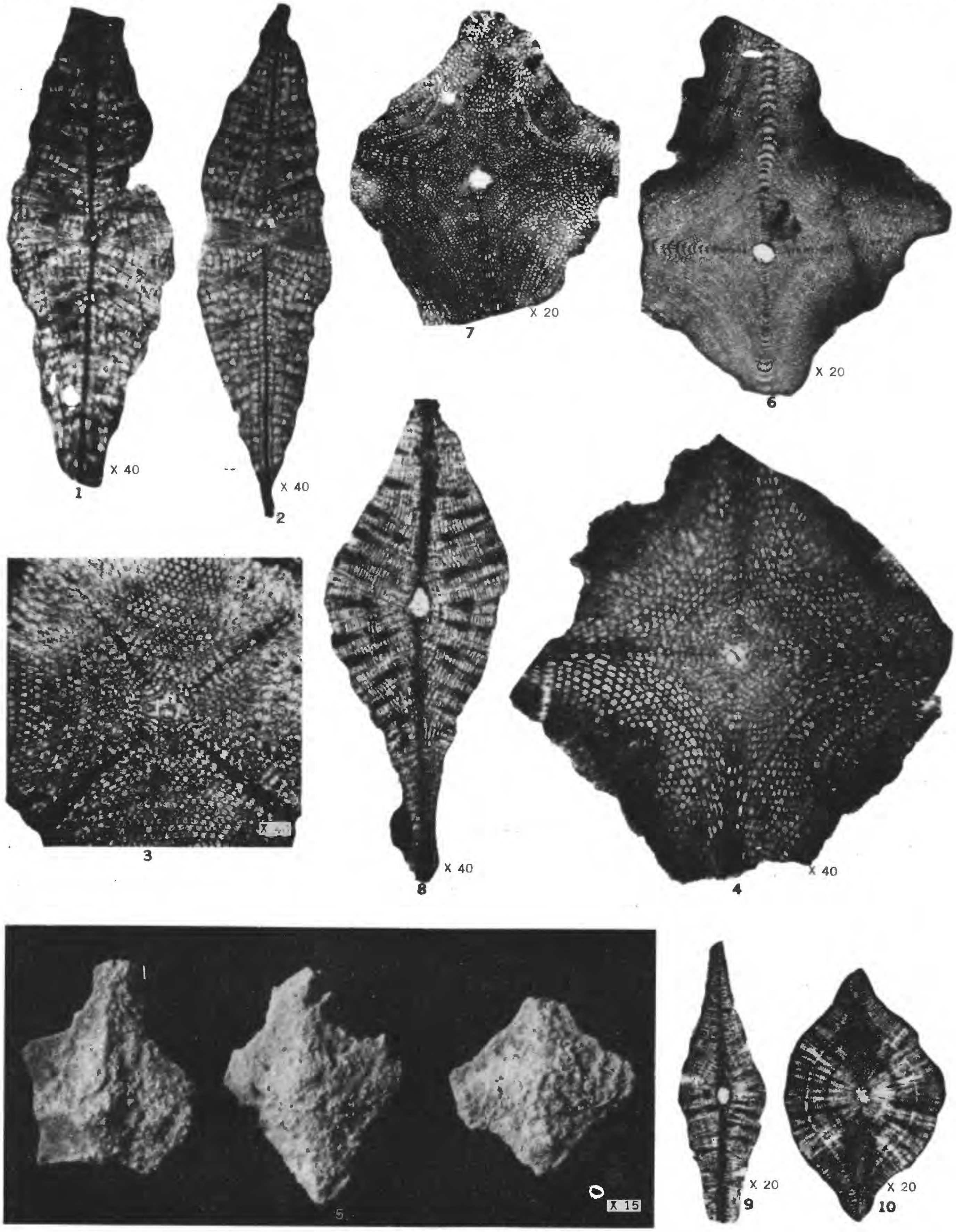
8. Enlargement of the embryonic chambers of figure 9; locality S188. USNM 624714.

9. Entire equatorial section; locality S188. USNM 624714.

10. External view; locality S259. USNM 624715.



UPPER EOCENE *ASTEROCYCLINA*



UPPER EOCENE *ASTEROCYCLINA*

PLATE 117

FIGURES 1–5. *Asterocyclina incisuricamerata* Cole, n. sp. (p. 349).
1. Vertical section; locality S259. USNM 624716.
2. Vertical section of the holotype; locality S259. USNM 624717.
3. Part of an equatorial section; locality S259. USNM 624718.
4. Equatorial section of a paratype; locality S259. USNM 624719.
5. External views; locality S259. USNM 624720.

6–10. *Asterocyclina matanzensis* Cole, n. sp. (p. 350).
6, 7. Equatorial sections; locality S259. USNM 624721.
8. Vertical section; locality S259. USNM 624722.
9. Vertical section of a compressed specimen; locality S259. USNM 624723.
10. Vertical section of an inflated specimen; locality S259. USNM 624724.

PLATE 118

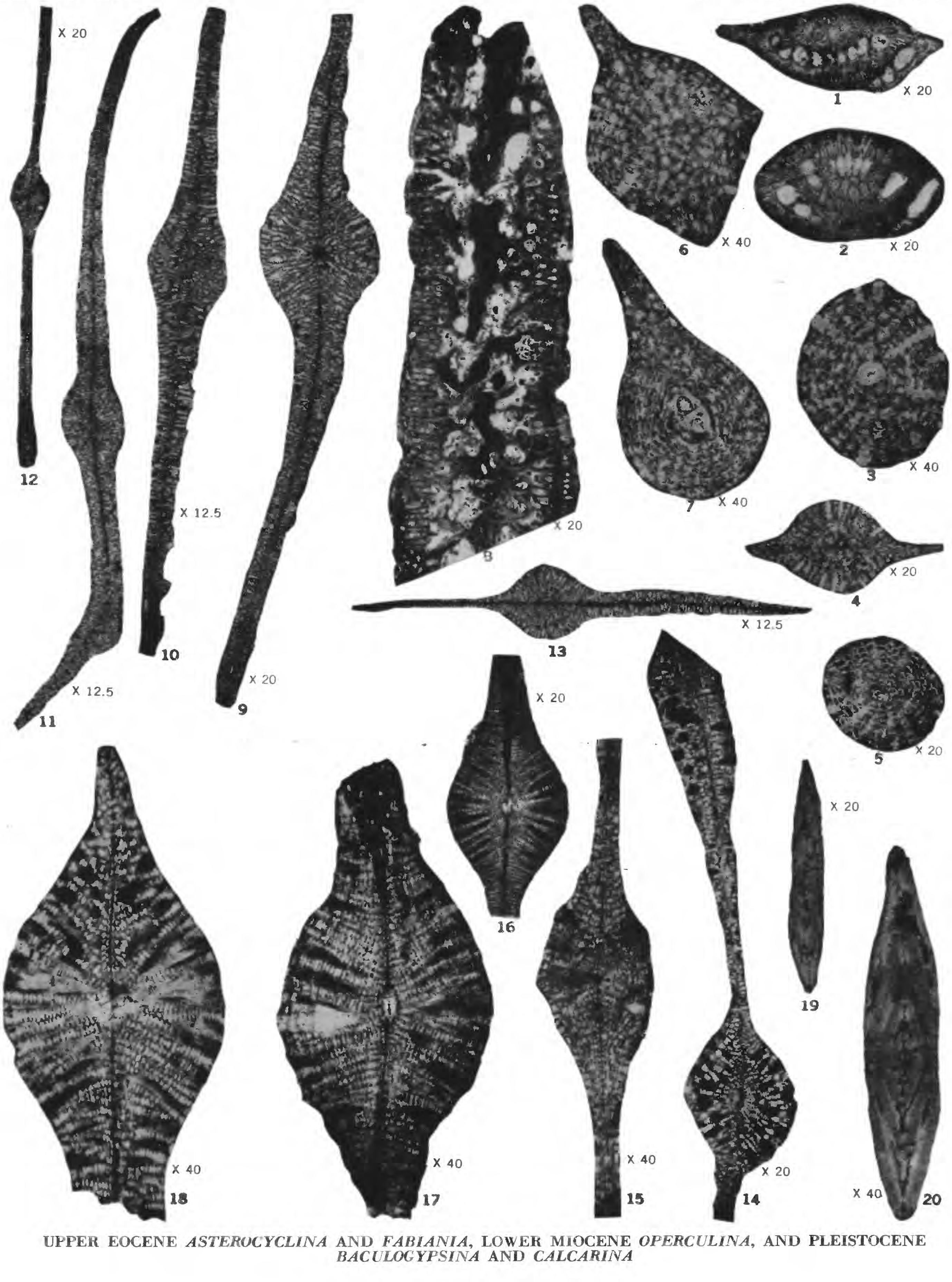
FIGURES 1, 2. *Calcarina spengleri* (Gmelin) (p. 336).
- 1. Transverse section showing peripheral spines; locality B231. USNM 624725.
- 2. Transverse section; locality B38. USNM 624726.

3–7. *Baculogypsina sphaerulata* (Parker and Jones) (p. 336).
- 3, 6. Locality B231. USNM 624727.
- 4. Locality B235. USNM 624728.
- 5. Locality B38. USNM 624729.
- 7. Locality B227. USNM 624730.

8. *Fabiania saipanensis* Cole (p. 337).
Transverse section of a compressed specimen which is similar in form to *Gunteria;* locality S253. USNM 624731.

9–18. *Asterocyclina matanzensis* Cole, n. sp. (p. 350).
All vertical sections showing variation in form and size.
- 9. Locality S125. USNM 624732.
- 10. Locality S292. USNM 624733.
- 11. Locality S125. USNM 624734.
- 12. Locality S604. USNM 624735.
- 13. Locality S133. USNM 624736.
- 14. Locality S286. USNM 624737.
- 15. Locality S604. USNM 624738.
- 16. Locality S134. USNM 624739.
- 17. Locality S259. USNM 624740.
- 18. Locality S202. USNM 624741.

19, 20. *Operculina complanata* (Defrance) (p. 330).
- 19. Transverse section; locality B433. USNM 624742.
- 20. Transverse section; locality B433. USNM 624743.



UPPER EOCENE *ASTEROCYCLINA* AND *FABIANIA*, LOWER MIOCENE *OPERCULINA*, AND PLEISTOCENE *BACULOGYPSINA* AND *CALCARINA*

Echinoids

By C. WYTHE COOKE

GEOLOGICAL SURVEY PROFESSIONAL PAPER 280-J

Introducing four new species of echinoids of Miocene age

CONTENTS

ILLUSTRATIONS

CHART

GEOLOGY OF SAIPAN, MARIANA ISLANDS

ECHINOIDS

By C. Wythe Cooke

ABSTRACT

Among echinoids obtained from Saipan, Mariana Islands, are the following species from the Miocene Tagpochau limestone: *Parasalenia marianae* Cooke, n. sp.; *Echinostrephus saipanicum* Cooke, n. sp.; *Heterocentrotus* sp.; *Acanthocidaris* sp.; *Echinoneus* sp.; *Clypeaster saipanicus* Cooke, n. sp.; *Sismondia polymorpha* Duncan and Sladen?; *Paraster saipanicus* Cooke, n. sp.; and *Echinolampas* sp. *Sismondia polymorpha,* though originally attributed to the Eocene Khirtar series of India, is probably restricted to the Miocene. It is the most abundant echinoid found in Saipan.

A few fragments of echinoids were also obtained from the Pleistocene(?) Mariana limestone, but the only recognizable Pleistocene(?) species is *Clypeaster reticulatus* (Linnaeus).

INTRODUCTION

Most of the few fossil echinoids reported on herein were obtained in 1949 by Preston E. Cloud, Jr., and Robert G. Schmidt from the Tagpochau limestone on Saipan, Mariana Islands. The age of this formation, as determined from other classes of organisms in the same limestone, is early Miocene. This correlation appears to be supported by the occurrence at several places in great abundance of a species of *Sismondia* tentatively identified as *S. polymorpha* Duncan and Sladen. This *Sismondia* has been reported under several different names in Miocene formations throughout the Indo-Pacific region. Other species of echinoids in the collection yield little evidence as to the age, for all are described as new.

Besides the Miocene species a few fragments of echinoids were obtained from the Pleistocene(?) Mariana limestone. The only species that has been identified is *Clypeaster reticulatus* (Linnaeus), which was found in fallen blocks at the foot of a bluff along the southeastern coast of Saipan (C46). The Recent species is widely distributed in Indo-Pacific waters. The Pleistocene(?) specimen measures 61 millimeters in length, larger than the usual size of the Recent forms, which range from 28 to 58 millimeters according to Mortensen's (1948, p. 73) table of measurements.

In lieu of detailed descriptions, localities referred to in the text are recorded on a gridded locality map (pl. 4) and there listed in numbered sequence. This map also includes stratigraphic assignment for each locality.

SYSTEMATIC DESCRIPTIONS

Parasalenia marianae Cooke, n. sp.

Plate 119, figures 1–3

Horizontal outline elliptical, longitudinally elongated; upper surface gently arched; lower surface has a concave longitudinal profile. Apical arrangement unknown; apical scar subpentagonal, longer than wide. Ambulacra about half as wide as interambulacral areas; poriferous zones uniserial, nearly straight above the ambitus, breaking into inclined groups of 3 pairs below the ambitus; 3 pairs to each plate. Peristome large, elliptical, slightly wider than long; gill slits very shallow. Primary tubercles large, one on each plate, which it nearly covers; larger on the interambulacral areas than on the ambulacra, where they are much reduced near the apex. Secondary tubercles small, lying in zigzag rows along the median suture lines and in straighter rows along the outer suture lines. Intermediate spaces covered by a fine granulation.

Occurrence.—S144, northwest-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, marly beds in inequigranular facies, *Sismonia* zone.

Type —USNM 561578.

Comparisons.—The apical system of *Parasalenia marianae* is subpentagonal, whereas those of the Recent *P. gratiosa* A. Agassiz and *P. pöhlii* Pfeffer as figured by Mortensen (1943, pls. 29–31) are plainly star shaped and proportionately larger. *Parasalenia marianae* is very similar to *P. prisca* (Cotteau) (Jackson, 1922, p. 25, pl. 1, figs. 21–24) from the Miocene of Anguilla, British West Indies, but its primary tubercles are larger and occupy a greater part of the plate, and its peristome is more weakly notched. I fail to find more than three pairs of pores on one ambulacral plate of any of the cotypes of *P. prisca,* and the longer diameter of the test seems to coincide with the longitudinal axis, as in *Parasalenia.* These features remove *P. prisca* from *Echinometra*, as was pointed out by Pomel (1883, p. 78).

Parasalenia marianae is more elongated than *P. fontannesi* Cotteau (1888, p. 266, pl. 9, figs. 9–13; 1889, p. 332, pl. 15, figs. 11, 12), but its primary tubercles and the arrangement of its pores are similar. The type is larger than Cotteau's figured specimens and has more secondary tubercles. *P. fontannesi* is from the Aquitanian of France.

Echinostrephus saipanicum Cooke, n. sp.

Plate 119, figures 4–6

Horizontal outline subpentagonal; lower surface nearly flat; upper surface moderately inflated; margin rounded. Apical system rather small; arrangement of plates obscure. Periproct central, small. Amublacra about half as wide as interambulacral areas; zygopores arranged in diagonal groups of 3; 1 row of primary imperforate tubercles adjacent to the poriferous zones, 1 tubercle to each compound plate, and 1 row of smaller tubercles adjacent to the median sutures, these tubercles rapidly dwindling in size away from the ambitus; several other very small tubercles on each plate. Interambulacral areas having 1 complete row of primary tubercles along each outer edge and 3 additional equally large tubercles on each plate in the ambital and subambital regions; intermediate regions above the ambitus bare except for very small secondaries; secondary tubercles also surround the primaries in the ambital region. Peristome large, occupying about half of the diameter; rather deeply notched. Horizontal diameter 21.8 mm; height 10 mm; diameter of peristome 10.7 mm; diameter of periproct about 2 mm.

Occurrence.—S617, northeast-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, tuffaceous facies.

Type.—USNM 561579.

Comparisons.—Apparently no fossil species of this rock-boring genus have been described, and only two Recent species are known—*Echinostrephus molare* (de Blainville) and *E. aciculatum* A. Agassiz, both Pacific species. *E. saipanicum* is more or less intermediate between these two and may be the ancestor of both. It resembles *E. molare* in having its zygopores in arcs of three, not four as in *E. aciculatum*, but seems to be closer to the latter in the arrangement of its tubercles.

Acanthocidaris sp.

Plate 119, figure 8

A fragment apparently represents an undescribed species of *Acanthocidaris* or a related genus.

Occurrence.—S673, east-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, transitional facies.

Figured specimen.—USNM 561580.

Heterocentrotus sp.

Plate 119, figure 7

A fragment of a *Heterocentrotus* has not been specifically identified.

Occurrence.—S673, east-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, transitional facies.

Figured specimen.—USNM 561581.

Echinoneus sp.

One small fragment apparently representing the genus *Echinoneus* but not specifically identifiable.

Occurrence.—S128, northeast-central Saipan.

Geologic horizon.—Miocene, from limestone block in Donni sandstone member of Tagpochau limestone.

Clypeaster saipanicus Cooke, n. sp.

Plate 119, figures 14–17

Horizontal outline oval, much longer than wide; petaloidal region moderately high; lower surface deeply concave; margin thick. Apical system having four genital pores rather close together. Petals short, anterior the longest; poriferous zones wide open at the outer ends; sides moderately curved. Peristome central, small. Ambulacral grooves not conspicuous. Periproct very near the margin. Tubercles deeply scrobiculate. Length 42.5 mm; width 30.9 mm; height 11 mm.

Occurrence.—S673, east-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, transitional facies.

Types.—Type, USNM 561582; paratype, USNM 561583.

Remarks.—This species seems to be quite different from any other described from the Indo-Pacific region. In shape it resembles the internal mold from Luzon figured without description by Pratt and Smith (1913, pl. 2, fig. 3) under the name *Laganum multiforme tayabum* and by Israelsky (1933, p. 302, pl. 1, figs. 2–4) as *Clypeaster* cf. *C. scutiforme* Gmelin. It is represented by the holotype, one broken paratype, and several smaller fragments.

Sismondia polymorpha Duncan and Sladen?

Plate 119, figures 9–13

?*Sismondia polymorpha* Duncan and Sladen, 1884, Palaeontologia Indica, ser. 14, v. 1, pt. 3, fasc. 3, p. 137, pl. 25, figs. 1–13.

?*Sismondia murravica* Tate, 1893, Royal Soc. New South Wales Jour., v. 27, p. 193, pl. 13, fig. 5.

Sismondia javana Gerth, 1922, Geol. Reichs-Mus. Leiden Samml., n. F., Band 1, Abt. 2, Heft 4, p. 502, pl. 62, figs. 4, 4a.
Sismondia convexa Nisiyama, 1937, Tokyo Imp. Acad. Proc., v. 13, no. 2, p. 41, figs. 1–13.
Sismondia javana Gerth. Jeannet and Martin, 1937, Leidsche Geol. Meded., Deel 8, Afl. 2, p. 241, figs. 24, 25.
?*Sismondia murravica* Tate. Clark, 1946, Carnegie Inst. Washington Pub. 566, p. 351.

Horizontal outline ovate to subpentagonal; upper surface nearly flat; lower surface slightly concave; margin thick, rounded. Apical system central, tumid, with 4 widely spaced genital pores and 1 variably placed madreporic pore. Ambulacra slightly tumid, much expanded near the margin, where they are 4 times as wide as the interambulacral areas; poriferous zones open at the apex, expanding and then becoming nearly straight and slightly flaring at the outer ends, which are wide open; inner pores circular; outer pores oval, conjugate; zygopores diagonal, becoming strongly slanted at the outer ends of the petals, which extend more than halfway to the margin; interporiferous zones about 3 times as wide as the poriferous zones. Peristome small, central, pentagonal, sunken; surrounded externally by 5 short, inconspicuous ambulacral grooves, forming the apices of 5 internal U-shaped ridges that extend to the margin, where they form buttresses. Periproct circular or oval, nearly as large as the peristome; on lower surface about halfway to the margin; the distance to the margin varies according to the degree of truncation of the posterior end of the test. Surface covered with widely spaced small imperforate tubercles in deep circular scrobiculi. Sutures between the plates bordered by very fine pores. Length of largest individual 19.5 mm; width 18.3 mm; height 5.6 mm.

Occurrence.—Very abundant at S144, northwest-central Saipan in marly beds of inequigranular facies, Tagpochau limestone. Also found at localities S541, C109, C110, C122, C130, C134, C141, and C150.

Geologic horizon.—Miocene, Tagpochau limestone; inequigranular, marly, rubbly, and tuffaceous facies.

Figured specimens.—USMN 561584.

Remarks.—The specimens from Saipan agree in all details with Duncan and Sladen's illustrations of *Sismondia polymorpha*, no specimens of which have been available for direct comparison, however. Their identification is questioned because such a distinctive species is unlikely to have such a long geologic range as from the Eocene (Khirtar series of India, from which the type is reported) to the early Miocene, where it is abundant in Saipan. However, as Duncan and Sladen report no other species from the same locality, they may have been mistaken as to its age.

Sismondia murravica from Australia is placed in the synonymy tentatively because Tate's illustrations of it are not detailed enough to prove its identity with *S. polymorpha*. Tate referred it to the Eocene, but according to Chapman (Clark, 1946, p. 351) it is Miocene.

There seems little doubt that the species from Saipan is the same as *Sismondia javana* Gerth from the Miocene of Java and *S. convexa* Nisiyama from the so-called Oligocene of Titi-zima, one of the Bonin Islands [Ogasawara-guntō]. The differences pointed out between these species and *S. polymorpha* appear to be individual variations.

The figures of *Laganum dickersoni* Israelsky (1933, pl. 2, figs. 1–9) bear some resemblance to this species, but they are about twice as large, and one (fig. 8) shows much more conspicuous ambulacral grooves, which may have been emphasized by retouching. The wide-open petals are unusual, to say the least, in the genus *Laganum*. *Laganum dickersoni* was described from the Pliocene Malumbang formation of the Philippines.

Paraster saipanicus Cooke, n. sp.

Plate 119, figures 18–21

Horizontal outline ovate-cordate, greatest width in front of the center; upper surface inflated, creased by a rounded anterior sulcus, which extends from the apex to the peristome; lower surface convex; posterior end truncated, overhanging. Apical system one-third the length from the posterior end; 4 genital pores arranged in a rectangle, the anterior pair smaller than the posterior and close to them. Petals deeply sunken; anterior pair curved forward to an angle of about 80° with each other, extending three-quarters of the way to the margin; posterior pair straight, more than half as long as the anterior pair, forming an angle of about 50° with each other; pores elongated, outer pores the longer, strongly conjugate; poriferous zones wider than the interporiferous. Anterior ambulacrum in a U-shaped, straight-sided sulcus; pores small, circular or oval; poriferous zones narrow; interporiferous zone very wide. Peristome semilunate, far forward, with a posterior lip. Periproct oval, higher than wide, high up on the posterior end. Peripetalous and lateral fascioles present. Length 30 mm; width 26 mm; height 18.5 mm.

Occurrence.—S144, northwest-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, marly beds in inequigranular facies.

Type.—USNM 561585.

Comparison.—The posterior truncation of the type of this species is not so steep as that of *Schizaster jeanneti* R. Martin as figured by Jeannet and Martin (1937, p. 293, figs. 63a–c, 64) from the Pliocene(?) of the Dutch East Indies. There may be other differences that are not apparent from the figures, for the differences between species of *Paraster* are generally so subtle and the individual variation or distortion so great that study of a large series is necessary to determine the specific peculiarities.

Echinolampas sp.

Plate 119, figures 22, 23

A large, badly crushed *Echinolampas* measuring 87 mm in length by 80 mm in width may represent *Echinolampas concavus* Hayasaka (1948, p. 89; Hayasaka and Morishita, 1947, pl. 9, fig. 2), a species described from the Kokan tuff of Formosa and attributed to the early Miocene. Its petals are rather short, and the poriferous zones are of unequal length.

Occurence.—C136, south-central Saipan.

Geologic horizon.—Miocene, Tagpochau limestone, marly facies.

Figured specimen.—USNM 561586.

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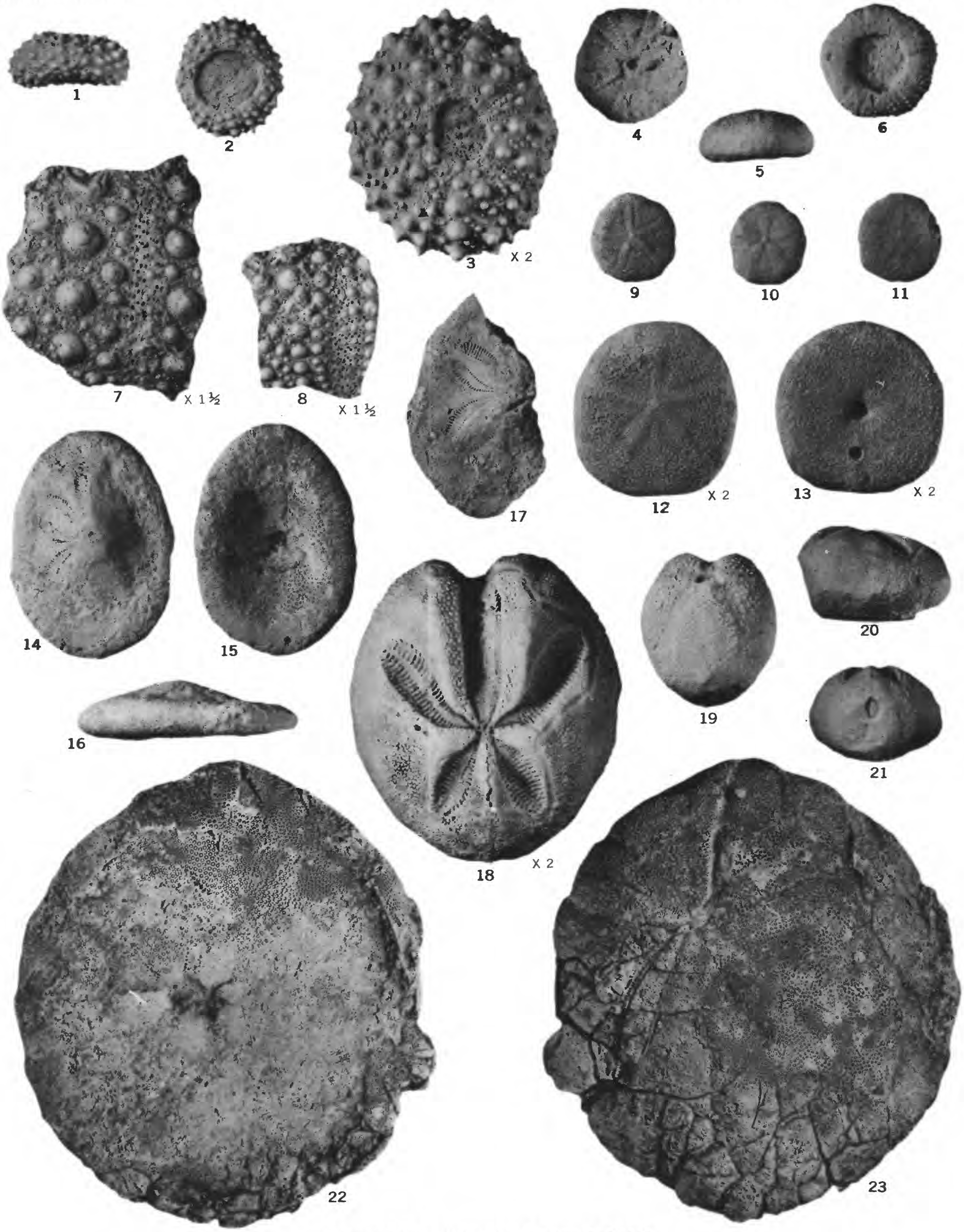
INDEX

[Italic numbers indicate descriptions]

PLATE 119

PLATE 119

FIGURES 1–3. *Parasalenia marianae* Cooke, n. sp. Type; 1, 2, × 1; 3, × 2. Loc. S144. (p. 361).
4–6. *Echinostrephus saipanicum* Cooke, n. sp. Type; all × 1. Loc. S617. (p. 362).
7. *Heterocentrotus* sp. × 1½. Loc. S573. (p. 362).
8. *Acanthocidaris* sp. × 1½. Loc. S673. (p. 362).
9–13. *Sismondia polymorpha* Duncan and Sladen? 9–11, × 1; 12, 13, × 2. Loc. S144. (p. 362).
14–17. *Clypeaster saipanicus* Cooke, n. sp. 14–16, type; 17, paratype; all × 1. Loc. S673. (p. 362).
18–21. *Paraster saipanicus* Cooke, n. sp. Type; 18, × 2; 19–21, × 1. Loc. S144. (p. 363).
22, 23. *Echinolampas* sp. × 1. Loc. C136. (p. 364).



MIOCENE ECHINOIDS FROM SAIPAN