NEOGENE
SMALLER FORAMINIFERA
FROM LAU, FIJI

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INTRODUCTION

PURPOSE AND SCOPE

Fossil Foraminifera were first described from Fiji in 1888, from the late Cenozoic "soapstone" of the large island of Viti Levu (Brady, 13).[1] All the assemblages subsequently described from the Fiji Archipelago (Whipple, 146; Cushman, 41, 44; Cole, 27; and others) have also been of Miocene or younger age. In this paper I record another suite of Neogene foraminiferal assemblages from Fiji and, insofar as possible, evaluate the contained microfossils as to faunal affinities, geologic age, and the natural conditions under which they may have lived.

The 25 assemblages described were collected in 1934 by Harry S. Ladd and J. Edward Hoffmeister during the University of Rochester-Bishop Museum Geological Expedition to the various islands in the easternmost group, or Lau Islands, of Fiji, a north-south belt of about 100 small islands located in the ethnic transition zone between Melanesia and Polynesia (Hoffmeister and Ladd, 79). (See figures 1 and 2.)

CONDITIONS OF STUDY, AND ACKNOWLEDGMENTS

The opportunity to study this material was first offered to me by Doctors Ladd and Hoffmeister in the fall of 1933, at the suggestion of Professor Hubert G. Schenck of Stanford University. In 1935, after the return of the expedition, Ladd sent me 27 samples of foraminiferal marl, tuff, and limestone. Following my own return from a trip to Fiji in the spring of that year, this study was begun in such time as I could spare from professional research for the petroleum industry in California. Through a grant-in-aid and the help of Mr. Ernest C. Quayle and, later, of Mrs. Helen Durrell, many of the more numerous and distinctive species were figured.

Presumably the opportunity to study these samples was originally afforded me on the basis of a supposed acquaintance with Pacific Basin middle and late Tertiary smaller-foraminifer faunas. However, it was soon apparent that, except for the cosmopolitan pelagic species and those cold-water forms which

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[1] Numbers in parentheses refer to Bibliography, page 79.

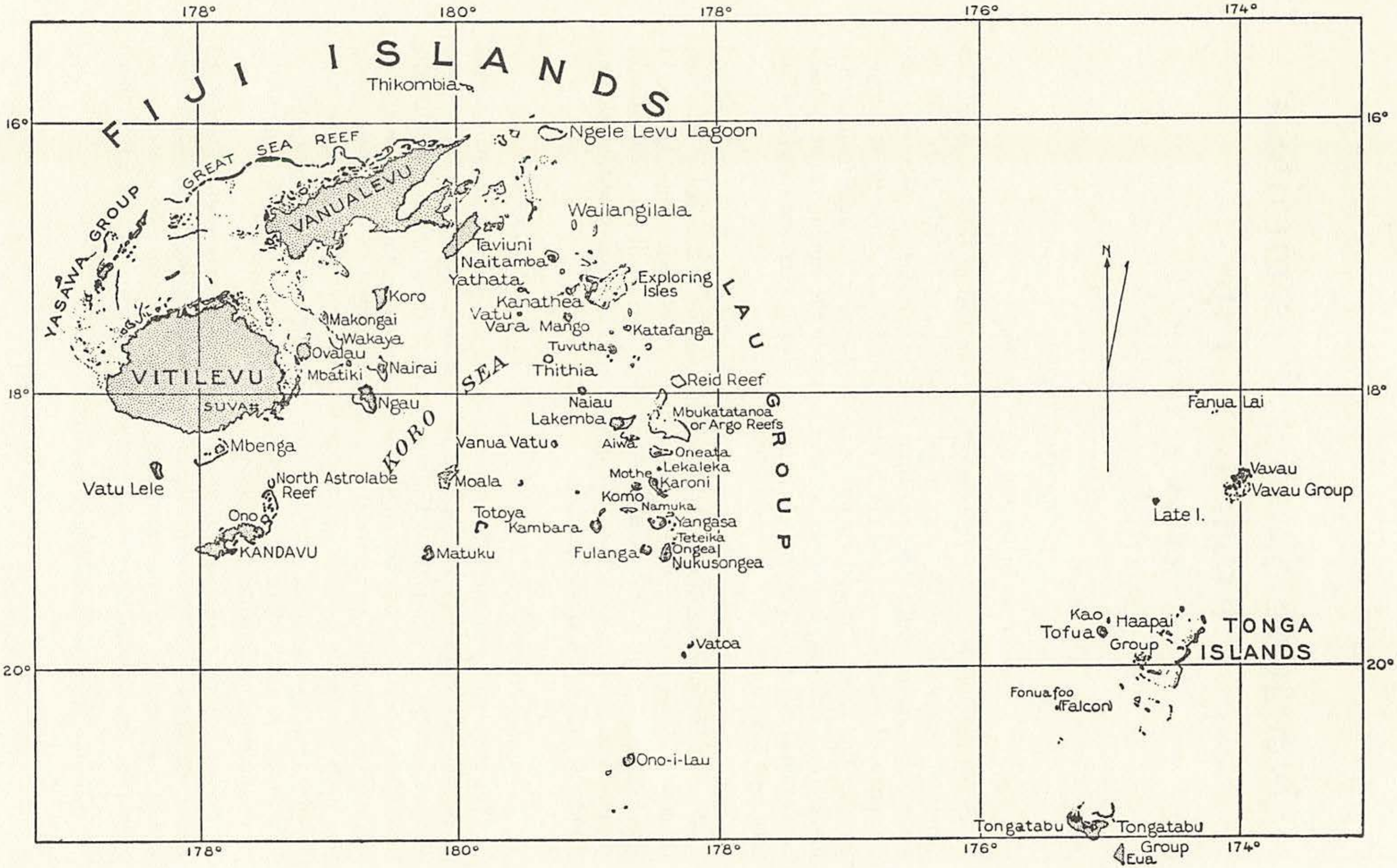

FIGURE 1.—Outline map showing position of Lau in relation to Tonga and western Fiji.

become widespread at the higher horizons, the Indo-Pacific and California microfaunas of the Neogene Pacific Basin had little in common. Progress on the project was slow.

Later, professional work was expanded to include the Philippines, permitting first-hand acquaintance with the occurrences of Indo-Pacific fossil foraminifers in the field; but the manuscript and notes were lost there during the war. This prevented the incorporation of a report on the smaller foraminifers in the compendium on the geology and paleontology of Lau which was published in 1945 by Bernice P. Bishop Museum (Ladd and Hoffmeister, 92, p. 5).

Completion of the illustrations has been made possible through the good offices of Mrs. Margaret Moore Hughes and the Department of Paleontology of the University of California. I am also indebted to Doctors Ladd and Hoffmeister and to Bishop Museum and the late Sir Peter H. Buck, its Director, for their assistance and especially for their remarkable reserves of patience; to the University of Rochester and to Mr. Quayle and Mrs. Durrell for earlier assistance, financial and artistic; to Doctor W. Storrs Cole for extensive and very helpful discussion; for the drafting of the correlation chart to Mr. Owen Poe; and for much curatorial and clerical assistance, to Mr. Zach Arnold and Mrs. Mary Major, of the University of California Museum of Paleontology.

PREVIOUS WORK

Early investigations of the paleontology of Fiji, and of the Lau Islands in particular, have been reviewed by Ladd and Hoffmeister (92, pp. 8-10). Subsequent to pioneer work such as that of Brady (13) the orbitoids and other large foraminifers have received particular attention from several micropaleontologists: Those of Viti Levu, from Ladd and Whipple (94) and from Whipple (146); those of the Lau Islands, from Sherlock (122), Yabe, Aoki, and Hanzawa (150), and Cole (27). Further records of smaller foraminifers from Viti Levu have been added by Cushman (41, 44).

Early in these investigations it was apparent that throughout much of Neogene time Fiji, along with the rest of Melanesia and Papua, was clearly a part of the ancestral Indo-Pacific marine invertebrate faunal province (Crespin, 30). Thus basically, if often indirectly so, any historical approach to the current understanding of Fijian late Cenozoic microfaunas immediately involves the student in the formidably extensive records of contemporaneous fossil foraminifers throughout the entire Indo-Pacific. During the Miocene, this large province extended even considerably beyond its present far-flung limits. On the northwest, the Miocene Indo-Pacific included most of Japan, at least as a subprovince, and similarly in the southwest much of Australia

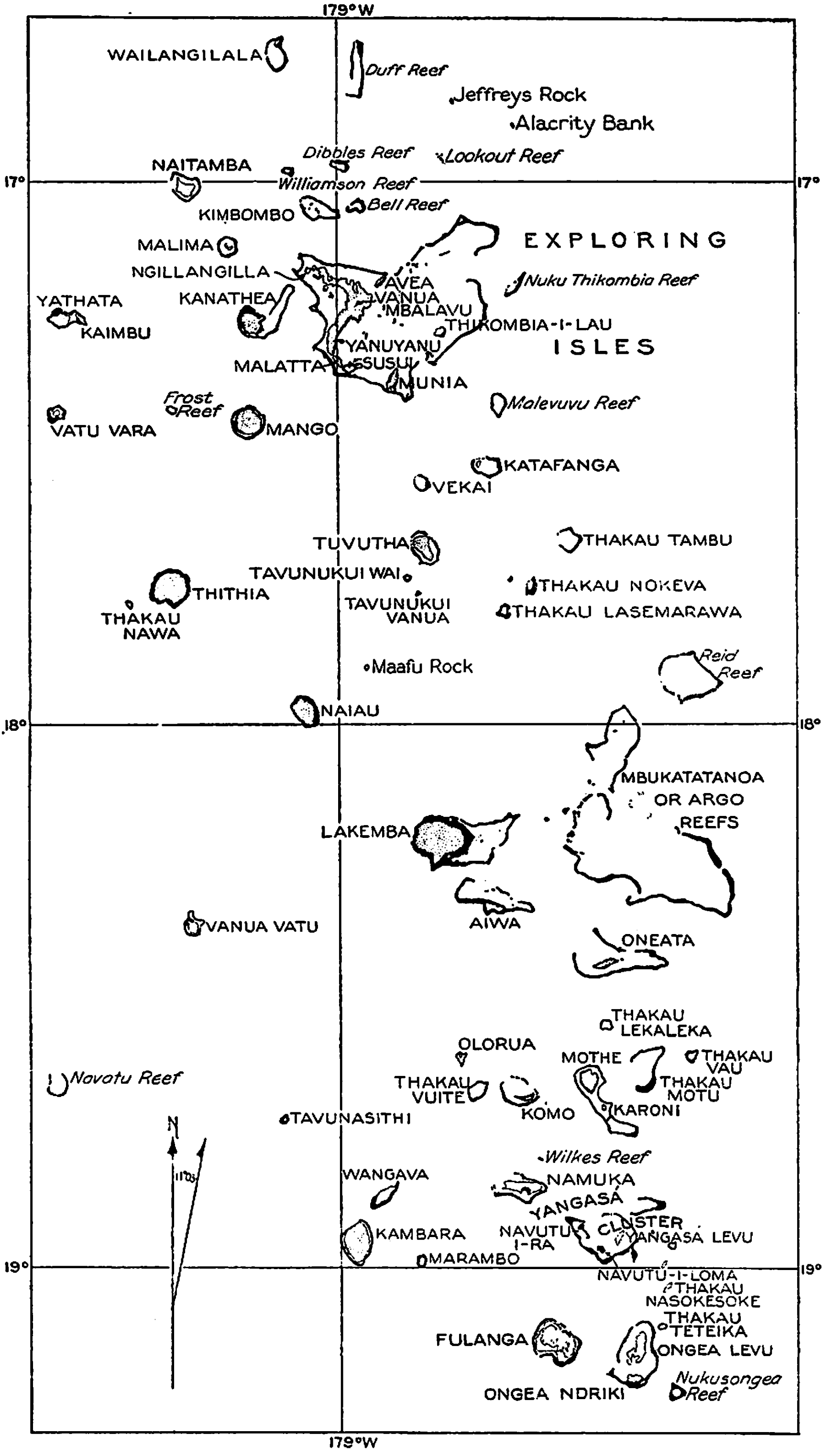

FIGURE 2.—Map of Lau, showing main islands (stippled) and reefs (black).

and New Zealand (Crespin, 33, 34); both are regions the faunas of which, though still in some ways related, are in large part zoogeographically distinct from the fauna of the Indo-Pacific today. Toward the southwest, also, much of the East African shore of the Indian Ocean probably was at least as closely related to the tropical south Pacific as it is today (Davies, 49; Cushman, 46, p. 45).[2]

Not only in Fiji, but throughout the Neogene extent of the province, the attention of micropaleontologists has long been concentrated upon its larger foraminifers. Their stratigraphic distribution, especially as superpositionally disciplined in the Netherlands East Indies, has become the basis for the most refined modern geologic time scale for the Cenozoic of this region (Leupold and Van der Vlerk, 101; Van der Vlerk, 137 and 140; Gerth, 68; Umbgrove, 134; Tan, 126).

Formal attention to the fossil smaller foraminifers, however, has been sporadic from the beginning. (See Stache, 125; Karrer, 84, 85; Schwager, 121; Brady, 11; Chapman, 17, 18, 21, 22; Schubert, 118, 119, 120; and others.) The search for petroleum in the Indies has stimulated and extended greatly the knowledge of these smaller foraminifers, especially in the period following the First World War. Recently, extensive lists and some comprehensive descriptions of certain local faunas, some of them in the very heart of the Indo-Pacific province, have begun to appear in print. (See Koch, 87, 89; Heron-Allen and Earland, 76; Hanzawa, 70; Yabe and Hanzawa, 154, 155; Caudri, 15, 16; Parr, 107-112; Thalmann, 130, 131; Boomgart and Vroman, 10; Cushman and Hanzawa, 47; Yabe and Asano, 151-153; Asano, 1-8; LeRoy, 96-100; Finlay, 57-59, 61, 62; Finlay and Marwick, 63; Boomgart, 9; and others.)

As the Tertiary background of the living Indo-Pacific smaller-foraminifer fauna has begun to unfold, the degree of relationship between the Fijian (and the entire Melanesian) fauna and that of the Indo-Pacific region as a whole has turned out to be quite comparable to the close relationship long known to exist between the Fijian-Melanesian and the Indo-Pacific Tertiary larger-foraminifer faunas. Thus all the previous work devoted to the Tertiary micropaleontology of the Indo-Pacific region as a whole is pertinent to a current understanding of these fossil smaller-foraminifer faunas of Lau. It is not always possible to have all this literature at one's elbow, but fortunately a great deal of it has been available in the library of the University of California.

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[2] Cushman recognizes three warm-water foraminiferal faunas and provinces in the Old World: Mediterranean, East African, and Indo-Pacific. Of these, the East African and Indo-Pacific faunas, which intermingle in the Bay of Bengal, together correspond in area of distribution to the Indo-Pacific province of the larger marine invertebrates. But these two foraminiferal faunas are more closely related to each other than to those of any other province, especially in the degree to which they both preserve as living relics more or less modified stocks of wider Miocene distribution.

STRATIGRAPHY

STRATIGRAPHIC ALLOCATION OF SAMPLES

The Neogene of Lau consists of an intermittently discontinuous marine sequence of limestones and marls locally conglomeratic and tuffaceous, with calcareous tuffs, agglomerates and other pyroclastics, and some interbedded lava flows. Ladd and Hoffmeister (92, pp. 11, 12, 162-166) have recognized and mapped a sequence of six formations. The particular formation from which each of the 25 foraminiferal samples was collected is indicated in the checklist (table 1), and locality descriptions are listed on pages 32-33. Graphically plotted, the geographic and geologic occurrences of these samples are more accurately shown in the previously published geological and hydrographic maps of the individual islands of Lau (Ladd and Hoffmeister, 92, figs. 3, 5, 14, 16, 17, 19, 21, 23, and 24).

LAU VOLCANICS

The lowest rocks in the Lau Neogene column are andesitic pyroclastics and flows. Sample 15A, stratigraphically the lowest sample in the Lau suite, was collected from tuffs in these so-called Lau Volcanics as developed on the little island of Yanuyanu off the southeast coast of the larger island of Vanua Mbalavu in the Exploring Isles, which are in the northern part of the archipelago (fig. 2). Two other samples from the same Lau Volcanics formation, one (15D) from very near the same Yanuyanu locality and the other (A5A) from the island of Avea, failed to yield identifiable foraminifer remains.

FUTUNA LIMESTONE

Overlying the Lau Volcanics is the Futuna formation. At its base the Futuna consists of a tuffaceous limestone—algal and foraminiferal—which, as a matrix, contains boulders of andesitic volcanic rock. This tuffaceous Lower member varies somewhat in thickness from island to island. Ladd and Hoffmeister describe it as a mappable unit 60 feet thick on Oneata, but as much thinner on Lakemba, Katafanga, and Vanua Mbalavu (92, p. 165).

All of the samples of smaller foraminifers from the islands of Oneata and Lakemba were collected from these basal tuffaceous limestones which constitute the Lower member of the Futuna formation. In table 1, the suites from Oneata and Lakemba and the individual samples comprising them have been arranged according to the stratigraphic sequence as it appears from the field data. However, for most of the individual samples this suggested sequence is questionable; and neither is it entirely certain for the Oneata suite as contrasted with the group from Lakemba. Paleontologically, there is little to distinguish the individual Oneata and Lakemba smaller-foraminifer assemblages one from another, so that it is perhaps conducive to little error to regard the entire lot as coming from nearly the same horizon.

Taken as a whole, the Lower Futuna assemblages of Oneata do differ slightly in facies from the Lower Futuna assemblages of Lakemba when similarly viewed as a single faunal aggregate. These minor distinctions and the probable significance of the orbitoidal horizons will be treated in greater detail in the discussion of ecology.

The tuffaceous Lower member of the Futuna formation grades into an Upper member of pure crystalline limestone. On Ongea and Namuka this non-tuffaceous Upper member includes true elevated coral reefs which appear to lie concordantly upon bedded limestone (Ladd and Hoffmeister, 92, p. 165).

All samples from Katafanga, Ongea Levu, and Namuka were collected from the crystalline limestone Upper member of the Futuna formation, as were samples 62 and 26 from Vanua Mbalavu. The Katafanga and Ongea Levu samples were taken from a small-foraminifer coquina, the partial cementing of which makes impossible the specific identification of many of the constituent forms, especially the rare ones; thus the check list hardly does justice to the faunas represented here. In addition, the Katafanga samples are conspicuously rich in buff-colored oolitic concretions, in appearance of the general sort first termed "sporbo" in the Coast Range Tertiary of California by H. M. Horton (Galliher, 67; Rogers, 115); but they appear to be calcareous in composition rather than phosphatic (Crickmay, Ladd, and Hoffmeister, 35).

To judge from the field evidence, all seven of the Futuna Upper member samples appear to be higher stratigraphically than the entire group from Oneata and Lakemba. However, except for sample 26 from Vanua Mbalavu, there is no reliable field evidence for arranging any of the individual Upper member samples according to their precise stratigraphic relations to each other. It has seemed best to consider them as a group representative of a certain stratigraphic interval rather than of any definite sequence of horizons. Sample 26, collected from approximately the contact of the uppermost Futuna with the overlying volcanics, is probably stratigraphically the highest of the seven samples from the crystalline Upper member of the Futuna Limestone formation.

KORO MBASANGA VOLCANICS

The volcanic formation which uncomformably succeeds the Futuna Limestone in a few of the islands consists of agglomerates and lava flows, chiefly of olivine basalt in contrast to the andesitic and much more widespread older volcanics (Ladd and Hoffmeister, 92, pp. 11-12, 165-166). These basaltic Koro Mbasanga Volcanics take their name from what appears to be one of their main centers of eruption in the north, on Vanua Mbalavu. (Though not identical, the name is reminiscent of still another seat of local Tertiary volcanism farther west in Fiji, the jagged mountain mass of Koro Mbasa Mbasanga that so conspicuously dominates the skyline of the hinterland behind the principal port of Suva on the large island of Viti Levu.)

No foraminiferal samples were collected from the Koro Mbasanga formation.

NDALITHONI LIMESTONE

Next highest in the Lau stratal sequence is the Ndalithoni Limestone. Locally, the basal conglomerate of this formation carries huge boulders of olivine basalt and patches of coral reef. This basal unit is succeeded upward by dense shell-rubble limestone which, with numerous coral heads and fragments, is more typical of the formation as a whole (Ladd and Hoffmeister, 92, pp. 11-12, 166). Samples 110B and 110C from Vanua Mbalavu and sample L344A from the island of Tuvutha were collected from the Ndalithoni formation.

FULANGA LIMESTONE

Another, higher limestone is recognized in southern Lau, the Fulanga formation, from which—on the islands of Fulanga and Ongea Ndriki, respectively—samples L10 and L137 were collected. According to Ladd and Hoffmeister (92, pp. 11-12, 166), the Fulanga Limestone appears to have been deposited only locally, on the islands of Fulanga, Ongea, and perhaps Wangava, as a vertical veneer on older limestones.

MANGO ODINITE

On Mango in the north and on Kambara in southern Lau, a third distinct volcanic formation appears, the Mango odinite. This lava is barren of any associated organic remains.

FOSSIL FORAMINIFERA

TECHNIQUES OF STUDY

About 100 species and varieties of fossil foraminifers have been identified in the 25 assemblages from Lau (table 1). Of these, the 18 species and varieties of truly larger foraminifers (camerinids and orbitoids) have been described by Cole (27). Some 12 additional forms include indeterminate or atypically small representatives of stocks (operculinellids, *Heterostegina, Marginopora,* and some indeterminate cycloclypeid and lepidocycline remains) that also occur generally as true larger foraminifers. Still another 10 forms (*Rotalia, Amphistegina, Planorbulinella,* and the calcarinids) are of a sort which, in size and morphological complexity, is intermediate between the so-called "larger" and "smaller" foraminifers proper and which does not readily lend itself to the techniques of "large-foraminifer" study. Further and more careful sectioning and a commensurately thorough study of the internal morphology of some of these forms may reveal information of greater significance than that tabulated here. For the purposes of this report, however, these intermediate forms and the smaller representatives of the "larger-foraminifer" stocks have, like the balance of this Lau material, been studied merely with the normal "smaller-foraminifer" techniques.

The large and small Lau foraminifers often occur together in the same matrix. With certain modifications in nomenclature, both taxonomic and stratigraphic, Cole's data on the truly larger foraminifers have been taken from his published report (27) and inserted in the checklist (table 1) as indicated. (See pages 10-13.)

Since they occur in marls, calcareous tuffs, and limestones, the smaller-foraminifer fossils from Lau are not as well-preserved as the remains of the same forms deposited in mudstones and shales. As revealed in the accompanying illustrations, secondary solution and deposition have affected the surface features of many of the forms. All the Namuka material, for example, is unique in a certain delicate surface texture in combination with a salmon-pink coloration. The marked development of heavy calcareous surface ornamentation is another conspicuous feature of many tropical foraminifers. In this the Lau forms are in no way exceptional. An almost parallel development of superficial ridges, bosses, papillae, and other excrescences is discernible in several groups that are only distantly related.

COMPOSITION OF ASSEMBLAGES

The great bulk of the Lau smaller foraminifers are perforate calcareous forms. Both arenaceous and imperforate calcareous elements, often locally abundant elsewhere in assemblages that are otherwise very similar, are present in some of the Lau samples; but in general, these other two types of test are conspicuously rare in the Lau material.

Likewise, among the perforate calcareous stocks, the Lagenidae and Buliminidae—often abundant and diverse in otherwise comparable assemblages, though due to other causes—are poorly represented. Phylogenetically, the Lau assemblages are composed mainly of rotalids and their derivative stocks, both large and small, and of the symmetrically coiled camerinids and near-camerinids, also of both the "larger" and the "smaller" sorts.

Another characteristic of the composition of the Lau assemblages is a strikingly disproportionate representation of individuals of the various stocks present. About three-fourths of the species are represented by only a few individual specimens. Preponderantly, *Operculinella, Amphistegina,* certain Rotaliidae, and (in some samples) the Globigerinidae dominate the assemblages.

Table 1.—Checklist of Lau Foraminifera

A = abundant, C = common, F = few, ● = recorded by Cole (1945), R = rare.

Species, Genus, and Family	Yanuyanu	Oneata						Lakemba						Namuka	Ongea Levu		Katafanga		Vanua Mbalavu					Tuvutha	Fulanga	Ongea Ndriki
	15	L469	L438	L443	L444	L466	L487	L306	L307	L308	L387	L388	L389	L232	L116	L196	L377	L378	62	26		110B	110C	L344A	L10	L137
ARENACEOUS:																										
Rhizamminidae																										
Bathysiphon arenacea Cushman																						F	C			
Textulariidae																										
Textularia hauerii d'Orbigny										R									R				R			
Textularia rugosa Reuss																								R		
IMPERFORATE CALCAREOUS:																										
Miliolidae																										
Quinqueloculina cf. circularis (Bornemann)																							F			
Quinqueloculina oblonga (Montagu)																						R	R			
Quinqueloculina parkeri (Brady)																						F				
Quinqueloculina seminula (Linné)										R													R			
Pyrgo lucernula (Schwager)								R		R													F			
Peneroplidae																										
Peneroplis carinatus d'Orbigny					?																	R	F			
Peneroplis pertusus Forskål																								R		
Orbitolinidae																										
Marginopora aff. vertebralis Blainville							R												R					R		
PERFORATE CALCAREOUS:																										
Lagenidae																										
Robulus orbicularis (d'Orbigny)																F	F	R	F							
Lagena costata (Williamson)	R																									
Lagena globosa (Montagu)	R																									
Nonionidae																										
Nonion pacificum lauensis, n. var.													R													
Nonion umbilicatulum (Montagu)																							F			

	15	L469	L438	L443	L444	L466	L487	L306	L307	L308	L387	L388	L389	L232	L116	L196	L377	L378	62	26		110B	110C	L344A	L10	L137
Elphidium crispum (Linné)		F	R				F	F	R	F			R									F	F	F		
Elphidium craticulatum (Fichtel and Moll)		R			R			R														?				
Elphidium macellum (Fichtel and Moll)		R								R																
Nummulitidae																										
Operculina ammonoides (Gronovius)				R	R		R		R			R	R													
Operculina bartschi Cushman													●													
Operculina complanata japonica Hanzawa		●		●	●	●	●		R				F	F	R									R		F
Operculina gaimardi d'Orbigny													R													
Operculina granulosa (Leymerie)																							F			
Operculina mbalavuensis Cole																			●							
Operculina (?) sp.									R			R											R	R		
Operculinella cumingii (Carpenter) (Cole 1945)		●		●	●																					
Operculinella cumingii (Carpenter)		C	R		R		C	A	A	F		C	F							R			R	R	F	
Operculinella cumingii (Carpenter) (immature)			F	F	R								R													
Operculinella (?) oneataensis Kleinpell, n. sp.		F	C	C	C	F		F	F	R	R	R	C	F						F				F		
Operculinella sp. cf. O. venosa (Fichtel and Moll)								F	C	R			R			?										
Operculinella sp. (Cole 1945)											●												●			
Heterostegina depressa d'Orbigny																			R							
Cycloclypeus indopacificus terhaari Tan										●			●													
Cycloclypeus inornatus inornata Tan				●	●			●	●	●																
Cycloclypeus reticulatus Caudri				●	●			●	●	●																
Cycloclypeus posteidae hexaseptus Tan																			●							
Cycloclypeus posteidae pentekaidekaseptus Tan																			●							
Cycloclypeus sp.															F											
Katacycloclypeus annulatus Martin																			●							
Buliminidae																										
Bolivina cf. hantkeniana Brady		R																								
Bolivina cf. zedirecta Finlay		R								R																
Uvigerina canariensis lakembaensis, n.var.					R				R	F																
Reussella spinulosa (Reuss)																							R			
Siphogenerina costulata Cushman										R																
Pleurostomella brevis Schwager	R																									
Cassidulina subglobosa Brady	F																									

TABLE 1.—CHECKLIST OF LAU FORAMINIFERA (Continued)

A = abundant, C = common, F = few, ● = recorded by Cole (1945), R = rare.

SPECIES, GENUS, AND FAMILY	YANUYANU	ONEATA						LAKEMBA						NAMUKA	ONGEA LEVU		KATAFANGA		VANUA MBALAVU					TUVUTHA	FULANGA	ONGEA NDRIKI
	15	L469	L438	L443	L444	L466	L487	L306	L307	L308	L387	L388	L389	L232	L116	L196	L377	L378	62	26		110B	110C	L344A	L10	L137
Rotaliidae																										
Discorbis globularis (d'Orbigny)																						R				
Discorbis laddi, n.sp.		R	R	F	F		C	R		F													F			
Discorbis cf. nitida (Williamson)					F														R			R				
Discorbis pileolus (d'Orbigny)																			R				R			
Valvulineria vilardeboana (d'Orbigny)																			R							
Valvulineria (?) sp.																						R	F			
Eponides cf. concameratus (Montagu)								R											F			R	R			
Eponides cf. dutemplei (d'Orbigny)							R																			
Eponides karsteni (Reuss)	R																									
Eponides procerus (Brady)			R																R							
Eponides cf. repandus (Fichtel and Moll)																			R							
Eponides sp.																						R				
Eponides (?) sp.							R			R													R			
Parrella bengalensis (Schwager)			F		F					?									F			R	?	F		
Rotalia calcar (d'Orbigny)				R	F		R	F	R	C		R	R						R	R		F	C	R		
Rotalia tuvuthaensis, n. sp.																						C	A	A		
Epistomina hoffmeisteri, n. sp.																R			R	F						
Pegidiidae																										
Pegidia (?) sp.																			R							
Amphisteginidae																										
Amphistegina lessonii d'Orbigny					R		R		F				F									C	A	C		
Amphistegina lessonii conoides, n. var.		F			F	R	F	F	C	F		F	F	F								F		R		
Amphistegina lessonii fijiensis, n. var.		R					R	R	F	R		F	R						A				?			
Amphistegina lessonii melanesiensis, n. var.			C	R					A			C	R						R			F	F			
Calcarinidae																										
Calcarina majori Cushman									F																	
Siderolites mbalavuensis, n. sp.																			F							
Baculogypsina sphaerulata (Parker and Jones)																			R					R		

	15	L469	L438	L443	L444	L466	L487	L306	L307	L308	L387	L388	L389	L232	L116	L196	L377	L378	62	26		110B	110C	L344A	L10	L137
Cymbaloporidae																										
Cymbalopora sp.																			R							
Cymbalopora (?) sp.										R												R	R			
Cymbaloporetta bradyi (Cushman)																								R		
Cymbaloporetta poeyi (d'Orbigny)												R														
Globigerinidae																										
Globigerina bulloides d'Orbigny	F	R		F	R	F	R			R							A	F	F			R		R		
Globigerina conglomerata Schwager		R			R		R	R											C			R				
Globigerina (?) sp.								R																		
Orbulina universa d'Orbigny		R	R	R	R	R	R	R	R	R			R						C							
Globorotaliidae																										
Globorotalia menardii fijiensis (Cushman)		R				R		R		R																
Globorotalia patagonica (d'Orbigny)																							R			
Globorotalia sacharina (Schwager)						R		R										F								
Anomalinidae																										
Anomalina glabrata Cushman																							R			
Anomalina grosserugosa Gümbel										R												R	R	R		
Anomalina (?) sp.													R													
Planulina sp.																							R			
Anomalinella rostrata (Brady)																							R			
Cibicides aknerianus (d'Orbigny)	F																									
Cibicides lobatulus (Walker and Jacob)			R																							
Cibicides refulgens (Montfort)							R																F			
Cibicidoides sp.						R										?			R				R			
Planorbulinidae																										
Planorbulinella larvata (Parker and Jones)					R			R														F	F			
Orbitoididae																										
Nephrolepidina sumatrensis inornata Rutten													●													
Lepidocyclina papulifera H. Douvillé							●						●													
Lepidocyclina stratifera Tan																			●							
Lepidocyclina sp.															F		F	F								
"Trybliolepidina" martini (Schlumberger)																			●							
"Trybliolepidina" oneataensis Cole		●			●	●																				
"Trybliolepidina" rutteni (van der Vlerk)																			●							
"Trybliolepidina" rutteni lauensis (Cole)																			●							

BIOSTRATIGRAPHIC GROUPINGS

In the absence of stratigraphic profiles paleontologically suited to the collection of detailed faunal sequences in the field, a formal biostratigraphic classification of the 25 assemblages from Lau is hardly justified here. It is apparent, however, that about nine fairly distinctive faunules are represented. These, in turn, represent three to perhaps five still larger faunal units. Seven faunules, those that occur stratigraphically through the middle of the Lau sequence, group readily into three such larger faunas, whereas the broader relationships of both the lowest and the highest faunules (from Yanuyanu and from Fulanga and Ongea Ndriki respectively) remain obscure. In terms of their component faunal elements, each of these groupings is, in turn, but a portion of the one larger foraminiferal fauna which is immediately ancestral to that of the Indo-Pacific province of today.

In this crude grouping of the Lau smaller-foraminifer assemblages it is immediately apparent that each of the five larger faunal groupings is directly associated with one of the five purely stratal units that are to be distinguished in a lithogenetic classification of the containing rocks. In other words, each of the fossiliferous formations and members recognized in the field by Ladd and Hoffmeister is characterized by a distinctive microfauna. The more finely distinguished unit aggregates, the faunules, are then variously distributed: those of the tuffaceous Lower Futuna fauna as two separate facies, one developed on Oneata and the other on Lakemba; the four Upper Futuna faunules more heterogeneous in their geographic occurrences; and the Ndalithoni fauna much the same for both Vanua Mbalavu and Tuvutha.

For purposes of further discussion, these various faunal groupings require a discriminate terminology of some sort. In the light of the close relationships between formations and faunas, perhaps the formational terminology will serve, at least tentatively, to designate and distinguish the contained foraminiferal faunas; and the diverse local faunular facies thereof may be referred to under correspondingly appropriate geographic terms. (See figure 3.)

BIOSTRATIGRAPHY AND ECOLOGY

GENERAL RELATIONS

The Lower Futuna, part of the Upper Futuna [the Namuka-Ongea and the Vanua Mbalavu (locality 26) faunules], the Ndalithoni, and the Fulanga faunas, which thus collectively include the majority of the Lau assemblages, consist of associations of much the same ecological type. In most respects these are quite typically marine shallow- and warm-water assemblages such as probably inhabited one or another niche within the littoral bathymetric district of the tropics in the geologic past. Although conclusions as to the absolute depths and temperatures at which they may have lived cannot be made with any such assurance, a postulate of a depth of more than 30 odd fathoms would seem excessive for the original habitat of any of these faunules.

On the other hand, the Vanua Mbalavu (locality 62) and the Katafanga-Ongea facies of the Upper Futuna fauna, although tropical, appear to have lived at somewhat deeper if still "shallow" or shallow "medium depth" levels, or within the neritic bathymetric district. Within this neritic district, its shallower portion (the sub-littoral district or at least adjacent bathymetric levels) is indicated rather than its deeper reaches. Nothing suggests a situation at or even near the outer edge of the continental shelf. Although indicative of waters deeper than those in which other Futuna faunules and the Ndalithoni and Fulanga faunas lived, in no sense are these Vanua Mbalavu (locality 62) and Katafanga-Ongea faunules of the Upper Futuna truly "deep-water" assemblages.

Pelagic globigerinids are more or less numerous in all but the Namuka-Ongea, Vanua Mbalavu (locality 26), and Fulanga-Ndriki faunules, suggesting that the general region was accessible to the currents of the open ocean throughout most of Miocene, if not all of Neogene, time.

Thus the Lau Neogene faunas appear to have lived mainly in shallow tropical waters having access to normal open-ocean currents. The few exceptions noted suggest that a more detailed examination of the ecologically pertinent data, faunule by faunule, may be pursued here to some advantage.

YANUYANU FAUNULE

The Yanuyanu faunule has thus far been omitted from the discussion. Except for its pelagic element, this solitary assemblage from the Lau Volcanics of Yanuyanu in the Exploring Isles is unlike any of the others. Though clearly of pelagic, even planktonic, origins, its globigerinids, like all the other elements in this sample, are either dwarfed or represented entirely by immature forms. The significance of this peculiar situation is not clear; its sheer occurrence within a tuff may by itself be of some ecologic significance. Perhaps, on the other hand, it could simply be termed a "larval" assemblage. It is also reminiscent of certain other assemblages composed entirely of tiny representatives of their species, pelagic and probably "larval," which tend to characterize past and present seaweed forests of the eastern north Pacific (Woodring, Bramlette, and Kleinpell, 147, pp. 135-137).

Lalicker (95) emphasizes that the dwarfing of living protozoans may be due to any or all of several factors, which include the kind and quantity of food, amount of light penetration, the temperature, the hydrogen-ion concentration, and other physical and chemical conditions of the water. Instances are cited wherein a fossil foraminiferal species with an environmental optimum of shallow, clean marine water and a sandy or silty bottom is dwarfed in down-dip mudstone; and wherein living species with tropical optima exhibit dwarfing

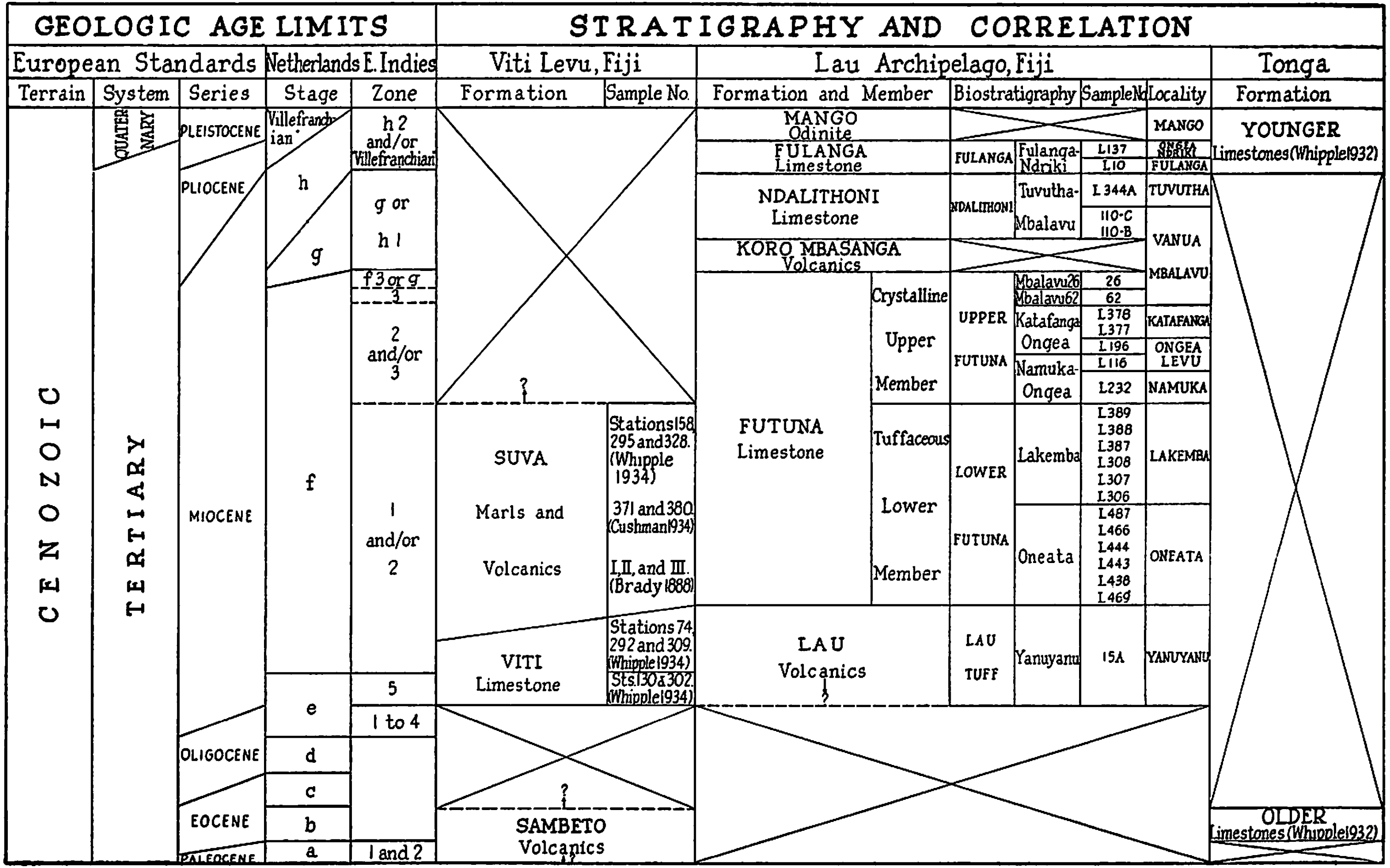

FIGURE 3.—Stratigraphical and age relationships of the Lau foraminiferal samples.

in their colder water, north Pacific representatives. That contemporaneous ash-falls may have affected the food of the Yanuyanu faunules and the general condition of the water is at least conceivable; and the unique presence of *Eponides karsteni* and numerous *Cassidulina* suggests a habitat colder than that indicated for any of the other Lau faunules.

FAUNULES OF LOWER FUTUNA FAUNA

The Lower Futuna fauna also has pelagic elements, both globigerinids and globorotalids, but herein they are allochthonous. Among its benthos, the mature and common *Operculinella* and *Amphistegina,* the numerous orbitoids, cycloclypei, *Operculina, Elphidium, Discorbis, Rotalia calcar,* and even the rare *Calcarina mayori, Planorbulina,* and cymbaloporids bespeak the warm and shallow water of the tropic littoral district. Within these limits are minor differences, between the Oneata suite of samples on the one hand and the Lakemba samples on the other, differences that point to local ecologic conditions at the time of deposition. These are so slight as to raise the question of false accuracy in pointing to their possible significance, yet both qualitatively and quantitatively they point consistently in the same direction.

The Oneata faunule has the more numerous globigerinids and more normally marine small rotalids and anomalinids. Conversely, the Lakemba faunule has the more numerous of the jointly common shallow-water operculinellids, amphisteginids, and *Rotalia calcar,* as well as the few textularids, buliminids, and cymbaloporids that are present in the Lower Futuna fauna as a whole. It also has the only representatives of those Miliolidae and *Nonion* which seem, among their living descendants, to show a degree of preference for current-sheltered spots and rocky bottoms. Thus during Lower Futuna deposition the tropical shallow waters of Lakemba seem to have differed in some respects from those of Oneata, a deviation which, in the case of Lakemba, is in a more non-pelagic and archipelagic direction.

A review of the quantitative data tabulated for the Lower Futuna samples (fig. 3) emphasizes the need to avoid pressing this interpretation too far. Yet the data, such as they are, tend independently to corroborate rather than to conflict with the conclusions previously arrived at independently from the evidence presented by the corals and mollusks and the inorganic data of geology (Ladd and Hoffmeister, 92, p. 261), to the effect "that Lakemba is probably the only island studied that projected above the sea during Futuna time."

However, another postulate, similarly derived, does not appear to be borne out by the same foraminiferal evidence as to the conditions of Lower Futuna deposition. This interpretation—that owing to "the widespread occurrence of well-developed bedding and the rarity of reef structure in the Futuna limestones . . . most of the mounds lay below the zone of coral reef growth . . ." during Futuna time (92, p. 261), that is "below 50 fathoms, the depth limit of reef-building corals" (92, p. 165)—is not corroborated by the evidence of the Futuna smaller foraminifers, except possibly in the case of the Upper Futuna samples of neritic facies previously noted (of the Vanua Mbalavu, locality 62, and Katafanga-Ongea faunules). Especially with reference to the tuffaceous Lower member of the Futuna, the smaller-foraminifer data are more in keeping with the noted "shallow-water" aspects of the molluscan fauna of which "most of the well-preserved Futuna fossils were collected from basal layers containing tuffaceous material" (92, p. 261). Seemingly the absence of well-developed corals in the Lower Futuna might be attributed to local current conditions, as may be inferred by the distinctive aspects of Lakemba, or to volcanic activity perhaps; but in any event, to some conditions other than depth.

UPPER FUTUNA FAUNA

Beyond distinguishing a littoral from a neritic facies of the Upper Futuna fauna, there is little apparent in the other minor differences that can be definitely interpreted as being of ecologic significance. The Vanua Mbalavu 26 and Namuka-Ongea faunules are meager assemblages of fairly large foraminifers of strictly shallow-water type, whereas the Vanua Mbalavu 62 faunule exhibits the only abundant development of a more characteristically medium-depth lagenid (*Robulus orbicularis*) in the entire Lau sequence. The absence of pelagic elements in the two Upper Futuna littoral faunules (Vanua Mbalavu 26 and Namuka-Ongea) distinguishes these from all of the other bathymetrically comparable assemblages lower in the same formation (those of the Lower Futuna fauna), as well as from both of those somewhat deeper-water (Vanua Mbalavu 62 and Katafanga-Ongea) neritic faunules of the contemporaneous Upper Futuna fauna in which pelagic elements attain their peak for the Lau Neogene.

Within these bathymetrically neritic facies of the Upper Futuna fauna, with their lagenid and pelagic maximums for Lau, the Katafanga-Ongea faunule differs from the Vanua Mbalavu 62 faunule only in its negative aspects; it simply lacks most of the species present in the rich Vanua Mbalavu 62 sample, a contrast with this sample 62 faunule that is shared by all of the other assemblages of the Upper Futuna fauna. Finally, in the light of the marked differences in the degree of preservation represented in the samples from Katafanga, Ongea Levu, and Namuka and in the two samples from Vanua Mbalavu (localities 62 and 26), perhaps some at least of the faunular distinctions within the Upper Futuna fauna as a whole may be more apparent than real.

NDALITHONI FAUNA

The Ndalithoni fauna in the samples from Vanua Mbalavu and Tuvutha exhibits the richest and most diverse small-foraminifer assemblages in the entire Lau suite. Ecologically, these are quite all of a piece. With their numerous *Elphidium, Rotalia,* operculinids, amphisteginids, calcarinids, cymbaloporids, and *Planorbulina* they are—like so many of the stratigraphically lower assemblages—typical of the littoral district within the tropics. In relation to the other small-foraminifer assemblages from Lau, ecologically, they are closest to those from the Lakemba facies of the Lower Futuna fauna. Apparent in this Vanua Mbalavu-Tuvutha faunule are, not only all the characteristic warm shallow-water elements and proportions of the Lakemba samples, but the otherwise absent arenaceous and imperforate calcareous stocks (including peneroplids) together with the same reduced proportions of pelagic globigerinids. Thus in the Ndalithoni fauna, as in the Lakemba facies of the Lower Futuna, there appears to be a more current-sheltered or archipelagic sort of faunule than in the general run of more typically oceanic assemblages from Lau. These ecological conclusions based on the small-foraminifer data seem to be in keeping with the evidence presented by the fossil mollusks and corals from the same Ndalithoni formation (Ladd and Hoffmeister, 92, pp. 263, 268-271).

FULANGA-NDRIKI FAUNULE

The operculinids from the Fulanga Limestone (the "Fulanga-Ndriki faunule" of fig. 3) are again indicative of warm, shallow marine waters: those of the littoral district within the tropics. On the basis of these extremely meager data little else in the way of ecologic conclusions can be added here.

AGE AND CORRELATION

SMALLER FORAMINIFERA

The stratigraphic ranges of smaller foraminifer species in the Cenozoic of the Indo-Pacific are still being worked out by the only known method for so doing, the "trial and error" method (Davies, 50, chapter 2). In this province, as in other comparable areas, the Tertiary time scale first to come into general use was based on units of Series magnitude and was blocked out primarily through the application by Karl Martin of Lyellian correlation methods to marine megafossils, particularly the molluscan faunas of Java (Leupold and Van der Vlerk, 101, p. 611). The more refined geologic age standards which followed, resulting in the so-called "letter classification" of East Indian Tertiary Stages and Zones (Leupold and Van der Vlerk, 101), have been based on the evolution and distribution in the Malay Archipelago of the larger foraminifers.

Although knowledge of the smaller foraminifers is currently accumulating and has already proved useful in the more local sort of correlations vital in petroleum exploration and development, this knowledge, especially its published portion, remains both meager in quantity and sporadic as to the distribution, in the column, of the materials treated. Many micropaleontologists engaged in the petroleum industry of the Netherlands East Indies have a far more comprehensive grasp of the Indo-Pacific Tertiary smaller-foraminifer faunas than will be immediately apparent to the paleontologist perusing the published literature on the subject; yet an adequate stratigraphic control on species ranges for the province alone (teilzones) still remains to be established. Even within the province, regional correlation on the basis of the smaller foraminifers alone is at this time possible only in the sense of a still very crude geologic time scale.

For example, the presence of *Orbulina universa* in most of the stratigraphically lowest Lau samples places the strata of all but the very lowest sample (15A, from which this species is absent) within the Neogene (LeRoy, 100); and the occurrence in sample 15A of *Pleurostomella brevis,* with a recorded Indo-Pacific range of Upper Miocene to Recent, suggests that this very lowest Lau sample is appreciably no older than the lowest *Orbulina*-bearing samples in the Futuna formation.

Though dubious conspecificity in many instances renders equally dubious the application of Lyellian correlation methods to the fossil smaller-foraminifer faunas of Lau, the greatly preponderant number of living species represented is at least adequate to corroborate this general Neogene correlation based on *Orbulina* and *Pleurostomella brevis.* There are also about twice as many extinct "Lyellian species" in the Futuna formation as in the higher Ndalithoni; but the percentage of living forms, even in the Futuna formation, does not approach Lyellian figures for the Miocene, even when the extinct larger foraminifers are included.

In terms of the smaller foraminifers, however, certain negative evidence does further emphasize the validity of a broad Neogene age designation. At the very most, only a half-dozen of the Lau species have been recorded from the pre-Neogene in the general Pacific area, and these are all long-ranging forms that are living today. In short, among small foraminifers Paleogene markers are entirely absent. For example, conspicuously lacking from the entire suite of Lau samples are certain fairly well-developed (though as yet undescribed) Indo-Pacific species that appear to range no higher in the column than the Paleogene. Among these are forms unknown from higher than the upper Eocene, such as certain buliminid species akin to *Bulimina jacksonensis* of the New World, which occur in Tertiary *c* strata of the East Indies. Among them are others ranging even higher, though apparently not above the Oligocene or lowermost Miocene, such as certain species of *Siphogenerina* related to *S. indica* LeRoy (98, pt. 1, p. 37, pl. 2, figs. 64, 65) from the East Indies Miocene and to *S. transversa* and *S. kleinpelli* and *S. branneri* of the Panamanian and Californian Oligo-Miocene, and of *Eponides* related to the living *E. praecinctus.* Both of the latter groups occur in, but no higher than, the Tertiary *e* strata of the Philippines.

Several of the Neogene Indo-Pacific species that are present in Lau appear conspicuously in published records from elsewhere in the province, especially at Miocene horizons; actually, only about six or seven of the Lau species—all Ndalithoni forms, incidentally (two miliolids, two peneroplids, a calcarinid, cymbaloporid, and globorotalid)—are known only from definitely post-Miocene horizons elsewhere in the Indo-Pacific. This might suggest a correlation of at least the Lau Volcanics-Futuna Limestone sequence with the lower rather than the upper portion of the Neogene; yet most of these species are indistinguishable from the representatives of the same stocks still living in the region. Even the few possibly extinct Lau species are apt to be long-ranging forms; at least they are species the upward ranges of which as recorded in the literature today still remain too ill-defined for the purposes of regional correlation. Similarly, the restriction in Lau to the Ndalithoni formation of a half-dozen species recorded in the Indo-Pacific only from the Recent or from the Pliocene to the Recent suggests the possible Pliocene age of that formation; yet, similarly, the first appearances (the downward ranges) of these species also remain ill-defined today.

However all this may be for the province as a whole, certain Lau species are clearly conspecific with forms present in the Miocene Suva formation of nearby Viti Levu: *Textularia hauerii, Pyrgo lucernula, Lagena costata, Bolivina hantkeniana, Pleurostomella brevis, Cassidulina subglobosa, Eponides* cf. *dutemplei* [="*Eponides* species (?)" of Cushman], *Parrella bengalensis, Orbulina universa* and at least two other globigerinids, and *Globorotalia menardii fijiensis.* And *Nonion pacificum lauensis* represents a local variety of a Suva species. Still, these are the rare and less characteristic Lau forms and are but a minor portion of the Suva assemblages. The most striking comparative feature here is the apparent lack of any strong relationship between these two faunas that occupy similar stratigraphic positions on island groups that are within the same archipelago. However, it seems that the obvious ecologic differences between them account readily enough for this situation. As already noted by Cushman (Ladd, 91; Crickmay, Ladd, and Hoffmeister, 35, pp. 94, 97), the Suva fauna with its abundant and diverse Lagenidae and Buliminidae is clearly of medium-depth (neritic to bathyal) origin, in contrast to the shallow-water (littoral to uppermost neritic at the deepest) nature of the Lau assemblages. Presumably, even though the two faunas were indubitably contemporaneous (as the larger foraminifers make abundantly clear in the case of the Lower Futuna and the Suva), only the more europic forms of the small-foraminifer benthos would appear in both.

In the light of these ecologic considerations, negative evidence again is largely in accord with the scanty positive evidence and supports the probability of a Miocene, rather than a Pliocene, age for all but the uppermost (Fulanga Limestone) Lau foraminifers. In these mainly shallow-water Lau microfaunas, the absence of certain post-basal Pliocene markers, widespread elsewhere in the shallow-water facies of the Indo-Pacific Neogene fauna, is very conspicuous. In the upper Miocene and lower Pliocene of the East Indies, and especially in such regions as Java and New Guinea and the Philippines where (as in contrast with much of southeastern Borneo, for instance) shallow-water assemblages are the rule rather than the exception, the base of the Pliocene (Tertiary *h*) is generally taken at the base of the so-called "Rotalia Zone." This key horizon, so widely employed in reconnaissance exploration, is characterized by the beginnings of an evolutionary efflorescence in at least one of the previously represented rotalid stocks. Involved is the sudden appearance in great numbers of more than one progressively ornate species closely related to *Rotalia papillosa*.[3] In the light of the comparably shallow-water origin of the Neogene assemblages from Lau, it is at least striking that—if Pliocene horizons are really involved in any of the foraminiferal Futuna and Ndalithoni beds—these otherwise ubiquitous Rotaliidae are not present. It is, in general, true that a diversity of local ecologic niches is at its maximum development in the shallow-water littoral district. It is also true that by uppermost Miocene (Tertiary *g*) and lowermost Pliocene (Tertiary *h*1) times, when Tertiary foraminiferal faunas, even at modern tropical latitudes such as those of the Malay Archipelago, were for the first time being drastically affected regionally by a temperature drop in world climates, the Fiji Islands may have temporarily passed beyond the limits of the Indo-Pacific province. If so, *Rotalia tuvuthaensis,* so conspicuous in the Ndalithoni fauna of Lau, might represent a local provincial parallel of that other rotalid evolution which was taking place about the same time farther west in Malaysia but only within the Indo-Pacific province proper.

Thus local differences in ecology or zoogeography rather than differences in age may account for the absence in Lau of these widespread post-Miocene markers of the Indo-Pacific. However, this absence from otherwise ecologically suitable assemblages in Lau is very conspicuous; and until further light is shed upon related matters of geographic distribution in the late Tertiary, this situation continues to loom as having possible chronological significance. In terms of distributional control, it probably outweighs the evidence, furnished by a half-dozen locally restricted but very rare species of known regional post-Miocene range, that favors a Pliocene age for the Ndalithoni formation.

For the present, expansion of the discussion of this phase of the correlation problems raised by the Lau smaller foraminifers seems unprofitable. Intrinsically, the smaller foraminifers furnish independent evidence for the age of the

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[3] Involved are several species and some diversity in terminological usage. Descriptions of form and locality may be found variously under *R. papillosa* and its variety *compressiuscula, R. schroeteriana* and its variety *inflata, R. annectens* and its variety *concinna, R.* (*Turbinolina*) *gaimardi, R. conoides, R. catilliformis,* and *R. alveiformis.* Some of these will be found also under the generic designations of *Rotaliatina* Cushman, *Streblus* Fischer, and especially *Asanoina* Finlay. (See Brady, 12; Millett, 104; Rutten, 116; Cushman, 36, 38, 46; Heron-Allen and Earland, 75; Koch, 88; Thalmann, 130; Yabe and Asano, 152; Finlay, 59; Ishizaki, 83; and Chapman, 23.)

Lau sequence only in the sense of a very crude chronology. However, it should be pointed out that, in terms of direct paleontological evidence, conclusions as to the age and correlation of the Lau Volcanics formation of Yanuyanu at the base of the Lau sequence still rest entirely upon such sketchy evidence as is furnished by the contained smaller foraminifers. It also should be pointed out that for conclusions as to the age of the Ndalithoni and Fulanga formations at the top of the same sequence there is available, in addition to the smaller foraminifers, only the suggestive but statistically inadequate Lyellian evidence furnished by the megafossils.

For the intervening Futuna Limestone interval, fortunately, a more reliable type of evidence is available, that of the large foraminifers. This evidence is described and evaluated in considerable detail by Cole (*27*, pp. *272-276*) ; and it unequivocally determines the Miocene Tertiary *f* age of the Futuna formation. It is not necessary to review Cole's data in their entirety; for the purposes of this report, only their bearing on the smaller foraminifer assemblages, some of which are directly associated with orbitoids and cycloclypeids, need be discussed. But in order that the correlations here employed may be viewed in their proper context, a prefatory word or two should be added on the general subject of correlation by means of the larger foraminifers in the Indo-Pacific as a whole.

ASSOCIATED LEPIDOCYCLINE ORBITOIDS

Requiring clarification at the outset are some of the differences in taxonomic terminology currently in use by various orbitoid specialists. Principally involved here are the usages of the subgeneric designations *"Eulepidina," "Trybliolepidina,"* and *"Nephrolepidina"* as employed, for example, by Leupold and Van der Vlerk in their East Indian Tertiary "letter classification" and by Cole in Lau. The validity of neither taxonomic usage is under discussion here, but rather the differences in substance that underly the usages of the same three subgeneric terms in these two instances.

Quite generally the name *"Trybliolepidina"* has been employed to designate lepidocyclines exhibiting a certain latitude in the morphology of their embryonic apparatus, a variability that seems to place this somewhat elusive group in a position taxonomically between two other subgenera, *Eulepidina* and *Nephrolepidina,* with which it seems to intergrade in both directions. Of the two earliest chambers in the megalospheric nephrolepidine, the first is only partly enclosed by the second, whereas in the eulepidines the second completely encloses the first except at the point where the smaller is attached to the wall of the larger. In those "trybliolepidine" forms that do not actually approach the nephrolepidine condition of partial enclosure these two chambers are flattened at the point of tangential juncture. In *Eulepidina sensu stricto,* however, the spherical chambers remain unflattened, and the area between the peripheries of the two chambers is of the shape of the two horns of a new moon instead of squarish as in the "trybliolepidines." Whatever taxonomic significance ultimately may be attributed to these clearly discernible morphologic features (see Cole, 27, pls. 22-28, and compare Whipple, 146, pl. 21), it is germane to the correlation of any Miocene strata within the Indo-Pacific province to compare, at the outset, the degree to which different morphologic features are included under the same taxonomic designation by different specialists in the field. Leupold and Van der Vlerk and others, writing of the stratigraphic distribution of lepidocyclines in the East Indies, distinguish the variable *"Trybliolepidina"* as a taxonomic entity, distinct from *Eulepidina sensu stricto* on the one hand and from *Nephrolepidina sensu stricto* on the other; whereas Cole apparently rejects the taxonomic reality as well as the name of *"Trybliolepidina,"* in practice dividing the trybliolepidine variables into two groups which he lumps with *Eulepidina* on the one hand and with *Nephrolepidina* on the other. For example, forms of the trybliolepidine sort represented by *Lepidocyclina oneataensis* Cole (Cole, 27, pls. 23-28), which would be a *"Trybliolepidina"* in the older usage of Leupold and Van der Vlerk, become *Eulepidina* in Cole's usage. The other type of variant, the *"Trybliolepidina"* as employed by Leupold and Van der Vlerk in their *"Trybliolepidina rutteni,"* for example, Cole now lumps under *"Nephrolepidina"* proper (27, p. 274). Thus if Cole's usage of *"Eulepidina"* is followed as the proper taxonomic designation here, it cannot be applied to the ranges given for that subgenus in the East Indian "letter classification" (Leupold and Van der Vlerk, 101, the two distribution charts opposite p. 648). Moreover, the lepidocycline species *"rutteni"* is the same species, whether listed under the subgenus *"Trybliolepidina"* as it was listed by Leupold and Van der Vlerk; or under *"Nephrolepidina,"* as listed by Cole; or, for that matter, under *"Eulepidina,"* as listed by Yabe and Hanzawa (154).

Without becoming further entangled in this taxonomic controversy, the stratigraphic significance of the various facts and terms involved can be further pursued here to considerable profit in terms of their correlative significance. On the basis of the extensive data on stratigraphic ranges assembled to date, the orbitoid genus *Lepidocyclina* arbitrarily serves, in the Indo-Pacific province, to establish the age of containing strata as between the base of Tertiary *d* and the top of Tertiary *f* (Leupold and Van der Vlerk, 101). Certain subgenera and species further serve to refine in varying degree the age designations within these broader limits. For example, *"Lepidocyclina (Eulepidina)" fide* Leupold and Van der Vlerk is a Tertiary *d*-to-*e* marker (Leupold and Van der Vlerk, 101); but *"L. (Eulepidina)" oneataensis* Cole, *"L. (Eulepidina)" radiata* (Martin) of Cole, and *"L. (Eulepidina)" transiens* Umbgrove of Cole (Cole, 27, p. 274) are not *"Eulepidina"* in the sense of this chronologically significant East Indian usage. These species are in this sense *"Try-*

bliolepidina" instead, a subgenus with a range from Tertiary *e*4 to *f*5 (Leupold and Van der Vlerk, 101). On the other hand, *L.* (*Eulepidina*) *formosa* Schlumberger of Cole (Cole, 27, p. 273 and Whipple, 146, p. 146) is "*Eulepidina*" in the East Indian sense of Leupold and Van der Vlerk. Moreover, "*L.* (*Nephrolepidina*) *martini* Schlumberger" of Cole, "*L.* (*N.*) *rutteni* Van der Vlerk" of Cole, and "*L.* (*N.*) *rutteni lauensis* Cole" (Cole, 27, p. 274) are not "*Nephrolepidina*," but "*Trybliolepidina*" in the East Indian sense of Leupold and Van der Vlerk (101); and this is in contrast to "*L.* (*N.*) *sumatrensis inornata* Rutten" of Cole (27, p. 274) which still are "*Nephrolepidina*" in the East Indian sense of Leupold and Van der Vlerk (101) with a range from Tertiary *e*1 to *f*3. With these considerations of taxonomic semantics in mind, discussion of the age and correlation of the Fijian lepidocyclines can proceed.

Cole has described and allocated 17 species or varieties of lepidocycline orbitoids from Lau (27, p. 274). Four subgenera are represented, of which one species each of the subgenera *Nephrolepidina* and "*Eulepidina*" (="*Trybliolepidina*") and one subgenerically unassigned microspheric form of the genus *Lepidocyclina* have also been recorded from Viti Levu in Fiji by Whipple, who in addition, records a single species each of *Multilepidina, Nephrolepidina, Eulepidina sensu stricto,* and a subgenerically unassigned microspheric *Lepidocyclina* (plus another distinct variety of this) from Viti Levu alone (Whipple, 146, p. 150). Of these 22 species or varieties of the genus *Lepidocyclina* thus far recorded from Fiji, five of the species have exhibited not only a widespread geographic distribution in the Malay Archipelago, but a notably restricted range in stratigraphic occurrence. Moreover, at least two of these five species are directly associated with the smaller-foraminifer assemblages in Lau. The presence of these lepidocycline species in Lau yields the most significant evidence as to the geologic age, not only of the Cenozoic formations of Lau, but (at least for the present) of the associated smaller-foraminifer assemblages there. The five stratigraphically diagnostic lepidocycline species recorded from Fiji are *L.* (*E.*) *formosa, L.* (*N.*) *taiwanensis, L.* (*N.*) *angulosa, L.* (*N.*) *sumatrensis ornata,* and *L.* ("*T.*") *rutteni.*

Lepidocyclina (*Eulepidina*) *formosa* Schlumberger is present at stations 74 and 292 on Viti Levu and serves to date the containing portion of the Viti Limestone of that large island as lying within the interval of Tertiary *d* to *e*5 time. In spite of the name of this species, it is as yet not recorded from the main island of Formosa but only from the little isle of Botel Tobago off the southwest coast. The species is especially abundant and widespread in Tertiary *e*5 strata of the Netherlands East Indies and in the Philippines where it was first recorded under the name of "*Lepidocyclina richthofeni* Smith" (W. D. Smith, 123 and 124, pp. 80, 316-322; Dickerson, 51, pp. 14-15 in part; Yabe and Hanzawa, 154, pp. 99, 105, 106). It has been identified by Harriet Williams Morrison and Roberto Grey and me, in samples collected by the geologists of the Philippines Petroleum Survey, as common in the lowest Tertiary beds of Cebu, the lowest beds of the typical Vigo formation of Luzon, and other Philippine strata of Tertiary *e*5 age. In the light of these and other regional data it seems highly probable that the marine inundation of Tertiary *e*5 time called the Beboeloe Transgression (Leupold and Van der Vlerk, 101, p. 631), which is such a widespread phenomenon throughout most of the Malay Archipelago and other islands off the southeast Asiatic mainland, extended still farther eastward into the Pacific, as far at least as Viti Levu in Fiji. But there is no evidence to clearly indicate that Tertiary marine deposition in the Lau Islands began this early, even though in the light of negative evidence it is entirely possible that the basal non-foraminiferal and tuffaceous Lau Volcanics formation at the bottom of the Lau Tertiary column (and perhaps even some of the barren basal Futuna Limestone as well) may be a correlative of the Viti Limestone of Viti Levu.

Lepidocyclina (*Nephrolepidina*) *taiwanensis* Yabe and Hanzawa is the commoner so-named species on the main island of Formosa (Taiwan). Slightly younger in age than *L.* (*Eulepidina*) *formosa*, it appears to be restricted to the Tertiary *f* Stage of the Indo-Pacific. As pointed out by Cole (27, pp. 273, 274, 291), its presence in the Futuna Limestone of Thikombia-i-lau (locality T16) and Vanua Mbalavu (locality 21) appears to place these, the oldest orbitoidal strata in Lau, within this Stage. Here, however, no smaller foraminifers are associated with the orbitoids.

Lepidocyclina (*Nephrolepidina*) *angulosa* Provale in the East Indies ranges from Tertiary *e*3 to *f*3 (Leupold and Van der Vlerk, 101). Beyond serving to place both locality 309 in the Viti Limestone of Koronisangana on Viti Levu (Whipple, 146, pp. 142, 150) and locality 34 on Vanua Mbalavu in Lau (Cole, 27, p. 274) within these age limits, its presence in either Fijian area throws no light on the age of either the smaller foraminifers or their containing strata.

Lepidocyclina (Nephrolepidina) sumatrensis inornata Rutten is the oldest orbitoid associated with smaller foraminifers in Lau. In the East Indies the species ranges from Tertiary *e*5 to *f*2 (Leupold and Van der Vlerk, 101). It is recorded by Cole from the Futuna Limestone, on Vanua Mbalavu at locality 43 and on Lakemba at locality L389 (Cole, 27, pp. 274, 291). Thus the smaller foraminifers from Lakemba sample L389 may be dated as within the interval Tertiary *e*5 to *f*2 and are the oldest Lau smaller foraminifers thus datable on the basis of associated orbitoids. On purely geologic grounds, sample L389 appears to be stratigraphically the highest sample of all those comprising the Lakemba and Oneata smaller-foraminifer suites; thus where smaller foraminifers have been collected on Oneata and Lakemba, the tuffaceous Lower member of the Futuna formation of Lau is no younger than Tertiary *f*2. What its lower limits may be is not so clear; but apparently no horizons older than those of the Tertiary *e*5 Beboeloe Transgression are involved, and such positive paleontological evidence as is available suggests a Tertiary *f* age for the oldest Lau strata, rather than *e*5.

Lepidocyclina ("Eulepidina" sensu lato = Trybliolepidina) rutteni Van der Vlerk appears to be stratigraphically the most restricted of the larger foraminifers recorded from Fiji. Widely throughout the Netherlands East Indies, it appears to be an important marker for Zone *f*3 of the Tertiary (Leupold and Van der Vlerk, 101; Van der Vlerk, 141; Crespin, 33; 34, p. 424), the interval of final orbitoid flowering there. It appears to be equally restricted in its geographically widespread stratigraphic occurrences in the Philippines, where its presence has already been recorded under the name of *"Lepidocyclina (Eulepidina) leyteensis* Yabe and Hanzawa" (Yabe and Hanzawa, 154, pp. 99, 101, 107; 155, p. 167) at the Villaba tar-sand locality in northwest Leyte and elsewhere. As a "large *Lepidocyclina*" (Dickerson, 51, p. 14), this species has been recorded from the limestones of Mount Morabi, a portion (the lower part) of the Canguinsa member of about the middle Vigo formation on the Bondoc Peninsula of Luzon.[4] *Lepidocyclina (T.) rutteni* occurs in a number of orbitoidal localities on Vanua Mbalavu (Cole, 27, p. 275); thus its presence seems to permit dating and correlating them accordingly. Of special interest here, moreover, is the presence of this zonally diagnostic orbitoid species at Vanua Mbalavu locality 62, where it is associated not only with several of the other species or varieties of *Lepidocyclina* known from Fiji but with one of the richest of the Lau smaller-foraminifer assemblages. Thus this rich smaller-foraminifer assemblage from locality 62 appears referable to Tertiary *f*3 in the East Indian Tertiary "letter classification" (fig. 3).

In closing the discussion of the associated lepidocyclines and smaller foraminifers, a word should be added on a comparison of these associations as developed in Viti Levu as well as in the Lau Islands. It has already been pointed out that of all the smaller-foraminifer bathymetric facies represented in Lau, the closest to those in the Suva formation of Viti Levu is that of Vanua Mbalavu locality 62; yet this Lau assemblage from the Upper member of the Futuna formation (the "Mbalavu 62 faunule," Upper Futuna fauna) is essentially no more closely related to that of the Suva formation than are the shallow-water assemblages from the Futuna Lower member. This is also true of the associated lepidocycline orbitoids in each case. Vanua Mbalavu locality 62 carries none of the lepidocyclines found in the Suva formation, whereas those species found in the Suva formation which also occur in Lau—*L. ("Trybliolepidina") radiata,* including the synonymous *"L. dilatata"* of Whipple, and *L. papulifera*—occur only in the tuffaceous Lower member of

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[4] In the references cited the "large lepidocyclinas" from the Canguinsa member and those from the lowest beds of the Vigo formation have all been lumped together, but only the lowest Vigo occurrences are *"L. richthofeni"* (= *L. formosa*); the lower Canguinsa forms are *"L. leyteensis"* (= *L. rutteni*).

the Futuna Limestone formation of Oneata and Lakemba. (See Whipple 146, pp. 141-142; stations 158, 295, 316, and 328.) Thus it seems that at least the sampled smaller-foraminiferal portions of the tuffaceous Lower member of the Futuna formation are the most probable correlatives, in Lau, of the smaller-foraminifer-bearing Suva formation of Viti Levu (already correlated with the Lower Rembang beds at Ngampel, Java, by Whipple, 146, p. 142), although of different bathymetric facies. It also seems that the crystalline Upper member of the Futuna Limestone formation of Lau is younger than any portion of the Suva formation of Viti Levu from which foraminifers have thus far been recorded.

ADDITIONAL ASSOCIATED LARGER FORAMINIFERA

Of larger foraminifers other than lepidocyclines, mention should be made of the recorded presence of *Miogypsina polymorpha* in the Viti Limestone of Viti Levu (Whipple, 146, pp. 142, 150). Since this species appears to be restricted to Tertiary *f* in the East Indies (Leupold and Van der Vlerk, 101), there is a basis for concluding that, locally, at least, the upper portion of the Viti Limestone (as at station 292 near Wailotua) extends upward beyond the lower beds of Tertiary *e*5 age and into the Stage of Tertiary *f*, to some portion of which the overlying Suva formation of Viti Levu belongs.

The additional presence of *Miogypsina thecideaeformis* on Viti Levu (Whipple, 146) and of *"M. neodispansa"* (of Cole, 27)[5] on Vanua Mbalavu in Lau, though significant in itself, throws no more than corroboratory light upon the correlations under discussion. *Miogypsina* is not associated with smaller foraminifers in Lau. Numerous other larger foraminifers, specifically cycloclypeid and operculinid Nummulitidae, have however been recorded in such association; and the occurrences of numerous additional representatives of these stocks are here tabulated in table 1. Among previously unrecorded larger foraminifers from Lau, a single small specimen of *Marginopora* corroborates the general Neogene age of all the Lau samples stratigraphically at or above the horizon of Oneata locality L487. The presence of abundant *Amphistegina* and of rare *Heterostegina,* though indicating a Cenozoic age, are less diagnostic. *A. lessonii,* however, does seem to be a Neogene species.

To my knowledge, the species of *Operculina* add little in the way of chronologically diagnostic information to the evidence from the orbitoids and cycloclypeids. Among the larger foraminifers, the genus *Operculinella* tells much the same story as that told by *Orbulina universa* among the smaller forms: a Neogene age for the containing strata. Special reference to these two camerinine stocks is required here only because of their presence in the Fulanga Limestone samples from the islands of Fulanga and Ongea Ndriki. Determination

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[5] Cole now states (written communication) that these specimens should be referred to *Miogypsinoides cupulaeformis,* a Burdigalian species.

of the age of these samples rests upon the evidence furnished by stratigraphic relations discernible in the field and by extra-foraminiferal paleontologic data. Among the larger foraminifers, *Operculina* and *Operculinella* (which are still living in the Indo-Pacific today, as are *Marginopora* and *Alveolinella*), have outlived most of the others. However, in regions where they are no longer found these stenothermal and stenobathic genera persisted in considerable numbers into early Pleistocene time, as for example in the Plio-Pleistocene Ryukyu Limestone of the Ryukyu (Loochoo) Islands (Yabe, 148; Yabe and Hanzawa, 153; Hanzawa, 72). In the typical Malumbang formation, Plio-Pleistocene of the northern Philippines, they are also well represented. Perhaps the Fulanga Limestone of southern Lau is a correlative, far to the southeast, of the Plio-Pleistocene Malumbang and Ryukyu Limestones of the northwestern Indo-Pacific; but if so, this is hardly in consequence alone of their containing, in common, numbers of these two operculinid genera.

Cole (27, pp. 272-275, 278-283) presents a detailed discussion and summary of the correlative significance of the species of cycloclypei found in Lau. Further comment here need not go beyond pointing out that some of the correlations of individual samples herein arrived at on the basis of the known ranges of species of *Lepidocyclina* in the Malay Archipelago will be found to conflict with those based on the more, or the less, "advanced" stages in *Cycloclypeus* evolution (Cole, 27, pp. 273-275) as demonstrated by Tan Sin Hok. Cole appears to have been well aware of this situation, as he indicates (27, p. 281) in his discussion of the age and stratigraphic relationships of the two stocks under *C. (Cycloclypeus) indopacificus terhaari* Tan. However inadequate may be the superpositional discipline determining the ranges of orbitoid species in the East Indies as used in the "letter classification," it is my opinion that currently these ranges are under abundantly more adequate stratigraphic control than are the ranges of the species and subspecies and varieties of *Cycloclypeus* in the remarkably comprehensive, if somewhat overly mechanical, classification of Tan. (See Cole, 27, p. 279.) For example, the actual clinical data behind the conflicting evidence presented by the two stocks in samples L389 from Lakemba and 62 from Vanua Mbalavu seem to me to be more than heavily weighted in favor of the orbitoid species. Moreover, the presence of *Lepidocyclina sumatrensis inornata* in L389 and of *L. rutteni* in 62 supports this evaluation in terms of their known stratigraphic ranges relative to each other within the same stock, as does such field stratigraphic evidence as is available even locally in Lau. Since L389 was collected from the tuffaceous Lower member and 62 from the Upper member of the same Futuna formation, some revision of the groupings of Cole (27, pp. 273-275) seems to be required. Thus, according to the correlations adopted in the present report, and specifically on the basis of the known ranges of the species of *Lepidocy-*

clina, his groups 4 and 5 appear to be older than his groups 2 and 3, rather than the other way round as shown on the basis of "more advanced" or less advanced stages of cycloclypeid evolution; that is, "if the evolutionary development of the cycloclypei is accepted as demonstrated by Tan" (27, p. 273).

In fact the situation postulated in the above-quoted statement, goes even beyond the matter of a "demonstrated . . . evolutionary development of the cycloclypei," or any other stock. Acceptance of the correlative significance of "stage of evolution," per se, in a stock of organisms is tantamount to acceptance of the telescoping of two entirely distinct phases of organic evolution, speciation and extinction. These natural processes are not at all the same, and the distinction is a vital one perhaps too often overlooked in matters of geologic chronology and correlation by paleontological methods. Adequately demonstrated, any "stage of evolution" yields a basis for a single delimiting age horizon in subsequent correlation, a horizon than which no subsequently encountered example of this "stage of evolution" can be any older; yet this in itself yields no age ceiling for such a subsequent find. Here, in addition to speciation, the factor of extinction becomes involved, for ancestral taxonomic units perhaps as often as not geologically outlive at least some of their own descendant stocks. The knowledge of extinction, required for the recognition of this higher horizon than which no subsequently encountered example of this "stage of evolution" can be any younger, is yielded only by the data of stratigraphy, with at least a relatively high degree of stratigraphic control required as well. Here again appears that unhappily requisite "trial and error" method of stratigraphic paleontology. Eventually, as the data of morphology and of detailed stratigraphic allocations thereof accumulate, a high degree of probability in correlations is attainable, though the acquisition of these critical facts of stratigraphic distribution remain, at best, a process of trial and error. This is attested by the celebrated finds of living *Trigonia* in Sydney Harbor; of living coelocanth fish off South Africa; of the "dawn redwoods" still living today in China; as well as by the many more, if also more prosaic, instances of that experience termed by Ulrich the "stratigraphic perfidy of fossils" which are so well known to the professional stratigraphic paleontologist.

ASSOCIATED MEGAFOSSILS

On the basis of its content of 29 percent, or six living mollusk species in a total of 21, an Upper Miocene age (Tertiary *g*) has, with reservations, been suggested for the Futuna Limestone (Ladd and Hoffmeister, 92, pp. 265-267). A correlation of this Futuna formation of Lau with the Miocene Suva formation of Viti Levu is also indicated by the evidence of megafossils. As noted by Ladd and Hoffmeister, these data simply corroborate the general correlation on the basis of the more trustworthy larger foraminifers of the Futuna formation with Miocene formations elsewhere. Several of the megafossil species involved here occur at the smaller-foraminifer localities: L438, L444, L466 and L487 on Oneata; L308 and L389 on Lakemba; L377 on Katafanga; and 62 on Vanua Mbalavu (92, table 17).

For the stratigraphically higher formations of Lau—the Ndalithoni and the Fulanga Limestones—megafossils furnish more significant evidence as to age, if for no other reason than that orbitoids are lacking.

From the Ndalithoni, nine living mollusk species out of 22 have yielded a figure of 41 percent Recent, suggesting an Upper Miocene stage Tertiary *g* age (Ladd and Hoffmeister, 92, p. 267). Four of the six echinoids are living species. According to Hoffmeister (92, p. 298), a comparable age "no earlier than the Miocene and no later than early Pliocene is indicated" by the Ndalithoni corals. Most of the corals and several of the mollusks and echinoids in the Ndalithoni formation were collected from the smaller-foraminifer localities 110B and 110C on Vanua Mbalavu and L344A on Tuvutha, localities which carry the richest smaller-foraminifer assemblages in Lau. These assemblages have already been discussed in this paper as post-Tertiary *f* in age, on the basis of stratigraphic relations described from the field, and as probably pre-Pliocene (pre-Tertiary *h*) in age on the basis of specific content. However, a Lower Pliocene (Tertiary *h*1) age is not entirely ruled out by this evidence.

The Fulanga Limestone has yielded four mollusk species, all living Indo-Pacific forms; three living out of four echinoid species; and one crustacean. Some of these occur at the foraminifer locality L10 on Fulanga. "The tentative reference of the limestone to the early Pleistocene is based almost entirely on field evidence" (Ladd and Hoffmeister, 92, p. 267).

SUMMARY

In the light of these paleontologic and stratigraphic data, 25 smaller-foraminifer samples and the faunal groupings and formations and members which they represent on various of the Lau Islands have been chronologically classified and correlated as shown in figure 3. These age assignments may be summarized as follows:

Lau Volcanics:

Age probably Neogene but not certain; probably middle Miocene within the interval Tertiary *f*1 to *f*2. Represented by sample 15A from Yanuyanu, oldest of the Lau foraminiferal localities.

Futuna Limestone:

Tuffaceous Lower member:

Age no younger than Middle Miocene Tertiary *f*2 and probably no older than Tertiary *f*1. Most probably a correlate of the foraminiferal portion of the Suva formation of Viti Levu. Represented in Lau by samples L438, L443, L444, L466, L469, and L487 from Oneata; samples L306, L307, L308, L387, L388, and L389 from Lakemba.

Crystalline Upper member:

Age Upper Miocene Tertiary *f*3. Younger than any of the foraminiferal horizons recorded from the Suva formation of Viti Levu, Fiji. Represented in Lau by samples L377 and L378 from Katafanga; samples L116 and L196 from Ongea Levu; sample L232 from Namuka; sample 62, and sample 26 from the very top of the Futuna formation, on Vanua Mbalavu.

Ndalithoni Limestone:

Age Upper Miocene or Lower Pliocene, most probably Tertiary *g*, or possibly Tertiary *h*1. Represented in Lau by samples 110B and 110C from Vanua Mbalavu and L344A from Tuvutha.

Fulanga Limestone:

Age late Neogene but otherwise uncertain, most probably Upper Pliocene and/or Lower Pleistocene ("Plio-Pleistocene," or the "Villafranchian" *auctores* of the Far East).[6] Represented in Lau by samples L10 from Fulanga and L137 from Ongea Ndriki.

LIST OF SMALLER-FORAMINIFER LOCALITIES

The following locality descriptions are taken from Ladd and Hoffmeister (92, pp. 175-190). For the same localities plotted graphically according to their topographic and geologic relationships (92), see their figures 3, 5, 15, 16, 17, 19, 21, 23, and 24.

Yanuyanu, Vanua Mbalavu

15. Volcanic, eastern end of small islet of Yanuyanu opposite village of Lomaloma; few feet above sea level.

Oneata

L438. Basal foraminiferal limestone, east side of Jiro Bay; altitude 0-20 feet.
L443. Basal foraminiferal limestone, high point near western end of island; altitude 105 feet.
L444. Basal foraminiferal limestone, northwest of Waingori; altitude 65 feet.
L466. Basal foraminiferal limestone, near western end of western lake; altitude about 15 feet.
L469. Algal nodules from basal foraminiferal limestone, near southwest shore of western lake; altitude about 25 feet.
L487. Basal foraminiferal limestone, fossils from various exposures above inner edge of coastal flat along southwest tip of island; altitude 5-50 feet.

Lakemba

L306. Weathered limestone and soil, Vatuloa on southwest coast; altitude 80-100 feet.
L307. Foraminiferal limestone, Vatuloa on southwest coast; altitude 87 feet.
L308. Foraminiferal limestone, Vatuloa on southwest coast; altitude 90 feet.
L387. Limestone boulder along trail near Tarakua on south side of island.
L388. Tuffaceous limestone, 0.5 mile southeast of Tumbou on south side of island; altitude 5-15 feet.
L389. Tuffaceous limestone on coast between Tumbou and Tarakua-wai; altitude 0-3 feet.

Namuka

L232. Foraminiferal limestone, southwest coast near Nambau; altitude 9-19 feet.

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[6] See Movius 105, table 11, for this usage.

Ongea Levu

L116.	Limestone, south coast; altitude 20-25 feet.
L196.	Limestone of eastern ridge near north end of island; altitude 133-148 feet.

Katafanga

L377.	*Globigerina* limestone on northeast coast immediately above sea level.
L378.	*Globigerina* limestone on northeast coast immediately above sea level.

Vanua Mbalavu

26.	Limestone-volcanic contact, western coast about 1 mile northwest of Ndalithoni.
62.	Limestone, cave on northern coast about 0.33 mile west of Futuna.
110B.	Conglomerate at Ndukelulu, point north of Ndalithoni village; altitude 15 feet.
110C.	Tuffaceous limestone, tip of Ndukelulu, point north of Ndalithoni village; 12 feet above sea level.

Tuvutha

L344A.	Coral heads from limestone, cave at Ndravuni, northwest coast, near sea level.

Fulanga

L10.	Limestone, western shore of inner lagoon; altitude 0-2 feet.

Ongea Ndriki

L137.	Limestone, high point northwest end of island; altitude 275 feet.

SYSTEMATICS

Type specimens of the smaller foraminifer species and varieties from Lau are the property of the Natural History Museum of the University of Rochester, but are deposited in the U. S. National Museum on an indefinite loan basis. Except for the forms represented by a single specimen, and so noted, duplicate material is on deposit in the Museum of Paleontology of the University of California at Berkeley.

In the following section there is no attempt at a complete synonymy, even for the Indo-Pacific province. Both the taxonomic data and the comparably incomplete distributional data, however, are considered representative for the general Indo-Pacific region. Synonymy is based almost entirely upon comparisons with published figures and descriptions of Indo-Pacific forms. Topotype material from the Suva formation of Viti Levu, Fiji (Cushman, 44), was available during the earlier phase of the work but was lost during the war. Many of the Lau species have been compared with still other collections of Indo-Pacific material from the Neogene of the Malay Archipelago and Japan farther west, yet very little of this comparative material—a fauna from the Santa Cruz marl of Luzon (Karrer, 85) is an exception—can be considered truly typical of any formally named, described, and published species of foraminifer.

Many species are represented in the Lau material by only a few specimens, some of which appear to be new and undescribed. Those in an excellent state of preservation and with clearly defined morphology are named and described but most are poorly preserved and are inadequate for formal taxonomic purposes. These I refer, with certain qualifications, to more or less related and better known species, or leave specifically unnamed.

FAMILY RHIZAMMINIDAE

Genus **Bathysiphon** M. Sars, 1872

Bathysiphon arenacea Cushman (pl. 1, fig. 1).

Bathysiphon arenacea Cushman, LeRoy, Colorado School of Mines Quart., vol. 39, no. 3, pt. 1, p. 13, pl. 1, fig. 44, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13592, from locality 110C.

Several broken fragments in the Lau material apparently represent this living species. A few such fragments may represent *B. irregularis* LeRoy (99, pt. 1, p. 13, pl. 5, fig. 24), but they have not been distinguished on the checklist.

The known range of *B. arenacea* is from Miocene to Recent (Kleinpell, 86, pp. 137, 184).

FAMILY TEXTULARIIDAE

SUBFAMILY TEXTULARIINAE

Genus **Textularia** Defrance, 1824

Textularia hauerii d'Orbigny (pl. 1, fig. 3).

Textularia hauerii d'Orbigny, Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 17, p. 628, pl. 47, figs. 21-25, 1915.—Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 105, pl. 19, fig. 6, 1921.—Ishizaki, Taiwan Tigaku Kizi, appendix, vol. 10 (1939-1940), p. 23, 1939.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 3, p. 112, pl. 1, figs. 23, 24, 1941.

Textularia cf. *hauerii* d'Orbigny, Cushman, B. P. Bishop Mus., Bull. 119, p. 105, pl. 10, fig. 5, *a, b,* 1934.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13593, from locality 110C.

A few poorly preserved fragments appear to be the same as the form figured from the Suva formation of Viti Levu. Cushman refers them doubtfully to d'Orbigny's West Indian species but remarks "that they are perhaps closer to a form from the Philippines . . . figured as *T. agglutinans* . . . ." The latter has also been recorded from the Miocene of Japan (Asano, 7, p. 423) and the Neogene of the East Indies (LeRoy, 98, pt. 1, p. 19, pl. 2, figs. 62, 63, var. *porrecta;* pt. 2, p. 69, pl. 2, figs. 33, 34; pt. 3, p. 111, pl. 2, figs. 33-35). As Finlay has pointed out (59, no. 2, pp. 89-90, pl. 14, figs. 63-66), it is also closely allied to *T. zeaggluta* and *T. cuspis* from the Eocene and Oligocene of New Zealand. (See also Dorreen, 52, pp. 284, 286, pl. 36, fig. 1.)

The Lau specimens are too few and too poorly preserved to shed further light on these problematical relationships.

Textularia rugosa Reuss (pl. 1, fig. 2).

Textularia rugosa Reuss, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 363, pl. 42, figs. 23, 24, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 284, pl. 29, fig. 2, 1897 (1899).

Textularia rugosa (Reuss), Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 17, pp. 625-626, pl. 47, figs. 7-9, 1915.—Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 114, pl. 23, figs. 3, 4, 1921.

?*Textularia rugosa* (Reuss) of Lalicker and McCulloch, Said, Cushman Found. Foram. Research, Contrib., vol. 1, pt. 2, p. 5, pl. 1, fig. 5, 1950.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13594, from locality L344A.

This living species is rare in Lau, occurring only in the Ndalithoni formation of Tuvutha. In fossil form it is recorded from beds as old as the Miocene of Australia (Heron-Allen and Earland, 77, p. 136).

FAMILY MILIOLIDAE

Genus **Quinqueloculina** d'Orbigny, 1826

Quinqueloculina cf. **circularis** (Bornemann) (pl. 1, fig. 5).

?*Miliolina circularis* Bornemann (?), Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 169, pl. 5, figs. 13, 14, 1884.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13595, from locality 110C.

Low and compressed forms more or less circular in outline may, in the Lau material, represent Bornemann's species as doubtfully identified and figured by Brady. The Lau specimens are neither numerous nor particularly well-preserved, and there is even some individual variation in the forms thus lumped here. Individual specimens vary respectively in the direction of three or four species figured from the East Indian Neogene by LeRoy (98) under various names: *Q. akneriana* d'Orbigny (pt. 2, p. 71, pl. 5, figs. 9, 10, 15, 16), *Q.* aff. *lamarckiana* d'Orbigny (pt. 2, p. 71, pl. 5, figs. 5, 6), *Q.* sp. C. LeRoy (pt. 1, p. 22, pl. 3, figs. 23-25), *Q.* sp. F. LeRoy (pt. 2, p. 71, pl. 5, figs. 3, 4).

Quinqueloculina oblonga (Montagu) (pl. 1, fig. 4).

Miliolina oblonga Montagu, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 160, pl. 5, fig. 4, 1884.—Millett, pt. 1, Roy. Microscopical Soc., Jour., p. 267, pl. 5, fig. 14, *a, b,* 1898.—Flint, U. S. Nat. Mus., Ann. Rept., p. 297, pl. 43, fig. 3, 1897 (1899).

Triloculina oblonga (Montagu), Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 69, pl. 26, fig. 3, text fig. 36, 1910-1917; Bull. 100, vol. 4, p. 459, pl. 92, fig. 3, *a-c,* 1921; Bull. 161, pt. 1, p. 50, pl. 11, fig. 10, *a-c,* 1932-1933.

Quinqueloculina oblonga (Montagu), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 71, pl. 5, figs. 7, 8, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13597, from locality 110B.

Chapman, in recording this form as "having been distributed by . . . Antarctic currents" in the cold waters southeast of Australia, refers it to Wiesner's 1931 genus *Miliolinella* (23, pp. 188, 206-207).

Poorly preserved specimens of the living Indo-Pacific species are rare in the Ndalithoni Limestone of Vanua Mbalavu. It has been recorded from the Miocene of Australia by Heron-Allen and Earland (77, p. 131); questionably from the Miocene of Espiritu Santo in the New Hebrides by Chapman (17, p. 268); from the Pliocene, Pleistocene, Holocene, and Recent of Japan by Ishizaki (83, pp. 42-43); and from the Pliocene and Pleistocene of Victoria, Australia (Kalimnan and Post-Kalimnan, subsurface) by Crespin (31, p. 255). Heron-Allen and Earland (75, pp. 566-567) record it living in the Kerimba Archipelago.

Quinqueloculina parkeri (Brady) (pl. 1, fig. 6).

Miliolina parkeri Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 177, pl. 7, fig. 14, *a-c,* 1884.—Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 17, p. 574, pl. 43, figs. 11, 12, 1915.

Quinqueloculina parkeri (Brady), Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 50, pl. 15, fig. 3, 1910-1917; Bull. 100, vol. 4, p. 440, pl. 86, fig. 4, *a-c,* 1921; Bull. 161, pt. 1, p. 25, pl. 6, figs. 3, 4, 1932-1933.—Said, Cushman Found. Foram. Research, Contrib., vol. 1, pt. 2, p. 5, pl. 1, fig. 8, 1950.

not *Miliolina parkeri* Brady, Millett, pt. 2, Roy. Microscopical Soc., Jour., p. 507, pl. 12, fig. 4, *a, b,* 1898.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13596, from locality 110B.

Rare among the microfossils in the Lau materials, this living Red Sea–Indo-Pacific species was found here in only one sample from the Ndalithoni Limestone of Vanua Mbalavu. Around Japan it is especially common in the shore sands of Okinawa of the Ryukyu Islands (Yabe and Hanzawa, 153). In the Japanese area it is known from the Pliocene and Recent (Hanzawa, 70; Ishizaki, 83, p. 33) but no older.

Quinqueloculina seminula (Linné) (pl. 1, fig. 7).

Miliolina seminulum Linné, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 157, pl. 5, fig. 6, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 297, pl. 43, fig. 2, 1897 (1899).

Quinqueloculina seminulum (Linnaeus), Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, pp. 44, 45, text fig. 29, pl. 11, fig. 2, 1910-1917; Bull. 100, vol. 4, p. 416, pl. 88, fig. 4, *a-c,* text figs. 19, 20, 1921.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 3 p. 112, pl. 3, figs. 13-15, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13598, from locality 110C.

Poorly preserved and very rare in the Lau material, this species has been widely recorded elsewhere in the late Tertiary and Recent of the Pacific area: the Mio-Pliocene of Kabu in eastern Java, by Koch (87, p. 342) ; in a varietal form in Java, in both the Njalindoeng and the Upper Miocene Tjilanang beds, by Van der Vlerk (139) ; questionably in the Lower Miocene (Tertiary *e*) of Papua, by Crespin (29, p. 9) ; in the Pliocene and Recent of Japan, by Ishizaki (83, p. 34) ; from the Lower Pliocene (Kalimnan) of Victoria, by Crespin (31, p..255) ; and as "one of the commonest miliolines, in shore sands on the coast of Victoria," by Chapman (23, p. 187). Heron-Allen and Earland (75, pp. 569-570) record it as living in the Kerimba Archipelago farther west.

Genus **Pyrgo** Defrance, 1824

Pyrgo lucernula (Schwager) (pl. 1, fig. 8).

Biloculina lucernula Schwager, Reise der Novara, Geol., vol. 2, p. 202, pl. 4, fig. 17, *a, b,* 1866.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 79, pl. 32, fig. 2, 1910-1917.

Pyrgo lucernula (Schwager), Cushman, B. P. Bishop Mus., Bull. 119, p. 108, 1934.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 72, pl. 2, figs. 27, 28, pl. 5, figs. 17, 18, 1941.

not *Biloculina lucernula* Schwager, Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 475, pl. 97, fig. 2, pl. 98, fig. 1, 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13599, from locality L308.

Several of these specimens appear to be identical to the fossil form figured by Schwager from Kar Nikobar. There is some variation in the Lau specimens of *Pyrgo,* however, and one or two could perhaps be referred to *P. murrhina* (Schwager) instead (121, pl. 4, fig. 15, *a-c*) ; yet none of them approaches the form figured as "*Biloculina lucernula* (*triloculine* Varietat)" by Schwager (121, pl. 4, fig. 14, *a-c*). In fossil form, the species has also been recorded from the Philippines by Karrer (85, p. 269) and from the Pliocene (and Recent) of Japan by Ishizaki (83, p. 47).

FAMILY PENEROPLIDAE

SUBFAMILY SPIROLININAE

Genus **Peneroplis** Montfort, 1808

Peneroplis carinatus d'Orbigny (pl. 1, fig. 10).

Peneroplis pertusus Forskål var. f, *Peneroplis carinatus* d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, pp. 204, 205, pl. 13, fig. 14, *a, b,* 1884.

Peneroplis pertusus (Forskål) var. *carinatus* d'Orbigny, Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 87, pl. 37, fig. 4, 1910-1917.

Peneroplis carinatus d'Orbigny, Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 482, 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13602, from locality 110C.

Of the seven species synonymized by Brady (12) with *P. pertusus* Forskål, the "variety f" (*P. carinatus* d'Orbigny) is the only one, other than the typical form, to be found among the Lau microfossils. Some specimens are more compressed than others, approaching *"P. planatus* Fichtel and Moll" of Brady (12, pl. 13, fig. 15, "var. a" of his *P. pertusus*) in this feature although the tendency toward the development of flaring later chambers, as in Brady's "var. a," is not apparent here.

Other records of this living Indo-Pacific form include Millett's (104, pt. 3, p. 613, 1898) from the Malay Archipelago, and that of Heron-Allen and Earland (75, p. 602) from the Kerimba Archipelago farther west.

Peneroplis pertusus Forskål (pl. 1, fig. 9).

Peneroplis pertusus Forskål var. b, *Peneroplis pertusus* Forskål, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 204, pl. 13, fig. 17, 1884.

Peneroplis pertusus Forskål, Flint, U. S. Nat. Mus., Ann. Rept., p. 304, pl. 48, fig. 4, 1897 (1899).—Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 86, pl. 36, fig. 1, pl. 37, figs. 1, 2, 1910-1917; U. S. Nat. Mus., Bull. 100, vol. 4, p. 481, 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13603, from locality L344A.

In the Lau material the typical "variety" of this living Pacific species (Heron-Allen and Earland, 75, p. 601 have also recorded it from the Kerimba Archipelago in the western Indian Ocean) is very rare and found only in the Ndalithoni Limestone of Tuvutha. As both a fossil (Pliocene and ?Pleistocene) and living form it is also known from Japan (Ishizaki, 83, p. 101), especially in the shore sands of Okinawa (Yabe and Hanzawa, 153). Whipple (145, table 5) records it in the "younger limestones" of the Tonga Islands along with other species that are still living in the Indo-Pacific region.

SUBFAMILY ORBITOLITINAE

Genus **Marginopora** Blainville, 1830

Marginopora aff. **vertebralis** Blainville (pl. 1, fig. 11).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13572, from locality L487.

Though rare, the genus is clearly represented among the Lau fossils. Perhaps it is *M. vertebralis* Blainville, to which most *Marginopora* are referred; certainly it is a closely related form, and in all probability it is ancestral to the living *Marginopora vertebralis* and the probably synonymous forms recorded under *"Orbitolites duplex," "O. complanata."* (See Van der Vlerk, 139, pp. 26, 27; Brady, 12, pp. 216, 218, pl. 16, figs. 5-7; Flint, 65, p. 305, pl. 51, fig. 2; Cushman, 36, pt. 6, pl. 38, figs. 3, 4.) Van der Vlerk (139) records *M. vertebralis* from the Njalindoeng beds of the Javanese Miocene. In Japan, *M. vertebralis* is recorded from the Pliocene to Recent (Ishizaki, 83, pp. 101-102), and Yabe and Hanzawa (153) note that it is common in the shore sands of Okinawa to the south. Whipple (145, table 5) records it in the "younger limestones" of the Tonga Islands. *"Orbitolites (Marginopora) vertebralis* Qu. u. Gaim." is recorded by Schubert (118, pp. 129-130) from the Tertiary of the Bismarck Archipelago. Chapman (22, p. 766) notes it with Miocene orbitoids in a subsurface section in Australia.

These few fossil forms from Lau are all conspicuously smaller than the form found living on the reef seaweed of Fiji today, however, especially those in sample L487 which do not exceed 1.8 mm. in diameter. These would be on the order of one-quarter of the size of the living forms referred by Cushman to *M. vertebralis* Blainville (42, pt. 2, p. 67, pl. 19, figs. 11, 12).

FAMILY LAGENIDAE

SUBFAMILY NODOSARIINAE

Genus **Robulus** Montfort, 1808

Robulus orbicularis (d'Orbigny) (pl. 2, fig. 1).

Cristellaria orbicularis (d'Orbigny), Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 549, pl. 49, fig. 17, 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 67, pl. 36, fig. 5, 1910-1917.

Cristellaria vortex Flint (not Fichtel and Moll), U. S. Nat. Mus., Ann. Rept., p. 317, pl. 65, fig. 1, 1897 (1899).

Robulus orbicularis (d'Orbigny), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 23, pl. 2, figs. 13, 14, 1941; vol. 39, no. 3, pt. 1, p. 17, pl. 4, figs. 15, 16, 1944.

not *Cristellaria orbicularis* d'Orbigny, Flint, U S. Nat. Mus., Ann. Rept., p. 317, pl. 64, fig. 3, 1897 (1899).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13577, from locality 62.

This living Indo-Pacific species is very common in one of the samples from the Futuna Limestone of Vanua Mbalavu, but it was not found except in this and other samples also from the crystalline Upper member of that formation. Poorly preserved specimens superficially resemble some species of the peneroplid genus *Archais* more than they do other species of this lagenid genus with which it belongs.

The species occurs widely in the Neogene and Recent of the Indo-Pacific. Koch (88, p. 208) records it from the Lower Pliocene of east Seran and (89, p. 726) from the Mio-Pliocene of eastern Borneo. Yabe and Hanzawa (153) record it in the Plio-Pleistocene Limestone of the Okinawa-Formosa area, and there are many records from the late Tertiary and Recent of Japan (Ishizaki, 83, p. 56). Cushman (38, p. 224) records it living around the Philippines, but the three varieties he figures are different from the species referred to here.

Chapman (23, pp. 153, 158) records this or a very closely related species living at 100 fathoms or less off the southeast coast of Australia, and (p. 206) among "forms typical of a 65 fathom level, northeast of Tasmania."

SUBFAMILY LAGENINAE

Genus **Lagena** Walker and Jacob, 1798

Lagena costata (Williamson) (pl. 2, fig. 2).

Lagena costata (Williamson), Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 21, pl. 9, fig. 6, pl. 10, fig. 1, 1910-1917; Bull. 161, pt. 2, p. 36, pl. 9, fig. 5, *a, b,* 1932-1933; B. P. Bishop Mus., Bull. 119, p. 118, pl. 13, fig. 10, 1934.—Ishizaki, Taiwan Tigaku Kizi, appendix, vol. 11, p. 73, 1940.

Lagena costata (Williamson) var., Millett, pt. 10, Roy. Microscopical Soc., Jour., p. 7, pl. 1, fig. 8, 1901.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13631, from locality 15A.

Unfigured, *L. costata* is recorded from Australia: from the Miocene by Heron-Allen and Earland (77, p. 150) and from the Recent of Australia by Chapman (23, p. 162). Heron-Allen and Earland (75, p. 656) also record it as living in the Kerimba Archipelago. A single specimen of this widespread fossil and living species was found here in the tuff sample from the Lau Volcanics of Yanuyanu.

Lagena globosa (Montagu) (pl. 2, fig. 3).

Lagena globosa (Montagu), Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 3, pl. 4, fig. 2, 1910-1917; Bull. 161, pt. 2, p. 20, pl. 4, fig. 10, *a, b,* 1932-1933.—Yabe and Asano, Tohoku Imp. Univ., Sci. Repts., ser. 2 (Geol.), vol. 19, no. 1, p. 118, fig. 4, 1937.—Ishizaki, Taiwan Tigaku Kizi, appendix, vol. 11, p. 74, 1940.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 29, pl. 3, fig. 104, 1941; vol. 39, no. 3, pt. 1, p. 22, pl. 1, fig. 10, pl. 8, fig. 64, pt. 2, p. 83, pl. 7, fig. 20, 1944.—Asano, Jour. Paleont., vol. 23, no. 4, pp. 424, 426, fig. 1, no. 33, 1949.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13591, from locality 15A.

This is a long-ranging species with an extensive record of fossil and living occurrences in Europe. In the Indo-Pacific it has been listed, in addition, from the Mio-Pliocene of the Philippines (Karrer, 85, p. 270), the Neogene of the Bismarck Archipelago (Schubert, 118, p. 67), and the Miocene of Australia (Heron-Allen and Earland, 77, p. 146). Millett (104, pt. 10, pp. 3, 4, 1901) records it as living in the Malay Archipelago; Heron-Allen and Earland (75, p. 654), in the Kerimba Archipelago; Cushman (38, p. 173), around the Philippines; and Chapman (23, p. 162), off southeastern Australia.

Only one specimen was found in Lau.

FAMILY NONIONIDAE

Genus **Nonion** Montfort, 1808

Nonion pacificum Cushman var. **lauensis,** new var. (pl. 2, figs. 5, 6).

The variety differs from the typical form, especially in the more nearly acute periphery. There is also less of a tendency for the final few chambers to flare, even slightly. In this feature the new variety resembles *N. umbilicatulum* (Montagu) *s. s.* under which, merely as a distinct variety in Samoan waters, *N. pacificum* was originally described (Cushman, 39, p. 48, pl. 16, fig. 3). The variety *lauensis,* however, is even more compressed than *N. pacificum s. s.,* which, in turn, is more compressed than *N. umbilicatulum.*

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13578, from locality L389. Paratype, Univ. California, Mus. Paleont., no. 36143, from locality L389.

A few specimens occur in one Lau sample only. Even among these rare individuals there is some variation, as shown in the two forms figured; yet they differ consistently from *N. pacificum* as found in nearby Viti Levu (Cushman, 44, p. 120, pl. 14, fig. 7, *a, b*) and in the East Indies (LeRoy, 98, pt. 1, p. 30, pl. 2, figs. 20, 21; "aff."), and also from the even less compressed and much more widespread *N. umbilicatulum,* to both of which this Lau variety is closely related.

Nonion umbilicatulum (Montagu) (pl. 2, fig. 7).

Nonionina umbilicatula Montagu, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 726, pl. 109, figs. 8, 9, 1884.

Nonionina umbilicatula (Montagu), Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 24, pl. 17, fig. 1, 1910-1917; Bull. 100, vol. 4, p. 365, pl. 74, fig. 3, *a, b,* 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13624, from locality 110C.

The species has also been listed, unfigured, from the Mio-Pliocene of eastern Java (Koch, 87, p. 357), from the Miocene of Australia (Heron-Allen and Earland, 77, p. 184), and from the Pliocene to Recent of Japan (Ishizaki, 83, pp. 92-93). Living records also include the Malay Archipelago (Millett, 104, pt. 17, p. 600, 1904), the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 730), and the muds below 100 fathoms (down to 505 fathoms) off southeastern Australia where Chapman (23, pp. 182, 206, 207) considers it to be "distributed by Antarctic currents."

Specimens in the Lau material are rather poorly preserved, and some in their slight asymmetry approach certain anomalinids; but the better specimens seem to represent this widespread living species of *Nonion*. The periphery is broadly rounded, as in the typical form, and the final chambers do not flare, as in *N. pacifica* (Cushman, 44, pl. 14, fig. 7) from the nearby Suva formation of Viti Levu.

Genus **Elphidium** Montfort, 1808

Elphidium craticulatum (Fitchtel and Moll) (pl. 2, fig. 4).

Polystomella craticulata Fichtel and Moll, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 739, pl. 110, figs. 16, 17, 1884.—Schubert, K. K. Geol. reichsanstalt, Abhandl., vol. 20, pt. 4, p. 91, text fig. 11, 1911.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 34, pl. 19, fig. 4, 1914.

Elphidium craticulatum (Fichtel and Moll), Cushman, U. S. Nat. Mus., Bull. 161, pt. 2, p. 48, pl. 11, fig. 5, *a, b,* 1932-1933.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 78, pl. 6, figs. 34-35, 1941.

Elphidium aff. *craticulatum* (Fichtel and Moll), LeRoy Colorado School of Mines Quart., vol. 39, no. 3, pt. 1, p. 24, pl. 8, figs. 36, 37, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13580, from locality L306.

The doubtfully identified forms in the Ndalithoni formation of Lau are smaller but otherwise typical.

This species is widespread in the late Tertiary and Recent of the Indo-Pacific (see above), including Japan (Ishizaki, 83, p. 95) and Okinawa (Yabe and Hanzawa, 153). Van der Vlerk (139) lists it in the Miocene Njalindoeng beds of Java and with *Trybliolepidina rutteni* in the Upper Miocene Tjilanang beds there. Umbgrove (133) has it with the uppermost orbitoids in Sumatra; Rutten (116, p. 287) records it from the Upper Miocene and Pliocene of eastern Borneo; and Koch (88, p. 209) identifies it questionably in the Lower Pliocene of eastern Seran. Schubert (118, pp. 91-92) notes its having been recorded from the Pliocene of the Solomon Islands (Guppy in 1887) and from the older Miocene coal-measures "von Zebu (sudlich Luzon)." It is a common species in the Neogene sediments of silty texture and shallow-water origin throughout the Philippines, where it is most often associated with operculinids.

LeRoy (96, p. 133) notes it as living along with *Operculina granulosa* (?) and *Calcarina spengleri* off the west coast of Java on a sea floor, dredged to a depth of 50 meters or less, "which . . . is coralline and is swept practically clean by the currents coming through the Straits, so only the coarser detritus was obtained." Millett (104, pt. 17, p. 604, 1904) records it as living elsewhere in the Malay Archipelago; Heron-Allen and Earland (75, p. 734), in the Kerimba Archipelago; Cushman (38, p. 368), around the Philippines.

Elphidium crispum (Linné) (pl. 2, figs. 8, 10).

Polystomella crispa Linné, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 736, pl. 110, figs. 6, 7, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 338, pl. 80, fig. 3, 1897 (1899).—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 32, pl. 18, fig. 1, 1910-1917.

Elphidium crispum (Linnaeus), Cushman, U. S. Nat. Mus., Bull. 161, pt. 2, p. 47, pl. 11, fig. 4, *a, b,* 1932-1933.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13571, from locality 110B. Hypotype, Univ. California, Mus. Paleont., no. 36135, from locality L306.

This species is well-developed in all the more richly foraminiferal formations of the Lau Neogene except the Upper member of the Futuna Limestone, which seems to have been deposited in waters a bit too deep for it to flourish.

Heron-Allen and Earland (77, p. 185) record it in the Miocene of Australia; Zuffardi-Comerci (157, p. 129), questionably, in the Miocene of Borneo; Crespin, in the Lower Pliocene and Pleistocene (Kalimnan and Post-Kalimnan, subsurface) of Victoria, Australia; Koch (88, p. 209), in the Lower Pliocene of eastern Seran in the East Indies. It is common in Japan from Pliocene to Recent (Ishizaki, 83, p. 95), and in the Plio-Pleistocene of Okinawa and Formosa (Yabe and Hanzawa, 153).

Millett (104, pt. 17, p. 603, 1904) records it as living in the Malay Archipelago; Heron-Allen and Earland (75, p. 733), in the Kerimba Archipelago; Cushman (38, p. 368), in the waters around the Philippines; and Chapman (23, p. 182), from southeast of Australia.

Elphidium macellum (Fichtel and Moll) (pl. 2, fig. 9).

Polystomella macella Fichtel and Moll, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 737, pl. 110, figs. 8, 9, 11, 1884.

Polystomella macella (Fichtel and Moll), Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 33, pl. 18, fig. 3, 1910-1917.

Elphidium jenseni (Cushman), U. S. Nat. Mus., Bull. 161, pt. 2, p. 48, pl. 11, figs. 6, 7, 1932-1933.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 78, pl. 6, figs. 32, 33, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13583, from locality L469.

In the Lau samples, this species occurs in all the variations pictured by Brady except perhaps the immature form (12, pl. 110, fig. 10). As in the Lau samples, these would include all those figured and synonymized under *"Elphid-*

ium jenseni (Cushman)" by Cushman (42, p. 48, pl. 11, figs. 6, 7), which at most seems only varietally distinct from *E. macellum.*

Heron-Allen and Earland record it in the Miocene of Australia (77, p. 185); Koch (88, p. 209) notes it in the Lower Pliocene of eastern Seran in the East Indies, where he also questionably identifies the immature form. Both *E. macellum* and *"E. jenseni"* are recorded from Pliocene to Recent in Japan (Ishizaki, 83, pp. 96-97); also as living off southeastern Australia (Chapman, 23, pp. 182). Heron-Allen and Earland (75, p. 734) record the species as living in the Kerimba Archipelago.

FAMILY NUMMULITIDAE

SUBFAMILY CAMERININAE

Genus **Operculina** d'Orbigny, 1826

In addition to the large species of *Operculina* already recorded by Cole (27, pp. 277-278), three smaller species of the genus are found in the Lau material. A few additional occurrences of smaller specimens of the species previously recorded and described are listed here as well.

Operculina ammonoides Gronovius (pl. 3, fig. 4).

Operculina ammonoides Gronovius, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 745, pl. 112, figs. 1, 2, 1884.

Operculina ammonoides (Gronovius), Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 37, pl. 14, fig. 7, 1910-1917.—Chapman and Parr (in part), Roy. Soc. Victoria, Proc., vol. 50 (new ser.), pt. 2, p. 290, pl. 17, fig. 12, 1937.—LeRoy, Colorado, School of Mines Quart., vol. 36, no. 1, pt. 2, p. 78, pl. 6, figs. 24, 25, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13605, from locality L444.

Among unfigured records, Heron-Allen and Earland (75, p. 737) list the species living in the Kerimba Archipelago. Cushman (38, p. 382) records it from Philippine waters. Under Japanese references to this species, Ishizaki (83, pp. 99-100) has included records of *Operculina complanata g*[*r*]*anulosa* and *Operculinella venosa.*

In the Lau material this small species occurs only in the samples from the Lower member of the Futuna formation. Most of the Lau specimens are broken in one way or another.

Operculina bartschi Cushman.

Operculina bartschi Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 376, fig. 13, 1921.—Cole, B. P. Bishop Mus., Bull. 181, p. 277, pls. 12, *H-K*, and 14, *I*, 1945.—Hanzawa, Tohoku Imp. Univ., Sci. Repts., ser. 2

(Geol.), vol. 18, no. 1, pp. 22-23, pl. 2, figs. 1-12, 1935.[7]—Crespin, Commonwealth Australia, Paleont. Bull., no. 2, pp. 4, 5, 6, pl. 1, fig. 12, 1936. —Chapman and Parr, Roy. Soc. Victoria, Proc., vol. 50 (new ser.), pt. 2, p. 292, pl. 17, figs. 17-20, 1938.

No additional occurrences.

Operculina complanata japonica Hanzawa (pl. 3, fig. 1).

Operculina complanata Defrance, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 743, pl. 112, fig. 4, 1884.—Chapman, Linn. Soc. N. S. Wales, Proc., pp. 753, 759, pl. 37, fig. 1, 1907.—Yabe, Tohoku Imp. Univ., Sci. Repts., ser. 2 (Geol.), vol. 4, no. 3, p. 120, pl. 17, figs. 1-7, 1918.

Operculina complanata Defrance var. *japonica* Hanzawa, Tohoku Imp. Univ., Sci. Repts., ser. 2 (Geol.), vol. 18, no. 1, pp. 19-20, pl. 1, figs. 4-28, 1935.

Operculina complanata japonica Hanzawa, Cole, B. P. Bishop Mus., Bull. 181, p. 278, pls. 12, *D-G,* and 13, *F-I,* 1945.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13633, from locality L389.

Hofker (80, 81) considers that all the Recent East Indies *Operculina* except *O. heterosteginoides* are *O. complanata* Defrance. This conclusion is not accepted by Chapman and Parr (24) in their revision of the Australian and New Zealand species of this group. The evidence available seems to indicate that, as in the case of Chapman's records from the Miocene and the post Miocene of Malekula Island in the New Hebrides, many if not most of the Indo-Pacific records of Defrance's species may be Hanzawa's subspecies rather than the typical one. It is common in the Miocene and Pliocene of Japan (Ishizaki, 83, p. 100). Heron-Allen and Earland (77, p. 186) record *O. complanata* from the Miocene of Australia; Schubert (118, pp. 96-97, fig. 12, pl. 2, fig. 3) notes it in the *Lepidocyclina*-bearing older Miocene of Suralil-Hiratan in the Bismarck Archipelago; Eveland (55, p. 230) notes it in the Lower Miocene of northern Luzon; Rutten (116, p. 287) and Van der Vlerk (138, p. 137) have it in the east Bornean Neogene; Millett (104, pt. 17, p. 605, 1904) records it as living in the Malay Archipelago; Cushman (36, pt. 4, p. 36), in the north Pacific; Heron-Allen and Earland (75, pp. 737-738), in the Kerimba Archipelago; and so forth.

Cole (27) records Hanzawa's subspecies from several of the Lau smaller-foraminifer samples under study here. Additional smaller specimens of the same subspecies, the tests usually more or less broken, have been found where Cole already has them on record and in some of the other samples as well.

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[7] For additional references to the occurrences in Japan where this and related forms are common throughout a Miocene to Plio-Pleistocene range, see Ishizaki (83, p. 100) and, especially, Yabe and Hanzawa (153, 156).

Operculina gaimardi d'Orbigny.

Operculina ammonoides (Gronovius) forma *O. gaimardi* d'Orbigny, Chapman and Parr, Roy. Soc. Victoria, Proc., vol. 50 (new ser.), pt. 2, pl. 17, fig. 15, 1938.

Rare fossil specimens from Lau seem to be d'Orbigny's species which, in its Recent occurrences on the Great Barrier Reef, Chapman and Parr consider a form of Gronovius' species. These do not seem to be the same as the distinctive form referred by Cushman (42, pt. 2, p. 55, pl. 13) to *O. gaimardi* d'Orbigny, which seems to approach *Operculinella* in many features. Yabe and Hanzawa (153) have recorded *O. gaimardi* from the Plio-Pleistocene Ryukyu Limestone of the Ryukyu Islands and Formosa.

Operculina granulosa (Leymerie) (pl. 3, fig. 2).

Operculina complanata Defrance var. *granulosa* Leymerie, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 743, pl. 112, figs. 6, 7, 9, 10, 1884.

Operculina complanata (Defrance) var. *granulosa* Leymerie, Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 37, pl. 19, fig. 3, 1910-1917.

Operculina granulosa (Leymerie), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 30, pl. 3, figs. 44, 45, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13634, from locality 110C.

In a late Tertiary varietal form, this was one of the earliest species to be recorded as one of the "principaux foraminiferes des Indes Neerlandaises" (Verbeek and Fennema, 144, vol. 2, p. 1183). In both the older and more recent literature it is variously treated as a distinct species or as a variety of *O. complanata* (Brady, 11; H. Douvillé, 54). As *O. c.* Defrance var. *granulosa* Leymerie, Zuffardi-Comerci (157, p. 129) lists it from the Miocene of Borneo, and Koch records it (88, p. 209) in the Lower Pliocene of east Seran. Heron-Allen and Earland (77, p. 186) record *O. granulosa* from the Miocene of Australia, Van der Vlerk (138) lists it from the orbitoidal facies of the east Bornean Miocene, and as such this same form has been recorded living in the Malay Archipelago (Millett, 104, pt. 17, p. 606, 1904), around the Philippines (Cushman, 38, p. 381), and in the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 738) far to the southeast. Cushman (42, p. 56, pls. 14, 15, pl. 16, figs. 1-3) has figured quite a wide variety of living Pacific forms as doubtfully referable to this species. Ishizaki (83, p. 99) lists the recorded Japanese occurrence of the species under *O. ammonoides.*

Specimens fairly small for the genus and apparently representing the species first described by Leymerie, with a limited amount of beadlike surface ornamentation between the sutures, were found in only one of the Lau samples.

Operculina mbalavuensis Cole.

Operculina mbalavuensis Cole, B. P. Bishop Mus., Bull. 181, p. 278, pl. 12, *L, M,* 1945.

No additional occurrences.

Operculina (?) sp. (pl. 3, fig. 3).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13626, from locality 110C.

Compressed small- to medium-sized, many-chambered, and symmetric-coiled perforate calcareous foraminifers of doubtful affinities—presumably small operculinids—occur rarely in samples from both the Lower Futuna and the Ndalithoni formations.

Genus **Operculinella** Yabe, 1918

The interrelationships of the camerinine genera of nummulites as currently treated in the literature leave something to be desired. This is especially true of Yabe's genus *Operculinella*. Nor is the treatment here accorded them as they occur in Lau calculated to clarify matters.

Apparently, much comparative work upon the internal and external structures of this group is needed and, especially, upon the facts of distribution involved, in order to clear up with a modicum of satisfaction their taxonomy and the terminology appropriate to this taxonomy. For example, certain *Camerina* (*"Numulites"*) from Batan Island in the Philippines, described by Douvillé (53) and referred by him to the Oligocene, have turned out to be stratigraphically well up within the Middle Miocene, according to the stratigraphic allocation of foraminiferal samples by Donald Birch of the Philippine Petroleum Survey. However, it is equally difficult, upon morphological grounds, to refer these Batan Island forms to *Operculinella,* as Yabe and Hanzawa (155, p. 138) have done, rather than to *Camerina,* where Douvillé places them. Until these anomalous occurrences can be further classified, a purely empirical and essentially Linnean approach to the more or less related material in the Lau samples is perforce employed here.

Operculinella cumingii (Carpenter) (pl. 4, figs. 1-3).

Nummulites cumingii Carpenter, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 749, pl. 112, figs. 11-13, 1884.—Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 17, p. 739 ("extremely rare"), 1915.

Nummulites cumingii (Carpenter), Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 39, pl. 14, fig. 6, 1910-1917.

Operculinella venosa (Fichtel and Moll), Cushman, U. S. Nat. Mus., Bull. 161, pt. 2, p. 54, pl. 18, figs. 2-6, 1932-1933.—Chapman and Parr, Roy. Soc. Victoria, Proc., vol. 50 (new ser.), pt. 2, p. 293, pl. 17, figs. 21, 22, 1938.

"Probably *Operculinella cumingii* (Carpenter)," Cole (in part), B. P. Bishop Mus., Bull. 181, p. 276, pl. 13, *D, E,* 1945.

Hypotypes, Univ. Rochester, Mus. Nat. Hist., nos. 13568, 13606, from localities L306 and L389 respectively. Hypotype, Univ. California, Mus. Paleont., no. 36133, from locality L487.

Koch (89, p. 728) lists "*Operculinella cumingii* (Carpenter) Yabe" from the late Miocene or Mio-Pliocene of eastern Borneo. Several other similarly intriguing references to this or closely related forms ("*O. venosa*" of Yabe and Hanzawa, 156, for example) are also left unfigured in the literature. Much earlier, in recording the living forms from the Malay Archipelago, Millett (104, pt. 17, p. 605) notes the generic position of the form he referred to under "*Amphistegina cumingii* Carpenter" as being in doubt. He writes: "Whether this species should be assigned to *Amphistegina* or to *Nummulina* is still undecided. The Malay specimens exhibit a greater affinity with *Operculina* than with *Nummulina*." Douvillé (54) reviewed this same and closely related generic problems at somewhat greater length. In one of the most recent accounts of the same form—an account, moreover, of this form as it is developed in precisely the same Neogene samples from Lau that are under discussion here—Cole (27, p. 277) concludes as follows:

> The specimens in this collection are identical with figures given of *O. cumingii*. These forms usually have been described under the specific name *venosa*, but Hanzawa (personal communication) informs me that the type of *venosa* is an *Amphistegina*. This specific name cannot be used, hence the *Operculinella* assigned to *venosa* must be referred to *O. cumingii* (Carpenter). Figure f, plate 8 of Fichtel and Moll (Test. Micr., 1798) shows the typical supplementary chambers exhibited on the ventral side of *Amphistegina*. This drawing is generalized, but there is little doubt that it is an *Amphistegina* and not an *Operculinella* as has been assumed by various authors.

Yabe, in erecting the genus *Operculinella*, seems thus to have solved the problems that troubled the earlier workers as to the generic position of the forms in question [Ishizaki (83, pp. 99-100), however, lists the Japanese references to "*Operculinella venosa*" under *Operculina ammonoides* (Gronovius).] Nevertheless, in any particular instance, a decision as to the generic position of certain forms still proves troublesome, owing it would seem to the strong degree of parallelism developed on the part of *Operculinella cumingii* in the one lineage and especially *Amphistegina lessonii* var. *melanesiensis* (which see), in the other. Nor does the ventral absence of "the typical supplementary chambers" of *Amphistegina* in many an *Amphistegina* come to the investigator's aid here. [See *A. lessonii* var. *fijiensis* of this paper, *A. campbelli* Stache, *A. aucklandica* Stache, Brady's figures 1, 3, and 4, pl. 111 (12), for example.] Forms with the supplementary ventral chamberlets are not *Operculinella*, in any event; and sections, exhibiting the internal structure, otherwise suffice to distinguish the two lineages in their surficial parallelisms. Yet in a rich assemblage of smaller specimens where both quantitative and qualitative data are desirable, this requisite technique may become impractical, to say the least. One surface feature does seem consistently to distinguish between the two parallelisms, at least in the Lau material: this is the nature of the sutures near the periphery (pls. 4, fig. 1; 8, fig. 5); although somewhat recurved near the periphery the sutures of *O. cumingii* are not sharply angled as they are in *Amphistegina,* even in *A. lessonii* var. *melanesiensis,* which of all the amphisteginids, seems to parallel the more nearly straight-sutured *Operculinella* most closely.

There remain the problems of specific interrelationships within *Operculinella.* One of the traits most diagnostic of this genus is "in the adult . . . a broadly flaring complanate border" (Cushman, 46, p. 239) ; that is, the eventual development of "a rather broad, flaring complanate boarder" in which "the coils expand slowly and regularly until the final portion of the last whorl which heightens more rapidly." (See Cole, 27, p. 277, pls. 12, *C,* 13, *A-C.*) Unfortunately, it seems that this feature, though clearly and definitely developed in some forms, is comparatively undeveloped in the great majority of the individual adult specimens referred to the genus, especially those now referred to the genotype, *O. cumingii* (Brady, 12, pl. 112, figs. 11-12; Cushman, 46, pl. 20, fig. 4, *a, b*).

As employed here, the name *O. cumingii* has been applied to the least complanate and least flaring forms as being the most typical of that species. In the Lau samples, as in Philippine material familiar to me, this is by far the most numerously represented variant; nor does it seem to intergrade conspicuously with the obviously related but more complanate variation of the genus (treated here tentatively as *Operculinella* sp. cf. *O. venosa*) which here generally exhibits a considerable umbilical boss not noticeable on *O. cumingii* proper.

Finally, the occurrences of fossil immature forms (pl. 4, fig. 3) of *O. cumingii,* comparable to Brady's (12, pl. 112, fig. 13, *a, b*) from the Recent, are here recorded separately on the checklist for Lau.

Operculinella sp. cf. **O. venosa** (Fichtel and Moll) (pl. 4, fig. 4).

Operculinella venosa (Fichtel and Moll), Cushman (in part), U. S. Nat. Mus., Bull. 100, vol. 4, p. 383, 1921.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 31, pl. 3, fig. 10, 11, 1941.

?*Operculinella cumingii* (Carpenter), Cole (in part), B. P. Bishop Mus., Bull. 181, p. 276, pls. 12, *C,* 13, *A-C,* 1945.

not *Operculinella venosa* (Fichtel and Moll), Cushman, U. S. Nat. Mus., Bull. 161, p. 54, pl. 18, figs. 2-6, 1932-1933.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13635, from locality L307.

Under "*Operculinella venosa* (Fichtel and Moll)," Cushman in 1921 (38, p. 383) wrote: "Brady's figures in the *Challenger* report illustrate the early stages of this species, but the Philippine specimens show later characters. These consist of a broadening of the test and the development of a thin flange-like portion of the periphery." This variant [of forms subsequently referred in general to *O. cumingii* (Carpenter) of Yabe], as described by Cushman (*loc. cit.*), is not only numerous in the modern seas adjacent to the Philippines, but is well-represented in the Philippine Neogene deposits. Moreover, morphological intergradation (with *O. cumingii* Carpenter) of this "variant," with its compressed final chambers and straight sutures and prominent umbilical boss, seems no more apparent in the Lau material than in the fossil assemblages from the Philippines. It seems to be sufficiently distinctive from the typical *O. cumingii* to be recorded separately here and elsewhere. A thorough study of the genus *Operculinella* as a whole is required in order to designate the relationships of these and other forms, but such comparative study is not possible here. For the present purposes, a tentative designation is employed.

Operculinella (?) **oneataensis,** new species (pl. 4, figs. 5-8).

Test of only moderate size for the genus, thickly disk-shaped, regularly and symmetrically coiled, involute, periphery subacute and almost circular in plan; chambers low, increasing faintly but regularly in size throughout the final coil, which has about 16 to 24 chambers; sutures flush to faintly depressed, obscure and often indistinct, nearly straight to faintly curved; wall calcareous, perforate, very thickly calcareous in final whorl often with a roughened surface of thick calcareous material tending to obscure the sutures and chambers, and with a thick umbilical development of shell material that forms a low boss externally and tends to obscure the earlier coils internally; aperture at base of apertural face, median.

Dimensions: diameter 1.5 to 0.8 mm. in thickness.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13636, from locality L438; paratype, natural cast, no. 13637, from locality L306. Paratypes, Univ. California, Mus. Paleont., nos. 36141, 36209, from localities L389 and L466, respectively.

In the nearly straight sutures and septa and the umbilical boss, this species is closest to "*O. venosa*" Cushman; but the boss is not so conspicuous and the test does not tend to become complanate, so that in transverse section the surface profile from umbilical area to periphery in any quadrant is convex, even more so than *O. cumingii,* rather than concave as in "*O. venosa*" Cushman. Furthermore, the indeterminate surface features and thick, roughly calcareous outer walls are very different from either of the other two species. Resemblances to these two species may be parallel rather than directly related. This species could be descended from and more closely related to some lower Tertiary New World *Operculinoides* which it also resembles in some of its more characteristic features.

Present in most of the Lau samples, this species is commonest in the Lower Futuna of Oneata. It is often represented by natural casts that show much of the internal structure; one of these is figured in plate 4, figure 6.

Operculinella sp.

Specifically unidentified representatives of the genus are recorded by Cole (27, p. 275) and are shown here in table 1.

SUBFAMILY HETEROSTEGININAE

Genus **Heterostegina** d'Orbigny, 1826

Heterostegina depressa d'Orbigny (pl. 3, fig. 5).

Heterostegina depressa d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 746, pl. 112, figs. 14-18, 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 38, pl. 19, fig. 5, 1910-1917; Bull. 161, pt. 2, pp. 56-57, pl. 16, figs. 4-9, 1932-1933.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13607, from locality 62.

Zuffardi-Comerci (157, pp. 129-130) lists the species as low stratigraphically as the *Eulepidina*-bearing (Tertiary *e*) Miocene of Borneo. Chapman (18, p. 753) records the species from the post Miocene of Malekula in the New Hebrides. Yabe and Hanzawa (153) record it in the Plio-Pleistocene and Recent of Formosa and the Ryukyu Islands, and northward in Japan it is recorded from both the late Tertiary and Recent (Ishizaki, 83, p. 100-101). Whipple (145, table 5) records it in an assemblage of "Recent species" from the "younger limestones" of Tonga. Brady's living forms are from the Admiralty Islands, Hawaiian Islands, Tonga, and Tahiti; Heron-Allen and Earland (75, p. 738) note them as living in the Kerimba Archipelago. Cushman (38, pp. 384-385) records Moebius' variety *tubercalata* (and also *H. orbicularis*) as living around the Philippines today; and Millett (104, pt. 17, p. 606, 1904) records living forms as ". . . represented in the Malay Archipelago by a few small examples . . ."

The fossil forms from Lau are also small, and few in number. A single incomplete individual might be closer to *H. curva* Moebius (Cushman, 42, pt. 2, p. 59, pl. 17, figs. 1-5).

Genus **Cycloclypeus** Carpenter, 1856

Small to very large specimens of the genus occur in several of the smaller-foraminifer samples from Lau. They have already been described and recorded by Cole (27, p. 274). Only one additional record of a doubtful and specifically indeterminate occurrence is added here.

Cole's records for the samples in question have also been incorporated in the checklist (table 1) under all but the first of the following names.

Cycloclypeus (?) sp.

Ill-defined sections, apparently representing the genus but doubtfully so, were apparent in an Upper Futuna Limestone sample from Ongea Levu.

Subgenus **Cycloclypeus** Tan, 1932

Cycloclypeus inornatus inornata Tan.

Cycloclypeus (Cycloclypeus) inornatus inornata Tan, Cole, B. P. Bishop Mus., Bull. 181, p. 281, pls. 18, *E-K*, 20, *K*, 1945.

Cycloclypeus indopacificus terhaari Tan.
Cycloclypeus (*Cycloclypeus*) *indopacificus terhaari* Tan, Cole, B. P. Bishop Mus., Bull. 181, p. 281, pls. 17, *A-K*, 19, *B*, *C*, 1945.

Cycloclypeus posteidae hexaseptus Tan.
Cycloclypeus (*Cycloclypeus*) *posteidae hexaseptus* Tan, Cole, B. P. Bishop Mus., Bull. 181, p. 280, pl. 15, *F-J*, 1945.

Cycloclypeus posteidae pentekaidekaseptus Tan.
Cycloclypeus (*Cycloclypeus*) *posteidae pentekaidekasepta* Tan, Cole, B. P. Bishop Mus., Bull. 181, p. 280, pl. 15, *A-E*, 1945.

Cycloclypeus reticulatus Caudri.
Cycloclypeus (*Cycloclypeus*) *reticulatus* Caudri, Cole, B. P. Bishop Mus., Bull. 181, p. 282, pls. 16, *F-G*, 18, *A-D*, 20, *A-C*, 1945.

Subgenus **Katacycloclypeus** Tan, 1932

Katacycloclypeus annulatus Martin.
Cycloclypeus (*Katacycloclypeus*) *annulatus* Martin, Cole, B. P. Bishop Mus., Bull. 181, p. 282, pls. 19, *A*, 20, *G*, *H*, 1945.

FAMILY BULIMINIDAE

SUBFAMILY VIRGULININAE

Genus **Bolivina** d'Orbigny, 1839

Bolivina cf. **hantkeniana** Brady (pl. 2, fig. 16).
?*Bolivina hantkeniana* Brady, LeRoy (in part), Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 80, pl. 1, fig. 4, pt. 3, p. 115, pl. 2, figs. 40, 41, 1941.
Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13585, from locality L469.

A single specimen from the tuffaceous Lower member of the Futuna Limestone on Oneata is close to Brady's species, recorded by him from the "soapstone" of Fiji (13, p. 8) and by Cushman (44, p. 124, pl. 15, fig. 5) from the same Suva formation of nearby Viti Levu.

LeRoy (98, pts. 2 and 3) figures similar *B. hantkeniana* in fossil form from western Java. And, figured or unfigured, very similar forms have been recorded under this specific name from several localities elsewhere in the Indo-Pacific Neogene and Recent; in the Lower Pliocene of Seran (Koch, 88, p. 208); from the Pliocene to Recent of Japan (Ishizaki, 83, p. 109); and from the living Pacific fauna (Cushman, 36, pt. 2, p. 42, fig. 68, *a*, *b*), especially in and around Philippine waters (Cushman, 38, p. 132, pl. 27, fig. 2).

Other figured references to this species are quite different from these and from the Lau forms (Brady, 12, p. 424, pl. 53, figs. 16-18; Millett, 104, pt. 9, pl. 4, fig. 9, *a, b,* 1900; LeRoy, 98, pt. 1, p. 33, pl. 2, figs. 98, 99; and others). The Lau specimen is even closer to some of the forms with less inflated chambers that have been grouped together under *Bolivina subcompacta* (Finlay, 61, p. 278, pl. 5, figs. 64-69) from the New Zealand Tertiary.

Bolivina cf. **zedirecta** Finlay (pl. 2, fig. 17).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13584, from locality L308.

Certain samples from the Lower member of the Futuna formation yield rare specimens of a *Bolivina* which, in many features, seems close to *B. zedirecta* Finlay from the Miocene and younger beds of New Zealand (Finlay, 61, p. 278, pl. 5, figs. 70-72). *B. zedirecta* has not as yet been recorded from farther west, in the Indo-Pacific province proper. These Lau forms appear to be as closely related to *B. granti* Rankin and *B. goudkoffi* Rankin (Cushman and Kleinpell, 48, p. 21, pl. 4, figs. 2, 3, pl. 4, figs. 4, 5) of the eastern Pacific Neogene (Upper Mohnian of the California Upper Miocene) as to the recorded Indo-Pacific representatives of the genus.

SUBFAMILY REUSSELLINAE

Genus **Reussella** Galloway, 1933

Reussella spinulosa (Reuss) (pl. 2, fig. 15).

Verneuilina spinulosa Reuss, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 384, pl. 47, figs. 1-3, 1884.—Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 141, pl. 27, fig. 5, 1921.

Reussella spinulosa (Reuss), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 36, pl. 2, figs. 100, 101; pt. 2, p. 81, pl. 5, figs. 19, 20; pt. 3, p. 116, pl. 1, figs. 35, 36, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13601, from locality 110C.

Rare specimens of this living species were found in the Ndalithoni Limestone of Vanua Mbalavu only.

Presumably the unfigured references to "*Verneuilina spinulosa* Reuss" in the literature on the Neogene and Recent of the Indo-Pacific refer to this species: Koch (89, p. 726), for the Mio-Pliocene of eastern Borneo; Millett (104, pt. 7, p. 11, 1900), for the living Malay Archipelago fauna; and Heron-Allen and Earland (75, pp. 630, 631), for that of the Kerimba Archipelago. As *Reussella,* although still unfigured, the species has also been listed from elsewhere in the East Indies (LeRoy, 99, pt. 2, p. 86) and from Japan (Ishizaki, 83, pp. 114, 115).

SUBFAMILY UVIGERININAE

Genus **Uvigerina** d'Orbigny, 1826

Uvigerina canariensis d'Orbigny var. **lakembaensis,** new variety (pl. 2, fig. 13).

The variety differs from the typical form in the fewer whorls and marked inflation of the very early chambers, producing a short, broad test of relatively few chambers that appears almost siphogenerine.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13582, from locality L307. Paratype, Univ. California, Mus. Paleont., no. 36199, from locality L307.

The aberrant morphology, suggesting arrested growth in hyper-inflated immature or "sport" individuals of d'Orbigny's smooth-surfaced living species, is consistently developed in all the Lau specimens which, though not common, occur in three of the samples from the Lower member of the Futuna formation. It is most numerous in the Lakemba material.

Other poorly preserved and incomplete or immature specimens at first suggest incomplete *Bulimina affinis* or *B. ovata,* but since these appear to be incomplete forms in which the uvigerinine neck has been broken off, these specimens have been included with the others. In some specimens the final chamber seems so large and terminal, and the aperture so centrally located, as to warrant possible reference to *Siphogenerina.* Yet if they do belong with this genus the consistent immaturity of their representatives in these otherwise normal assemblages is singular.

Other than their obvious similarity in certain respects to smooth and inflated uvigerinines of the *U. canariensis* stock, there are few clues as to their further specific relationships. A possible Indo-Pacific close relative is the larger and more typical *Uvigerina canariensis* var. *australis* Heron-Allen and Earland from the Miocene of Australia (Heron-Allen and Earland, 77, p. 164, pl. 11, figs. 67-70). Another possible relative in the Indo-Pacific Neogene may be included (in part) under "*Dimorphina zitteli* Karrer" (Karrer, 85, p. 278, pl. f, fig. 7), which though revealing biserial earliest whorls in the figure of the microspheric form, shows triserial early whorls in the megalosphere and the section.

Genus **Siphogenerina** Schlumberger, 1883

Siphogenerina costulata Cushman (pl. 2, fig. 14).

?*Sagrina striata* Schwager, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 584, pl. 75, fig. 26, 1884.

?*Siphogenerina raphanus* (Parker and Jones), LeRoy, Colorado School of Mines Quart., vol. 39, no. 3, pt. 2, p. 86, pl. 2, figs. 28, 29, 1944.

Siphogenerina raphanus (Parker and Jones) var. *costulata* Cushman, U. S. Nat. Mus., Proc., vol. 51, p. 662, 1917; U. S. Nat. Mus., Bull. 100, vol. 4, p. 281, pl. 56, fig. 6 *a, b,* 1921.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 82, pl. 1, fig. 8, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13600, from locality L308.

Cushman (38, p. 281) writes: "This variety differs from the typical in its much more cylindrical form, its very few definite costae, and the very short, wide neck without a lip. This variety does not always occur with the typical, but in all the material seen there appear to be no intermediate forms." Though its generic position remains none too clear—were it referred to Mathew's 1945 genus *Rectouvigerina* on purely morphological grounds, it still does not seem to be directly in the lineage of the genotypical *R. multicostata* (Cushman and Jarvis)—Cushman's variety *costulata* clearly seems to be a separate species distinct from both *S. striata* and *S. raphanus.* [By way of contrast, compare the typical forms of Schwager and of Parker and Jones; also "*Sagrina striata* Schwager" of Brady (12, pl. 75, fig. 25) and of LeRoy (98, pt. 1, p. 37, pl. 3, figs. 88, 89); and "*Sagrina raphanus* Parker and Jones" of Brady (12, pl. 75, fig. 21).] It seems to be much more closely related to the Oligocene and Miocene species of *Siphogenerina* from New Zealand (Finlay, 59, no. 2, pp. 106-110, pl. 13). More and better-preserved material is needed to clarify the generic position of this form within the uvigerinine Buliminidae.

A few small specimens, some broken but otherwise well-preserved, occur in one of the Futuna Lower member samples from Lakemba. The same form is quite common in the Miocene of the Philippines.

SUBFAMILY ELLIPSOIDININAE

Genus **Pleurostomella** Reuss, 1860

Pleurostomella brevis Schwager (pl. 2, fig. 11).

Pleurostomella brevis Schwager, Reise der Novara, Geol., vol. 2, pt. 2, p. 239, pl. 6, fig. 81, 1866.—Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 411, pl. 51, fig. 20, *a, b,* 1884.—Cushman, B. P. Bishop Mus., Bull. 119, p. 128, pl. 15, fig. 13, 1934; Geol. Soc. Japan, Jour., vol. 46, p. 153, pl. 10, figs. 14-16, 1939.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13590, from locality 15A.

Tiny specimens from the Lau tuffs of Yanuyanu appear to represent Schwager's species, except that they are either dwarfed or immature forms and the very earliest whorl is triserial. In all other respects they appear to be typical ellipsoidinids. Perhaps this tends to corroborate Cushman's derivation of this stock from buliminid ancestry through the genus *Virgulina* (Cushman, 46, p. 276), and to emphasize the affinities of the ellipsoidinids with the basic buliminid stock, affinities that are probably as strong as those of other lineages usually treated as subfamilies (Uvigerininae, Reussellinae, and so forth).

This is a widespread Neogene and living Indo-Pacific species. It has been recorded from East Borneo (Koch, 89, p. 727) to Kar Nikobar, from the Tertiary of the Bismarck Archipelago and living off the Kei Islands (Schubert, 118, p. 56), and also from the Suva formation of Viti Levu by both Brady (13, pp. 5, 8) and Cushman.

SUBFAMILY CASSIDULINIDAE

Genus **Cassidulina** d'Orbigny, 1826

Cassidulina subglobosa Brady (pl. 2, fig. 12).

Cassidulina subglobosa Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 430, pl. 54, fig. 17, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 293, pl. 38, fig. 4, 1897 (1899).—Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, p. 98, fig. 152, *a-c*, 1910-1917; Bull. 100, vol. 4, p. 171, pl. 32, fig. 2, 1921.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 85, pl. 6, figs. 16, 17, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13588, from locality 15A.

Immature or possibly dwarfed forms with somewhat atypically flattened sides are among the more numerous constituent elements in the distinctive Lau Volcanics assemblage from Yanuyanu.

Recorded as making its first appearance in the Porangan uppermost Lower Eocene of New Zealand (Finlay and Marwick, 64, p. 232) but merely questionably referred to elsewhere in the Eocene of New Zealand (Dorreen, 52, pp. 285, 298), this widespread species is more often listed from the Neogene and Recent (Schubert, 118, p. 61; Heron-Allen and Earland, 75, pp. 652-653 and 77, p. 146; Koch, 87, p. 352 and 89, p. 727; Finlay, 59, no. 2, p. 112; Ishizaki, 83, p. 140; Chapman, 23, p. 168; Said, 117, p. 8).

FAMILY ROTALIIDAE

SUBFAMILY DISCORBINAE

Genus **Discorbis** Lamarck, 1804

Discorbis globularis (d'Orbigny) (pl. 5, fig. 1).

Discorbina globularis d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 643, pl. 86, figs. 8, 13, 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 11, pl. 9, fig. 4, text figs. 10, 11, 1910-1917.—Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 17, p. 694, pl. 51, figs. 36-39, 1915.—Flint, U. S. Nat. Mus., Ann. Rept., p. 327, pl. 72, fig. 2, 1897 (1899).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13627, from locality 110B.

This living Pacific species is rare in Lau. It was found only in the Ndalithoni formation. It has also been listed from the Miocene of Australia (Heron-Allen and Earland, 77, p. 169), the late Tertiary and Recent of Japan (Ishizaki, 83, p. 122), and in the living faunas of the Malay Archipelago (Millett, 104, pt. 15, p. 698, 1903) and southeast of Australia (Chapman, 23, p. 173).

Discorbis laddi, new species (pl. 5, figs. 4, 5).

Test small, rotaliform, plano-convex, and ventrally flattened, compressed but somewhat variably so; periphery essentially circular and subacute with a definite flange that is a continuation of the limbate spiral suture; chambers distinct but uninflated, low but very broad in their oblique elongation, about 7 to 9 in final coil, two or three much smaller earlier whorls visible dorsally; sutures flush with surface to faintly raised in occasional individuals, broadly limbate especially on the slightly convex dorsal side, nearly straight ventrally but slightly curved and meeting the periphery at a very acute angle on the low dorsal spire; wall calcareous, finely perforate; aperture is typically developed in the genus, but inconspicuous.

Dimensions: diameter, up to 0.4 mm.; thickness, 0.17 mm.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13574, from locality L443. Paratype, Univ. California, Mus. Paleont., no. 36139, from locality L443.

This Lau form, though somewhat variable locally and closely related to more than one other Indo-Pacific species, still appears to be distinct from those so far described. There are more, also more elongated, chambers than in the less compressed *Discorbis valvulata* (d'Orbigny) (Brady, 12, pl. 87, figs. 5-7); and there is not the ventrally enlarged final chamber of *D. orbicularis* (Terquem) (Brady, 12, pl. 88, figs. 4-8; Cushman, 36, pt. 5, pl. 11, fig. 1). The dorsal side is much like those of *D. opercularis* (d'Orbigny) and the less-compressed *D. pileolus* (d'Orbigny) (Brady, 12, pl. 89, figs. 2-4, figs. 8, 9).

Discorbis cf. **nitida** (Williamson) (pl. 5, fig. 3).

?*Discorbis nitida* (Williamson), Cushman, Foraminifera, their classification and economic use, pl. 29, fig. 17, *a-c,* 1948.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13638, from locality 62.

A distinctive form of *Discorbis,* comparable to Williamson's species but more than twice as large, is present in a few of the Lau samples. The apertural characters are not clear, and surface shell material developed on the dorsal side obscures the earlier coils of the test. Heron-Allen and Earland have recorded Williamson's tiny species from the Miocene of Australia (77, p. 167) and from the living fauna of the western Indian Ocean (75, p. 691), but the relations of the Lau forms to these and other *Discorbis* referred to Williamson's species remain uncertain. Other close relatives may be included among records of the apparently variable "*Discorbina bertheloti* d'Orbigny" (Brady, 12, pl. 89, figs. 10-12; Millett, 104, pt. 15, p. 702, 1903; Heron-Allen and Earland, 77, p. 168) and the variety *bacomica* (Hantken) (Heron-Allen and Earland, 77, p. 169; Koch, 89, p. 728).

Discorbis pileolus (d'Orbigny) (pl. 5, fig. 2).

Discorbina pileolus d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 649, pl. 89, figs. 2-4, 1884.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13613, from locality 110C.

A few small specimens of this living species occur in the Futuna and Ndalithoni formations of Vanua Mbalavu. It has also been recorded from the Miocene of Australia (Heron-Allen and Earland, 77, p. 170). In some of the Lau specimens the plan of growth is ventrally ill-defined, owing to poor preservation.

Genus **Valvulineria** Cushman, 1926

Valvulineria vilardeboana (d'Orbigny) (pl. 5, fig. 6).

Discorbina vilardeboana d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 645, pl. 86, figs. 9, 12, 1884.

Discorbina vilardeboana (d'Orbigny), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 14, pl. 9, fig. 2, text fig. 14, *a-c,* 1910-1917.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13576, from locality 62.

Additional records include the late Tertiary and Recent of Japan (Ishizaki, 83, p. 124), the living fauna of the Malay Archipelago (Millett, 104, pt. 15, p. 699, 1903), and the living fauna of the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 692).

A single specimen from the Upper member of the Futuna Limestone of Vanua Mbalavu represents this widespread late Tertiary and living species in the Lau material.

Valvulineria (?) sp. (pl. 5, fig. 7).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13632, from locality 110B.

A few specimens in the Ndalithoni formation of Vanua Mbalavu are possibly related to middle Tertiary eastern Pacific species of this genus, but the apertural characters remain obscure. Another possible relative is the living "*Discorbina bertheloti* d'Orbigny" as figured by Flint (65, p. 327, pl. 72, fig. 4).

SUBFAMILY ROTALIINAE

Genus **Eponides** Montfort, 1808

Eponides cf. **concameratus** (Montagu) (pl. 6, fig. 1).

?*Pulvinulina concamerata* (Montagu), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 52, pl. 25, fig. 1, 1910-1917.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13616, from locality 62.

This Lau form with its conspicuously raised and limbate sutures may be new and distinctive here, but very few specimens were found. They seem closest to the form now living off Japan and referred by Cushman to Montagu's species. They are also close to a form which Flint (65, p. 334, pl. 78, fig. 1) figures as "*Truncatulina praecincta* Karrer" but which is not the *Eponides praecincta* of subsequent literature. It also resembles *Eponides* ("*Pulvinulina*" or "*Discorbina*") *berthelotiana* (d'Orbigny) and some of its varieties as figured or recorded by various authors from the Neogene and Recent of the Indo-Pacific (Brady, 12; Flint, 65; Millett, 104; Cushman, 38; Koch, 88; LeRoy, 98, 99; Said, 117; and others). However, as those forms are figured, there appear to be certain marked differences in the Lau forms, notably a much less flattened ventral side.

Eponides cf. **dutemplei** (d'Orbigny).

?*Truncatulina dutemplei* d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 665, pl. 95, fig. 5, *a-c,* 1884.

not *Truncatulina dutemplei* (d'Orbigny), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 37, pl. 15, fig. 2, text fig. 40, 1910-1917.

Hypotype, Univ. California, Mus. Paleont., no. 36208, from locality L487.

A single, poorly preserved, small specimen was found in the Lower member of the Futuna Limestone on Oneata. It appears to be very close to the form which, rare in the Suva formation of Viti Levu, Cushman figured but left specifically unidentified (Cushman, 44, p. 131, pl. 17, fig. 1, *a-c*). In the modern literature d'Orbigny's species is sometimes referred to *Cibicides* (the Japanese occurrences listed by Ishizaki, 83, p. 152, for example) rather than *Eponides*.

Eponides karsteni (Reuss) (pl. 6, fig. 6).

Pulvinulina karsteni Reuss, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 698, pl. 105, figs. 8, 9, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 330, pl. 74, fig. 5, 1897 (1899).

Pulvinulina karsteni (Reuss), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 63, pl. 26, fig. 1, 1910-1917.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13620, from locality 15A.

A single specimen of this living species, figured by Brady from the Strait of Magellan, is present in the Lau Volcanics sample from Yanuyanu. It is very small but well-preserved. Except for the size and also perhaps for being slightly more compressed, it seems quite typical. Notable in the Miocene to Recent faunas of Japan (Ishizaki, 83, p. 127; Asano, 7, p. 424), in the inshore fauna of the Falkland Islands, and off the southeast coast of Australia (Chapman, 23, p. 173), this species would seem to have a cool-water environmental optimum.

Eponides procerus (Brady) (pl. 6, fig. 5).

Pulvinulina procera Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 698, pl. 105, figs. 7, *a-c*.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 62, pl. 24, fig. 2, pl. 25, fig. 2, 1910-1917; U. S. Nat. Mus., Bull. 100, vol. 4, p. 342, pl. 69, fig. 1, *a-c,* 1921.

Eponides procerus (Brady), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 83, pl. 3, figs. 31-33, 1941; vol. 39, no. 3, pt. 2, p. 88, pl. 5, figs. 1-3, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13614, from locality 62.

As *"Pulvinulina procera* Brady," Heron-Allen and Earland record this species from both the Miocene of Australia (77, p. 180) and the Recent of the Kerimba Archipelago (75, p. 717). *"Discorbis procerus* (Brady)," listed by Ishizaki (83, pp. 123, 124) from the late Tertiary and Recent of Japan, is presumably the same form.

Specimens of this plano-convex species are rare in the Lau material.

Eponides cf. **repandus** (Fichtel and Moll) (pl. 6, fig. 3).

?*Pulvinulina repanda* Fichtel and Moll, Flint, U. S. Nat. Mus., Ann. Rept., p. 328, pl. 72, fig. 8, 1897 (1899).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13618, from locality 62.

This form is very rare, in the Upper Futuna Limestone of Lau. It is of small to medium size for the genus, with limbate sutures, unequally biconvex but dorsally not as convex as in the typical *E. repanda* (Fichtel and Moll) and with a wall somewhat more coarsely punctate. It closely resembles the living form figured under that name by Flint.

Eponides sp. (pl. 6, fig. 4).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13617, from locality 110B.

This conspicuously cone-shaped, plano-convex species, medium-sized to large for the genus, with eight chambers in the final coil and with the dorsal sutures meeting the periphery at a sharp angle, occurs rarely in the Ndalithoni formation of Lau.

Eponides (?) sp. (pl. 6, fig. 2).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13619, from locality 110C.

This small plano-convex rotalid, apparently an *Eponides,* is not common in the Lau material but is present in more than one sample, both in the Lower Futuna and the Ndalithoni formation.

Genus **Parrella** Finlay, 1939

Parrella bengalensis (Schwager) (pl. 6, fig. 7).

Anomalina bengalensis Schwager, Reise der Novara, Geol., vol. 2, p. 259, pl. 7, fig. 111, 1866.

Pulvinulinella bengalensis (Schwager), Cushman, B. P. Bishop Mus., Bull. 119, p. 131, pl. 17, fig. 6, *a-c,* 1934.

Parrella bengalensis (Schwager) Finlay, Roy. Soc. New Zealand, Trans. and Proc., vol. 68, no. 1, pp. 523, 532, 1939.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13639, from locality 62.

The few Lau specimens are not very well preserved but are clearly Schwager's species from the Mio-Pliocene of Kar Nikobar. Among the erstwhile *"Pulvinulinella,"* they are thus referable to the species chosen by Finlay as genotype for his new genus *Parrella.*

Genus **Rotalia** Lamarck, 1804

Rotalia calcar (d'Orbigny) (pl. 7, figs. 5, 6).

Rotalia calcar d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 709, pl. 108, fig. 3, *a-c,* 1884.

Rotalia calcar (d'Orbigny), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 69, pl. 28, fig. 2, pl. 29, fig. 2, 1910-1917; Bull. 100, vol. 4, p. 350, pl. 71, fig. 3, *a, b,* 1921.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 2, p. 84, pl. 7, figs. 1-3, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13579, from locality L389. Hypotype, Univ. California, Mus. Paleont., no. 36144, from locality L306.

This distinctive species, though seldom common, is one of the most widely distributed in the Lau material. It is a *Rotalia* well on the way toward becoming a *Calcarina* and has often been called *"Calcarina calcar,"* a designation probably just as accurate taxonomically as the usage followed in this paper.

Especially in the shallow-water assemblages is it generally widespread throughout the Neogene and Recent Indo-Pacific region. Heron-Allen and Earland (75, p. 720) record it also from the Kerimba Archipelago. Millett (104, pt. 16, p. 506, 1904) records it from the Recent of the Malay Archipelago, where LeRoy (96, p. 132) notes it particularly in a rather meager and brackish-water assemblage at 2 to 18 meters, and also in a more characteristically tropical assemblage of "protected shoal facies" ranging from 7 to 26 meters, on the east side of Sunda Straits. Heron-Allen and Earland (77, pp. 180-181) record it from the Miocene of Australia; and it is, in turn, very close to *Calcarina nikobarensis* Schwager (Schwager, 121, pl. 7, fig. 114) from far to the west in the Indo-Pacific.

Rotalia tuvuthaensis, new species (pl. 7, figs. 1-4).

Test fairly large, robust, most convex ventrally but biconvex and nearly bilaterally symmetrical; almost circular in side view, periphery nonlobulate, rounded but not broadly so in peripheral view; final few of numerous chambers in the final whorl visible ventrally on some forms, all chambers more often obscured entirely by surface ornamentation both ventrally and dorsally; sutures broadly but not very deeply depressed where discernible, generally obscured by surface ornamentation; wall perforate, double (with internal canal system), exterior ornamented with many fine parallel concentric striae most conspicuous toward the periphery, side-wall surface covered with excessive and roughly papillate to mammillary shell-growth, concentrated especially around the ventral umbo but characteristically on both sides, and often extending to periphery on both sides to cover entire test; aperture obscured by surface ornamentation.

Dimensions: diameter, 0.7 to 0.9 mm.; thickness, 0.65 mm.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13569, from locality L344A, Tuvutha. Paratype, Univ. Rochester, Mus. Nat. Hist., no. 13570, from locality 110C, Vanua Mbalavu; paratypes, Univ. California, Mus. Paleont., nos. 36134, 36190, 36210, 36211, from locality L344A, Tuvutha.

One of the most beautiful and most distinctive species of the Lau assemblages, this is common in the Ndalithoni Limestone and restricted to it. The forms from Tuvutha are of a salmon-pinkish color, those from Vanua Mbalavu, white. The species is closest to *Rotalia multicamerata* LeRoy (99, pt. 1, p. 35, pl. 7, figs. 22-24), but the periphery is more rounded, and the surface ornamentation has increased greatly, obscuring the chambers entirely in many specimens and, at the very least, all but the final few in all of them. Although much more ornate, it is apparently also closely related to *Rotalia reticulata* Cushman, as recorded from the Australian Miocene (Heron-Allen and Earland, 77, p. 181, pl. 14, figs. 114-116).

SUBFAMILY SIPHONININAE

Genus **Epistomina** Terquem, 1883

Epistomina hoffmeisteri, new species (pl. 5, fig. 8).

Test fairly large for the genus, trochoid, ventrally somewhat flattened but almost equally biconvex, periphery acute and in plan nearly circular; chambers and whorls relatively indistinct dorsally, not inflated, about 9 or 10 in final coil; sutures flush with surface, very slightly curved and very broadly limbate and hialine ventrally, but indistinct dorsally; wall calcareous, finely perforate, dorsal side smooth to point of obliteration of normal traces of plan of growth, faintly developed pustules ventrally on surface of earlier chambers of final coil; aperture large, at base of chamber near umbilicus on ventral side.

Dimensions: diameter, up to 0.5 mm.; thickness, 0.25 mm.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13640, from locality 26.

The Lau species is close to the widespread *E. elegans;* but the smooth dorsal surface, on which the plan of growth is almost obliterated, and the ventral pustules, are distinctive.

FAMILY PEGIDIIDAE

Genus **Pegidia** Heron-Allen and Earland, 1928

Pegidia (?) sp. (pl. 6, fig. 8).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13604, from locality 62.

A single poorly preserved specimen in the Lau material may represent Heron-Allen and Earland's genus, perhaps *P. dubia* (d'Orbigny) (= *P. papil-*

lata Heron-Allen and Earland) (see Cushman, 46, pl. 31, figs. 10, *a-c*), or *P. pulvilla* Heron-Allen and Earland.

FAMILY AMPHISTEGINIDAE

Genus **Amphistegina** d'Orbigny, 1826

This is one of the most abundant groups in the Neogene samples from Lau, and within it a considerable morphologic diversity is locally apparent. The scope of this study hardly permits the clarification of the taxonomy involved, yet attention should be called to the diversity within this unity. The literature on the genus as a whole reveals considerable latitude in the morphologic diversity of individual specimens lumped under d'Orbigny's specific designation *lessonii*. In general, the situation is still much as Cushman stated it more than 30 years ago: "This species is used at the present time to include various forms which may be distinct" (36, pt. 4, p. 36).

In its typical form, this species is well-represented in Lau; and present are more than one of the variants which have been included in the species as recorded elsewhere. The phylogenetic significance of these local variations, however, is not immediately apparent. Clarification requires much more material and comparative study of both the internal and external structures of these "semi-large" forms than I am either prepared or qualified to undertake; but at least four distinctive, if closely related, morphologic types are apparent enough and call for figuring and discussion as such.

All four Lau variants intergrade, apparently with the typical form rather than with each other; but only a relatively few specimens in any of the individual Lau suites are involved in this morphologic intergradation. Moreover, the distribution of the four variants seems sufficiently irregular to warrant their separate recording and formal designation. For the present, a strictly Linnean handling of this amphisteginid material seems the only treatment justified. Consequently, that taxonomically noncommital entity, the variety, has been employed.

Amphistegina lessonii d'Orbigny (*sensu stricto*) (pl. 8, fig. 1).

Amphistegina lessonii d'Orbigny, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 740, pl. 111, figs. 5, *a-c,* 6, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 338, pl. 80, fig. 4, 1897 (1899).—LeRoy Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 41, pl. 3, figs. 18, 19, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13575, from locality 110B.

Present in the lower part of the Lau section, this typical variety of the species is well-developed; and it is common only higher in the column, in the Ndalithoni formation.

Sherlock (122, p. 351) records this species among a half-dozen fossil foraminiferal species from the island of Mango in the Lau Islands, from 10 feet below, from 90 feet above, and from the same horizon as the occurrence of "*Orbitoides sumatrensis* Brady," a *Lepidocyclina* which he figured (fig. 1) and considered Miocene in age. He also lists and figures a section of it from Singatoka on Viti Levu (122, pp. 355, 356, fig. 5), he records it from terraces on Eua and Vavau in the Tonga Islands, and he records the genus questionably from limestone on Makatea in the Tuamotus still farther to the east (122, pp. 359, 360, 361).

Chapman records it (17, p. 264) with *Lepidocyclina martini* in limestone on Wai Malikoliki, Espiritu Santo Island in the New Hebrides; with *Miogypsina* and other less determinate smaller foraminifers in "decomposed friable rock just below the limestone" there; and with *Lepidocyclina insulae-natalis, L.* (?) *sumatrensis, L.* cf. *martini* and others, at Wai Bubo, Espiritu Santo (17, pp. 266-268), noting that it is "[Usually the small, compressed, lenticular variety]" of *Amphistegina lessonii* (17, p. 271) that occurs in the Miocene of this part of Melanesia. Chapman (18, p. 753) also records it from both the Miocene and post Miocene of Malekula Island in the New Hebrides. Whipple (145, table 5) lists it from the "younger limestones" of the Tonga Islands.

Heron-Allen and Earland (77, pp. 185-186) record the species in the Miocene of eastern Australia; Crespin (31, pp. 254-255) records it as ranging through the Middle Miocene in a subsurface section there, and (34, p. 426) as characteristically present in the upper Middle Miocene Balcombian Stage of Australia. Crespin (29, p. 10) notes it in the Lower Miocene (Tertiary *e*) of Papua. According to Finlay and Marwick (63, pp. 94, 95, 118), it makes its first appearance in New Zealand in the Miocene.

Schubert notes the presence of the species in the older Miocene of Suralil-Hiratan in the Bismarck Archipelago (118, p. 95, pl. 3, fig. 1), as well as in the Miocene and younger beds of Celebes (119, p. 147), and of Letti in the East Indies (120, p. 180). Rutten (116, p. 287) lists it in both the older and younger Miocene of eastern Borneo; Zuffardi-Comerci (157, p. 129) also lists it there, along with *Eulepidina;* and Van der Vlerk (138, p. 137) records it from the orbitoidal facies of the Miocene in both east Borneo and (139) Java. It is common in the shallow-water facies of the Philippine Neogene (Yabe, 149, p. 37; Yabe and Hanzawa, 154, p. 99) and that of Japan (Ishizaki, 83, p. 135), as well as in the intervening Okinawa-Formosa area (Yabe and Hanzawa, 153). Koch records it (88, p. 209), along with a new variety *ornata* (p. 211, fig. 6, *a, b*), in the lower Pliocene of eastern Seran.

In living form, *Amphistegina lessonii* is recorded by Millett (104, pt. 17, p. 605) in the Malay Archipelago; by Cushman (38, pp. 370-372), in three varietal forms (the species *sensu stricto,* d'Orbigny's variety *madagascariensis* and the Fichtel and Moll variety *radiata*) around the Philippines and northward to the coast of southern Japan (Ishizaki, 83, p. 135); and by Heron-Allen and Earland (75, pp. 736-737), in three varietal forms (the species *sensu stricto,* Fichtel and Moll's variety *radiata* and d'Orbigny's variety *gibba*) from the Kerimba Archipelago at the opposite end of the Indian Ocean. It is recorded from as deep as 505 fathoms off southeast Australia (Chapman, 23, p. 177), but the genus as a whole is not apt to occur in great numbers (such as in the Lau Neogene) below 30 fathoms (Cushman, 46, pp. 300-301).

Amphistegina lessonii d'Orbigny var. **conoides,** new variety (pls. 7, fig. 10; 8, figs. 3, 4).

Amphistegina lessonii d'Orbigny, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 740, pl. 111, fig. 7, 1884.

The variety differs from the typical form in its asymmetrical nearly plano-convex form. The fossil specimens from Lau seem, on the whole to have fewer and higher chambers than the living plano-convex variant figured by Brady from the Atlantic, but in most respects they appear to be very close.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13566, from locality L389. Paratypes, Univ. California, Mus. Paleont., nos. 36130, 36212, from locality L308; no. 36131, from locality L466.

Present throughout most of the Lau section, this variety is common only in the Lower Futuna samples from Lakemba, where other elements present suggest not only especially shallow water, but a habitat relatively current-sheltered and on, or adjacent to, a rocky bottom.

Amphistegina lessonii d'Orbigny var. **fijiensis,** new variety (pls. 7, fig. 11; 8, fig. 2).

Amphistegina lessonii d'Orbigny, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 740, pl. 111, figs. 1-4, 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 35, pl. 19, fig. 2, 1910-1917.—?Crespin, Commonwealth Australia, Paleont. Bull., no. 2, pp. 4, 5, 6, pl. 1 fig. 9, 1936.

This typically compressed lenticular variety of d'Orbigny's species is nevertheless atypical in being involute on both sides, not exhibiting the ventral chamberlets characteristic of this species and of the genus as a whole. Also, as in the similar variant figured by Brady (as "typical") from Fiji and the Admiralties and Bermuda, it has lower and more numerous individual chambers.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13567, from locality 62. Paratype, Univ. California, Mus. Paleont., no. 36132, from locality L388.

This variety may be synonymous with *A. campbelli* Karrer (Karrer, 84, p. 84, pl. 16, fig. 18). Topotypical material of Karrer's species has not been available for comparison; and synonymy on the basis of the older, often more stylized, illustrations alone seems inadvisable, especially in the light of the entirely different faunal associations and the stratigraphic disparities involved. As do the other related local variants, the variety *fijiensis* occurs sparingly throughout most of the Lau Neogene sequence; it is abundant only in sample 62. Other elements in this Upper Futuna assemblage from Vanua Mbalavu suggest that it lived in somewhat deeper water on the continental shelf than did the balance of the Lau faunules.

Amphistegina lessonii d'Orbigny var. **melanesiensis,** new variety (pl. 8, fig. 5).

The variety differs from the typical form in its doubly involute test, in the absence of ventral chamberlets, in the less angled sutures, and in the development of a thick umbilical boss not projecting above the general surface of the test, being about equally prominent ventrally and dorsally. Though comparably involute on both sides and lacking chamberlets, it is conspicuously thicker than the compressed lenticular variety *fijiensis,* and it has the higher and less numerous chambers of the typical variety. From the variety *conoides,* it differs in its biconvexity and the prominent development of umbonal shell material on both sides. In all but the smaller number of individual chambers, which are correspondingly of higher dimension, this variety approaches *A. aucklandica* Karrer, as figured from the Greensand of New Zealand.

Variety *melanesiensis* brings into strong relief the difficulties that have arisen in the terminological history of the phylogenetically unrelated genus *Operculinella;* for although of different origins, this form of *Amphistegina* seems to parallel at least one species of *Operculinella* quite closely.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13641, from locality 110B. Paratypes, Univ. Rochester, Mus. Nat. Hist., no. 13648, from locality L307; Univ. California, Mus. Paleont., no. 36213, from locality L307.

In its distribution in the Lau samples, this variety is more closely associated with the plano-convex *conoides* than with any of the other local varieties, being most abundant in the lower Futuna samples, especially in certain of those from Lakemba.

FAMILY CALCARINIDAE

Genus **Calcarina** d'Orbigny, 1826

Calcarina mayori Cushman (pl. 7, fig. 7).

Calcarina mayori Cushman, Carnegie Inst. Washington, Pub. 342, vol. 21, p. 44, pl. 14, figs. 4-7, 1924.

Calcarina aff. *majori* Cushman, LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 41, pl. 3, figs. 37-39, 46-48, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13586, from locality L307.

The Lau forms appear to be conspecific with those from the shallow-water Neogene of the Netherlands Indies which, in turn, are closely related to Cushman's living Samoan species. Whipple (145, table 5) records it in the "younger limestones" of Tonga.

Genus **Siderolites** Lamarck, 1801

Siderolites mbalavuensis, new species (pl. 7, fig. 9).

Test with early stages rotaliform but obscured by surface shell material, laterally compressed, fragile, periphery with four or more fairly long and slender fragile spinose projections essentially in a single plane; wall calcareous, perforate, with pillars ending at the surface in raised bosses closely but more or less irregularly distributed; apertural characters obscure.

Dimensions: diameter, excluding spines up to 0.8 mm. (including spines up to 1.5 mm.); thickness, 0.3 mm.

Holotype, Univ. Rochester, Mus. Nat. Hist., no. 13609, from locality 62. Paratype, Univ. California, Mus. Paleont., no. 36171, from locality 62.

Several specimens, ranging in degree of preservation from fragments to essentially complete forms, are present in one of the localities of the Upper Futuna Limestone of Vanua Mbalavu. Their taxonomic position within the Calcarinidae is not clear, though they would seem to represent no more than a single species. The chambers are entirely too indistinct for them to be considered a species of the ancestral *Calcarina,* though otherwise they would seem not far removed from *Calcarina spengleri.* The tests remain too compressed and delicate to be grouped under *Baculogypsina* (a species of which is represented in the same sample), the reticulation of connecting rods between the surface bosses of which are not developed in these forms. Apparently they represent a relatively primitive species of *Siderolites.*

Genus **Baculogypsina** Sacco, 1893

Baculogypsina sphaerulata (Parker and Jones) (pl. 7, fig. 8).

Tinoporus baculatus (Montfort?) Carpenter, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 716, pl. 101, figs. 4-6, 1884.

?*Tinoporus baculatus* Montfort, Sherlock, Mus. Comp. Zoöl. Harvard, Bull., vol. 38, p. 357, fig. 8, 1903.—Millett, pt. 17, Roy. Microscopical Soc., Jour., art. 11, p. 598, 1904.

Tinoporus baculatus [Montfort?] Carpenter, Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 73, pl. 27, fig. 3, 1910-1917.

?*Baculogypsina baculata* [Montfort] Carpenter, Koch, Eclogae Geol. Helvetiae, vol. 19, no. 1, p. 208, 1925.

Baculogypsina sphaerulatus (Parker and Jones), Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 359, pl. 75, fig. 6, 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13608, from locality L344A.

Sherlock's record is from the 70-foot terrace on Niue (Savage Island). Whipple (145, table 5) records it in the "younger limestones" of the Tonga Islands. Yabe and Hanzawa (Ishizaki, 83, p. 136) record it from both the Pliocene and Recent in the Ryukyu Islands, far to the northwest.

In Lau, very rare but well-preserved specimens occur in both the Upper Futuna and Ndalithoni formations.

FAMILY CYMBALOPORIDAE

Genus **Cymbalopora** Hagenow, 1851

Cymbalopora sp. (pl. 9, fig. 1).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13610, from locality 62.

A few delicate, conical, and tiny-chambered forms from Vanua Mbalavu appear to represent *Cymbalopora;* but only a most indistinct plan of growth is apparent ventrally (traces suggest either *Cymbalopora* or *Discorbis tabernacularis* of Brady, 12, pl. 89, fig. 5, *b;* and of Cushman, 36, pt. 5, p. 18, pl. 5, fig. 4, text fig. 20). No growth plan at all is discernible dorsally.

Cymbalopora (?) sp. (pl. 9, fig. 2).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13573, from locality 110C.

Certain poorly preserved microfossils in the Lau material suggest the possible presence of *Cymbalopora radiata* Hagenow (Cushman, 46, pl. 32, fig. 13, *a*) ; yet the few comparable forms that exhibit a well-preserved flat basal surface are clearly not *Cymbalopora* nor, seemingly, even Foraminifera for certain. No plan of chamber-growth, but a pore-and-lattice structure, is revealed "ventrally." The possibility remains that the genus may be present in some of the "ventrally" poorly preserved material, and the records on the accompanying checklist (table 1) are based upon this possibility. A well-defined example of the microfossil of dubious affinity, which may be represented throughout instead, is shown in the accompanying figure.

Genus **Cymbaloporetta** Cushman, 1928

Cymbaloporetta bradyi (Cushman) (pl. 9, fig. 3).

Cymbalopora poeyi, var., Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 637, pl. 102, fig. 14, *a-d,* 1884.

Cymbalopora poeyi (d'Orbigny) var. *bradyi* Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 25, pl. 10, fig. 2, pl. 14, fig. 2, 1910-1917; Bull. 100, vol. 4, p. 308, 1921.

Cymbaloporetta bradyi (Cushman), Asano, Geol. Soc. Japan, Jour., vol. 43, p. 609, 1936; Saito Ho-on Kai Mus., Research Bull. 13, p. 117, 1937.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13612, from locality L344A.

A single specimen of this very compressed form occurred in the Ndalithoni formation of Tuvutha.

Cymbaloporetta poeyi (d'Orbigny) (pl. 9, fig. 4).

Cymbalopora poeyi d'Orbigny, Brady (in part), Rept. Voy. Challenger, Zool., vol. 9, p. 636, pl. 102, fig. 13, *a-c,* 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 326, pl. 72, fig. 1, 1897 (1899).—Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 24, pl. 10, fig. 1, pl. 14, fig. 5, text fig. 28, 1910-1917.

Cymbaloporetta poeyi (d'Orbigny), Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 308, pl. 59, fig. 2, *a-c,* 1921.

Cymbaloporetta squamosa (d'Orbigny), Cushman, Foraminifera, their classification and economic use, p. 308, pl. 32, fig. 15, *a-c,* 1948.

Cymbaloporetta poeyi (d'Orbigny), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 42, pl. 3, figs. 12-14, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13611, from locality L388.

A single specimen of d'Orbigny's strongly trochoid species, *"Rosalina squamosa,"* was found in the Lower member of the Futuna formation of Lakemba. As the species *"squamosa,"* it has been recorded from tropical brackish water at 2 to 18 meters (LeRoy, 96, p. 132). (See Ishizaki, 83, p. 137, for records around Japan.)

As *"Cymbalopora poeyi"* it has been recorded, also unfigured, from the later Tertiary of the Bismarck Archipelago (Schubert, 118, p. 114); from the Lower Pliocene of eastern Seran in the East Indies (Koch, 88, p. 209); and living in the Malay Archipelago (Millett, 104, pt. 15, p. 696, 1903) and the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 687); also as rare in the shore sands of Okinawa (Yabe and Hanzawa, 153).

FAMILY GLOBIGERINIDAE

SUBFAMILY GLOBIGERININAE

Genus **Globigerina** d'Orbigny, 1826

Globigerina bulloides (d'Orbigny) (pl. 9, fig. 8).

Globigerina bulloides d'Orbigny, Karrer, Comision del Mapa Geol. España, Bol., vol. 7, p. 279, 1880.—Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 593, pl. 77, figs. 1-7, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 321, pl. 69, fig. 2, 1897 (1899).—Schubert, K. K. Geol. reichsanstalt, Abhandl., vol. 20, pt. 4, p. 99, 1911.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 5, pl. 2, figs. 7-9, pl. 9, 1910-1917.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 3, p. 118, pl. 3, figs. 27, 28, 1941; vol. 39, no. 3, pt. 1, p. 39, pl. 3, figs. 28, 29, pl. 7, figs. 40-42, 1944.—

Said, Cushman Found. Foram. Research, Contrib., vol. 1, pt. 2, p. 8, pl. 1, fig. 27, 1950.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13642, from locality 62.

This is the commonest species among the numerous Lau globigerinids. In the first record of fossil foraminifers from Fiji, Brady (13, p. 9) records it as present in all three of his Viti Levu stations, and it is generally dominant in the *"Globigerina* marls" so often described from various portions of the Indo-Pacific Neogene. Chapman (17, pp. 263-268) records it as numerous in the Miocene of Espiritu Santo and (18, p. 753) in the Miocene and post Miocene of Malekula, both in the New Hebrides. Heron-Allen and Earland (77, p. 165) record it from the Miocene of Australia, and Crespin (31, pp. 253-255) notes it in a subsurface section in Victoria from the Lower Miocene to the Pleistocene (Janjukian to Post-Kalimnan). Koch (87, p. 354) records it in the Mio-Pliocene of Kabu in east Java (88, p. 208), in the Lower Pliocene of eastern Seran, and (89, p. 727) in the lower part of the *Globigerina* marl which overlies the *Lepidocyclina* limestones of east Borneo. It is common from Miocene to Recent horizons from Japan to Formosa (Yabe and Hanzawa, 153; Ishizaki, 83, p. 143). It is also the best known and the most widespread of the living species of *Globigerina*. Unfigured Indo-Pacific records include the Malay Archipelago (Millett, 104, pt. 15, p. 685, 1903), the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 678), and Philippine waters (Cushman, 38, p. 285). Chapman (23, p. 179) records it from cooler waters southeast of Australia.

Globigerina conglomerata Schwager (pl. 9, fig. 10).

Globigerina conglomerata Schwager, Reise der Novara, Geol., vol. 2, pt. 2, p. 255, pl. 7, fig. 113, 1866.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13643, from locality 62.

Many of the globigerinids from Lau agree closely with Schwager's Kar Nikobar species, with four large and inflated chambers closely clustered in the final whorl. Though perhaps ancestral, they do not agree with the living forms [*"Globigerina dutertrei* H. B. Brady . . . (not d'Orbigny) . . ." and *"Globigerina dubia* H. B. Brady . . . (not Egger) . . ."] which Cushman (44, p. 134) has also synonymized with Schwager's species as found in Viti Levu. Both of Brady's two living Pacific Ocean species referred to by Cushman have more chambers in the final whorl, in which they form more of a coil than a cluster. Since he has not figured the forms referred to as living around the Philippines (38, p. 295), some doubt is also thrown on Cushman's synonymy of these with Schwager's fossil species. The living species is recorded by Chapman (23, p. 179) as "an Eastern Pacific form," found also off southeast Australia.

Globigerina (?) sp. (pl. 9, fig. 9).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13587, from locality L306.

Rare forms, distinctive but of dubious affinity, occur in one of the Futuna Lower member samples from Lakemba.

SUBFAMILY ORBULININAE

Genus **Orbulina** d'Orbigny, 1839

Orbulina universa d'Orbigny (pl. 9, fig. 11).

Orbulina universa d'Orbigny, Karrer, Comision del Mapa Geol. España, Bol., vol. 7, p. 279, 1880.—Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 608, pl. 78, pl. 81, figs. 8-26, pl. 82, fig. 1, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 323, pl. 69, fig. 1, 1897 (1899).—Cushman, U. S. Nat. Mus., Bull. 71, pt. 4, p. 14, pls. 6, 7, 1910-1917.—Koch, Eclogae Geol. Helvetiae, vol. 19, no. 3, pp. 727, 737, fig. 18, *a, b,* 1926.— LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 44, pl. 1, fig. 4, pt. 2, p. 87, pl. 1, fig. 27, pt. 3, p. 118, pl. 1, fig. 17, 1941; vol. 39, no. 3, pt. 1, p. 41, pl. 3, figs. 44, 45, pt. 2, p. 91, pl. 3, fig. 19, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13644, from locality 62.

Cushman (44, p. 135) records this species from the Suva formation of Viti Levu, where Brady (13, p. 9) also records it from all three of his Fiji "soapstone" stations.

Schubert (118, p. 103, pl. 5, fig. 2) notes its presence in *Lepidocyclina*-bearing *Globigerina* marls of Kapsu in the Bismarck Archipelago; Chapman (18, p. 753) notes it in both the Miocene and post Miocene of Malekula in the New Hebrides; Oppenoorth (106), throughout some 20 to 50 meters of marl in northern Sumatra; Koch (87, p. 354), in the Mio-Pliocene of Kabu in east Java. In Japan, it is recorded from Miocene to Recent (Ishizaki, 83, p. 146). Crespin (31, p. 255) notes it in the sub-surface Lower Pliocene (Kalimnan) of Victoria, Australia. Finlay and Marwick (64, p. 234) record the "entry" of the genus into New Zealand during the Clifdenian (uppermost Lower Miocene) as "spectacular." Indo-Pacific records of the species as found living include the Malay Archipelago (Millett, 104, pt. 15, p. 690, 1903), the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 681), the Red Sea (Said, 117, p. 9), the Philippines (Cushman, 38, p. 295), and southeast of Australia (Chapman, 23, pp. 180, 206, 207), where "from Tasmania to the Antarctic Ice Barrier" (in the dredgings of the *Aurora* and the *Endeavor*) he thinks it "distributed by . . . Antarctic currents."

FAMILY GLOBOROTALIIDAE

Genus **Globorotalia** Cushman, 1927

Globorotalia menardii (d'Orbigny) var. **fijiensis** Cushman (pl. 9, fig. 5).

Globorotalia menardii (d'Orbigny) var. *fijiensis* Cushman, B. P. Bishop Mus., Bull. 119, p. 136, pl. 17, fig. 5, *a-c,* 1934.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13645, from locality L466.

This form is commonly represented in the Lau material by partial casts in which, nevertheless, the distinctive features of the variety are still clearly discernible.

Globorotalia patagonica (d'Orbigny) (pl. 9, fig. 7).

Pulvinulina patagonica d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 693, pl. 103, fig. 7, *a-c,* 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 57, text fig. 56, 1910-1917.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13615, from locality 110C.

These forms are very rare in the Lau material; but as represented here, they seem, like Brady's living North Pacific forms, to be globorotalids. In listing living species southeast of Australia, Chapman (23, p. 181) does not consider d'Orbigny's and Brady's forms as the same, and synonymizes Brady's *"Pulvinulina patagonica"* with *"Pulvinulina scitula* Brady 1882"; these he then lists among those forms from the muds below the 100-fathom line (down to 505 fathoms here) which are regarded "as having been distributed by . . . Antarctic currents" (23, pp. 206-207). Millett (104, pt. 16, p. 500, 1904) records it from the East Indies; Heron-Allen and Earland (75, p. 716), from the Kerimbas.

Globorotalia sacharina (Schwager) (pl. 9, fig. 6).

Discorbina sacharina Schwager, Reise der Novara, Geol., vol. 2, pt. 2, p. 257, pl. 7, fig. 106, 1866.

Hypotype, Univ. Rochester, Nat. Hist. Mus., no. 13646, from locality L466.

The Lau forms are much closer to Schwager's Kar Nikobar species than to *G. menardii,* with which Cushman (44, p. 136) suggests a possible synonymy as these are figured from the later Tertiary of the Malay Archipelago (LeRoy, 98, pt. 1, pl. 1, figs. 17-19; pt. 2, pl. 4, figs. 4-6; pt. 3, pl. 1, figs. 6-8) or from the present Pacific Ocean (Brady, 12, pl. 103, figs. 1, 2). Under *"Pulvinulina,"* Koch (87, p. 356) has recorded Schwager's species as a synonymous form under d'Orbigny's *menardii,* in the Mio-Pliocene of east Java.

FAMILY ANOMALINIDAE

SUBFAMILY ANOMALININAE

Genus **Anomalina** d'Orbigny, 1826

Anomalina glabrata Cushman (pl. 10, fig. 1).

Anomalina glabrata Cushman, Carnegie Inst. Washington, Pub. 342, vol. 21, p. 39, pl. 12, figs. 5-7, 1924.—LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 45, pl. 1, figs. 90-92, pt. 2, p. 88, pl. 3, figs. 16-18, pt. 3, p. 119, pl. 2, figs. 19-21, 1941; vol. 39, no. 3, pt. 2, p. 92, pl. 6, figs. 16-18, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13625, from locality 110C.

This fairly large species, rare but well-defined in the Ndalithoni Limestone of Lau, is known from the Miocene of Australia, the Neogene of Borneo and Java, and as a living species from Pago Pago Harbor, Samoa, to Tasmania and the Antarctic (Chapman, 23, p. 175). Chapman (p. 206) notes it among "forms typical of a 65 fathom level, northeast of Tasmania."

Anomalina grosserugosa Gümbel (pl. 10, fig. 3).

Anomalina grosserugosa Gümbel, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 673, pl. 94, figs. 4, 5, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 335, pl. 78, fig. 5, 1897 (1899).

Anomalina grosserugosa (Gümbel), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 45, pl. 20, fig. 1, text fig. 50, 1910-1917; Bull. 100, vol. 4, p. 323, pl. 62, fig. 3, 1921.

Anomalina aff. *grosserugosa* Gümbel, LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 46, pl. 1, figs. 108-110, 1941.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13622, from locality L308.

Unfigured additional Indo-Pacific records include the Miocene of Australia (Heron-Allen and Earland, 77, p. 178) and that of eastern Borneo (Koch, 89, p. 728), the late Tertiary and Recent of Japan (Ishizaki, 83, pp. 150, 151), and as living in the Malay Archipelago (Millett, 104, pt. 16, p. 495, 1904).

This species seems much more closely related to *Cibicides cicatricosa* (Schwager) (Cushman, 44, p. 137, pl. 18, fig. 1, *a-c*) from the Suva formation of Viti Levu than the generic disposition of Schwager's species (Cushman, 45, p. 153) would suggest. Schwager's original figure (Schwager, 121, p. 260, pl. 7, fig. 108) would seem to be an *Anomalina* closely related to, though not conspecific with, *A. grosserugosa* Gümbel as figured by Brady in the living form and as encountered in Lau. This is true also of the Suva formation form referred to *"Cibicides cicatricosa"* (Cushman, 44). On the other hand, the form figured as *"cicatricosa"* from the topotypical Kar Nikobar material (Cushman, 45, pl. 10, figs. 19, *a-c*) seems to parallel these in surface ornamentation but to be a true *Cibicides* more nearly related to *C. aknerianus* (d'Orbigny). There are closely related fossil species among the Tertiary Anomalinidae of New Zealand (Finlay, 59, no. 4).

Anomalina (?) sp. (pl. 10, fig. 2).

These rare and ill-defined specimens with smooth surface features that obscure even the sutures and chambers are apparently *Anomalina.* They appear to be most closely related to, though not conspecific with, *Anomalina salinasensis* Kleinpell (86) from the Miocene of California; but the resemblance may be superficial. *Anomalina ammonoides* Reuss, as figured by Flint (65, p. 335, pl. 78, fig. 4), may also be close.

Type, Univ. Rochester, Mus. Nat. Hist., no. 13613, from locality L389.

Genus **Planulina** d'Orbigny, 1826

Planulina sp. (pl. 10, fig. 4).

A fairly large and compressed but plano-convex anomalinid with more or less depressed sutures and a lobulate periphery, a flaring final chamber, and a coarsely punctate wall, seems to be a *Planulina* of the somewhat variably growing sort.

Type, Univ. Rochester, Mus. Nat. Hist., no. 13630, from locality 110C.

Specimens are very rare in the Ndalithoni formation.

Genus **Anomalinella** Cushman, 1927

Anomalinella rostrata (Brady) (pl. 10, fig. 5).

Truncatulina rostrata Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 668, pl. 94, fig. 6, *a-c*, 1884.—Heron-Allen and Earland, Zool. Soc. London, Trans., vol. 20, pt. 18, pp. 709-710, pl. 52, figs. 33-36, 1915.—Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 321, 1921.

Anomalinella rostrata (Brady), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 46, pl. 3, figs. 99, 100, 1941; vol. 39, no. 3, pt. 2, p. 92, pl. 3, figs. 17, 18, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13621, from locality 110C.

Koch (88, p. 208) also lists this species from the Lower Pliocene of eastern Seran in the East Indies.

A single specimen in the Lau material appears to be Brady's living Pacific species. Unfortunately the test is worn at the peripheral corner of the final chamber so that the supplementary aperture so distinctive of the genus is not apparent. In every other respect, however, it seems characteristic of this well-defined species that is so widespread in the Miocene and later Tertiary of the entire Indo-Pacific area.

SUBFAMILY CIBICIDINAE

Genus **Cibicides** Montfort, 1808

Cibicides aknerianus (d'Orbigny) (pl. 10, fig. 8).

Truncatulina akneriana d'Orbigny, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 663, pl. 94, fig. 8, *a-c*, 1884.—Flint, U. S. Nat. Mus., Ann. Rept., p. 333, pl. 77, fig. 5, 1897 (1899).

Truncatulina akneriana (d'Orbigny), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 35, pl. 16, fig. 3, text fig. 38, 1910-1917; Bull. 100, vol. 4, p. 316, pl. 63, fig. 3, *a-c,* 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13589, from locality 15A.

Dwarfed forms in the assemblage from the Lau Volcanics of Yanuyanu are typical of this living Pacific species, except for the notably smaller size and the development ventrally of a small but conspicuous umbilical boss.

Additional but unfigured Indo-Pacific records include the Miocene of Australia (Heron-Allen and Earland, 77, p. 176) and the Pliocene and Recent of Japan (Ishizaki, 83, p. 152); also the living faunas of the Kerimbas (Heron-Allen and Earland, 75, p. 709), the Malay Archipelago (Millett, 104, pl. 16, p. 494, 1904), and the cooler waters southeast of Australia (Chapman, 23, p. 176).

Cibicides lobatulus (Walker and Jacob) (pl. 10, fig. 7).

Truncatulina lobatula Walker and Jacob, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 660, pl. 92, fig. 10, pl. 93, fig. 1, *a-c,* 1884.

Truncatulina lobatula (Walker and Jacob), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 31, pl. 15, fig. 1, text fig. 34, 1910-1917; Bull. 100, vol. 4, p. 313, pl. 63, fig. 2, *a-c,* 1921.

Cibicides aff. *lobatulus* (Walker and Jacob), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 47, pl. 2, figs. 120-122, 1941.

Cibicides lobatulus (Walker and Jacob) LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 3, p. 119, pl. 1, figs. 12-14, 1941.

Cibicides cf. *lobatulus* (Walker and Jacob), Asano, Jour. Paleont., vol. 23, no. 5, p. 476, fig. 2, no. 7, *a, b,* 1949.

not *Truncatulina lobatula* Walker and Jacob, Flint, U. S. Nat. Mus., Ann. Rept., 333, pl. 76, fig. 4, 1897 (1899).

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13628, from locality L438.

This living species is very rare in Lau and is found in one sample only. It is widely recorded from the Indo-Pacific Neogene as follows: by Karrer (85, p. 280) in the Philippine Mio-Pliocene; questionably, by Chapman (17, pp. 263, 269) from Espiritu Santo in the New Hebrides; by Koch (87, p. 356) from the east Java Mio-Pliocene; by Schubert (118, pp. 104-105) from the Bismarck Archipelago; by Heron-Allen and Earland (77, p. 175) from the Miocene of Australia; by Koch (88, p. 208) from the Lower Pliocene of east Seran and (89, p. 728) from slightly older beds in east Borneo; from the Japanese Miocene (Ishizaki, 83, p. 153; Asano, 7, p. 425) to Recent; and as living in the Malay Archipelago (Millett, 104, pt. 16, pp. 491-492, 1904), in the Kerimbas (Heron-Allen and Earland, 75, p. 706), and off southeastern Australia (Chapman, 23, p. 176).

Cibicides refulgens (Montfort) (pl. 10, fig. 9).

Truncatulina refulgens Montfort, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 659, pl. 92, figs. 7, 8, 1884.

Truncatulina refulgens (Montfort), Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 30, pl. 12, fig. 2, text fig. 33, 1910-1917; Bull. 100, vol. 4, p. 312, pl. 63, fig. 1, *a-c*, 1921.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13629, from locality 110C.

This is a somewhat variable living species that occurs rarely in both the Futuna and Ndalithoni formations of Lau. Although unfigured more often than not, it is recorded widely through the Neogene and Recent of the Indo-Pacific (Millett, 104, pt. 16, p. 491, 1904; Chapman, 17, p. 269; Heron-Allen and Earland, 75, p. 707, and 77, p. 175; Koch, 88, p. 208; Ishizaki, 83, pp. 153, 154; and Chapman, 23, pp. 177, 206, 207). According to Chapman (p. 206), this is one of the group "typical of the blue, grey, and green muds below the 100 fathom line" which he thinks of "as having been distributed . . . by Antarctic currents."

As recorded on the checklist for Lau, a poorly preserved individual or two of *Cibicides concavus* Dorn (LeRoy, 98, pt. 1, p. 47, pl. 2, figs. 82-84) or *"Discorbis rarescens"* (Brady, 12, p. 651, pl. 90, figs. 2, 3) may be included.

Genus **Cibicidoides** Brotzen, 1936

Cibicidoides sp. (pl. 10, fig. 6).

Compressed, though biconvex, rotalids with typically anomalinid apertures, evolute on both sides, occur rarely in several of the Lau samples. Their affinities are not certain, but they should be referred to *Cibicidoides* and may prove to be related to *C. pseudoungerianus* or *"Planulina" fijiensis* Cushman (44, pl. 18, fig. 4, *a-c*) or to *"P." wuellerstorfi* (Schwager) of Cushman (44, pl. 18, fig. 3, *a-c*).

Type, Univ. Rochester, Mus. Nat. Hist., no. 13647, from locality 62.

FAMILY PLANORBULINIDAE

Genus **Planorbulina** d'Orbigny, 1826

Planorbulinella larvata (Parker and Jones) (pl. 9, fig. 12).

Planorbulina larvata Parker and Jones, Brady, Rept. Voy. Challenger, Zool., vol. 9, p. 658, pl. 92, figs. 5, 6, 1884.—Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 27, pl. 8, fig. 2, text fig. 30, 1910-1917.

Planorbulina larvata var. *inaequilateralis* Heron-Allen and Earland, Roy. Microscopical Soc., Jour., art. 7, p. 174, pl. 12, figs. 85-90, 1924.

Planorbulinella larvata (Parker and Jones), LeRoy, Colorado School of Mines Quart., vol. 36, no. 1, pt. 1, p. 47, pl. 3, fig. 43, pt. 2, p. 89, pl. 5, fig. 39, 1941; ?LeRoy, *op. cit.*, vol. 39, no. 3, pt. 2, p. 93, 1944.

Hypotype, Univ. Rochester, Mus. Nat. Hist., no. 13581, from locality L306.

Nowhere common in the Lau material, this living species is most numerous in the Ndalithoni formation but also occurs in the Lower member of the Futuna. The Lau forms are quite variable and include Heron-Allen and Earland's variant, which they list (77, p. 173) along with the species *sensu stricto* from the Filter Quarry deposits (Australian Miocene). Individual specimens also approach the more robust species *Planorbulinella zelandica* from the middle Tertiary of New Zealand (Finlay, 61, p. 290, pl. 8, figs. 119-124). Crespin (29, p. 10) records it as rare in the Lower Miocene (Tertiary *e*) of the upper Fly River drainage area of Papua. It is recorded from the Miocene of east Borneo (Van der Vlerk, 138, p. 137) and of southeastern Luzon (Yabe and Hanzawa, 154, p. 101), from the Miocene to Recent in the Ryukyu Islands and Formosa (Yabe and Hanzawa, 156; Ishizaki, 83, p. 155), and living around the Philippines (Cushman, 38, p. 310), the Malay Archipelago (Millett, 104, pt. 16, p. 490, 1904), and the Kerimba Archipelago (Heron-Allen and Earland, 75, p. 706).

Family ORBITOIDIDAE

Subfamily ORBITOIDINAE

Genus **Lepidocyclina** Gümbel, 1870

Cole (27, p. 274) has already recorded and described those orbitoid species from Lau which occur in the samples carrying smaller foraminifers. Except for specifically unidentifiable *Lepidocyclina* in certain Upper Futuna Limestone samples from Katafanga and Ongea Levu, no additional records are added here; but these and Cole's records are shown in table 1.

Lepidocyclina sp.

Varied cross sections of several specimens of the genus, in which neither species nor subgenus could be determined, were apparent in three of the limestone samples from the crystalline Upper member of the Futuna formation.

Lepidocyclina papulifera H. Douvillé.

Lepidocyclina (*Eulepidina*) *dilatata* Whipple, not Michelotti, B. P. Bishop Mus., Bull. 119, pp. 147-148, pl. 21, fig. 2, pl. 22, fig. 1, 1934.

Lepidocyclina papillifera H. Douvillé, Cole, B. P. Bishop Mus., Bull. 181, p. 294, pls. 29, *A-F*, 30, *H*, 1945.

Lepidocyclina stratifera Tan.

Lepidocyclina stratifera Tan, Cole, B. P. Bishop Mus., Bull. 181, p. 295, pl. 30, *A-C*, 1945.

Subgenus **Nephrolepidina** H. Douvillé, 1911

As used here in table 1 and in the discussion of correlation and age, this subgenus includes that of Cole only in part.

Nephrolepidina sumatrensis inornata Rutten.

Lepidocyclina (*Nephrolepidina*) *sumatrensis inornata* Rutten, Cole, B. P. Bishop Mus., Bull. 181, p. 291, pl. 24, *J-L*, 1945.

Subgenus **"Trybliolepidina"** Van der Vlerk, 1928

As used here in a Linnean manner, and applied to those forms in which the initial and embryonically embraced chamber tends generally to have its side walls perpendicular to its attached side and in which the two "arms" of the embracing chamber terminate bluntly and squarishly instead of in two points, this "subgenus" includes the subgenera *Nephrolepidina* (in part) and *"Eulepidina"* Cole (not H. Douvillé, 53) of Cole (*27*).

"Trybliolepidina" oneataensis (Cole).

Lepidocyclina (*Eulepidina*) *oneataensis* Cole, B. P. Bishop Mus., Bull. 181, p. 292, pl. 26, A-J, 1945.

"Trybliolepidina" martini (Schlumberger).

Lepidocyclina (*Nephrolepidina*) *martini* Schlumberger, Cole, B. P. Bishop Mus., Bull. 181, p. 288, pl. 25, *A-M*, 1945.

"Trybliolepidina" rutteni (Van der Vlerk).

Lepidocyclina rutteni Van der Vlerk, Wetensch. Meded., no. 1, p. 17, pl. 3, figs. 1-4, 1924.

Lepidocyclina (*Eulepidina*) *leyteensis* Yabe and Hanzawa, Tohoku Imp. Univ., Sci. Repts., ser. 2 (Geol.), vol. 7, no. 4, pp. 107-108, pl. 25, figs. 8, 9, 1925.

Lepidocyclina (*Nephrolepidina*) *rutteni* Van der Vlerk, Cole, B. P. Bishop Mus., Bull. 181, p. 289, pl. 27, *A-G*, 1945.

"Trybliolepidina" rutteni lauensis (Cole).

Lepidocyclina rutteni lauensis Cole, B. P. Bishop Mus., Bull. 181, p. 290, pls. 27, *H*, *I*, 28, *A*, 1945.

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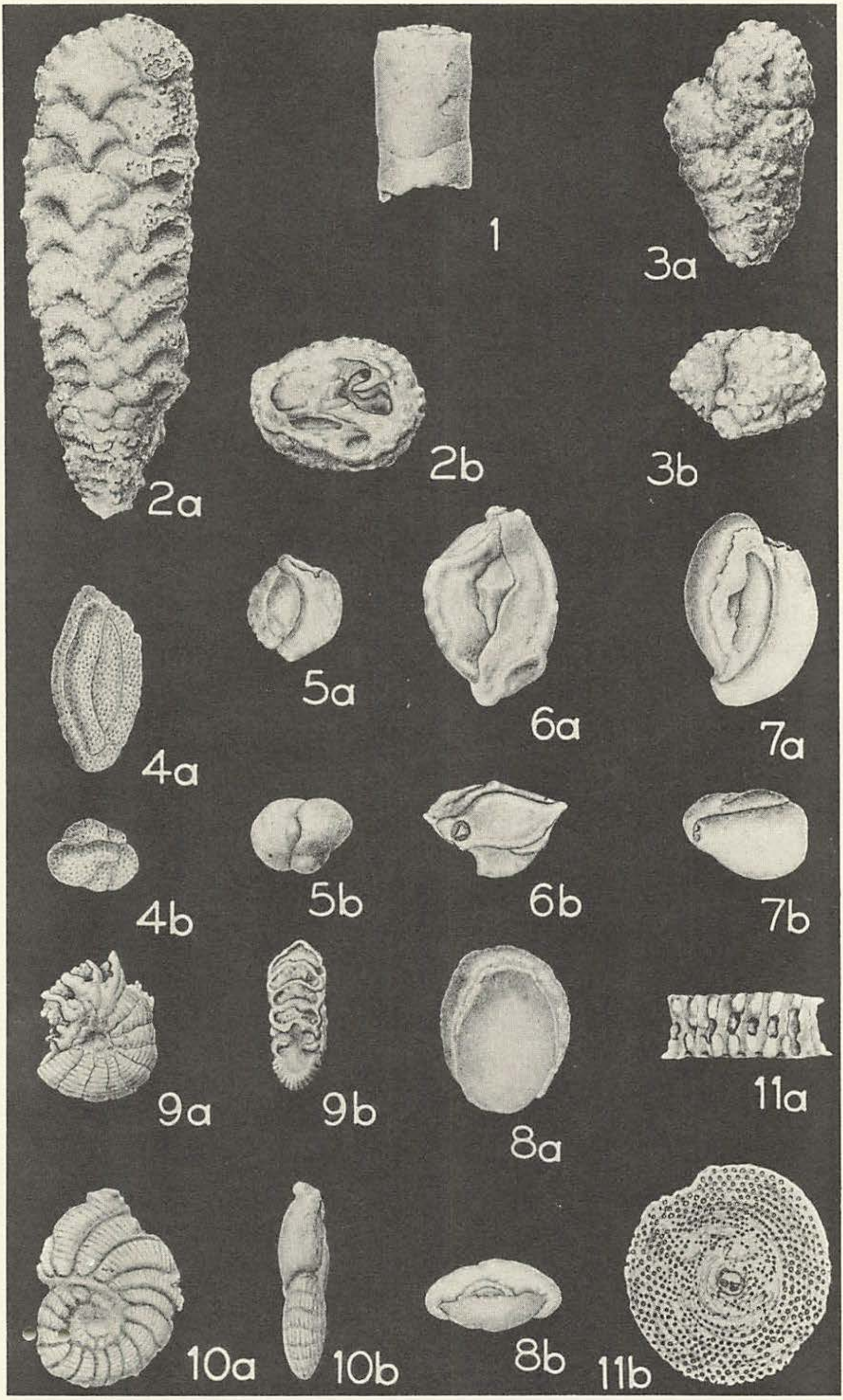
PLATE 6.—(1) *Eponides* cf. *concameratus: a,* ventral view; *b,* apertural view; *c,* dorsal view; × 30; from sample 62. (2) *Eponides* (?) sp.: *a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 25; from sample 110C. (3) *E.* cf. *repandus: a,* ventral view; *b,* dorsal view; *c,* apertural view; × 25; from sample 62. (4) *Eponides* sp.: *a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample 110B. (5) *E. procerus: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample 62. (6) *E. karsteni: a,* ventral view; *b,* peripheral view; *c,* dorsal view; × 30; from sample 15A. (7) *Parrella bengalensis: a,* ventral view; *b,* peripheral view; × 20; from sample 62. (8) *Pegidia* (?) sp.: *a,* peripheral view; *b,* dorsal view; *c,* ventral view; × 30; from sample 62.

PLATE 7.—(1) *Rotalia tuvuthaensis,* dorsal view; × 22.5; from sample L344A. (2) *R. tuvuthaensis,* ventral view, × 20; from sample L344A. (3) *R. tuvuthaensis,* ventral view, × 25; from sample 110C. (4) *R. tuvuthaensis: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 20; from sample L344A. (5) *R. calcar,* dorsal view, × 25; from sample L389. (6) *R. calcar: a,* peripheral view; *b,* side view; × 25; from sample L306. (7) *Calcarina mayori: a,* peripheral view; *b,* side view; × 25; from sample L307. (8) *Baculogypsina sphaerulata: a,* peripheral view; *b,* side view; × 25; from sample L344A. (9) *Siderolites mbalavuensis: a,* peripheral view; *b,* side view; × 25; from sample 62. (10) *Amphistegina lessonii* var. *conoides,* × 32.5; from sample L308. (11) *A. lessonii* var. *fijiensis,* × 32.5; from sample 62.

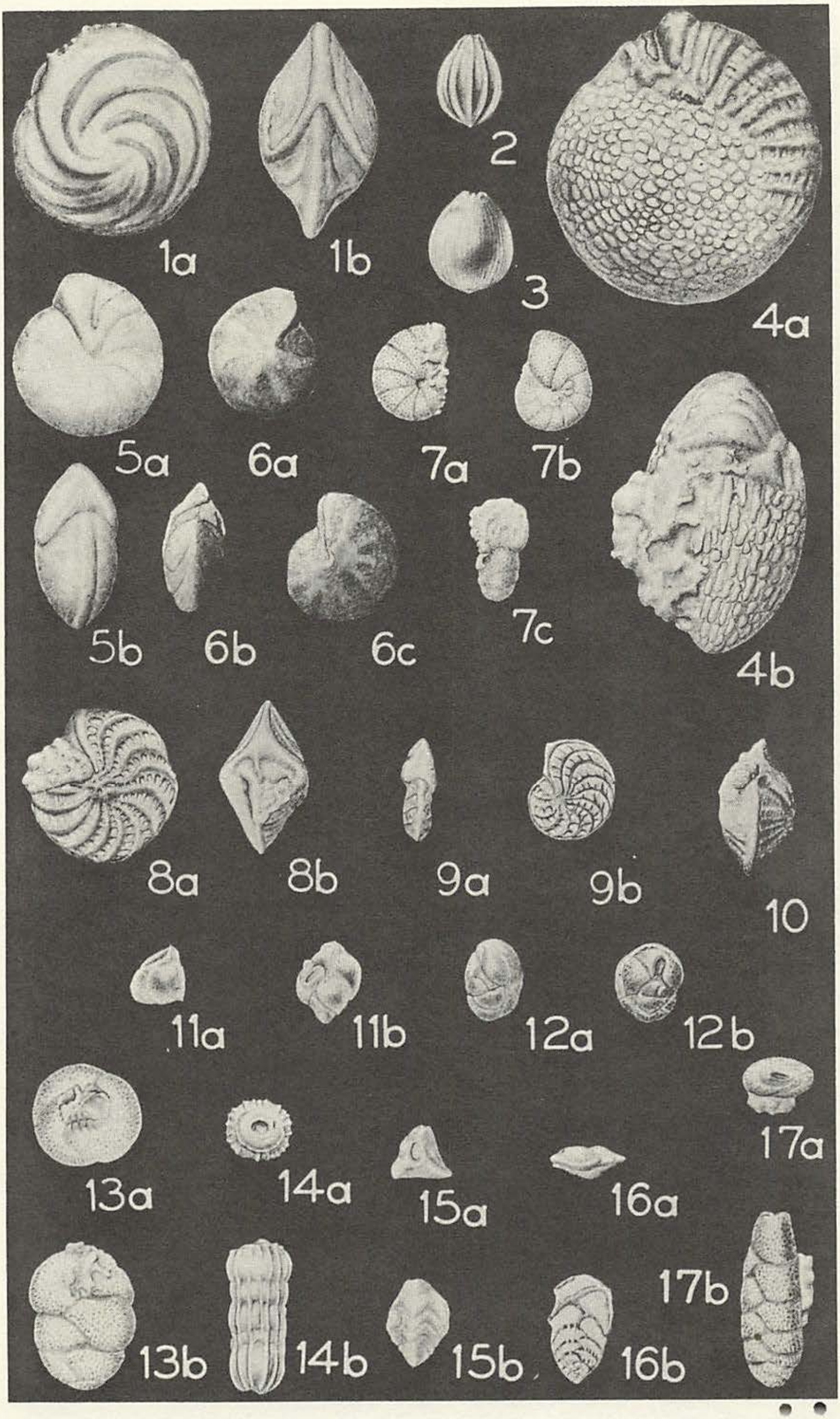
PLATE 8.—(1) *Amphistegina lessonii: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 50; from sample 110B. (2) *A. lessonii* var. *fijiensis: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 32.5; from sample L388. (3) *A. lessonii* var. *conoides: a,* dorsal view; *b,* peripheral view; × 32.5; from sample L487. (4) *A. lessonii* var. *conoides: a,* ventral view; *b,* peripheral view; × 20; from sample L466. (5) *A. lessonii* var. *melanesiensis: a,* side view; *b,* peripheral view; × 32.5; from sample 110B.

PLATE 9.—(1) *Cymbalopora* sp.: *a,* ventral side; *b,* peripheral view; *c,* dorsal view; × 30; from sample 62. (2) *Cymbalopora* (?) sp.: *a,* viewed from above; *b,* peripheral view; × 30; from sample 110C. (3) *Cymbaloporetta bradyi: a,* ventral view; *b,* peripheral view; *c,* dorsal view; × 30; from sample L344A. (4) *C. poeyi: a,* ventral view; *b,* peripheral view; *c,* dorsal view; × 30; from sample L388. (5) *Globorotalia menardii* var. *fijiensis: a,* dorsal view; *b,* apertural view; *c,* ventral view; × 25; from sample L466. (6) *G. sacharina: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 25; from sample L466. (7) *G. patagonica: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 35; from sample 110C. (8) *Globigerina bulloides,* × 50, from sample 62. (9) *Globigerina* (?) sp.: *a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample L306. (10) *G. conglomerata,* × 50; from sample 62. (11) *Orbulina universa,* × 50; from sample 62. (12) *Planorbulinella larvata: a,* side view; *b,* peripheral view; × 50; from sample L306.

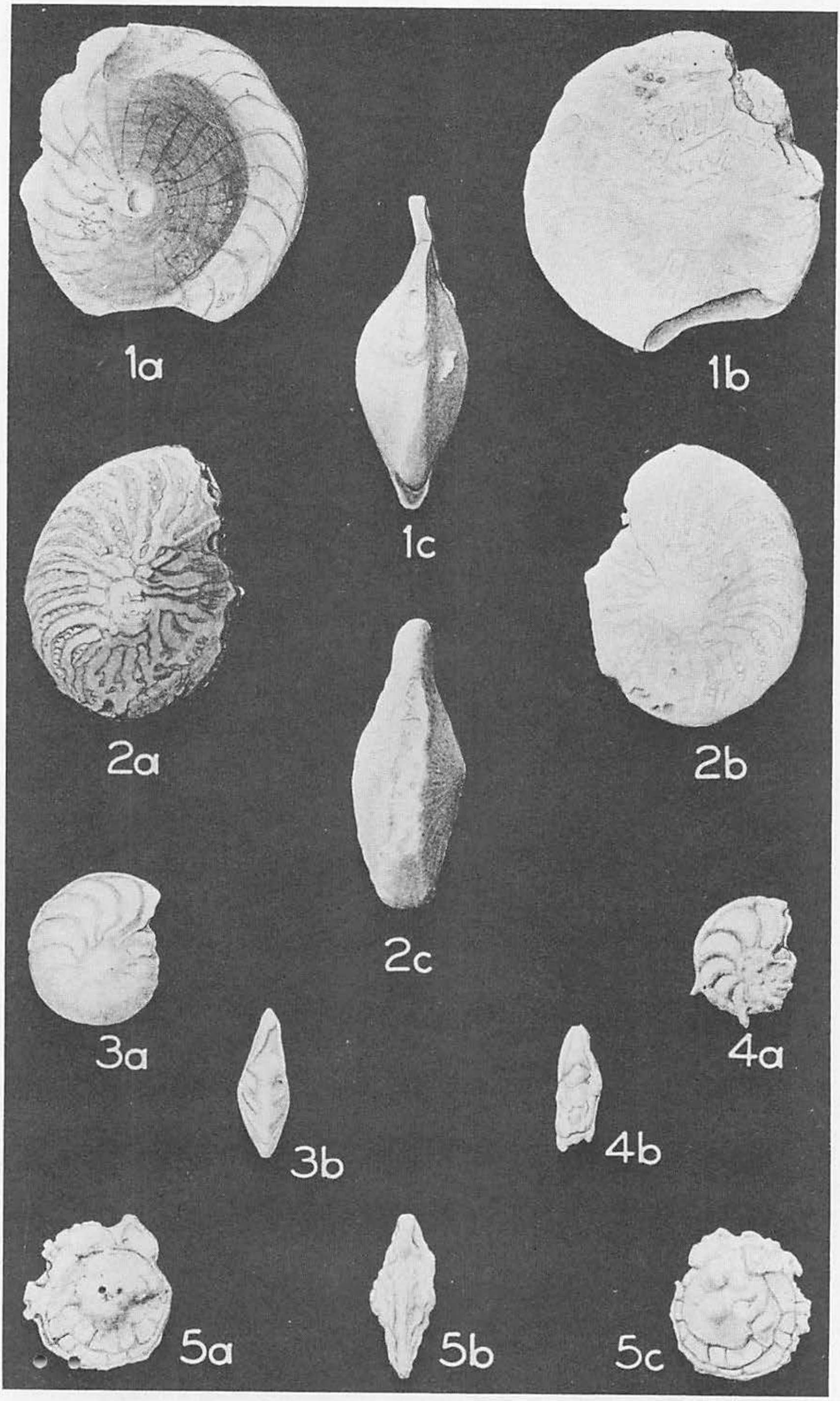
PLATE 10.—(1) *Anomalina glabrata: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample 110C. (2) *Anomalina* (?) sp.: *a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample L389. (3) *A. grosserugosa: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample L308. (4) *Planulina* sp.: *a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 30; from sample 110C. (5) *Anomalinella rostrata: a,* peripheral view; *b,* side view; × 30; from sample 110C. (6) *Cibicidoides* sp.: *a,* ventral view; *b,* apertural view; *c,* dorsal view; × 32.5; from sample 62. (7) *Cibicides lobatulus: a,* dorsal view; *b,* ventral view; *c,* apertural view; × 50; from sample L438. (8) *C. akneriamus: a,* ventral view; *b,* dorsal view; *c,* apertural view; × 50; from sample 15A. (9) *C. refulgens: a,* dorsal view; *b,* peripheral view; *c,* ventral view; × 50; from sample 110C.



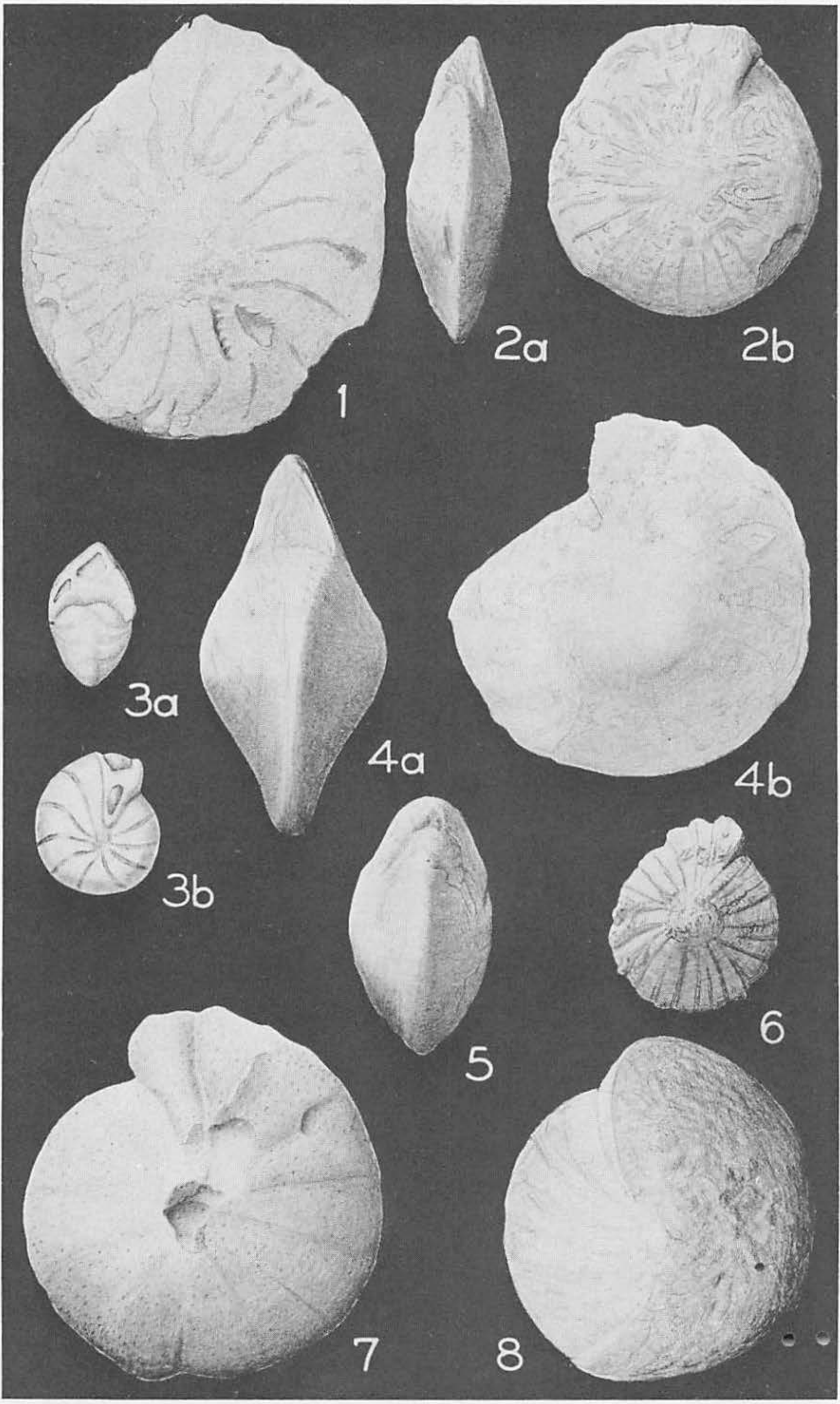
1, *BATHYSIPHON ARENACEA*; 2, *TEXTULARIA RUGOSA*; 3, *T. HAUERII*; 4, *QUINQUELOCULINA OBLONGA*; 5, *Q.* CF. *CIRCULARIS*; 6, *Q. PARKERI*; 7, *Q. SEMINULA*; 8, *PYRGO LUCERNULA*; 9, *PENEROPLIS PERTUSUS*; 10, *P. CARINATUS*; 11, *MARGINOPORA* AFF. *VERTEBRALIS*.



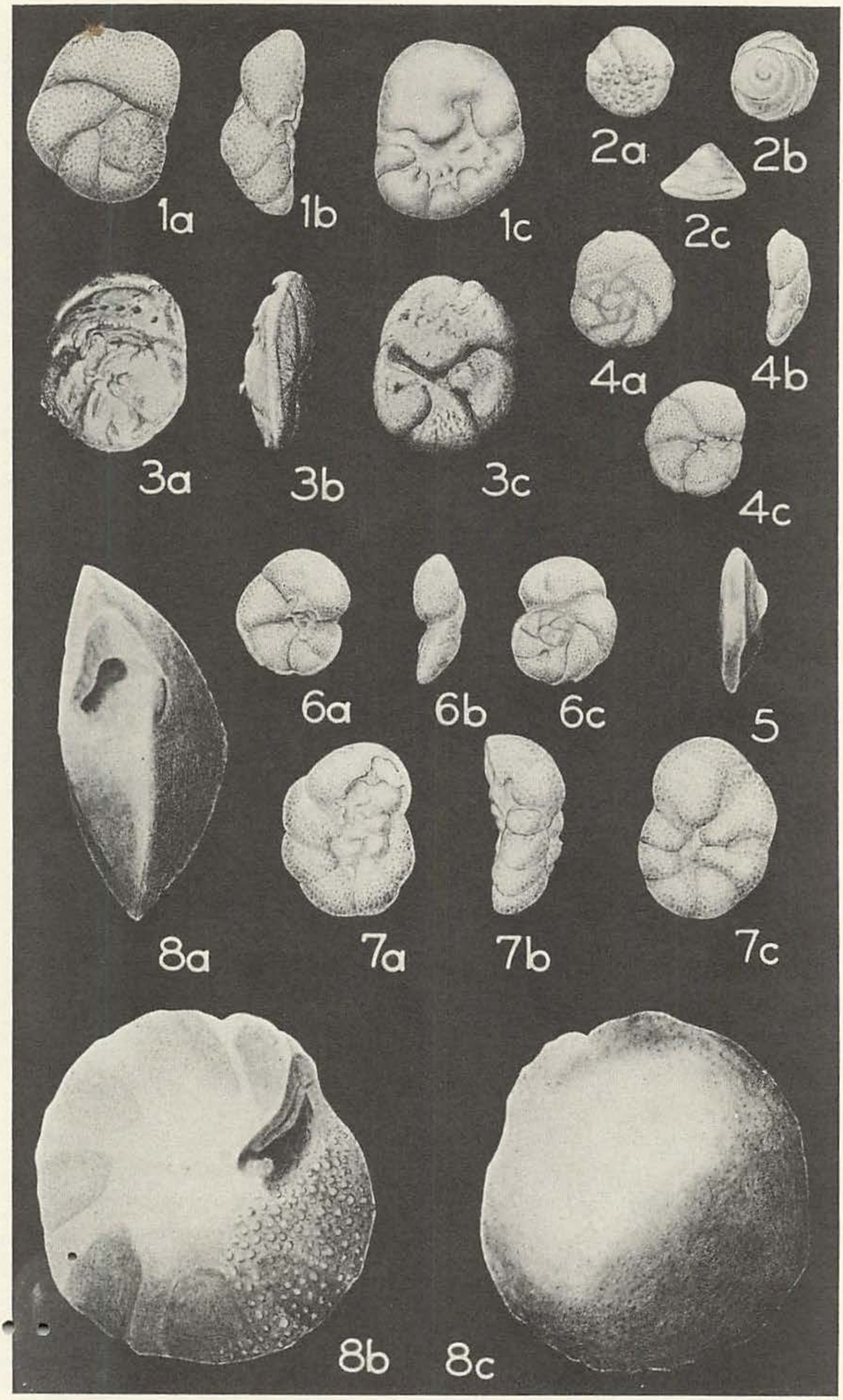
1, *ROBULUS ORBICULARIS*; 2, *LAGENA COSTATA*; 3, *L. GLOBOSA*; 4, *ELPHIDIUM CRATICULATUM*; 5, 6, *NONION PACIFICUM* VAR. *LAUENSIS*; 7, *N. UMBILICATULUM*; 8, 10, *ELPHIDIUM CRISPUM*; 9, *E. MACELLUM*; 11, *PLEUROSTOMELLA BREVIS*; 12, *CASSIDULINA SUBGLOBOSA*; 13, *UVIGERINA CANARIENSIS* VAR. *LAKEMBAENSIS*; 14, *SIPHOGENERINA COSTULATA*; 15, *REUSSELLA SPINULOSA*; 16, *BOLIVINA* CF. *HANTKENIANA*; 17, *B.* CF. *ZEDIRECTA*.



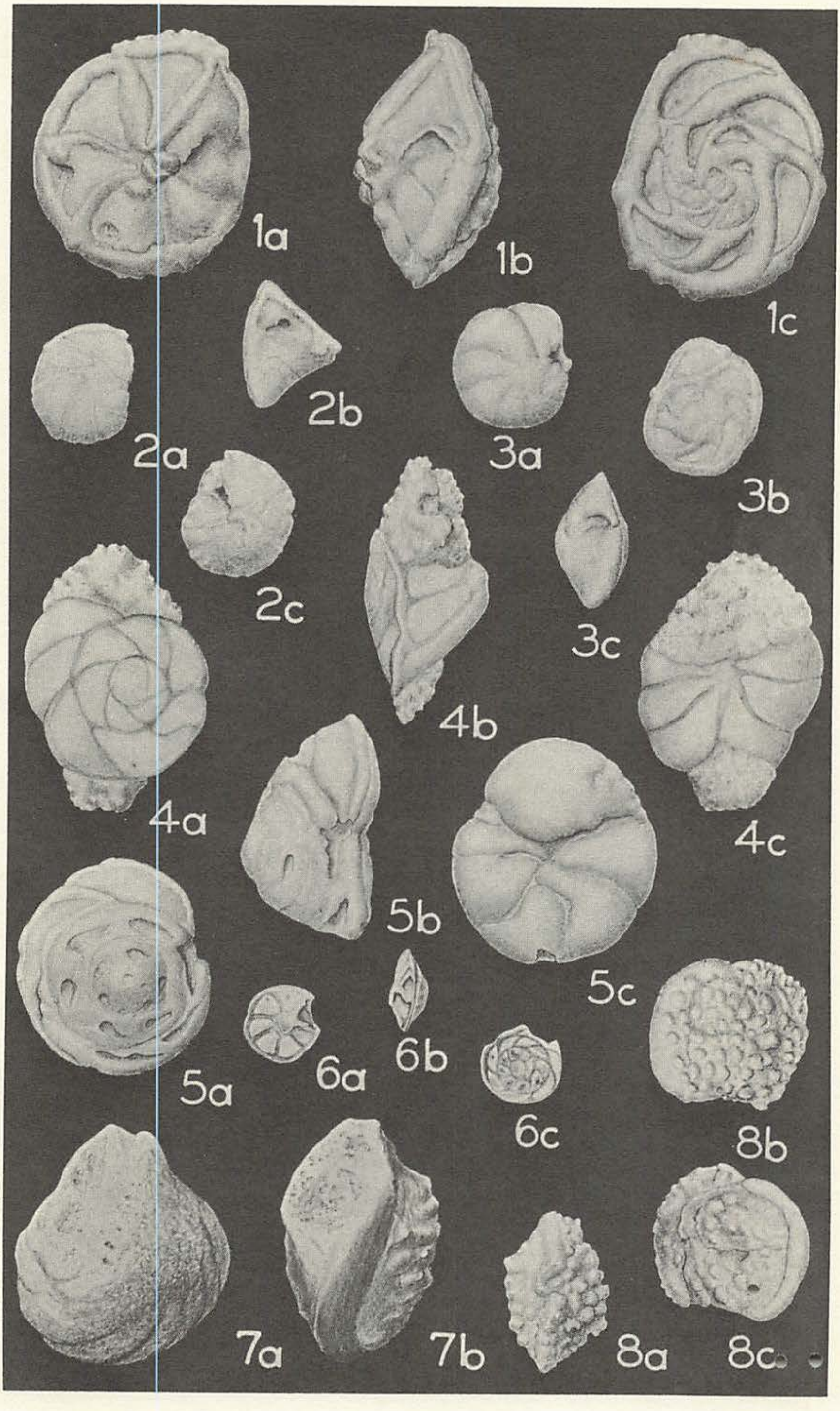
1, *OPERCULINA COMPLANATA JAPONICA;* 2, *O. GRANULOSA;* 3, *OPERCULINA* (?) SP.; 4, *O. AMMONOIDES;* 5, *HETEROSTEGINA DEPRESSA.*



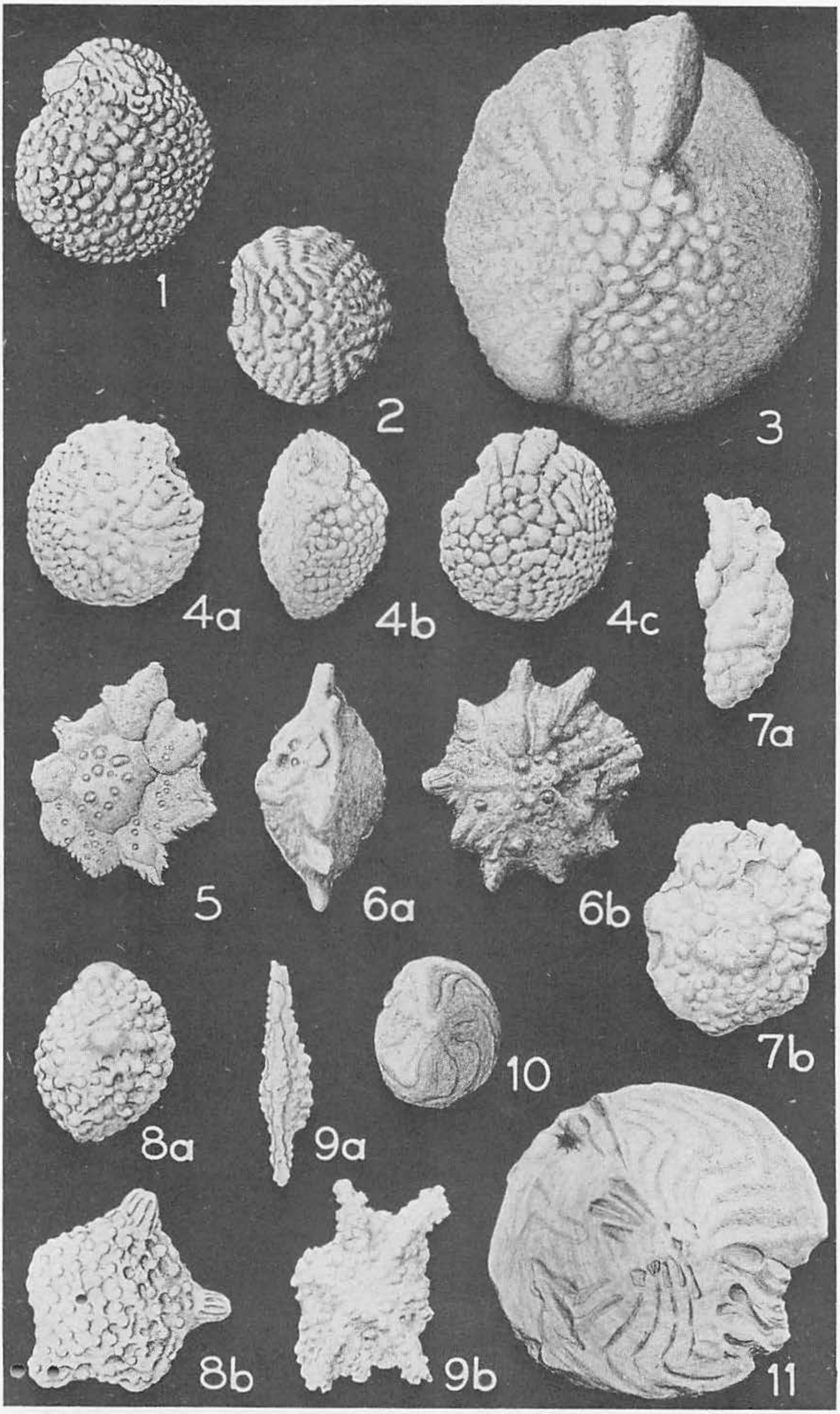
1–3, *OPERCULINELLA CUMINGII;* 4, *OPERCULINELLA* SP. CF. *O. VENOSA;* 5–8, *O.* (?) *ONEATAENSIS.*



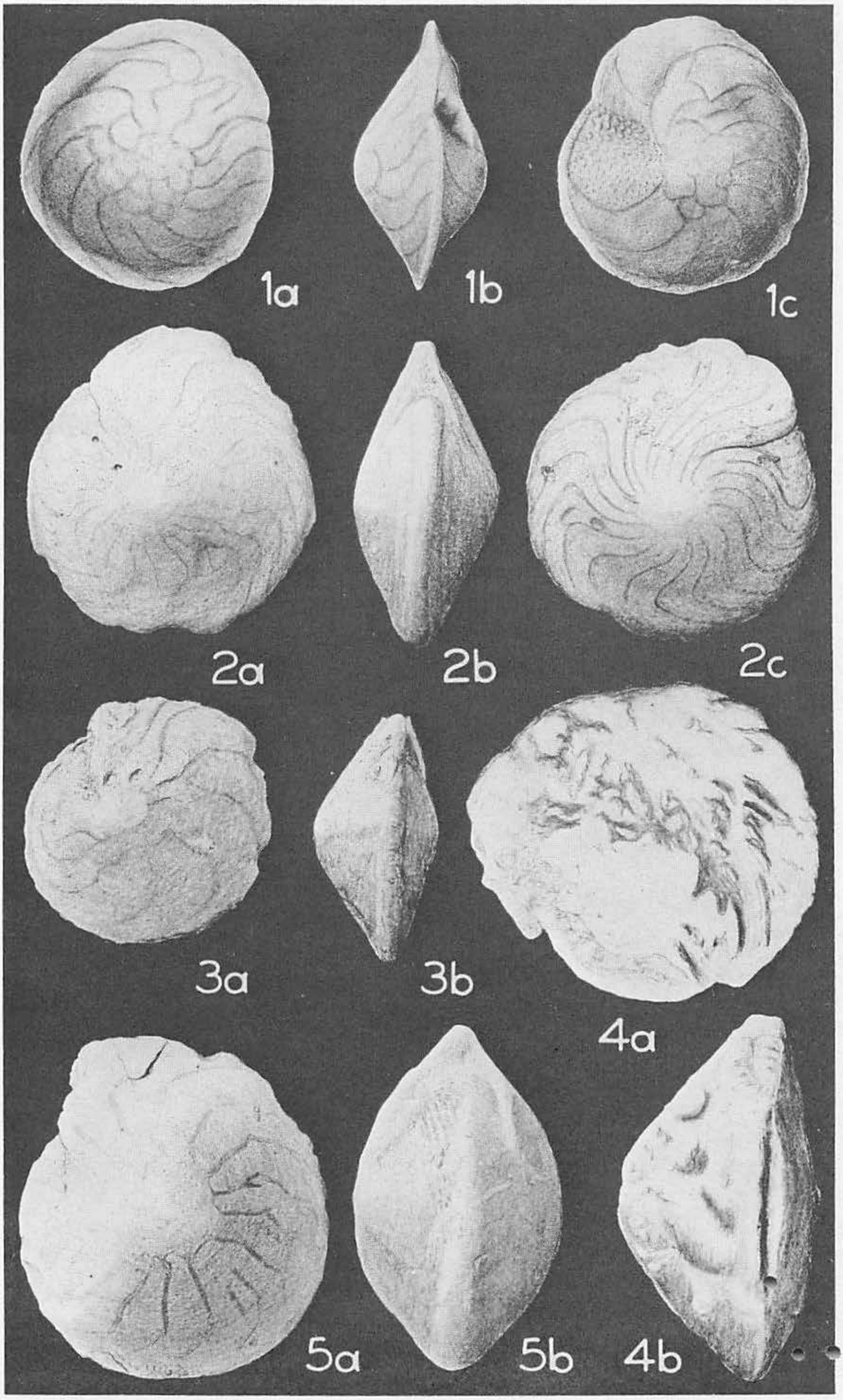
1, *DISCORBIS GLOBULARIS;* 2, *D. PILEOLUS;* 3, *D.* CF. *NITIDA;* 4, 5, *D. LADDI;* 6, *VALVULINERIA VILARDEBOANA;* 7, *VALVULINERIA* (?) SP.; 8, *EPISTOMINA HOFFMEISTERI.*



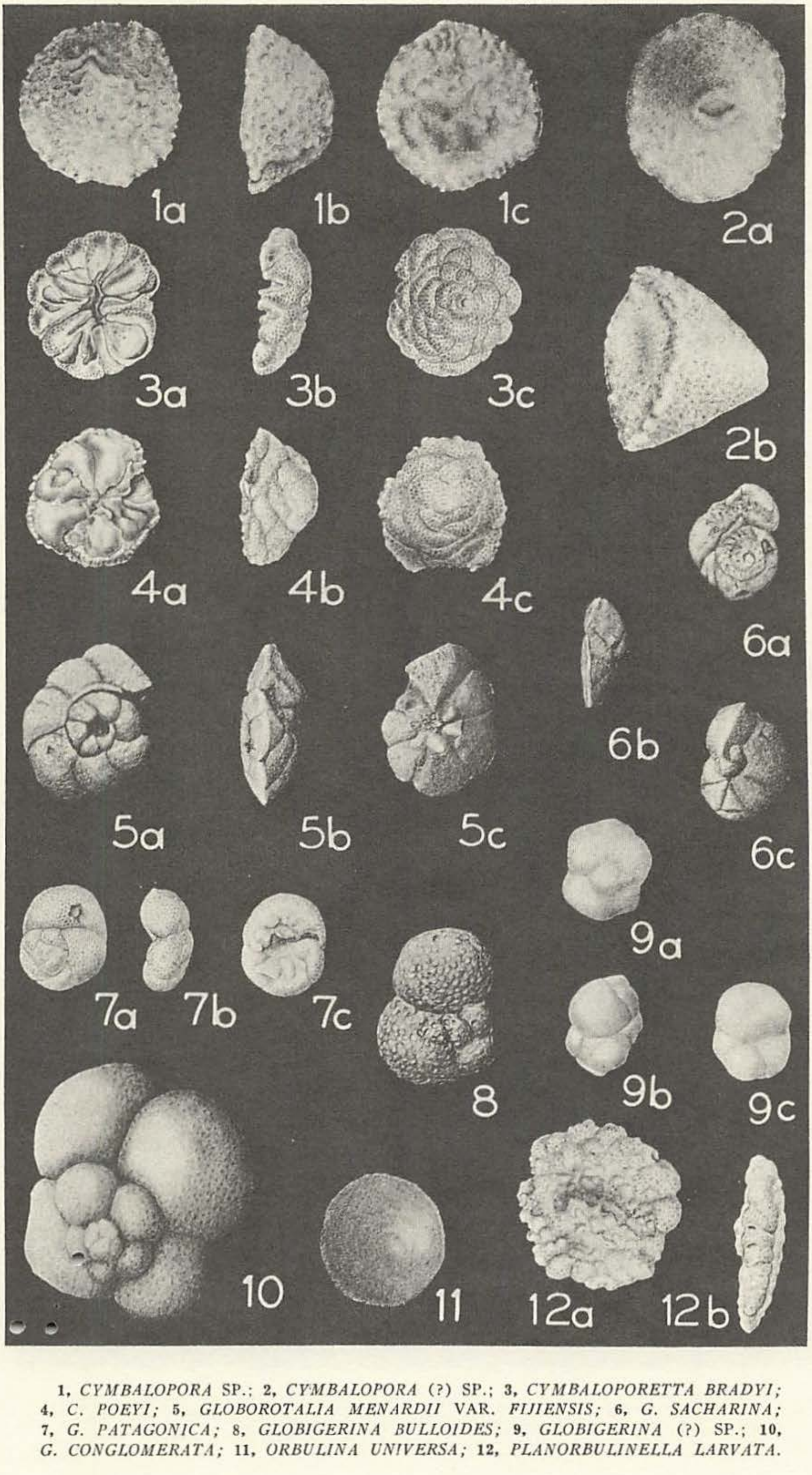
1, *EPONIDES* CF. *CONCAMERATUS;* 2, *EPONIDES* (?) SP.; 3, *E.* CF. *REPANDUS;* 4, *EPONIDES* SP.; 5, *E. PROCERUS;* 6, *E. KARSTENI;* 7, *PARRELLA BENGALENSIS;* 8, *PEGIDIA* (?) SP.



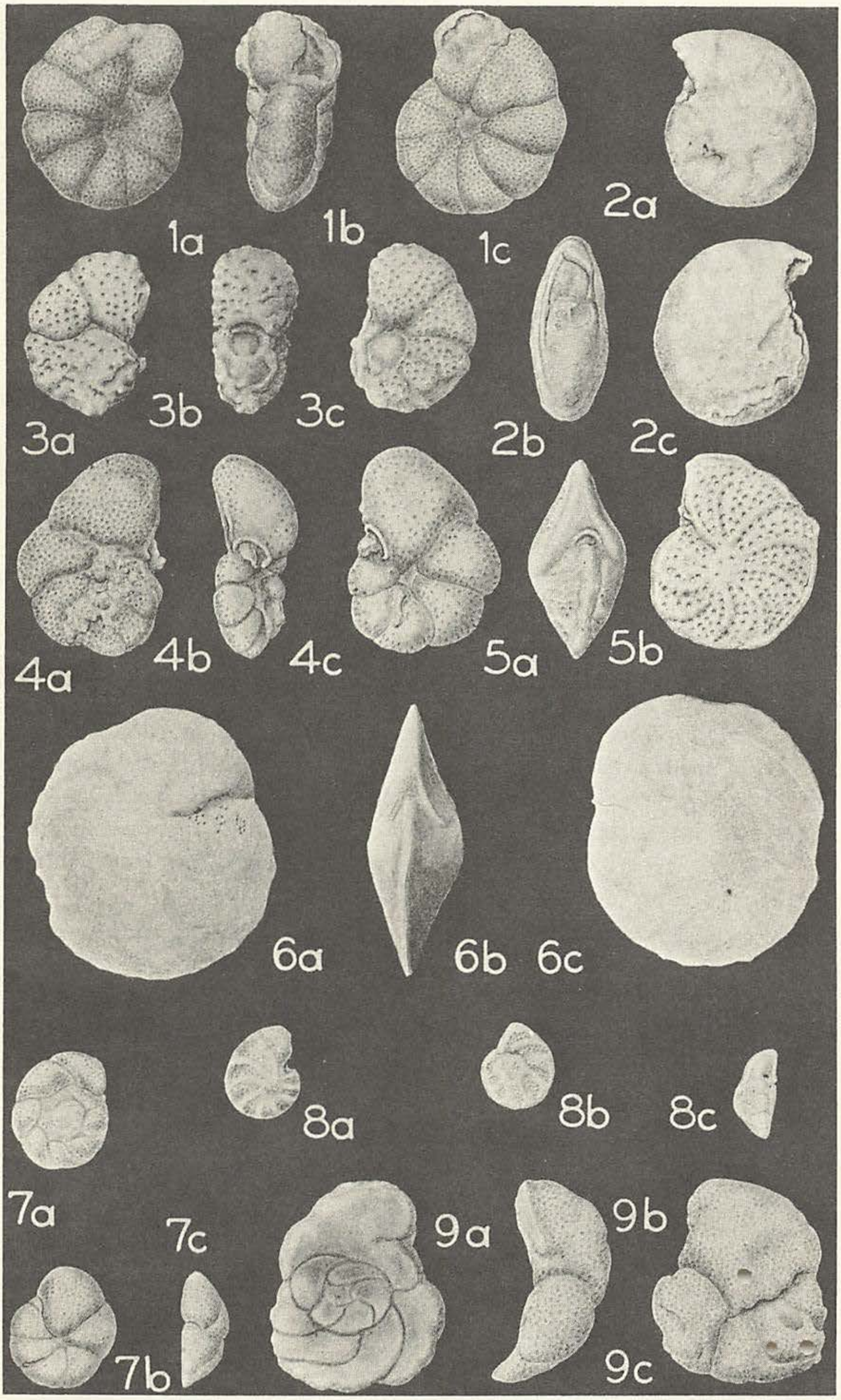
1–4, *ROTALIA TUVUTHAENSIS;* 5, 6, *R. CALCAR;* 7, *CALCARINA MAYORI;* 8, *BACULOGYPSINA SPHAERULATA;* 9, *SIDEROLITES MBALAVUENSIS;* 10, *AMPHISTEGINA LESSONII* VAR. *CONOIDES;* 11, *A. LESSONII* VAR. *FIJIENSIS.*



1, *AMPHISTEGINA LESSONII*; 2, *A. LESSONII* VAR. *FIJIENSIS*; 3, 4, *A. LESSONII* VAR. *CONOIDES*; 5, *A. LESSONII* VAR. *MELANESIENSIS*.



1, *CYMBALOPORA* SP.; 2, *CYMBALOPORA* (?) SP.; 3, *CYMBALOPORETTA BRADYI;* 4, *C. POEYI;* 5, *GLOBOROTALIA MENARDII* VAR. *FIJIENSIS;* 6, *G. SACHARINA;* 7, *G. PATAGONICA;* 8, *GLOBIGERINA BULLOIDES;* 9, *GLOBIGERINA* (?) SP.; 10, *G. CONGLOMERATA;* 11, *ORBULINA UNIVERSA;* 12, *PLANORBULINELLA LARVATA.*



1, *ANOMALINA GLABRATA*; 2, *ANOMALINA* (?) SP.; 3, *A. GROSSERUGOSA*; 4, *PLANULINA* SP.; 5, *ANOMALINELLA ROSTRATA*; 6, *CIBICIDOIDES* SP.; 7, *CIBICIDES LOBATULUS*; 8, *C. AKNERIANUS*; 9, *C. REFULGENS*.