GEOLOGY OF VITILEVU, FIJI

BY

HARRY S. LADD

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CONTENTS

ILLUSTRATIONS

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INTRODUCTION

Historical Sketch

Fiji includes some 250 islands; most of them are small, many of them mere isolated reefs. Less than half of them are inhabited. The two larger islands are Vitilevu, in the west-central portion of the archipelago, and Vanualevu, about 40 miles to the northeast. Vitilevu, with an area of 4,053 square miles, is one of the three largest islands in the open Pacific; it is exceeded in size only by New Caledonia and the island of Hawaii.

As recorded in native chants which have been handed down from generation to generation, the earliest Fijians came to western Vitilevu from some country far to the west. They were led by ancestral gods whose canoe was driven ashore at or near the site of the village now called Viseisei. These pioneer settlers traveled inland and established themselves in the hills of the Nakauvandra Range, and as the population increased, developed numerous small but independent villages. Later came migrations toward the coastal districts and the establishment of powerful native confederacies near the mouths of the larger streams. These organizations waged fierce wars upon each other. In the early years of the nineteenth century white men began to arrive in increasing numbers and some of them took active part in the tribal wars. Thereafter for 50 years the history of Fiji was a history of wars.

The first European to see Fiji was the Dutch navigator, Abel Jansen Tasman, who visited some of the northeastern islands in 1643 and christened them "Prins Wilhelm's Eylanden," disregarding the native name "Viti." About 100 years later D'Urville, Wilkes, and others explored some of the islands, and at the beginning of the nineteenth century trading vessels manned by Europeans touched at Fiji not infrequently.

It is interesting to note that Thakombau, last ruling king of Fiji, at one time offered the islands to the United States. This country, however, was in the midst of the Civil War, and no action was taken. Later, in 1874, Great Britain accepted the islands, after having refused to annex them in 1859.

Fiji is now a British Crown Colony. Suva, the capital, on the southeastern coast of Vitilevu, is located on the wet and less desirable side of the island because of an excellent natural harbor.

The population of the colony is a mixture, with the native Fijians and the imported Indians far outnumbering all other races. Published estimates show that in 1926 Europeans formed less than $2\frac{1}{2}$ percent of a total population numbering nearly 172,000 (41, p. 130).*

Scope and Method

The primary purpose of the present investigation is to work out the geological history of Vitilevu with the aid of detailed paleontological studies. Fiji affords an interesting field to the student of Pacific paleontology because of the generally accepted belief in its continental origin. Obviously, if the archipelago was once part of a larger land mass, a study of its fossils should yield evidence of such a connection.

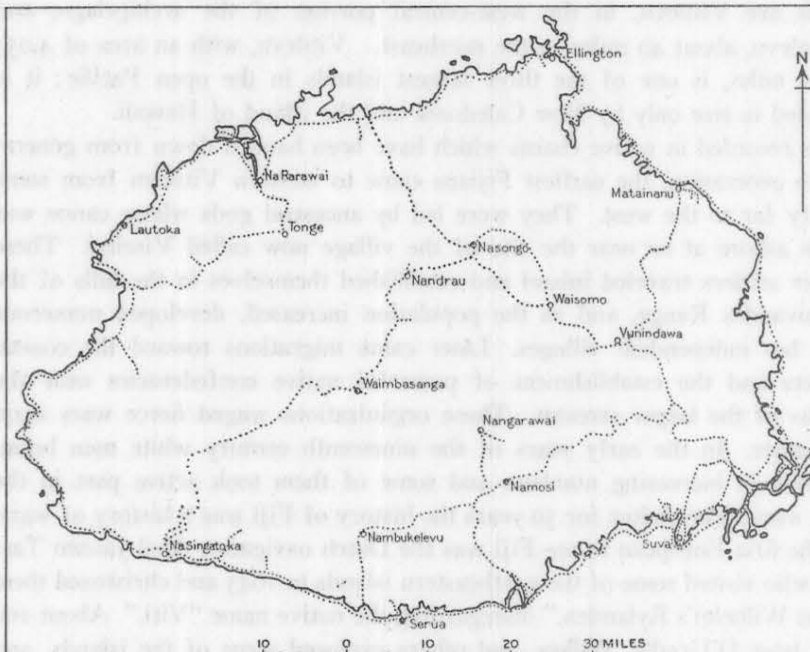

FIGURE 1.—Outline map of Vitilevu, showing lines of main traverses.

Field work on which the present report is based was done in 1926 and 1928. On the first expedition I arrived in Suva on January 2, 1926, and departed September 3, but spent two of the months intervening on a trip to Australia and New Zealand. Two traverses were made across Vitilevu, in addition to a number of shorter excursions, and considerable time was spent in the Suva district collecting fossils from numerous quarries and making a collection of Recent mollusk shells for comparative studies. On the second expedition (1928) the months of June, July, and August were given almost entirely to a study of the geology of the interior of Vitilevu (fig. 1).

* Numbers in parentheses refer to the bibliography, page 247.

Most of the work was done on foot, as the few miles of paved roads on the island are along the coast near the larger towns. The main rivers may be ascended for some distance in small boats, beyond which it is necessary to follow the native trails. Many of these trails can be traversed on horseback, but steep slopes, bogs, and numerous rocky fords make progress difficult. Nearly all the outcrops are in the valleys, though high cliffs may be found near the summits of the mountains. Rock exposures off the beaten track are very difficult to reach. A trail must be cut with bush knives, a task often more difficult in the dense reeds of the dry side of the island than in the rain forest of the opposite side. On the windward side drenching rains and swollen streams add greatly to the difficulties of getting about.

The coastal areas are easily accessible. On the west a narrow-gauge railroad runs from Na Singatoka to Na Rarawai. On the north a fairly good road runs from Na Rarawai to Ellington; there are also good roads in the district around Suva. Access to other parts of the coast is by small sailing skiffs.

No detailed maps of Vitilevu have yet been made. The best outline map available was issued by the Lands Department in Suva in 1924. Though on a small scale (10 miles to an inch), this map is accurate and shows cultural features in addition to drainage lines and principal mountain ranges. The heights of many of the hills and mountains were accurately determined by a trigonometrical survey completed in 1916 (85). Elevations of outcrops and other features described in the present report were determined by an aneroid barometer. The readings were corrected as frequently as possible by reference to sea level or to established points. The distribution of the modern reefs is well shown by the British Admiralty charts.

Acknowledgments

I am deeply under obligation to Bernice P. Bishop Museum and to Yale University for the liberal support which made the two expeditions to Fiji possible. It is also a pleasure to acknowledge the receipt of generous grants from the Research Committee of the University of Virginia and from the Committee on the Marsh Fund of the National Academy of Sciences which aided in completing the report after the return from the field. The University of Virginia also cooperated by granting me leave of absence during the spring of 1928. The officials of the United States Geological Survey and of the Geological Survey of the State of Iowa kindly loaned instruments for use in the field.

Grateful appreciation is expressed to His Excellency, Sir Eyre Hutson, the Governor of Fiji, to the Hon. Douglas Roy Stewart, the Acting Colonial

Secretary, and to other officers of the Fijian Government for many courtesies. The Hon. C. A. Holmes, Commissioner of Lands, furnished maps and information which greatly aided the work in the interior. The Museum Committee, headed by the Hon. R. Boyd, provided a work room and storage space at the Fiji Museum, where I was pleasantly associated with Mr. G. Wright, the Curator. Mr. R. W. Paine, of the Agricultural Department, and Mr. C. R. Harley-Nott of the Colonial Secretary's Office accompanied me on numerous collecting trips in southeastern Vitilevu and aided in many other ways. While traveling over the island I was received and given assistance by Government officials and others, among them Messrs. R. R. Anson, A. J. Armstrong, C. V. Caldwell, E. C. Connelly, P. Costello, A. H. Irvine, S. Reay, G. K. Roth, J. E. Windrum, and A. A. Wright. I am particularly indebted to Mr. W. T. C. Edwards, Road Overseer, for courtesies too numerous to mention. While engaged in collecting Recent mollusks on the island of Mbau I was hospitably entertained by Ratu Pope. I also received various courtesies from Ratu J. L. V. Sukuna. The hospitality of the Fijian people in the villages of the interior made it unnecessary to carry burdensome camping equipment.

Dr. J. Edward Hoffmeister of the University of Rochester worked a month with me in the field. It is a pleasure to acknowledge this assistance and also the many helpful suggestions made at later dates. To Dr. W. A. Setchell and Dr. T. Wayland Vaughan of the University of California I am indebted for advice and encouragement.

The Fiji collections were taken to the United States National Museum, where Dr. Paul Bartsch kindly furnished working quarters and gave access to the Museum collections. In identifying the fossils many helpful suggestions were made by Drs. Paul Bartsch, G. A. Cooper, August F. Foerste, Julia A. Gardener, Wendell C. Mansfield, Ralph Stewart, and Wendell P. Woodring. Dr. Woodring has also been kind enough to read and criticize the entire manuscript. Certain groups of fossils were submitted for study to specialists whose reports are included in the present paper, as is also a petrographic report by Dr. Arthur A. Pegau. Photographs of the mollusks were made by Mr. W. O. Hazard and retouched by Miss Frances Wieser. Miss Laura Thorwarth aided greatly in preparing the final copy of the manuscript. Most of the maps were drafted by Mr. Lewis Pusey of the United States Geological Survey.

Previous Investigations

One of the early papers dealing with the geology of Vitilevu is by Kleinschmidt (67), who found in place the plutonics described by Wichmann (122). The most important and, on the whole, the most complete reports are by Woolnough (128, 129), who spent six weeks in the field in 1903 and almost three months in 1905. Although handicapped by unfavorable weather and other discomforts, he accomplished a large amount of work. He described granite and quartz-diorite areas and what appeared to be metamorphosed sedimentary rocks associated with the plutonics. These he recognized as a pre-Tertiary group of great antiquity, and thus firmly established the continental origin of Vitilevu. Lying unconformably above this older series of rocks he found younger formations, both volcanic and sedimentary. He subdivided the volcanic rocks into a southern andesitic series and a northern basaltic series. Woolnough's geological map covers most of the eastern half of Vitilevu. Important geologic and topographic evidence regarding lines of faulting was obtained, and a differential uplift of over 4,000 feet was demonstrated.

In 1909 Cochrane, who was employed by the Fijian Government as Mining Adviser, spent nearly a year in the colony, devoting most of his time to a study of the possible mineral resources of Vitilevu (14, 15).

Foye, who spent nearly eight months in Fiji in 1915-1916, was interested primarily in the structure of islands surrounded by coral reefs. The following quotations from his abstract (45, pp. 9-10) deal particularly with Vitilevu:

> The larger islands of Vitilevu and Vanualevu have central cores of deeply eroded plutonic rocks and are thought to be remnants of an older continental mass.
>
> There have been four periods of volcanism in Fiji. An early period of rhyolitic eruptivity was followed, without a perceptible erosion interval, by a first period of andesitic eruptivity. After erosion and subsidence, a succeeding uplift was accompanied by a second period of andesitic eruptivity. Erosion and renewed subsidence were followed by another period of uplift initiating a series of basaltic eruptions.
>
> There are two series of sedimentary rocks in Vitilevu. The folded series of the interior resemble the folded series of the New Hebrides, which Mawson believes to be Miocene. The coastal-plain series have low dips and, by fossil evidence, are apparently post-Tertiary in date.
>
> The folding of the rocks of the interior of Vitilevu corresponds to the trend lines discerned by Suess elsewhere in Oceania.
>
> Certain reefs near Suva are growing on the delta flat of the Rewa River, as did other, now uplifted, reefs in a previous epoch.

In 1923 Brock (11) spent a month on Vitilevu in a study of the district around Suva and made an east-west traverse from Suva to Lautoka. In 1926 Mansfield (77) described a number of fossils from Vitilevu in the U. S. National Museum and compiled an exceedingly valuable annotated bibliography. In a short but important contribution Matley and Davies (83) described the limestones of Walu Bay and Kalambu and included paleontological notes on these and other localities. The most recent paper dealing with the geology of Vitilevu is by Yabe, Aoki, and Hanzawa on the limestone at Suva (133).

PHYSIOGRAPHY

DRAINAGE

More than two thirds of the island of Vitilevu—96 miles in greatest length and 63 miles in greatest width—is drained by four large rivers. These, in order of size, are the Rewa, the Na Singatoka, the Navua, and the Mba. (See fig. 2.) The Tuva, the Nandi, and the Sambeto drain the western coast, and numerous small streams drain a narrower strip along the coast elsewhere.

The drainage pattern of Vitilevu is an unusual one. There is a marked tendency for the streams to arrange themselves in rectangular patterns, the consequence, it is believed, of block faulting. Because Vitilevu is a high land mass in the belt of the southeast trade winds the windward side receives a heavy rainfall, whereas the leeward side is comparatively dry. This relation helps to explain the fact that the Rewa system drains nearly one third of the entire island. In the past it may have drained nearly one half, because it is possible that its basin then included all the area now drained by the upper Navua. (See p. 64.)

PHYSIOGRAPHIC PROVINCES

The topography of Vitilevu is varied and the origin of some of its features obscure. Over large areas the contour of the surface is determined entirely by subaerial erosion on nearly horizontal rocks of uniform resistance, but elsewhere peculiar rock structures and faulting have interfered with normal physiographic development.

For purposes of description the island has been divided into a number of physiographic provinces—a series of plains, mountains, and plateaus (fig. 2). These are based primarily on topographic form, but many reflect fundamental differences in structure or in the lithology of the underlying rocks. In their origin and development the provinces present features of unusual interest. (See p. 58.)

PLAINS

The flat lands that border most of the coast of Vitilevu constitute three major physiographic provinces: Rewa Plain, Na Singatoka-Nandi Plain, and Mba Plain. (See fig. 2.)

1. Rewa Plain. The Rewa Plain province is a broad, rectangular area in the southeastern corner of the island that extends westward as a narrow strip along the south coast to Vatukarasa Bay. For the sake of convenience the narrow strip of rugged coastal topography between Tanavuso Point and Vitilevu Bay is also included.

2. Na Singatoka-Nandi Plain. The Na Singatoka-Nandi Plain is an irregularly shaped area in southwestern Vitilevu which includes the coastal districts from Vatukarasa Bay to Nandi Bay and extends inland to the mountains. Its length from north to south is approximately 35 miles and its width

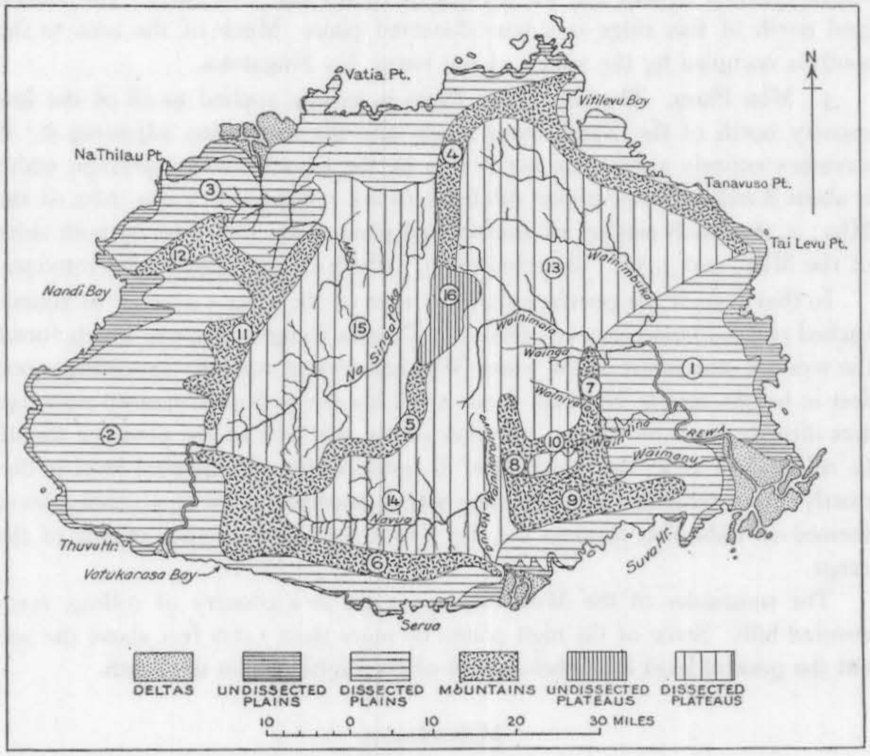

FIGURE 2.—Sketch map of Vitilevu, showing physiographic provinces.

1. Rewa Plain
2. Na Singatoka-Nandi Plain
3. Mba Plain
4. Nakauvandra Range
5. Tikituru Range
6. Lokalevu Range
7. Mendrausuthu Range
8. Nambui Range
9. Namosi—Rewa Range
10. Nakasavu Ridge
11. Naloto Range
12. Thonoa Range
13. Plateau of Tholo East
14. Navua Plateau
15. Plateau of Tholo West
16. Navosa Plateau

about half as much. Except for the portion east of the Na Singatoka River this province is fringed by a strip of undissected coastal plain lying close to sea level. In the vicinity of Nandi Bay this flat stretches inland for a distance of more than 5 miles along the Nandi and Sambeto rivers. North of the Sambeto the flat is abruptly constricted by the Thonoa Range, which trends southwestward from Koro Yanitu to the sea. The remainder of the province may be looked upon as an uplifted plain which has been considerably dissected by erosion. On the west the general level rises to meet the Naloto Range and several points are in excess of 1,000 feet. From Koromba (Pickering Peak) at the southwest tip of the Naloto Range a ridge that extends southwestward toward the sea divides the plain into two parts. The rolling land north of this ridge is a true dissected plain. Much of the area to the south is occupied by the valley of the lower Na Singatoka.

3. Mba Plain. The term Mba Plain is loosely applied to all of the low country north of the Nandarivatu scarp and the mountains adjoining it. It stretches entirely across the north side of the island, and its average width is about 8 miles. Three minor subdivisions are recognized: 1, the delta of the Mba; 2, the small patches of undissected plain along the coast on both sides of the Mba; and 3, the "dissected plain," which covers most of the province.

In that part of the province that lies west of the Mba a number of round-backed ridges extend seaward from the Thonoa Range. The one which forms the western watershed of the lower Mba has several summits exceeding 1,000 feet in height, and at Nathilau Point a hill known as Koroivunatoto rises 740 feet directly from the shore. Whether or not this part of the province should be referred to as a "dissected plain" is questionable. Its general level is distinctly lower than that of the range which borders it, but it probably never formed an unbroken plain as did the Nandi area on the opposite side of the range.

The remainder of the Mba Plain province is a country of rolling, reed-covered hills. Some of the high points lie more than 1,000 feet above the sea, but the general level is far below that of the highlands on the south.

Mountains

Imposing ranges and lines of volcanic peaks separate the plains of the coastal districts from the plateaus of the interior and in addition form a north-south backbone almost directly across the center of the island. All of the peaks have native names. These have been given preference in the present report even though some of them are unwieldy. This practice is in accordance with the ruling of the Permanent Committee on Geographical Names (first list of names in Fiji Royal Geog. Soc., 1925). Well-known European names are given in parentheses. To ranges that have no special names the name of the most prominent or the most centrally located peak has been applied. (See fig. 3.)

1. Nakauvandra Range. The Nakauvandra Range forms the northern portion of the island's backbone. From the northwest corner of the Navosa Plateau it extends northward through Tomanivi (Mount Victoria) to Ulunda, which lies only 5 miles from the north coast. At this point it turns eastward

and divides into two branches. The shorter of these ends in Supani on the coast north of Vitilevu Bay, but the other parallels the northeast coast for 30 miles to terminate near Tai Levu Point in the peak known as Vatukalikali. (The name Nakauvandra has usually been restricted to the mountains between Tomanivi and the head of Vitilevu Bay.) Tomanivi (altitude 4,341 feet), the highest point on the island, is not a prominent mountain because its sides are gently sloping and bush-covered and it lies in a region where

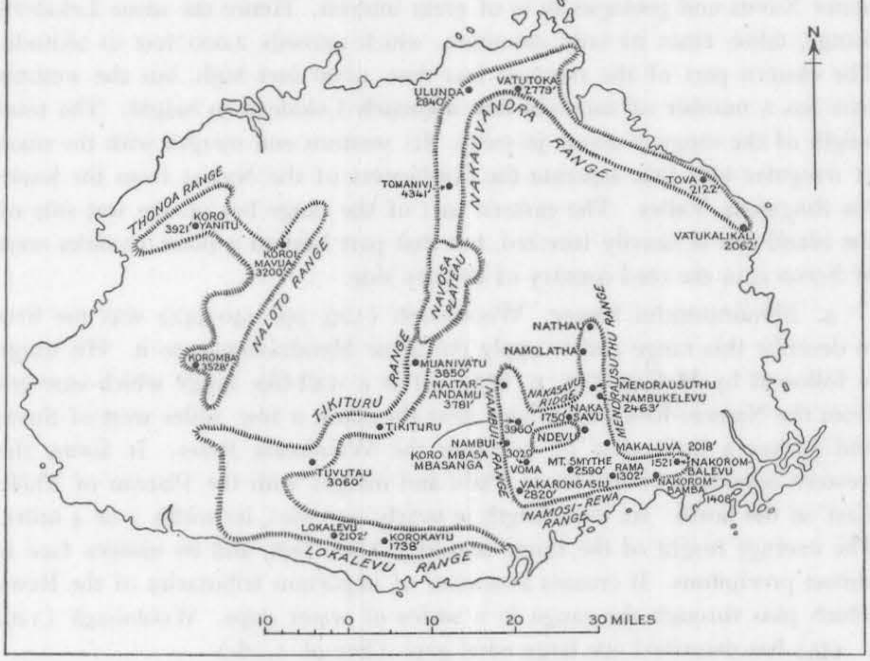

FIGURE 3.—Sketch map of Vitilevu, showing important peaks and ranges.

the general level is high. Beyond Tomanivi, according to McCaw (85, pp. 277, 280), the range is almost severed by a great rift at the source of the Wainimbuka River. Part of the range which trends southeastward from Vatutoka is a forest-covered ridge whose even-crested summit lies about 1,000 feet above sea level. The highest point is Tova, a double-crested mountain near Tanavuso Point.

2. Tikituru Range. The southern part of Vitilevu's backbone is formed by a series of ridges which begins at the southern tip of the Navoso Plateau in the peak known as Muanivatu and trends in a general southwest direction through Tikituru to Tuvutau (Mount Gordon). This range, which seems to have been given no special name, is here referred to as the Tikituru Range,

after its central high point. Its total length is about 20 miles. To the southwest it merges with the hills of the upper Navua basin. The high, sinuous ridges composing it are almost unbroken, there being only three passes through the range.

3. Lokalevu Range. The line of hills that parallels the south coast between the mouths of the Navua and the Na Singatoka possibly should not be dignified with a special name. Certainly it is much less imposing than the high Namosi-Rewa Range to the east, but it forms the south watershed of the upper Navua and geologically is of great interest. Hence the name Lokalevu Range, taken from its only mountain, which exceeds 2,000 feet in altitude. The eastern part of the range is less than 1,000 feet high, but the western part has a number of summits that approach Lokalevu in height. The total length of the range is about 30 miles. Its western end merges with the mass of irregular hills that separate the headwaters of the Navua from the lower Na Singatoka Valley. The eastern part of the range lies on the wet side of the island and is heavily forested, but that part beyond a point 12 miles west of Serua is in the reed country of the dry side.

4. Mendrausuthu Range. Woolnough (129, pp. 440-442) was the first to describe this range and to apply the name Mendrausuthu to it. His usage is followed by McCaw (85, p. 257). It is a wall-like range which emerges from the Namosi-Rewa mountains near the coast, a few miles west of Suva, and strikes a little west of north to the Wainimala River. It forms the western boundary of the Rewa Plain and merges with the Plateau of Tholo East on the north. Its total length is nearly 20 miles, its width 3 or 4 miles. The average height of the range is nearly 2,000 feet, and its eastern face is almost precipitous. It crosses a number of important tributaries of the Rewa which pass through the range in a series of water gaps. Woolnough (129, p. 443) has described one large wind gap. (See pl. 1, *A*.)

5. Nambui Range. The Nambui Range parallels the Mendrausuthu Range along a line lying 10 miles to the west. It is not so continuous or so wall-like as the Mendrausuthu, but it stands well above the Navua Plateau to the west. Its length is about 15 miles. Its name is taken from the high, west-facing cliff, Nambui, near the center of the range.

6. Namosi-Rewa Range. A belt of mountains 30 miles long and 3 to 5 miles wide parallels the south coast from Suva to the Navua Plateau. It is referred to as the Namosi-Rewa Coast Range by McCaw (85, p. 257). It is bordered on the south, east, and northeast by the lowlands of the Rewa Plain province. (See pls. 1, *B*; 2, *B*.)

7. Nakasavu Ridge. The comparatively low ridge which connects the Mendrausuthu and Nambui ranges north of the Waindina River is here referred to as the Nakasavu Ridge. The name is taken from the highest point.

This ridge, together with higher mountains on either side, forms the great north-facing "Soloira Amphitheater."

8. Naloto Range. The little-known Naloto Range, which bounds the Na Singatoka Valley on the west, has two peaks, Koroimavua and Koromba (Pickering Peak), that exceed 3,000 feet in height. The range is about 25 miles long. On the southwest it continues as a ridge on the plains, and on the northwest it merges with the high plateau country drained by the upper Mba. From a point near the center of the range several ridges strike northwestward and form the watershed between the Mba and Sambeto-Nandi rivers. These ridges culminate in Koro Yanitu (Mount Evans), the highest point in western Vitilevu.

9. Thonoa Range. The name Thonoa is used on the Admiralty charts for the short range that rises abruptly from the west coast of Vitilevu near the head of Nandi Bay and extends for a distance of nearly 15 miles to the northeast. The summits of the range do not form a jagged skyline as do those of the Naloto Range, but at least three of them exceed 2,000 feet. The range continues northeastward from Koro Yanitu for a distance of 5 miles to Koromomo, at which point it descends to the Mba Plain. (See pl. 2, *A*.)

Plateaus

1. Tholo East. The plateau of Tholo East covers nearly 700 square miles in the eastern half of Vitilevu and includes nearly all of the Rewa tributaries. It is almost completely surrounded by mountains but stands above the Rewa Plain on the southeast. The plateau is characterized by irregular hills and sharp, even-crested ridges. In the eastern part of the province many of the high hills exceed 1,000 feet. Near the western border Vatuvula rises to nearly 3,000 feet. Much of the country is in ideal maturity, and the province as a whole may be looked upon as a dissected plateau.

2. Navua Plateau. An irregular area of some 300 square miles in south-central Vitilevu is drained by the Navua River and its tributaries. This area, the Navua Plateau, is surrounded by mountains on three sides, merges with the Plateau of Tholo East on the northwest, but stands above the coastal plain on the southeast. It was probably a flat plateau originally but is now dissected into an area of considerable relief.

3. Tholo West. The plateau of Tholo West forms a large rectangular area in the western part of Vitilevu. Its average length from north to south is 32 miles, its width 16 miles, and its area about 550 square miles. It lies below the surrounding lands on three sides, but its northern edge, the Nandarivatu scarp, rises 2,000 feet above the coastal plain to form the most striking topographic feature of Vitilevu. The plateau is drained by the Na Singatoka and Mba rivers, which have carved it into a series of deep valleys and high,

sharp ridges. In the northeast corner there are several points which rise above 3,000 feet; elsewhere the surface is considerably lower, though the wooded point known as Malua on the Na Singatoka-Mba watershed reaches a height of 3,294 and a number of hills to the south of it exceed 1,000 feet. The entire province lies on the dry side of Vitilevu. The ridges are clad only in grass and reeds. Some of the steep gullies support a growth of trees, but there is little or no rain forest.

4. Navosa Plateau. The Navosa Plateau is a high, flat tableland about 50 square miles in area, almost in the center of Vitilevu. Its general shape is that of an isosceles triangle with the apex directed a little west of south and the basal portion extending to the north. Near the apex Muanivatu rises high above the general surface, and to the north the plateau merges into the high ridges that join it to Tomanivi. On the east and west its sides are precipitous. The remarkably flat surface of the plateau reaches an elevation of more than 3,000 feet. Rainfall is heavy, but drainage is poor. On the plateau rise some of the headwaters of the island's two most important rivers, the Rewa (Wainimala branch), which drains the northern and eastern parts, and the Na Singatoka, which drains a much smaller area to the south and west. Most of the streams are small and flow in broad, shallow depressions. Other depressions are occupied by small (temporary?) lakes (pl. 4, *A*). Navosa is the name applied by Woolnough (129, p. 466). McCaw (85, p. 261) uses the term Rairaimatuku. The Navosa Plateau is uninhabited and has never been thoroughly explored. Little-used native trails cross it, but the best of these is none too good. In wet weather they are well-nigh impassable. The western edge of the plateau, combined with the mountain ranges that extend north and south of it, makes a formidable barrier across the island. This barrier is the boundary between the wet and dry sides of the island.

Climate

Vitilevu is not in the belt of the perpetual southeast trade winds, but from April to November the winds are fairly constant between southeast and east-northeast. Because the island has mountain ranges sufficiently high to obtain moisture from these normally dry winds it has a wet windward side and a comparatively dry leeward side. From December to March the winds are uncertain. Although, strictly speaking, Fiji is not within the area of the northwest monsoon, northerly winds often replace the trades during the months from December to March. These winds bring heavy rains and the severe storms that characterize the "hurricane season." Periods of heavy rain are interrupted by a few days of fine weather when the trades prevail, but the season as a whole is humid and hot, especially on the lowlands near the coast. The contrast between the wet and dry seasons is more distinct on the leeward side than on the windward. The amount of rainfall varies with elevation, location, and season of the year. The higher portions of the windward side receive tremendous amounts during the months from December to March. (See pls 1, *C*; 3, *C*; 4, *C*.)

Near sea level the mean annual temperature averages 78 degrees. From December to March monthly means are about 80, and in the colder season, July and August, they are several degrees lower. At Suva temperatures above 90 degrees have been recorded in all months of the year. The maximum is 98 degrees. Minimum temperatures slightly below 60 degrees have been recorded from June to September.

STRATIGRAPHY

GENERAL FEATURES

Brock (11, p. 66) saw clearly that a satisfactory account of the geology of Vitilevu must await detailed mapping, but "for the sake of clearness" he attached formation names to what appeared to be the main groups of rocks, thus giving his descriptions "a definiteness that is, perhaps, not wholly warranted." Although this implied definiteness is not entirely warranted, the names applied by Brock are useful, and most of them, therefore, have been accepted. Certain of the "formations" are really series. Each probably comprises several distinguishable units. Future work will doubtless restrict the area covered by each "formation" and add new units. For this reason a certain outcrop section in each formation is designated the "type section."

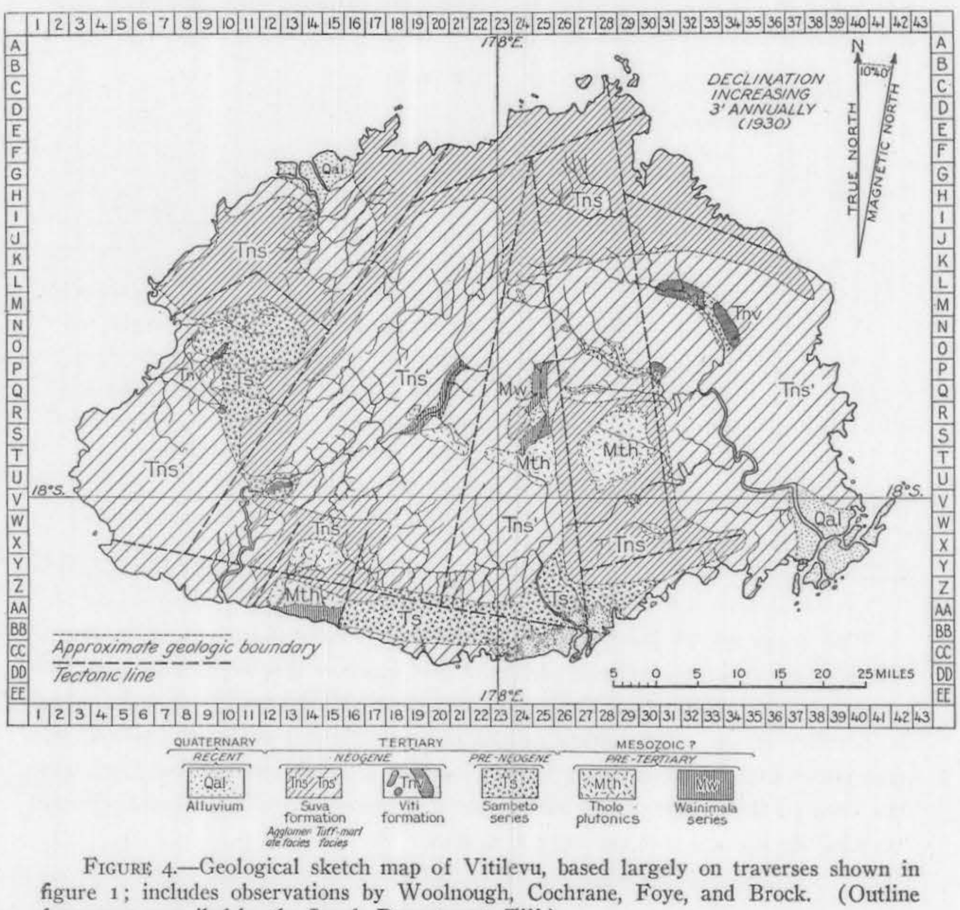

FIGURE 4.—Geological sketch map of Vitilevu, based largely on traverses shown in figure 1; includes observations by Woolnough, Cochrane, Foye, and Brock. (Outline from map compiled by the Lands Department, Fiji.)

The geological map (fig. 4) represents an attempt to show the general distribution of the recognized rock units. The published observations of earlier workers, particularly the maps of Woolnough and Foye, have been incorporated. The map shows the location of known exposures of the older rocks, but it is not accurate in detail. Future work will reduce the areas covered by the Suva formation and will certainly shift the tentative and highly generalized boundaries. All the important locality names are shown in figure 10. A few names that are used in the text are located with reference to points shown on the maps.

Table 1. Table of Formations.

Group	System	Series	Terms Used in This Report	Terms Used by Brock
Cenozoic	Quaternary	Recent	Alluvium, etc.	
		Pleistocene?	Reef Limestone, etc.	
	Tertiary	Neogene	Suva Formation	Recent Volcanics
				Suva Formation
				Ba Volcanics
			Viti Formation	Viti Formation
			Sambeto Series	Singatoka Volcanics
Mesozoic?	Cretaceous?		Tholo Plutonics	Tholo Plutonics
			Wainimala Series	Wainimala Formation

The rocks of Vitilevu may be grouped into two main series: 1, a pre-Tertiary series which includes plutonics and more or less metamorphosed volcanics and sediments; 2, a Younger series of relatively unaltered rocks which is Tertiary in age. The nature of the rocks of the Older series and the fact that they outcrop beneath the Younger series indicate clearly that they form the core of the entire island and make it extremely probable that they once formed the surface rock of the entire area.

OLDER SERIES

Following the terminology suggested by Brock (11, pp. 67-70), the Older series is divided into two formations or subseries—the Wainimala and the Tholo. The Wainamala consists largely of ancient volcanics but includes some sediments; the Tholo consists entirely of plutonics. It is believed that the Wainimala rocks are the older and that they were intruded by the Tholo plutonics, but the evidence on this point is not entirely conclusive. (See p. 19.)

WAINIMALA SERIES

The name "Wainimala formation" was applied by Brock to the metamorphic rocks of Vitilevu, particularly to those described by Woolnough. In the present report the Wainamala rocks are described as a series because they include a considerable variety of lithologic types.

Woolnough described two belts of metamorphosed rocks in the valley of the Wainimala, the two being separated by a belt of granite. The more southerly of these two belts, here considered the type section of the Wainimala series, outcrops along the trail which follows the Wainimala, from a point about a quarter of a mile north of the village of Nasavu (Nasava, Nazava, Nagara) to Narokorokoyawa, an airline distance of 4 miles. Woolnough originally described the rock as a fine, slaty, highly jointed quartzite of undoubted sedimentary origin (128, pp. 474-475) but later concluded that the rocks probably represent highly metamorphosed trachytic lavas and possibly tuffs and other sediments (129, pp. 455-456). Woolnough reported many good sections along the trail. Later writers on the geology of Vitilevu have not visited this locality.

In addition to the type section and the belt of outcrop lying north of it, the Wainimala series outcrops in the valley of the Na Singatoka from Sauvakarua to a point below Waimbasanga and along the south coast from Vatukarasa to Korolevu. Boulders of these rocks are found in Younger conglomerates elsewhere.

The series is composed mainly of altered volcanics and tuffs but includes true schists or gneisses were found. Field relations indicate that the Wainimala series was invaded by the Tholo plutonics.

THOLO PLUTONICS

DISTRIBUTION AND LITHOLOGY

Tholo was the name applied by Brock (11, pp. 67, 69, 70) to all the plutonics of Vitilevu. On the upper Wainimala Rvier in the district of Tholo East, these rocks are widely exposed in association with those of the

Wainimala series. The belt of granite crossing the Wainimala River north of the village of Narokorokoyawa, here designated the type locality of the Tholo plutonics, was mapped and described by Woolnough (128, pp. 475, 501-506; 129, p. 455).

The island's largest three rivers—the Rewa, the Na Singatoka, and the Navua—have uncovered the Tholo plutonics in parts of their basins, and a considerable area is exposed close to sea level along the south coast. No outcrops are known in the valley of the Mba, nor in the northern and eastern parts of the island. A single pebble of granite, collected from the Nandi River, suggests that outcrops may yet be found on the western side of the island.

True granites are found in the type locality and in several other places, but the series also includes a number of such related rocks as quartz monsonite, diorite, and gabbro. Most of the rocks are medium-grained and contain considerable biotite with some hornblende. Jointing is generally developed. Petrographic studies show evidence of crushing and hydrothermal alteration. (See p. 47.)

STRATIGRAPHIC RELATIONS

The relations of the Tholo plutonics to the rocks of the Wainimala series have not been clearly seen in the field, though in several places they outcrop in closely adjacent areas. In the type localities on the upper Wainimala, Woolnough was unable to find a contact between the two or to obtain any definite proof of their relative ages. Finding no granitic veins in the slaty Wainimala rocks, he suggested that the plutonic series might be the older (129, p. 457). In the area near Waimbasanga, on the Na Singatoka, dark inclusions were seen in an outcrop of quartz diorite (Station 30). In this area Foye (45, p. 12) observed a slatelike inclusion in a diorite boulder and inferred that the plutonics had intruded the slaty rocks. The numerous inclusions of diabase in granite outcrops (No. 108) and the basalt inclusions in the granite boulders (Nos. 93, 94, 95) on the south coast are sharply angular, and some of them resemble fragments of slate. The distribution of the basaltic masses indicates that they are inclusions rather than fractured or brecciated dike rock. Where the diorite appears in the form of narrow stringers between fairly large inclusions its texture is finer than elsewhere. As basalt is the most abundant volcanic of the Wainimala series, its appearance in the form of inclusions in the plutonics makes it extremely probable that the plutonics invaded the Wainimala rocks.

The Tholo plutonics are overlain unconformably by the younger Tertiary formations. (See pp. 20, 21, 33.)

YOUNGER SERIES

The sediments and flows of the Younger series overlie the plutonics and metamorphics of the Older series unconformably. Contacts have been observed in a few places and boulders of the older rocks are widely distributed in conglomerates of the Younger series, but the most convincing evidence of unconformity is the difference in degree of alteration. Over wide areas the rocks of the Younger series are poorly consolidated and the beds lie at low angles. The Younger series outcrops from sea level to elevations exceeding 4,000 feet and forms the surface rock over most of the island.

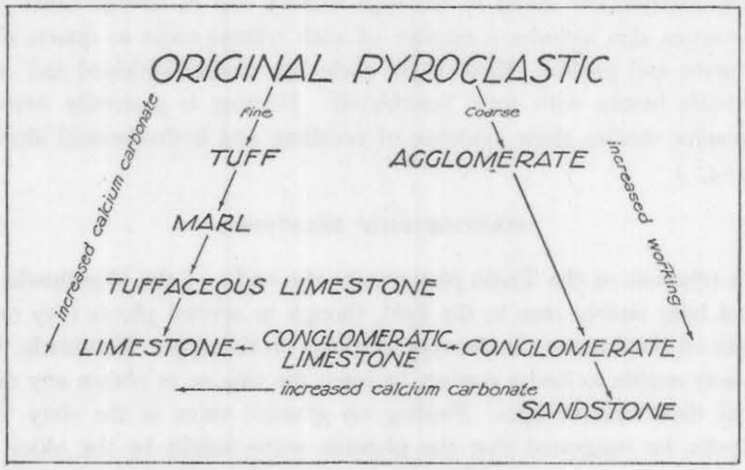

FIGURE 5.—Diagram showing relationship of pyroclastic rocks to other rocks of the Suva formation.

The Younger series is composed predominantly of pyroclastic material, much of which, however, appears to have been reworked before coming to final rest. It seems that during late Tertiary time pyroclastic action dominated all other forms of volcanic activity in Vitilevu. Enormous quantities of volcanic agglomerate were thrown out of linear volcanic vents or lines of individual vents. The eruptions resulted in high mountain ranges composed almost exclusively of agglomerates that form the parent rock of most of the sediments of the Younger series. Genetically associated with the agglomerates are great thicknesses of tuffs. Over large areas the agglomerates and tuffs were reworked by streams or waves before coming to final rest. During this process much clay from weathered volcanic rock and much calcareous shelly material was added, so that many of the rocks may now be classed as marls. In a few places thin limestones are interbedded with the tuffaceous rocks (fig. 5).

Sambeto Series

Distribution and Lithology

Brock (11, pp. 67, 70, 71) placed the rocks of the Sambeto Valley in his "Singatoka volcanics," a unit containing andesites, rhyolites, and agglomerates. His type locality is presumably in the Na Singatoka Valley, but no specific section was designated. The volcanics seen by Brock near Nakuilau and Korolevu on the Na Singatoka are here placed in the older Wainimala series. The andesite flows noted by Foye (45, p. 12) near Waimbasanga on the Na Singatoka were not seen during the present survey, and Foye's description of the locality is too indefinite to be shown satisfactorily on the areal map. Because of these difficulties the suggested name, Singatoka, has been abandoned and the name Sambeto substituted. (See Table 1.)

The valley of the Sambeto River from a point about 2½ miles above its mouth to the village of Navilawa, near its head, is designated the type locality of the Sambeto series. The series is designed to include all the volcanics and associated sediments which lie above the plutonics and below the massive limestone of the Viti formation.

In addition to the exposure in the type locality and the area adjoining it on the south, the Sambeto series is exposed in the Lokalevu Range along the south coast. Smaller areas appear in several of the tributaries of the Rewa in the east-central part of the island. More detailed mapping will doubtless reveal other outcrops.

The Sambeto series is made up chiefly of volcanics, andesite being the type most commonly encountered. The andesites of the Sambeto Valley are grayish green and have a typical "salt-and-pepper" appearance. Outcrops are highly jointed and many show evidences of faulting. Fissures are filled with secondary minerals, usually of hydrothermal origin. Other volcanics placed in the series include rhyolites, dacites, and altered basaltic glass. Associated with the volcanics and showing a similar degree of alteration are agglomerates, tuffs, and small amounts of marl. These sediments are more compact and more altered than similar types in the Suva formation.

No identifiable fossils have been found in the Sambeto series, but the tuffs at Station 67 (24-M)* contain poorly preserved stems and leaves. The tuffs at Station 353 (10-N) show fragmentary plant impressions, small pieces of carbonaceous material, and very questionable foraminifera.

Stratigraphic Relations

The Sambeto series apparently overlies the plutonics with distinct unconformity, but no good exposures of the contact were seen in the field. At Sta-

* Figures given in parentheses after a station indicate the location of the station in figure 10.

tion 290 (33-M) an agglomerate belonging to the Sambeto series contains fragments of diorite from the Tholo series. The Sambeto and the Tholo were found in contact near the village of Rewasau, but apparently the contact is due to faulting. The plutonic at Station 14 (24-M) is a gabbro (essexite). It outcrops in the stream bed below the village as a vertical face 35 feet high. The stream falls over this face into a deep pool. Volcanic tuffs (Station 67) overlain by vesicular andesite (Station 44) outcrop on both sides of the pool and abut against the vertical face of gabbro. The beds of tuff are contorted near the contact and the lower surface of the andesite dips downward as the contact is approached. In places the Sambeto series conformably underlies the Viti formation.

Viti Formation

distribution

The Viti formation as defined by Brock (11, pp. 67, 71-73), includes the massive limestones of the interior together with other sediments and "probably some volcanic material." No type locality was designated. In the present report the name Viti is applied only to the massive limestones. The type section is that exposed at the entrance of Wailotua cave (Station 74) about 1½ miles northeast of the village of Wailotua in the valley of the Wainimbuka. At this place an exposure of 45 feet of limestone in a vertical face has yielded diagnostic fossils. If the type section is combined with additional outcrops which appear on the hill above the main cliff and with other outcrops which appear in the left bank of the Wailotua River one fourth mile to the southwest (Station 292), the formation is seen to have a thickness of at least 100 feet in the type locality. The base of this 100-foot section lies 120 feet above sea level, and the fact that springs issue from the limestone at this horizon suggests that the contact with the impervious volcanic rocks is located just below the river level.

Limestones of the Viti formation are known to outcrop in four widely separated localities, as follows:

1. Wainimbuka Valley. In addition to the exposures in the vicinity of Wailotua Cave limestone appears several miles farther upstream near the mouth of a left tributary to the Wainimbuka called the Waisomo. On the left bank of the stream above the point where the Naloto-Nayavu trail crosses (Station 78), a series of disconnected outcrops extends for a distance of 60 feet. The total thickness exposed is only about 10 feet, the base of the outcrop lying about 210 feet above sea level.

A thickness of 100 feet of limestone is exposed in a hill near the northwest edge of the village of Nayavu at the junction of the Waisomo and Wainimbuka Rivers. The base of this section (Station 80) lies 170 feet above sea level. Outcrops are said to continue in the valley of the Wainimbuka to a point about a mile above the village of Namoulini, which lies more than 10 miles northwest of the type section, near Wailotua. This gives a considerable area of outcrop in the valley of the Wainimbuka, to the east of the line of the Mendrausuthu Range.

2. Wainimala Valley. In ascending the Wainimala, outcrops are first encountered at a point about a quarter of a mile above the village of Nairukuruku. At this place an irregular outcrop rises 20 feet above the stream, in the left bank (Station 12). The base of the exposure lies 205 feet above sea level. The rock is overlain by a breccia (Station 126) containing numerous fragments of the limestone. A thick section of the limestone is exposed in a hill near the village of Korosuli (Stations 52, 302), about 2 miles northwest of Nairukuruku. These are the only places where the limestone was seen in the Wainimala Valley, but it is probable that detailed mapping would show much of the rock between Korosuli and Wailotua.

3. Na Singatoka Valley. In the lower Na Singatoka Valley the Viti limestone appears just north of the village of Tumbairata, where it caps an imposing river bluff that extends upstream almost continuously for nearly 5 miles to a point north of Koronisangana. At Koronisangana the bluff rises 760 feet above the river; the limestone cap is at least 200 feet thick (Stations 287 and 309). The right bank of the river, in this area, was not visited, but from a distance no limestone outcrops could be seen on its reed-covered hills.

4. Western Vitilevu. Small patches of Viti limestone (Stations 130, 280) and of brecciated Viti limestone (Station 129) were found in the faulted area between the Nandi and Sambeto Rivers. Other outcrops lie nearly 10 miles to the south in the valley of Nawaka Creek (Stations 155, 156), a total thickness of nearly 200 feet being present in this area.

LITHOLOGY

At its type locality the Viti formation is a massive, dense, gray, mottled limestone. At Station 78 it is somewhat lighter in color and is much fractured, some of the cracks being filled with calcite, others with chalcedonic quartz; small vugs are lined with minute quartz crystals. The limestone in the section at Nayavu (Stations 79, 80) shows variation in color from pure white through shades of yellow and pink to dark brown and gray. Some parts of the outcrop are finely granular, resembling Italian marble.

In the Wainimala Valley near Nairukuruku (Station 12) the rock shows traces of alteration, particularly along a series of well-developed joints. It is greenish gray, slightly schistose, and breaks into thin slabs. In thin section, alteration is seen in a parallelism of the minerals and in a slight recrystallization of the calcite. Fragments of this rock from the overlying breccia show thin bands of pinkish-gray limestone alternating with bands of light green. Though much of the Viti limestone is well jointed, none of it shows well-developed bedding. The surfaces of many outcrops are pitted and carved into sharp-edged pinnacles, and extensive caves are present in all important areas.

Most of the western outcrops are similar to those in other parts of the island, but near the upper part of the 70-foot section (Station 280) the limestone becomes tuffaceous. At Station 130 the rock is much fractured and slickensided; a mineral resembling epidote is abundantly developed along the fracture planes. The limestone at Station 156 is also somewhat brecciated.

STRATIGRAPHY

The total thickness of the Viti formation is not known. In the type locality it is at least 100 feet thick, and natives claim that the hills bordering the Wailotua, near by, are capped by the same rock. This would give it a thickness of about 300 feet. The maximum measured thickness was at Korosuli on the Wainimala, where 230 feet of the formation is present.

The formation is primarily a foraminiferal limestone, though most of its outcrops exhibit banded structure, due to *Lithothamnion*. As corals are almost entirely wanting, the formation can not possibly be looked upon as an uplifted coral reef rock. No identifiable corals were found in any of the eastern outcrops, though two specimens that seemed to show coral structure were collected at Station 78. The western outcrops contain a few corals (*Porites* and *Acropora* at Station 280) together with equally rare mollusks and echinoids. In the type locality and at Koronisangana (Stations 287, 309) the limestone contains *Lepidocyclina, Myogypsina,* and other foraminifera which, according to Whipple, clearly indicate a lower Miocene age. (See p. 142.) At Korosuli (Station 302) and in the western part of the island (Station 130) the assemblage of foraminifera is somewhat different but still indicates a lower Miocene age, according to Whipple.

In the valley of the Na Singatoka south of the village of Koronisangana the massive Viti limestones overlie tuffs of the Sambeto series with apparent conformity. The exposed base of the limestone maintains the same level in the high cliffs of the left wall of the valley for a distance of several miles. Level-bedded tuffs are exposed beneath the limestone at several points, but at others the tuffs are inclined. The dip, however, is invariably into the hill, which suggests that it is a local effect caused by the inability of the weaker tuffs to support the great thicknesses of massive limestone that overlie it. At the village of Nayavu, on the Wainimbuka, the Viti limestone is associated with a badly weathered purplish-red agglomerate. The agglomerate is believed to underlie the limestone. If it does, the contact between the two is irregular, because at several points the elevation of the agglomerate exceeds that of the nearby limestone. An actual contact was not found.

The Viti limestones contain very little volcanic material, which suggests that they were deposited after the volcanism of Sambeto times had entirely ceased. At Stations 79 (33-M) and 280 (9-O) the limestones contain small amounts of tuffaceous material, but the only outcrop of igneous rock interbedded with the Viti limestones was found in the section at Korosuli (Station 60). In this section a small mass of porphyritic rhyolite outcrops at an elevation of about 350 feet. It is underlain and overlain by limestone, but the rhyolite itself may not be in place. It is probable that the Viti and Sambeto formations are unconformable.

Suva Formation

General Features

The name "Suva formation" was applied by Brock (11, pp. 67, 73-74) to the coastal sediments of southeastern Vitilevu and equivalent beds elsewhere, the type locality being the town of Suva. Brock also recognized a formation called the "Ba volcanics," which he placed between the Viti formation and the Suva formation. He stated that it included the basic andesites, olivine basalts, agglomerates, and tuffs which form the summits of many of the higher mountains as well as much of the coast and inner margin of the coastal plain. He noted that boulders of these rocks appeared in the "basal" conglomerates near Suva and elsewhere and concluded that the rocks were therefore older than the Suva formation.

There seems to be no reason for looking upon the conglomerates of the Suva area as basal conglomerates. Hence the occurrence of pebbles of volcanic rock has no great significance. Probably many of the gently dipping bedded marine rocks of the coastal district are the equivalents of terrestrial agglomerates, tuffs, and flows in the mountains and in other parts of the interior. The reworked tuffs and marls are not appreciably older than the volcanics nearer the vents. As volcanism and sedimentation went hand in hand during Suva time, in the present report the "Ba volcanics" are included in the Suva formation. In fact, all the rocks formed after the massive Viti limestone are here mapped as Suva formation. (See Table 1, p. 17.) Small dikes, sills, and flows which were formed after the Suva rocks were laid down can not be mapped. Some of the post-Suva volcanics ("Recent volcanics" of Brock) may be Pleistocene or even Pliocene.

The highly fossiliferous section on the south side of Walu Bay, an arm of Suva Harbor, is here designated the type section of the Suva formation. (See pl. 6, *C*.) Near the entrance of the bay an old quarry face, trending roughly east-west, exposes a thickness of about 85 feet. Though this exposure is cut by a series of small block faults, the sequence of beds has not been obscured at any point. Most of the Suva area is underlain by tuffs and marls ("soapstones") which have rarely yielded fossils other than smaller foraminifera. The Walu Bay section, however, shows conglomerate and limestone in addition to the marly "soapstones," and these rocks have yielded mollusks and many other fossils in addition to the foraminifera. The lithology of the section varies laterally as well as vertically, as shown in the following two detailed sections, one measured at the western end of the outcrop, and the other at the eastern end.

As shown on the map (fig. 4), the Suva formation covers most of Viti-levu. Its foraminiferal marls ("soapstones") are best developed in the valleys of the Rewa and the Mba and along the west coast. Tuffs are interbedded with these marls and are widespread in the interior, being replaced by agglomerates as the mountains are approached. Conglomerates and limestones are best developed along the south coast.

1. Section at eastern end of quarry face on south side of Walu Bay.

Station		Thickness (Feet)
298.	Marl. Soft, porous gray "soapstone" with considerable calcareous material; bivalves and other fossils, most of them preserved as molds, abundant near base	30
297.	Coralliferous limestone. Soft, porous yellow limestone composed mainly of the molds of reef corals; contains near the top, where it grades into the overlying marl, a few pebbles and a large number of mollusks	18½
297.	Foraminiferal limestone. Soft gray rock made up almost exclusively of foraminifera; cidarid spines not uncommon; grades into coralliferous limestone above and below	11
297.	Coralliferous limestone. Gray limestone with large heads of coral seemingly in place; practically free of pebbles	1½
160.	Conglomeratic limestone. Large heads of coral, which appear in positions of growth, surrounded by marl containing a few small pebbles and worn coral fragments	2¼
160.	Conglomerate. Well-rounded pebbles and boulders of volcanic, plutonic, and sedimentary rocks together with waterworn coral heads and mollusk shells in a matrix of tuffaceous shell rubble; some boulders reach a diameter of 6 inches; rock soft at surface but exceedingly resistant where unweathered; in most places only a few inches thick, but locally in excess of 10 feet	¼
296.	Marl. A fine greenish-gray "soapstone" carrying a few mollusks	6
	Total	69½

2. Generalized section at western end of quarry face on south side of Walu Bay.

	Marl. Typically bedded gray "soapstone"	45
329, 328, 327.	Foraminiferal limestone. Soft, yellowish-white limestone composed largely of foraminifera; some tuffaceous material; mollusks abundant near the top where the limestone grades into marl	16

Station	Thickness (Feet)
Coralliferous limestone. Massive reef corals as much as 2 feet in diameter; a few mollusks and echinoid spines; corals appear to be in positions of growth	13
Conglomerate. Igneous and sedimentary boulders and worn fossils in a matrix of tuffaceous shell rubble	½
Marl. Greenish-gray well-bedded "soapstone" with limonitic concretions up to 4 inches in diameter; a few mollusk shells present	11
Total	85½

LITHOLOGY

Agglomerates. The typical agglomerates of the Suva formation are made up of sharply angular blocks of glassy basalt or porphyritic basalt embedded in a tuffaceous matrix which is either coarse or fine. In many places the angular blocks measure 2 or 3 feet in diameter; elsewhere they are smaller, and as they decrease in size the rock grades into coarse tuff. Many of the agglomerates appear to have been deposited close to the center of eruption and show no indications of sorting. In many exposures the angular blocks are concentrated at certain levels, forming a rude bedding. Other outcrops show fairly well developed stratification, and in a few places marine fossils are present. At Station 304 (16-J) a coarse agglomerate contains numerous well-preserved mollusks. As the angularity of the blocks in the agglomerate decreases they pass into conglomerates.

The agglomerates exhibit a wide range of color, depending in large part upon the amount of weathering which they have suffered. Fresh exposures are dark gray, brown, or even black, but where decomposition is well advanced brilliant reds, purples, and yellows appear. In general, the fresh agglomerates are to be found on the wet windward side of the island and the deeply weathered agglomerates on the leeward side where it is comparatively dry. Many outcrops show spheroidal weathering beautifully developed.

Many exposures are friable or but poorly cemented with calcite, but in others the fragments are firmly bound together. Regardless of the degree of cementation, however, the rock is a most remarkable cliff maker. Cliffs on Vitilevu are of two general types, those forming the immediate banks of streams and those found a short distance below the summits of the higher mountains. Nearly all the cliffs are composed of agglomerate. Many of the streams whose valleys exhibit such cliffs are very small.

In most outcrops of agglomerate all the angular blocks are composed of the same kind of volcanic rock, but in a few places fragments of older rocks are included. In the vicinity of Vunayava (14-Y) the agglomerates contain numerous angular fragments of granite. Most of these were probably torn from the vents in the granite through which the volcanic material was ejected, but some of them may have been carried in by outside agencies as the agglomerate was accumulating. At Station 126 (31-Q) on the Wainimala fragments of Viti limestone are present in an agglomerate or breccia. Some of the fragments are rounded.

Tuffs. The tuffs of the Suva formation are gray, drab, green, or chocolate brown and of variable texture. The fragments composing the more typical examples range up to 2 mm. in diameter. These fragments commonly include broken feldspars, volcanic glass (some of it palagonitized), and crystals of augite. Many are stained with limonite. Most of them are loosely consolidated, the commonest cementing substance being calcite. Gentle dips and uniform bedding, together with the widespread appearance of foraminifera and other shells, indicate that most of the tuffs are marine. Over large areas the tuffs were reworked by streams and waves before coming to final rest. During this process much clay from the weathered volcanics and much calcareous shelly material was added, so that all gradations between tuffs and marls may be found.

Marls. The marls of the Suva formation are soft buff to gray well-bedded sediments. They are locally known as "soapstones" because they become very soft and slippery when wet. They are made up chiefly of clay from weathered volcanic rocks mixed with considerable calcium carbonate in the form of foraminifera tests.

At many places in the Suva district the marls contain great numbers of foraminifera. Those from Stations 371 and 380 are described by Cushman (p. 102). In a few places other fossils are found with the foraminifera.

Station 305 (35-Z). In the left bank of Leveti Creek, near its mouth, marls are well exposed in an old quarry face. The maximum height of the exposure is only 12 feet, but the beds, dipping 13 degrees to the west, are exposed for a distance of nearly 1,000 feet. The base of the exposure lies only 3 feet above high tide. The rock is a soft-bedded gray marl containing numerous minute augite crystals. The beds are irregularly fractured, and many of the joint faces are stained. Fossils are not abundant, but this is the locality which yielded the species described from Mr. J. B. Turner's collection—large echinoids, a few mollusks, plant remains, and a bird's egg. Foraminifera are present, but are less abundant than at Station 371, near by.

Station 374 (35-Z). Some years ago considerable excavating was done at the site now occupied by Waimanu Mansion at Mark Street and Waimanu Road in the town of Suva. At a level of 40 feet below the surface and about 30 feet above sea level a number of fossils were obtained from marl similar to that at Station 305. These included echinoids, identical with those obtained at Station 305, abundant siphonal tubes of *Kuphus*, and the impressions of a tree fern scar. The collection was deposited in the Suva Museum by the Hon. H. Marks. Mr. Marks states that the tooth of a large shark was obtained from the marl at about the same level immediately across Waimanu Road.

Corals (*Porites* species) and mollusk shells were collected from the marls at Station 245 (20-Y) on the upper Navua River. Bits of shell and fragments of coral were also obtained from the marls at Station 378 (21-N) on the upper Na Singatoka, but the material was too poorly preserved for identification.

At Station 193 on the south side of Vitilevu Bay (30-F) the waves have cut two nips or gouges in the agglomerate. One of the nips lies at present high tide level and is still being deepened; the center of the other lies 5 feet higher. On the west coast the tip of the Thonoa Range shows a wave-cut bench above present high tide. The bench is 25 feet wide, is cut in agglomerate, and the center of the nip at its landward edge lies 4 feet above high tide. In other parts of Vitilevu, due probably to the presence of the barrier reef or to the nonresistancy of the shore rocks, no "elevated" strand-line features have been found.

Stream and wind deposits. Stream terraces are well developed along tributaries to the Rewa and in the lower Navua valleys and deltas at the mouths of many streams. Sand dunes lie along the southwest coast.

PETROGRAPHIC STUDY OF THE ROCKS OF VITILEVU, FIJI

By Arthur A. Pegau

INTRODUCTION

This petrographic report is based on the laboratory study of a suite of specimens collected by Dr. H. S. Ladd from the island of Vitilevu, Fiji. Of approximately 300 specimens in this suite, 132 were sectioned. In preparation of the report, the field descriptions, the base map upon which the specimen numbers were plotted, and a number of reprints loaned by Dr. Ladd have been an invaluable aid.

In the text, the rock types found in the various series and formations are described in chronological order beginning with the oldest rocks, those of the Wainimala series. The specimens are referred to by numbers which correspond with those on the map (fig. 10) and are located by coördinates placed in parentheses after each specimen number.

WAINIMALA SERIES

Rock types found in the Wainimala series include quartzites, compact sandstones, altered tuffs, and altered volcanics. Many of them show such evidences of dynamic pressure as compact structure and welding. Some of the specimens exhibit a slaty structure, but schists and gneisses are absent. Hydrothermal alteration is also common.

Quartzite and Compact Sandstone

The quartzites and compact sandstones in the collection are fine-grained, massive, and hard, ranging in color from greenish gray to buff. Some appear to be made of acid material (arkose), and others are formed from basic rocks (graywackes). Under the microscope they are seen to have a very fine-grained texture and to be made up of small grains of quartz, feldspar, epidote, kaolinite, and chlorite. They appear to be compact pyroclastics rather than compact cataclastics; that is, the quartzites seem to be compact tuffs and agglomerates rather than metasediments.

Specimen no. 107 (12-AA) appears from a megascopic and microscopic examination to be a quartzite, but whether it is of cataclastic or pyroclastic origin could not be determined. (See pl. 8, *H*.) This rock is fine grained, dense, even grained, chocolate colored. The microscope shows a slightly schistose texture with a tendency toward maculose, and a fine-grained matrix made up of feldspar, quartz, and secondary minerals stained with limonite. Included in the matrix are angular fragments of quartz, feldspar, and magnetite.

Specimen no. 109 (13-Z) is a compact sandstone or quartzite. (See pl. 9, *A*.) It is a fine-grained, greenish-gray rock with distinct slaty cleavage. The cleavage planes are spaced about 1 cm. apart. The microscope shows that it has allotriomorphic texture in which the individual grains show definite parallel orientation. The chief mineral is quartz, but minor amounts of feldspar, hornblende, and magnetite also appear.

Specimens nos. 110 and 115 (13-Z) are banded compact sandstones or quartzites. Other quartzites include nos. 91, 201, 203, 204, and 205 (21-CC).

Altered Tuffs

Metamorphosed tuffs are represented by specimen no. 33 (18-S), a light-gray, fine-grained, earthy rock with black, cherty inclusions that effervesce slightly. The individual minerals which under the microscope, even with high power, are scarcely distinguishable appear to be feldspar, quartz, and a green isotropic substance that is probably an altered glass. Specimens nos. 212, 213, and 214 (12-AA) are also tuffs. Unfortunately these three rocks were not sectioned, but the megascopic characters suggest a compact, metamorphosed tuff. They are hard, dense, fine-grained rocks, gray, greenish gray to brownish gray in color, and laminated in structure.

Altered Volcanics

The altered volcanics include rocks that vary in composition from rhyolites to basalts. They show a large development of secondary minerals, so much so that many of the hand specimens have a slaty appearance. The basalts are the more common type. Some of them are amygdaloidal, the amygdules being filled with incipient crystallizations of feldspar.

Rhyolite. Specimen no. 27 (21-P) is a light greenish-gray, dense, mottled rock. The mottling results from the presence of weathered feldspar phenocrysts in a greenish-gray matrix. The texture as revealed by the microscope is rhyolitic, made up of a mosaic of small grains of feldspar and quartz. Biotite, partially altered to chlorite, appears as lath-shaped grains with a fluxion arrangement. Calcite is rather abundantly present as fine-grained bodies up to 0.5 mm. in diameter.

Dacite. Specimen no. 9 (21-P) in the field outcrops near no. 27 and is like the rhyolite in megascopic appearance. The microscope reveals a rhyolitic matrix similar in composition to no. 27, in which appear phenocrysts of andesine, calcite as fine-grained patches up to 2 millimeters in diameter, and chlorite as round bodies that exhibit a radiate spherulitic texture. Specimen no. 211 (15-BB) is an altered rhyolite or trachyte. Specimen no. 103 (15-BB) is an altered dacite.

Porphyritic andesite glass. Specimen no. 102 (15-BB) is a fine-grained, dark-brown, earthy rock which under the microscope is seen to be made up chiefly of a slightly polarizing palagonite with phenocrysts of andesite and magnetite. It is cut by veinlets of quartz and calcite. Field observations show that it is a sill, 5 feet thick and showing poorly developed hexagonal jointing. It may have been intruded during Sambeto time.

Altered basalt and diabase. Five specimens of altered basalt and diabase were collected from the Na Singatoka Valley, nos. 10 (21-P), 28 (21-P), 29 (21-P), 32 (19-S), and 150 (19-P). Megascopically the rocks are hard, dense, fine-grained, and porphyritic, with visible phenocrysts of feldspar, augite, epidote, and pyrite. (See pl. 7, *D*.) The microscope shows a matrix made up of interlacing laths of feldspar, the interstices of which are in places filled with augite and in other places with chlorite. Some whole slides are covered by a mesh of the secondary minerals chlorite, calcite, and epidote. The phenocrysts are chiefly feldspar (labradorite), usually partially altered to epidote, augite partially or wholly changed to chlorite, calcite, and pyrite. The rocks are cut by many veinlets of epidote and of calcite. The outcrop at Station 29 (21-P) showed well-developed color bands.

Specimen no. 111 (13-Z) is a metamorphosed diabase. It is a banded rock in which dark greenish-gray bands alternate with light greenish-yellow ones. The microscope shows that the darker bands are an altered diabase in which the secondary minerals epidote, chlorite, and hornblende have been developed. The lighter bands are a less altered diabase. These bands are separated by a layer of epidote 0.5 millimeter wide.

Other altered volcanic rocks of basaltic composition include nos. 89, 98, 99 (21-DD); 92, 200 (21-CC), 100 (16-BB), 114 (13-Z). Specimen no. 217 (13-Z) is a dense, fractured epidotized rock.

Tholo Plutonics

CHARACTERISTIC FEATURES

The Tholo plutonics include granite, quartz monzonite, quartz diorite, diorite, and gabbro (essexite). These rock types are much more closely related petrographically than their names indicate. The most common type is a calcic granite containing biotite and some hornblende. It resembles very closely a quartz monzonite, a rock often found in large bodies formed in connection with mountain building.

The plutonics are generally massive and even-grained, though some specimens are porphyritic. Most of them are fine-medium to medium-grained; a few are coarse-grained. Some of the specimens, especially those from the southern outcrops, show considerable crushing. In a few mortar structure has been developed. Hydrothermal alteration is very common. Some of the specimens have angular inclusions of basalt. (See pl. 8, *E*.)

As seen in the hand specimens, the Tholo plutonics are generally light-gray to gray rocks with rare phenocrysts of feldspar. The minerals visible to the unaided eye are gray to pink feldspar, greasy gray quartz, black biotite, greenish-black hornblende, and yellowish-green epidote.

Under the microscope the rocks are seen to be composed predominantly of feldspar and quartz.

The grains average 1 to 2 mm. in diameter. Feldspar, the chief constituent, is usually of the calci-alkalic variety (oligoclase to andesine) and the potash varieties (orthoclase and microcline). In most of the diorites the feldspar (andesine) is zoned, and in all rock types it is altered along cleavage cracks to sericite, epidote, and other secondary minerals. Quartz forms about one third of the slides and appears as anhedral grains or rarely as graphic intergrowths with feldspar. Biotite and hornblende are the chief femic minerals; biotite is more abundant in the granite varieties, and hornblende in the diorite varieties. A few hypersthene and augite crystals were observed. Accessory minerals include apatite, magnetite, ilmenite, and zircon. The secondary minerals are titanite, sericite, chlorite, epidote, and limonite.

ROCK TYPES

1. Granite. A calcic granite that is near a quartz monzonite in composition is exposed at a number of points near the Mbusa River.

The following specimens were collected from this area: nos. 104, 105 (14-AA) (pl. 8, *G*), 106 (14-Z), 108, 215 (13-Z), 210 (15-BB). The structure of these rocks varies from granulose to mylonose, and the texture may best be described as mortar in which fragments of quartz and feldspar 1 to 2 mm. in diameter occur in a finely granulated mixture of quartz and feldspar. At Station 108 the granite contains numerous large angular inclusions of hornblende diabase. Granites were also collected in other areas: nos. 93, 94, 95 (21-CC); 1, 15, 43 (25-V); 112, 113 (13-Z); 243 (20-Z).

2. Quartz monzonite. Quartz monzonites are represented by specimens also collected at several places: nos. 5 (25-V); 31 (19-S); 88 (21-DD); 132 (9-P).

Specimen no. 132 (9-P) is a medium-grained, porphyritic, light-gray rock made up of gray feldspar, greasy-gray quartz, and dark-green hornblende. The texture, as seen under the microscope, is what may be termed mortar. Grains of oligoclase 1 to 3 mm. in diameter occur in a matrix of granulated material made up of quartz and feldspar in nearly equal amounts with minor amounts of magnetite and the secondary minerals epidote and chlorite.

3. Quartz diorite. The quartz diorites collected in other places are: nos. 90, 236 (21-DD); 4 (19-S).

Specimen no. 4 (19-S) is a medium to coarse-grained, light-gray, even-granular rock made up of light-gray feldspar, gray quartz, and greenish-black hornblende and biotite. When examined under the microscope, the chief mineral is seen to be andesine (extinction 15 degrees), which occurs as tabular equidimensional grains that measure 1 to 3 mm. in diameter and exhibit zonal structure. Quartz, the next most abundant mineral, is present as anhedral grains up to 3 mm. in diameter. Some of the crystals show fracturing. Hornblende and biotite occur sparingly. Magnetite is the chief accessory mineral.

4. Diorite. Diorite is represented by nos. 30 (19-S) and 2 (25-V).

Specimen no. 30 (19-S) has megascopic characters similar to no. 4 (quartz diorite). The microscope shows the chief minerals to be andesine and hornblende with quartz and magnetite as the chief accessory minerals. A small amount of apatite and titanite occurs. Much of the feldspar shows fracturing and zonal growth. Dark inclusions were noted in this rock in the field.

5. Gabbro (essexite).

Megascopically the gabbro is a greenish-gray, medium-grained rock made up of gray feldspar, yellowish-green augite, and minor amounts of biotite and magnetite. The microscope reveals a rather interesting assemblage of feldspar (orthoclase and andesine-labradorite), augite, olivine, biotite, and magnetite, together with the secondary minerals iddingsite, sericite, calcite, serpentine, and chlorite.

SAMBETO SERIES

General Features

The rock types included in the Sambeto series are agglomerate, tuff, marl, arkosic sandstone, and volcanics. Of these types the volcanics are the most abundant, and of the volcanics, the andesites. The rocks, generally massive, jointed, and faulted, are in many places cut by fissures which are filled with secondary minerals—hydrothermal minerals, as a rule. Some of the rocks are brecciated.

Agglomerate

The agglomerates in the Sambeto series are more compact and altered than are those found in the younger Suva formation. They are apparently widespread, generally much weathered, and contain fragments of volcanic rocks and of sediments. The two sections made of these rocks are from included fragments.

Specimen no. 75 (33-N) is a dark greenish-gray, dense, mottled rock of basaltic composition. The microscope shows it to be made up of a light-green to brown glass which is studded with light-green bodies, some of which are faintly polarizing. Secondary calcite is also shown. No. 76 (33-N) was cut from a reddish-gray rhyolite porphyry. All of the minerals are partially altered.

Agglomerates believed to belong to the Sambeto series were also collected at Stations 234 (11-N); 271 (10-Q); 276, 277 (9-N); 278 (9-Q); 253 (26-AA), 290 (33-M).

Tuffs

Most of the tuffs are massive and fine-grained with a fragmental texture. These fragments resolve themselves under the microscope into volcanics that range in composition from rhyolite to basalt and are highly altered. Some of the tuff has weathered to a light-blue earthy material. The blue color is intensified by weathering.

Specimen no. 34 (13-V) is a light-brown, fine-grained, sandy rock which exhibits a very fragmental texture and heterogeneous composition under the microscope. The matrix is made up of a flourlike mixture of quartz, feldspar, calcite, magnetite, and other minerals; all are stained by limonite. Imbedded in this matrix are fragments of feldspar (labradorite chiefly) and a few grains of zircon. Veinlets of calcite cut across the other minerals.

Specimen no. 67 (24-M) is a greenish-gray rock containing limonite bands and showing considerable variation in texture and hardness. The microscope shows a uniform, fragmental texture. The minerals are feldspar, quartz, magnetite, and altered glass.

Specimen no. 56 (29-P) is a greenish-gray, very fine-grained, even-textured rock which under the microscope exhibits a fine rhyolitic texture. The minerals are quartz, feldspar, and sericite.

Specimen no. 61 (29-P) is a dark-green aphanitic rock. Under the microscope it is seen to have a palagonite matrix with rhyolite inclusions 0.1 to 0.5 mm. in diameter (pl. 7, *F*). The rhyolite areas contain numerous grains of chlorite. Feldspar and quartz occur in the inclusions and as phenocrysts.

Specimens nos. 272 (10-P) and 353 (10-N) are well-bedded tuffs. They contain occasional bodies of carbonaceous material and some questionable foraminifera. Tuffs referred to the Sambeto series were also collected as follows: Stations 67 (24-M); 167 (29-Q); 180, 184 (34-Q); 189, 190 (33-M).

Marl

Marl is interbedded with and grades into tuff. It is a bluish-gray to chocolate-colored rock that is massive, fine-grained, and apparently barren of fossils. In some places jointing is developed. The rock is distinguished from tuff by its effervescence. Specimens were collected at Stations 265 (27-O) and 354 (10-N), but no thin sections were made.

Arkosic Sandstone

Arkosic sandstone is represented by two boulders from the mainland boulder locality (21-CC), nos. 96 and 97. The rock is chalky, white to light gray. friable, medium to fine-grained, and contains quartz grains in a matrix of weathered feldspar (pl. 8, *F*).

As seen under the microscope, the structure is cataclastic. The chief minerals, feldspar and quartz, appear as irregular grains that range from 0.5 to 3 mm. in diameter. Feldspar is almost wholly changed to a fine, scaly, brightly polarizing, sericitic mineral. Quartz is present as round grains that appear quite fresh. Biotite occurs as jagged shreds that are greatly altered. Magnetite and limonite are uniformly distributed throughout the mass. The rock is cut by numerous veinlets filled with a brilliantly polarizing mineral that resembles sercite.

Volcanics

Most of the volcanic rocks in the Sambeto series are altered andesites, though specimens of rhyolite, dacite, and altered basaltic glass were also included in the collection studied.

1. Andesites. The most abundant variety of andesite is a greenish-gray, dense rock that has a mottled appearance due to the presence of white, chalky feldspar grains in a dense, light-green matrix.

Under the microscope the rock appears so altered that positive identification of the minerals is difficult. The texture is usually trachytic, and the minerals are chiefly a sericitized andesine with chlorite occurring in the interstices as a weblike coating over the other minerals and as radiating spherulitic bodies. Epidote, calcite, hornblende, and zeolites are present also.

The andesites of the type locality (upper Sambeto valley) exhibit a rather wide range of color and texture but in most places have a "salt-and-pepper" appearance due to the presence of black to greenish-black grains of hornblende and biotite and white crystals of feldspar in a dense greenish-gray matrix.

The matrix, as seen under the microscope, is a trachytic, feltlike mass of tabular crystals of andesine dotted with microscopic grains of magnetite (pl. 9, *D*). The phenocrysts, which average 0.5 mm. in diameter, include euhedral crystals of hornblende, subhedral grains of a basic andesine, irregular to quadratic grains of magnetite, brownish shreds of biotite, together with minor amounts of the secondary minerals iddingsite, chlorite, calcite, and serpentine. Apatite occurs but sparingly.

The andesites and other Sambeto volcanics of the type area are almost invariably altered, apparently by hot solutions, as is evidenced by the presence of chlorite, calcite, iddingsite, and serpentine, and in some specimens by sericite, epidote, and pyrite. Some of the rocks showed the copper sulphides chalcopyrite and bornite, together with malachite and other secondary copper minerals. Many of the specimens were fractured, with mineralization along the fracture planes.

Andesites from the type area include the following: nos. 121 (10-N); 228, 229, 230, 231 (12-M); 233 (11-N); 270 (10-Q); 281 (8-Q). Other andesites referred to the Sambeto series are nos. 44 (24-M); 53 (29-P); 122 (19-BB); 159 (30-P); 161, 162 (29-V); 237 (19-CC); 239 (19-AA); 252 (25-AA); 263 (27-O).

2. Rhyolite and dacite. Two specimens of rhyolite and one of dacite are among the rock types studied.

Specimens nos. 128 (10-Q) and 131 (9-N) are rhyolites. They are gray to cream colored, fine-grained, dense rocks which under the microscope exhibit a rhyolitic ground mass in which occur grains of feldspar, quartz and some pyrite.

Specimen 120 (12-M) is a light greenish-gray, fine-grained dacite which under the microscope shows a fine-grained inequigranular texture. It is made up chiefly of andesine with smaller but essential amounts of quartz and biotite. The secondary minerals chlorite and calcite also are present. The rock is considerably altered.

3. Basaltic glass. The Sambeto basalts usually have a glassy matrix which is altered partially or wholly to palagonite. The phenocrysts include augite, labradorite, and olivine. The olivine is almost invariably altered to serpentine.

Specimen 125 (25-Z), a basaltic glass, is brown to greenish brown and under the microscope exhibits a glassy ground mass in which are included rhyolitic, trachytic, and diabasic bodies. Palagonite is developed along fractures and labradorite occurs as phenocrysts. Secondary minerals include epidote and chlorite.

Three other representatives of basaltic glass were collected, nos. 77, 81, 82 (33-M). They show a glassy matrix of partially altered glass, much of which shows incipient crystallizations. (See pl. 8, *C*.) The phenocrysts include augite, labradorite, and zeolites. Some of the larger grains of zeolites contain embayments and inclusions of glass. The hand specimens generally have a pitchy luster, a dark-gray color, and a few of them show vesicles filled with zeolitic minerals. Some of the specimens contain criss-crossing veinlets of opal.

VITI LIMESTONE

The limestone of the Viti formation is massive, fine-grained, and in coloring ranges from light gray to shades of cream, pink, and red. Most of the specimens are fractured and some of them are brecciated. The fractures are usually filled with a more coarsely crystalline calcite (pl. 8, *A*), but some of them with quartz. In a few specimens miaroliticlike cavities occur and are lined with tiny crystals of clear quartz. A few specimens are slightly schistose and break into thin slabs. These specimens are light green and have a very fine texture.

As seen under the microscope the rock is made up principally of a very fine-grained calcite, the grains averaging 0.1 mm. or less. Relatively larger grains of calcite, 0.1 to 1 mm. in diameter, are usually mixed rather uniformly with the finer-grained variety. The larger grains rarely comprise more than one third of the rock and usually less. A few fragments of volcanic rocks as much as 1 mm. in diameter are present as inclusions in the limestone (pl. 8, *B*). Most of them are altered andesites or altered glassy basalts, apparently derived from the Sambeto series. Numerous cross sections of fossils were also noted. (See pl. 8, *A*.)

The schistose specimens are made up predominantly of a fine-grained calcite with minor amounts of a very fine-grained, light-green, slightly pleochroic chlorite arranged in thin bands. Specimen no. 12 (31-Q) exhibits incipient recrystallization. A crystal of calcite 2 mm. in diameter occurs as an augen, which has resulted from the force of recrystallization in the growing calcite crystal. (See pl. 7, *B*.)

In many of the slides there are cross sections of fossils which are fractured, the fractures being cemented with a later, recrystallized calcite. Magnetite, much of it limonitized, is common.

Other specimens of Viti limestone are nos. 60 (30-P); 74 (34-Q); 260 (30-P); 269 (8-Q); 273 (10-Q); 292 (34-Q).

SUVA FORMATION

General Features

The Suva formation includes the following lithologic types: conglomerate, agglomerate, tuff, marl, limestone, and volcanics. The relative proportions of these could not be determined from the specimens, but it seems that the most widespread types are agglomerate, tuff, and marl, with the volcanics next most abundant, and limestone and conglomerate the least numerous.

Conglomerate

Most of the conglomerate is a gray, rather loosely consolidated rock, with a medium to fine-grained matrix in which are embedded pebbles ranging from 1 inch to 1 foot or more in diameter. These pebbles vary greatly in composition and include practically every rock type from all the formations and series on Vitilevu. Fossils are also found in the conglomerates in some localities.

Additional Suva conglomerates were found at Stations 13 (19-R); 19, 20 (25-M); 21 (24-M); 41, 42 (35-W); 46, 47 (19-R); 71 (33-Y); 123 (20-Y); 144 (24-M); 199 (21-DD); 202 (18-CC); 238 (21-DD); 250 (21-G); 358 (20-Y).

Agglomerate

The agglomerate in the Suva formation is most commonly a fresh-looking, loosely consolidated rock that varies considerably in color. The rock is made up of a fine to coarse tuffaceous matrix in which are embedded angular blocks that vary from less than 1 inch to more than 1 foot in diameter. The blocks are usually fine-grained rocks that range from acid to basic, with the intermediate types the most common. The agglomerates are fossiliferous in a few places. The matrix was not sectioned, but a close megascopic examination indicates that it is an andesitic tuff. Several thin sections were made of the included fragments.

Specimen no. 50 (27-K) exhibits a very fine matrix of feldspar, augite, and magnetite containing phenocrysts of feldspar which are crushed and recemented with a serpentine-like material. Specimen no. 54 (28-N) reveals a fine-grained diabasic texture and has the composition usual for a diabase. Calcite is abundantly developed as a secondary mineral. Specimen no. 191 (30-F) is a fine-grained, dark-gray rock of basaltic composition that contains distinct black crystals of augite in a dark-brown glassy matrix.

Additional agglomerates were collected from the Suva formation in the following places: Stations 57 (26-K); 136 (13-H); 173 (33-G); 195 (35-J); 216 (13-Y); 259 (31-Q); 291 (36-X); 293 (14-L); 318, 321 (35-J).

Tuff

The tuff in the Suva formation grades into agglomerates with an increase in the number and size of fragments and into marls with an increase in the amount of calcite. Most of the specimens are fine-grained or slightly agglomeratic and are earthy and loosely consolidated. The color varies from light gray to dark gray with shades of red, brown, and green.

Thin sections of this rock type exhibit a very fragmental texture, the fragments ranging from 0.1 to 2 mm. in diameter. Many of the fragments consist of minerals such as feldspar, augite, and calcite; others are of rocks, most of them volcanics, and a few are of fossils. (See pl. 7, *G.*) Most fragments are embedded in a fine-grained matrix composed of what appears to be an ash. In places this ash is mixed with calcite. The tuffs are acid to basic in composition and some of them show the effects of hydrothermal alteration, as evidenced by the development of epidote and chlorite.

Additional Suva tuffs were collected at Stations 18 (16-J); 26 (21-N); 48, 58 (30-Q); 65 (17-S); 66 (8-P); 69 (35-Z); 73 (33-Y); 137 (14-H); 139, 141 (16-J); 142 (15-J); 147 (22-N); 149 (21-N); 163 (33-V); 170 (27-K); 197, 198 (20-G); 218 (9-Z); 224 (16-F); 300 (31-Q); 343 (10-Y); 344 (9-Z).

Marl

Most of the marls are light gray to brown, fine-grained, dense to earthy rocks in which the individual minerals are rarely distinguishable. They effervesce in cold dilute acid. A few of these marls were sectioned.

Specimen no. 70 (35-Z) is a typical marl or "soapstone." (See pl. 7, *H.*) The matrix is fine-grained and nearly opaque. As seen with very high power and convergent light the material is doubly refracting and appears to be calcite intermixed with variable amounts of sericite and kaolinite and dotted with grains of magnetite and limonite. In the matrix are included numerous cross sections of foraminifera that range in diameter from 0.1 to 0.5 mm. The shells are made up of a very fine-grained calcite and are filled with the matrix material. There are also spherical bodies of calcite that exhibit a uniaxial cross under crossed nicols.

Additional marls studied are Nos. 101 (15-BB); 134 (31-Q); 143 (24-L); 146 (22-M); 154 (17-S); 164, 168, 169, 171 (31-Q); 178 (37-L);

194 (34-M); 219 (10-Y); 223 (16-K); 241 (19-Z); 244 (20-Z); 247 (22-X); 248 (22-Y); 249 (22-W); 283, 285, 286 (35-Y); 299 (31-Q); 312 (25-W); 314 (25-X); 315 (36-X); 355 (9-N); 368 (35-Y); 370 (24-L).

Limestone

The limestones from the Suva formation are usually conglomeratic or tuffaceous. Some of them are brecciated, and many are very fossiliferous. They are more porous than the limestones in the Viti formation.

The microscope shows the rock to have a fine-grained fragmental texture. The interstitial material is a very fine-grained calcite. The fragments range in size from a small fraction of a millimeter to 1 mm. in diameter. Most of the fragments are composed of green to brown glass. Some are of volcanic composition, as rhyolites, trachytes; others are of a single mineral, as feldspar, augite, serpentine, calcite, or magnetite.

Additional limestones studied are Nos. 119 (9-Z), (pl. 9, C); 152 (17-S); 177 (36-X); 308 (17-S); 316 (36-X); 357 (20-Z).

Volcanics

Almost without exception the volcanic rocks of the Suva formation have been derived from a basic magma. They vary in texture from glassy to rather coarsely diabasic, and most of their minerals are much less altered than are those of basic rocks in the Older series.

1. Basalts. Suva basalts studied are Nos. 7 (21-N); 8 (22-I); 11 (35-X); 16 (13-G); 17 (15-J); 22 (22-M), (pl. 7, *C*); 23 (22-M); 24 (22-N); 25 (21-N); 37, 38 (36-X); 49 (25-L); 51 (27-L); 62 (31-P); 63 (27-L); 72 (33-Y); 85 (35-J); 86 (29-D); 116, 117 (12-AA); 148 (21-N); 151 (19-S); 166 (28-M); 176 (36-X); 186 (33-M); 193 (30-F); 196 (20-G); 208 (16-BB); 225 (13-L); 240, 242 (19-Y); 262 (28-P); 266 (26-N); 268 (22-I); 284 (35-Y). The following are typical examples:

Specimen no. 7 (21-N) is a fine-grained, dark-gray, vesicular rock whose vesicles are filled with a radiating white zeolitic mineral. As seen under the microscope the matrix has a feltlike texture, is of a greenish-brown color, and is made up of a partially devitrified glass. The phenocrysts are almost entirely of augite, ranging up to 2 mm. in diameter. Some of them show zonal structure. A zeolite is excellently developed in round grains with a radiate form. It is colorless and has a low index of refraction. The rock is a porphyritic basaltic glass (pl. 7, *A*).

Specimen no. 49 (25-L), another basaltic glass, is very similar in appearance to no. 7. It contains an almost perfect cross section of augite (pl. 9, *G*). Olivine is also present.

Specimen no. 25 (21-N) is a dark-gray, aphanitic, basaltic obsidian. In thin section it exhibits a dark-brown, glassy matrix with numerous brown rodlike inclusions. The phenocrysts are chiefly of augite, but olivine and a zeolitic mineral appear sparingly (pl. 9, *H*).

Specimen no. 117 (12-AA) is an amygdaloidal, glassy basalt. It is a dense yellowish-green rock whose amygdules are filled with a development of orthoclase and quartz.

These elliptical bodies are surrounded by rodlike incipient crystallizations that penetrate inward (pl. 9, *B*).

Specimen no. 208 (16-BB) is an olivine basalt. It is a dark-gray rock in which phenocrysts of a green olivine occur in a dark-gray, nearly black, dense matrix. In the field the rock appears to be a sill and shows beautifully developed hexagonal and polygonal jointing.

2. Diabase. The following specimens are representative of the diabases in the Suva formation:

Specimen no. 35 (36-X) is a dark-gray, dense, vesicular diabase. Some of the larger cavities measure 1 cm. across and are partially filled with a zeolitic mineral. The texture as seen under the microscope varies from glassy to fine diabasic. The minerals of the matrix are labradorite, augite, and magnetite; the phenocrysts are of labradorite, augite, and altered olivine. The secondary minerals include chlorite, calcite, serpentine, and iddingsite. The last-named mineral is a brown, faintly polarizing, high-index substance that has the form and cleavage of olivine, from which it was derived. Some of the grains are 2 mm. in diameter. (See pl. 7, *E*.) The mineral was formed from primary olivine by the action of hot solutions from the parent magma, a process known as deuteric action.

Specimen no. 84 (36-J) is an olivine diabase from Tova Peak. It appears quite fresh under the microscope and is no doubt from the younger series of basalts (pl. 8, *D*). Specimen no. 83 (36-J) shows two distinct grain sizes: one ranges from 1 to 0.5 mm.; the other is smaller. Other diabases from the Suva formation include nos. 55 (31-P); 87 (29-C); 209 (14-AA); 226 (11-L).

3. Rhyolites and felsites.

Specimen no. 124 (20-Y) is a dark, greenish-gray rhyolite. The microscope reveals a rhyolitic texture and the minerals feldspar and quartz over which appears a light-green, almost isotropic web of a chloritic mineral (pl. 9, *E*). Specimen no. 123 (20-Y) is similar megascopically to no. 124, but the microscope shows a diabasic texture in which the laths are andesine and the interstitial minerals quartz and chlorite with some calcite. The altered nature of these two rocks, both from the same locality, suggests that they belong to an older series, probably the Sambeto. Specimen no. 211 (15-BB) is a felsite of uncertain age, and no. 222 (3-U) is probably a volcanic.

Structure

The rocks of the Suva formation, which are of sedimentary or volcanic origin, are generally loosely consolidated and earthy. In some rocks from the bottom of the formation or along a fault plane or adjacent to an igneous intrusion, a more dense and compact structure has been developed. The igneous rocks in this formation usually possess the primary igneous textures and such structures as jointing, that may have resulted from the cooling of the magma.

The rocks of the older formations exhibit structures that have resulted from the various kinds of metamorphism they have undergone. The first structural change observed is that of increased compactness, and the next of brecciation, which is especially developed along fault planes and is most pronounced in the limestones.

Some of the most common structures are those that have developed as a result of crushing, mashing, grinding, and granulation. These structures include cataclasose, mylonose, and mortar and were observed frequently in the Tholo plutonics and in the rocks of the Wainimala series, and to a less extent in the rocks of the Viti formation. Some of the Tholo plutonics, when examined under the microscope, exhibit a mortar structure in which grains of feldspar 2 mm. in diameter occur in a matrix made up of a granulated mixture of feldspar and quartz. Some of the arkosic quartzites in the Wainimala series appear to be made up of a mashed granite that has been compressed and welded together again, and others appear to have resulted from the compacting of an agglomerate or tuff.

Structures resulting from recrystallization are not so numerous. A maculose structure was observed in some of the Viti limestones in which crystals of recrystallized calcite 1 to 2 mm. in diameter occurred in a slightly schistose mass of fine-grained calcite and chlorite.

Distinct and well-developed schistose structure was not observed, but indistinct or incipient schistose structure was seen in some of the specimens of the Viti limestone, in a few of the Sambeto volcanics, and in quite a number of the Wainimala basalts. This structure has resulted largely from the formation of the platy mineral chlorite. The chlorite, in turn, has been developed partly by hydrothermal alteration and partly by heat and pressure.

The absence of well-developed schists or gneisses suggests that the rocks of Vitilevu have never been subjected to extensive regional metamorphism. Most of the structures, apparently, have resulted from local metamorphism, as faulting, igneous intrusion, and hot solutions, or by static or load pressure.

Metamorphism

Deuteric or autometamorphism brought about by the liquids or gases from the parent magma acting upon the minerals already formed was observed in some of the youngest rocks. Thus in the olivine diabase of the Suva formation the olivine has been partially or wholly altered to iddingsite. It is quite likely that much of the palagonite was developed in this way.

Hydrothermal metamorphism, which may be in part pneumatolytic metamorphism, is the type most commonly observed. It is especially pronounced in the andesites of the Sambeto series and in the basalts of the Wainimala series. In many of the specimens from these rocks the original minerals have been completely changed to secondary minerals, most commonly chlorite, sericite, epidote, and calcite. Chlorite is particularly abundant in the Sambeto andesites and the Wainimala basalts, and sericite is present in many of the Tholo plutonics.

Contact metamorphism developed by the intrusion of a younger rock into an older one was observed in a few places. Metamorphism developed along faults was frequently observed. It has developed breccias, crushed, mashed, and sheared rocks, and affords an easy entrance for hot solutions.

Pressure metamorphism, which appears to have been chiefly static, has resulted in the development of a more compact structure. It has also produced cataclasose, mylonose, maculose, and incipient schistose structures.

The laboratory study of hand specimens and slides was not sufficient to determine the order of intrusion of the various igneous bodies. In general, it seems that basalt is one of the oldest rocks in that it is found included in the Tholo plutonics and on the other hand one of the youngest, for it intrudes rocks of the Suva formation. Rocks formed between these extremes are generally of an intermediate character, as andesites. Hence the predominance of andesitic rocks in the Sambeto series.

GEOLOGICAL HISTORY

REGIONAL EVENTS

Origin of the Fijian Archipelago

For a long time biologists and geologists have demanded land connections more extensive in the South Pacific than those existing today. They agree in recognizing important changes in the distribution of land and sea but express widest disagreement as to the extent of these changes and the causes which produce them. Most students of Pacific geology include the larger islands of Fiji in the hypothetical land masses and place the structural boundary of the Pacific basin east of Fiji.

A glance at any map of the Pacific Ocean shows that most of its hundreds of islands are concentrated in a comparatively small area in the southwest corner. A study of the rocks of which these islands are composed has led to the recognition of two types: oceanic islands, composed entirely of volcanic rocks and organic limestone or sediments derived from these; and continental islands made up of plutonic or metamorphic rocks in addition to the types of rock found on the oceanic islands. As shown on the map (fig. 6), all of the continental islands lie west of an imaginary line drawn from Yap southeastward through Truk, New Ireland, the Solomon Islands, and Fiji to Tonga, thence southwestward through the Kermadecs to include New Zealand and certain of its outlying islands.

The rocks of a number of these continental islands have yielded Paleozoic and Mesozoic fossils (fig. 6). Though some of the island groups in Melanesia have not been thoroughly explored, and though future investigations may shift some of the suggested boundaries eastward, the known distribution of the Paleozoic and Mesozoic rocks indicates that much of Melanesia has been above the ocean depths for considerable periods of time, even reckoned geologically.

The occurrence of plutonic rocks, especially in islands such as Vitilevu where the rocks are definitely in place, suggests that tremendous thicknesses of rocks have been removed by erosion. This in turn implies more extensive land areas. Even more significant is the widespread presence of metamorphic rocks, which demands powerful earth forces that surely could not have been generated on small isolated islands. The statement by Hobbs (61) that granite on Pacific islands originated in magma pockets beneath growing anticlines and that "the presence of granites if on islands cannot be taken to indicate that they are relics of former continents" seems inadequate as an explanation for the distribution of the metamorphic and pre-Tertiary rocks.

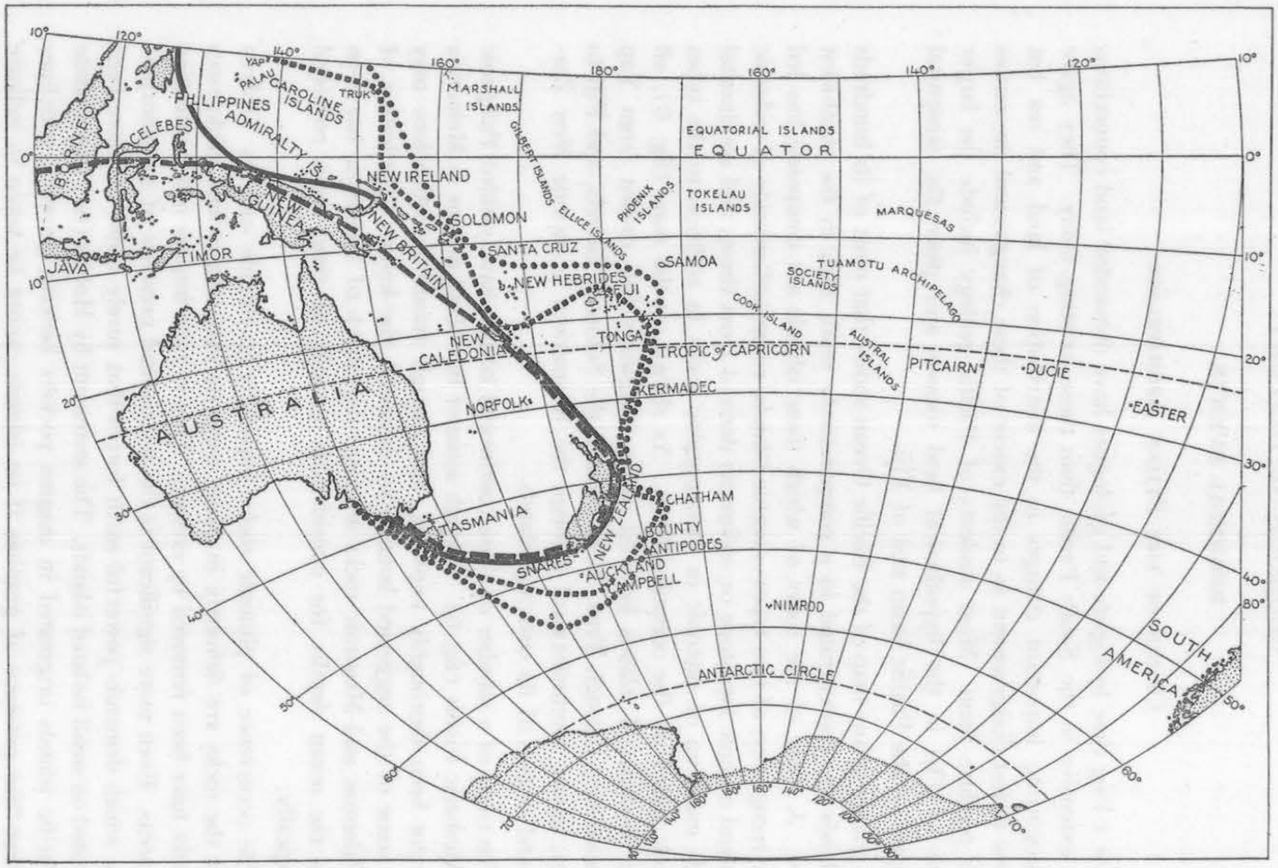

FIGURE 6.—Map of the South Pacific: — —, outlines areas within which Paleozoic rocks are present; ——, outlines area showing Mesozoic rocks; - - - -, outlines area showing metamorphic or plutonic rocks; . . . ., probable boundary of former Melanesian continent and true structural boundary of the Pacific basin.

Many biologists believe that additional land connections are needed in Melanesia and other parts of the Pacific to explain the present distribution of organisms. It is claimed that certain types of land shells, crustaceans, insects, spiders, reptiles, mammals, and plants now found on isolated islands or archipelagos could not have migrated to their present positions without the aid of land bridges. For some organisms the high percentage of endemic families, genera, and species suggests that the original migration, followed by the destruction of the land bridge and isolation, must have occurred in Tertiary times or even earlier.

The origin of Pacific faunas and plants is a problem outside the scope of the present paper. The voluminous literature dealing with the subject has been digested by Gregory (53). A recent contribution by Germain (50) outlines continental areas over which the land and fresh-water mollusks of Fiji are thought to have come from the northwest.

Melanesian Continent

The Melanesian continent connected Asia to Australia and extended southeastward into the present Pacific basin. Its probable boundaries on the south and east are indicated in figure 6. The widespread occurrence of metamorphic and plutonic rocks suggests that the area was originally built up as a series of folded mountains and existed as a continental surface during much of early geologic time. Though looked upon as a continent it was not always a land area, for shallow seas shifted over portions of it—as they have over other continental surfaces or platforms.

The destruction of the Melanesian continent was one of the major events of earth history. A consideration of the methods by which it may have occurred is of interest to geologists because it suggests serious objections to the universal application of the belief in the permanence of the ocean basins and continental platforms. In no other part of the world is there such clear evidence indicating that a considerable area, once land, is now covered by deep ocean.

Faulting

It is well known that in many folded areas the period of compression was followed by one of tension which resulted in normal faulting. Such may have been the sequence of events in Melanesia. As pointed out by Allan (5), Henderson (59), Süssmilch (100, 101), Louderback (75), Tsujimura (106), and others, there has been a great deal of such faulting in the southern Pacific in late geologic time, and faulting of this type may have been primarily responsible for the breaking up of the Melanesian continent. The exact date of the break-up has not been accurately determined. It was probably prolonged over a considerable period of geologic time. Schuchert (91, p. 100) cites biological evidence to show that Australia has been an island continent at least since late Eocene time. He believes that intermittent land connections between Australia and Asia probably persisted to the end of Cretaceous time. There is some evidence which indicates that in the southeast marginal zone much of the disruption occurred during the Miocene, though it may have been initiated somewhat earlier.

One of the characteristic features of the borderland of Melanesia is the linear arrangement of volcanic vents—an arrangement most satisfactorily explained by assuming the extrusion of volcanic material along major fault planes. This is not altogether an assumption because in New Zealand fissure eruptions have actually occurred along known fault lines. The volcano Tarawera in North Island is situated along the line of the great Whakatane Fault, and in the year 1886, in less than four hours, it opened up a rent trending northeast-southwest for a distance of nearly 9 miles. This tremendous fissure —in places more than 1 mile wide and nearly 1,000 feet deep—engulfed two lakes, and the pyroclastic ejecta buried Maori villages but no flowing lava reached the surface (89, pp. 167-175).

Tarawera lies on a remarkable ridge which can be traced for more than 1,000 miles from New Zealand nearly to Samoa. This ridge and the deep which parallels it on the southeast lie at right angles to the Australasian arcs. The southwest portion of the line marks a fault which crosses New Zealand from one end to the other. As shown by Park (89), the rocks traversed by the fault are " . . . . . broken, sharply folded, faulted, sheared, and uptilted." In South Island the Triassic beds are faulted against the Miocene (89, p. 262); in North Island the line passes through a series of active and dormant volcanos and a geyser basin to White Island, an active cone in the Bay of Plenty. To the northeast it continues as a submarine ridge through the volcanic Kermadecs and a long line of Tongan volcanoes. In New Zealand other major faults parallel it, and a second series of faults lies at right angles to these.

Other evidence suggesting faulting along this line is seen in the high terraced islands of Tonga—elevated to their present positions by intermittent movements. In this connection it should also be pointed out that the mountain backbone of Vitilevu trends in a northeast-southwest direction and parallels the regional tectonic line.

If this relation between volcanism and faulting is of fundamental importance today it may well have been so during the Tertiary. Such an interpretation lends great significance to the occurrence of thick deposits of Miocene pyroclastics on Vitilevu, those reported by Mawson (84) on New Hebrides and by Hoffmeister (62) on Tonga. These pyroclastics may record a period of Miocene faulting which was primarily responsible for the breaking up of the margin of the continent. As shown by Hoffmeister (62, p. 35) in Tonga the process may have begun somewhat earlier. Some of Mawson's interpretations (84, pp. 400-485) of structural conditions differ from those here set forth, but he does state that faulting in late Tertiary time was responsible for the deep water now existing between the New Hebrides and Fiji.

EVENTS ON VITILEVU

Formation of the Wainimala Series

Very little is known of that part of Vitilevu's history during which the Wainimala rocks were formed—a series that consists chiefly of volcanic rocks but also includes a considerable bulk of sediments. During Wainimala time Vitilevu formed a part of the Melanesian continental platform, and large quantities of basic volcanics were extruded. These rocks apparently were formed at a very early date, for they were intruded by the Tholo plutonics and deeply eroded—so as to expose the plutonics over wide areas—prior to the Neogene. The absence of boulders carrying Eogene or Mesozoic fossils in the conglomerates of the Neogene suggests that Vitilevu was a land area for a very long time. The possibility that the Wainimala rocks are Paleozoic in age is not to be excluded.

Mountain-building and Intrusion of Tholo Plutonics

The ancient Wainimala rocks were folded and intruded by batholiths which solidified as granite, diorite, and gabbro. Vitilevu at this time became an area of folded mountains and probably was tied by actual land connections to New Zealand, Australia, and Asia. It is impossible to date the period of folding accurately, but suggestions as to its probable age may be obtained by considering known periods of folding elsewhere in Melanesia.

Marshall (80) has pointed out that in New Zealand a prolonged period of folding was initiated at the close of the Jurassic period. Willbourn (123, pp. 445, 446, 450) states that the rocks of Malaysia were folded at the close of the Mesozoic, and that the folding was accompanied by some faulting and by the intrusion of granites in the centers of the anticlines. The folds which elevated Malaysia are part of a series of arcs of folding which extended through Borneo, the Philippines, and Japan. It seems reasonable to assume that the effects of this widespread deformation extended to the eastern border of Melanesia.

After the mountain-building of Tholo times Vitilevu was subjected to a prolonged period of erosion which unroofed the plutonics and left only remnants of the Wainimala rocks included in them. This probably occupied most if not all of the Eogene. The sediments formed as a result of this erosion are not now accessible. They probably lie far beyond the present shores of Vitilevu.

Formation of the Sambeto Series and Submergence

Near the close of the Eogene or very early in the Neogene the eroded surface of Vitilevu was partially covered by the andesitic and rhyolitic lavas of the Sambeto series. This volcanism was accompanied, or immediately followed, by submergence, and near the close of Sambeto time the area lay beneath the sea.

There seem to be no good reasons for believing that the Sambeto rocks entirely covered Vitilevu, hence their absence in certain areas does not establish a post-Sambeto period of erosion. The extrusion of the lavas and the subsidence may have been the initial steps in the breaking up of the continental border, but the main period of deformation probably came later and caused the prolonged pyroclastic eruptions of Suva time. In this connection it is interesting to note the conclusion of Hoffmeister (62, p. 37) that the island of Eua, on the margin of the continental area to the southeast, was beneath the sea during upper Eocene time, and that the limestones formed during this period are underlain by bedded tuffs.

Deposition of the Viti Limestone

The Viti limestone which is referred to the lower Miocene was deposited on a sea floor which lay below the depth of reef coral growth. Viti time was an appreciable interval, as several hundred feet of foraminiferal and algal limestones accumulated. The remarkable purity of the limestone indicates that volcanic activity had ceased temporarily and also suggests that no part of the immediate area was above water undergoing erosion.

Faulting, Volcanic Activity, and Uplift in Suva Time

Following the deposition of the Viti limestone a period of volcanic activity was inaugurated and ranges of agglomerate mountains were built above sea level. It is thought that the pyroclastics were ejected along earth fractures some of which were coincident with major fault lines. Much of the local alteration exhibited by the Sambeto and Viti rocks probably occurred at this time, and at the same time Vitilevu seems to have lost its continental connections. Brock (11, pp. 67, 80, 81) referred to the deformation which followed the deposition of the Viti limestone as a period of mountain-building which he termed the "Viti revolution." There is, however, little evidence of regional metamorphism in the rocks of the Younger series. All high dips in the Younger rocks appear to be exceedingly local and are perhaps best explained as a result of faulting or igneous intrusion. Additional evidence favoring this interpretation was obtained by Pegau in his study of thin sections.

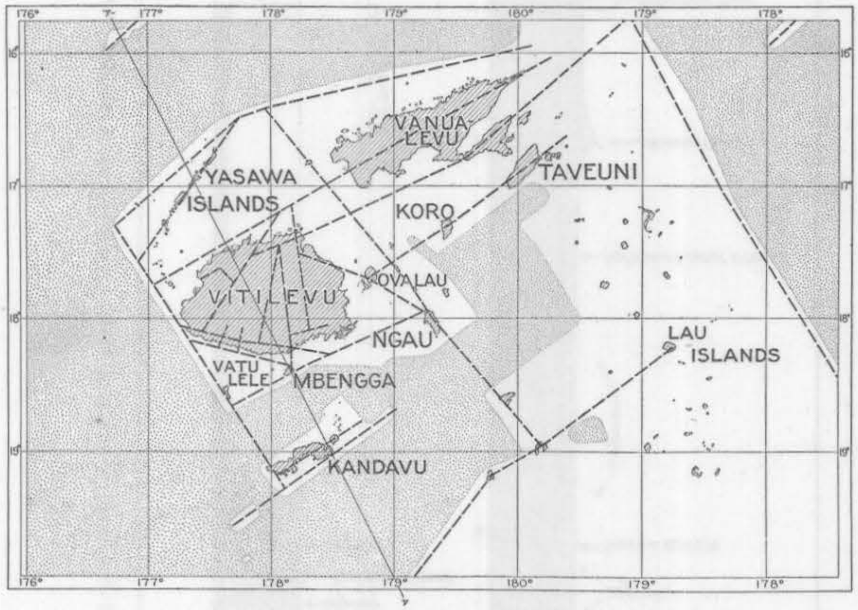

FIGURE 7.—Sketch map of Fiji, showing probable tectonic lines. Depth over stippled area exceeds 1,000 fathoms.

A tentative arrangement of probable tectonic lines for Fiji as a whole and for Vitilevu is shown in figures 4, 7, and 10, and a diagrammatic structure section along the line A-A′ is shown in figure 8.

In placing these lines the following geologic and topographic criteria were used: 1, trends of pyroclastic mountains; 2, alignment of volcanic islands; 3, distribution of rocks of Older series; 4, actual exposures of faults; 5, direction of island axes or elongation of submarine banks; 6, trends of sea reefs; 7, abrupt changes in type of coast line—emerged to submerged; 8, water gaps and wind gaps.

The lines which coincide with volcanic mountains probably mark important earth fractures, an interpretation expressed in the diagrammatic structure section (fig. 8). However, it is not certain that faulting has taken place along all such lines.

The pyroclastics and lavas extruded during the early part of Suva time were eroded and reworked to form the thick sediments of the Suva formation, referred to the Miocene.

During Suva time Vitilevu began to feel the effects of the regional uplift

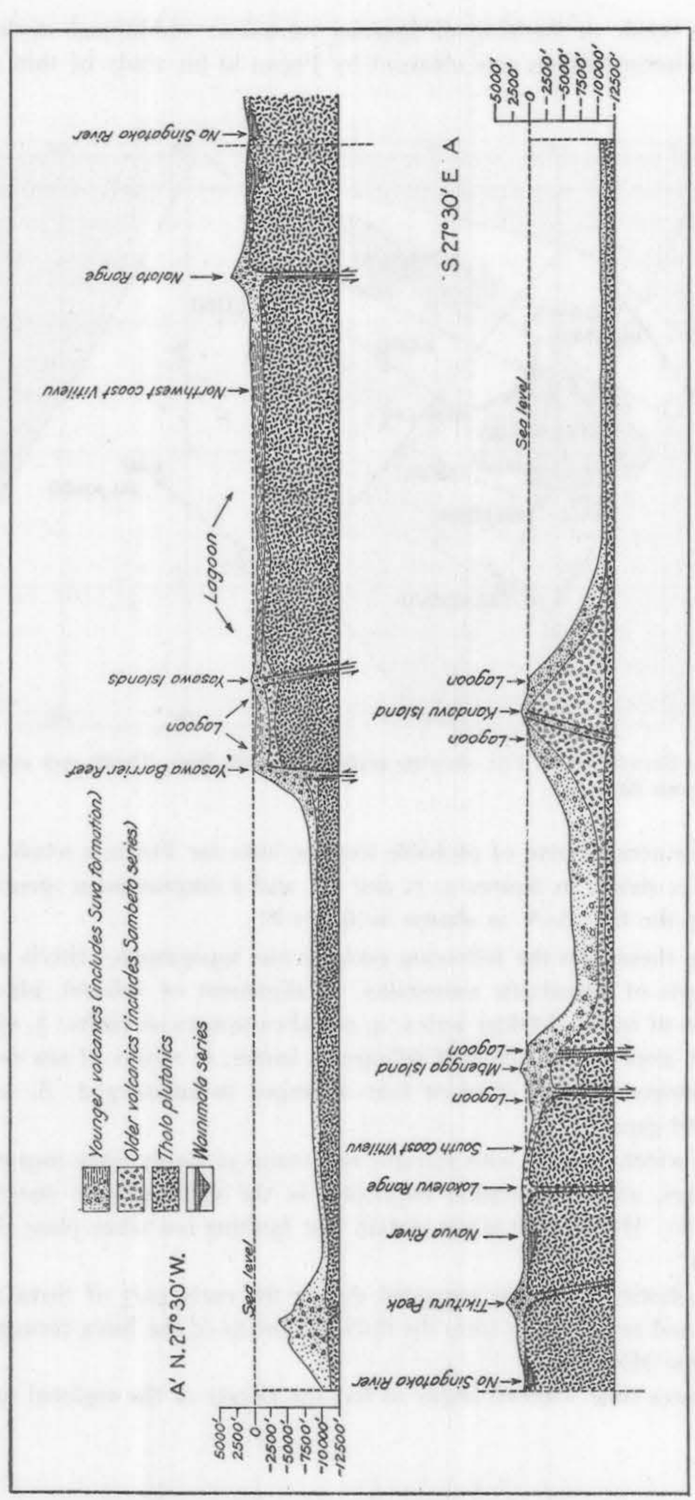

FIGURE 8.—Diagrammatic structure section through Vitilevu and Kandavu. Horizontal scale 1:734,000 (approximate); vertical scale 1:150,000.

that affected many of the island remnants of Melanesia. Parts of the island were uplifted more than 2,000 feet. At Station 143 (24-L) near Nasongo the Suva marls carrying foraminifera lie at an elevation of about 2,175 feet, and at Nandrau Station 147 (22-N), on the opposite side of the Navosa Plateau, level-bedded tuffs with foraminifera and mollusks lie 2,000 feet above sea level. The horizontal tuffs of Nandrau are a part of the series that underlies the Navosa Plateau whose flat surface stands more than 3,000 feet above sea level. The entire series forming the plateau is probably marine, and the maximum uplift doubtless exceeded 3,000 feet.

Apparently the uplift began early in Suva time, for the younger beds of the formation now lie at lower levels than the older and seaward of them. This arrangement is similar to that described by Martin (81, p. 764) from Java. In Vitilevu the mollusks of the type section of the Suva formation at sea level on the coast show clearly that the beds are younger than the elevated mollusk-bearing beds of the interior. It is even conceivable that the high-level fossiliferous beds of the Nasongo area are older than the Viti limestone which outcrops between Nasongo and the coast. Block-faulting and volcanic extrusion apparently accompanied uplift during Suva time. Locally, at least, the Viti limestones were exposed because boulders of the limestone are included in the coastal sediments of the Suva formation.

The uplift may still be going on in such areas as the "Navua horst," but in other areas blocks have slipped from positions once somewhat higher.

Events During the Pleistocene

The fossiliferous beds of the late Tertiary are not overlain by younger marine deposits, but the volcanic activity that characterized Suva time probably continued into the Pleistocene and many of the fresh agglomerates, such as those of the Mendrausuthu Range, may have been extruded after the deposition of the Suva formation. Minor intrusions cut the Suva marls and pyroclastics in a number of places. Foye (45, pp. 13, 20) noted a diabase dike cutting the limestone at Na Sana Sana (5-Y). Many of these intrusions are probably Pleistocene and some may be even younger. Some of the older stream deposits, as the higher terraces of the Rewa valley, are probably Pleistocene in age.

Doubtless the island was subjected to low level abrasion during the Pleistocene, but the evidence to support this view must await a study of the origin of the modern reefs. Several parts of the island's coast exhibit evidence which points to a recent negative shift in the strand line of 6 feet or more. It is believed that this shift can be correlated with a world-wide sinking of sea level which occurred at the close of the Pleistocene.

GEOMORPHOLOGY

PLAINS

Rewa Plain

The Rewa Plain includes the deltas of the Rewa and the Navua rivers. The Rewa delta is a broadly triangular area that extends upstream from the coast to Nandurulоulou. Much of it, especially the wide, rich flats northeast of the stream, is cultivated, but its seaward portions are covered by impenetrable swamps of tangled mangroves. Because the Rewa drains an area underlain chiefly by fine tuffs, marls, and lateritized volcanics and is very sluggish in its lower reaches, only the finer materials are contributed to the delta. No coarse gravel reaches Nandurulоulou at the head of the delta.

The Navua, a smaller and swifter stream that drains an area where plutonics are widely exposed, brings a great deal of sand to its mouth. Its delta plain, according to Foye (45, p. 26), was developed by the submergence of an eroded surface of andesitic agglomerate, the higher portions of which are preserved as isolated, deeply lateritized hills. The sand of the series of beaches which are developed west of the river's mouth for a distance of 5 or 6 miles has evidently been carried westward by waves and currents generated by the prevailing southeast trades. Some of the lower coastal hills, superficially at least, resemble wooded dunes. Due, possibly, to the character of the river's load, no extensive mangrove swamps fringe the Navua delta plain.

Both sides of the delta of the Rewa and the western side of the delta of the Navua merge into strips of undissected coastal plain. North of the Rewa this flat coastal plain persists all the way to Tanavuso Point. Apparently it has been uplifted very recently, for near the Rewa the flat stands above present sea level and low cliffs face the sea.

The major part of the Rewa Plain province consists of the Rewa Valley and the lower portions of its four important tributaries, the Waimanu, the Waindina, the Wainimala, and the Wainimbuka. Considered as a whole the area is one of elevated, nearly horizontal marls, and reworked tuffs which represent an old delta plain now dissected into a mature topography of rolling hills.

Between Nandurulоulou and Viria the Rewa receives the Waindina as a right tributary (fig. 10). This portion of the Rewa Valley is still mature and there are patches of terrace 25 feet above the present valley flat. There are large sandbars at the bends of the river, and gravel beds are interstratified with the muds of the flood plain, which is appreciably narrower above the mouth of the Waindina. Marls, dipping gently downstream, outcrop at numerous points. Hills near the river rise to heights of 150 feet above the stream. Above Viria outcrops become more numerous and some of the smaller tributaries enter the main stream from hanging valleys. As the mouth of the Wainimbuka is approached, the valley flat reappears. Remnants of the 25-foot terrace are seen to be well preserved. This terrace is also well developed in parts of the lower Waindina Valley. Above the mouth of the Wainimbuka the Rewa is known as the Wainimala.

Just above Nairukuruku, a village near the mouth of the Wainga, the Wainimala enters a deep gorge which marks the edge of the plateau. Immediately below this point the flood plain is still well developed and broken by two district terraces, the higher one lying 35 feet above the present flat. This 35-foot terrace is also well developed between Vunindawa and the mouth of the Wainimbuka, where in places it is at least half a mile wide.

The Wainimbuka, a shallow, clear, swift stream that drains an area equal to that of the Wainimala, has a volume considerably less than the Wainimala, which heads in the center of the island where rainfall is excessive. The basin of the Wainimbuka includes extensive limestone. At Station 179 (34-O) near the junction of the Rewa Plain with the plateau of Tholo East the Wainimbuka carries coarse gravel, also boulders, a few of which exceed 6 inches in diameter. Some of the pebbles are well rounded, others subangular; a variety of basalts and tuffs are present but the plutonics are not represented.

Along the south coast of Vitilevu, between the coast line and the east-west Namosi-Rewa and Lokalevu ranges, a strip of sediments has been uplifted and carved into a youthful topography. In the part of the strip that lies east of the Navua River these sediments, mainly of tuffs and marls with lenses of limestone, resemble those of the Rewa Valley. West of the Navua River, however, the sediments consist almost entirely of conglomerates, though finer sediments and volcanic rocks are present in minor amounts. The streams draining the strip are short. Most of them are swift, but for a mile or two near the coast their valleys are broad and open. The Tamunua, which enters Vatukarasa Bay, has a much larger basin than the other stream, for it heads in the mountains 10 miles from the coast.

North of the Rewa Plain province a strip of deeply embayed coast extends from Tanavuso Point to the headlands of the north shore of Vitilevu Bay. This area of dissected plain (fig. 2), 20 miles long and about 5 miles wide, lies between the eastern limb of the Nakauvandra Range and the sea. It should not be grouped with the Rewa Plain because it is an area that has been submerged, whereas the Rewa Plain proper has been emerged. The contrast between the two areas can be clearly seen from the summit of Tova Peak which lies at the border line. Along the coast northwest of Tova deep bays alternate with bold promontories, many of them dipping steeply to the sea. High cliffs can be seen in many places and rocky stacks are present off shore. The landscape is mature; there are no flat areas in the valley bottoms or on the divides. The sharp ridges that run down to the shore are covered only by reeds, but heavy bush is present in the gullies and a thick growth of mangroves fills the heads of some of the bays. The coastal ridges rise steeply to the Nakauvandra Range, whose even-crested summit in this area lies about 1,000 feet above sea level.

This stretch of submerged coast between Tanavuso Point and Vitilevu Bay terminates almost as abruptly on the north as on the south. Immediately beyond the headland known as Supani on the north side of Vitilevu Bay a prominent cliffed spur marks the end of the deeply embayed coast. At this point the mountains swing westward, the coast line becomes somewhat straighter, and a strip of coastal plain appears. The north coast of Vitilevu has also been submerged in past time, but the evidence is not nearly so striking as for the region about Vitilevu Bay.

Na Singatoka-Nandi Plain

Unlike the Rewa Plain, the Na Singatoka-Nandi Plain is not an uplifted plain of nearly horizontal rocks. The rocks of the lower Na Singatoka and those of the Nandi and Sambeto valleys are highly tilted at many points, cut by important faults, and in a few places mineralized. The wide undissected flats along the Nandi and Sambeto rivers and the higher dissected flats to the east were certainly not developed by the two small streams that now cross them. Brock (11, p. 65) is doubtless right in suggesting that they are the result of sea erosion. The sheer face of the lower Thonoa Range certainly suggests wave erosion.

The Na Singatoka River, though second only to the Rewa in size, has built no large delta. From the decomposed crystalline rocks widely exposed in its basin it brings down a considerable volume of sand and gravel. The sands, as Foye (45, p. 14) has pointed out, are less cohesive above the low tide mark than are the muds brought down by the Rewa. They dry out quickly and are blown into dunes, many of them as high as 130 feet. The dunes form a belt about one quarter of a mile wide and under the influence of the prevailing trades are traveling northwest. Additional material for the dunes is the sand supplied by the erosion of granites exposed near sea level in the Sovi Bay area east of the mouth of the Na Singatoka and brought westward along the coast.

Foye also noted that corals form a fringing reef close to the mouth of the river, and that the channel is kept open only by the scour of the stream and tidal currents. He seems to infer that the absence of mud and silt is responsible for developing a fringing rather than a barrier reef. It seems probable, however, that the type of reef present is determined by other causes, but that the presence of the fringing reef makes the waves and shore currents more effective and tends to prevent delta formation. The barrier reef off the Navua River becomes a fringing reef to the west, but the change occurs long before the mouth of the Na Singatoka is reached.

Fifteen miles above its mouth the valley of the Na Singatoka is abruptly constricted by two ranges of hills at the landward edge of the plain (fig. 2). South of this constriction the stream flows through rolling grass and reed country where hills are rounded and gullies steep. The river itself, however, has reached a later stage of development. It has a broad flat, and near Nakambuta, 5 miles above its mouth, it has built up low natural levees. Outcrops are not numerous in this area. The rich soil of the Na Singatoka Valley is extensively cultivated, and numerous villages are scattered over the lower portion of the valley. (See pl. 4, *B*.)

Mba Plain

The Mba River, like the Rewa, drains an area of marls, tuffs, and weathered volcanoes; no crystalline rocks are known to outcrop in its basin. It brings tremendous quantities of mud to the sea. Its very large delta bears mangrove forests estimated by Mead (87, p. 17) to cover 12,000 acres, an area which greatly exceeds even that overgrown by mangroves on the Rewa delta and adjoining coast. In addition to the Mba, many of the smaller streams along the north coast have built deltas.

Much of the north coast of Vitilevu is bordered by a narrow strip of undissected, flat-lying land close to sea level and fringed with mangrove swamps. The flat is best developed between Lautoka and Na Rarawai, but even in this area its width, though showing considerable variation, rarely exceeds 2 miles. At intervals along the remainder of the north coast, from the Mba River eastward, there are small patches of coastal flat.

The "dissected plain" which lies west of the valley of the Mba is crossed by a number of ridges which extend seaward from the Thonoa Range. Agglomerate seems to be the dominant rock, but most of the area is covered by a deep mantle of red clay.

The valley of the Mba between the head of its delta and the gorge above Tonge where it enters the hills of the interior is developed in flat-lying marls not unlike those of the Rewa Plain, but the flats of the Mba are much less extensive than those of the Rewa and no terraces were noted.

East of the valley of the Mba a series of rolling, reed-covered hills lies between the Nandarivatu scarp and the sea. The scarp rises 2,000 feet above Waikumbukumbu and parallels the north coast for a distance of 15 miles. Though a very impressive feature today, it has apparently suffered considerable erosion. Many of the high hills which now lie north of the main scarp were once connected with it. Some of these hills show rude planes of stratification that probably represent the eroded edges of nearly horizontal flows such as those found in the main scarp. It seems probable that the Naloto Range once continued northeastward to join the northern portion of the Nakauvandra Range and that erosion is responsible for the present discontinuity. In this connection it should be noted that Koroimavua (3,200 feet) in the Naloto Range, Korondene (2,913 feet) and Yoo (3,456 feet) on the plateau of Tholo West, Natambuvakandua (2,254 feet) on the Mba Plain, and Ulunda (2,840 feet) at the northern tip of the Nakauvandra Range are in almost perfect alignment and that the northeast-southwest line thus formed may be continued to the southwest as the Naloto Range and to the northeast to Supani on the coast.

The hills north of the Nandarivatu scarp are composed mainly of agglomerate with minor amounts of tuffs and surface flows, but over much of this area the surface rock is deeply lateritized. The topography along the coast is in late maturity and near Ellington large areas are under cultivation. The Mba Plain Province includes some of the most valuable cane land on Vitilevu.

MOUNTAINS

Nakauvandra and Tikituru Ranges

The Nakauvandra and Tikituru ranges, combined with the centrally located Navosa Plateau, form the north-south backbone of Vitilevu. They have not been examined in many places. Woolnough (129, p. 464) found that the upper 1,000 feet of Muanivatu consists of a mass of pyroxene andesite which he thought might represent a sill but more probably a flow. He also stated (128, p. 478) that Tomanivi consists largely of tuffs and flows. It is possible, therefore, that coarse pyroclastics are not the dominant rocks in these ranges. Agglomerates, however, are widely developed in the upper Wailoa basin near Tomanivi and are present in a number of places in that part of the Nakauvandra Range which parallels the northeast coast. Tova Peak is formed by a dike which is intruded into the agglomerates of the range. The dike strikes parallel with the coast and the range and dips to the southwest at a high angle. Its exact trend could not be determined because on the summit of Tova the compass needle is deflected as much as 90 degrees in a distance of 25 feet.

Lokalevu and Mendrausuthu Ranges and Nakasavu Ridge

The Lokalevu Range is lower than most mountains on Vitilevu and its rocks are older than those of the other ranges. Sambeto volcanics outcrop in a number of places, and the abundance of Wainimala and Tholo boulders in the conglomerates that outcrop on the south flank of the range suggests that even older rocks may be exposed locally. This range is evidently one of the oldest physiographic features of the island. Its presence explains the unusual course of the Navua, which parallels the south coast for more than 20 miles before cutting southward to the sea.

The Mendrausuthu Range appears to be built almost entirely of coarse agglomerate. This structure, the general appearance of youth, and the exposure of rocks of the Older series in the high area immediately to the west, support the belief that the range marks an important fault along which the area to the west has been elevated, an interpretation first suggested by Woolnough. (See pl. 1, *A*.)

The Nakasavu Ridge, which lies north of the Waindina and connects the Mendrausuthu and Nambui ranges, has not been visited by geologists.

Nambui Range

The Nambui Range parallels the Mendrausuthu Range along a line 10 miles to the west. It may be seen to good advantage from points on the Navua Plateau. The most prominent feature of the range is the series of five peaks known as Koro Mbasa Mbasanga. Woolnough (128, p. 473), who climbed the most southern of these peaks, comments as follows:

> The most remarkable feature of the climb, which was very steep, was the complete absence of solid rock. Everything was rich soil, arising probably from the decomposition of the tuff, of which the mountain is largely built. Not a single outcrop, nor even a loose piece of rock, was met with all the way to within 200 feet of the saddle, where the base of a great precipice of agglomerate is seen some distance away. . . .
>
> The southern summit arises from the backbone of the mountain as a column, roughly elliptical in shape, some 150 to 200 feet in average diameter, and bounded by perpendicular cliffs at least 50 feet in height. The actual summit is quite another 50 feet higher. The height above sea-level of the base of the column is 3025 feet (aneroid). The rock of which this column is composed is agglomerate. The ground mass is made up of comminuted fragments of the rock supplying the larger fragments which are up to 6 feet in length. . . . Time and weather did not permit of the examination of the other peaks, but their structure is certainly identical with that of the one examined, and there is no doubt that the whole mountain is a huge volcano, or rather a line of closely packed sister cones. The summits represent the consolidated fragmental materials which filled the funnels when activity ceased.

In company with Messrs. Paine and Nott of Suva I attempted to climb the higher peak lying north of the one ascended by Woolnough. A start was made from the village of Wainimakutu which lies almost due west of the mountain. Without native guides and with only a short time available the party only succeeded in reaching an altitude of 3,010 feet. The climb was made through dense bush, and the only rocks encountered were boulders of tuff. A better approach to the mountain top is from Namosi or the town lying to the west.

From a fly camp near the base of the mountain the peak could probably be climbed in a day without difficulty.

The Nambui Range, like the Mendrausuthu Range, is composed mainly of pyroclastic material. Woolnough suggested that both ranges mark important faults and that the area between them has been uplifted as a horst. He pointed out that the trend of the main (east-flowing) Navua River is very nearly concurrent with that of the Waindina and suggested that prior to the postulated faulting the Navua continued eastward through the valley of the Waindina. He also described the low divide that now separates the two basins as a wide pass with a level floor bounded on the north and south by high cliffs similar in all respects to the cliffs which bound the gorges of the Mendrausuthu Range. Woolnough (129, pp. 445-447) interpreted this pass with its bordering cliffs as a former water gap recently elevated by faulting along the line of the Nambui Range. Cochrane (14, p. 6), on the other hand, considered the pass to be a great volcanic rent. Observations made during a brief examination of this area favor the explanation of Woolnough. One of the chief objections is the wide distribution of the rocks of the Older series in the area west of the postulated horst.

Namosi-Rewa Range

The highest peaks of the Namosi-Rewa Range are found in the western half of the mountainous belt which terminates in Vakarongasiu (Nakorolo) (fig. 3), a peak said by McCaw (85, p. 258) to be connected with Tonga, a higher double peak lying about 2 miles northeast by an eruptive dike. The eastern peaks of the Namosi-Rewa Range are 1,000 to 1,500 feet high. Rama (Joske's Thumb), the sharp spine which stands out so prominently across Suva harbor, is probably a volcanic neck, but Korombalevu, the most eastern summit of the range, has a broad, flattened summit. (See pl. 1, *B*.) A third peak, Korombamba, has two summits. The higher summit (1,408 feet) which lies near the coast between the Lami and Visari rivers is built up of agglomerates and tuffs. The agglomerates contain blocks up to 5 feet in diameter, most of them angular, and bedding is suggested by stringers of coarse tuffaceous material. The tuffs are coarse in texture and appear to overlie the main mass of the agglomerate. Some of them are conglomeratic. Others contain foraminifera.

An irregular mountain range said by McCaw to lie between the Waindina and Waimanu rivers is here included as the north-central part of the Namosi-Rewa Range (figs. 2, 3). Of the 7 or 8 summits in the range the 3 principal ones lie in a northeast-southwest line. Makaluva (2,018 feet) is the second highest of the three.

Naloto and Thonoa ranges

Very little is known of the Naloto Range. Cochrane (14, p. 8), who crossed it near its center, noted agglomerates with tuffs and stratified "soapstones," the finer sediments continuing to the top of the range at the point where the trail crossed. The upper Mba River, skirting the northeast end of the range, issues from the highlands between steep walls composed mainly of agglomerate.

The Thonoa Range reaches its highest point in Koro Yanitu (Mt. Evans). I ascended this peak along the steep trail which leads from the village of Navilawa in the Sambeto Valley to the main ridge at a point about ½ mile south-southwest of the summit, thence along the crest to the highest point. Much of the lower part of the climb was over a forested talus slope, but agglomerate was found in place at 1,500 feet and cliffs of the same rock just above the 2,600 foot level. Other outcrops appeared to be lava flows. Many of the large blocks along the trail are agglomerate, and numerous smaller ones are tuff. Koro Yanitu is not a peak but a high point on a ridge of the knife-edged type so common in the mountainous areas of Vitilevu. (See pl. 2, *A*.)

Cochrane (14, p. 4) noted the great cleft that divides Koro Yanitu and thought it due to faulting with the upthrow to the northeast. Such is quite possibly the explanation, for the bedding planes (or edges of flows?) seem to dip strongly into the cleft on the northeast side.

PLATEAUS

Tholo East

Nearly all of the plateau of Tholo East is drained by the Wainimala and the Wainimbuka Rivers. The Wainimala issues from the plateau through a water gap that marks the northern end of the Mendrausuthu Range. Between this point and the mouth of the Waisomo the stream flows through country that is not unlike that of the Rewa Plain. Tuffs and marls outcrop at a number of places, but some of the hills are composed of Viti limestone. The stream is fairly swift and contains numerous gravel bars. A flood plain is developed at intervals, and there are patches of higher terraces. At the mouth of the Waisomo the Wainimala meanders broadly. Above this point it is noticeably swifter and crossings are difficult. Beyond the village of Nasalia the valley walls are very steep, patches of valley flat are few, and the stream contains extensive bars of boulders. Near Laselevu the river turns abruptly, its valley stretching southwestward for a distance of 15 miles to its source in the heights between the Nambui and Tikituru ranges.

The Wainimala receives two important tributaries from the north, the Waisomo and the Wailoa. The Waisomo flows through a hilly country which is blanketed with red soil but shows a few outcrops of conglomerate, tuff, and altered volcanic rock. The valley of the Wailoa is narrow and gorgelike in its lower part but becomes more open a few miles above its mouth. A swift stream with numerous rapids, it flows through heavy bush and abundant clumps of bamboo. The tributary streams are numerous and swift, many of them have falls and rapids. The headwaters of the Wailoa and its tributaries are mountain torrents whose beds are choked with blocks of agglomerate and lava up to 25 feet in diameter. The streams are clear and very swift, pouring over boulders and rock jams in a continuous series of cascades and rapids. These streams have their sources in the amphitheater-headed valleys on the slopes of Tomanivi and the lower mountains which buttress it.

The Wainimbuka River issues from the plateau of Tholo East about 8 miles above its junction with the Wainimala. The river's bed at the edge of the plateau is only about 160 feet above sea level. The stream has an extremely narrow and discontinuous flood plain which lies 10 feet above normal river level. Remnants of a terrace on both sides of the stream lie 35 feet above the present valley flat. The village of Malambi stands on this terrace. The same terrace is present in the lower Wainimala valley and points to a recent uplift of 35 feet in this part of the island.

The valley of the Wainimbuka is youthful above Malambi, its banks rising 150 to 200 feet at an angle of 45 degrees. In the vicinity of Naloto, still farther upstream, the country is in maturity. Hills several hundred feet high border the main valley. Their lower slopes are cut by V-shaped valleys between which sharp spurs run out to the edge of the elevated terrace. The terrace itself is trenched by gullies. The higher slopes are heavily forested, but the lower slopes and the terraces are cleared and cultivated. There is no flat land on the intervalley divides; about nine tenths of the entire country lies at an angle of 45 degrees. Some of the higher slopes are very steep, but no cliffs were seen. Much of this part of the Wainimbuka Valley is underlain by agglomerate, but the Viti limestone is widely exposed.

Navua

The Navua Plateau includes the basin of the Navua River and its tributaries. The main Navua heads in the mountains at the southern end of the Tikituru Range, flows eastward parallel to the coast for a distance of 25 miles, then turns abruptly southward through a magnificent gorge to reach the sea. At the turning point it receives the Wainikoroiluva from the north, but this stream is much smaller than the main (east-flowing) Navua.

The Wainikoroiluva hugs the Nambui Range in its lower reaches and in this part of its valley is steep-walled. North of Nambui itself the valley is more open, but the stream continues fairly close to the highlands that lie eastward. Plutonic rocks are uncovered by the Wainikoroiluva, which is also mainly responsible for the large amounts of sand in the lower Navua.

The main Navua and its tributaries are engaged in dissecting a plateau underlain by soft, nearly horizontal beds of tuff, marl, and conglomerate. The streams are in earliest youth, and many flow through deep and narrow gorges whose walls are vertical. (See pl. 3, *B, C*.)

THOLO WEST

The plateau of Tholo West includes most of the basin of the Na Singatoka River and the upper part of the basin of the Mba. So deep and gorge-like are the upper tributaries of the Na Singatoka that natives living along them claim never to see the sun before 10 in the morning or after 4 in the afternoon. These valleys in the northern part of the province are cut in an enormously thick series of tuffs and marls which are level-bedded over wide areas. The series is largely marine, but deposition was interrupted from time to time by submarine lava flows. Since deposition the sediments have been intruded by sills of volcanic rock.

The upper Na Singatoka stays close to the eastern side of its basin. Near the center of the island its short tributaries from the Navosa Plateau expose plutonics and other rocks of the Older series at a number of points. Near Tawaleka the river is deflected northward in a great bend by a group of high hills. One of these, known as Koroiamaia, has a measured altitude of 2,023 feet. Having skirted these hills, the river resumes its course to the southeast and cuts through a considerable area of Viti limestone. High bluffs along the stream in this area are fantastically carved into knife-edged pinnacles and pierced by fissures and caverns of all sorts. The stream finally issues from the plateau near Tumbairata after passing through a constriction caused by a series of high hills on the east which trend westward toward the Koromba highlands.

The upper Mba River drains the northwestern quarter of the plateau of Tholo West. This part of the Mba valley has not been examined by any geologist but the drainage pattern is very unusual and, as Woolnough (129, p. 471) pointed out, suggests that the Mba has enlarged itself at the expense of the Na Singatoka. The Mba issues from the plateau through a steep-walled gorge at the northern end of the Naloto Range. The walls of the gorge rise 500 feet above the stream, vertical cliffs in the left bank exceeding 400 feet in height.

Navosa

No outcrops have been found on the high, flat surface of the Navosa Plateau. A few blocks of marl and volcanic rock were seen, but the surface is covered by a heavy clay which, over most of the plateau, supports a dense growth of forest. Sufficient exposures have been found on the sides of the tableland, however, to indicate that it is largely built up of level-bedded tuffs and marls.

REEFS

Description

The shores of Vitilevu are well protected by reefs. In most places the reef is a barrier, but in others it swings to the land and becomes a fringing platform. The reefs exhibit great diversity in size, configuration, and constitution. They are broad flats which in many places are easily accessible at low tide. The average width of the exposed flat exceeds half a mile and in a few localities the width is more than twice as great. The surf breaks heavily on the projecting seaward edge and pours over the marginal zone, which is not defended by a distinct *Lithothamnion* ridge. Colonies of living corals are abundant in many places near the seaward border and in the tide pools elsewhere. Viewed at close range they make a strikingly beautiful sight, but the reef as a whole gives the impression of a drab and featureless plain whose monotonously level surface is here and there broken by large blocks of blackened coral or by hummocks of finer debris. The tide pool depressions, nearly filled with water, do not detract from the general impression of levelness. (See pl. 5.)

In spite of much local variation a generalized section across the surface of the reef representative of most, if not all, of the reefs of the island can be constructed. In such a section, beginning at the seaward edge of the reef, the following zones occur:

1. A narrow, flattish marginal zone where corals are in places accompanied by calcareous algae.
2. A broader zone where *Acropora* is the dominant coral.
3. A zone where *Porites* replaces *Acropora*.
4. A broad flat which is scored by echinoid borings or silted over with sand and coarser reef debris.

Other zones of living corals are present in certain sections. In general there is a variety of living corals, but only rarely do they cover large areas of the reef.

The surges of the open sea spend their force upon the edge of the barrier, which is admirably constructed to withstand their attack. The seaward face of the reef is channeled and cavernous, so that the impact of each wave is spread over an exceedingly large surface. Heavy storm waves are able to tear giant blocks of rock from the reef margin, and these are sometimes cast upon the seaward part of the reef to form the well-known "nigger heads." On the reef surface they are soon riddled by boring organisms and eventually battered to pieces by heavy surf. The ordinary waves being weaker than the storm surges and lacking tools with which to work, do little to modify the reef front. Small fragments which they may dislodge from the reef margin may sink beneath the overhanging reef edge, be jammed into crevices (and cemented there), or, as frequently happens, they may be carried landward to come to rest on the broad reef flat, in a tide pool or in the lagoon itself. The lagoon is really a great settling basin which eventually receives all sediments.

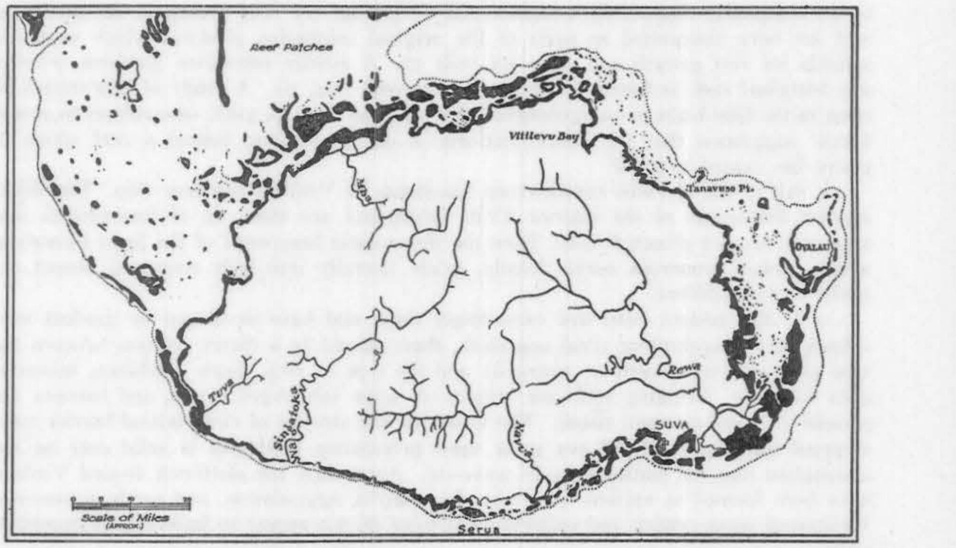

FIGURE 9.—Sketch map of Vitilevu, showing distribution of reefs. Dotted line marks depth of 100 fathoms. (Data from British Admiralty chart.)

None of the reefs of Vitilevu are in a flourishing condition today. Living corals are restricted to rather definite zones, on many reefs to a narrow marginal zone. Even in these restricted zones no close relationship between corals and algae exists, such as may be seen in other parts of the Pacific. For example, on the west side of Apia harbor the marginal zone is a mass of living *Acropora*—the colonies tightly cemented together and partially overgrown with living nullipores.

ORIGIN

It seems certain that no one of the several theories for the origin of coral reefs can explain satisfactorily all of the reefs of Vitilevu. The reef rock seems to form but a relatively thin veneer over the surface of preëxisting platforms. This belief is supported by several types of evidence, which may be briefly stated as follows:

1. The observed thinness of dead fringing reefs in the Suva area. About 1 mile south of Suva Post Office a dead and eroded fringing reef is exposed at low tide. The reef is more than 400 feet wide near the edge of the lagoon, its general direction is N. 15° E., but as it approaches the land it curves almost due north and ends on shore a few rods from the old Fiji Museum building. It rests directly upon the gently dipping marls of the Suva formation, which outcrop on the tidal flat between the reef and the shore. A dead fringing reef very similar to the one south of Suva is exposed on the north side of Suva harbor, and Setchell tells me that a reef of this same type was encountered during the construction of the dock at Suva. After boring for a distance of about 20 feet the drills suddenly went through into softer muds.

2. The submerged platform forming the lagoon floor to the northwest of Vitilevu is not completely rimmed by a barrier reef. (See fig. 9.) The breaks in the encircling reef are here interpreted as parts of the original submarine platform which were not suitable for reef growth and were not built up. A similar submarine platform, without any marginal reef, is found off the northeast coast (fig. 9). A study of this stretch of coast in the field leads to an agreement with Vaughan (112, p. 310), who refuses to accept Davis' suggestion that the entire platform is due to infilling behind a reef which in places has ceased to grow.

3. All of the elevated coralliferous limestones of Vitilevu are very thin. The thick, massive limestones of the interior (Viti formation) are made up of foraminifera and algae and are not elevated reefs. Even the thin coastal limestones of the Suva formation, which contain numerous corals locally, grade laterally into beds composed almost entirely of foraminifera.

4. If the modern reefs are exceedingly thick and have developed by gradual subsidence and compensating coral upgrowth, there should be a direct relation between the type of coast (submerged or emerged) and the type of reef. Such a relation, however, does not exist. Fringing reefs are present off some submerged coasts, and barriers are present off some emerged coasts. The view that the absence of cliffs behind barrier reefs is proof that the reefs did not grow upon preëxisting platforms is valid only on the assumption that the platforms were wave-cut. Apparently the platforms around Vitilevu have been formed in various ways—by degradation, aggradation, and earth movements. Pleistocene wave-cutting and uniform subsistence do not appear to have played important parts.

ECONOMIC GEOLOGY

LIMESTONE, SAND, AND CLAY

Limestone like that quarried for road metal at Tamavua and Lami has been found at a number of places in the Suva district but is not widely distributed. A limestone similar to that at Tamavua is quarried at Ravuka but except for patches near Natuatuathoko was not seen elsewhere on the island. The widely distributed Viti limestone is also suitable for road metal. Basalt and diabase are quarried for road-building at Nasinu and near-by places and are common elsewhere.

No deposits of pure silica sand are to be found on Vitilevu. The extensive deposits of river sand, which are piled into dunes west of the mouth of the Na Singatoka, contain a considerable amount of angular quartz, but also large amounts of magnetite and ferro-magnesian minerals. The sands of the north side of Suva harbor locally show a high percentage of clear angular quartz and are nearly free of magnetite. They contain, however, considerable amounts of ferro-magnesian minerals and some calcareous material and grade laterally into shelly rubble composed almost entirely of calcium carbonate. Impure calcareous beach sand is found along the south coast, west of the Navua, and a comparatively pure calcareous sand at Savusavu, on the west coast. Elsewhere, due to the prevalence of agglomerates, tuffs, and marls, the coastal deposits contain little sandy material.

Attempts to make good brick from the clays on the island have thus far been unsuccessful, but the materials have not been systematically tested. Likewise the materials for making cement have not been investigated, but there is reason to believe that they could be found.

COAL

The prospects of finding workable seams of coal on Vitilevu are not promising. Thin seams of lignite and fragments of carbonized logs have been found at a number of places in the tuffs and marls of the Suva formation, but apparently the land was not stable for a sufficiently long time; or, if this condition was met, there was not sufficient growth of vegetable matter to allow for the accumulation of the great thicknesses of peat that are essential for coal formation. Furthermore, many of the Younger sediments on Vitilevu were laid down in salt water and were rapidly accumulated. Workable coal deposits are notably rare in tropical islands, though small deposits of Tertiary lignites and bituminous coals are widely distributed in the Philippines (49, 42, 43). Wentworth (120, p. 16) and Christophersen (13, pp. 45-56) have described a modern peat on Washington Island. So far as known, the "coal seams" reported by natives on Vitilevu have no commercial value.

PETROLEUM

From time to time there has been speculation regarding the possibilities of finding oil in Vitilevu. It is reported that a shallow well was drilled as a dry hole on the left bank of the Rewa River about 3 miles above Nanduruloulou, but it appears very unlikely that commercial deposits of petroleum will ever be found on the island, for the following reasons:

1. There are no rocks from which the oil might have been derived. The sediments of the Older series are thin and show no trace of organic matter. In most places the rocks of the Younger series are barren of fossils and elsewhere show little evidence that considerable quantities of organic matter have been preserved. They contain a few thin seams of lignite and bits of carbonized wood, and fragmentary plant remains in the form of carbonaceous films are abundant on many of the bedding planes; but no bituminous matter has been found. In this connection it should be borne in mind that only a small part of the Younger series accumulated slowly as sediments resulting from erosion. Most of them are the result of volcanic eruptions which allowed little time for the incorporation of organic matter.

2. The reservoir rocks are not ideal. The true sandstones in the Older series have been rendered exceedingly dense by metamorphism. In the Younger series some of the tuffs are sandy and some of the marls, agglomerates, and lenticular limestones are quite porous. If other conditions were favorable, these rocks might serve as reservoirs and such rocks as the widespread lava flows as impervious caps.

3. Structural conditions are unfavorable. Over much of Vitilevu the rocks of the Younger series lie horizontally or dip seaward at very low angles. No folds capable of serving as oil structures have been located, though detailed mapping might reveal them. In general, folding seems to be subordinate to faulting, but some of the faults may have sealed the upper ends of monoclinal beds, thus creating reservoirs.

4. The total thickness of the Younger series is probably not great. Most of the large rivers of Vitilevu have exposed the plutonic core of the island. The faults may well have served, therefore, as avenues of escape for any oil in the Younger series rather than as channels of migration which might bring oil from deeply buried horizons to reservoirs nearer the surface.

5. No active oil seeps, impregnations, or gas seeps have been found. If extensive deposits of petroleum existed, some indications of oil should have been found in the faulted areas. Cochrane (14, pp. 15-16) mentions "petroleum scum" at Namena and in the Rewa district, but attaches little significance to it. The only scums seen during the course of the present survey were the ferruginous films common in swampy areas where there is much decomposing vegetation.

THERMAL SPRINGS

Thermal springs have been reported from several Fijian islands. The list given by Guppy (55, pp. 21-22) includes Vanualevu, Ono, Kandavu Ngau, Rambi, and Vanua Mbalavu. The best-known springs are those at Savusavu, on Vanualevu, a recent analysis of which has been published by Wright (130, pp. 5-7). For Vitilevu the preliminary descriptions of hot springs by Macdonald (76) at "Na Seivau" (Naseuvou) and that near Waimbasanga by Horne (64, p. 163) have been followed by fuller accounts.

The following list includes the hot springs visited during the present investigation; from some, samples of water were collected. Reports of numerous other springs indicate general distribution over the island. As shown by the analyses (Table 2), the waters of hot springs on the islands of Ngau and Vanualevu differ considerably from those on Vitilevu. The analysis for Savusavu agrees fairly well with one published by Wright (130), except that Wright lists no iron, aluminum, and phosphoric acid. The water from Waikana is described as "clear," "slight organic" sediment, with strong odor of H_2S; that from Savusavu as lacking in sediment and odor.

1. Sambeto. Right bank of Sambeto River, 2 miles inland, altitude 95 feet; issues from soil; forms pool 2 feet across, 4 inches deep, surrounded by area of marshland 10 by 30 feet.

2. Mba. Mouth of Mba River, on coast of Namaka Island; sea level; issues from soil; irregular leaf-filled pool 10 by 20 feet with a depth of 8 feet; few gas bubbles given off; water salty, owing probably to infiltration of sea water.

3. Tavua. Right bank Nasivi River, 3 miles inland, altitude 125 feet; issues from series of openings in middle of a field; spring area artificially walled in with banks of earth to form a subcircular bog about 100 yards in circumference; abundant growth of plants, surface of water covered by thick film of greenish-yellow slime; some gas given off; water too hot for hand, and natives claim the spring sometimes boils up a foot or more.

4. Mbusa (lower spring). One-fourth mile west of Mbusa River, 2 miles inland, altitude 200 feet; issues from altered granite (Tholo plutonics) from two openings 15 feet apart; water just cool enough to permit the hand to be immersed indefinitely without discomfort; rock shows evidence of crushing.

5. Mbusa (higher spring). On tributary to Mbusa River about 1½ miles N. 20° W. of lower Mbusa spring, altitude 400 feet; water issues at several points, two of which are in altered granite; rock bluish white, decomposed, shows slickensides; water too hot for hand, has slight mineral taste.

6. Waimbasanga (lower spring). Left bank Wailato River, 23½ miles inland close to village of Waimbasanga, altitude 430 feet; issues from soil; water just too hot for hand; faint odor of hydrogen sulphide.

7. Waimbasanga (higher spring). Left bank Wailato River, ¼ mile above lower spring close to the contact between Wainimala and Suva rocks, altitude 430 feet; issues from basalt (Suva formation); slight mineral taste; water hotter than lower spring; growth of brown mossy plants around rim of spring.

8. Naseuvou (southern spring). Left bank of Waindina River, 24 miles inland, altitude 250 feet; issues from fissure in andesite (Sambeto series) rock fractured, the cracks filled with some hydrothermal mineral; water just cool enough to permit the hand to be immersed indefinitely.

9. Naseuvou (northern spring). Left bank Waindina River, about ¾ mile N. N. W. of southern spring, altitude 250 feet; issues from andesitic agglomerate (Sambeto series); marshy ground surrounds openings; water too hot for hand, temperature recorded by Macdonald (76, p. 250) as 106° and 140° F.

Guppy (55, pp. 42-43) found thermal springs in 23 localities on the island of Vanualevu. Most of them were situated along stream courses or on tidal flats; all lay below an elevation of 300 feet, and all were confined to the areas of basic rocks. These facts led Guppy to believe that the springs were largely supplied from the "soakage" of the heavy rainfall in the moun-

Table 2. Analyses of Hot Waters from Fiji.

(Analysis furnished by Colin L. Southall, Government Chemist)

	Sambeto	Mba[a]	Tavua	Mbusa (lower)	Mbusa (higher)	Waimbasanga[b]	Wakima, Ngau	Nakama, Savusavu, Vanualevu
$MgCO_3$	3.1	....	4.4	0.5	1.1	........?	....	....
$CaCO_3$	....	....	25.4	2.0	2.8	....	16	....
$CaSO_4$	106.9	81.6	51.0	1.8	4.1	78.9	Trace	35.2
Na_2SO_4	....	....	37.8	13.1	10.9	36.4[c]	....	....
$NaCl$	117.4	467.0	52.0	3.1	3.8	14.0 }		319.7
$CaCl_2$	17.8	394.0	....	....	....	.... }	46	451.8
$MgCl_2$	15.7	10.9	....	....	....	.... }		1.9
H_2S	....	....	....	....	....	....	4	....
H_3PO_4	....	....	....	....	....	....	....	Trace
Iron	....	....	....	....	....	....	Considerable	Trace
Silica	....	....	....	....	....	....	Trace	14.9
Aluminum	....	....	....	....	....	....	....	Considerable
Total solids, Parts per 100,000	260.9	953.5	170.6	20.5	22.7	129.3	16 Organic 62 Mineral	851 Mineral

[a] Probably contains some sea water; a trace of iodine is present.
[b] Neutral to litmus.
[c] Magnesium and alkali sulphates.

tains. On Vitilevu, though hot springs have been found in only six localities, it is obvious that generalizations similar to the above will not hold. With the exception of those at Mbusa, all the springs lie close to fairly important streams, but 2 of the 6 springs issue at elevations of 400 feet or more and the springs are not confined to areas of basic rock. It seems probable that some of the hot springs on Vitilevu, particularly the Mbusa springs, which issue from crushed and slickensided granite, are fed by hypogene waters which migrate upward along fault planes from considerable depths. The Mba spring, on the other hand, issues at the edge of a tidal flat in an area where there seems to be no evidence of major faulting. The Waimbasanga springs are situated close to the contact between the Older and the Younger rocks. Further generalizations as to the origin of Vitilevu's springs must await additional data.

SOILS

In two short accounts Wright (131, 132) has described many types of Fijian soil from Vitilevu. He reports that the marls of the southeastern part yield a red and a black soil. In some places the red soil occupies the higher elevation. In others the black is found above the red. In general, the red soils are thick, the black thin, and over large areas bare marls outcrop at the surface. Weathering of volcanic rocks in place gives rise to red lateritic materials.

METALS

Rocks on Vitilevu show slight mineralization, and though no deposits of economic value have yet been discovered the outlook is by no means unpromising. The island has not yet been systematically and thoroughly prospected.

One of the minerals most commonly reported is copper, which appears as sulphides (chalcopyrite and bornite) in the volcanics of the Sambeto series. In the upper Sambeto Valley where these rocks are shattered, faulted, and are almost invariably altered apparently by hot solutions, the copper sulphides and pyrite, together with malachite and other secondary copper minerals, are present in the andesites. Similar mineralization has been observed in these rocks elsewhere.

Traces of gold have been found in the valley of the Waimanu and in the Sambeto-Nandi area, but thus far no rich deposits have been located. As shown by Henderson (60), conditions on the nearby island of Vanualevu are more promising.

Small amounts of other minerals have also been reported, but copper and gold appear to be the most likely prospects. Areas underlain by the Sambeto series should be given careful attention. There is also the possibility of finding valuable deposits in areas where the Tholo plutonics cut the older Wainimala rocks.

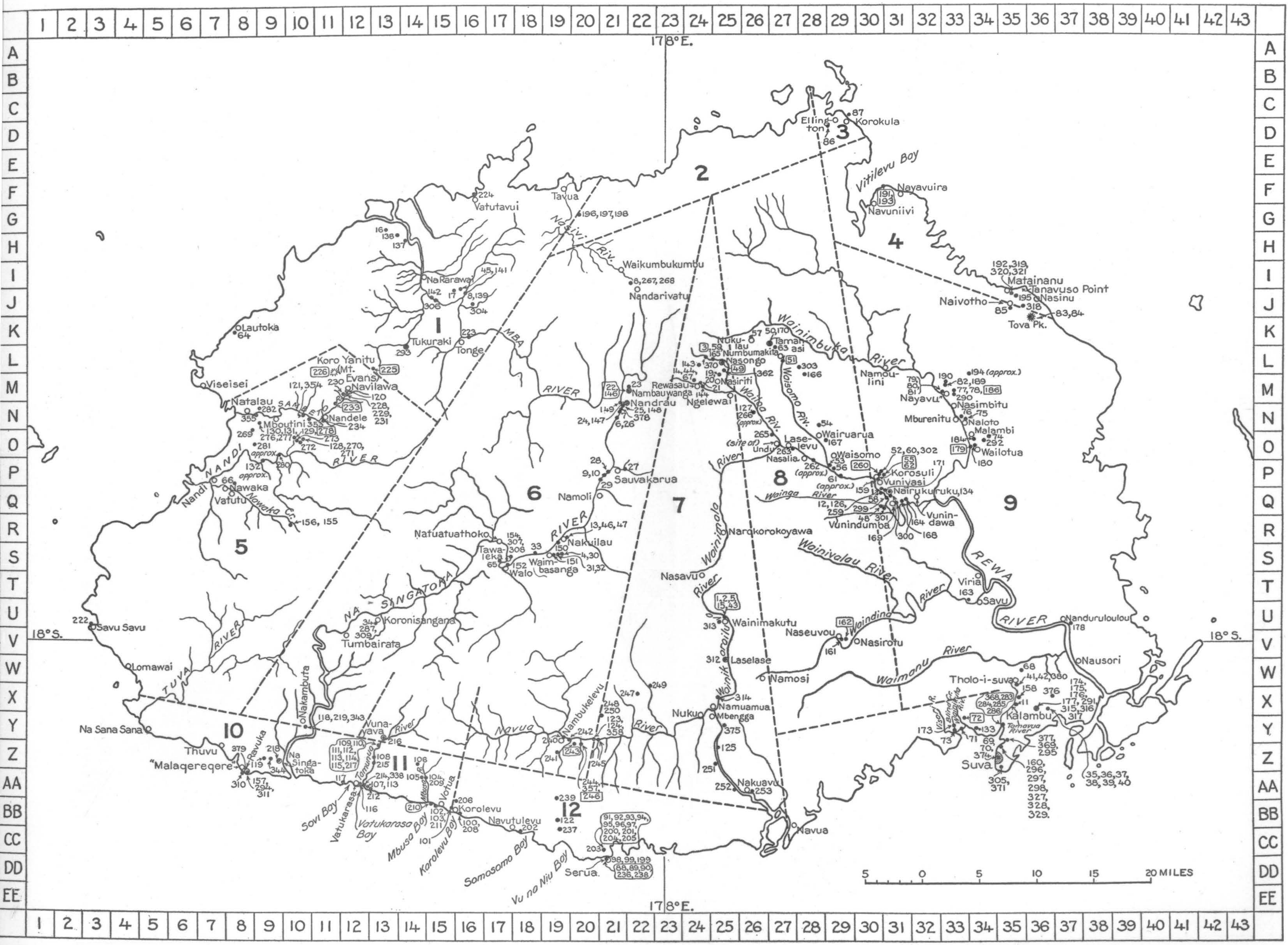

FIGURE 10.—Map of Vitilevu, showing stations where specimens were collected. At stations where the sample was not found in place the station number is encircled. The large num-

LIST OF STATIONS

All stations from which fossils or rock samples were collected are listed below. The cöordinates, in the second column, indicate the position of the stations on the maps (figs. 4, 10). The elevations given record the altitude of the base of the outcrop above sea level.

1, 2	(25-U).	Near Wainimakutu; boulder in Wainikoroiluva River.
3	(25-L).	Wailoa River, about 1 mile west of Nasongo, boulder; elevation about 990 feet.
4	(19-S).	Right bank of Wailato River (tributary to Na Singatoka), about 1 mile above Waimbasanga, elevation 500 feet.
5	(25-U).	Same as Station 1.
6, 7	(21-N).	Upper Na Singatoka River, ¾ mile below mouth of tributary that flows past Nandrau; elevation 1,275 feet.
8	(22-I).	Along road that climbs Nandarivatu scarp between Waikumbukumbu and Nandarivatu; elevation about 1,625 feet.
9, 10	(21-P).	Right bank of Na Singatoka River 1¾ miles above Namoli; elevation about 880 feet.
11	(35-X).	Abandoned quarry 5 miles from Suva, on the Prince's Road to Nausori; elevation 355 feet.
12	(31-Q).	Left bank of Wainimala River about ¼ mile above Nairukuruku; elevation 205 feet.
13	(19-R).	Nakuilau, upper Na Singatoka basin; elevation 410 feet.
14	(24-M).	In creek crossed by Nasongo-Rewasau trail immediately below Rewasau, outcrop a few rods above trail crossing; elevation 945 feet.
15	(25-U).	Same as Station 1.
16	(13-G).	On road to Lautoka, 5½ miles from bridge over Mba River.
17	(15-J).	Three miles southeast of Na Rarawai.
18	(16-J).	About 4 miles southeast of Na Rarawai.
19, 20	(25-M).	About 1 mile out of Nasongo, on trail to Rewasau; elevation about 1,120 feet.
21	(24-M).	Left bank of creek which is crossed by Nasongo-Rewasau trail immediately below Rewasau; vertical face 40 feet high exposed a few rods below trail crossing; elevation 795 feet.
22	(22-M).	Along stream immediately above village of Nambauwanga; sample from 25-foot boulder at elevation of 2,010 feet (rock in place at a higher elevation).
23	(22-M).	A short distance north of Nambauwanga, in the right valley wall of a tributary to the Na Singatoka.
24	(22-N).	Nandrau; elevation about 2,000 feet.
25	(21-N).	About ½ mile southwest of Nandrau, in right bank of tributary to Na Singatoka; elevation 1,415 feet.
26	(21-N).	Na Singatoka River ¾ mile below mouth of Nandrau tributary; elevation about 1,275 feet.
27	(21-P).	About ½ mile above Sauvakarua on small stream known as Solikana.
28	(21-P).	Na Singatoka River, about 2 miles north of Namoli; high bluff on right bank; elevation of base of outcrop about 900 feet.
29	(21-P).	Right bank of Na Singatoka about 1½ miles above Namoli; elevation about 855 feet.

30	(19-S).	Left bank of Wailato River (a tributary to the Na Singatoka) about 1 mile west of Waimbasanga; elevation about 500 feet.
31, 32	(19-S).	Left bank of Wailato River (a tributary to the Na Singatoka) about ¾ mile west of Waimbasanga; elevation about 490 feet.
33	(18-S).	Right bank of Na Singatoka River about 1¼ miles below Waimbasanga; small outcrop along trail.
34	(13-U).	Koronisangana, on the Na Singatoka River; rock oucrops below limestone in lower portion of prominent bluff on left bank of river; elevation of base of outcrop about 335 feet (260 feet above river); thickness of 20 feet exposed.
35	(36-X).	Nasinu quarry, 6 miles northeast of Suva; sample from near base of exposed portion of lower flow.
36	(36-X).	Same as Station 35; sample from upper portion of lower flow.
37	(36-X).	Same as Station 35.
38	(36-X).	Same as Station 35.
39	(36-X).	Same as Station 35; sample from cracks in upper surface of lower flow.
40	(36-X).	Same as Station 35; sample from upper of two flows.
41, 42	(35-W).	Quarry near Tholo-i-suva, some 9 miles from Suva, on Prince's Road to Nausori; elevation 505 feet.
43	(25-U).	Same as Station 1; boulder.
44	(24-M).	Same as Station 14; elevation about 950 feet.
45	(16-J).	About 3½ miles southeast of Na Rarawai.
46	(19-R).	Same as Station 13.
47	(19-R).	Same as Station 13.
48	(3-Q).	Gorge of Wainga River several hundred yards above river's mouth.
49	(25-L).	Village of Nasongo; boulder from elevation of 820 feet.
50	(27-K).	Close to Tamanasi, about 1½ miles out of Numbumakita en route to Nasongo; large block in tributary to Waisomo; elevation about 905 feet.
51	(27-L).	Near Numbumakita; pebble from Waisomo River.
52	(30-P).	Hill close to Korosuli; outcrop in creek bed; elevation about 290 feet.
53	(29-P).	Left bank Waisomo River, a few rods above its mouth; elevation about 225 feet.
54	(28-N).	About 1 mile out of Wairuarua, en route to Numbumakita; elevation about 290 feet.
55	(31-P).	Hill near village Korosuli; boulder.
56	(29-P).	On trail between Korosuli and Waisomo, hill on left bank of Wainimala River, immediately below mouth of Waisomo River; elevation about 365 feet.
57	(26-K).	Close to Nukulau, about 3 miles northwest of Numbumakita; outcrop in tributary to Waisomo; elevation 1,120 feet.
58	(30-Q).	Right bank of Wainimala River about ¼ mile above Nairukuruku; vertical cliff, about 170 feet high, rising from point a few feet above the river; elevation of base of outcrop about 200 feet.
59	(25-L).	Right bank of Wailoa River about 1 mile west of Nasongo; elevation 995 feet.
60	(30-P).	Hill near Korosuli; elevation about 350 feet; rock may not be in place.
61	(29-P).	Wainimala River, below mouth of Waisomo.
62	(31-P).	Same as Station 55; boulder.
63	(27-L).	About 1 mile out of Numbumakita, en route to Nasongo; 25-foot exposure in tributary to Waisomo; elevation 895 feet.

64 (8-K). Immediately south of Lautoka, on road to Nandi; 25-foot exposure.
65 (17-S). Left bank of Na Singatoka between Walo and Tawaleka.
66 (8-P). North side of Nawaka Creek, about 1 mile north of Vatutu; elevation about 60 feet.
67 (24-M). Same as Station 14; elevation about 950 feet.
68 (35-W). Abandoned quarry 10 miles from Suva, on Prince's Road to Nausori.
69 (35-Z). Suva.
70 (35-Z). Knollys Street, near the center of Suva.
71 (35-Y). Along coastal road northwest of Suva, about ½ mile east of Blind Creek; elevation 5 feet.
72 (33-Y). In left tributary which joins Wainikuta about ½ mile above its mouth; boulders.
73 (33-Y). Left bank of Blind Creek at landward edge of mangrove swamp; exposure just above sea level.
74 (34-Q). Wailotua Cave, about 1½ miles northeast of village of Wailotua; 45-foot face whose base lies about 140 feet above sea level.
75 (33-N). On Wailoa Creek about ⅜ mile above its mouth; 25-foot exposure; elevation 210 feet.
76 (33-N). Along trail north of Naloto, in left valley wall of Wainimbuka River; elevation about 135 feet.
77 (33-M). In Waisomo River where Naloto-Nayavu trail crosses stream; elevation about 200 feet.
78 (33-M). Short distance upstream from Station 77.
79 (33-M). Village of Nayavu; thickness of 100 feet exposed; sample from upper half of outcrop; base of section 170 feet above sea level.
80 (33-M). Same as Station 79; sample from lower half of section.
81 (33-M). Right bank Waisomo River at junction with the Wainimbuka, eastern edge of Nayavu; 10-foot exposure.
82 (33-M). About 1 mile north of Nayavu; 15-foot exposure along trail; elevation 240 feet.
83 (36-J). Higher of two summits of Tova Peak; elevation 2,122 feet.
84 (36-J). Tova Peak along trail some 300 feet below summit; elevation about 1,820 feet.
85 (35-J). Hill immediately south of Naivotho.
86 (29-D). About 1 mile southwest of Ellington; in bed of small stream south of Ellington-Penang Railroad track; elevation 200 feet.
87 (29-C). Between Ellington and Korokula; exposure on tidal flat.
88 (21-DD). Island of Serua; boulder on shore.
89 (21-DD). Same as Station 88; boulder on shore.
90 (21-DD). Same as Station 88; boulder on shore.
91 (21-CC). Mboalu Creek, a right tributary to Talenawa River, near its mouth, immediately west of the island of Serua; boulder; elevation 450 feet.
92 (21-CC). Same as Station 91; boulder; elevation 330 feet.
93 (21-CC). Same as Station 91; boulder; elevation 250 feet.
94 (21-CC). Same as Station 91; boulder; elevation 250 feet.
95 (21-CC). Same as Station 91; boulder; elevation 250 feet.
96 (21-CC). Same as Station 91.
97 (21-CC). Same as Station 91.
98 (21-DD). Same as Station 88; from boulder in conglomerate at sea level.
99 (21-DD). Same as Station 88; from boulder in conglomerate at sea level.
100 (16-BB). East shore of Korolevu Bay, outcrop at landward edge of beach.
101 (15-BB). Western shore of Korolevu Bay, 15-foot sea cliff.

102	(15-BB).	Along shore between Votua and head of Mbusa Bay.
103	(15-BB).	Same as Station 102.
104	(14-AA).	Valley of Mbusa River 2 miles above mouth; thickness of 30 feet exposed, base 30 feet above sea level.
105	(14-AA).	About ¼ mile west of Mbusa River about 2 miles from the south coast; elevation 200 feet.
106	(14-Z).	About 3½ miles N. N. W. of mouth of Mbusa River, outcrop along tributary to Mbusa; elevation 400 feet.
107	(12-AA).	Along east shore of Vatukarasa Bay, about 100 yards from tip of Vatuvula Point.
108	(13-Z).	Left bank of Tamunua River, 2¾ miles from south coast; elevation 60 feet.
109	(13-Z).	Tamunua River, about 4 miles from south coast; boulder.
110	(13-Z).	Same as Station 109; boulder.
111	(13-Z).	Same as Station 109; boulder.
112	(13-Z).	Same as Station 109; boulder.
113	(13-Z).	Same as Station 109; boulder.
114	(13-Z).	Same as Station 109; boulder.
115	(13-Z).	Same as Station 109; boulder.
116	(12-AA).	Immediately east of Vatukarasa; elevation 75 feet.
117	(12-AA).	Along shore ¼ mile west of west headland of Sovi Bay.
118	(10-Y).	Along road on right bank of Na Singatoka, near Nakambuta; elevation 105 feet.
119	(9-Z).	About 1 mile west of Government Station at Na Singatoka; rock caps high bluff along Na Singatoka River; sample from talus blocks.
120	(12-M).	In tributary to Sambeto River at Navilawa; elevation about 900 feet.
121	(10-N).	Along trail on left bank of Sambeto River at point 2 miles west of Nandele; elevation about 220 feet.
122	(19-BB).	In bed of Mbosiwa River about 2 miles above mouth (Mbosiwa reaches south coast at head of Vu na Niu Bay); elevation 265 feet.
123, 124	(20-Y).	Head of gorge of upper Navua River, 2¾ miles east of Nambukelevu; elevation about 345 feet.
125	(25-Z).	Immediately below Namato Rapid at head of gorge on lower Navua River, about 2½ miles S. S. E. of Mbengga.
126	(31-Q).	Left bank of Wainimala River about ¼ mile above Nairukuruku; elevation about 220 feet.
127	(26-N).	Near mouth of Waikuru River, a right tributary to the Wailoa, where Laselevu-Ngelewai trail crosses Waikuru.
128	(10-O).	About 2¾ miles southwest of Nandele; outcrop in creek; elevation 175 feet.
129	(10-O).	About 2¼ miles southeast of Mboutini; elevation about 200 feet.
130, 131	(9-N).	About 1½ miles southeast of point where main road leading south from Lautoka crosses Sambeto River; thickness of about 30 feet exposed.
132	(9-P).	Lower Nandi River; pebble.
133	(34-Y).	Lami Quarry, on the coast 3 miles northwest of Suva.
134	(31-Q).	Left bank of Wainimala River at Nairukuruku; elevation about 210 feet.
137	(14-H).	About 3½ miles from bridge over Mba River on Na Rarawai-Lautoka road; 18-foot road cut.
138	(13-H).	About 4¼ miles from bridge over Mba River on Na Rarawai-Lautoka road; 8-foot road cut.

139 (16-J). About 4 miles southeast of Na Rarawai; 6-foot exposure along road.

141 (16-J). About 3½ miles southeast of Na Rarawai; along road, 125 feet south of Station 45.

142 (15-J). Right bank of Mba River 2 miles south of Na Rarawai; 6-foot outcrop about 40 feet above river level.

143 (24-L). About 2 miles from Nasongo on trail to Nandarivatu; elevation about 2,175 feet.

144 (24-M). In creek crossed by Nasongo-Rewasau trail immediately below Rewasau; outcrop downstream from trail crossing and Station 21.

146 (22-M). Along stream immediately north of Nambauwanga; sample from blocks on talus slope.

147 (22-N). Nandrau; elevation 2,000 feet; a few rods from Station 24, which stratigraphically directly underlies beds at Station 147.

148 (21-N). Right bank of tributary to upper Na Singatoka River ½ mile below Nandrau; elevation 1,415 feet.

149 (21-N). Upper Na Singatoka River, 300 yards above mouth of tributary that flows past Nandrau; elevation about 1,320 feet.

150 (19-R). Left bank of Na Singatoka River about ½ mile below Nakuilau; 50-foot face exposed, base 390 feet above sea level.

151 (19-S). Left bank of Wailato (a tributary to the Na Singatoka), ¼ mile west of Waimbasanga; elevation 430 feet.

152 (17-S). Right bank of Na Singatoka River immediately west of Walo; 25-foot exposure, base 25 feet above river.

154 (17-S). Above cave near Tawaleka.

155 (10-R). Right bank of Nawaka Creek about 6½ miles southeast of village of Nawaka; elevation about 515 feet.

156 (10-R). Same as Station 155; rock in place in wall of small cavern; elevation about 335 feet.

157 (8-AA). On beach at Ravuka.

158 (35-X). Abandoned quarry 6¼ miles from Suva, on Prince's Road to Nausori; elevation about 555 feet.

159 (30-P). Along trail ½ mile beyond Vuniyasi, en route to Korosuli.

160 (35-Z). Abandoned quarry on south side of Walu Bay, near entrance; a few feet above sea level.

161 (29-V). Naseuvou, on the Waindina River; elevation 250 feet.

162 (29-V). Along trail between Nasirotu and Naseuvou; boulder.

163 (33-U). Left bank of Waindina River about 1½ miles above Savu; elevation 80 feet.

164 (31-Q). Along trail on left bank of Wainimala, about 1 mile west of Vunindawa.

165 (25-L). A few yards upstream from Station 59; 2 or 3 feet exposed for distance of 30 feet at water's edge; beds probably overlie those of Station 59.

166 (28-M). About 6½ miles beyond Wairuarua, en route to Numbumakita; outcrop in small creek; elevation about 740 feet.

167 (29-O). Along trail about 1½ miles beyond Waisomo, en route to Wairuarua; elevation about 355 feet.

168 (31-Q). Along trail at top of small hill about 1½ miles west of Vunindawa; elevation 235 feet.

169 (31-Q). Immediately above village of Nairukuruku, on trail to Vunindawa; elevation 350 feet.

170 (27-K). Same as Station 50; rock in place; elevation about 905 feet.

171 (31-Q). Along trail near Nairukuruku.

173 (33-Y). Outcrop at fork in Blind Creek ½ mile above mouth of creek.

174	(36-X).	Upper (north) entrance to cave at Kalambu; 6-foot exposure; elevation about 85 feet.
175	(36-X).	Same as Station 174; 15 feet exposed above beds of Station 174.
176	(36-X).	West side of lower (south) entrance to cave at Kalambu; elevation about 85 feet.
177	(36-X).	Same as Station 174; 20 to 25 feet overlies beds of Stations 174 and 175; elevation about 106 feet.
178	(37-U).	Left bank of Rewa River ½ mile southeast of Nanduruloulou; 15-foot road cut whose base lies about 25 feet above river level; elevation about 50 feet.
179	(34-O).	Wainimikuta River at Wailotua; gravel from river.
180	(34-O).	Left bank of Wailotua River near junction with the Wainimbuka; 6-foot exposure at water's edge; elevation 120 feet.
184	(34-O).	Along trail immediately south of Malambi; 5-foot outcrop, in tributary to Wainimbuka River.
186.	(33-M).	Short distance upstream from Station 77; boulder from stream; elevation about 210 feet.
189	(33-M).	Same as Station 82; elevation about 240 feet.
190	(33-M).	A few rods north of Station 82; elevation about 280 feet.
191	(30-F).	Along shore of Vitilevu Bay about halfway between Nayavuira and Navuniivi; large block from cliff.
192	(35-J).	Along trail between Naivotho and Matainanu; 15 feet exposed; elevation 245 feet.
193	(30-F).	Same as Station 191; probably not in place.
194	(34-M).	In Wailou River, a left tributary to Wainimbuka, where Naloto-Matainanu trail crosses stream; elevation about 195 feet.
195	(35-J).	Along trail between Matainanu and Nasinu, near coast N. 35° W. of Tova Peak; elevation 60 feet.
196	(20-G).	About 2¾ miles south and a little east of Tavua; ¼ mile north of Tavua hot spring and on opposite side of small right tributary to Nasivi River; elevation about 200 feet.
197	(20-G).	Same as Station 196; underlies rock of Station 196.
198	(20-G).	Same as Station 196.
199	(21-DD).	Same as Station 88; rock in place; forms hill 60 feet high.
200	(21-CC).	Same as Station 91; boulder at elevation of 390 feet.
201	(21-CC).	Same as Station 91; boulder at elevation of 335 feet.
202	(18-CC).	Point of land immediately east of Navutulevu; outcrop along shore.
203	(21-CC).	Same as Station 91; rock in place; elevation 315 feet.
204	(21-CC).	Same as Station 91; boulder; elevation 160 feet.
205	(21-CC).	Same as Station 91; boulder; elevation 115 feet.
206	(16-BB).	About ½ mile north of Korolevu; 20-foot exposure on hill; elevation about 290 feet.
208	(16-BB).	Same as Station 100; outcrop at landward edge of beach.
209	(14-AA).	Same as Station 104; elevation 30 feet.
210	(15-BB).	Eastern shore of Mbusa Bay; boulder.
211	(15-BB).	Same as Station 102.
212	(12-AA).	On shore about 100 yards east of tip of Vatuvula Point.
213	(12-AA).	Same as Station 107.
214	(12-AA).	Head of Vatukarasa Bay; outcrop along shore.
215	(13-Z).	Left bank of Tamunua River about 2½ miles from south coast; outcrop in cut along trail 20 feet above river; elevation 50 feet.
216	(13-Y).	Village of Vunayawa, on Tamunua River 4½ miles from south coast.
217	(13-Z).	Same as Station 109; boulders.

218 (9-Z). Na Singatoka; exposure along tramway; elevation 15 to 20 feet.

219 (10-Y). Same as Station 118; sample from outcrop 85 yards south of Station 118; elevation 60 feet.

222 (3-U). Savusavu; outcrop on tidal flat.

223 (16-K). In left bank of Mba River about ½ mile above Tonge; elevation about 80 feet.

224 (16-F). Near Vatutavui; outcrop on tidal flat.

225 (13-L). Along trail between Tukuraki and Navilawa where trail crosses high ridge leading east from Koro Yanitu (Mt. Evans); boulder; elevation about 2,000 feet.

226 (11-L). Near summit of Koro Yanitu (Mt. Evans); boulder; elevation about 3,900 feet.

228 (12-M). Left bank of Sambeto River ¼ mile below Navilawa; sample from dump at abandoned prospect hole; elevation about 740 feet.

229 (12-M). Above Station 228; sample from abandoned prospect drift; elevation 940 feet.

230 (12-M). Right bank of Sambeto River about ¼ mile south of Navilawa; sample from dump at abandoned prospect hole; elevation 945 feet.

231 (12-M). Same as Station 228; sample from wall of abandoned prospect hole 10 feet above stream; elevation 740 feet.

233 (11-N). Along trail about 1½ miles south of Navilawa; boulder.

234 (11-N). In left tributary to Sambeto River about ½ mile southwest of Nandele; elevation 300 feet.

236 (21-DD). Same as Station 88; boulders on shore.

237 (19-CC). Right bank of Mbosiwa about 1 mile above mouth; elevation 70 feet.

238 (21-DD). Same as Station 88; boulders on shore.

239 (19-AA). Along trail on spur south of main Lokalevu Range north of Vu na Niu Bay.

240 (19-Y). In bed of Navua River near village of Nambukelevu; elevation about 320 feet.

241 (19-Z). About 1 mile south of Nambukelevu, along trail to Vu na Niu Bay; elevation about 530 feet.

242 (19-Y). Valley of upper Navua River about ½ mile east of Nambukelevu; 15 feet exposed in Navua and in small right tributary; elevation about 400 feet.

243 (20-Z). In right tributary to upper Navua River about 1 mile E. S. E. of Nambukelevu; questionable outcrop and large boulders; elevation about 370 feet.

244 (20-Z). Along trail 1½ miles E.S.E. of Nambukelevu, in valley of upper Navua River; 2-foot exposure; elevation about 520 feet.

245 (20-Y). Gorge of the upper Navua River nearly 3 miles east of Nambukelevu; 5-foot bed whose base lies 15 feet above river and about 360 feet above sea level.

246 (20-Z). Same as Station 244; questionable outcrop along trail; elevation about 585 feet.

247 (22-X). Left tributary to Navua River about 7½ miles E. N. E. of Nambukelevu, on trail to Nuku; outcrop in steep-sided gorge 100 feet deep.

248 (21-Y). Left tributary to Navua River about 4 miles E. N. E. of Nambukelevu, on trail to Nuku; outcrop in steep-sided gorge 35 feet deep; elevation about 370 feet.

249 (22-W). In Mavuvu River, a left tributary to Navua, about 9 miles out of Nambukelevu on trail to Nuku.
250 (21-Y). Same as Station 248; elevation about 370 feet.
251 (25-Z). Right bank of Navua River about 4 miles south of village of Mbengga (air line); outcrop immediately below mouth of the Wainikavika.
252 (25-AA). Right bank of lower Navua River about 1 mile northwest of Nakuavu; this is lower end of gorge.
253 (26-AA). Waiyanitu Creek, a left tributary entering the Navua about ½ mile below Nakuavu; station near house owned by Mr. Livingstone.
259 (31-Q). Same as Station 126; elevation about 220 feet.
260 (30-P). Korosuli; boulders in small left tributary to Wainimala River; elevation about 210 feet.
262 (28-P). Wainimala Valley between mouth of the Waisomo and Nasalia.
263 (27-O). Right bank of Wainimala River at crossing immediately below Laselevu; elevation 270 feet.
265 (27-O). About ¾ mile north of the site of the village of Undu, on trail from Nasalia to Nasongo; elevation 525 feet.
266 (26-N). Same as Station 127.
267 (22-I). Same as Station 8; elevation 1,650 feet.
268 (22-I). Same as Station 8; elevation 1,650 feet.
269 (8-O). Near main road leading south from Lautoka, about 1½ miles south of Sambeto River crossing; elevation 250 feet.
270 (10-O). Same as Station 128; 3 feet exposed; elevation about 175 feet.
271 (10-O). Same as Station 128; elevation about 175 feet.
272 (10-O). About 3 miles southwest of village of Nandele.
273 (10-O). About 2½ miles southwest of village of Mboutini.
276 (9-N). About 200 yards southeast of Station 130; elevation 190 feet.
277 (9-N). About 150 yards southeast of Station 130; elevation about 200 feet.
278 (10-O). Same as Station 129; boulders.
280 (9-O). Left bank of Nandi River due south of Mboutini; 20-foot exposure, the base 70 feet above sea level.
281 (8-O). Short distance north of Nandi River about 2½ miles from coast.
282 (9-N). Hill north of Sambeto River about 2 miles from coast; elevation 200 feet.
283 (35-Y). Left bank of Tamavua River immediately above bridge on Suva-Lami road; blocks at elevation of about 100 feet.
284 (35-Y). Same as Station 283; boulders; elevation about 100 feet.
285 (35-Y). Same as Station 283; boulders; elevation about 100 feet.
286 (35-Y). Same as Station 283; boulder; elevation 5 feet.
287 (13-U). Top of bluff forming left wall of Na Singatoka Valley at Koronisangana; 200 feet exposed; sample, elevation about 835 feet.
290 (33-M). About 1¼ miles N. 20° E. of village of Nasimbitu, on trail between Naloto and Nayavu; outcrop in left bank of small stream; elevation about 200 feet.
291 (36-X). East side of lower (south) entrance to cave at Kalambu; elevation about 85 feet.
292 (34-O). Wailotua River 1¼ miles northeast of village of Wailotua; 20 feet exposed; elevation 120 feet.
293 (14-L). Tukuraki; from large block at base of cliff at western edge of village; elevation 810 feet.
294 (8-AA). Quarry operated by Colonial Sugar Refining Co. at Ravuka; 35-foot face exposed; base 10 feet above sea level.

295 (35-Y). Tamavua Quarry, at head of Walu Bay; 41 feet exposed; base 144 feet above sea level.
296 (35-Z). Directly underlies rock of Station 160; few feet exposed immediately above sea level.
297 (35-Z). Directly overlies rock of Station 160; about 30 feet exposed.
298 (35-Z). Same section as Station 160; directly overlies rock of Station 297; about 30 feet exposed.
299 (31-Q). Left bank of Wainimala River about ¼ mile below Nairukuruku.
300 (31-Q). Along trail ⅛ mile east of Vunindumba; elevation 200 feet; rock overlies beds of Station 299.
301 (31-Q). Right bank of Wainga River immediately above junction with Wainimala; sample from base of cliff about 300 feet high.
302 (30-P). Same as Station 52; 10 feet exposed; base 330 feet above sea level.
303 (28-L). About 6¼ miles out of Wairuarua en route to Numbumakita; 5 feet exposed; elevation 1,015 feet.
304 (16-J). About 5½ miles southeast of Na Rarawai.
305 (35-Z). About 1¾ miles S. S. E. of Suva Post Office; old quarry face on left bank of creek which enters sea near tip of Suva Point; 12 feet exposed, base lying 3 feet above high tide level.
306 (15-J). Right bank of Mba River about 2¼ miles south of Na Rarawai; 65 feet exposed; base at river's edge.
307 (17-S). Near hill called Korombulia, close to Tawaleka on the Na Singatoka River; elevation 615 feet.
308 (17-S). Entrance to cave near Tawaleka on Na Singatoka River.
309 (13-U). Blocks from talus slope of river bluff at Koronisangana.
310 (8-AA). "Malaqereqere," 4½ miles west of the mouth of the Na Singatoka River; bench whose upper surface lies 2 to 6 feet above high tide.
311 (8-AA). On coast at Ravuka; beds on floor of sea cave 5 to 6½ feet above high tide.
312 (25-W). Valley of the Wainikoroiluva ¼ mile above Laselase; 5 feet exposed in right bank of small creek; elevation about 435 feet.
313 (25-U). Near village of Wainimakutu; elevation about 750 feet.
314 (25-X). About 1 mile northeast of Namuamua, on trail to Namosi; elevation about 280 feet.
315 (36-X). Village of Kalambu; elevation about 220 feet.
316 (36-X). Same as Station 174; elevation about 120 feet.
317 (36-X). Same as Station 176; overlies beds at Stations 176 and 291; elevation about 85 feet.
318 (35-J). In bed of small stream about 1¾ miles southeast of Matainanu, on trail to Tova Peak.
319 (35-J). Same as Station 192; 15 feet exposed; base 95 feet above rock at Station 192, and 355 feet above sea level.
320 (35-J). Same as Station 192; 5 feet exposed; base 50 feet below rock at Station 192, and 195 feet above sea level.
321 (35-J). Same as Station 192; about 25 feet exposed; base 115 feet below rock at Station 192, and 130 feet above sea level.
327 (35-Z). Abandoned quarry on south side of Walu Bay, near entrance; sample from lower part of limestone near western end of quarry face (collections from limestone at eastern end of quarry are referred to Station 297).
328 (35-Z). Same as Station 327, but from middle of limestone mass.
329 (35-Z). Same as Station 327, but from upper part of limestone mass.
338 (12-AA.) Head of Vatukarasa Bay, on beach immediately below high tide level.

343	(10-Y).	Same as Station 118; sample from outcrop 35 yards north of Station 118.
344	(9-Z).	About ¾ mile northwest of Na Singatoka.
353	(10-N).	In bed of small left tributary to Sambeto River about 1½ miles west of Nandele; elevation 260 feet.
354	(10-N).	Cut in hill along trail on left bank of Sambeto River about 2 miles west of Nandele; elevation about 220 feet.
355	(9-N).	Left bank of Sambeto River about ¾ mile east of Natalau; elevation about 60 feet.
357	(20-Z).	Same as Station 244; 20-foot cliff near trail at elevation of about 455 feet.
358	(20-Y).	Same as Station 123; elevation about 345 feet; directly overlies rock at Station 123.
362	(25-L).	About 1 mile north of Nasiriti, on trail to Nasongo; more than 20 feet exposed in bed of small creek crossing trail; elevation 1,110 feet.
368	(35-Y).	Same as Station 283; not in place.
369	(35-Y).	Directly overlies rock at Station 295.
370	(24-L).	Right bank of Wailoa River about 1½ miles west of Nasongo.
371	(35-Z).	About 1¾ miles S. S. E. of Suva Post Office, less than ¼ mile from coast; elevation about 10 feet.
374	(35-Z).	Mark Street and Waimanu Road, Suva; elevation about 30 feet.
375	(25-Y).	Near mouth of Wainikovu Creek, a left tributary to the Navua River 1¼ miles below Namuamua; prominent cliff, elevation at base about 150 feet.
376	(36-X).	About 7¼ miles northeast of Suva Post Office; small outcrop in creek at Government Experimental Farm.
377	(35-Y).	Directly underlies rock at Station 295.
378	(21-N).	Na Singatoka River immediately below mouth of tributary that flows past Nandrau.
379	(8-Z).	Near coast 3 miles E. S. E. of Thuvu; elevation about 10 feet.
380	(35-W).	Along road a few yards from Station 41; about 20 feet exposed; elevation 550 feet; overlies rock of Station 41.

PALEONTOLOGY

SCOPE AND METHOD

Most of the fossils described in this paper were collected during the expeditions of 1926 and 1928, but the molluscan material collected by Alexander Agassiz (1896), E. C. Andrews (1898), the United States Fish Commission (*Albatross,* 1899), A. G. Mayor (1920), Coleman C. Wall (date unknown), and A. O. Thomas (1922) has also been studied. These collections, all of them small, are deposited in the United States National Museum and include the material described by Mansfield (77, pp. 85-104). I am indebted to the committee in charge of the Fiji Museum, and to Mr. Percy Turner and Mr. W. T. C. Edwards of Suva for gifts and loans of rare fossils from their collections.

The fact that many of the fossil mollusks from Vitilevu are represented by but one or two specimens makes it obvious that only a small part of the faunas has been collected. As road-building and quarrying operations continue, much additional material will most certainly be obtained. Therefore it has seemed advisable not to attach names to some of the incomplete or obviously immature specimens, or to species represented by a single specimen, particularly if the species seemed closely related to a described Recent shell. One can not determine the range of variation from one or two specimens. However, a number of such unnamed species have been placed in their proper subgenera or sections and have been figured in the hope that future collecting will yield suitable type material for those that actually represent undescribed forms.

I have attempted to place each species in its proper subgenus or section and have cited the genotype or the section type, its occurrence, and the source of my information. The following references have been used in this connection: Baker (9), Cossmann (16), L. R. Cox (17), M. A. Cox (18), Dall (20, 21, 23), Grant and Gale (52), Harris (57), Hay (58), Marwick (82), Stewart (97, 98), Suter (102), Thomson (105), Van der Vlerk (108), and Woodring (126, 127). In the discussion following the formal description the species is briefly compared to the type or to other species of its group to which it seems even more closely related. Synonymies have been given for previously described species from the Suva formation, but these are not all complete. A number of well-known Recent species were identified from the late Pleistocene or Recent deposits at Stations 157 and 311, and for these the synonymies are omitted as the species are figured and described in most of the standard manuals.

All holotypes have been deposited in Bernice P. Bishop Museum. In so far as practicable topotypes have been deposited in the United States National Museum.

Measurements, except for very large specimens, have been made with a caliper rule reading to tenths of a millimeter.

There is a confusing lack of agreement among paleonotologists in the use of the terms "mold" and "cast." These terms are here used as defined by Challinor (12, pp. 410-411):

> A cast consists of material which replaces the original shell, reproducing it in size, shape, and surface features. An internal mold is the material that fills the interior of the shell; an external mold is the material that surrounds the exterior of the shell.

ECOLOGY

General Relations

It is difficult and perhaps unwise to attempt to interpret the ecological conditions under which the various Fijian faunas lived during the Neogene. That only a very small fraction of the total number of Neogene species has been collected is indicated by the fact that about half of the species of larger fossils are represented in the collections by only one or two specimens. Furthermore, the various fossil localities are widely scattered over an area of 4,000 square miles and range through a vertical section of about 1,000 feet. The varying lithology and the faunal variation which accompanies it indicate clearly that several facies are represented, but too little is known about the faunas of individual localities to allow for much in the way of ecological interpretations. The smallness of many of the collections is due to the fact that the rocks were poorly exposed and quarrying operations difficult. Many of the larger collections were obtained in the Suva area, and one reason for this is the presence in that area of a number of quarries where good sections are exposed.

Viti Time

The remarkable purity of the Viti limestone, its wide distribution, which seems to bear no relation to prevailing winds and currents, and the almost complete absence of all fossils other than foraminifera and algae suggest that Vitilevu was completely submerged to a considerable depth during Viti time, that no extensive land area was being eroded near by, and that volcanic activity had temporarily ceased. Such deductions, based largely on negative evidence, are of questionable value—especially when it is realized that the limestone has been closely examined in only a few widely scattered sections. However, until clastic sediments interbedded with the Viti limestones are found, or until a development of reef corals or other shallow-water organisms is discovered, the above interpretation must stand.

Table 3. Faunal List.

Includes all Fossils except Foraminifera and corals. (See Tables 5-7.)
A = abundant; F = few; R = rare (one specimen only).

	SUVA FORMATION																									PLEISTOCENE?	
	OLDER FAUNA								YOUNGER FAUNA																		
	LEEWARD								LEEWARD					WINDWARD													
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379	157	311
Echinoderms																											
Echinoids																											
Phyllacanthus species														R		F	A	R	R	F							
"Cidaris" species																	A				R						
Psammechinus species																R											
Arbacina cf. stellulata (Duncan and Sladen)																R											
Opechinus cf. affinis (Duncan and Sladen)																F											
Clypeaster cf. pulvinatus (Duncan and Sladen)																R											
Fibularia species																F											
Eurhodia species																F											
"Maretia" species																R											
Molluscoids																											
Bryozoa																											
Lichenopora species																	R										
Lunulites species																	R										
Membranipora species																						R					
Cellepora species																	R										
Brachiopods																											
Terebratulina waimanensis Ladd										R						A											
Dallina vitilevensis Ladd																F											
Mollusks																											
Pelecypods																											
Glycymeris (Glycymeris) fijiensis Ladd																	R										
Glycymeris (Glycymeris) species a																R											
Glycymeris (Glycymeris) species b																	F										
Arca (Arca) thomasi Ladd		A						A																			
Arca (Arca) species a																			F								
Arca (Arca) species b																			F								
Barbatia (Acar) species																	R										

Table 3. Faunal List (Continued).

	SUVA FORMATION																										
	Older Fauna								Younger Fauna																	Pleistocene?	
	Leeward								Leeward					Windward													
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379	157	311
Mollusks																											
Pelecypods (continued)																											
Barbatia (Obliquarca) javana Martin																	A			A							
Navicula species																	R										
Ostrea cf. baribisiana Martin																							R				
Ostrea aff. virleti Deshayes												R			R												
Ostrea species															F												
Pecten (Pecten) suvaensis Mansfield															R		R		F					R			
Pecten (Chlamys) lamiensis Ladd															F												
Pecten (Chlamys) nausorensis Ladd															F	R			F								
Pecten (Pallium) waluensis Hertlein															R	A			R			F					
Pecten (Aequipecten) exaratus Martin														F			R						A	F			
Pecten (Aequipecten) corymbiatus talicus Ladd										F						R											
Pecten mirificus Reeve																R											
Pecten species a																R											
Pecten species b																F											
Plicatula species																	R										
Lima (Lima) kavorica Ladd																	R										
Lima (Limatula) morioria? Marwich																F											
Lithophaga species	F																R		F								
Coralliophaga laseona Ladd																	A										
Chama lazarus Linnaeus												R							F								
Chama species																	F										
Cardium rewaense Ladd																	A										
Cardium species a																			F								
Cardium (Trachycardium) orbita Broderip and Sowerby, new subspecies?																	F	R									
Cardium (Fragum?) species																								R			
Cardium (Laevicardium) species a												R							F					R			
Cardium (Laevicardium) species b										F				R					F								
Tridacna mbalavuana Ladd																	F										

Table 3. Faunal List (Continued).

	SUVA FORMATION: Older Fauna, Leeward								Younger Fauna, Leeward					Younger Fauna, Windward												Pleistocene?	
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379	157	311
Mollusks																											
Pelecypods (continued)																											
Hippopus hippopus Linnaeus																										R	
Meiocardia species a																			R								
Meiocardia species b																	R										
Antigona species																			R?	R?							
Antigona (Dosina) puerpera waluensis Ladd																			R?	R							
Antigona (Ventricola) vitiensis Ladd																	F			R							
Dosinia wailoaense Ladd		F																									
Dosinia? species																			F								
Irus mamaricus Ladd																	R										
Tellina suvaensis Mansfield																			A								
Donax species								R																			
Asaphis species																			R?								
Solecurtus species																											
Mactra (Mactrotoma) tholoensis Ladd			R					A											R								
Mactra (Mactrotoma?) vitiensis (Davies)								F																			
Mactra (Coelamoctra) nasongoensis Ladd		F																									
Lutraria (Psammophila) species																			F								
Kuphus species													A														
Scaphopods																											
Dentalium (Dentalium) species																	R										
Dentalium (Graptacme) species																	A										
Cadulus? species									R																		
Chitons																											
(Unidentifiable plate)																	R										
Gastropods																											
Helcioniscus? species											R																
Trochus (Trochus) maculatus Linnaeus																											R
Trochus (Trochus) species																	R		F	R							
Trochus (Rochia) niloticus Linnaeus																											R
Monilea (Monilea) mateana Ladd																	A										

Table 3. Faunal List (Continued).

	SUVA FORMATION																									Pleistocene?	
	Older Fauna								Younger Fauna																		
	Leeward								Leeward					Windward													
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379	157	311
Gastropods (continued)																											
Turbo (Turbo) petholatus thanus Ladd																	F										
Turbo (Senectus) chrysotomus Linnaeus																											A
Turbo (Senectus) crassus Wood																										R	A
Turbo (Ocana) cf. gruneri Philippi																F	R	F	A	F	R						
Astraea species																			R								
Astraea (Calcar) species a																	F										
Delphinula distorta (Linnaeus)																	R										
Delphinula species																	R										
Neritopsis radula (Linnaeus), new subspecies?																	R										
Nerita (Amphinerita) polita Linnaeus																											F
Nerita (Theliostyla?) species		R																									
Theodoxus (Clithon) corona (Linnaeus)																	R										
Natica (Natica) marochiensis (Gmelin)																	A										
Polinices (Polinices) mamilla (Linnaeus)																	A										
Polinices (Polinices) melanostoma Gmelin																											R
Polinices (Polinices) species																	R										
Globularia (Waluia) edwardsi Ladd																R	R		F								
Cheilea species																	R										
Hipponix species																	A										
Architectonica (Architectonica) perspectiva (Linnaeus), new subspecies?			R																								
Heliacus species																	R										
Pyrazsu (Pyrazus) species																	R										
Strombus floridus Lamarck																											A
Strombus urceus Linnaeus																											R
Tibia cf. powisii modesta (Martin)			R			A	A																				
Cypraea (Cypraea) tigris Linnaeus																											R
Cypraea (Cypraea) species																	R										
Cypraea (Talparia) isabella lekalekana Ladd																	F										

Table 3. Faunal List (Continued).

	SUVA FORMATION																										Pleistocene?	
	Older Fauna								Younger Fauna																			
	Leeward								Leeward					Windward														
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379	157	311
Gastropods (continued)																											
Cypraea (Erosaria) agassizi Ladd																	R										
Cypraea (Monetaria) annulus sosokoana Ladd																	F										
Trivia (Trivia) koroensis Ladd																	F										
Tonna? species																R											
Cassis species																			R								
Semicassis (Semicassis) vavakuana Ladd		F																									
Gyrineum species						R																					
Septa rubecula (Linnaeus), new subspecies?																	R										
"Thais" species		R																									
Murex (Murex) aff. recurvirostris Broderip		F	R																								
Phos vitiensis Ladd			A			F																					
Mitra (Tiara) fijiensis Ladd			R																								
Mitra (Tiara) nasongoensis Ladd			R																								
Vexillum (Vexillum) gembacana (Martin)		R	F																								
Oliva carneola (Gmelin)																	R										
Oliva woolnoughi Ladd		A			R																						
Oliva makawana Ladd		R	F			R																					
Cancellaria tholoensis Ladd		R																									
Conus affinis Martin		F																									
Conus pertusus? Hwass																											F
Conus pulicarius? Hwass																	R										
Conus species a																	R										
Conus species b					R																						
Conus species c					R																				R		
Conus species d		R																									
Terebra (Strioterebrum) species		R																									
Styliola acicula (Rang)				F			A																				
Cavolina telemus rewaensis Ladd			R				A									F			F					R			
Cavolina globulosa Rang							F																				

Table 3. Faunal List (Continued).

	SUVA FORMATION																										PLEISTOCENE?	
	OLDER FAUNA								YOUNGER FAUNA																			
	LEEWARD								LEEWARD					WINDWARD														
	45	59	165	300	303	304	306	362	296	298	305	369	374	68	133	158	160	294	295	297	307	317	319	320	379		157	311
Gastropods (continued)																												
Cavolina osoica Ladd						A	F																					
Cavolina species										R						A												
Diacria mbaensis Ladd						F	A																					
Cructaceans																												
Decapods																												
Maja laddi Rathbun																F												
Parthenope (Platylambrus) fijiensis Rathbun																R												
Chlorodiella junghuhni (K. Martin)?			R																									
Etisus laevimanus Randall																												R
Montezumella lamiensis Rathbun															R													
Myra? fijiensis Rathbun															R													
Cycloes granulosa de Haan																								R				
Coenobita granulatus Bouvier																												R
Birgus latro (Linnaeus)																								R				
Dardanus gemmatus (Milne Edwards)																												R
Scyllarus vitiensis (Dana)																												R
Vertebrates																												
Fishes																												
Hemipristis serra Agassiz																				R								
Carcharodon megalodon Agassiz																R			F									
Trygon (or Myliobatis) species?																	R											
Diodon? species																				R								
Birds																												
(Egg of Rail?)											R																	
Plants																												
Lithoporella pacifica Foslie																R												
Lithothamnion aff. simulans Foslie																R												
Cyathea aff. affinis (Forster)													R															
TOTALS	1	14	11	1	3	6	6	4	1	4	2	3	2	3	8	28	53	3	26	9	2	2	2	7	1		2	14

Suva Time

The fauna of the Suva formation can hardly be treated as a unit, because the formation represents a considerable time interval and several facies of deposition. If the various fossil localities are plotted on a map it is seen that all the known occurrences of limestone and highly calcareous clastics are found on the southeast half of the island. This fact is certainly significant and apparently is directly related to the prevailing southeast trade winds and the ocean currents engendered by them. The fauna of the highly calcareous rocks may be called the "windward facies," that of the pyroclastics and "soapstone" marls the "leeward facies." This terminology is not strictly in accord with the facts because the highly calcareous rocks form but a very small part of the section, and hence the leeward facies is by no means limited to the leeward side of the island.

WINDWARD FACIES

The windward facies is best developed in the calcareous conglomerate (Station 160) and the overlying limestone (Station 297) in the type section of the Suva formation on Walu Bay (35-Z). The same limestone is exposed at Station 295. These exposures have yielded most of the larger fossils and will, therefore, be the ones described. The other localities show only minor faunal and lithologic differences, and it seems clear that all are of essentially the same age as the type section and were formed under very similar conditions. In the leeward facies, on the other hand, two distinct faunas seem to be represented. One of these is associated with the rocks of the windward facies, but the other may be considerably older.

It is unfortunate that nearly half of all the mollusks collected from the rocks of the windward facies are known only from the conglomerate at Station 160 because many of the shells in the conglomerate are badly worn, suggesting that the fauna is not a group of species that actually lived together in one environment. In spite of the fact that the conglomerate occurs in a section of marly "soapstones," many of whose beds are typical *Globigerina* oozes, it certainly is a shallow-water deposit. It contains a variety of igneous boulders—both volcanic and plutonic—and many of these are large and well rounded. Their presence indicates that there was a powerful stream somewhere in the vicinity. The igneous boulders are mixed with a large number of well-rounded coral heads and worn fragments of branching corals. These worn corals indicate wave action.

The molluscan fauna totals 46 species, of which 26 are gastropods. Many of the gastropods belong to genera that are abundant on reefs and tidal flats—*Turbo, Cypraea, Oliva,* and *Conus*. Littoral and sublittoral genera which are capable of living close to the mouths of rivers are also represented—*Natica* and *Polinices*. The *Natica* is especially abundant and though it is a thin-shelled species the fossils show no evidence of wear. The single shell of *Theodoxus corona* (Linnaeus), however, is badly worn. This species lives today in the rivers of Melanesia, and the fossil shell was evidently carried in along with the river boulders. The genera *Cheilea* and *Hipponix*, which include shallow-water shells that cling to rocks or to other mollusks, are also represented. The pelecypods show a large number of shallow-water genera—*Arca, Pecten, Chama, Tridacna,* and others. Many of the shells of *Arca* are badly worn and have possibly been transported some distance. Strangely enough, not a single oyster shell was found in the conglomerate. Boring mollusks, as *Lithophaga* and *Coralliophaga,* are found inside the worn coral boulders.

Deposition of coarse clastic material ceased as abruptly as it had begun, and the bed of conglomerate served as a satisfactory foundation for the growth of reef coral. Many of the large heads now to be seen in the quarry faces at Stations 297 and 295 are apparently in their original positions of growth. The corals are accompanied by numerous foraminifera and by a number of the same species of mollusks that occur in the conglomerate below. The growth of corals was evidently local, for in the type exposure the coralliferous limestone grades laterally into a foraminiferal limestone. Cushman, who examined a sample of the foraminiferal limestone, writes me (May 24, 1932) that it contains all large foraminifera belonging either to *Operculina* or *Operculinella* and indicates a depth of less than 30 fathoms.

LEEWARD FACIES

Younger fauna. The marly "soapstones" that make up a large part of the Suva formation in many parts of Vitilevu are abundantly fossiliferous at a number of horizons in the Suva area. Cushman (Table 5) identified 95 species of smaller foraminifera from Station 371, which lies only 2 miles from the type section on Walu Bay and at about the same elevation. The same marls outcrop at many points between the two stations, and as all of them are horizontal it is certain that the marls of Station 371 are very close stratigraphically to the type section of the Suva formation. The marls at Station 371, however, form a *Globigerina* ooze whose foraminifera lead Cushman to believe that deposition took place in water 100 to 250 fathoms deep (p. 102). At Station 305, which lies only a few yards from Station 371 and at the same elevation, the beds contain fewer foraminifera but yielded some specimens of a remarkable large echnoid which F. A. Bather is describing as the type of a new genus. To this same genus he refers *Crystechinus crassus,* a fossil species from Barbados described by Gregory, who regarded the Barbados species as a deep-sea echinoid. Matley (83), in discussing the Vitilevu occurrence, states that the Suva examples evidently came "from the soapstones associated with the shallow-water and conglomeratic limestone of Walu Bay and are clearly not of deep-sea origin." It should also be pointed out that the beds at Station 305 yielded, in addition to the echinoids, a fossil bird's egg, various plant remains, and the mold of a limpet (*Helcioniscus*? species). If the Walu Bay conglomerate were the only conglomerate, sudden elevation and subsidence might conceivably be called upon to explain it. But there are a number of other lenticular masses of conglomerate in the Suva area, and all of them could hardly be explained in such a fashion. The almost entire absence of shallow-water Miliolidae in the samples studied by Cushman (p. 103) indicated to him that the beds "originated in water certainly of more than 30 fathoms and in all probability very considerably more." All of the marl beds are not as rich in foraminifera as are the beds at Station 371. It seems, however, that the evidence of depth suggested by the absence of Miliolidae in the rich foraminiferal layers is outweighed by other considerations, as set forth above.

Mollusks are exceedingly rare in the younger fauna of the leeward facies; the complete list includes only 6 pelecypods, 2 gastropods, and 1 questionable scaphopod. In the same area 6 of the 9 species also appear in the calcareous rocks of the windward facies. At Station 374 the marls yielded numerous siphonal tubes of *Kuphus*, a mud borer.

Older fauna. Collections from eight localities are referred to the Older fauna of the leeward facies. Five of these localities lie in the interior of the island, and three in the valley of the Mba. A number of the genera of the windward facies are represented, but the composition of the two facies is quite different. In the Older fauna gastropods outnumber pelecypods by more than 3 to 1. The specific break is almost complete, as only one windward species appears in the Older leeward rocks. This species is a pteropod, *Cavolina telemus rewaensis*, new subspecies, the type of which was collected at Station 158. Foraminifera are much less abundant in the Older fauna, and corals are exceedingly rare.

The largest collections were made from the conglomerate and marl (Stations 59 and 165, respectively). Judging from the size and variety of the well-rounded boulders in it, the conglomerate represents a near-shore deposit. This view is strengthened by the presence of root casts, plant stems, and a great abundance of such shells as *Arca, Mactra, Oliva,* and *Conus*. *Oliva* and *Conus* are represented by two species each, one of the Olivas in great abundance.

The tuffs at Station 362 have yielded four species of shallow-water bivalves and some fragmentary plant remains. Davies (83, pp. 72-75), having only poorly preserved internal molds to work with, tentatively referred one of the bivalves to *Nodularia,* a genus of fresh-water shells. I was fortunate in obtaining better specimens, and after examining photographs of this material Davies (31, p. 48) agrees that his *Nodularia vitiensis* is probably a *Mactra.* Though the fauna is now considered to be marine, it probably represents a near-shore environment.

Pteropods are present at 4 of the 8 localities and are especially abundant at Stations 304 and 306. The beds at Station 306 are typical "soapstone" marls, but at Station 304 the situation is somewhat unusual. The rock is a poorly bedded, coarse volcanic agglomerate made up of blocks of lava embedded in a matrix of coarse tuff. Most of the blocks are sharply angular, and some of the largest exceed a foot in diameter. Mollusk shells are fairly abundant and are exceptionally well preserved. Were it not for the shells, it would hardly be suspected that the agglomerate was anything but a terrestrial deposit.

AGE

General Relations

As Vitilevu lies more than a thousand miles from the nearest well-known Tertiary section, the problem of determining the ages of its formations is unusually difficult. It has not been surprising to discover that the Fijian faunas are more closely related to the Tertiary faunas of the tropical East Indies than to those from sections in New Zealand and Australia which lie somewhat closer but in more southerly latitudes. In the East Indies, thanks to the untiring efforts of Professor K. Martin, the Tertiary sequence has been quite satisfactorily determined and the faunas have been monographed. Leupold and Van der Vlerk (74), who have recently published an excellent summary of the Tertiary stratigraph of the East Indian area, point out that Martin laid down two fundamental principles upon which later investigations were built: "In the first place he showed that during the Tertiary an autochthonous fauna developed in the East Indies, and in the second place he insisted that a subdivision of the Tertiary systems can only be obtained by comparing their fossil contents with the fauna that still exists in these regions and not with the European Tertiary fossils." These principles are sound. In my study of the fossil mollusks of Vitilevu comparison has been made with closely related Recent species from the Indo-Pacific area. For most of them living relatives have been found.

Eventually, with the aid of intermediate localities such as those in India, it may be possible to correlate the late Tertiary sections of the southwest Pacific with those of Europe in a satisfactory manner, but at the present time it is impossible to say with any assurance that what is called Miocene in the East Indies is the exact equivalent of what is defined as Miocene in the type sections of Europe. In the present report, therefore, when the term Miocene is used in connection with the Fiji rocks it refers to what has been called Miocene in the East Indies rather than to the Miocene of Europe.

In commenting on Martin's refusal to hunt for guide fossils in the domain of the Mollusca, Van der Vlerk (108, pp. 290-291) expresses the belief that the time is now ripe to list a few mollusks that up until now have been found only within certain stratigraphical limits. His lists include no Fijian shells. In collaborating with Umbgrove, however, Van der Vlerk (109) has subdivided the Tertiary of the East Indies by using foraminifera, and, as noted by Whipple (p. 141), some of the East Indian larger foraminifera do occur in Vitilevu. Under the foraminiferal scheme the major subdivisions, or stages, of the Tertiary are designated by letters and the minor ones, called zones, by numbers. Van der Vlerk (108) gives a table which shows the relations of the foraminiferal stages to the conventional divisions of the Tertiary as used by Martin, and he gives Martin's figures of the percentages of still living species possessed by each division. This information is summarized in Table 4, where also the two fossiliferous Vitilevu formations are given tentative positions.

Table 4. Subdivisions of the Tertiary in the East Indies and Possible Equivalents in Vitilevu.

	Van der Vlerk-Umbgrove stages		Percentages of species still living (Martin)	Possible equivalents in Vitilevu	
		Quaternary	70+		
Upper Tertiary	h	"Pliocene"	50-70±		Neogene
	g	"Upper Miocene"	20-50±	Suva Formation	
	f				
	e	"Lower Miocene"	8-20±	Viti limestone	
	d				Eogene
		"Oligocene"			
Lower Tertiary	c				
	b	"Eocene"	0		
	a				

Viti Formation

The Viti formation has yielded no diagnostic fossils except the larger foraminifera studied by Whipple, which indicates that it belongs to stage *e* of the Van der Vlerk-Umbgrove classification (Table 4).

Suva Formation

Whipple recognizes that the larger foraminifera of the Suva formation are younger than those of the Viti limestone but believes that they are still old enough to place it in stage *e* of the foraminiferal time scale. However, the testimony of the other groups of fossils—many of which actually appear in beds with the larger foraminifera—suggests that much of the formation is younger than stage *e*. The problem of determining the exact age of the Suva beds is thus greatly complicated.

In their attempts to determine the age of the Suva formation earlier workers, most of whom studied only small collections of fossils, reached various conclusions. Brady (10), after studying the smaller foraminifera, pronounced the beds post-Tertiary. Dall (22) identified 10 genera of mollusks, all of which still live, and, after remarking that the rock looked decidedly too old for Pleistocene, expressed the opinion that the fossils might be either Miocene or Pliocene. David (30) cited the occurrence of *Carcharodon* teeth and a species of *Tridacna* in the Walu Bay outcrops and inferred that the rocks were at least as old as Pliocene but not as old as the early Tertiaries. Woolnough (128, p. 464) believed that the fossils of the Walu Bay limestone indicated an age not younger than Pliocene. As quoted by Guppy, Martin (55, p. 376) believed that fossil shells found in the tuffs of Vitilevu and other Fijian islands were Tertiary in age, but not older than Miocene. Vaughan (45, p. 85) identified the corals collected by Foye as Pleistocene or Recent, but later (115, p. 187) stated that the presence of *Carcharodon megalodon* Agassiz and the fossil mollusks in the quarries on Walu Bay indicated that the rocks were probably late Miocene in age, possibly Pliocene. Brock (11, pp. 67, 74, 76) referred the Suva beds to the Pleistocene or late Pliocene. Mansfield (77, p. 94), after describing several small collections of fossils from Walu Bay, stated that the fauna suggested a Tertiary age, probably late Miocene or early Pliocene. Matley and Davies (83, p. 75) agreed with Mansfield as regards the age of the Walu Bay deposits and held that the limestone at Kalambu represented an older horizon, probably lower Miocene. They thought the high level fossiliferous beds near Nasongo to be almost certainly Tertiary and perhaps Miocene. Yabe, Aoka, and Hanzawa (133) studied the foraminifera from the limestone of Walu Bay and referred the deposit to the Miocene. Whipple (121) published a list of the Miocene foraminifera from the Viti and Suva formations. Cushman (19) expressed the opinion that the Suva marls were Pliocene in age.

Many objections have been raised against the Lyellian method of determining the age of Tertiary beds by ascertaining the percentage of Recent species which they contain. In discussing some of the defects of the method. Vaughan (117, pp. 685-686) points out that it is based on two assumptions, "one of which is that the standard of the discrimination of species of mollusks by Deshayes will be the standard of other workers, and the other is that the rate of organic change is the same for all parts of the earth." As a matter of fact, as Vaughan also points out, species are much more closely discriminated now than they were in the days of Lyell and Deshayes. Furthermore, there is evidence which indicates that during the Cenozoic evolution proceeded at a slower rate in the Tropics than elsewhere; climatic conditions did not suffer as much change as they did in more temperate latitudes. Many paleontologists also believe that evolution has been slower in the Pacific than in the Atlantic. Although the Lyellian method is not altogether satisfactory, when allowance is made for differences in the rate of evolution the difficulties mentioned above and the percentages for the various Tertiary epochs are revised (as Martin has done for the East Indies) the method is usable; no better method of measuring Tertiary time has yet been devised. The results of the Lyellian method are not particularly significant if they are based on the study of such small and incomplete faunas as those of the Suva formation. Future work may alter the figures considerably.

The following Recent species of mollusks have been identified from the Suva formation:

Windward facies and Younger fauna of leeward facies:
- Pecten mirificus Reeve
- Chama lazarus Linnaeus
- Delphinula distorta (Linnaeus)
- Theodoxus corona (Linnaeus)
- Natica marochiensis (Gmelin)
- Polinices mamilla (Linnaeus)
- Oliva carneola (Gmelin)

Older fauna of leeward facies:
- Styliola acicula (Rang)
- Cavolina globulosa Rang

The 7 species of the Younger fauna form about 21 percent of the 33 named species, disregarding questionable identifications. The 2 species of the Older fauna form about 9.5 percent of its 21 named species. If these figures alone are considered, the Older fauna of the Suva formation would fall in Martin's lower Miocene, the Younger fauna in his upper Miocene. The Suva faunas have been placed in these positions in Table 4 but not altogether on the basis of the percentages of Recent mollusks. The evidence of Suva mollusks known only as fossils elsewhere, as listed by Van der Vlerk (108), and the evidence of other groups have been taken into account.

Windward facies, Suva formation:
- Barbatia javana Martin—upper Miocene of Java
- Pecten exaratus Martin—Neogene of Java

Older fauna of leeward facies, Suva formation:
- Vexillum gembacana Martin—lower and upper Miocene of Java; upper Miocene (?) and Pliocene of Timor; Pliocene of Seran; Quaternary of Celebes
- Conus affinis Martin—upper Miocene of Java

Barbatia javana Martin belongs in the subgenus *Obliquarca.* According to Woodring (126, p. 39), *Obliquarca* is represented in the Eocene of the Paris basin and southern Europe, in the late Tertiary of the Mediterranean region, and in the Miocene of Jamaica, but has not yet been recognized in Recent faunas.

The larger foraminifera, considered alone, would place even the windward facies of the Suva formation in Tertiary *e* (lower Miocene). The smaller foraminifera, however, are looked upon by Cushman as Pliocene, and Hoffmeister believes that the few well-preserved corals indicate an age not older than Pliocene. The evidence of the echinoids studied by Hawkins, however, "while admittedly weak, is essentially consistent with a 'Gaj' Miocene date . . . . ." According to Umbgrove (107, p. 94), Vredenburg has pointed out a faunistic resemblance between the mollusks of the Lower Gaj series of India and those of the Javanese Rembang beds (Tertiary *e* and *f*). The Lower Gaj resembles the Aquitanien of Europe. Of 6 crustaceans identified by Rathbun and collected from the rocks of the windward facies of the Suva formation, 4 are new and 2 are identical with Recent species. The seventh species, from the Older fauna of the leeward facies, appears to be identical with a species described by Martin from the Tertiary of Java. The sharks' teeth from the windward facies of the Suva formation suggest a Miocene age.

Taking all available evidence into consideration, it seems probable that the older fauna of the leeward facies of the Suva formation is lower Miocene in age. The remainder of the formation is certainly younger and probably should be referred to the upper Miocene. However, the Miocene and Pliocene do not appear to be sharply separated in the southwest Pacific sections. In Vitilevu the evidence of the smaller foraminifera and the corals indicate that the rocks of the windward facies of the Suva formation and those containing the younger fauna of the leeward facies are quite young. The possibility that part of them may be Pliocene is still admitted. Hence the usage of the term Neogene (approximately Miocene and Pliocene) to include all of the fossiliferous sediments.

SMALLER FORAMINIFERA FROM VITILEVU, FIJI

By Joseph A. Cushman

Introduction

The late Tertiary deposits of the Indo-Pacific region have a great similarity in many respects. Most of them represent faunas which are characteristic of fairly deep waters and though closely allied to the living faunas of similar habitats nevertheless show distinctions which may be easily recognized.

Brady (Geol. Soc. London, Quart. Jour., vol. 44, pp. 1-10, pl. 1, 1888) collected three samples of the "soapstone" on Vitilevu, which he describes as follows:

> I. Light-gray rock from a cutting on the shore road close to the sea level.
>
> II. Similar material, of rather lighter color, from an elevation of 100 feet or more.
>
> III. Nearly white, somewhat harder and more compact specimen from an intermediate point.
>
> So far as the Microzoa are concerned, the first two present no important differences—none that might not be observed in dredgings from the recent sea bottom, taken at similar depths a little distance apart. Of foraminifera they have 36 species in common. The whiter sample, No. III, differs from the others in the comparative absence of *Lagenae* and *Nodosarinae* and appears, from both positive and negative indications, to have been deposited in somewhat deeper water. In all three there is a remarkable scarcity of arenaceous forms.

In all, Brady lists 92 species and varieties of foraminifera. His Station I, with 70, has the largest list, and Station II, with 51, includes 14 which are additions to the first station. Only 8 of those listed from Station III do not occur in one of the others.

The present paper is based upon collections made on the island of Vitilevu, Fiji, by H. S. Ladd, especially on two collections which have proved to be rich in species of foraminifera. The material, in general, represents a *Globigerina* ooze, but it is rich in Lagenidae particularly, indicating a condition of depth of 100 to 250 fathoms based on similar faunas from the Philippines. As is usual with such material, there are many species represented by but few specimens. The two Ladd stations are as follows:

> Station 371. Marl. About 1¾ miles S. S. E. of Suva Post Office, less than ¼ mile from coast, about 10 feet above high tide.
>
> Station 380. Marl. Near Tholo-i-suva, some 9 miles from Suva, on Prince's Road to Nausori; elevation about 550 feet.

The species of these two stations are listed in Table 5, together with such of Brady's list as can reasonably be determined without actually seeing the Brady specimens.

Five species are found at all five stations. Of the 118 species and varieties in the two Ladd stations, about half are distinct from Brady's list, a considerable proportion of these, due to the large number of Lagenas and the nodosarian forms, difficult to place surely in Brady's list. Taking out those species which occur in both Ladd stations and in some of Brady's, there are left 46 species found in the Ladd collections at one or the other station and also at one or more of Brady's stations. Of these, 39 are found at Station 371, and the few others only at Station 380. It is evident therefore that Ladd Station 371 has the same fauna as Brady Stations I-III, particularly his Station I.

Station 380, though it carries numerous foraminifera, does not have as rich a fauna as Station 371. A study of those species peculiar to Station 380 is enlightening. The appearance of heavy species of *Textularia, Gaudryina,* and *Cavulina angularis* would tend to indicate shallower water than the fauna of Station 371. Taking into account the difference in elevation alone, if the two lots of material were laid down contemporaneously and then lifted to their present level the lower elevations of Station 371 would place the origin of this deposit more than 90 fathoms below that of Station 380. This is probably enough to account for the difference in the two faunas and would account for the heavier arenaceous species present at Station 380 and absent from Station 371. On the other hand, this difference might partially account for the greater numbers of *Lagena,* though this may be in part accounted for by the better condition of the washed material from Station 371.

The almost entire absence of shallow-water Miliolidae would indicate that both stations originated in water of certainly more than 30 fathoms and in all probability considerably more. Brady's estimate that his collections originated at depths "of from 150 to 250 fathoms (more rather than less)" seems a fair one and one that is confirmed by the Ladd collections. (See p. 95.)

As is to be expected, there are a number of new species. Most of the species, however, are identical with those described by Schwager from the Pliocene of Kar Nicobar. Many of the species are also recorded by Karrer from the late Tertiary of Luzon, Philippines, by Schubert from the Pliocene and Pleistocene of the Bismarck Archipelago, and by Koch from the late Tertiary of Java and East Borneo. I have many of the same species from material of probable Pliocene age from the East Indies, Japan, and the west coast of North America. The fauna is widely distributed in the late Tertiary of the Indo-Pacific, and most of the species are still living in the same general area.

Certain of the species, such as *Ehrenbergina bicornis* H. B. Brady, known only from the marls of Fiji, and others known only from Schwager's description, have been of especial interest.

In the working up of this paper it has been of great help to have at hand a portion of the original collection of material from Kar Nicobar studied by Schwager, from which I have been able to obtain topotype specimens of many of Schwager's species. The types of the new forms here described, together with the Fijian forms previously described (Cushman Lab. Foram. Research, Contr., vol. 7, pp. 25-32, 1931), are to be deposited in Bernice P. Bishop Museum.

Although the material has been carefully searched, additions have been made from time to time as portions have been restudied. As the foraminifera from other stations are much less well preserved, it has seemed best to include in this paper only the fauna of the foraminifera marls.

My thanks are due to Miss Margaret S. Moore for painstaking work in preparing the original drawings for the plates, and to my daughter, Alice E. Cushman, for her care with the preparation of the manuscript.

Description of Species

Family Textularidae

Subfamily Spiroplectammininae

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina parallela Cushman (pl. 10, fig. 1).

Spiroplectammina parallela Cushman: Cushman Lab. Foram. Research, Contr., vol. 7, p. 26, pl. 4, fig. 1, *a, b,* 1931.

Test elongate, slender, sides nearly parallel for most of the length, compressed, periphery acute; early portion composed of planispirally coiled chambers, later ones biserial, fairly distinct, not inflated, often 8 to 10 pairs in the adult; sutures fairly distinct, very slightly depressed, oblique; wall of fine sand grains with much cement; aperture at the base of the inner margin of the chamber, textularian. Length 0.65 mm.; breadth 0.20 mm.; thickness 0.10 mm.

Holotype, B. P. Bishop Mus. Geol. No. 1300, Station 371, H. S. Ladd.

This species occurs in the late Tertiary of the Pacific region and is still living in the Pacific. It has been referred to as "*Spiroplecta annectens*" but is not that species from the Lias. Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 5, 1888) records it fossil from Fiji.

Subfamily Textulariinae

Genus TEXTULARIA Defrance, 1824

Textularia solita (Schwager) (pl. 10, fig. 2, *a, b*).

Plecanium solitum Schwager: Novara Exped., Geol. Theil, vol. 2, p. 195, pl. 4, fig. 6, *a-c,* 1866.

Test fairly large, much compressed, angles acute, in front view rapidly widening from the acute initial end to the broad apertural end, narrow rhomboid in end view; chambers numerous, low, and narrow, distinct, but only very slightly inflated; sutures oblique, distinct, slightly depressed; wall thin, especially in the later chambers which are somewhat inflated and often broken; aperture narrow, at or slightly above the basal margin of the inner side of the chamber. Length 0.80 mm.; breadth 0.55 mm.; thickness 0.45 mm.

This is one of the species described by Schwager from the Pliocene of Kar Nicobar. It seems to be a distinctive species with characteristic form and very thin test.

Textularia cf. **lythostratum** (Schwager) (pl. 10, fig. 3).

The figured specimen is somewhat roughened, the periphery rounded, and the test compressed. It may be an adult specimen of a species of which Schwager's *"Plecanium lythostratum"* is the immature form. Not enough specimens were available to make this more than a suggestion, but more specimens will undoubtedly show the true relations of these two forms.

Textularia species (?) (pl. 10, fig. 4, *a, b*).

The specimen figured is evidently a young specimen, though it is of large size. It is difficult to place such specimens until the adult stages are found. It is therefore useless to describe it, but the figure will serve to identify it in future collections.

Textularia cf. **hauerii** d'Orbigny (?) (pl. 10, fig. 5, *a, b*).

The very large species of *Textularia* here figured may possibly be referred to *T. hauerii* d'Orbigny. The specimens do not have as inflated chambers as those figured by Heron-Allen and Earland in their Kerimba report. They are perhaps closer to a form from the Philippines that I have figured as *T. agglutinans,* but which is not the same as d'Orbigny's West Indian species.

The broken specimen figured was 2.80 mm. long, and 1.40 mm. wide.

Genus VULVULINA d'Orbigny, 1826

Vulvulina nicobarica (Schwager) (pl. 10, fig. 6, *a, b*).

The specimen figured is evidently the early stage of *Vulvulina,* probably *V. nicobarica* (Schwager), described from the Pliocene of Kar Nicobar as *Bigenerina nicobarica* Schwager (Novara Exped., Geol. Theil, vol. 2, p. 196, pl. 4, fig. 7, *a-c,* 1866). Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 8, 1888) lists *"Bigenerina capreolus* d'Orbigny" from the "soapstone" of Fiji, and this may be the same as Schwager's species.

Family Verneuilinidae

Genus VERNEUILINA d'Orbigny, 1840

Verneuilina bradyi Cushman (pl. 10, fig. 7, *a, b*).

Verneuilina pygmaea H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 385, pl. 47, figs. 4-7, 1884 (not *Bulimina pygmaea* Egger).

Verneuilina propinqua Goës, Harvard Mus. Comp. Zool., Bull., vol 29, p. 38, 1896 (part).

Verneuilina bradyi Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, p. 54, fig. 87, *a, b* (in text), 1911. Pearcey, Roy. Soc. Edinburgh, Trans., vol. 49, p. 1013, 1914. Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 141, pl. 27, fig. 4, 1921; and Bull. 104, pt. 3, p. 59, pl. 11, fig. 1, 1922. Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 39 (table), 1925 (1926), Yabe and Hanzawa, p. 50. Cushman, Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 137, 1927.

This smoothly finished arenaceous species is widely distributed in fairly deep water. It may be noted that Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 8, 1888) records *"Verneuilina pygmaea"* from the "soapstone" of Fiji. Schubert (K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 64, 1911), from the late Tertiary of the Pacific islands, and Koch (Schweiz. Pal. Gesell., Ber., vol. 18, p. 352, 1923) from the late Tertiary of Java.

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina lacerata (Schwager) (?) (pl. 10, fig. 9, *a, b*).

Ataxophragmium laceratum Schwager, Novara Exped., Geol. Theil, vol. 2, p. 194, pl. 4, fig. 3, *a-c*, 1866.

This large *Gaudryina* may be related to Schwager's form. It is 2.90 mm. long, and 1.30 mm. wide. The sutures in this large adult specimen are not well shown. More specimens are needed to place it with certainty.

Gaudryina baccata Schwager.

Gaudryina baccata Schwager, Novara Exped., Geol. Theil, vol. 2, p. 200, pl. 4, fig. 12, *a, b*, 1866.

Rather typical specimens of this species, described by Schwager from the Pliocene of Kar Nicobar, occurred in the Fiji material. Brady does not record it, nor is it recorded from the late Tertiary of the Indo-Pacific region by other authors. Most of the references to this species are to the large Atlantic variety.

Genus CLAVULINA d'Orbigny, 1826

Clavulina variabilis Schwager (pl. 10, fig. 8, *a, b*).

Clavulina variabilis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 197, pl. 4, fig. 8, *a-c*, 1866.

This species has the surface slightly roughened, and the primitive character is revealed by the irregularity of the sutures. The uniserial stage is occasionally taken on after an irregular biserial stage, and the chambers even of the uniserial portion are not always uniform. *Clavulina communis* is listed by

Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 8, 1888) from the Fiji "soapstone." This late Tertiary fossil material is different from typical *Clavulina communis* from the Pliocene of Italy and from the Recent Adriatic collections.

Clavulina angularis d'Orbigny (?) (pl. 10, fig. 10, *a*, *b*).

The figured specimen is triangular in transverse section with the angles slightly carinate. Such forms are rare in the collections and nothing referable to it is included in Brady's list from the "soapstone" of Fiji. It is nearer d'Orbigny's species than any other and may be left under this name until a larger series is available.

Family Miliolidae

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina eborea Schwager (?).

There are a very few specimens which seem to be identical with the form named by Schwager. A larger suite of specimens would be necessary to determine whether or not this is identical with any of the older species.

Genus SIGMOILINA Schlumberger, 1887

Sigmoilina celata (Costa).

There are a few specimens that may be referred to this species. The synonymy of this and *S. schlumbergeri* Silvestri has been published (U. S. Nat. Mus., Bull. 104, pt. 6).

Genus PYRGO Defrance, 1824

Pyrgo murrhina (Schwager).

Biloculina murrhina Schwager, Novara Exped., Geol. Theil, vol. 2, p. 203, pl. 4, fig. 15, *a-c*, 1866. Munier-Chalmas and Schlumberger, Soc. Geol. France, Bull., 3d ser., vol. 13, p. 283, figs. 9, 10, p. 290, figs. 15, 16, 1885. Schlumberger, Soc. Geol. France, Mem., vol. 4, p. 165, pl. 9, figs. 52, 53, and 8, 9, in text, 1891. Egger, K. Bayer. Akad. Wiss. München, Abh., Cl. 2, vol. 18, pl. 1, figs. 19, 20, 1893. Goës, Harvard Mus. Comp. Zool., Bull., vol. 29, p. 87, 1896. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 122, text-fig. 17, 1911. Pearcey, Roy. Soc. Edinburgh, Trans., vol. 49, p. 994, 1914. Cushman, U. S. Nat. Mus., Bull. 71, pt. 6, p. 19, text-fig. 25; p. 75, pl. 28, fig. 3; pl. 29, fig. 1, 1917. U. S. Nat. Mus., Bull. 100, vol. 4, p. 470, 1921. Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 140, 1927.

Biloculina depressa d'Orbigny, variety *murrhyna* H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 146, pl. 2, figs. 10, 11, 1884. J. Wright, Roy. Irish Acad., Proc., 3d ser., vol. 1, p. 462, 1891. Chapman, Zool. Soc. London, Proc., 1895, p. 7. Bagg, U. S. Nat. Mus., Proc., vol. 34, p. 117, 1908. Chapman, Linnaean Soc. London, Jour., Zool., vol 30, p. 395, 1910; Endeavour, Zool. Results, vol. 1, pt. 3, p. 310, 1912; vol. 3, pt. 1, p. 5, 1915. Sidebottom, Roy. Micr. Soc., Jour., 1918, p. 3. Heron-Allen and Earland, British Antarctic (*Terra Nova*) Exped., Zool., vol. 6, p. 62, 1922.

Pyrgo murrhina Cushman, U. S. Nat. Mus. Bull. 104, pt. 6, p. 71, pl. 19, figs. 6, 7, 1929.

Test in front view in young specimens nearly circular, in adult specimens somewhat longer than broad, in end view ellipsoid, with the borders extended and carinate, the carina interrupted at the point opposite the aperture, leaving a sinus, rather deep and often with a long spine at each angle in young specimens; in adults sinus less deep and the spines usually reduced or wanting; wall smooth; aperture in the young with a neck not exceeding the periphery of the test; in adults with a prominently exserted tubular neck with a bifid tooth partially filling the nearly circular opening; wall smooth.

This is one of the species originally described by Schwager from the Pliocene of Kar Nicobar which has a very wide geographic distribution. The Fiji material is typical.

Pyrgo lucernula (Schwager).

Biloculina lucernula Schwager, Novara Exped., Geol. Theil, vol. 2, p. 202, pl. 4, figs. 14, *a-c*, 17, *a, b,* 1866.

There are specimens which seem identical with this species described by Schwager from the Pliocene of Kar Nicobar.

Family Lagenidae

Genus ROBULUS Montfort, 1808

Robulus cushmani Galloway and Wissler (pl. 11, fig. 1, *a, b*).

Cristellaria polita Schwager (not Reuss, 1856), Novara Exped., Geol. Theil, vol. 2, p. 242, pl. 6, fig. 86, 1866. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 350, 1923.

Robulus cushmani Galloway and Wissler, Jour. Pal., vol. 1, p. 51, pl. 8, fig. 11, *a, b,* 1927.

Test large, close coiled, thickened in the umbonal region, tapering to the keeled periphery, central umbos of clear shell material showing the early chambers through; chambers usually eight in the last-formed coil, not inflated; sutures distinct, limbate, not depressed, slightly curved; wall smooth; aperture radiate with the ventral slit enlarged. Diameter of figured specimen 0.85 mm.; thickness 0.35 mm.

This is identical with the species described by Schwager from the Pliocene of Kar Nicobar, but preoccupied by Reuss's name of 10 years earlier. It is common in the late Tertiary about the Pacific. Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 9, 1888) probably had it from Fiji, as he records both *"Cristellaria rotulata"* and *"C. cultrata."*

Robulus foliatus (Stache) (pl. 11, fig. 2, *a*, *b*).

Robulina foliata Stache, Novara Exped., Geol. Theil, vol. 1, p. 245, pl. 23, fig. 24, *a*, *b*, 1864.

Cristellaria cf. *foliata* Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 83, 1911.

Test small, close coiled, thickened in the umbonal region, tapering to the somewhat keeled periphery, central umbo of clear shell material; chambers usually six to eight in the last-formed coil, not inflated; sutures distinct, slightly limbate, not depressed, very strongly curved, the anterior end of the chamber extending forward so that each suture has a very strongly curved anterior portion; wall smooth; aperture radiate with the ventral slit elongate. Diameter of figured specimen 0.40 mm.; thickness 0.18 mm.

Some of the forms recently described by Koch from the late Tertiary of the East Indies are very close to this species. Schubert had it from the late Tertiary of the Bismarck Archipelago. Brady does not seem to have had this species in his Fiji material.

Robulus calcar (Linné).

There are a few smooth specimens with peripheral spines that may be referred to this species. It is recorded by Koch (Schweiz. Pal. Gesell., Ber., vol. 18, p. 350, 1923) from the late Tertiary of Java, but not included by Brady in his list from Fiji.

Robulus nicobarensis (Schwager).

Cristellaria nicobarensis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 243, pl. 6, fig. 87, 1866. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 349, 1923.

This species is very close to Schwager's *C. polita*, but the sutures are not so curved and the test is more compressed. Schwager describes it from the Pliocene of Kar Nicobar, and Koch records it from the late Tertiary of Java.

Genus LENTICULINA Lamarck, 1804

Lenticulina echinata (d'Orbigny) (pl. 11, fig. 3, *a*, *b*).

"Nautili Echinati" etc., Soldani, Testaceographia, vol. 1, pt. 1, p. 65, pl. 59, figs. *qq*, *rr*, 1789.

Nautilus calcar, variety *E*, Fichtel and Moll, Testacea Microscopica . . . , p. 74, pl. 12, figs. *a-c*, 1803.

Robulina echinata d'Orbigny, Foram. Foss. Bassin Tert. Vienne, p. 100, pl. 4, figs. 21, 22, 1846.

Cristellaria (*Robulina*) *echinata* Carpenter, Parker and Jones, Introd. Foram., pl. 12, fig. 3, 1862.

Cristellaria echinata H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 554, pl. 71, figs. 1-3, 1884. Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 73, pl. 34, fig. 5, 1913; and Bull. 100, vol. 4, p. 233, pl. 45, fig. 4, *a, b*, pl. 46, fig. 1, *a, b*, 1921.

Test large, close coiled, thickest at the umbonal region, thence tapering to the acute periphery which has long acicular spines at the junction of the chambers, decreasing in length in the later portion; chambers 7 to 10 in number, distinct, not inflated; sutures distinct, raised, and ornamented by a row of large tubercles, those near the center the largest and decreasing in size toward the periphery, curved; wall of the early portion ornamented with fine tubercles especially on the peripheral portions of each chamber, the inner portion smooth and almost or wholly smooth in the last few chambers; aperture radiate, the slits nearly equal. Diameter of figured specimens without spines, 2 mm.; thickness 0.85 mm.

From the available records this species described by d'Orbigny from the Miocene of the Vienna Basin is found living in the Mediterranean and Indo-Pacific. It occurs in the late Tertiary material of Fiji, but is not referred to by Brady.

Genus PLANULARIA Defrance, 1824

Planularia species (?) (pl. 11, fig. 5, *a, b*).

There is a large smooth species of *Planularia* in the Fiji collections which is probably the form recorded by Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 9, 1888) as "*Cristellaria cassis* Fichtel and Moll sp. (?)." I have hesitated to assign it to a definite species until more material is available.

Planularia crepidula (Fichtel and Moll) (pl. 11, fig. 6, *a, b*).

Nautilus crepidula Fichtel and Moll, Testacea Microscopica . . . . , p. 107, pl. 19, figs. *g-i*, 1803.

Cristellaria crepidula d'Orbigny, in De la Sagra, Hist. Fis., Pol., Nat., Cuba, "Foraminiferas," p. 64, pl. 8, figs. 17, 18, 1839. H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 542, pl. 87, figs. 17, 19, 20, 1884. Goës, Harvard Mus. Comp. Zool., Bull., vol. 29, p. 57, 1896. Flint, U. S. Nat. Mus., Rept., 1897, p. 316, pl. 63, fig. 2, 1899. Cushman, U. S. Nat. Mus. Bull. 71, pt. 3, p. 70, pl. 29, figs. 5, 6?; pl. 31, figs. 2-5, 1913; and Bull. 104, pt. 4, p. 117, pl. 35, figs. 3, 4, 1923. Heron-Allen and Earland, Roy. Irish Acad., Proc., vol. 31, pt. 64, p. 57, 1913.

Test elongate, somewhat compressed, the early chambers coiled, later ones becoming uncoiled, periphery rounded; chambers distinct, not inflated, very variable in number and amount of the extension backward on the inner border; sutures distinct, not depressed, curved; wall smooth; aperture radiate. Length of figured specimen 1.30 mm.; breadth 0.45 mm.; thickness 0.30 mm.

This is a widely distributed and variable species which has had many names.

Genus SARACENARIA Defrance, 1824

Saracenaria acutauricularis (Fichtel and Moll) (pl. 11, fig. 4, *a*, *b*).

"*Hammoniae subrotundae*" Soldani, Testaceographia, vol. 1, pt. 1, p. 61, pl. 49, fig. 10, 1789.

Nautilus acutauricularis Fichtel and Moll, Testacea Microscopica . . . , p. 102, pl. 18, figs. *g-i*, 1803.

Cristellaria acutauricularis Parker and Jones, Anns. and Mag. Nat. Hist., 3d ser., vol. 5, p. 114, 1860. H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 543, pl. 114, fig. 17, *a*, *b*, 1884.

The specimen figured may be referred to this species which is also recorded from Fiji by Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 9, 1888). The specimens are large and of the form figured.

Genus DENTALINA d'Orbigny, 1826

Dentalina tauricornis (Schwager) (pl. 11, fig. 10).

Nodosaria tauricornis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 228, pl. 6, fig. 61, 1866.

Test large, the earlier portion slightly curved, very elongate, enlarging from the pointed initial end; chambers numerous, distinct, the later ones slightly more elongate and inflated; sutures distinct, slightly depressed in the later portion; wall smooth; aperture terminal, radiate. Length of figured specimen 4.8 mm.; diameter 0.60 mm.

This is a very large species and agrees well with the species described by Schwager from the Pliocene of Kar Nicobar.

Dentalina neugeboreni (Schwager) (pl. 11, fig. 9).

Nodosaria neugeboreni Schwager, Novara Exped., Geol. Theil, vol. 2, p. 232, pl. 6, fig. 67, 1866.

This name of Schwager's is used, though it may be better later to unite this under one of the names which are used to include numerous forms of this same general sort. The specimens in their general characters are similar to Schwager's figures.

Dentalina perprocera (Schwager) (pl. 12, fig. 5).

Cristellaria perprocera Schwager, Novara Exped., Geol. Theil, vol. 2, p. 241, pl. 6, fig. 84, 1866.

The figured specimen is referred to Schwager's species, which seems to belong to *Dentalina*. The early sutures are very oblique, becoming somewhat less so in the later portion where the chambers also become more inflated.

Dentalina elegans d'Orbigny (pl. 12, fig. 4).

Schwager figures a specimen as *Nodosaria elegans* which is very close indeed in its characters to the specimen figured here. It is a slender, very elongate, and slightly curved species probably referred usually to "*Nodosaria consobrina*, var. *emaciata*," as is done by Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 9, 1888) in his Fiji list.

Dentalina insecta (Schwager) (pl. 12, figs. 2, 3).

Nodosaria insecta Schwager, Novara Exped., Geol. Theil, vol. 2, p. 224, pl. 5, figs. 53, 54, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 89, 1878, Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 77, text-fig. 6, 1911. Cushman, U. S. Nat. Mus. Bull. 100, vol. 4, p. 189, pl. 34, fig. 3, 1921. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 347, 1923.

Nodosaria pauperata Bagg (not d'Orbigny), U. S. Geol. Survey Bull. 513, p. 57, pl. 16, fig. 2, *a-f*, 1912.

Dentalina baggi Galloway and Wissler, Jour. Pal., vol. 1, p. 49, pl. 8, figs. 14, 15, 1927.

Test elongate, slightly tapering, slightly curved; chambers numerous, distinct, in the megalospheric form with the proloculum longer than the following chambers, in the microspheric form tapering, initial end with a distinct spine which is eccentric in position; sutures distinct, depressed, sometimes limbate; wall smooth; aperture radiate. Length up to 3 mm.; diameter 0.30 mm.

This species has a wide distribution in the late Tertiary and Recent of the Indo-Pacific region. It is known from the Pliocene of Kar Nicobar (Schwager), from the late Tertiary of Luzon (Karrer), late Tertiary of Bismarck Archipelago (Schubert), Recent of Philippine region (Cushman), late Tertiary, Java (Koch), Pleistocene or Pliocene of California (Bagg, Galloway, and Wissler).

The initial spine is usually present and is usually eccentric.

Dentalina spirostriolata (Cushman) (pl. 12, fig. 1).

Nodosaria spirostriolata Cushman, U. S. Nat. Mus., Proc., vol. 51, p. 656, 1917. U. S. Nat. Mus., Bull. 100, vol. 4, p. 212, pl. 38, fig. 4, 1921. Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 41 (table), 1925 (1926), Yabe and Hanzawa, p. 51.

Test much elongate, slightly curved, very slightly tapering toward the initial end, which is broadly rounded; chambers numerous, short, elliptical in side view; slightly inflated; sutures distinct, slightly depressed; wall ornamented with numerous fine costae, spirally arranged; aperture radiate. Length of Fiji specimens up to 3 mm.

This has heretofore been known as a Recent species from off the Philippines and Japan.

Genus **NODOSARIA** Lamarck, 1812

Nodosaria arundinea Schwager (pl. 11, fig. 7).

Nodosaria arundinea Schwager, Novara Exped., Geol. Theil, vol. 2, p. 211, pl. 5, figs. 43-45, 1866. Karrer, in von Drasche, Frag. Geol. Insel

Luzon, p. 89, 1878. Sherborn and Chapman, Roy. Micr. Soc., Jour., 2d ser., vol. 6, p. 747, pl. 14, figs. 28, 29, 1886. Guppy, Geol. Mag., decade 5, vol. 1, p. 246, pl. 8 figs. 14, 15, 1904. Heron-Allen and Earland Roy. Micr. Soc., Jour., 1911, p. 322. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 72, 1911. Heron-Allen and Earland, Roy. Micr. Soc., Jour., 1924, p. 154. Cole, Bull. Am. Pal., vol. 14, no. 53, p. 220 (20), 1928.

Test elongate, very slender; chambers very elongate, cylindrical, the megalospheric proloculum bulbous, later chambers becoming very elongate and usually the test is broken due to the weakness at the sutures; sutures distinct, depressed; wall smooth.

There are records for the species from the late Tertiary of Kar Nicobar (Schwager), Luzon (Karrer), and Bismarck Archipelago (Schubert). The other records are more scattered. Brady records it from Fiji as "*Nodosaria longiscata* d'Orbigny," which it closely resembles. Similar specimens occur in the Eocene, Chapapote formation, of Mexico (Cole), and also in the Alazan clays, two formations which have their faunal affinities with the Indo-Pacific.

Nodosaria brevicula Schwager (pl. 11, fig. 8).

Nodosaria brevicula Schwager, Novara Exped., Geol. Theil, vol. 2, p. 234, pl. 6, fig. 71, 1866. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 346, 1923.

Test of few chambers, the proloculum globular with a central basal spine, other chambers slightly elongate, the later ones more distinctly so; sutures deeply depressed; wall smooth; aperture slightly extended, radiate. Length about 1 mm.

The only other records for this species are that of Schwager from the Pliocene of Kar Nicobar and that of Koch from the late Tertiary of Kabu, Java.

Nodosaria koina Schwager (pl. 12, fig. 8).

Nodosaria koina Schwager, Novara Exped., Geol. Theil, vol. 2, p. 220, pl. 5, fig. 47, 1866. Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, p. 56, pl. 7, fig. 6, 1926.

Test slender, very greatly tapering, initial end rounded; chambers numerous, 5 to 10 or more, inflated, gradually increasing in size as added; sutures distinct, depressed; wall smooth, matte; aperture radiate. Length up to 1.6 mm.

Schwager's specimens are from the Pliocene of Kar Nicobar, and I have had it from the Miocene of California as well as from the late Tertiary of Fiji.

Nodosaria glandigena Schwager (pl. 12, fig. 9).

Nodosaria glandigena Schwager, Novara Exped., Geol. Theil, vol. 2, p. 219, pl. 5, fig. 46, 1866. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 346, 1923.

Test composed of but few chambers, 4 or 5, increasing in length as added, inflated, broadest near the base and tapering toward the apertural end; sutures distinct, depressed; wall smooth; aperture radiate. Length up to 1 mm.; diameter 0.30 mm.

Schwager's specimens are from the Pliocene of Kar Nicobar, and Koch records it from the late Tertiary of Kabu, Java. It may have been recorded by Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 9, 1888) as "*Nodosaria radicula*, var. *annulata*."

Nodosaria perversa Schwager (pl. 12, fig. 14).

Nodosaria perversa Schwager, Novara Exped., Geol. Theil, vol. 2, p. 212, pl. 5, fig. 29, 1866. H. B. Brady, Voy. Challenger Rep., Zool., vol. 9, p. 512, pl. 64, figs. 25-27, 1884; Geol. Soc. London, Quart. Jour., vol. 44, p. 9 (table), 1888. De Amicis, Soc. Geol. Ital., Boll., vol. 12, fasc. 3, p. 89, 1893. Egger, K. Bayer. Akad. Wiss. München, Cl. 2, vol. 18, p. 344, pl. 11, fig. 42, 1893. De Amicis, Nat. Sicil., anno 14, p. 93, 1895. Dakin, Ceylon Pearl Oyster Fish., Rep., vol. 5, p. 235, 1906. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 74, 1911. Pearcey, Roy. Soc. Edinburgh, Trans., vol. 49, p. 1021, 1914. Chapman, Endeavour Zool. Results, vol. 3, pt. 1, p. 23, 1915. Halkyard, Manchester Lit. and Philos. Soc., Mem.-Proc., vol. 62, p. 75, 1918 (1919). Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 208, pl. 37, fig. 2, 1921; and Bull. 104, pt. 4, p. 88, 1923. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 347, 1923. Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 141 (table), 1925 (1926).

Test elongate, subcylindrical, chambers comparatively few, inflated initial end rounded; sutures depressed; wall with numerous longitudinal costae, the last chambers somewhat smooth; apertural end with a more or less extended neck. Length 1 to 1.5 mm.

There are numerous records for this species, especially from the Indo-Pacific. There is some variation in the apertural characters and in the number of the chambers.

Nodosaria stimulea Schwager (?) (pl. 12, fig. 7).

Nodosara stimulea Schwager, Novara Exped., Geol., Theil, vol. 2, p. 226, pl. 6, fig. 57, 1866.

This species as described by Schwager is a very large one measuring 5.4 mm. for its average length. The proloculum is long and pointed at the base. The specimen figured here may belong to this species.

Nodosaria equisetiformis Schwager (pl. 12, fig. 6).

Nodosaria equisetiformis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 23, pl. 6, fig. 66, 1866. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 74, 1911.

Test elongate, composed of numerous chambers gradually increasing in length as added, the last-formed chamber nearly twice as long as broad; sutures slightly depressed, distinct; wall ornamented by very numerous fine longitudinal costae; aperture radiate. Length up to 2.75 mm.; diameter 0.55 mm.

Schwager described this species from the Pliocene of Kar Nicobar, and Schubert records it from the region of the Bismarck Archipelago. Hantken has recorded it from the Tertiary of central Europe, but it is evident that his specimens do not belong to this species. They are more like *Dentalina spirostriolata*. The specimens from Fiji are large, and though they do not have as many chambers as Schwager's figure, are of the same general character, especially the ornamentation.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina legumen (Linné) (pl. 12, figs. 10, 11).

The specimens figured are large and typical, the largest measuring 4.25 mm. It is surprising that Brady did not have this species from Fiji, as it is such a large and striking one. Schubert records it from the region of the Bismarck Archipelago.

Family Polymorphinidae

Genus PYRULINA d'Orbigny, 1826

Pyrulina labiata (Schwager) (pl. 12, fig. 12).

Polymorphina labiata Schwager, Novara Exped., Geol. Theil, vol. 2, p. 246, pl. 7, fig. 90, 1866.

Pyrulina labiata Cushman and Ozawa, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 53, pl. 12, fig. 4 *a, b*, 1930.

Test elongate, about three times as long as broad, the later chambers much elongate, giving a fusiform shape to the test; the last-formed chamber reaching back two thirds of the way to the base, outline very slightly lobed; sutures distinct but only slightly depressed; wall smooth; aperture radiate. Length 0.75 mm.; breadth 0.27 mm.

The figured specimen is evidently this species described by Schwager and is to be looked for elsewhere in the fossil and Recent Indo-Pacific material. The last two chambers make up a large proportion of the surface of the test. Brady records *Polymorphina angusta* Egger and his specimens may be the same as this.

Pyrulina extensa (Cushman) (pl. 12, fig. 13).

Polymorphina longicollis H. B. Brady, Voy. Challenger Rep., Zool., vol. 9, p. 572, pl. 73, figs. 18, 19, 1884. Egger, L. Bayer. Akad. Wiss. München, Abh., Cl. 2, vol. 18, p. 310, pl. 9, fig. 21, 1893.

Polymorphina extensa Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 90, pl. 41, figs. 1-3, 1913; Bull. 104, pt. 4, p. 156, pl. 41, figs. 7, 8, 1923.

Pyrulina extensa Cushman and Ozawa, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 53, pl. 12, fig. 5 *a-c*, 1930.

This species is a unique one with the neck and lip in the normal form, but in the figured specimen it appears with fistulose processes. The surface is hispid. The other records for this species are from deep water.

Genus LAGENA Walker and Jacob, 1798

Lagena sulcata Walker and Jacob, variety **alticostata** Cushman (pl. 13, figs. 1, 6).

Lagena sulcata Walker and Jacob, variety *alticostata* Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 23, pl. 9, fig. 5, 1913.

Test subglobular, ornamentation consisting of a few prominent primary costae high, thin, and platelike, running from the aperture to the apical end of the test; between these, secondary costae, running only to the base of the neck, the alternating ones of these being shorter; aperture small, rounded. Length 0.30 mm.; breadth 0.20 mm.

This variety was described from the Pacific so it is not surprising to find it in some numbers in the late Tertiary of Fiji.

Lagena gracilis Williamson (pl. 13, fig. 5).

The form figured here is very close to the specimen figured by Schwager from the Pliocene of Kar Nicobar under this same name. Our specimen has the apertural end broken but otherwise is very close to Schwager's figure.

Lagena punctulata Sidebottom (pl. 13, fig. 2).

Lagena apiculata Reuss, variety *punctulata* Sidebottom, Quekett Micr. Club, Jour., vol. 11, p. 382, pl. 14, figs. 21-23, 1912; vol. 12, p. 165, 1913; Roy. Micr. Soc., Jour., 1918, p. 129.

Test elongate, asymmetrical basal end somewhat pointed; apertural end blunt; chambers 2 or 3 times as long as broad; wall with numerous rather coarse perforations giving a peculiar mottled appearance to the test. Length 0.45 mm.; breadth 0.15 mm.

The three records given by Sidebottom are from the South Pacific. The Fiji specimens agree perfectly with his figure, showing that this is probably a species which has been localized in this region since the Pliocene, at least.

This may belong in *Entosolenia*.

Lagena marginata (Montagu) (pl. 13, fig. 3).

Specimens of this variable species occur in the late Tertiary of Fiji. It was recorded in Brady's list.

Lagena striata (d'Orbigny), variety **substriata** Williamson (pl. 13, fig. 4).

Specimens like that figured probably belong in the variety described by Williamson. Such specimens are widely distributed in both fossil and Recent collections.

Lagena plumigera H. B. Brady (pl. 13, fig. 8).

Lagena plumigera H. B. Brady, Micr. Sci., Quart. Jour., vol. 21, p. 62, 1881; Voy. Challenger Rep., Zool., vol. 9, p. 465, pl. 58, figs. 25, 27, 1884; Geol. Soc. London, Quart. Jour., vol. 44, p. 9 (table), 1888. Egger, K. Bayer. Akad. Wiss. München, Abh., Cl. 2, vol. 18, p. 329, pl. 10, figs. 37, 38, 1893. Millett, Roy. Micr. Soc., Jour., 1901, p. 490, pl. 8, fig. 8. Goddard, Australian Mus., Records, vol. 6, p. 307, 1905-1907. Sidebottom, Quekett Micr. Club, Jour., vol. 12, p. 173, pl. 15, fig. 26, 1913. Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 25, pl. 12, fig. 4, 1913. Sidebottom, Roy. Micr. Soc., Jour., 1918, p. 130. Heron-Allen and Earland, British Antarctic (*Terra Nova*) Exped., Zool., vol. 6, p. 147, 1922.

Test flask-shaped, broadest near the base, tapering to a long, slender neck; wall ornamented with 7 to 12 longitudinal costae, platelike, at the aboral end of the test spreading into winglike expansions showing transverse striations. Length 0.40 mm.; breadth 0.16 mm.

There are numerous records for this species almost entirely either fossil or Recent of the Indo-Pacific. It is a striking species and the specimens from the late Tertiary of Fiji are very typical.

Lagena costata Williamson, variety **amphora** Reuss (pl. 13, fig. 9).

Specimens similar to that figured I have already recorded under this name from the Pacific (U. S. Nat. Mus., Bull. 71, pt. 3, p. 21, pl. 10, figs. 2, 3; pl. 12, fig. 2, 1913).

Lagena striata d'Orbigny, variety **haidingeri** (Czjzek) (pl. 13, fig. 7).

Specimens of the form figured are best referred to this variety in which the body of the test has numerous fine longitudinal costae with a few large platelike structures running from the apertural end of the neck down onto the body of the test; the basal end of the chamber often with a spine.

Lagena alveolata H. B. Brady (pl. 13, fig. 12).

Lagena alveolata H. B. Brady, Voy. Challenger, Rep. Zool., vol. 9, p. 487, pl. 60, figs. 30, 32, 1884. Chapman, Linnaean Soc. London, Jour., Zool., vol. 30, p. 411, 1910. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 70, 1911. Sidebottom, Quekett Micr. Club, Jour., vol. 11, p. 424, pl. 21, figs. 1, 2, 1912; vol. 12, p. 202, pl. 18, figs. 11, 12, 1913. Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 33, pl. 18, fig. 1, 1913. Pearcey, Roy. Soc. Edinburgh, Trans., vol. 49, p. 1020, 1914. Heron-Allen and Earland, British Antarctic (*Terra Nova*) Exped., Zool., vol. 6, p. 167, 1922.

Test compressed pyriform, lateral edges obtuse or rounded; base broad and round in outline, rarely mucronate; furnished with a median and two lateral carinae, which unite so as to form two loops on each side of the test, usually separated by a central depression. Length 0.33 mm.; breadth 0.23 mm.

Most of the records for this species, at least of typical form, are from the Indo-Pacific. The Fiji specimens are typical. The forms recorded by Sidebottom from the Mediterranean are quite different from those of the Indo-Pacific.

Lagena costata (Williamson) (pl. 13, fig. 10).

Specimens of the form figured may be referred to Williamson's species. Such forms are widely distributed in both fossil and Recent collections.

Lagena fimbriata H. B. Brady (pl. 13, fig. 13).

This species, from the records, is a very widely distributed one, there being records for it from various parts of the Atlantic as well as from the Recent and Tertiary of the Indo-Pacific. It probably should be placed under *Entosolenia.*

Lagena formosa Schwager (pl. 13, fig. 11).

Lagena formosa Schwager, Novara Exped., Geol. Theil, vol. 2, p. 206, pl. 4, fig. 19, *a, d* (not 19, *b, c*), 1866.

Schwager included two species under this name, one which may be taken as the typical and the other the species here named *Lagena schwageriana* new species. In the typical form, the test has a very elongate neck, the peripheral keel with numerous elongate, more or less radiate depressions of considerable width, the body of the test with a raised edge and just inside it a series of small depressions. Length 0.45 mm.; breadth 0.22 mm.

Schwager described this species from the Pliocene of Kar Nicobar, and it has been widely recorded by many authors. A glance at the figures given, however, will show that many of the things referred to it are not at all this species. Typical specimens have been figured by Millett, from the Malay Archipelago (Roy. Micr. Soc., Jour. 1901, p. 624, pl. 14, figs. 10, 12, not fig. 11); Sidebottom (Quekett Micr. Club, Jour., vol. 11, pl. 19, figs. 6, 7, 1912); H. B. Brady (Voy. Challenger, Rep., Zool., vol. 9, pl. 60, figs. 18, 19, 1884).

Lagena schwageriana Cushman (pl. 13, figs. 14, 15, 17).

Lagena formosa Schwager (in part), Novara Exped., Geol. Theil, vol. 2, p. 206, pl. 4, fig. 19, *b, c* (not *a, d*), 1866.

Lagena schwageriana Cushman, Cushman Lab. Foram. Research, Contr., vol. 7, p. 26, pl. 4, fig. 2, 1931.

Test with a central body and a peripheral fringe, the latter marked by numerous fine tubules extending out in a radial manner, the body of the test smooth and without a definite raised border, apertural end with a definite neck ending in a broad, raised, hood-like structure confluent with the peripheral fringe. Length 0.35 to 0.75 mm.; breadth 0.25 to 0.50 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1301, Station 371, H. S. Ladd.

This species is very different from the typical form of *Lagena formosa* described by Schwager and already noted. The apertural end, the ornamentation, and the keel are all very different.

Lagena castrensis Schwager (pl. 13, fig. 16).

Schwager's original description and figure of this species would seem to indicate that the ornamentation is a series of raised pustules, but most of the other figures referred to it have these represented as depressions. The specimens from Fiji, one of which is here figured, also show the body of the test with depressions.

Lagena orbignyana (Seguenza) (pl. 13, figs. 18, 19).

There are numerous specimens from the late Tertiary of Fiji similar to those figured here which in their general characters may be referred to Seguenza's species. Some of these are large, that represented by figure 18 being 1 mm. long.

Lagena tubulata Sidebottom (pl. 14, fig. 1).

Lagena hispida Reuss, variety *tubulata* Sidebottom, Quekett Micr. Club, Jour., 2d ser., vol. 11, p. 385, pl. 15, figs. 3-5, 1912.

Test with the body globular, the neck very long, often twice as long as the diameter of the body, cylindrical and with a lip, body of the test with stout hollow spines, often broken at the end. Length 0.60 mm.; diameter, with spines, 0.30 mm.

Specimens were described by Sidebottom from the Southwest Pacific and I recorded it from off Celebes. The specimens from Fiji are very typical, as will be seen by the figure.

Lagena spiro-striolata Cushman (pl. 14, fig. 2).

Lagena lineata Sidebottom (part) (not Williamson), Quekett Micr. Club, Jour., 2d ser., vol. 11, p. 387, pl. 15, fig. 15, 1912.

Lagena spiro-striolata Cushman, Cushman Lab. Foram. Research, Contr. vol. 7, p. 27, pl. 4, fig. 3, 1931.

Test often slightly longer than broad, the apertural end not extended; wall ornamented by numerous fine costae arranged in a spiral manner. Length 0.30 mm.; breadth 0.20 mm.

Holotype B. P. Bishop Mus., Geol. No. 1302, Station 371, H. S. Ladd. This specimen, as will be seen by the figure, agrees very perfectly with that figured by Sidebottom, in the above reference, from the Southwest Pacific. It is evidently a species to be looked for in the late Tertiary and Recent collections from the general Indo-Pacific region.

Lagena spino-alata Cushman (pl. 14, fig. 3).

Lagena spino-alata Cushman, Cushman Lab. Foram. Research, Contr., vol. 7, p. 27, pl. 4, fig. 4, 1931.

Test subglobular, slightly broader toward the base, the periphery with a peculiarly shaped keel consisting of four parts, outer ones somewhat hollow, and the two central ones flattened and toothed; wall smooth or punctate. Length 0.25 mm.; breadth, with spines, 0.50 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1303, Station 371, H. S. Ladd.

This is a very beautifully ornamented little species which might best be referred to *Entosolenia*. Similarly ornamented forms have been referred to *Lagena alveolata* by some authors.

Lagena mucronulata Reuss (pl. 14, fig. 4).

The figured specimen resembles ones that I have referred to this species of Reuss's (U. S. Nat. Mus., Bull. 71, pt. 3, p. 25, pl. 8, fig. 4, 1913).

Lagena staphyllearia Schwager (pl. 14, fig. 5).

This species was described by Schwager from the Pliocene of Kar Nicobar. It has been widely recorded, with numerous variations, from widely distributed areas.

Lagena basi-striatula Cushman (pl. 14, fig. 6).

Lagena basi-striatula Cushman, Cushman Lab. Foram. Research, vol. 7, pt. 2, p. 27, pl. 4, fig. 5, 1931.

Test elongate, fusiform, greatest breadth toward the base, 5 or 6 times as long as broad, base ending in a spine, apertural end extended into a tapering, cylindrical neck, surface ornamented by elongate pits arranged more or less in lines, the basal portion with numerous distinct longitudinal costae. Length 0.50 mm.; breadth 0.10 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1304, Station 371, H. S. Ladd.

This is a very distinct, ornamented species which occurs in some numbers in the Fiji collections.

Family Nonionidae

Genus NONION Montfort, 1808

Nonion stelligera d'Orbigny (pl. 14, fig. 9, *a*, *b*).

The specimens referred to this species, one of which is figured, have, like Recent Indo-Pacific specimens, usually about 5 or 6 chambers and the intermediate stellate portion comparatively large.

Nonion pacifica Cushman (pl. 14, fig. 7, *a*, *b*).

Nonionina umbilicatula (Montagu), variety *pacifica* Cushman, Carnegie Inst. Washington, Pub. 342, p. 48, pl. 16, fig. 3, 1924.

This form, which is much compressed, was originally described from Recent material of Samoa. Very similar specimens occur in the late Tertiary of Fiji. It may be noted in this connection that Brady (Geol. Soc. London, Quart. Jour., vol. 44, p. 10, 1888) records *Nonionina umbilicatula* Montagu from the so-called "soapstone" of Fiji.

Nonion galeata Cushman (pl. 14, fig. 8, *a*, *b*).

Nonion galeata Cushman: Cushman Lab. Foram. Research, Contr., vol. 7, pt. 2, p. 28, pl. 4, fig. 7, *a*, *b*, 1931.

Test close-coiled, bilaterally symmetrical, somewhat compressed, the periphery very broadly rounded, sides deeply umbilicate, chambers 10 to 12 in number, distinct, slightly inflated, the inner end projecting into the central depression; sutures distinct, slightly depressed, very slightly curved; wall smooth, except about the umbilical depression where there are, in the early chambers, roughened areas at the inner part of each chamber; aperture broad and low, extending completely along the base of the final chamber, and with a slight lip, the sides of the chamber extending somewhat outwardly over the umbilical depression. Length 0.65 mm.; breadth 0.35 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1305, Station 371, H. S. Ladd.

The form of the chambers in this species is peculiar and reminds one strongly of the German war helmet. The umbilical region is also distinctive.

Genus NONIONELLA Cushman, 1926

Nonionella limbato-striata Cushman (pl. 14, fig. 10, *a-c*).

Nonionella limbato-striata Cushman: Cushman Lab. Foram. Research, Contr., vol. 7, pt. 2, p. 30, pl. 4, fig. 8, *a, c*, 1931.

Test much longer than broad, trochoid, completely involute on the ventral side, whole test compressed, very narrow in peripheral view, the periphery rounded; chambers distinct, 8 to 10 in number in the last-formed coil, gradually increasing in length, especially in the last few chambers, not inflated; sutures distinct, curved, limbate, very broad on the ventral side; wall smooth, finely perforate; aperture, a narrow slit in the base of the apertural face. Length 0.30 mm.; breadth 0.15 mm.; thickness 0.06 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1306, Station 371, H. S. Ladd.

This is a small but very distinct species; the broad sutures are of peculiar type and will at once distinguish it from other species of the genus.

Nonionella clavata Cushman (pl. 14, fig. 11, *a-c*).

Nonionella clavata Cushman: Cushman Lab. Foram. Research, Contr., vol. 7, pt. 2, p. 30, pl. 4, fig. 9, *a-c*, 1931.

Test elongate, broadest near the outer end, making the shape in peripheral view clavate, periphery very broadly rounded; chambers 8 to 10 in the last-formed coil, distinct, the later ones very much elongated; sutures distinct, limbate, slightly curved; wall smooth, finely perforated; aperture, a very narrow slit at the base of the apertural face. Length 0.55 mm.; breadth 0.30 mm.; thickness 0.18 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1307, Station 371, H. S. Ladd.

This is a very peculiarly shaped species, the last chambers being very greatly extended and swollen at the outer end. The test is not entirely bilaterally symmetrical but nearly so.

Family Heterohelicidae

Subfamily Bolovitinae

Genus BOLIVINITA Cushman, 1927

Bolivinita quadrilatera (Schwager) (pl. 14, fig. 12, *a, b*).

Textularia quadrilatera Schwager, Novara Exped., Geol. Theil, vol. 2, p.

253, pl. 7, fig. 103, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 95, 1878. H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 358, pl. 42, figs. 8-12, 1884; Geol. Soc. London, Quart. Jour., vol. 44, p. 5, 1888. Millett, Roy. Micr. Soc., Jour., 1898, p. 559. Dakin, Ceylon Pearl Oyster Fish., Rep., vol. 5, p. 233, 1906. Goddard and Jensen, Linnaean Soc. New South Wales, Proc., vol. 32, p. 294, pl. 6, fig. 1, 1907. Bagg, U. S. Nat. Mus., Proc., vol. 34, p. 131, 1908. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 87, 1911. Cushman, U. S. Nat. Mus. Bull. 71, pt. 2, p. 24, figs. 42-44, 1911. Sidebottom, Roy. Micr. Soc., Jour., p. 20, 1918. Cushman, U. S. Nat. Mus. Bull. 100, vol. 4, p. 125, pl. 23, fig. 2, *a, b,* 1921. Yabe and Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 50, 1925 (1926).

Bolivina quadrilatera Wright, Roy. Irish Acad., Proc., 3d ser., vol. 1, p. 475, 1889-1891. Cushman, U. S. Nat. Mus., Bull. 104, pt. 3, p. 44, pl. 8, fig. 2, 1922.

Test elongated, slender, very slightly tapering, in end view quadrilateral, the angles usually carinate; chambers high and narrow, running back obliquely on the outer border, compressed; the initial end of the test often with a stout spine, occasionally with several small spines, or smooth and broadly rounded, the early chambers sometimes with one or more longitudinal raised costae for a short distance; wall hyaline, distinctly perforate; aperture at one side near the distal end of the chamber, sometimes obliquely elongate, but somewhat variable.

Schwager described this species from the Pliocene of Kar Nicobar. It is recorded from numerous Indo-Pacific localities both Recent and fossil. Brady records it from Fiji, Karrer from the late Tertiary of Luzon, and Schubert from the Bismarck Archipelago. There are other records for the species not given here but which are more or less uncertain as to their identity.

Subfamily Eouvigerininae

Genus NODOGENERINA Cushman, 1927

Nodogenerina protumida (Schwager) (?) (pl. 14, fig. 13).

Specimens like that figured seem to be closely related to Schwager's species. The aperture is formed by a long tubular neck with a definite lip which would seem to place it in this genus.

Nodogenerina lepidula (Schwager) (pl. 14, figs. 15, 16).

Nodosaria lepidula Schwager, Novara Exped., Geol. Theil, vol. 2, p. 210, pl. 5, figs. 27, 28, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 88, 1878. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 75, text-fig. 5, *a-f,* 1911. Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 203, pl. 36, fig. 6, 1921. Koch, Schweiz. Pal. Ges., Ber., vol. 19, no. 3, p. 725 (list), 1926.

Test elongate, composed of several chambers increasing gradually in size, as added, the basal point of each broad and somewhat excavated; periphery with a series of short-pointed spines or scallops; suture depressed, distinct; wall smooth; aperture with an elongate neck and broad lip. Length up to 1 mm.; diameter 0.15 mm.

This was described by Schwager from Kar Nicobar and is recorded in the late Tertiary of the Indo-Pacific, by Karrer from Luzon, by Schubert from the Bismarck Archipelago, and by Koch from Java.

Nodogenerina spinata Cushman, new species (pl. 14, fig. 14).

Test elongate, slender, tapering at the base, but the later chambers of almost equal size; sutures distinct, depressed; wall covered with acicular spines extending backward, especially prominent on the last few chambers; apertures with a cylindrical neck and phialine lip. Length 0.70 mm.; breadth 0.18 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1308, Station 371, H. S. Ladd.

This is a distinctive small species but well marked by its surface characters and the general form.

Family BULIMINIDAE

Subfamily TURILLININAE

Genus GLOBOBULIMINA Cushman, 1927

Globobulimina pacifica Cushman (pl. 15, fig. 1).

Bulimina pyrula H. B. Brady (not d'Orbigny), Voy. Challenger, Rep., Zool., vol. 9, p. 399, pl. 50, figs. 7-10, 1884. Bagg, U. S. Geol. Survey, Bull. 513, p. 39, pl. 9, fig. 1, *a-e*, 1912.

Globobulimina pacifica Cushman, Cushman Lab. Foram. Research, Contr., vol. 3, p. 67, pl. 14, fig. 12, 1927; Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 153, pl. 3, fig. 1, 1927. Galloway and Wissler, Jour. Pal., vol. 1, p. 74, pl. 11, fig. 18, 1927.

Test subglobular to pyriform, in the adult, the last three chambers making up the exterior but enclosing the preceding ones, somewhat inflated; wall thin, finely perforate, smooth; sutures distinct, slightly depressed; aperture loop-shaped with a slight border, a broad apertural tooth or plate, and an internal spiral tube. Length up to 1½ mm.; breadth 1 mm.

This is a common species in the Indo-Pacific and it is not surprising to find it well characterized in this late Tertiary material from Fiji.

Genus BULIMINA d'Orbigny, 1826

Bulimina inflata Seguenza.

Schwager records this species from Kar Nicobar. His specimens are slightly coarser and the spinose processes somewhat more flaring than those from Fiji, but, in general, the two are very similar. Brady records both *B. inflata* and *B. buchiana* in his Fiji list.

Bolivina globigera (Schwager) (pl. 15, fig. 2).

Textilaria globigera Schwager, Novara Exped., Geol. Theil, vol. 2, p. 252, pl. 7, fig. 100, 1866.

Test very small, periphery rounded and rapidly enlarging from a subacute base; chambers comparatively few, globular, very rapidly enlarging toward the apertural end; sutures distinct, depressed; wall smooth, finely perforate; aperture, a narrow slit at the inner margin of the last-formed chamber. Length 0.15 to 0.40 mm.; breadth 0.10 to 0.25 mm.

This species, originally described by Schwager from the Pliocene of Kar Nicobar, occurs in typical form in the Fiji collection. The original specimen, figured by Schwager, is apparently microspheric, and this one (pl. 15, fig. 2) is megalospheric.

Bolivina reticulata Hantken (?) (pl. 15, fig. 4).

There are a few small specimens of *Bolivina* similar to the one figured which may be referred with some question to Hantken's species. The surface is not regularly reticulate but made up of a series of broken, raised lines. Such forms are common in the Indo-Pacific.

Bolivina hantkeniana d'Orbigny (pl. 15, fig. 5).

Bolivina hantkeniana H. B. Brady, Micr. Sci., Quart. Jour., vol. 21, p. 58, 1881; Voy. Challenger, Rep., Zool., vol. 9, p. 424, pl. 53, figs. 16-18, 1884. Egger, K. Bayer. Akad. Wiss. München, Abh., Cl. 2, vol. 18, pl. 8, figs. 40-42, 1893. Millet, Roy. Micr. Soc., Jour., 1900, p. 546, pl. 4, fig. 9. Bagg, U. S. Nat. Mus., Proc., vol. 34, p. 137, 1908. Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, p. 42, fig. 68 (in text), 1911. Sidebottom, Roy. Micr. Soc., Jour., 1918, p. 127. Cushman, U. S. Nat. Mus., Bull. 100, vol. 4, p. 132, pl. 27, fig. 1, 1921; Carnegie Inst. Washington, Pub. 342, p. 16, pl. 6, figs. 1, 2, 1924.

Test broad, much compressed, usually completely surrounded, except at the aperture, by a broad winglike flange, either entire or variously lobed; chambers inflated somewhat; sutures very distinct, slightly depressed; wall calcareous, with a few short longitudinal costae, usually confined to the limits of the chamber on which they originate; aperture narrow, oval, with a single toothlike projection in the orifice; color white.

Most of the records for this species are from the Indo-Pacific, where it is rather definitely restricted, so far as available records show, to an area bounded by Hawaii and Japan south to Samoa and Australia and westward to the larger East Indies.

Genus VIRGULINA d'Orbigny, 1826

Virgulina cf. **schreibersiana** Czjzek (pl. 15, fig. 3).

There are a few specimens of *Virgulina* similar to that figured here which may be referred to Czjzek's species. Schubert records this same form from the late Tertiary of the Bismarck Archipelago.

Subfamily UVIGERININAE

Genus UVIGERINA d'Orbigny, 1826

Uvigerina nitidula Schwager (pl. 15, fig. 6).

Uvigerina nitidula Schwager, Novara Exped., Geol. Theil, vol. 2, p. 248, pl. 7, fig. 93, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 94, 1878.

Test about twice as long as broad, quickly reaching the maximum diameter; chambers inflated, distinct, generally triserial; sutures depressed, distinct; wall marked by a series of raised longitudinal costae, 10 to 15 to each chamber, sharply raised above the surface; aperture with a slender neck and phialine lip. Length up to 1 mm.; breadth 0.40 mm.

Schwager's types are from the Pliocene of Kar Nicobar. Karrer records it from the late Tertiary of Luzon, so it is not surprising to find rather typical specimens in the late Tertiary of Fiji.

Uvigerina gemmaeformis Schwager (pl. 15, fig. 7).

Uvigerina gemmaeformis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 247, pl. 7, fig. 92, 1866.

Test stout, the early portion tapering, greatest width at about the middle, tapering slightly toward the apertural end; chambers distinct, inflated, irregularly triserial; sutures distinct, slightly depressed; wall ornamented by longitudinal costae, only slightly raised, 10 or more on each adult chamber; aperture depressed, with a very short neck. Length 1 mm.; breadth 0.55 mm.

There seem to be no other records since the description of this species by Schwager from Kar Nicobar. The Fiji specimens, as a comparison of the figures will show, are very similar in form, ornamentation, and very short neck.

Uvigerina crassicostata Schwager (pl. 15, fig. 8).

Uvigerina crassicostata Schwager, Novara Exped., Geol. Theil, vol. 2, p. 248, pl. 7, fig. 94, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 94, 1878. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 353, 1923.

Test large, stout, broadest toward the apertural end; chambers somewhat indistinct due to the ornamentation which consists of raised longitudinal costae, those of the early chambers irregular, high, and platelike; sutures obscured; aperture with a very short neck and tubular lip. Length 1 mm. or more; breadth 0.60 to 0.75 mm.

Schwager described this species from the Pliocene of Kar Nicobar. Karrer records it from the late Tertiary of Luzon, and Koch from the late Tertiary of Kabu, Java.

Uvigerina hispida Schwager (pl. 15, fig. 9).

Uvigerina hispida Schwager, Novara Exped., Geol. Theil, vol. 2, p. 249, pl. 7, fig. 95, 1866. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 353, 1923.

This species closely resembles some of the forms described from the Miocene of the Vienna Basin and elsewhere. It may be that the two are really one species.

Uvigerina proboscidea Schwager (pl. 15, fig. 10).

Uvigerina proboscidea Schwager, Novara Exped., Geol. Theil, vol. 2, p. 250, pl. 7, fig. 96, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 94, 1878. Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 94, pl. 42, fig. 2, 1913. Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 42 (table), 1925 (1926).

Test ovate or fusiform, tapering at each end; chambers inflated, irregularly triserial; sutures depressed; wall hispid with very fine aculei; aperture with a tapering, tubular neck, its greatest diameter near the base, the outer end with a slightly phialine lip. Length up to 0.85 mm.; breadth 0.40 mm.

This is one of the species described by Schwager from the Pliocene of Kar Nicobar, and by Karrer from the late Tertiary of Luzon. Other records are from the Indo-Pacific. Brady records *U. asperula* and variety *ampullacea* from Fiji, which may be this species.

Genus SIPHOGENERINA Schlumberger, 1883

Siphogenerina dimorpha (Parker and Jones), variety **pacifica** Cushman.

Uvigerina (*Sagrina*) *dimorpha* Parker and Jones (part), Philos. Trans., vol. 155, p. 420, 1865.

Sagrina dimorpha H. B. Brady (part), Voy. Challenger, Rep., Zool., vol. 9, p. 582, pl. 76, figs. 1-3, 1884. Bagg, U. S. Nat. Mus., Bull. 34, p. 152, 1908. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 86, 1911. Sidebottom, Roy. Micr. Soc., Jour., 1918, p. 148. Heron-Allen and Earland, British Antarctic (*Terra Nova*) Exped., Zool., vol. 6, p. 186, 1922.

Siphogenerina dimorpha Egger, K. Bayer. Akad. Wiss. München, Cl. 2, vol. 18, p. 317, pl. 9, fig. 30, 1893. Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 106, pl. 45, figs. 3, 4, 1913; Bull. 100, pt. 4, p. 279, pl. 56, fig. 8, 1921.

Siphogenerina dimorpha (Parker and Jones), variety *pacifica* Cushman, U. S. Nat. Mus., Proc., vol. 67, art. 25, p. 13, pl. 2, fig. 9, pl. 3, fig. 6, *a, b,* 1926.

Variety differing from the typical in the greater number of uniserial chambers, the cylindrical form of the test, and the much more prominent depressions at the base of the chambers along the sutures.

There are numerous records for this species in the present waters of the Indo-Pacific region. Schubert records it in a *Globigerina* marl of late Tertiary age from Panaras, in the Bismarck Archipelago, and Koch from the late Tertiary of Kabu, Java. Brady lists it from Fiji also.

Genus SIPHONODOSARIA A. Silvestri, 1924

Siphonodosaria fijiensis Cushman (pl. 15, fig. 12).

Siphonodosaria fijiensis Cushman, Cushman Lab. Foram. Research, vol. 7, pt. 2, p. 30, pl. 4, fig. 10, 1931.

Test elongate, slender, very slightly tapering, base broadly rounded; chambers 6 to 10 in number, very slightly inflated especially toward the apertural end, partially involute, the later ones increasing somewhat in length; sutures distinct, very slightly depressed; wall smooth, except for rather prominent perforations or depressions of the surface giving a peculiarly pearly appearance to the test; apertural end extended into a slightly tapering, elongate, tubular neck with a slight lip. Length 0.75 mm.; breadth 0.10 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1309, Station 371, H. S. Ladd.

This is a rather handsome small species with its pearly luster, few chambers, uniform diameter, and definite tubular neck.

Genus ANGULOGERINA Cushman, 1927

Angulogerina fijiensis Cushman (pl. 16, fig. 1).

Angulogerina fijiensis Cushman, Cushman Lab. Foram. Research, vol. 7, pt. 2, p. 31, pl. 4, fig. 11, 1931.

Test elongate, tapering rapidly at the ends; chambers triserial, generally triangular in section, the later ones somewhat separated from adjacent ones, the lower side excavated; sutures distinct, depressed; wall ornamented by longitudinal costae, several grouped at the angles of the chambers; apertural end produced into a slightly tapering, tubular neck with longitudinal costae, the outer end with a definite lip. Length 0.60 mm.; breadth 0.15 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1310, Station 371, H. S. Ladd.

This is a distinctive species with its somewhat separated chambers and peculiar ornamentation. Brady records *Uvigerina porrecta* from Fiji, but this is very different from that species.

Genus TRIFARINA Cushman, 1923

Trifarina bradyi Cushman (pl. 15, fig. 11).

Rhabdogonium tricarinatum H. B. Brady (not *Vaginulina tricarinata* d'Orbigny), Voy. Challenger Rep., Zool., vol. 9, p. 525 (in part), 1884; Geol. Soc. London, Quart. Jour., vol. 44, p. 9 (table), 1888;

Goës, Harvard Mus. Comp. Zool., Bull., vol. 29, p. 64, 1896. Bagg, U. S. Nat. Mus., Proc., vol. 34, p. 145, 1908. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 80, 1911. Sidebottom, Roy. Micr. Soc., Jour., 1918, p. 137, 1918. Heron-Allen and Earland, British Antarctic (*Terra Nova*) Exped., Zool., vol. 6, p. 175, 1922.

Triplasia tricarinata Cushman, U. S. Nat. Mus., Bull. 71, pt. 3, p. 62, pl. 39, fig. 2, 1913; Bull. 100, vol. 4, p. 219, 1921.

Trifarina bradyi Cushman, U. S. Nat. Mus., Bull. 104, pt. 4, p. 99, pl. 22, figs. 3-9, 1923; Carnegie Inst. Washington Pub. 342, p. 27, pl. 7, fig. 5, 1924. Hanzawa, Jap. Jour. Geol. Pal., vol. 4, p. 50, 1925 (1926), Yabe and Hanzawa, p. 41 (table). Cushman, Cushman Lab. Foram. Research, Contr., vol. 1, pt. 4, p. 86, 1926. Chapman and Parr, Linnaean Soc. London, Jour., Zool., vol. 36, p. 386, pl. 20, fig. 52, 1926.

Above are given some of the Pacific records for this species. The Pacific form is usually slightly smaller than the Atlantic one, the sides are less concave, the carinae at the angles less prominent, the wall thicker and more distinctly perforate.

It is recorded by Brady from Fiji, by Schubert from the late Tertiary of the Bismarck Archipelago, and by Hanzawa from the late Tertiary of the Riukiu Islands.

Family Ellipsoidinidae

Genus PLEUROSTOMELLA Reuss, 1860

Pleurostomella brevis Schwager (pl. 15, fig. 13).

Pleurostomella brevis Schwager, Novara Exped., Geol. Theil, vol. 2, p. 239, pl. 6, fig. 81, 1866. H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 411, pl. 51, fig. 20, *a, b*, 1884. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 56, 1911. Koch, Schweiz. Pal. Ges., Ber., vol. 19, p. 727 (list), 1926. Cushman and Harris, Cushman Lab. Foram. Research., Contr., vol. 3, p. 129, pl. 25, fig. 6, 1927. Nuttall, Geol. Soc. London, Quart. Jour., vol. 84, p. 74, pl. 3, fig. 12, 1928.

The short, stout form figured and described by Schwager from the Pliocene of Kar Nicobar occurs in typical form in the Fiji collection. It is recorded from the late Tertiary of the Bismarck Archipelago by Schubert and from East Borneo by Koch. There are records from the Tertiary of Trinidad by Nuttall, and by Liebus from Dalmatia.

Pleurostomella alternans Schwager (pl. 16, figs. 3, 4).

Pleurostomella alternans Schwager, Novara Exped., Geol. Theil, vol. 2, p. 238, pl. 6, figs. 79, 80, 1866. Karrer, in von Drasche, Frag. Geol. Insel Luzon, p. 91, 1878. Terrigi, Accad. Pont. Nuovi Lincei, Atti, vol. 33, p. 77, pl. 2, fig. 46, 1880. H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, p. 412, pl. 51, fig. 23 (not 22), 1884. Silvestri, Accad. Pont. Nuovi Lincei, Mem., vol. 22, p. 253, fig. 6, *a, b, d* (in text). Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, p. 50, fig. 81 (in text), 1911. Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, pt. 4, p. 56, 1911. Koch, Schweiz. Pal. Ges., Ber., vol. 18, p. 353, 1923. Cushman and Harris, Cushman Lab. Foram. Research, vol. 2, p. 129, pl. 25, figs. 7, 8, 28, 1927.

There are many other records for this species than those given above, but for the most part they are without figures or are not the same as this species. There is a great difference in the microspheric and megalospheric forms. The microspheric form (pl. 16, fig. 3, *a, b*) has a very pointed initial end, many more chambers than the megalospheric form (pl. 16, fig. 4, *a, b*), and the ultimate length is much greater. The same characters are shown by Schwager in his original figures.

The species is known from the late Tertiary of Kar Nicobar, Luzon, Bismarck Archipelago, and Java. It probably occurs also in Borneo, and as a living species at least in the Indo-Pacific. There are numerous records from the Pliocene of the Mediterranean region, and it is recorded as far back as the Gault, but the Cretaceous and perhaps the earlier Tertiary forms are not the same.

Pleurostomella alternans Schwager, variety **telostoma** Schubert (?) (pl. 16, fig. 6).

Pleurostomella alternans Schwager, variety *telostoma* Schubert, Deutsch. Naturwiss. Med. Ver. Böhmen "Lotos," Sitzb., vol. 20, p. 224, pl. 5, fig. 5, *a, b,* 1900. Cushman and Harris, Cushman Lab. Foram. Research, Contr., vol. 3, p. 130, pl. 25, fig. 9, 1927.

In numerous forms there is a tendency for the last-formed chamber to be only partially developed, and the aperture tends to become terminal. Schubert has given the varietal name *"telostoma"* to specimens of this sort. The specimen figured here is somewhat more coarsely perforate than typical *P. alternans,* but otherwise is much the same but for the small last chamber.

Pleurostomella sapperi Schubert (pl. 15, fig. 14).

Pleurostomella sapperi Schubert, K. K. Geol. Reichsanstalt, Abh., vol. 20, p. 56, fig. 3, *a, b* (in text), 1911. Cushman and Harris, Cushman Lab. Foram. Research, Contr., vol. 3, p. 129, pl. 25, fig. 4, 1927.

This form was described and figured by Schubert in his paper on the late Tertiary of the Bismarck Archipelago. It is rare in the collection from Fiji, but has the characteristic elongate form, and the early portion is longitudinally costate.

Genus NODOSARELLA Rzehak, 1895

Nodosarella pacifica Cushman (pl. 16, figs. 7, 8).

Nodosarella pacifica Cushman, Cushman Lab. Foram. Research, Contr., vol. 7, p. 31, pl. 4, figs. 12, 13, 1931.

Test elongate, slightly tapering, the last formed chamber with the greatest diameter, rounded in transverse section; early chambers at least in the microspheric form showing traces of the biserial character but later ones all uniserial, slightly involute, later chambers somewhat inflated; sutures but little depressed; wall smooth; aperture, a narrow opening with a slight hooded upper edge or even double in the large specimens. Length of microspheric form 4 mm.; breadth 0.95 mm.

The megalospheric form is much smaller and has fewer chambers, usually showing little trace of the biserial arrangement in the young. The microspheric form grows to large size.

Holotype, B. P. Bishop Mus., Geol. No. 1311, Station 371, H. S. Ladd.

Genus ELLIPSOLAGENA A. Silvestri, 1923

Ellipsolagena fijiensis Cushman (pl. 16, figs. 2, 5).

Ellipsolagena fijiensis Cushman, Cushman Lab. Foram. Research, Contr., vol. 7, p. 32, pl. 4, fig. 6, 1931.

Test small, compressed, obovate, greatest width toward the base; single-chambered; wall smooth; aperture elongate, with one side forming a distinct hood. Length 0.25 mm.; breadth 0.10 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1312, Station 371, H. S. Ladd.

This is a very small, somewhat elongate, compressed species. It is to be looked for elsewhere in the late Tertiary of the Indo-Pacific.

Family Rotaliidae

Subfamily Discorbisinae

Genus GYROIDINA d'Orbigny, 1826

Gyroidina nitidula (Schwager).

Rotalia nitidula Schwager, Novara Exped., Geol. Theil, vol. 2, p. 263, pl. 7, fig. 110, 1866.

Specimens very similar to those figured under the above name by Schwager, from Kar Nicobar, appear in the Fiji collection. Whether this is distinct from *Gyroidina soldani* d'Orbigny is a question, but there are certain differences which larger series may show to be constant.

Genus EPONIDES Montfort, 1808

Eponides umbonata (Reuss), variety **multisepta** Koch (pl. 17, fig. 4, *a-c*).

Our figured specimen seems to be very close to this variety, as described and figured by Koch from the middle Tertiary of East Borneo.

Eponides species (?) (pl. 17, fig. 1, *a-c*).

The figured specimen must be left for more material before its specific determination can be made sure. There are but few chambers in the coil and the slightly channeled appearance of the dorsal side gives a suggestion of *Gyroidina,* but the ventral side is that of *Eponides.*

Subfamily SIPHONININAE

Genus SIPHONINA Reuss, 1849

Siphonina australis Cushman.

Siphonina australis Cushman, U. S. Nat. Mus., Proc., vol. 27, art. 20, p. 8, pl. 2, fig. 6, *a-c*, pl. 3, figs. 7, *a-c*, 8, *a-c*, 1927.

This species is especially common in the Miocene of Australia and it is not surprising to find it in this late Tertiary material from Fiji.

Family CASSIDULINIDAE

Subfamily CERATOBULIMININAE

Genus PULVINULINELLA Cushman, 1926

Pulvinulinella bengalensis (Schwager) (pl. 17, fig. 6, *a-c*).

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

Test close-coiled, trochoid, unevenly biconvex, ventral side the more strongly convex, periphery keeled; chambers numerous, 10 to 15 in the last-formed whorl, those of the last half of the whorl distinct, others indistinct; sutures strongly oblique on the dorsal side, tangential, ventrally slightly curved, limbate, not depressed; wall smooth; aperture, a narrow slit on the ventral side at nearly right angles to the ventral edge of the chamber. Diameter 1.50 mm.

The figured specimen has the aperture broken away, but in well-preserved specimens it is very narrow and slitlike. The other characters made this the best specimen otherwise for illustration.

Brady records *"Truncatulina culter"* from Fiji in his 1888 list, which probably should be referred to Schwager's species.

Subfamily CASSIDULININAE

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina murrhyna (Schwager).

Sphaeroidina murrhyna Schwager, Novara Exped., Geol. Theil, vol. 2, p. 200, pl. 7, fig. 97, 1866.

This species described and figured from Kar Nicobar by Schwager under the above name is most nearly related to *Cassidulina subglobosa* H. B. Brady but is much more pointed. I have topotype material from Kar Nicobar which is very similar to the Fiji specimens.

Cassidulina subglobosa H. B. Brady, variety **ornata** Cushman (pl. 16, fig. 13).

Cassidulina subglobosa H. B. Brady, variety *ornata* Cushman, Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 167, pl. 6, fig. 6, 1927.

Test small, differing from the typical in the ornamentation of the chambers, the earlier portion of the test being covered with a series of irregular, raised reticulations, the last-formed chamber usually smooth.

It may be noted that this variety does not seem to occur with the typical form, and it may be of specific value.

Cassidulina delicata Cushman (pl. 16, fig. 12).

Cassidulina delicata Cushman, Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 168, pl. 6, fig. 5, 1927.

Test much compressed, broadly ovate, periphery subacute; chambers very distinct, broad, four pairs making up the last-formed coil, the chambers of the opposite series barely showing as very small triangles near the periphery, inflated; sutures very distinct, depressed, not limbate; wall very thin, very finely perforate, smooth, and polished; aperture, a very elongate, narrow slit, following the curve of the previous chamber from umbilical end to periphery, of uniform width. Diameter of figured specimen 0.40 mm.

This species has been recorded from several stations on the west coast of North America, and this is its first appearance as a fossil.

Genus CASSIDULINOIDES Cushman, 1927

Cassidulinoides bradyi (Norman) (pl. 16, fig. 9).

The figured specimen is evidently an immature one. Brady records "*Cassidulina bradyi*" from Fiji in his list in 1888. There are many records for this species from about the British Isles and also from the Indo-Pacific.

Subfamily Ehrenbergininae

Genus EHRENBERGINA Reuss, 1850

Ehrenbergina pacifica Cushman (pl. 16, fig. 14).

Ehrenbergina serrata H. B. Brady (part) (not Reuss), Voy. Challenger, Rep., Zool., vol. 9, pl. 55, figs. 6, 7, 4 (?) (not 2, 3, 4 ?), 1884. Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, p. 101, fig. 155, *a, b* (in text), 1911.

Ehrenbergina pacifica Cushman, U. S. Nat. Mus., Proc., vol. 70, art. 16, p. 5, pl. 2, fig. 2, *a-c*, 1927.

Test triangular in front view, chambers numerous, low and broad, dorsal side convex, ventral side with a narrow median furrow which may be entirely closed; sutures distinct, on the dorsal side flush with the surface, on the ventral side depressed; periphery with long spinose processes from the upper angle of each chamber extending straight out from the test, each chamber with the ventral angle having a raised ridge continuing to the spine at the periphery; aperture elongate, narrow.

This is a common species in the Pacific at the present time. It was recorded by Brady from Fiji as *"E. serrata."* It should be noted also that Schubert records *"E. serrata"* as fossil from the Bismarck Archipelago, but he does not figure it.

Ehrenbergina bicornis H. B. Brady (pl. 16, figs. 10, 11).

Ehrenbergina bicornis H. B. Brady, Geol. Soc. London, Quart. Jour., vol. 44, p. 5, pl. 1, fig. 3, *a, b,* 1888. Cushman, U. S. Nat. Mus., Proc., vol. 70, art. 16, p. 2, pl. 1, fig. 5, *a, b,* 1927.

Brady's original description is as follows:

Test subspherical, regularly biserial, earlier portion helicoid; margin entire, armed with two stout spines, one at each side, directed outwards.

The only known record for this species has been that of Brady from the so-called "soapstone" of Fiji. It has been one of the interesting finds of this collection. After 40 years, it now appears in typical form from the type locality. Our specimens are not quite as high in the coil as that figured by Brady, and the spines are relatively somewhat larger. It was evidently a species of local distribution, as might have been suspected from the very large spine, and has not persisted, as far as known, in the present oceans.

Family Chilostomellidae

Subfamily Allomorphininae

Genus ALLOMORPHINA Reuss, 1850

Allomorphina trigona Reuss (pl. 17, fig. 2, *a, b*).

This widely distributed species does not seem to have been recorded in the late Tertiary of the Indo-Pacific. The specimens are similar to those now found living in this same general region.

Subfamily Chilostomellinae

Genus CHILOSTOMELLA Reuss, 1850

Chilostomella oolina Schwager (pl. 17, fig. 3, *a, b*).

Brady records *"Chilostomella ovoidea* Reuss" from Fiji in his 1888 list. The specimens we have are to be referred to Schwager's species rather than to that of Reuss. Schwager's species is longer and more nearly cylindrical, whereas that of Reuss is broader, fusiform, and the ends usually more pointed.

Subfamily Allomorphinellinae

Genus PULLENIA Parker and Jones, 1862

Pullenia sphaeroides d'Orbigny.

Brady records this species from Fiji in his 1888 list. Schubert records it from the late Tertiary of the Bismarck Archipelago, and Koch from Java and east Borneo. Karrer records *P. bulloides* from the late Tertiary of Luzon.

Pullenia quinqueloba Reuss.

Specimens referable to this species are not common. It is recorded by Schubert from the late Tertiary of the Bismarck Archipelago, and by Koch from East Borneo. Brady did not recognize it from Fiji.

Subfamily Sphaeroidininae

Genus SPHAEROIDINA d'Orbigny, 1826

Sphaeroidina bulloides d'Orbigny (?).

There are fairly numerous specimens which are very close indeed to d'Orbigny's model. Schwager figures a much more compact specimen which he refers to *S. austriaca* d'Orbigny, but it does not fit that species. In the original Kar Nicobar material I have from Schwager's collection, there are numerous specimens that can best be referred to *Globigerinoides conglobata* (H. B. Brady), which have the form figured by Schwager as *Sphaeroidina austriaca* and may perhaps be what he had.

Family Globigerinidae

Subfamily Globigerininae

Genus GLOBIGERINA d'Orbigny, 1826

Globigerina conglomerata Schwager.

Globigerina conglomerata Schwager, Novara Exped., Geol. Theil, vol. 2, p. 255, pl. 7, fig. 113, 1866. Cushman, Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 172, 1927.

Globigerina dutertrei H. B. Brady, Voy. Challenger, Rep., Zool., vol. 9, pl. 81, fig. 1, *a, c* (not d'Orbigny), 1884.

Globigerina dubia H. B. Brady, Voy. Challenger, Rep. Zool., vol. 9, pl. 79, fig. 17, *a-c* (not Egger), 1884.

Test subglobose, in the early stages consisting of but 4 chambers in each coil, closely grouped, in later stages with 5 or 6 chambers in the coil, the last coil usually below the level of the others and with a distinct umbilicus; aperture small, with a distinct lip.

This is a common species not only in the late Tertiary of the Pacific, but also as a living form in the same area.

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides sacculifera H. B. Brady.

This widely distributed species is common in the Fiji material. Brady records it from Fiji also. I found it in some numbers in the original Schwager material from Kar Nicobar, but he did not record it.

Genus GLOBIGERINELLA Cushman, 1927

Globigerinella aequilateralis H. B. Brady.

Specimens are fairly common in the Fiji collections. Brady also records it. It is the more common Pacific type which has a much less open coil than the tropical Atlantic form.

Subfamily ORBULININAE

Genus ORBULINA d'Orbigny, 1826

Orbulina universa d'Orbigny.

Specimens of this species are very abundant in the Fiji collections. Brady records it from all three of his Fiji stations. I found it to be abundant in the original Kar Nicobar material, but, strangely, it was not recorded by Schwager.

Subfamily PULLENIATININAE

Genus SPHAEROIDINELLA Cushman, 1927

Sphaeroidinella seminulina (Schwager).

Globigerina seminulina Schwager, Novara Exped., Geol. Theil, vol. 2, p. 266, pl. 7, fig. 112, 1866.

In this species the opening between the chambers is not so fully developed as in *S. dehiscens*. The early chambers are much more globigeriniform and the whole species is a more primitive one. It is abundant in the original material of Schwager that I have from Kar Nicobar and is very common in the Fiji material. The Recent Indo-Pacific material should be compared with typical Atlantic specimens to determine their possible differences.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia tumida (H. B. Brady).

This species was originally described by Brady from Tertiary material of the Pacific region. It is very common in the Fiji collections.

Globorotalia menardii (d'Orbigny), variety **fijiensis** Cushman, new variety (pl. 17, fig. 5, *a-c*).

Variety differing from the typical form in the greater number of chambers in the last-formed whorl and the distinct lobing of the later part of the whorl.

Holotype, B. P. Bishop Mus., Geol. No. 1313, Station 371, H. S. Ladd.

The Fiji material is very distinctive in its characters, noted above. On the other hand, Kar Nicobar specimens that may be referred to Schwager's *Discorbina sacharina* are much more like typical *G. menardii.*

Globorotalia scitula H. B. Brady.

Pulvinulina scitula H. B. Brady, Roy. Soc. Edinburgh, Proc., vol. 11, p. 716, 1882.

Pulvinulina patagonica H. B. Brady (not *Rotalia patagonica* d'Orbigny), Voy. Challenger, Rep., Zool., vol. 9, p. 693, pl. 103, fig. 7, *a-c,* 1884. Cushman, U. S. Nat. Mus., Bull. 71, pt. 5, p. 57 (not fig. 56 in text), 1915.

Globorotalia scitula Cushman, Scripps Inst. Oceanography, Bull., tech. ser., vol. 1, p. 175, 1927.

This is a fairly well distributed species in the present Pacific ocean. It is rare at Fiji in the collections examined, although Brady records it from all three of his stations.

Family Anomalinidae

Subfamily Anomalininae

Genus PLANULINA d'Orbigny, 1826

Planulina wuellerstorfi (Schwager) (pl. 18, figs. 3, *a-c,* 5, *a-c*).

Anomalina wuellerstorfi Schwager, Novara Exped., Geol. Theil, vol. 2, p. 258, pl. 7, figs. 105, 107, 1866.

Many forms have been recorded under this name. I have topotype specimens from Schwager's material, and the specimens fit well with his original figures. The species is close to *P. ornata* (d'Orbigny), but the sutures are not so highly developed, especially in the later portion. There are a number of specimens with higher spires and obscure surface which may be the microspheric form of this species. There are many intermediates between them. A similar series occurs in the west coast material of *P. ornata* (d'Orbigny).

Planulina fijiensis Cushman, new species (pl. 18, fig. 4, *a-c*).

Test large, nearly equally biconvex, trochoid, periphery carinate, last coil spreading; chambers distinct, about nine in the last-formed whorl; sutures strongly limbate, but only slightly if at all raised above the general surface, on the dorsal side strongly oblique, ventrally strongly curved; wall smooth, conspicuously perforate; aperture largely ventral, but coming to the periphery and a little way over onto the dorsal side. Diameter 1.35 mm.; thickness 0.65 mm.

Holotype, B. P. Bishop Mus., Geol. No. 1314, Station 380, H. S. Ladd.

This is a large, conspicuous species, common in the Fiji collection, hardly to be confused with any other species of the genus.

Genus LATICARININA Galloway and Wissler, 1928

Laticarinina tenuimargo (H. B. Brady) (pl. 18, fig. 2, *a-c*).

Truncatulina tenuimargo H. B. Brady, Voy. Challenger, Rep., Zool., vol 9, p. 662, pl. 93, figs. 2, 3, 1884.

There are a great many records for this species, a very few of which are accompanied by figures. The species is found in the Indo-Pacific and seems to be very distinctive. Sidebottom as well as Heron-Allen and Earland have figured extreme forms from the Australian region in which the chambers on the ventral side become very high. Our specimen, here figured, is very close to the original of Brady.

If the genus *Laticarinina* is recognized for those forms of *Cibicides* which have a wide flange, this species of Brady must belong there. It is closely allied to *L. pauperata* (Parker and Jones) which Brady records from Fiji, but the two are distinct. They form an extreme development from *Cibicides* and *Planulina*.

Subfamily CIBICIDINAE

Genus CIBICIDES Montfort, 1808

Cibicides cicatricosa (Schwager) (pl. 18, fig. 1, *a-c*).

Anomalina cicatricosa Schwager, Novara Exped., Geol. Theil, vol. 2, p. 260, pl. 7, fig. 108, 1866.

Test close-coiled, nearly planispiral in the last-formed whorl, both sides slightly concave in the middle region; periphery broadly rounded; chambers in the later portion distinct, earlier ones obscured by the surface ornamentation and the highly involute character of the chambers themselves, 10 or 11 chambers in the last-formed whorl; sutures in the later portion distinct and slightly depressed, the earlier sutures with a high ridge fusing with that of the spiral suture and central portion to form a type of ornamentation which obscures the structure; wall very coarsely punctate; aperture extending on both sides of the test, on the dorsal side with a definite lip. Diameter 0.75 mm.; thickness 0.35 mm.

Schwager described and figured this species from the Pliocene of Kar Nicobar. It has a highly ornamented central portion on the dorsal side which, in our figured specimen, has been carried to a greater extreme than in the specimen figured by Schwager. Topotype specimens from Kar Nicobar show this same range of ornamentation.

Table 5. Distribution of the Smaller Foraminifera

	Ladd Station 371	Ladd Station 380	Brady Station I	Brady Station II	Brady Station III
Spiroplectammina parallela Cushman	×	—	×	—	—
Textularia solita (Schwager)	×	—	—	—	—
Textularia cf. lythostratum (Schwager)	—	×	—	—	—
Textularia species (?)	—	×	—	—	—
Textularia cf. hauerii d'Orbigny (?)	—	×	—	—	—
Vulvulina nicobarica (Schwager)	—	×	—	—	×
Verneuilina bradyi Cushman	×	—	—	×	—
Gaudryina lacerata (Schwager) (?)	—	×	—	—	—
Gaudryina baccata Schwager	—	×	—	—	—
Clavulina variabilis Schwager	×	×	×	—	—
Clavulina angularis d'Orbigny (?)	—	×	—	—	—
Quinqueloculina eborea Schwager (?)	×	—	×	×	×
Sigmoilina celata (Costa)	×	×	×	×	×
Pyrgo murrhina (Schwager)	×	—	×	×	—
Pyrgo lucernula (Schwager)	×	—	×	×	—
Robulus cushmani Galloway and Wissler	×	—	×	×	×
Robulus foliatus (Stache)	×	—	—	—	—
Robulus calcar (Linné)	—	×	—	—	—
Robulus nicobarensis (Schwager)	—	×	×	×	—
Lenticulina echinata (d'Orbigny)	—	×	—	—	—
Planularia species (?)	—	×	×	—	—
Planularia crepidula (Fichtel and Moll)	—	×	—	×	—
Saracenaria acutauricularis (Fichtel and Moll)	—	×	×	—	—
Dentalina tauricornis (Schwager)	×	×	—	—	—
Dentalina neugeboreni (Schwager)	×	—	—	—	—
Dentalina perprocera (Schwager)	×	—	—	—	—
Dentalina elegans d'Orbigny	×	—	—	—	—
Dentalina insecta (Schwager)	×	×	—	—	—
Dentalina spirostriolata (Cushman)	—	×	—	—	—
Nodosaria arundinea Schwager	—	×	—	×	×
Nodosaria brevicula Schwager	—	×	—	—	—
Nodosaria koina Schwager	×	—	—	—	—
Nodosaria glandigena Schwager	×	—	—	—	—
Nodosaria perversa Schwager	×	—	—	×	—
Nodosaria stimulea Schwager (?)	×	—	—	—	—
Nodosaria equisetiformis Schwager	—	×	—	—	—
Vaginulina legumen (Linné)	—	×	—	—	—
Pyrulina labiata (Schwager)	×	—	×	×	—
Pyrulina extensa (Cushman)	×	—	×	×	—
Lagena sulcata Walker and Jacob, variety alticostata Cushman	×	—	—	—	—
Lagena gracilis Williamson (?)	×	—	—	—	—
Lagena punctulata Sidebottom	×	—	—	—	—
Lagena marginata (Montagu)	×	—	×	—	—
Lagena striata (d'Orbigny), variety substriata Williamson	×	—	—	—	—
Lagena plumigera H. B. Brady	×	—	—	×	—
Lagena costata Williamson, variety amphora Reuss	×	—	—	—	—

Table 5. Distribution of the Smaller Foraminifera (Continued)

	Ladd Station 371	Ladd Station 380	Brady Station I	Brady Station II	Brady Station III
Lagena striata d'Orbigny, variety haidingeri (Czjzek)	×	—	—	—	—
Lagena alveolata H. B. Brady	×	—	—	—	—
Lagena costata (Williamson)	×	—	—	—	—
Lagena fimbriata H. B. Brady	×	—	—	—	—
Lagena formosa Schwager	×	—	—	—	—
Lagena schwageriana Cushman	×	—	—	—	—
Lagena castrensis Schwager	×	—	—	—	—
Lagena orbignyana (Seguenza)	×	—	—	×	—
Lagena tubulata Sidebottom	×	—	—	—	—
Lagena spiro-striolata Cushman	×	—	—	—	—
Lagena spino-alata Cushman	×	—	—	—	—
Lagena mucronulata Reuss	×	—	—	—	—
Lagena staphyllearia Schwager	×	—	—	—	—
Lagena basi-striatula Cushman	×	—	—	—	—
Nonion stelligera d'Orbigny	×	—	—	—	—
Nonion pacifica Cushman	×	—	×	×	×
Nonion galeata Cushman	×	—	—	—	—
Nonionella limbato-striata Cushman	×	—	—	—	—
Nonionella clavata Cushman	×	—	—	—	—
Bolivinita quadrilatera (Schwager)	×	—	×	×	×
Nodogenerina protumida (Schwager) (?)	—	×	—	—	—
Nodogenerina lepidula (Schwager)	×	—	×	×	×
Nodogenerina spinata Cushman, new species	×	—	—	—	—
Globobulimina pacifica Cushman	×	—	—	—	—
Bulimina inflata Seguenza	×	—	×	×	×
Bolivina globigera (Schwager)	×	—	—	—	×
Bolivina reticulata Hantken (?)	—	×	—	—	—
Bolivina hantkeniana d'Orbigny	×	—	×	×	×
Virgulina cf. schreibersiana Czjzek	×	—	—	—	—
Uvigerina nitidula Schwager	×	—	×	×	×
Uvigerina gemmaeformis Schwager	×	—	×	—	—
Uvigerina crassicostata Schwager	—	×	—	—	—
Uvigerina hispida Schwager	×	×	×	—	—
Uvigerina proboscidea Schwager	×	—	×	—	—
Siphogenerina dimorpha (Parker and Jones) variety pacifica Cushman	×	—	×	—	×
Siphonodosaria fijiensis Cushman	×	—	—	—	—
Angulogerina fijiensis Cushman	×	—	—	×	—
Trifarina bradyi Cushman	×	×	×	—	—
Pleurostomella brevis Schwager	×	—	×	—	—
Pleurostomella alternans Schwager	×	×	×	×	×
Pleurostomella alternans Schwager, variety telostoma Schubert (?)	×	—	—	—	—
Pleurostomella sapperi Schubert	×	—	—	—	—
Nodosarella pacifica Cushman	×	×	—	—	—
Ellipsolagena fijiensis Cushman	×	—	—	—	—
Gyroidina nitidula (Schwager)	×	—	×	×	×

Table 5. Distribution of the Smaller Foraminifera (Continued)

	Ladd Station 371	Ladd Station 380	Brady Station I	Brady Station II	Brady Station III
Eponides umbonata (Reuss), variety multisepta Koch	×	—	×	×	×
Eponides species (?)	×	—	×	×	—
Siphonina australis Cushman	×	—	—	—	—
Pulvinulinella bengalensis (Schwager)	×	—	—	—	×
Cassidulina murrhyna (Schwager)	—	×	×	×	×
Cassidulina subglobosa H. B. Brady, variety ornata Cushman	×	—	—	—	—
Cassidulina delicata Cushman	×	×	×	—	×
Cassidulinoides bradyi (Norman)	×	—	×	—	—
Ehrenbergina pacifica Cushman	×	—	×	—	×
Ehrenbergina bicornis H. B. Brady	×	—	×	—	×
Allomorphina trigona Reuss	×	—	—	—	—
Chilostomella colina Schwager	×	—	—	×	—
Pullenia sphaeroides d'Orbigny	×	—	×	—	×
Pullenia quinqueloba Reuss	×	×	—	—	—
Sphaeroidina bulloides d'Orbigny (?)	×	×	×	—	—
Globigerina conglomerata Schwager	×	×	×	×	×
Globigerinoides sacculifera (H. B. Brady)	×	×	×	×	×
Globigerinella aequilateralis (H. B. Brady)	×	×	×	×	—
Orbulina universa d'Orbigny	×	×	×	×	×
Sphaeroidinella seminulina (Schwager)	×	×	×	×	×
Globorotalia tumida (H. B. Brady)	×	×	—	—	—
Globorotalia menardii (d'Orbigny), variety fijiensis Cushman, new variety	×	—	×	×	×
Globorotalia scitula H. B. Brady	×	—	×	×	×
Planulina wuellerstorfi (Schwager)	×	—	×	×	×
Planulina fijiensis Cushman, new species	—	×	—	—	—
Laticarinina tenuimargo (H. B. Brady)	×	×	×	—	×
Cibicides cicatricosa (Schwager)	×	—	—	—	—

LARGER FORAMINIFERA FROM VITILEVU, FIJI

By G. Leslie Whipple

Introduction

The collections on which this report is based were made by Dr. Harry S. Ladd during his geological exploraiton of the island of Vitilevu, Fiji. In 1926 he sent to Scripps Institution of Oceanography a collection of rock specimens from 16 different localities distributed over the island of Vitilevu. Another collection received from him in 1928 included 19 new localities. Of the 35 localities represented, 12 yielded larger foraminifera. The specimens from five of these are dense foraminiferal limestones which could be studied only by means of thin sections, whereas the others are calcareous conglomeratic rocks from which it was possible to separate many beautifully preserved specimens.

I am grateful to Dr. T. Wayland Vaughan, Director of Scripps Institution of Oceanography, under whose direction this work was done, for suggestions and criticisms during the progress of this paper, and also to Dr. B. L. Clark of the University of California for much assistance and encouragement while at the University.

Photographs for plates 19-23 were made by the U. S. Geological Survey, except plate 19, figures 2, 4, 5; plate 20, figures 5-9; plate 21, figures 4-6; plate 22, figure 3; and plate 23, figures 2, 3, which were photographed by me.

The material described in this paper is from the following stations as numbered by Ladd (p. 76): 68 (35-W), conglomeratic limestone; 74 (34-O), limestone; 130 (9-N), limestone; 158 (35-X), conglomeratic limestone; 292, (34-Q), limestone; 295 (35-Y), limestone; 302 (30-P), limestone; 309 (13-U), limestone; 316 (36-X), limestone; 327, 328, 329 (35-Z), limestone.

The sediments of Vitilevu here considered may be divided into three horizons on the basis of the contained foraminiferal faunas:

1. Dense foraminiferal limestones from Korosuli (Station 302) and the west coast (Station 130) contain abundant *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger together with *Lithothamnion* species, *Carpenteria* species, and *Heterostegina* species. No other species of *Lepidocyclina* were found, and *L. formosa* was not collected elsewhere on the island.

2. A second horizon outcrops extensively in the vicinity of Suva. The fauna is best developed at Station 158, 6¼ miles from Suva, on Prince's Road to Nausori, where *Cycloclypeus annulatus* Martin, *C. neglectus* Martin, *Lepidocyclina* (*Cyclolepidina*) *suvaensis* Whipple, new species, *L.* (*Eulepidina*) *dilatata* (Michelotti), and *L.* (*Eulepidina*) *dilatata laddi* Whipple, new variety, occur abundantly together with the rather rare

form *L.* (*Eulepidina*) *radiata* (Martin).[1] This fauna is somewhat analogous to that reported by H. Douvillé (4)[2] from the lower Rembang "beds" of Java, from which he recorded *C. annulatus* Martin and *L.* (*Nephrolepidina*) *radiata* (Martin) associated with a *L.* (*Eulepidina*) species which he later (6, p. 99) indicated might belong to *L. dilatata* (Michelotti). In addition to those already listed, *L. papulifera* H. Douvillé, which occurs at Tamavua (Station 295) and near entrance to Walu Bay (Station 328), was first described from the Rembang beds at Ngampel. It is probable that half of the species from the vicinity of Suva are identical with those from the Rembang horizon. For the time being, these formations may be considered equivalent in age.

3. The third division, which contains an association of *Lepidocyclina* and *Miogypsina*, is represented at Koronisangana (Station 309) and near the village of Wailotua (Stations 74, 292) by dense forominiferal limestones. The fauna consists of *L.* (*Nephrolepidina*) *angulosa* Provale, *L.* (*Nephrolepidina*) species, and *L. flexuosa* Rutten, together with *Miogypsina polymorpha* Rutten, *M. thecideaeformis* Rutten, *Cycloclypeus* species, *Carpenteria* species, and *Lithothamnion* species.[3]

The entire assemblage from Vitilevu belongs to the "older Miocene;" or, according to a recent division of the Tertiary formations of the Orient by Van der Vlerk and Umbgrove (32), it may be assigned to the Tertiary *e*. All described species of *Lepidocyclina* reported from here are found in formations considered by Van der Vlerk (31) to belong to this horizon.

Description of Species

Family Camerinidae

Genus CYCLOCLYPEUS W. B. Carpenter

Cycloclypeus annulatus Martin (pl. 19, fig. 1).

Martin (9, p. 157, pl. 28, fig. 1; 10, p. 4, pl. 1, figs. 2-5). Rutten (22, p. 307; 23, p. 12). Douvillé (4, p. 30, pl. 5, fig. 6, pl. 6, figs. 1-4). Van der Vlerk (28, p. 62). Yabe and Hanzawa (37, pp. 72-73, pl. 3, figs. 1, 2, pl. 4, fig.1).

Specimens of *C. annulatus* occur at Stations 68, 158, 295, and 316. It is easily recognized by its large size (the specimens from Vitilevu measure 40 mm. in diameter) and its strong annular inflations. The surface is granulate with the granules arranged in concentric rings.

The species has been reported from numerous localities in Borneo, Java, Philippines, Madura, Celebes, New Guinea, and Sumbawa, and it is abundant in the collections from Vitilevu.

[1] Since writing the above Mr. Whipple has examined a sample collected by Mr. E. C. Andrews near the west coast, 3 miles E. S. E. of Thuvu, Station 379. He has identified *Cycloclypeus annulatus* Martin, *Amphistegina lessonii* d'Orbigny, *Gypsina* species, and *Carpenteria* species, and writes, June 19, 1932: "While this is not final, I believe you are fairly safe in correlating the limestone from the Na Singatoka area with those from the Suva area." Additional evidence favoring this correlation is given on page 30.—H. S. Ladd.

[2] Numbers in parentheses refer to literature cited, p. 151.

[3] Whipple believes that the limestones of his horizon 1 (Stations 130, 302) are stratigraphically lower than the limestones of his horizon 3 (Stations 74, 292, 309). This interpretation is based on the occurrence of *Lepidocyclina formosa* Schlumberger at Stations 130 and 302. Whipple writes (May 24, 1932) that it is quite possible, however, that the rocks of all five stations belong to the same formation. In the present report all have been placed in the Viti formation.—H. S. Ladd.

Cycloclypeus neglectus Martin (pl. 19, fig. 2).

Martin (9, p. 156, pl. 27, fig. 3; 10, p. 4). Rutten (22, p. 304, pl. 24, figs. 1, 2; 23, p. 42). Oppenoorth (16, p. 251). Yabe (35, p. 19). Van der Vlerk (28, p. 66; 29, p. 10, pl. 4, fig. 16; 30, p. 18, pl. 1, fig. 11, pl. 2, fig. 20, pl. 4, figs. 36, 37, and text-figs. *a, b*).

This species is the most abundant in the collection, having been found in great numbers at Stations 158, 295, 316, 327, 328, and 329.

The surface of the forms from Vitilevu at first appears smooth, but a careful examination reveals annular rows of pillars covering the whole surface. The test is lenticular with a diameter of 3 mm. and a thickness of 1 mm.

The embryonic apparatus consists of a spherical initial chamber partly surrounded by a second larger chamber which in the typical form is followed by about 10 discontinuous curves of chamberlets before the first closed annulet. There appears to be wide variation in the number of discontinuous curves in the Vitilevu specimens, some having as few as five before the first closed curve. However, all have the same arrangement of the chamberlets immediately following the embryonic apparatus and seem to agree with the arrangement in *C. neglectus.* Near the center the radial diameter of the equatorial chambers is a little less than the traverse, but toward the periphery this gradually changes until the radial may exceed the transverse.

Although the specimens in this collection differ somewhat from the typical *C. neglectus,* it does not seem advisable to describe it as a different species.

Family ORBITOIDIDAE

Genus LEPIDOCYCLINA Gümbel

Subgenus CYCLOLEPIDINA Whipple, new subgenus

Embryonic apparatus consists of a large central chamber partly or wholly surrounded by several smaller chambers. Equatorial chambers spatulate to hexagonal; length of the radial diameter exceeds that of the transverse diameter.

In the characters of the embryonic chambers this subgenus resembles *Pliolepidina,* but it differs in the features of its equatorial chambers and the arrangement of the interchamber communications. There is a tendency for the nucleoconch in *Cyclolepidina* to be larger than in *Pliolepidina,* but this may not always be true. Figure 11, *a* is a diagrammatic representation of the chamber communications in *L. (Pliolepidina) tobleri* H. Douvillé. In this species the equatorial chambers have curved outer walls and converging inner walls. The converging inner walls are formed by the walls of two adjacent chambers of the preceding annulus and give a pointed or truncate shape to the proximal end of the chambers. In some specimens it appears that the inner ends of the distal walls do not quite reach the outer walls of the chambers in the preceding annulus. In most the inner ends of the distal walls reach the outer walls of the chambers in the preceding annulus and are pierced by stoloniform passages through the proximal ends. This arrangement of the interchamber communications in *Pliolepidina* gives the effect of two sets of outwardly convex curves which cross each other at or near the apex of the curved outer wall of each chamber. (See pl. 20, fig. 9.)

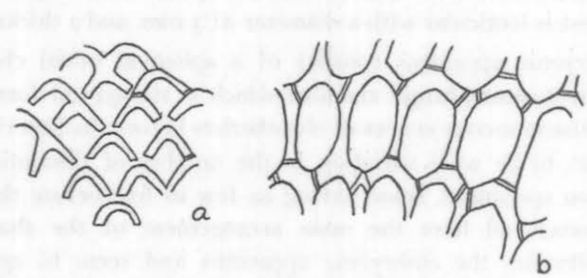

FIGURE 11.—Diagrammatic representation of the chamber communications: *a, Lepidocyclina (Pliolepidina) tobleri* H. Douvillé; *b, Cyclolepidina* Whipple.

The passages in *Cyclolepidina* are so arranged as to allow communication between the chambers of the preceding and succeeding annulae and with those of the same annulus. Stoloniform passages occur at the proximal ends of the radial walls in each chamber (fig. 11, *b*), connecting adjacent chambers of the same annulus. At the distal end of each chamber occurs one, and in many instances two, passages leading to one or two chambers in the succeeding annulus. By this arrangement direct communication is maintained between each chamber and 4, 5, or 6 surrounding chambers. In the type species the size of these stoloniform passages varies from 8 to 12 μ in diameter.

In a vertical section of the type species the stoloniform passages between adjacent chambers in the same annulus are represented by apertures, usually two in number, at the proximal end of the chamber. The communications between preceding and succeeding annulae are also shown in this section by 2 or 3 stoloniform passages in the proximal and distal wall of each chamber. (See pl. 20, figs. 6, 8.)

Communication between the lateral chambers is by means of cribriform perforations in the roofs and floors and also by means of stoloniform passages through the end and side walls.

Type species: *Lepidocyclina* (*Cyclolepidina*) *suvaensis* Whipple, new species. Suva formation, Station 295.

It seems probable that those species which have been referred to *Pliolepidina* from the Orient should be placed in this subgenus. *Lepidocyclina (Pliolepidina) luxurians* Tobler (26) and *L. (Pliolepidina) stigteri* Van der Vlerk (30) both appear to have the characters of *Cyclolepidina* in the large embryonic apparatus composed of several chambers and the elongate hexagonal equatorial chambers.

Lepidocyclina (Cyclolepidina) suvaensis Whipple, new species (pl. 20, figs. 1-8).

Test rather small, 5 to 6 mm. in diameter, 2 mm. thick in the center; radiate, usually 9 or 10 arms which radiate from the center and are clearly visible externally, but are only slightly indicated in the arrangement of the equatorial chambers; surface granulate.

The embryonic chambers consist of a large central chamber, 400 to 600 μ in diameter, surrounded by 3 to 5 smaller chambers. Outer walls of the surrounding embryonic chambers are at least twice as thick as those of the initial chamber. The former are 40 μ thick and the latter 16 μ thick. Diameter of the nucleoconch, 900 to 1,200 μ.

The first two cycles of equatorial chambers immediately following the embryonic apparatus usually have curved outer walls, pointed inner ends, and shorter radial than transverse diameters. These intergrade with elongate hexagonal chambers such that at a point 0.5 to 0.75 mm. from the center the radial diameter is 150 μ $\pm$ and the transverse diameter 50 μ $\pm$. The chambers of some specimens, but not all, have a tendency to be arranged in polygons. The equatorial layer may or may not increase in thickness from the center toward the periphery.

The lateral chambers are arranged in more or less regular tiers, 8 to 10 on each side of the equatorial plane over the center. The length of the lateral chambers over the center near the periphery is 240 μ $\pm$; height 60 μ $\pm$; and the thickness of the walls about 18 μ.

Type, B. P. Bishop Mus., Geol. no. 1315, limestone in Tamavua Quarry (Station 295), head of Walu Bay, Vitilevu. Also abundant in samples from Stations 158, 316, 327, 328, and 329.

Externally this species resembles *L. martini* Schlumberger, from which it differs in the size and other features of its embryonic apparatus, and its larger equatorial chambers.

Subgenus NEPHROLEPIDINA H. Douvillé

Lepidocyclina (Nephrolepidina) angulosa Provale (pl. 21, fig. 5).

Lepidocyclina tournoueri variety *angulosa* Provale (18, p. 28, pl. 3, figs. 13-15).

Lepidocyclina angulosa Yabe and Hanzawa (37, p. 74, pl. 9, figs. 1-2, pl. 10, figs. 1-2, pl. 11, figs. 1-2, pl. 12, figs. 1-6; 39, p. 622, pl. 1, figs. 9-10, pl. 2, fig. 9, pl. 3, figs. 3-7).

Amphilepidina angulosa Douvillé (6, p. 112).

Lepidocyclina angulosa Van der Vlerk (28, p. 22, pl. 1, fig. 3; 31, p. 190, pl. 14, *a-c*).

The specimens from Station 309 here referred to *L. angulosa* are rather small inflated forms, 2.5 mm. in diameter and 1.7 mm. thick; some with, others without, a narrow flange. Equatorial chambers hexagonal, arranged in polygons. Lateral chambers large, length 170 to 320 μ, height 40 μ $\pm$; 12 to 16 at the center on each side of the equatorial plane. Several large pillars, 370 μ in diameter, emerge on the central part of the test.

L. angulosa is described by Van der Vlerk (31) as having 3 to 5 large pillars over the center, 600 μ $\pm$ in diameter, and 12 lateral chambers, 150 to 350 μ long by 40 μ high. The specimens from Vitilevu have smaller pillars than *L. angulosa,* but the large lateral chambers distinguish it from *L. douvillei* Yabe and Hanzawa (36), which it closely resembles.

Van der Vlerk (28) lists numerous localities in Sumatra, Borneo, Java, Philippines, and Sumbawa from which this form has been reported.

Lepidocyclina (Nephrolepidina), species indeterminate (pl. 21, fig. 6).

A small species of the subgenus *Nephrolepidina,* 3.5 mm. in diameter and 1.2 to 1.5 mm. thick, in a limestone from Stations 74 and 292, near Wailotua. Diameter of the initial chamber 120 μ; of the nucleoconch, 240 μ $\pm$. Equatorial chambers spatulate to hexagonal, arranged in circles with the radial diameter equal to or slightly greater than the transverse diameter. Thickness of the equatorial layer increases slightly toward the periphery. Pillars small or entirely lacking; 12 to 14 lateral chambers over the center on each side of the equatorial plane; chamber walls thin, 18 μ thick over the center. Length of the lateral chambers 125 μ $\pm$, height 25 μ $\pm$.

These specimens resemble *L. verbeeki* Newton and Holland but are much smaller and lack the large pillars of that species. In *L. verbeeki* the lateral chambers are regularly arranged in tiers, about 12 chambers in a tier, on each side of the equatorial layer at the center. This regular arrangement is not clearly shown in the specimens from Vitilevu.

Subgenus EULEPIDINA H. Douvillé

Lepidocyclina (Eulepidina) formosa Schlumberger (pl. 21, figs. 1, 3).

Lepidocyclina (*Eulepidina*) *formosa* Schlumberger (25, p. 251, pl. 7, figs. 1-3).

Lepidocyclina raulini Provale (17, p. 76, pl. 6, figs. 6-8).

Lepidocyclina richthofeni Douvillé (3, p. 71, pl. *D,* figs. 2-5).

Lepidocyclina formosa Rutten (20, p. 1149; 21, p. 214; 22, p. 297).

Lepidocyclina murrayana Newton (13, p. 12).

Lepidocyclina formosa Yabe (35, p. 43, pl. 6, figs. 1, *b,* 4, *b,* 6, 7, *b,* pl. 7, figs. 1, *b,* 4, 6, 12, *b,* 14, *b*).

Eulepidina formosa Douvillé (6, p. 97).

Lepidocyclina formosa Yabe and Hanzawa (38, p. 105, pl. 25, figs. 1-2, pl. 26, figs. 3-4, pl. 27, figs. 4-8). Van der Vlerk (28, p. 28; 30, p. 19, figs. 10, 28, 29, 45). Umbgrove (27, p. 34). Van der Vlerk (31, p. 196, figs. 4, 42, *a-b*).

This species occurs in the lowest horizon on the island from which orbitoid foraminifera were collected. It occurs in two widely separated localities: at Korosuli (Station 302), and 1 mile north of the Nandi River (Station 130). At both localities there is a dense foraminiferal limestone made up almost entirely of megaspheric individuals of *L. formosa*.

L. formosa has been reported from several localities in Borneo, Sumatra, Philippines, New Guinea, Nais, Sumbawa, Celebes, and German East Africa(?).

Lepidocyclina (Eulepidina) dilatata (Michelotti) Lemoine and R. Douvillé (pl. 21, fig. 2; pl. 22, fig. 1).

Orbitoides dilatata Michelotti (12, p. 17, pl. 1, figs. 1, 2). Gümbel (7, p. 139, pl. 4, figs. 45, 46).

Lepidocyclina dilatata Lemoine and R. Douvillé (8, p. 12, pl. 1, fig. 2, pl. 2, figs. 8, 21, pl. 3, figs. 10, 15).

Lepidocyclina dilatata Vredenberg (33, p. 67). Douvillé and Verbeek (2, p. 692).

Lepidocyclina dilatata variety *schlumbergeri* Lemoine and R. Douvillé (8, p. 14, pl. 1, fig. 10, pl. 2, fig. 6. Provale (17, p. 76).

Lepidocyclina dilatata Richardson (19, fossil table 2, opp. p. 268).

Eulepidina dilatata Douvillé (5, p. 48, pl. 2, fig. 3; 6, pp. 71, 99, pl. 4, figs. 1-4, pl. 5, figs. 1-4. Nuttall (14, p. 331, pl. 13, figs. 1-4). Van der Vlerk (31, p. 193, figs. 3, *a-c*, 38).

Test flat-lenticular, central boss small, sometimes indistinct, surface papillate, the papillae of equal size over the entire surface. The maximum diameter of the Vitilevu specimens is 43 mm., thickness 4.5 mm.

Equatorial chambers hexagonal, radial diameter about twice the transverse, arranged in circles, increase in size toward the periphery. (Plate 22, figure 1, shows the arrangement of the equatorial chambers.) The equatorial layer increases in thickness from the center toward the periphery; at the center it measures about 80 μ and near the periphery 140 μ.

There are from 20 to 30 lateral chambers on each side of the equatorial layer, arranged in regular tiers with walls 20 to 25 μ thick, and with length and height of 100 to 300 μ and 50 μ, respectively. (In figure 1, plate 22, may be seen the polygonal pillars, formed at the junction of the walls of the lateral chambers.) Specimens of only the microspheric forms were collected.

Good specimens of this species were collected at Stations 158 and 316 and fragments which may be referred to *L. dilatata* were present in the samples from Stations 295, 328, and 329. It was first described from Molere, northern Italy, and has been reported to occur in the Nari series of western India and the lower part of the Asmari limestone of southwest Persia, associated with *Camerina intermedia;* and in the Orient it has been reported from several localities in Borneo (here associated with *L. formosa*), Cebu (Philippines), New Guinea, Sumatra, Sumbawa, Molucca Islands, and New Zealand.

Lepidocyclina (Eulepidina) dilatata laddi Whipple, new variety (pl. 22, figs. 2, 3).

This variety differs from *L. dilatata* by its more or less rayed test, the rays being produced by an undulation of the border into 4 or 6 distinct folds. These folds are shown internally by the polygonal arrangement of the equatorial chambers within a radius of 5 mm. from the center, after which the regular circular arrangement appears. This polygonal arrangement of the chambers themselves is due to a slight elongation of the chambers in a direction which seems to correspond with the crests of the folds, as shown on the surface of the test. Early chambers, which have curved outer walls with converging inner walls, grade in form into spatulate and then into the typical hexagonal chambers of *L. dilatata*.

The vertical sections show no difference between the variety and typical specimens of the species. Both have the same number, size, and arrangement of lateral chambers. Only the microspheric form was collected.

Type, B. P. Bishop Mus., Geol. no. 1316, Station 158. This form is rather abundant at Station 158, where it is found in association with *L. dilatata*, with which it appears to intergrade. It is also present in the sample from Station 316. Fragments which may belong to it were found at other localities.

Lepidocyclina (Eulepidina) radiata (Martin) H. Douvillé (pl. 19, figs. 3-6).

Orbitoides radiata Martin (9, p. 163, pl. 28, fig. 4).

Lepidocyclina radiata Douvillé (4, p. 26, pl. 5, fig. 4).

Amphilepidina radiata Douvillé (6, p. 113).

Lepidocyclina radiata Van der Vlerk (28, p. 38; 31, p. 202, fig. 25).

Several microspheric specimens of this species were found at Station 158. The test is stellate, polygonal in outline, with a central boss from which radiate 6 to 10 arms; except for 8 to 15 pustules covering the central boss the surface is smooth. Diameter of test, 9 mm., of boss, 1.5 to 2 mm.; thickness 1.6 mm. From the inflated central boss the thickness rapidly decreases into a flange about ⅛ mm. thick.

The embryonic chambers are of the embracing type with an initial chamber 280 by 200 μ in diameter and a second chamber 520 by 380 μ in diameter. The wall of the initial chamber is 60 $\mu \pm$ thick and that of the second chamber 80 to 100 μ thick.

The equatorial chambers are spatulate to hexagonal and are arranged in circles.

At the center of the test the lateral chambers are regularly arrangd in tiers between the pillars, usually about 10 chambers in a tier over the center on each side of the equatorial plane. Over most of the flange there are usually two layers of lateral chambers on each side of the equatorial plane, but near the periphery lateral chambers are often entirely absent. Length of the lateral chambers over the center near the periphery, 180 μ; height, 40 $\mu \pm$.

Associated with the macrospheric forms was a single broken specimen which appears to be the microspheric form of this species. As a detailed study was impossible from a single specimen, more material might show it to be a distinct species. Plate 19, figure 3, shows the individual 24 mm. in diameter with a central boss, measuring 1.5 mm. in diameter, from which radiate 10 arms. It differs from the macrospheric form in the smooth surface (the central pustules are absent). The rays are much less pronounced and the central boss much smaller in proportion to the size of the test. As it appears that the microspheric form of this species has not been described, it is to be regretted that more material is not at hand for study.

This is a common species in the lower Rembang beds of Java. It is also found at Preangor, Java, from which place it was first described by Martin.

Lepidocyclina flexuosa Rutten (pl. 21, fig. 4).

Lepidocyclina flexuosa Rutten (20, p. 1153, fig. 3; 22, p. 304, pl. 23, figs. 6-8). Van der Vlerk (28, p. 354, pl. 1, fig. 6).

Amphilepidina flexuosa Douvillé (6, p. 105).

Lepidocyclina flexuosa Van der Vlerk (30, p. 21, figs. 1, 34, 61). Umbgrove (27, p. 6). Van der Vlerk (31, p. 195, figs. 41 *a-c*).

Several sections of a species of *Lepidocyclina* obtained in the limestone at Station 292 seem to belong to this species. The test is about 7 mm. in diameter and 2.5 mm. thick; there is no flange, and a few large pillars are scattered over the surface. In a vertical section there are, over the center, about 20 layers of small lateral chambers which are regularly arranged in tiers and are 70 μ $\pm$ long, 40 μ $\pm$ high, and have walls 35 to 50 μ thick.

L. flexuosa is found in Borneo and Sumbawa.

Lepidocyclina papulifera H. Douvillé (pl. 23, fig. 1).

Lepidocyclina papulifera H. Douvillé (4, p. 22, pl. 3, figs. 1-3). Van der Vlerk (28, p. 37).

Amphilepidina papulifera Douvillé (6, p. 102).

Lepidocyclina papulifera Van der Vlerk (31, p. 201, fig. 51).

Several poorly preserved specimens referable to this species were found at Stations 228 and 295. Test flat-lenticular, 30 to 40 mm. in diameter and 3 to 4 mm. thick; surface covered with a fine-mesh structure from the walls of the lateral chambers; pillars, confined to the central part, about 25 in number.

The specimens from Vitilevu are so poorly preserved that the superficial structure and pillars are lacking in nearly all specimens, hence the specific determination may be questionable.

The only other known occurrence of this species is the type locality at Ngampel, Java.

Genus MIOGYPSINA Sacco

Miogypsina polymorpha Rutten (pl. 23, fig. 2).

Miogypsina polymorpha Rutten (21, p. 207, pl. 12, figs. 6-9). Van der Vlerk (28, p. 55). Yabe and Hanzawa (37, p. 74, pl. 9, figs. 1-2; pl. 11, fig. 1).

Specimens referable to this species occur in the limestone at Station 292. The test is nearly always strongly folded, 3 to 4 mm. in diameter, with numerous small pillars

Table 6. List of Larger Foraminifera.

	Stations											
	68	74	130	158	292	295	302	309	316	327	328	329
Cycloclypeus annulatus Martin	×	—	—	×	—	×	—	—	×	—	—	—
Cycloclypeus neglectus Martin	—	—	—	×	—	×	—	—	×	×	×	×
Lepidocyclina (Cyclolepidina) suvaensis Whipple, new species	—	—	—	×	—	×	—	—	×	×	×	×
Lepidocyclina (Nephrolepidina) angulosa Provale	—	—	—	—	—	—	—	×	—	—	—	—
Lepidocyclina species indeterminate	—	×	—	—	×	—	—	—	—	—	—	—
Lepidocyclina (Eulepidina) formosa Schlumberger	—	—	×	—	—	—	×	—	—	—	—	—
Lepidocyclina (Eulepidina) dilatata (Michelotti)	—	—	—	×	—	?	—	—	×	—	?	?
Lepidocyclina (Eulepidina) dilatata laddi Whipple, new variety	—	—	—	×	—	—	—	—	×	—	—	—
Lepidocyclina (Eulepidina) radiata (Martin)	—	—	—	×	—	—	—	—	—	—	—	—
Lepidocyclina flexuosa Rutten	—	—	—	—	×	—	—	—	—	—	—	—
Lepidocyclina papulifera H. Douvillé	—	—	—	—	—	×	—	—	—	—	×	—
Miogypsina polymorpha Rutten	—	—	—	—	×	—	—	—	—	—	—	—
Miogypsina thecideaeformis Rutten	—	—	—	—	×	—	—	×	—	—	—	—

traversing the lateral chamber layers and forming at the surface minute papillae. Lateral chambers small and indistinct in many specimens.

This appears to be the only record of the species outside of Borneo.

Miogypsina thecideaeformis Rutten (pl. 23, fig. 3).

Miogypsina thecideaeformis Rutten (20, p. 1135; 21, p. 204, pl. 12, figs. 1-5). Van der Vlerk (28, p. 56, pl. 2, fig. 7). M. Davies (1, p. 9, pl. 2, figs. 1-8).

Identified in the limestones at Stations 292 and 309. Test small, 1.5 to 2 mm. in diameter and 1 to 1.5 mm. thick; surface papillate, the papillae formed by the ends of minute pillars which radiate from the equatorial plane. Although obscure in all sections studied, the nucleoconch appears to consist of two subequal chambers situated at the edge of the test and surrounded by a cycle of smaller, rounded chambers before the normal diamond-shaped equatorial chambers are formed. Whether the second chamber of the nucleoconch is larger than the first could not be definitely ascertained, though several sections seemed to show such an arrangement. Lateral chambers few in number and rather large. In the thickest portion of the test there are 5 or 6 layers.

The size of the test, together with the arrangement of the chambers, seems to agree with specimens from Borneo.

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FOSSIL CORALS FROM VITILEVU, FIJI

By J. Edward Hoffmeister

The rocks of the large island of Vitilevu have yielded relatively few well-preserved corals. Dr. H. S. Ladd has collected them from several localities, but of most only the genus can be recognized. The best collection was made by Ladd and me from a conglomerate at the abandoned quarry near the mouth of Walu Bay, Suva, Fiji (Station 160). The face of the quarry trends roughly east-west and exposes a thickness of about 85 feet of sediments which are cut by a series of small faults. The conglomerate occurs near the base of the exposed section. It is of variable thickness usually only a few inches but reaching a thickness of 15 feet in places. The conglomerate contains well-rounded pebbles and boulders up to 6 inches in diameter. These include plutonics, volcanics, sediments ("soapstone"), and worn pieces of coral. The matrix is a mixture of tuffaceous material and calcareous rubble which includes coral fragments. The conglomerate lies only a few feet above sea level. The corals from this locality are described here in biologic order. Those from other localities are merely listed in Table 7.

Seriotopora hystrix Dana.

Seriotopora hystrix Vaughan, Carnegie Inst. Washington, Pub. 213, p. 73, pl. 20, figs. 1, *a-c,* 2, *a,* 1918.

Many small fragments of the branches of this species were obtained from the conglomerate at Station 160. Dana's type (no. 346, U. S. Nat. Mus.) is from the living reefs of Fiji. The species is well known in the Pacific to-day and has been reported from the following localities: Fiji, Amboyna, Murray Island, Australia.

Pocillopora species.

Several small fragments of *Pocillopora,* all of which appear to belong to the same species, were obtained from the conglomerate at Station 160. They belong to a subgeneric group in which each species contains 12 well-developed septa. The weathered condition of the fossils makes it impossible to say much concerning the columella, though in all probability this too was distinct. The species to which it is most closely related is *P. lingulata* Dana. This living species is well represented in the United States National Museum. Verrill in his redescription of Dana's types of *P. lingulata* and *P. plicata* retained the latter name for the Fijian specimens and gave the name *P. aspera* variety *lata* to those from the Hawaiian Islands. Quelch, Gardiner, and Vaughan, however, consider the Hawaiian and Fijian specimens as belonging to the same species. Vaughan (U. S. Nat. Mus., Bull. 59, p. 94, 1907) places Dana's specimens of *P. plicata* from Fiji in the synonymy of *P. lingulata*.

Stylophora aff. **mordax** (Dana).

Sideropora mordax Dana, U. S. Expl. Exped., Zooph., p. 518, pl. 49, figs. 1, 1 *a*, 1 *b*, 1846.

Stylophora mordax Vaughan, Carnegie Inst. Washington, Pub. 213, p. 81, pl. 25, figs. 1, *a*, 2, *a*, *b*, 1918.

Dana's type of *S. mordax* (no. 344, U. S. Nat. Mus.) is from Fiji.

As Vaughan has pointed out, this species is very similar to *S. pistillata* (Esper) but can be separated from it by the greater width of the branches. The calices of *S. mordax*, I believe, are usually somewhat more crowded than those of *S. pistillata*. The conglomerate at Station 160 has yielded a large number of fragments which I have placed with this species with some slight hesitancy. It is impossible to reconstruct the growth form of the colony from these fragments. The width of the branches and their tendency to become meandriform, however, cause me to believe that they had the growth form of *S. mordax*. *S. pistillata* (Esper)? has been recorded by Vaughan from the raised reefs of Nasangalau, Lakemba, in the Lau group of the Fijian islands. Both species are common on living reefs to-day. *S. pistillata* has been recorded by Felix from the Pliocene of Timor and the Miocene of Java, and by Gerth from the upper Miocene of Borneo.

Stylophora species.

A massive, nodular form of the genus. It measures 7 cm. in the direction of its longest axis and 5 cm. in thickness. The worn surface is irregular and undulating. The normal calice measures slightly more than 1 mm. The intercalicular space is narrow, measuring about 0.5 mm.

Station 160, Vitilevu, Fiji.

Galaxea aff. **fascicularis** (Linnaeus).

Galaxea fascicularis Hoffmeister, Carnegie Inst. Washington, Pub. 343, p. 21, 1925.

Galaxea fascicularis Hoffmeister, B. P. Bishop Mus., Bull. 96, p. 60, 1932.

This species is represented in the collection by a number of individual corallites separated from the peritheca. The larger corallites show four cycles of septa and the smaller ones three cycles with the beginning of a fourth. It is known to be living at the following localities: Red Sea, Indian Ocean, Great Barrier Reef of Australia, Philippine Islands, Fiji, Samoa. Felix has reported it as *G. haligena* from the Pliocene of Java; Gerth has found it in the Miocene of Borneo; Umbgrove in the Neogene of Sumatra, and I in the Pliocene of Eua, Tonga.

Station 160, Vitilevu, Fiji.

Table 7. List of Corals.

	Stations																		
	45	59	133	157	158	160	245	294	295	297	299	301	304	310	311	357	375	376	377
Seriotopora hystrix Dana	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Pocillopora species	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	×	—
Pocillopora species ?	—	×	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Stylophora aff. mordax (Dana)	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Stylophora species	—	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—	—	—	—
Orbicella species ?	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Cyphastrea species	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	×?	—
Galaxea aff. fascicularis (Linnaeus)	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Favia aff. speciosa Dana	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Favia aff. favus (Forskål)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Goniastrea retiformis (Lamarck)	—	—	—	—	—	×	—	—	—	—	—	—	—	×?	—	—	—	—	—
Leptoria cf. gracilis (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Leptoria aff. phrygia (Ellis and Solander)	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Maeandra species	—	—	—	—	—	×	—	—	×	×	—	—	—	—	×	—	—	—	×
Fungia species	—	—	—	—	×	×	—	×	×	×	—	—	—	—	—	—	—	—	—
Pachyseris species	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Dendrophyllia species ?	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Acropora species	—	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Porites species	—	—	—	—	×	×	×	—	×	×	—	—	—	—	×	—	—	—	—
Porites species ?	×	—	×	—	—	—	—	—	—	—	×	×	×	—	×	×	—	—	—
Distichophora species	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	×	—	—

Goniastrea retiformis (Lamarck).

Goniastrea retiformis Hoffmeister, Carnegie Inst. Washington, Pub. 343, p. 26 (with synonymy), 1925.

Goniastrea retiformis Hoffmeister, B. P. Bishop Mus., Bull. 96, p. 65, 1932.

A few specimens from Vitilevu correspond closely to this species, which is well represented by Recent and fossil specimens in the collections of the U. S. National Museum. It is one of the commonest fossil species found in the elevated reefs of the Pacific. It is known to be living at the following localities: Red Sea, Indian Ocean, Great Barrier Reef of Australia, Amboyna, Philippine Islands, eastward in Pacific to Samoa. It has been reported from the Pleistocene reefs of the Red Sea, the Pliocene of Ceram and Dutch New Guinea, the Pliocene or Pleistocene of Timor and Christmas Island, and from the Pliocene of Eua, Tonga.

Station 160, Vitilevu, Fiji.

Besides the above-recorded species the following genera can be recognized in the collections from Station 160:

Cyphastrea species	Dendrophyllia species?
Maeandra species	Acropora species
Fungia species	Porites species
Fungia species?	Distichophora species

Because of the relatively few well-preserved corals in the collection, age determinations are difficult. The largest number of species obtained from any one locality was 14 from Station 160. Of these, only two were definitely determined, two more with some slight doubt, and the others only generically determined. All the genera and species represented are well known on the living reefs of the Pacific to-day. *Goniastrea retiformis* (Lamarck) has been reported from the Pleistocene and Pliocene and *Galaxea fascicularis* (Linnaeus) from Miocene, Pliocene, and Pleistocene rocks of this general region. So far as the evidence of the corals is concerned, the conglomerate at Station 160 is not older than Pliocene and may well be younger than this. The corals of the other stations are too few in number to place their age.

Dr. T. Wayland Vaughan listed five species of corals collected by Prof. W. G. Foye (Am. Acad. Arts and Sci., Proc., vol. 54, no. 1, p. 85, 1918) in Vitilevu. Only one of these could be determined specifically. This was *Diploastrea heliopora* (Lamarck), obtained 3½ miles east of Na Sana Sana, southwest Vitilevu, at an elevation of 10 to 15 feet. This species could not be recognized in Ladd's collection. The other genera listed by Vaughan were also obtained by Ladd. Vaughan pronounced the corals of the Foye collection Pleistocene or Recent.

FOSSIL ECHINOIDEA FROM VITILEVU, FIJI

By

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A small series of echinoids collected by Dr. H. S. Ladd in Vitilevu was submitted by him to Dr. F. A. Bather, F. R. S., through whose kind offices I was entrusted with the examination and description of the material. Numerous factors have contributed to the delay in the appearance of this report, not the least being the peculiarly unresponsive nature of the matrix with which the tests are encrusted. The separation of fossil from rock, where both are uniformly colorless and calcitic, has been laborious and only occasionally successful. No single specimen is perfectly preserved and few are adequately exposed. Hence it will be understood that the material is difficult to appraise.

I have rarely ventured beyond generic approximations. There seems good reason to believe that new species, and even a new genus, are represented, but I feel that it would be imposing a useless burden on later workers to describe, under new names, forms in which some essential taxonomic feature is obscure. I can but hope that the implications of my provisional classification of the material may help toward a determination of the age of the rocks from which it was collected. I may state, at the outset, that I fail to find any indication of more than one facies and, broadly speaking, one faunal horizon in the whole series.

The fossils studied came from the following localities as listed by Dr. Ladd (p. 76).

Station 68 (35-W), conglomeratic limestone: *Phyllacanthus* species (broken primary radiole).

Station 158 (35-X), conglomeratic limestone: *Phyllacanthus* species (3 fragments of primary radioles); *Psammechinus* species; *Arbacina* cf. *stellulata* (Duncan and Sladen); *Opechinus* cf. *affinis* (Duncan and Sladen) (2 specimens); *Clypeaster* cf. *pulvinatus* (Duncan and Sladen); small clypeastrid (or laganid); *Fibularia* species (3 fragmentary specimens); *Eurhodia* species (3 specimens); "Maretia" species (or new genus).

Station 160 (35-Z), conglomerate: *Phyllacanthus* species (16 primary radioles and 18 fragmentary radioles); *"Cidaris"* species (6 secondary radioles).

Station 294 (8-AA), limestone: *Phyllacanthus* species (primary radiole).

Station 295 (35-Y), limestone: *Phyllacanthus* species (fragment of primary radiole).

Station 297 (35-Z), limestone above conglomerate of Station 160: *Phyllacanthus* species (2 fragmentary radioles).

Station 307 (17-S), limestone: *"Cidaris"* species (fragment of radiole).

Phyllacanthus species.

The bulk of the collection consists of more or less broken radioles of a cidarid that seems certainly to have been a *Phyllacanthus*. Specimens were collected at Stations 63, 158, 160, 294, 295, and 297.

In size and all visible characters these radioles are very like those of *P. imperialis* (Lamarck), one of the most familiar living echinoids of the district. At first sight, the preponderance of these radioles, with their "modern" aspect, led me to expect that the entire collection must have come from deposits not older than the Pliocene. But the taxonomic value of a cidarid radiole (at least in fossil material) is very slight, and, though I still consider these to represent a true *Phyllacanthus,* I lay no stress on their resemblance to those of the living species. The genus *Phyllacanthus* is known to range from the Miocene to the Recent in the Indo-Pacific region; hence these radioles give scarcely any help in the stratigraphical problem. No doubt all of those I have listed under this name are conspecific. Whether the radioles from Stations 160 and 307, which I have called *"Cidaris"* species, represent another form or not I can not say. They are almost indeterminable and hardly more informative than the *Pholas* crypts associated with them.

Psammechinus species.

This specimen is crushed, split, and hopelessly encrusted on the adapical surface. It was apparently about 30 mm. across and about 15 mm. high, the peristome being relatively large. The ambulacral pore pairs are strongly triserial, the innermost member of a triad being almost in line with the main tubercle series of its column. Such features as can be seen (mainly those of the adoral surface) suggest *Psammechinus* as a probable identification, but there is not enough evidence for specific comparison. Cataloged as B. P. Bishop Mus., Geol. no. 1332, Station 158.

Arbacina cf. **stellulata** (Duncan and Sladen).

This is a small form, very incomplete adapically but in good condition adorally. It is about 12 mm. across and its height was perhaps half as much. The small portion of the adapical surface still remaining shows an exquisite stellate ornament linking the main tubercles and a strongly zigzag ridging between the ambulacral pore pairs that interferes slightly with the uniserial sequence of the pairs. I know of no other form than *"Temnechinus" stellulatus* that has ornamentation on this plan, and indeed the comparison in every available particular is very close. Duncan and Sladen's species is from the Miocene ("Gaj") of India. The Fijian specimen (B. P. Bishop Mus., Geol. no. 1333) is from Station 158.

Opechinus cf. **affinis** (Duncan and Sladen).

Two charming but rather small specimens of a "temnechinid" seem very closely comparable with this species. At any rate they can scarcely fail to be congeneric with it and one would assume that the two are contemporary. *"Temnechinus" affinis* is another Indian Miocene form. The Fijian specimens (B. P. Bishop Mus., Geol. nos. 1334, 1335) are from Station 158.

Clypeaster cf. **pulvinatus** Duncan and Sladen.

This comparison is merely based on shape and is therefore of small value taken alone. The specimen is, or rather was, deeply embedded in a peculiarly recalcitrant matrix and such parts of the test as could be exposed have lost all surface ornament in the process. If shape is a feature of any real value in the determination of Clypeasters, this specimen is as near to *C. pulvinatus* (from the Gaj Miocene) as can be. It was probably about 37 mm. long, 31 mm. broad, and perhaps 10 mm. high at the rather pointed apex. No internal structures are visible in the places where the test is broken. Cataloged as B. P. Bishop Mus., Geol. no. 1336, Station 158.

"Maretia" species.

This fairly well preserved spatangoid is in many ways the most interesting specimen in the collection, as it may represent an undescribed genus. One half of the adapical surface is missing, but the rest of the test (including the apical system with its four genital pores) has cleaned up very well. Superficially it is remarkably like *Breynia carinata* d'Archiac and Haime, but there is not the slightest trace of any fascioles on the adapical surface. I feel certain that the absence of fascioles is real, for every detail of ornament is perfectly plain in parts of the several regions where they might be expected. Except for slight indications of an incomplete subanal fasciole, the test is devoid of such structures. The few large tubercles (7 on each of the lateral interambulacra and none on the posterior one) are confined within the ambit of the petals and so suggest inclusion in a peripetalous fasciole, but there is none. Adorally the form is an absolutely typical *Maretia*. Its proportions are not altogether unlike those of the Recent *Pseudomaretia alta*, but the periproct of the Fijian specimen shows none of the peculiarities that distinguish the Recent type, and the large tubercles are quite differently disposed. Indeed, this form could be considered a kind of simplified type from which, by the development of fascioles in appropriate regions and other minor modifications, *Maretia, Pseudomaretia, Gonimaretia, Lovenia, Eupatagus,* or *Breynia* could be produced. It would, however, be safer to await further material before adding yet another to the bewildering welter of spatangoid genera. Possibly this may be an abnormal specimen—it might even be a true *Breynia carinata* which by some mischance had failed to develop fascioles. The test (B. P. Bishop Mus., Geol. no. 1337) is 36.2 mm. long, 28.8 mm. broad, and 20.9 mm. high. Collected at Station 158.

Conclusions

The only part of the collection that contains material capable of approximate determination is that from Station 158. Of the six species represented in this conglomeratic limestone, the *Phyllacanthus* is equivocal, and yet may be taken as useful in its wide occurrence, implying the similarity of horizon of all the other localities. The two other regular echinoids can be matched very closely (indeed, virtually identified) with two forms from the Miocene of northern India. The *Clypeaster,* though poor evidence, suggests a similar correlation. The fragments of *Eurhodia,* though not worth description, seem fairly definite, and again afford a link with the Indian Miocene. The *"Maretia"* would be *Breynia carinata* if it had the necessary fascioles—it is homoeomorphic in most respects with d'Archiac and Haime's Miocene species. Hence the evidence of the echinoids, while admittedly weak, is essentially consistent with a "Gaj" Miocene date for the rocks of Station 158, and presumably for the other localities represented in the collection. It is greatly to be hoped that further material from Fiji may be forthcoming, for the indications point to the existence there of a rich echinoid fauna that might serve to link the Miocene faunas of India and New Zealand. There is much in common between the Miocene echinoids of New Zealand and Cutch (strangely enough Australia seems to have been an independent province at that period), and Doctor Ladd's collection puts a valuable and suggestive link between these two rather remote extremes.

MOLLUSCOIDEA

Class Bryozoa

An unusual feature of the fossil faunas of Vitilevu is the scarcity of Bryozoa. Though a search was made at all fossil localities, particular attention being paid to the coralliferous limestones, specimens of Bryozoa were found at only three localities.

From the conglomerate at Station 160 worn fragments of *Lichenopora* species, *Lunulites* species, and *Cellspora* species were collected. From the conglomeratic limestone at Station 317 a fossil belonging to the long-lived genus *Membranipora* was collected, but as it is without ovicell it can not be placed exactly. From the agglomerates exposed at Station 304 questionable Bryozoa were collected. Dr. R. S. Bassler, who has kindly examined the material, reports (May 3, 1932) that no specific determinations can be made. The specimens are of no value in determining the age of the beds containing them.

Class Brachiopoda

Order Telotremata

Superfamily Terebratulacea

Family Terebratulidae

Subfamily Cancellothyrinae Thomson

Genus TEREBRATULINA d'Orbigny

Terebratulina d'Orbigny, Acad. Sci. Paris, Compt. Rend., vol. 25, p. 268, (no ex. cited), 1847; Annales Sci. Nat., 3d ser., vol. 8, Zool., p. 249, pls. 7, 8, 17, 1847.

Type (by original designation), *Anomia caput-serpentis* Linnaeus, 1767 = *Anomia retusa* Linnaeus, 1758. Recent, northeast Atlantic (*fide* Thomson).

Terebratulina waimanensis Ladd, new species (pl. 24, figs. 1-3).

Shell small, ovate, longer than wide; posterolateral margins straightened, lateral margins broadly rounded, anterior margin straightened; valves moderately and uniformly convex. Ventral valve slightly deeper than dorsal, bearing a broad and poorly defined median depression; beak prominent; foramen large and subcircular; cardinal margins bordering foramen slightly auriculated; posterolateral areas depressed. Dorsal valve gently convex with little or no trace of median fold; sides of umbo slightly auriculated. Surface of both valves marked by fine rounded ribs which are widely spaced in the posterolateral areas, but closely set over the remainder of the shell; ribs increase by bifurcation, some 60 being present along the margin of each valve; concentric lines of growth few and inconspicuous; shell surface densely punctate.

Holotype (B. P. Bishop Mus., Geol. no. 1120): ventral valve, length 12.8 mm., width 10.1 mm., convexity 3.8 mm.; dorsal valve, length 11.9 mm., width 10.1 mm., convexity 3.4 mm. Topotype in U. S. National Museum (Cat. no. 87226).

Localities: holotype from Station 158, appears also at Station 298.

Family Terebratellidae

Subfamily Dallininae Beecher

Genus **DALLINA** Beecher

Dallina Beecher, Conn. Acad. Arts. Sci., Trans., vol. 9, pp. 377-382, 1893.

Type (by original designation, Beecher, 1893), *Terebratula septigera* Lovèn. Recent, northern Norway (Finmarken). Now known to range southward to Canary Islands and Mediterranean Sea, and has been reported from the Miocene and younger rocks of Sicily and Italy and from the Quaternary of Norway (*fide* Thomson).

Dallina vitilevensis Ladd, new species (pl. 24, figs. 4-7).

Shell medium sized, globose, subrectangular in outline, much longer than wide; widest at midpoint, thence tapering but little to the straightened anterior margin. Ventral valve much deeper than dorsal; with a prominent sulcus, which begins posterior to the midpoint and extends anteriorly to meet a shorter and less conspicuous fold in the dorsal valve; margins of sulcus merge laterally into rather sharp folds which extend anteriorly to meet shallow sulci in the brachial valve; anterior commissure intraplicate; lateral slopes of ventral valve steep. Beak strong and curved; foramen large, circular, permesothyrid. Brachial valve very shallow except near the anterior margin, where it extends ventrally into the folds of the opposite valve. Surface smooth except for punctate and concentric lines of growth. The median septum in the dorsal valve, which can be seen through the shell, extends forward for about two thirds the length of the valve.

Holotype (B. P. Bishop Mus., Geol. no. 1119); ventral valve, length 14.4 mm., width 9.3 mm., maximum convexity 6.6 mm.; dorsal valve, length 12.1 mm., width 9.3 mm., convexity 5.7 mm.; both valves locked together, convexity 9.0 mm. Topotype in U. S. National Museum (Cat. no. 87225).

Type locality, Station 158.

The species is very closely related to the Recent *D. raphaelis* Dall, the type of which was available for comparison. The Fiji species, however, is smaller, proportionately longer, and more sharply folded. It is still closer to a specimen labeled "*Dallina raphaelis* Dall, var. *minor*" in the U. S. National Museum (Cat. no. 110792). This specimen is about the same size as *D. vitilevensis* but is more globose, broader, and somewhat less sharply folded. It is a Recent specimen from Japan, obtained in 103 fathoms of water. Apparently Dall (U. S. Nat. Mus., Proc., vol. 57, pp. 357-359, 1920) did not consider it a valid subspecies, as he placed it with the type of *D. raphaelis* and did not recognize it in his discussion of the genus.

MOLLUSCA

Class Pelecypoda

Order Prionodesmacea

Superfamily Arcacea

Family Glycymeridae

Subfamily Glycymerinae

Genus GLYCYMERIS da Costa

Glycymeris da Costa, Brit. Conch., p. 168, pl. 11, fig. 2, 1778.

Subgenus GLYCYMERIS sensu stricto

Type (by absolute tautonymy), *Arca glycymeris* Linnaeus (*fide* Grant and Gale). Recent, seas of Europe.

Glycymeris (Glycymeris) fijiensis Ladd, new species (pl. 24, figs. 8, 9).

Shell medium-sized, orbicular, moderately inflated, thick; umbo low, beak small and turned very slightly backward. (In *Glycymeris*, contrary to the general rule, the beaks are equilateral or directed slightly backward). Sculpture consisting of 26 strong, rounded (holotype and only specimen is worn), radiating ribs which are separated by equally wide interspaces; irregularly spaced concentric lines, present near the margins of the shell, give the ribs a somewhat nodular appearance. Cardinal area narrow, short, and marked with chevron-shaped ligament grooves. Hinge plate arched; teeth strong and arranged in two series, which are separated medially; 10 to 11 teeth in each series. Internally, the posterior adductor scar is trapezoidal in outline, slightly larger than the triangular anterior scar, and is bordered by an elevated ridge. The margin of the lower half of the shell is strongly fluted.

Holotype (B. P. Bishop Mus., Geol. no. 1144), a left valve: length 37.2 mm., height 37.1 mm., thickness 8.9 mm.

Type locality, Station 160.

Coarsely ribbed glycymerids of this general type are abundant in the southwest Pacific to-day, especially in the Philippine Islands, but none of them appear to be very closely related to *G. fijiensis*.

Glycymeris (Glycymeris) species A.

A single internal mold of a right valve of a strongly ribbed *Glycymeris* (B. P. Bishop Mus., Geol. no. 1146) was collected from the Suva formation at Station 158. The species is proportionately longer than *G. fijiensis* Ladd, new species, and has many more ribs (about 40 as against 26 in *G. fijiensis*). Twenty-one strong teeth form a continuous series; muscle scars strongly elevated. Measurement: length 27.4 mm., height 24.5 mm., thickness 6.4 mm.

Glycymeris (Glycymeris) species B (pl. 24, fig. 10).

Shell small, suborbicular, subequilateral, moderately convex, thick; beaks turned backward. Sculpture consisting of very numerous fine bifurcating riblets, each fourth or fifth near the margin being slightly larger than those intervening; riblets faintly beaded by close-set concentric lines. Cardinal area short and narrow wth prominent chevron-shaped ligament grooves diverging from beneath the beak. Hinge plate narrow and broadly arched; teeth in two series, which almost meet medially; 11 to 12 teeth in each series. Ventral margin of shell strongly crenulate internally. The figured specimen (B. P. Bishop Mus., Geol. no. 1145), a right valve, which is slightly broken along the margins, measures: length 12.8 mm., height 12.1 mm., thickness 3.7 mm.

Associated with *G. fijiensis* at Station 160.

This species is represented by two valves, a right and a left. Neither is complete and both are probably immature. Hence, though it has not been possible to identify them with described species, it seems best not to name the shells until better type material is available.

Family Arcidae

Genus ARCA Linnaeus

Arca Linnaeus, Syst. Nat. 10th ed., pp. 693-695, 1758.

Subgenus ARCA sensu stricto

Type (by subsequent designation, Schumacher, 1817), *Arca antiquata* Linnaeus (*fide* Grant and Gale). Recent, type locality unknown. Reported from the upper Tertiary and younger beds in Java, etc. (*fide* Van der Vlerk).

Arca noae Linnaeus is commonly cited as the type of *Arca* sensu stricto, the group typified by *A. antiquata* forming the subgenus *Anadara* Gray. Stewart (Acad. Nat. Sci. Phila., Special Pub. 3, pp. 83-86, 1930) has discussed this matter fully. It is possible that at some future date the International Commission on Zoological Nomenclature may waive the rules and establish *A. noae* as the type species of *Arca*, but, pending such a decision, I prefer to follow the rules and accept Schumacher's designation of *A. antiquata*.

Arca (Arca) thomasi Ladd, new species (pl. 24, figs. 11-14).

Shell medium sized, trapezoidal in outline, higher than long, strongly inflated, thick; umbos high, beak strongly arched; cardinal area fairly wide, bearing two ligament grooves which diverge from beneath the beak at an obtuse angle and parallel the margins of the area; area also marked by fine striae, which run parallel to the hinge line. Line of hinge teeth continuous, those near the extremities being longer and slightly oblique. Sculpture consisting of 25 to 26 strong, flattened radial ribs separated by wide, channeled interspaces. All of the ribs of the left valve are conspicuously beaded; the ribs of the right valve are narrower, and those near the middle of the shell are not beaded. Internally the shell shows faint radial ribs; internal margin strongly fluted.

Young shells are subtrigonal in outline and are uniformly inflated; adult shells are trapezoidal in outline and are flattened in the posterodorsal and anteroventral regions.

Holotype (B. P. Bishop Mus., Geol. no. 1138), a left valve: length 19.2 mm., height 23.2 mm., convexity 9.7 mm., length of hinge 11.1 mm. Paratype *A* (B. P. Bishop Mus., Geol. no. 1234), a right valve, is incomplete. Paratype *B* (B. P. Bishop Mus., Geol. no. 1137), an immature left valve, measures: length 12.4 mm., height 14.4 mm., convexity 6.9 mm., length of hinge 7.5 mm. Topotype in U. S. National Museum (Cat. no. 372676).

Types from Station 59; specimens also collected at Station 362.

The Fijian species, with its short hinge and subtrigonal outline, greatly resembles a number of species which have been placed in Dall's section *Cunearca*. The type of *Cunearca* is *A. incongrua* Say, a Recent species occurring from North Carolina to Texas.

A. thomasi is closely related to *A. pilula* Reeve, a Recent southwest Pacific species, but the Recent shell is nearly quadrate in outline, rather uniformly inflated, and has narrower ribs than *A. thomasi*.

Arca (Arca) species **A** (pl. 24, figs. 15, 16; pl. 25, fig. 1).

Arca (*Scapharca*) species *a* Mansfield, Carnegie Inst. Washington, Pub. 344, pp. 88-89, pl. 3, fig. 5, *a-c*, 1926.

Original description:

The shell is of medium size, subquadrate and oblique; disks depressed at the anterior third of length and expanded at the posterior angle. Beaks are situated at the anterior third of dorsal line and are low and apparently separated by a narrow cardinal area. Anterior end of valves moderately rounded and gently slope to the margin; posterior end steeply sloping; posterior ridge prominent and roundly angular. Dorsal margin apparently nearly straight; ventral margin broadly rounded; anterior margin narrowly rounded; posterior margin nearly staight. Sculpture consists of about 40 ribs (est.), each medially incised over the middle of the disk and increased by more incisions on the ribs over the posterior slope, forming four narrow, longitudinal, raised bands on each rib.

The specimen (U. S. Nat. Mus., Cat. no. 352413) measures: length, 48 mm.; height, 40 mm.; greatest thickness, 27 mm.

Locality, Station 295 of Ladd (= locality 1/132 of Mansfield).

I obtained additional material, but all the specimens are too poorly preserved to be made types. Mansfield pointed out that the species is apparently related to *A. sedanensis* Martin, from the "Altmiozän (nur Rembangsch)" of Java.

Arca (Arca) species **B** (pl. 25, figs. 2, 3).

Arca (*Scapharca*) species *b* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 89, pl. 4, fig. 1, *a-b*, 1926.

Original description:

The shell is of medium size, elongate and subrhomboidal. Beaks are moderately high, separated by a wide, concave cardinal area, and situated near the anterior extremity of the shell. Anterior end of shell short and well rounded over the shoulder; posterior end elongate and gently sloping to margin and rounding over the shoulder. Hinge margin straight; ventral margin slightly diverging and widening from the hinge line in advancing posteriorly. The sculpture consists of moderately wide ribs, separated by narrower interspaces, the exact number of ribs indeterminable, probably about 30. As the shell is corroded and the extremities partially broken away, a fuller description is not practicable. The specimen (U. S. Nat. Mus., Cat. no. 352414) measures: length, 47 mm.; height, 33 mm.; greatest thickness, 27 mm.

Associated with *Arca* (*Arca*) species *a* at Station 295 (locality 1/132 of Mansfield). The material collected by me is even less well preserved than the specimen figured by Mansfield.

Genus BARBATIA Gray

Barbatia Gray., Zool. Soc. London, Proc., pt. 15, p. 197, 1847.

Subgenus ACAR Gray

Acar Gray, Ann. Mag. Nat. Hist., 2d ser., vol. 19, p. 369, 1857.

Type (by subsequent designation, Woodring, 1925), *Arca gradata* Broderip and Sowerby. Recent, Pacific coast of Mexico and Central America.

Barbatia (Acar) species (pl. 25, figs. 4, 5).

Shell small, trapezoidal in outline, moderately inflated, thick. Anterior margin broadly rounded, ventral and posterior margins nearly straight. Beak small, depressed, strongly incurved, located less than one third of the length from the anterior end. From the beak a low keel extends to the posteroventral margin, which is produced into a blunt point; posterior to the keel a broad, shallow depression extends from the beak toward the byssal gape, but becomes very obscure ventrally. Cardinal area small, flattened, widest anterior to the beak; the narrow part behind the beak bears four oblique ligament grooves. Hinge teeth in a single series, those anterior to the beak irregular. Internally, the muscle scars are noticeably elevated and the margins of the valve are strongly crenulated except at the narrow byssal gape on the ventral margin. Sculpture consisting of closely set radials elevated into frills by heavy concentric lines.

Represented by a single left valve (B. P. Bishop Mus., Geol. no. 1139), which measures: length 17.8 mm., height 9.8 mm., convexity 4.4 mm., length of hinge 11.3 mm.

Locality, Station 160.

The Fijian shell is more sharply produced posteroventrally than the type species and has a much less prominent keel. The Fijian fossil may represent a new species, but shells of *Acar* show considerable variation in shape and until additional fossils have been collected it seems advisable to withhold a specific name.

Subgenus OBLIQUARCA Sacco

Obliquarca Sacco, I molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 26, p. 16, 1898.

Type (by original designation), *Arca modioliformis* Deshayes. Eocene, Paris basin (*fide* Woodring, 1925).

Barbatia (Obliquarca) javana Martin (pl. 25, figs. 6-8).

Shell medium-sized, elliptical in outline, rather strongly inflated, very inequilateral, the beaks being placed about one fourth the length from the anterior end; posterior margin sharply rounded, anterior margin broadly rounded, ventral margin straight or with a broad median indentation or gap; posterior ridge broad, low. Cardinal area very narrow; the part lying beneath the beak, and anterior to it, is slightly elevated and marked by faint longitudinal striations; posteriorly the area bears deep ligament grooves. Hinge continuously toothed; near the center the teeth are short and nearly vertical, but they become progressively longer, heavier, and more oblique toward the extremities. Along the flattened inner edge of the shell, in front of the line of teeth, a series of elongated, oblique ridges alternate with shallow depressions; a similar series is present posterior to the line of teeth. These grooves and ridges doubtless function as supplementary teeth. They are not visible on worn valves. Disk marked by numerous radial ribs which are slightly beaded by regularly spaced concentric lines; anteriorly the ribs are coarser and show a tendency toward bifurcation; above the posterior ridge they are widely spaced, less uniform in size, and more strongly beaded. Near the margins of the shell the concentric sculpture is more pronounced.

Internally the valves show a smooth elevated border, within which are short grooves converging toward the beak. Posterior muscle scar larger than anterior.

The left valve (figs. 7, 8, pl. 25) (B. P. Bishop Mus., Geol. no. 1140), measures: length 30.6 mm., height 19.4 mm., convexity 7.6 mm. The right valve (fig. 6) (B. P. Bishop Mus., Geol. no. 1141), measures: length 28.8 mm., height 18.7 mm., convexity 6.9 mm.

Localities: conglomerate at Station 160; internal molds that apparently represent the same species occur in the limestone immediately above (Station 297). Martin's single valve was collected from the upper Miocene of Java.

The shells of *B.* (*Obliquarca*) *javana* are not modioloid as is the type of *Obliquarca,* but they have the teeth and cardinal area of that species. Young specimens of *Barbatia* sensu stricto have a hinge of this type, but many of the two dozen fossil specimens certainly are adult shells. The species, therefore, seems a true *Obliquarca.* The type of *Obliquarca* is an Eocene shell from the Paris Basin. Other species are known from the late Tertiary deposits of the Mediterranean region, and Woodring (Carnegie Inst. Washington, Pub. 366, pp. 38-40, 1925) has described three species from the middle Miocene of Jamaica. No recent species of *Obliquarca* have as yet been recognized.

Genus NAVICULA Blainville

Navicula Blainville, Dict. des Sci. Nat., vol. 10, p. 216, 1818.

Type (by monotypy), *Arca noae* Linnaeus (*fide* L. R. Cox). Recent, Mediterranean Sea.

Navicula species (pl. 25, figs. 9, 10).

Shell small, elongate, moderately inflated, very inequilateral; posterior keel sharp but not undercut, median depression broad and very shallow. Sculpture consisting of numerous rounded radial ribs which, in the area posterior to the keel, are large and sharply separated by only slightly narrower interspaces; over the middle of the shell the ribs are fine and close set, but anteriorly they become coarse and well spaced; six ribs occur in the area posterior to the keel; entire shell marked by prominent and regularly spaced concentric laminae, which give the center of the disk a reticulated appearance while the margins appear strongly beaded. Cardinal area rather wide and flat with a single pair of ligament grooves diverging at an acute angle from beneath the beak; faint longitudinal striations are also present. Hinge teeth numerous and not interrupted medially.

Description based on an incomplete right valve (B. P. Bishop Mus., Geol. no. 1142) that measures: length 14.2 mm., height 9.6 mm., convexity 4.9 mm., maximum width of cardinal area 2.2 mm.

Locality, Station 160.

This species belongs to the group of *A. maculata* (Sowerby), a Recent Pacific form, and is quite closely related to an undescribed Recent species from the Hawaiian islands, examples of which are in the collections of the U. S. National Museum (Cat. nos. 190446 and 335696). Small arks of this type, however, are not limited to the Pacific. The Fijian fossil is characterized particularly by the sharpness of the posterior keel, the strength and regularity of the concentric lamellae, and the flatness of its cardinal area. It is related to *Arca kelirensis* Martin, from the lower Miocene of Java (Die Altmiocäne Fauna des West-Progogebirges auf Java: Geol. Reichs Mus., Leiden, Samml., new ser., vol. 2, pt. 7, p. 265, pl. 4, figs. 101, *a*, 102, 1917), but that species has a very prominent median depression.

Superfamily Ostracea

Family Ostreidae

Genus OSTREA Linnaeus

Ostrea Linnaeus, Syst. Nat., 10th ed., p. 696, 1758.

Type (by subsequent designation, Children, 1823), *Ostrea edulis* Linnaeus (*fide* Stewart, 1930). Recent, seas of Europe.

Ostrea cf. **baribisiana** Martin (pl. 26, figs. 5, 6).

Ostrea baribisiana Martin, Die Fossilien von Java: Geol. Reichs Mus., Leiden, Samml., new ser., vol. 1, p. 340, pl. 47, figs. 26, *a*, 27, 1909.

Shell small, rather thin, rhomboidal in outline. The hinge area, which lies at one of the angles, is small, rhomboidal, concave, and smooth. External sculpture consisting of prominent ridges, which are weakly impressed on the interior. The most prominent ridge extends from the beak to the ventral margin; from this main ridge branches extend anteriorly and posteriorly, some simple, others bifurcating. Margins plicate.

The above description of this unusual oyster is based on a single right valve. The measurements of the specimen (B. P. Bishop Mus., Geol. no. 1171) are: length 34.2 mm., height 39.7 mm., convexity 15.8 mm.

Locality, Station 319.

The collection of additional material may prove that this species is identical with *O. baribisiana* Martin, from the Pliocene (?) of Java.

Ostrea aff. **virleti** Deshayes (pl. 26, figs. 1, 2).

Shell large, elliptical, subequilateral, moderately thick. Left valve convex and plicate; plications strongest on the median portion of the disk, beginning anterior to the beak, becoming increasingly prominent ventrally where they give rise to other folds by bifurcation; entire shell marked by concentric laminae, which form hollow spines on the crests of the plications. Ligamental area obtusely triangular with a shallow central depression for the resilium; this depression rounded ventrally. Margins of valve crenulated below the hinge, especially on the anterior side, and plicated ventrally. Muscle scar large, subquadrate, corrugated, and slightly depressed. Right valve unknown.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1128), a left valve: length 68.6 mm., height 90.4 mm., convexity 31.5 mm.

Locality, marl at Station 369; a fragment from the conglomeratic limestone at Station 133 may represent this species.

The Fijian species is similar in many ways to *Ostrea virleti* Deshayes of the Mediterranean Miocene and its younger allies in the Indo-Pacific area. (See Cox, L. R., Neogene and Quaternary Mollusca from the Zanzibar Protectorate, pp. 66-69, 1927.) It also resembles *O. haitensis* Sowerby, a variable West Indian species which has been widely reported from the lower and middle Miocene. In view of the great variability of such oysters, however, it is impossible definitely to identify the single complete Fijian valve.

Ostrea species (pl. 26, figs. 3, 4).

Valves small, thin, crescentic in outline; left valve convex, right valve slightly concave. Hinge areas obliquely triangular and sharply set off from remainder of valves; resilium pit in left valve narrowly triangular and opposed by a slightly elevated area in the right valve; hinge areas longitudinally striate. External sculpture consisting of prominent concentric growth lines at irregular intervals. Internally, the dorsal margins of the right valve have a series of widely and regularly spaced pustules which fit into a series of circular sockets on the opposite valve. Muscle scar large and elongate-ovate in outline.

Measurements of the figured specimens are: right valve (B. P. Bishop Mus., Geol. no. 1169), length 17.6 mm., height (incomplete) 30.6 mm., left valve (B. P. Bishop Mus., Geol. no. 1170), length 13.6 mm., height (incomplete) 20.9 mm., convexity 7.8 mm.

Locality, Station 133.

Superfamily PECTINACEA

Family PECTINIDAE

Genus PECTEN Müller

Pecten Müller, Zool. Dan., p. 248, 1776.

Key to the Vitilevu Species

Shell equilateral
  Ribs numerous, subequal in size
    Shell large, ribs 18 to 20
      Ribs rounded .... **P. suvaensis**
      Ribs broad and flattened .... **P. species A**
    Shell small, ribs more than 30 .... **P. species B**
  Ribs few, unequal in size .... **P. mirificus**
Shell inequilateral
  Auricles unequal
    Shell wider than long, ctenolium present .... **P. lamiensis**
    Shell longer than wide, ctenolium absent .... **P. nausorensis**
  Auricles subequal
    Hinge short .... **P. waluensis**
    Hinge long
      Ribs without imbricating scales .... **P. exaratus**
      Ribs with imbricating scales .... **P. corymbiatus talicus**

Subgenus **PECTEN** sensu stricto

Type (by subsequent designation, Schmidt, 1818), *Ostrea maxima* Linnaeus. Recent, northern seas of Europe (*fide* Stewart, 1930).

Pecten (Pecten) suvaensis Mansfield (pl. 27, figs. 1-4).

Pecten (*Chlamys*) *suvaensis* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 89, pl. 4, fig. 2, *a*, *b*, 1926.

Original description:

The shell is of medium size, orbicular, solid, equilateral, moderately inflated over the disk, and slightly compressed medially at and near the beak. The disk is radially sculptured by 18 low-keeled, nearly rounded ribs with interspaces of about half their width, in which there is a low, medial thread, becoming more prominent on nearing the margin; submargins about 3 mm. wide, without radial ribs; whole surface of shell ornamented with close-set, threadlike, concentric sculpture, becoming crowded and imbricated near and at the margins. Ears nearly equal, anterior ear slightly broken away at the byssal area, radially marked with low ribs, the anterior with 5, the posterior with 4, all overrun by fine, close-set imbrications. Type, right valve (U. S. Nat. Mus. Cat. no 352415), measures: length, 50 mm., est. (25 mm. from posterior margin to middle between 9th and 10th ribs); height, 45 mm.; thickness, 8 mm.

The interior characters are not well shown on the holotype, but a topotype (B. P. Bishop Mus., Geol. no. 1101), a right valve, shows that the resilium pit is large, deep, and sharply set off from the adjoining areas, though not bordered by a distinctly elevated ridge. Two prominent cardinal crura diverge from the apex of the pit on either side and tend to parallel the hinge border;

the upper pair extend to the edge of the auricles, but the lower ones are only half as long. The cardinal edge of the auricles is bent downward. The external ribbing is strongly impressed on the interior as a series of low, broad radial ribs and equally wide interspaces, the ribs having thickened borders. Another right valve (B. P. Bishop Mus., Geol. no. 1102) (pl. 27, figs. 3, 4) is from a slightly older horizon and is thinner and smaller than the type. It appears to be a young shell, and the spaces between the ribs fail to show the median thread which is present near the margins of the larger shells. In other respects it agrees with the type except that the anterior ear carries six ribs and is slightly higher than in the type. The left valve of this species is unknown.

Topotype (B. P. Bishop Mus., Geol. no. 1101): length 50.7 mm., height 46.7 mm., depth 8.0 mm. Homeotype (B. P. Bishop Mus., Geol. no. 1102): length 31.4 mm., height 31.4 mm., depth 4.6 mm.

Localities: type from Station 295 (Mansfield's Station 1/132); also collected from Stations 320, and 133, the latter being a questionable identification.

As Mansfield has pointed out, *P. suvaensis* is related to *P. leopardus* Reeve, but the ribs of the latter are more diverging and lack a medial keel, and the interspaces are wider and lack the median thread. According to Van der Vlerk (Leidsche Geolog. Mededeel. vol. 5, p. 268, 1921), *P. leopardus* has been reported from the Neogene of Madoera, the Miocene and Pliocene (?) of Java, the Pliocene and Quaternary of Timor.

It is possible that *P. suvaensis* does not belong to the subgenus *Pecten*. The left valve is unknown and the right valve lacks the numerous radial threads of the type species. It seems closer to *Pecten* sensu stricto, however, than to *Chlamys,* where it was originally placed. The gently sloping dorsal margins, the subequal ears, and the equilateral outline do not suggest *Chlamys*. It should also be pointed out that the right valve is not deeply indented, there is no ctenolium, and there are at least two pairs of prominent cardinal crura.

Subgenus CHLAMYS Bolten

Chlamys Bolten, Mus. Boltenianum, pt. 2, p. 161, 1798.

Type (by subsequent designation, Dall, 1898), *Pecten islandicus* Müller. Recent, seas of Europe (*fide* Woodring, 1925).

Pecten (Chlamys) lamiensis Ladd, new species (pl. 27, figs. 5-7).

Shell medium sized, suborbicular, wider than long, thick, left valve more convex than right; sculpture similar on both valves, consisting of about 24 strong radial ribs indistinctly marked by fine grooves; grooves better developed in the interspaces and also in the lateral areas where they merge with the ribs as the latter decrease in size; ventral half of shell marked by closely set concentric rows of thin lamellae which are nearly erect on the submargins, giving this portion of the shell a very scaly appearance. Ears large, the anterior longer; cardinal margins of ears thickened and bent downward, especially on right valve; ears marked exteriorly by radial riblets crossed by numerous concentric lamellae. Internally, the main ribs produce a series of well-marked grooves; right valve shows a ctenolium with four heavy teeth. Resilium pit small, deep, and flanked by two pairs of cardinal crura, the ventral pair merging with the elevated border of the pit; crura very prominent on right anterior auricle.

Holotype (B. P. Bishop Mus., Geol. no. 1103), a left valve: length (est.) 68.0 mm., height (est.) 70.0 mm., depth 13.8 mm. Paratype *A* (B. P. Bishop Mus., Geol. no. 1104), a right valve: length (incomplete) 48.3 mm., height 52.3 mm., depth 7.4 mm. Paratype *B* (B. P. Bishop Mus., Geol. no. 1105), margins incomplete.

Type locality, Station 133.

The Fijian species bears a general resemblance to *Chlamys kebolintangensis* Martin, from the Pliocene (Sondé beds) of Java. In both species the ribs, which are so prominent over the disk, decrease in size anteriorly and posteriorly, but the Fijian shells have more numerous ribs than those from Java.

Pecten (Chlamys) nausorensis Ladd, new species (pl. 27, figs. 8, 9).

Shell medium in size, suborbicular, slightly longer than wide, thick; valves compressed, the left a trifle deeper than right; inequilateral, both valves being somewhat produced anteriorly. Anterior auricle slightly larger than posterior, marked by 4 or 5 very fine riblets which are crossed by numerous incremental lines. Valves each with 18 rounded or slightly angled ribs and fine closely set lines of growth; submargins prominent and unribbed. Cardinal margins of auricles slightly bent over; chondrophore broadly triangular and moderately deep, flanked by a pair of prominent cardinal crura. Ctenolium absent.

Holotype (B. P. Bishop Mus., Geol. no. 1107), a right valve; length 41.1 mm., height 38.3 mm., depth 6.0 mm. Paratype (B. P. Bishop Mus., Geol. no. 1108), a left valve: length 39.6 mm.; height 38.7 mm.; depth 6.6 mm.

Localities: holotype from Station 158; paratype from Station 133.

The dorsal margins of this species do not slope as steeply as in the type of *Chlamys*, no ribs are added by implantation, and there is no ctenolium. The species, however, seems closer to *Chlamys* than to the other recognized subgenera.

Subgenus PALLIUM Schumacher

Pallium Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 120, 1817.

Type (by monotypy), *Pallium striatum* Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 120, pl. 4, fig. 4 = *Pecten plicatus* Chemnitz, Conchyl. Cab., vol. 7, p. 292, pl. 62, fig. 598, *a, b,* 1784 = *Ostrea plica* Linnaeus, Syst. Nat., p. 697, 1758. Recent, Japan (*fide* Grant and Gale).

Pecten (Pallium) waluensis Hertlein (pl. 28, figs. 1-3).

Pecten (*Chlamys*) *thomasi* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 90, pl. 5, fig. 1, *a, b,* 1926.

Pecten waluensis Hertlein, Nautilus, vol. 47, p. 62, 1933.

Original description:

Shell of medium size, oblique-ovate, solid, moderately inflated over the middle of the disk and compressed forward at the umbonal area. Hinge line short. Ribs 15 in number, low-keeled above and only slightly below, becoming more rounded distally; ribs separated by interspaces of about one half their width. Radially sculptured over the whole surface of the disk and submargins by fine lines, being stronger over the ribs than interspaces; concentrically sculptured by close-set, minute, nearly erect, imbricated lamellae. Anterior ear small, marked by 3 to 4 fine, minutely crenulated radials within the byssal area and 3 stronger ones in front of it; posterior ear terminally broken off, but indicates similar markings to that of the anterior. Within, the resilium pit is triangular and large, on either side of which there are two other pits, the approximate ones marginate the ligamental area and the distal ones enter it.

The type is founded upon one left valve. Dimensions: length 42 mm., height 45 mm. [This type now in the U. S. National Museum as no. 372662.]

The right valve is slightly more convex than left but similarly sculptured. Neither valve quite bilaterally symmetrical, being produced posteriorly below. Resilium pit in right valve deeper and more sharply set off than in left valve. Two pairs of cardinal crura are well developed on each valve, and on the left valve the broadly elevated margins of the ligamental pit may be looked upon as a third pair.

Homeotypes: left valve (B. P. Bishop Mus., Geol. no. 1125), length 39.3 mm., height 43.7 mm., depth 6.0 mm.; right valve (B. P. Bishop Mus., Geol. no. 1126), length 40.0 mm., height 45.1 mm., depth 7.9 mm.

Localities. Type from Station 295, given by Mansfield as "Walu Bay, Fiji Islands." The type was collected by the late A. O. Thomas and is in a matrix of limestone. Such limestones are exposed in two quarries on Walu Bay—Stations 295 and 297, but Thomas stated to me in 1926 that he had not visited the abandoned quarry at Station 297. Also collected from Stations 158, 317, and 133. The specimen from Station 133 is poorly preserved and only tentatively referred to *P. waluensis*.

This species may be easily distinguished from the other Fijian fossil pectens by its striking external sculpture and by the development of the strong cardinal crura. As noted by Mansfield, the sculpture is similar to that found in *P.* (*Chlamys*) *radula* (Linnaeus), a Recent southwest Pacific species, but the shortness of the hinge and the prominent crura seem to place the species in the subgenus *Pallium,* in spite of the excessive number of ribs and the absence of any contraction around the basal margin.

Subgenus AEQUIPECTEN Fischer

Aequipecten Fischer, Man. Conchyl., p. 944, 1887.

Type (by monotypy), *Ostrea opercularis* Linnaeus. Recent, seas of Europe (*fide* Woodring, 1925).

Pecten (Aequipecten) exaratus Martin (pl. 28, figs. 4-9).

Pecten exaratus Martin, Die Tertiärschichten auf Java, p. 122, pl. 20, figs. 5, 9, 1880.

Shell medium sized, thick, oblique-elliptical, slightly longer than high, produced posteriorly; valves but little inflated, the right a trifle deeper than left. Auricles subequal, posterior sinus poorly developed; anterior auricles more sharply defined, the right one being deeply insinuated; auricles with 4 or 5 riblets, those on the right anterior being most prominently developed; riblets crossed by numerous concentric laminae which give the surface a somewhat scaly appearance. Sculpture consisting of 21 strong ribs on each valve. Each rib of the left valve bears a median and two lateral riblets, the surface of the entire valve being marked with closely set concentric laminae. On eroded shells the laminae are preserved only between the ribs or riblets so that each main rib has a striking trilobate cross section. Ribs of right valve without grooves or with riblets but faintly indicated. Submargin smooth. Main ribs not strongly impressed on the interior except near the margins of the valves; cardinal margin of auricles of right valve strongly bent down; auricles of left valve not bent; chondrophore broad and shallow, flanked by a pair of strong cardinal crura.

Measurements of figured specimens (pl. 28), as follows: Figures 4 and 5 (B. P. Bishop Mus., Geol. no. 1109), a right valve—length 24.2 mm., height 22.8 mm., depth 5.2 mm. Figures 6 and 7 (B. P. Bishop Mus., Geol. no. 1110), a left valve—length 22.6 mm., height 22.2 mm., depth 3.9 mm. Figure 8 (B. P. Bishop Mus., Geol. no. 1111), a right valve—length 25.5 mm.; height 24.4 mm., depth 6.0 mm. Figure 9 (U. S. N. M. Cat. no. 372672), a left valve—length 23.2 mm., height 21.8 mm., depth 5.0 mm.

Localities: Stations 319 and 320; questionable specimens from Stations 68 and 160. Types from Neogene ("Jüngeres Miocaen") of Java.

Martin states that the Java specimens show only 18 to 20 ribs. In the Fijian shells the right valve is slightly more inflated than the left, but in *P. opercularis,* the type species of *Aequipecten,* the reverse is true.

Pecten (Aequipecten) corymbiatus talicus Ladd, new subspecies (pl. 29, figs. 1, 2).

Shell small, orbicular, equilateral, solid; valves only moderately inflated and nearly equal, the right being slightly deeper. Anterior auricles larger than posterior and bearing 4 or 5 nodose riblets; similar number of riblets crossing posterior auricles, but considerably finer and more threadlike; byssal notch prominent and below it lies a ctenolium with three strong teeth. Marked by 18 to 20 prominent ribs, each of which is divided into three parts by a pair of well-defined longitudinal grooves; entire shell latticed by close-set lamellae, which are most prominent in the broad depressions separating the ribs. The holotype is an unusually well-preserved shell, and on parts of it small imbricating scales, or blisters, are superimposed upon the ribs, each rib having two series which meet centrally. Lateral areas free of ribs. Exterior sculpture weakly impressed on interior of shell except near margins, which are distinctly plicate; cardinal margins of auricles on right valve strongly bent downward, margins of auricles of left valve not bent; chondrophore wide and moderately deep; bounded by a pair of very thick cardinal crura; in the right valve these crura merge with the greatly elevated margin of the chondrophore.

Holotype (B. P. Bishop Mus., Geol. no. 1112), a right valve: length 11.1 mm., height 11.0 mm., depth 3.4 mm. Paratype (B. P. Bishop Mus., Geol. no. 1113), a left valve: length 10.9 mm., height 11.4 mm., depth 2.6 mm.

Localities: type from Station 298; a questionable specimen from Station 158.

The Fiji specimens are very closely related to the Recent species described as *Chlamys corymbiatus* by Hedley (Linnaean Soc. New South Wales, Proc., vol. 34, pt. 3, p. 423, pl. 36, figs. 1-4, 1909), from Queensland, Australia. Hedley's figures are excellent, and a specimen collected by Hedley and Gabriel in the type area (U. S. N. M. Cat. no. 348647) was available for study (pl. 29, fig. 3). Like the paratype of the new subspecies, here described, this specimen is worn and fails to show the epidermal scales. Hedley, however, has described them as follows:

Each rib is tripartite and decorated by small epidermal blisters which resolve into a median, lateral, and connecting series. The median and lateral blisters assume the form of imbricating scales, the intermediate ones are like berries.

The Fijian subspecies exhibits only two rows of scales, these completely covering the grooves in the ribs. The Fijian shell is likewise smaller, thinner, and somewhat less inflated, but these differences may be due largely to the immaturity of the type specimens.

Worn specimens of the new subspecies also resemble immature specimens of *P. exaratus* Martin but are thinner and are more nearly equilateral.

It is interesting to note that Hedley found *Chlamys corymbiatus* abundantly off the Hope Islands and in other parts of tropical Queensland in 6 to 15 fathoms of water.

Genus PECTEN sensu lato

Pecten mirificus Reeve (pl. 29, fig. 4).

Pecten mirificus Reeve, Conch. Icon., vol. 8, *Pecten,* pl. 26, fig. 104, 1855.

Shell small, subcircular, nearly equilateral, thin, hinge line exceeding half the length of the shell. Right valve flattened, bearing 9 ridges which vary considerably in size; 4 are much larger than the others and each carries several erect hollow spines; surface of entire valve marked by numerous exceedingly fine incremental lines. Auricles subequal, the anterior one with two low spinose ridges, one median in position, the other close to the hinge margin; posterior auricle with similar ribs, but much more weakly developed. Chondrophore broad and shallow, flanked by a pair of low cardinal crura.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1114), a right valve, are: length 24.5 mm., height 24.2 mm.

Locality, Station 158.

This species was originally described from Amboyna, in the Moluccas. No specimens from the type locality are available for comparison, but the Fijian fossil is identical with Recent shells from the Philippine Islands (U. S. Nat. Mus., Cat. no. 293105). The species does not seem to fit well into any of the described subgenera of *Pecten.* The simple hinge and the fact that the right valve is flattened differentiate it from *Pecten* sensu stricto.

The species is very closely related to an undescribed Recent species from Hawaii (U. S. Nat. Mus. Cat. nos. 173195 and 337548). The Hawaiian shell is smaller, exhibits coarser concentric sculpture, and has a somewhat different coloration.

The Philippine shells were collected in 32 fathoms, but both specimens are worn. A delicate and unworn specimen of the related Hawaiian species was dredged in 70 to 99 fathoms.

Pecten species **A.**

At Station 158 were collected two specimens of a moderately large species of *Pecten* which, though distinct from described species, are too worn and incomplete to be made type material. The species equals *P.* (*Chlamys*) *lamiensis* Ladd, new species, in size but shows marked differences in sculpture. It has only 19 or 20 ribs which in the ventral portions of the shell are very broad and flattened with a slight tendency to trilobation. They are crossed by numerous fine concentric lines. Locality and horizon, Station 158.

Pecten species **B** (pl. 29, fig. 5).

A single, incomplete valve of a small, flattened species of *Pecten*. It shows 33 rounded ribs, which are crossed by fine, concentric lines. Auricles large and bearing four prominent riblets. Distinguished by its sculpture from other described species. Catalogued as B. P. Bishop Mus., Geol. no. 1106.

Locality and horizon, Station 158.

A fragmentary specimen that superficially resembles the above-described form was collected from Station 41. It, however, is proportionately higher than *Pecten* species *b* and has only about 22 ribs. It probably is a distinct species.

Family SPONDYLIDAE

Genus PLICATULA Lamarck

Plicatula Lamarck, Système des animaux sans vertèbres, p. 132, 1801.

Type (by subsequent designation, Schmidt, 1818), *Spondylus plicatus* Linnaeus (*fide* Stewart, 1930). Recent, Pacific Ocean.

Plicatula species (pl. 29, fig. 6).

This genus is represented only by a single worn valve, which is probably immature and can not be determined specifically. Shell small, suborbicular, flattened; hinge with a narrow, elongate, median chondrophore, bordered by two shallow and equally elongate sockets which, in turn, are bordered by two prominent crenulated teeth converging at the beak. Adductor scar large, ovate, and slightly elevated. Surface of valve irregular, but showing traces of radial ribs and concentric lines. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1175) are: length 11 mm., height 12.6 mm., convexity 2.1 mm.

Locality, Station 160.

Family LIMIDAE

Genus LIMA Bruguière

Subgenus LIMA sensu stricto

Lima Bruguière, Tableau encyclopedique et methodique des trois regnes de la nature, . . . coquilles, . . . pt. 19 (Plates), pl. 206, 1797.

Type (by absolute tautonymy, Cuvier, 1798), *Ostrea lima* Linnaeus. Recent, Mediterranean Sea (*fide* Grant and Gale).

Lima (Lima) kavorica Ladd, new species (pl. 29, figs. 7, 8).

Shell small, subelliptical, obliquely inequilateral, moderately inflated, solid; margin somewhat straightened anteriorly, produced posteriorly with slight gape. Auricles small, the anterior one a trifle the larger. Posterior submargin a long, wide, slightly concave area sharply set off from remainder of valve; marked by ribs which are beaded by the crossing of concentric lamellae. Anterior submargin shorter and narrower; sculpture similar to posterior submargin but coarser. Valve crossed by 21 high, narrow ribs, which are separated by wider interspaces; ribs bearing a few short scales near the ventral border and crossed by numerous concentric lines of growth. Hinge line short with two irregular tubercles on each side; ligamental area broadly triangular with a wide, triangular, and very shallow ligamental pit; external ribbing faintly impressed on interior.

Holotype (B. P. Bishop Mus., Geol. no. 1121), a right valve: length (incomplete) 14.7 mm., height (incomplete) 18.7 mm., depth 3.6 mm., length of hinge 4.7 mm.

Type locality, Station 160.

L. mestayerae Marwick, from the Pliocene of New Zealand (New Zealand Inst., Trans. and Proc., vol. 55, p. 192, pl. 16, figs. 11, 12, 1924), is more straightened anteriorly, has a narrower and deeper ligament pit, and only a single tubercle on each side of the hinge line.

Subgenus LIMATULA Wood

Limatula Wood, Mag. Nat. Hist., new ser., vol. 3, p. 235, 1839.

Type (*fide* G. F. Harris), *Pecten subauriculatus* Montagu. Recent, seas of Europe.

Lima (Limatula) morioria? Marwick (pl. 29, fig. 9).

Limatula morioria Marwick, New Zealand Inst., Trans. and Proc., vol. 58, p. 461, fig. 35, 1928.

Shell medium sized, subrectangular, much higher than long, equilateral, rather strongly inflated, without noticeable gape. Sculpture consisting of about 30 sharp-crested ribs separated by wide interspaces and crossed by numerous concentric lines; ribbing most pronounced medially, becoming almost obsolete near the lateral margins. External sculpture only faintly impressed on the interior, but a pronounced median depression on external molds of the shell indicates that a median rib was present on the inside of the shell.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1122), an internal mold of one valve, are: length 7.4 mm., height 12.0 mm., depth 3.4 mm.

Locality, Station 158. Marwick's type material was collected in the Chatham Islands, in rocks believed to be upper Oligocene or lower Miocene (op. cit., pp. 434-435).

These Fijian specimens are smaller than the type specimen and apparently have more straightened sides. They may represent a new species, but since only three specimens were found, none of which show the hinge characters, it seems advisable to await better material before making an exact determination or designating types. The Fijian specimens are more rectangular than *L. subauriculata,* the type of the subgenus, their sculpture is coarser, and the ribs fewer in number. The genotype shows two prominent internal ribs located slightly to one side of the median line.

Superfamily MYTILACEA

Family MYTILIDAE

Genus LITHOPHAGA ("Bolten") Roeding

Lithophaga Roeding, Mus. Boltenianum, pt. 2, p. 156, 1798.

Type (by monotypy), *Lithophaga mytuloides* ("Bolten") Roeding = *Mytilus lithophagus* Gmelin (*fide* Grant and Gale).

Lithophaga species (pl. 29, figs. 10, 11).

Represented by internal molds of the shell and by flask-shaped molds of bore holes, none of the material being identifiable specifically. Mansfield's figures of a specimen (U. S. Nat. Mus. Cat. no. 352433) from Station 295 (Station 4370 of Mansfield) are reproduced on plate 29. At Station 160 a more perfect mold was obtained from a boulder of *Porites* in which it was associated with *Coralliophaga laseona* Ladd, new species. This mold (B. P. Bishop Mus., Geol. no. 1181) measures: length 32.9 mm., height 11.2 mm., convexity (both valves) 10.2 mm.

Localities, Stations 45, 160, and 295.

Associated with the molds of *Lithophaga* at Station 295 are subspherical molds of another type of borer. Some of them occur in coral heads and can not, therefore, be referred to *Teredo*. The material is too poorly preserved for identification but probably represents a pholad of some sort.

Order Telodesmacea

Superfamily Cypricardiacea

Family Pleurophoridae

Genus CORALLIOPHAGA Blainville

Coralliophaga Blainville, Man. Malacol., vol. 1, p. 560, 1825.

Type (by absolute tautonymy), *Chama coralliophaga* Gmelin. Recent, West Indies; also reported from Pliocene and Pliestocene of same area (*fide* Dall, 1903).

Coralliophaga laseona Ladd, new species (pl. 29, figs. 12-14; pl. 30, fig. 1).

Shell small, elongate-ovate, thin, moderately inflated; beaks inconspicuous, located close to anterior margin. Marked by numerous radiating striae, particularly in the ventral and posterior portions of the shell, and by irregularly spaced concentric lines, some of which become quite prominent near the margins. Hinge plate narrow, bearing in each valve two thin, platelike cardinals and a thin, posterior lateral. The cardinals tend to parallel the hinge line and the posterior one in the left valve is slightly bifid. Posterior muscle scar larger than anterior, pallial line slightly indented, internal margins smooth.

Right valve of holotype (B. P. Bishop Mus., Geol. no. 1182): length 26.2 mm., height 11.4 mm., thickness 4.7 mm. Left valve of paratype (B. P. Bishop Mus., Geol. no. 1150): length 14.4 mm., height 8.7 mm., thickness 2.6 mm. Topotype in U. S. National Museum (Cat. no. 372679).

Numerous specimens, including the types, were obtained from borings in a boulder of *Porites* in the conglomerate at Station 160.

Dall (Wagner Free Inst. Sci., Trans., vol. 3, pt. 6, p. 1499, 1903) has pointed out that *Coralliophaga* is found in borings "which appear in many cases to have been originally made by *Lithophaga* or other borers. In such cases *Coralliophaga* is apt to take the elongated subcylindric form of the precursor." These observations are borne out by the Fijian fossils, which were found associated with *Lithophaga* in a boulder of coral and which exhibit considerable variation in shape. The form of the holotype seems typical, but other specimens (particularly young shells such as the figured paratype) are proportionately much shorter, other shells are proportionately longer, others more inflated posteriorly. The sculpture, likewise, varies somewhat. In many specimens, as in the holotype, the radial sculpture is coarse, but in some others it is only faintly shown, owing to the development of strong growth lines.

The fossil species is not abruptly truncated posteriorly as is the genotype, *C. coralliophaga* Gmelin, and it lacks the erect concentric frills of that species. The new species is closely related to *C. rosea* (Gould), a Recent Fijian species, but the type specimen (U. S. Nat. Mus. Cat. no. 5920) is even more sharply truncated posteriorly than are specimens of the genotype. *C. rosea* is apparently a larger and heavier shell than *C. laseona* and shows much coarser concentric sculpture than any of the fossil specimens.

Superfamily CHAMACEA

Family CHAMIDAE

Genus CHAMA Linnaeus

Chama Linnaeus, Syst. Nat., 10th ed., p. 691, 1758.

Type (by subsequent designation, Children, 1823), *Chama lazarus* Linnaeus (*fide* Grant and Gale). Recent, Indo-Pacific.

Chama lazarus Linnaeus (pl. 30, figs. 2-4).

Chama lazarus Linnaeus, Syst. Nat., 10th ed., p. 691, 1758; 12th ed., p. 1139, 1767 (*fide* Sherborn, Manchester Mus., Pub. 25, 1899). Reeve, Conch. Iconi., vol. 4, *Chama*, pl. 2, fig. 4, *a-b*, 1847.

Chama damaecornis Lamarck, Animaux sans vertèbres découverts dans le bassin de Paris, vol. 6, pt. 1, p. 93, 1819.

Chama species Mansfield, Carnegie Inst. Washington, Pub. 344, p. 90, pl. 5, fig. 3, *a-b*, 1926.

The following description is based on the fossil material:

Shell medium to large, thick, rhomboidal in outline, higher than long, both valves inflated, the left slightly larger and deeper than the right. Dorsal margin nearly straight, broadly rounded posteriorly and ventrally, posteroventral and anteroventral margins straight or slightly concave; anterior margin more sharply rounded than posterior; beaks very prominent, especially the left one. Muscle scars large, pallial line simple, internal margin smooth. Sculpture of right valve consisting of wide concentric lamellae or frills which are produced at intervals into long wavy fronds. Radial sculpture obscure except on fronds, which are distinctly striated. Frills of left (attached) valve lower and more irregular than those of right valve.

The figured specimen (B. P. Bishop Mus., Geol. no. 1172) is an internal mold of both valves and an external mold of portions of both valves. Internal mold: length 38.4 mm., height 40.0 mm., convexity (right valve) 7.7 mm., convexity (left valve) 13.5 mm. A larger specimen, an internal mold in the Agassiz collection, measures: length 60.0 mm., height 64.1 mm., convexity (right valve) 20.4 mm., convexity (left valve) 22.6 mm.

Localities: figured specimen from Station 369; other specimens collected by Alexander Agassiz from the limestone immediately below the marl at the head of Walu Bay (Station 295 of Ladd); specimen described by Mansfield is from his Station 4370 (Station 295 of Ladd). The Recent *C. lazarus* is widely distributed in the Indo-Pacific region.

Like the shells of most attached mollusks, those of *Chama* exhibit great variation in general shape and proportion. An examination of a series of specimens of *C. lazarus* shows that the fossil specimens fall within the range of variation exhibited by the species, though they may show minor differences when compared with a given shell, or shells, from a particular locality. The outline of Recent Fijian specimens is variable but in none of them is it so strikingly rhomboidal as in the fossils. Yet Recent specimens from Mauritius have an outline identical with that of the fossils and have a convexity equal to that of the fossils, though the Recent Fijian specimens are shallower. The umbo of the right value in the fossil specimens is perhaps a little higher than in any of the Recent shells examined.

Chama species (pl. 30, figs. 5, 6).

Three small and obviously immature right valves of a species of *Chama* in the collections from Station 160 are probably distinct from *C. lazarus* Linnaeus and may be briefly described as follows:

Shell small, thick, suborbicular, nearly flat, umbo low and slightly twisted. Hinge consisting of an elongate, toothlike ridge paralleling the shell margin and divided into two parts by a longitudinal groove whose outer wall bears small denticles; an elongate pit is present below the anterior end of the toothlike ridge. Sculpture consisting of concentric lamellae produced at intervals into short curved tubular spines. Inner margin crenulate. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no 1173) are: length 12.8 mm., height 11.9 mm., convexity 3.9 mm.

Superfamily CARDIACEA

Family CARDIIDAE

Genus CARDIUM sensu lato

Cardium Linnaeus, Syst. Nat., 10th ed., p. 678, 1758.

Type (by subsequent designation, Children, 1823), *Cardium costatum* Linnaeus (*fide* Stewart, 1930). Recent, Indo-Pacific.

Cardium rewaense Ladd, new species (pl. 30, figs. 7, 8).

Shell very small, orbicular, equilateral, length equaling height, moderately inflated, beaks small and inconspicuous. Hinge plate curved, that of the left valve having two strong cardinal teeth, the anterior the larger, and an anterior and a posterior lateral, which are grooved ventrally. Hinge of right valve consisting of a heavy posterior cardinal, a weak anterior cardinal, and an anterior and a posterior lateral. Exterior of the valves glossy and marked by 33 or 34 strong flat-topped ribs separated by narrower, channeled interspaces. Both ribs and interspaces crossed by numerous fine regularly spaced concentric lines which are gently curved dorsally on the surface of each rib. External sculpture not impressed on the interior; anterior muscle scars depressed; internal margins crenulate.

Measurements of the holotype (B. P. Bishop Mus., Geol. no. 1183), a left valve, are: length 9.4 mm., height 9.5 mm., convexity 3.7 mm. The paratype (B. P. Bishop Mus., Geol. no. 1184), a right valve, measures: length 9.7 mm., height (estimated) 9.8 mm., convexity 3.6 mm. Topotype in U. S. National Museum (Cat. no 372625).

Type locality, Station 160.

This species is particularly characterized by its small size, rounded outline, and unusual sculpture, the flat-topped ribs being marked only by fine concentric lines. The 10 specimens collected at Station 160 are as small as the types, which seems to indicate that all are adult shells.

Cardium species **A** (pl. 30, fig. 9).

Distinct from the other species of *Cardium* but preserved only as internal molds which can not be identified specifically. Mansfield (Carnegie Inst. Washington, Pub. 344, p. 90, 1926) commented as follows:

The shell was large and elongate-ovate; its anterior side rounded, posterior side steeply sloping and flattening out marginally; ribs more than 25.

A single valve from Station 1/131 [Station 295 of Ladd] (U. S. N. M. Cat. No. 352418) measures: length, 67 mm.; height, 92 mm.; thickness, 26 mm.

The specimen from Ladd Station 295 is similar to that described by Mansfield and is from the same horizon and locality, in the Suva formation at Tamavua Quarry, on Walu Bay.

The species is unusual in that the pronounced ribbing of the shell is strongly impressed on the interior.

Subgenus **TRACHYCARDIUM** Mörch

Trachycardium Mörch, Cat. Conchyl. D. A. d'Aguirra et Gadea, Comes de Yoldi, pt. 2, p. 34, 1853.

Type (by subsequent designation, von Martens, 1869), *Cardium isocardia* Linnaeus. Recent, West Indies (*fide* Stewart, 1930).

Cardium (Trachycardium) orbita Broderip and Sowerby, new subspecies? (pl. 30, figs. 10, 11).

Shell medium to large, subelliptical in outline, height exceeding length, nearly equilateral, moderately inflated, umbos low, beaks inconspicuous. Hinge plate of right valve with two cardinal teeth, the posterior much the larger, and two anterior and posterior laterals. Hinge of left valve with two cardinals, the anterior much larger, and an anterior and posterior lateral, both the laterals being faintly grooved below. Sculpture consisting of 35 narrow, strongly arched ribs separated by deeply excavated interspaces of about equal width. Over the middle portion of the valve the ribs bear small, close-set oblique scales on their sides, some of them projecting upward above the crest of the rib; anteriorly the ribs are beaded by thick scales; posteriorly the ribs are broader, lower, and each bears a series of elevated oblique scales on its posterior side. Internally, the anterior laterals rise from rather sharply elevated platforms, which are represented by abrupt depressions on internal molds of the valves. External ribbing faintly impressed on the interior; margins crenulated.

Measurements of the figured mold (B. P. Bishop Mus., Geol. no. 1168) are: length 55.3 mm., height 66.9 mm., diameter (right valve only) 18.2 mm.

Localities, Stations 160 and 294.

Ostergaard (B. P. Bishop Mus., Bull. 51, p. 8, 1928) obtained a few specimens of *C. orbita* from elevated limestones on Oahu, Hawaii. The limestones are believed to be no older than Pleistocene.

The Recent *C. orbita* is widely distributed in the Pacific and has been collected in Fiji.

Only one of the three fossil specimens preserves the original shell and the details of its sculpture. This specimen has only 35 ribs. Most Recent shells have 42, but the number actually varies between 39 and 44. If additional fossils are collected and consistently show a low rib count, a subspecific name might be justified. At the present time, however, it seems best to refer the fossils to the Recent species because in all other features they fall within the range of variation exhibited by the Recent shells.

Subgenus FRAGUM ("Bolten") Roeding

Fragum Roeding, Mus. Boltenianum, pt. 2, p. 189, 1798.

Type (by absolute tautonymy), *Cardium fragum* Linnaeus (*fide* Grant and Gale). Recent, Indo-Pacific.

Cardium (Fragum?) species.

Represented by a single small imperfectly preserved left valve, which is subrhomboidal in outline and strongly inflated. Anterior margin broadly rounded, posterior margin and base nearly straight. Posterior ridge subangular, the area behind it being very gently convex. Sculpture consisting of numerous flat-topped ribs. The single specimen (B. P. Bishop Mus., Geol. no. 1176) measures: length 7.3 mm., height 9.3 mm., convexity 4.0 mm.

Locality, Station 320.

Subgenus LAEVICARDIUM Swainson

Laevicardium Swainson, Treatise on Malacol., p. 373, 1840.

Type (by subsequent designation, Bucquoy, Dautzenberg, and Dollfus, 1887), *Cardium europaeum* Wood (= *C. norwegicum* Spengler). Recent, west coast of Europe and Mediterranean (*fide* Woodring, 1925).

Cardium (Laevicardium) species **A** (pl. 31, fig. 1).

Laevicardium species Mansfield, Carnegie Inst. Washington, Pub. 344, p. 91, pl. 6, fig. 1, 1926.

Poorly preserved molds of a species of *Laevicardium* were present in the collections studied by Mansfield. He noted that the shell was high, subovate, inequilateral; one end oblique, produced, and nearly straight; the other end rounded; the sculpture consisting of many narrow, close-set radials. The shell is produced posteriorly. Measurements of Mansfield's figured specimen (U. S. Nat. Mus., Cat. no. 352419; fig. 1, pl. 31) are: length 35 mm., height 55 mm., thickness (one valve) 15 mm.

Localities, Stations 295 and 369. A small specimen from Station 320 may also belong to this species.

Cardium (Laevicardium) species B.

Shell large, broadly ovate, slightly higher than wide, nearly equilateral, moderately inflated, beaks prominent. Lateral teeth large, curved outward and upward. Sculpture consisting of numerous fine radiating ribs and close-set incremental lines. Internal margin finely crenulated.

The species is represented only by somewhat incomplete internal molds. Measurements of a typical specimen from Station 298 are: length 50.8 mm., height 57.7 mm., depth 19.0 mm. The specimens from Station 295 are somewhat larger.

Localities: Station 298; specimens which probably represent the same species, Stations 68 and 295.

This species differs from *C.* (*Laevicardium*) species *a* in being proportionately much longer.

Subfamily Tridacnacea

Family Tridacnidae

Genus TRIDACNA Bruguière

Tridacna Bruguière, Tableau encyclopedique et methodique des trois regnes de la nature, . . . coquilles, . . . pt. 19 (Plates), pl. 235, 1797.

Type (by subsequent designation, Children, 1823), *Chama gigas* Linnaeus. Recent, Indo-Pacific seas. Also reported from the lower and upper Miocene of Java and the Quaternary of Celebes (*fide* Van der Vlerk).

Tridacna mbalavuana Ladd, new species (pl. 31, figs. 2, 3).

Shell small, elongate, moderately inflated, thick; greatly produced posteriorly, the beak located anterior to the midpoint. Byssal gape moderate, posterior laterals elongated. Marked by seven large rounded ribs or folds, which are separated by narrower interspaces; ribs becoming increasingly broad posteriorly; secondary riblets well developed in the spaces between the folds, 3 or 4 riblets occupying each interspace; in the younger portions of the shell traces of these riblets are also present on the folds; projecting scales and heavy concentric lines of growth well developed near the ventral and lateral margins.

Measurements of the holotype (B. P. Bishop Mus., Geol. no. 1124), a nearly complete right valve, are: length 53.1 mm., height 27.5 mm., depth 13.8 mm.

Type locality, Station 160.

The new Fijian species appears to differ from all described species in that the valves are greatly elongated posteriorly. It is possible that the holotype is somewhat immature, but two other specimens from the same locality are no larger.

Genus HIPPOPUS Lamarck

Hippopus Lamarck, Soc. Hist. Nat. Paris, Mem., p. 86, 1799.

Type (by monotypy), *Chama hippopus* Linnaeus. Recent, Indo-Pacific seas.

Hippopus hippopus Linnaeus.

A large worn shell of this well-known Recent species was found embedded in the lithified beach sand at Ravuka (Station 157). It is shorter than typical examples of *H. hippopus* and its beak is more highly curved, but it seems to fall within the range of variation exhibited by the Recent shells. Measurements of the single specimen, a left valve, are: length 206 mm., height 188 mm., thickness 94 mm.

Hippopus is a monotypic genus that is widely distributed in eastern seas. The Fijian occurrence is apparently the first fossil record, but it is not particularly significant as the deposit is certainly no older than late Pleistocene.

Superfamily ISOCARDIACEA

Family ISOCARDIIDAE

Genus **MEIOCARDIA** H. and A. Adams

Meiocardia Adams, Genera of Recent Mollusca, vol. 2, p. 461, 1858.

Type (by subsequent designation, Dall, 1900), *Chama moltkiana* Chemnitz. Recent, southwest Pacific.

Meiocardia species **A** (pl. 31, figs. 4, 5).

This is the species which Mansfield identified from Walu Bay and briefly commented on (Carnegie Inst. Washington, Pub. 344, p. 91, 1926), as follows:

> This questionable genus . . . is represented by an internal cast [mold] of the umbonal part of the original shell. The cast [mold] is nearly flat over its middle area, strongly ridged from the beak distally at the dorsal-posterior angle, and concave behind this ridge. The sculpture, as faintly indicated, consisted of concentric markings.

Measurements of the above specimen (U. S. Nat. Mus., Cat. no. 352435; figs. 4, 5, pl. 31), a right valve, are: length 24.4 mm., height 21.9 mm., thickness 7.7 mm.

Locality, Station 295 (Station 4370 of Mansfield).

Meiocardia species **B** (pl. 31, figs. 6, 7).

Shell small, subtriangular in outline, very inequilateral, slightly longer than high, inflated. Beak located close to the anterior margin, involuted; shell bearing a sharply keeled ridge which leads from the beak to the posteroventral margin, the area behind this ridge being notably concave; sculpture not well preserved, but apparently consists of fairly strong concentric ridges, which are much less prominent in the concave area behind the ridge. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1136), a left valve: length 10.0 mm., height 9.4 mm., thickness 4.4 mm.

Locality, Station 160.

The species is smaller than *Meiocardia* species *a,* is more highly arched, more nearly triangular in outline, and less flattened medially.

Superfamily VENERACEA

Family VENERIDAE

Genus ANTIGONA sensu lato

Antigona Schumacher, Essai d'un nouveau système des habitations des vers testacés, p. 154, 1817.

Type (by monotypy), *Antigona lamellaris* Schumacher. Recent, Indo-Pacific (*fide* Woodring, 1925).

Antigona species (pl. 32, fig. 4).

Antigona species *b* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 91, pl. 6, fig. 5, 1926.

Original description:

This species is represented by a poorly preserved single right valve, which is broken away over the middle of the disk and at the margins. The shell is of medium size and suborbicular in form, strongly arched over the posterior angle and slightly depressed below, near the dorsal and posterior margins. Anterior end rounded over the shoulder and side. The sculpture consists of erect, concentric lamellae and rather coarse radials.

Figured specimen (U. S. Nat. Mus., Cat. no. 352422) is from Mansfield Station 1/129 (either Station 295 or 297 of Ladd). It measures: length 62 mm., height 54 mm., thickness 19 mm. A fragment from Mansfield Station 1/130 (Ladd, Station 297) was tentatively referred by him to this species.

Mansfield pointed out that the species belongs to the group of *"Venus" listeri* Gray, a species which, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 280, 1921), has been reported from the lower Miocene of Java, the Pliocene of Timor and New Guinea, and the Quaternary of Billiton.

Subgenus DOSINA Gray

Dosina Gray, Analyst, vol. 8, p. 308, 1838.

Type (by subsequent designation, Palmer, 1927), *Venus reticulata* Linnaeus. Recent, Indo-Pacific.

Antigona (Dosina) puerpera waluensis Ladd, new subspecies (pl. 32, figs. 5-7).

Antigona species *a* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 91, pl. 6, fig. 4, 1926.

Shell large, suborbicular, inequilateral, moderately convex. Umbo inconspicuous and placed one fourth of the length from the anterior end; lunule fairly large and bounded by a deep groove; escutcheon flattened and depressed; dorsal and posterior margins straightened, the angle between the two being slightly obtuse; posteroventral and anterior margins broadly and uniformly rounded. Marked by numerous radials, which are narrower than the interspaces, especially in the anterior and posterior regions;

Genus IRUS Oken

Irus Oken, Lehrb. Naturgesch. (Zool.), pt. 3, vol. 1, p. 230, 1815. Type (by absolute tautonomy), *Donax irus* Linnaeus (*fide* Stewart, 1930). Recent, seas of Europe.

Irus mamaricus Ladd, new species (pl. 32, figs. 8, 9).

Shell small, elongate, subrhomboidal, slightly inflated, moderately thick. Dorsal, ventral, and anterior margins straightened, but posterior margin broadly rounded. Beak small and located close to the anterior margin; lunule absent, escutcheon (on left valve) elongate, flattened, and with comparatively inconspicuous sculpture. Sculpture consisting of numerous slightly wavy radiating riblets, which are broad and flat-topped over the disk, but narrower and more rounded near the extremities; ribs crossed by concentric lines produced at intervals into prominent wavy laminae, which are broadest in the posteroventral region, where they project beyond the margin of the valve. The holotype, a left valve, shows three cardinal teeth, all slightly broken; also an elongate ligamental depression posterior to the beak. Pallial sinus ascending, broadly rounded; internal margins smooth.

Holotype (B. P. Bishop Mus., Geol. no. 1135), a left valve, measures: length 7.8 mm., height 4.6 mm., thickness 1.6 mm.

Type locality, Station 160.

Irus mamaricus is very closely related to a Recent species from Fiji, an unidentified specimen of which is in the United States National Museum (Cat. No. 333629). The dorsal margin of the fossil species is proportionately shorter and straighter and the beaks are more nearly terminal than in the Recent form. The Recent species is pure white in color except for the beaks, which are rose-colored.

Superfamily TELLINACEA

Family TELLINIDAE

Genus TELLINA sensu lato

Tellina Linnaeus, Syst. Nat., 10th ed., p. 674, 1758.

Type (by subsequent designation, Children, 1823), *Tellina radiata* Linnaeus (*fide* Stewart, 1930). Recent, West Indies.

Tellina suvaensis Mansfield (pl. 32, figs. 10, 11; pl. 33, figs. 1, 2).

Tellina suvaënsis Mansfield, Carnegie Inst. Washington, Pub. 344, p. 92, pl. 6, figs. 6, *a*, *b*, 1926.

Original description:

The shell is large, subovate, nearly equilateral, and posteriorly laterally flexuous. Right valve inflated at anterior end and slopes at low angle to margins; posterior end with two narrow, prominent, diverging radial ridges separated by a shallow sulcus; the anterior one more prominent and forms the ridge of the posterior shoulder; marginal posterior area steeply sloping. Left valve less inflated anteriorly than right, medially inflated over region opposite to depression on right valve. Sculpture consists of microscopic radials and many close-set, erect, concentric lamellae.

Mansfield's type (U. S. N. M. Cat. No. 352423) consists of an external mold of the right valve and an internal mold of both valves of the same specimen. Bits of the original shell are preserved on both molds. The measurements of the type are as follows: External mold of right valve, length 48 mm., height 32 mm.; internal mold, length 43 mm., height 33 mm.; convexity (both valves) 11 mm.

In describing *T. suvaënsis,* Mansfield pointed out its close resemblance to *T. plicata* Valenciennes, described and figured by Reeve (Conch. Icon., vol. 17, pl. 26, fig. 142, 1867). Mansfield noted that the radials on the posterior side of *T. suvaënsis* were less diverging and separated by a shallower sulcus than those on *T. plicata* Valenciennes.

I collected two additional specimens from the type locality. One of these topotypes is an internal mold of the right valve and is not complete. The other, a complete individual, preserving most of the original shell substance (B. P. Bishop Mus., Geol. No. 1134), measures: length, 53.5 mm., height, 42.7 mm., thickness, 13.5 mm. These specimens agree with the type in all important features. The writer collected a single left valve of a species that lives at the present time along the northeast coast of Vitilevu. This specimen appears to be identical with *T. suvaënsis* Mansfield and, like the fossil specimen, is very closely related to *T. plicata* Valenciennes.

All of the fossil specimens, including the type, were collected from Station 295. A Recent shell, not alive when taken, was found on the tidal flat east of Ellington. (See pl. 33, fig. 2.)

It should be pointed out that the habitat of *T. plicata* Valenciennes, as described by Reeve (op. cit., pl. 26), is unknown; no examples of the species are present in the collections of the U. S. National Museum. Martin (Die Tertiärschichten auf Java, Leiden, p. 95, tab. 15, fig. 15, 1880) figured a poorly preserved specimen of *T. plicata* Valenciennes from Java. He gave its range as "Jungmiozän (nur Tjilanangsch.); rezent" (Unsere Palaeazoologische Kenntnis von Java: Geol. Reichs Mus. Leiden, Samml., Beilage-Bd. für 1919, p. 68).

In all the fossil specimens and in the Recent Fijian specimen the radials on the posterior side are less diverging and are separated by a shallower sinus than are those shown in Reeve's figure of *T. plicata.* The number of laminae seems a variable character, those on the type of *T. suvaënsis* being more numerous than on the other fossil specimens or on the Recent Fijian specimen.

Possibly *T. suvaënsis* Mansfield should be identified with *T. plicata* Valenciennes, but until actual specimens of the latter are available for comparison the writer prefers to retain the name *T. suvaënsis* for both the fossil and the Recent shells from Vitilevu.

Family DONACIDAE

Genus DONAX Linnaeus

Donax Linnaeus, Syst. Nat., 10th ed., p. 682, 1758.

Type (by subsequent designation, Schumacher, 1817), *Donax rugosa* Linnaeus (*fide* Stewart, 1930). Recent, West Indies.

Donax species (pl 33, fig. 3).

A single poorly preserved right valve is the only representative of this genus in the collections from Vitilevu. The shell is small and triangular with the anterior side much longer than the posterior; posterior end abruptly truncated, the truncated portion slightly concave and separated from the remainder of the shell by a sharp ridge. The small portions of the original shell which are preserved show concentric laminae and obscure radials. Characters of the hinge inaccessible. Length 12.2 mm., height 9.2 mm., depth 3.6 mm. Cataloged as B. P. Bishop Mus., Geol. no. 1230.

Locality, Station 362.

Family GARIDAE

Genus ASAPHIS Modeer

Asaphis Modeer, K. Svenaka Vet.-Akad., Nya Handl., vol. 14, pp. 176, 182, 1793.

Type (by monotypy), *Venus deflorata* Linnaeus. Recent, West Indies (*fide* Stewart, 1930).

Asaphis species (pl. 33, fig. 4).

A species representing this genus was identified by Mansfield (Carnegie Inst. Washington, Pub. 344, p. 92, 1926) from the limestones of Walu Bay and described as follows:

> The species is represented by a single left valve which is somewhat crushed and corroded. The shell is moderately high, inequilateral, and slightly medially inflated. Anterior end is rounded at the shoulder; posterior end more angled and elongate. Sculpture consists of about 100 fine, close-set radials; the ornamentation on the anterior and posterior slopes indicates a more scabrous and cancellated structure. The specimen [U. S. Nat. Mus., Cat. no. 352424] . . . measures: length 52 mm., height 33 mm., thickness 15 mm.

Collected at Mansfield Station 1/129, which may be either Station 295 or 297 of Ladd.

As Mansfield has pointed out, the species is similar to *A. deflorata* (Linnaeus), the type of the genus.

Superfamily SOLENACEA

Family SOLENIDAE

Genus **SOLECURTUS** Blainville

Solecurtus Blainville, Dict. des Sci. Nat., vol. 32, p. 351, 1824.

Type (by subsequent designation, Anton, 1839), *Solen strigilatus* Linnaeus. Recent, Mediterranean Sea (*fide* Stewart, 1930).

Solecurtus species (pl. 33, fig. 5).

This genus is represented by a single poorly preserved mold of a right valve. Shell medium-sized and subrectangular in outline, the length more than twice the height; dorsal and ventral margins straightened and subparallel; ends broadly rounded; beak located about two fifths of the length from the anterior end; valve gapes at both ends, the posterior gape somewhat the greater. Hinge characters and other features of the interior are imperfectly preserved. The single valve measures: length 49.3 mm., height 22.7 mm., convexity 5.0 mm. In general shape and proportion this species is not unlike the genotype, but specific characterization is lacking.

Locality, Head of Walu Bay near Suva (probably Station 295 of Ladd). Collected by Alexander Agassiz.

Superfamily MACTRACEA

Family MACTRIDAE

Subfamily MACTRINAE

Genus **MACTRA** Linnaeus

Mactra Linnaeus, Syst. Nat., 12th ed., p. 1125, 1767 (*fide* Sherborn).

Key to Vitilevu Species

Shell subelliptical, not strongly inflated
- Beak subcentral........................ **M. (Mactrotoma) tholoensis**
- Beak distinctly anterior........................ **M. (Mactrotoma?) vitiensis**

Shell subtrigonal, strongly inflated........................ **M. (Coelomactra) nasongoensis**

Subgenus **MACTROTOMA** Dall

Mactroma Dall, Nautilus, vol. 8, p. 26, 1894.

Type (by original designation), *Mactra fragilis* Gmelin. Recent, east coast of the Americas.

Mactra (Mactrotoma) tholoensis Ladd, new species (pl. 33, figs. 6-8).

Shell medium sized, thin, subelliptical, moderately inflated; posterior end somewhat more extended and more abruptly rounded than anterior. Umbo low; beak inconspicuous and located slightly anterior to the median line. Shell thin and marked by numerous fine incremental lines. Hinge of the right valve consisting of two cardinal teeth, which lie anterior to the chondrophore and meet at an angle near the dorsal margin, and two anterior and two posterior lateral laminae; the callus of the ligament lies dorsal to the chondrophore.

Holotype (B. P. Bishop Mus., Geol. no. 1115), a right valve, measures: length 36.9 mm., height 26.9 mm., convexity 7.0 mm. Paratype *a* (B. P. Bishop Mus., Geol. no. 1116) is an incomplete mold of the interior of a right valve. Paratype *b* (B. P. Bishop Mus., Geol. no. 1117), an internal mold of a left valve, is practically complete. It measures: length 18.7 mm., height 14.4 mm., convexity 3.3 mm. Topotype in U. S. National Museum (Cat. no. 372677).

Type locality, Station 362. This is the locality from which Matley (Geol. Mag., vol. 64, pp. 74-75, 1927) obtained the specimens which were described by Davies as *Nodularia vitiensis*. Of the 7 specimens which Matley obtained, 3, Davies writes (Oct. 11, 1929), may be referred to *M. tholoensis* as here described. These three specimens are deposited in the British Museum and have the following catalog numbers: B. M. L44215 (two of the three specimens bearing this number) and B. M. L44213. The specific name *vitiensis* is retained for the other four specimens which, however, are placed in the genus *Mactra* (this with the approval of Dr. Davies, who has compared my figures and descriptions with his material). The species also occurs at Station 165.

The hinge plate of this species shows that it is undoubtedly mactroid, but there may be some question as to its reference to the genus *Mactra*; it may be a *Spisula*. As defined by Dall (Wagner Free Inst. Sci., Trans., vol. 3, pt. 4, pp. 862-891, 1895), these two genera differ in two important features: 1, in *Mactra* the ligament is set off from the chondrophore by a shelly lamina, whereas in *Spisula* this lamina is absent; 2, in *Mactra* the opposed surfaces of the laterals are smooth or finely granular, whereas in *Spisula* they are transversely grooved. The single Fijian specimen which shows the hinge plate is a mold of the interior of the right valve. At the base of the protuberance representing the filling of the chondrophore a very faint groove is present. This groove is believed to represent a very low shelly lamina which separated the chondrophore from the ligament. In some Recent species of *Mactra* (for example, *M. californica* Conrad) this lamina is equally inconspicuous. Furthermore, the opposed faces of the grooves, formerly occupied by the lateral laminae, in the Fijian specimen show no trace of transverse markings. It appears almost certain, therefore, that the species is a *Mactra*. Because of the characters of the hinge plate it is referred tentatively to the subgenus *Mactrotoma,* though the shell is not notably elongate, nor are the dorsal areas bordered by an impressed fasciole.

M. tholoensis is very closely related to *M. vitiensis* (Davies) and somewhat similar to *M. depressa* Spengler, a Recent species from Tasmania, and *M. californica* Conrad, from the west coast of North America.

Mactra (Mactrotoma?) vitiensis (Davies) (pl. 33, fig. 9).

Nodularia vitiensis Davies (Matley and Davies). Some observations on the geology of Vitilevu: Geol. Mag., vol. 64, pp. 72-75, fig. 3, 1927. (See also Davies, A. Morley, Fossils from Vitilevu: Geol. Mag., vol. 67, p. 48, 1930.)

Original description:

Oval, rather compressed, height about two thirds the length; umbo low, placed two fifths of the length from the anterior end; siphonal ridge present but obscure; interior marked by growth lines, but neither beak sculpture nor muscle scars clearly recognizable. Hinge teeth: in the right valve, a short, slightly curved dental lamella extending from the umbo obliquely forward and downward, and a long straight lamella extending back, the angle of divergence of the lamellae being about 145 degrees (in the left valve, two short anterior lamella placed *en échelon* and diverging at an acute angle, and one long posterior lamella).

Holotype: British Museum L44211. Internal cast of right valve: length 14 mm., height 9.5 mm., anterior lamella 3 mm., posterior lamella 7 mm.

Paratype on which the diagnosis of left valve characters is based: British Museum L44212. Internal cast of left valve: length 18 mm., height 12.5 mm.

This species is very closely related to *M. tholoensis,* new species, and occurs with it at Station 362. The two differ chiefly in that *M. vitiensis* is proportionately longer, is less inflated, and has its beak closer to the anterior end. These differences are not fundamental, but they appear to be persistent and the two species can be separated without difficulty. Likewise, most of the specimens of *M. tholoensis* are larger than the types of *M. vitiensis.*

Matley collected the types from an exposure above Nasongo, on the trail to Ngelewai, at an elevation of about 1,140 feet. Mr. F. R. Charlton, who accompanied Matley in the field, told me that the locality lay very close to Nasongo, "along the trail just after losing sight of the town." I found an exposure at this place (Station 362) in the bed of a tiny creek that crosses the trail. The outcrop extends upstream for an undetermined distance. The base of the exposure is at the level of the trail, 1,110 feet, and beds outcrop upstream to the 1,130-foot level and beyond (readings by aneroid, uncorrected). This rock is similar to that described by Matley, but where fresh it is slaty gray in color and the fossils retain their original shell substance. It may not be the exact horizon and locality visited by Matley, but it is very close to it, in any event.

Associated with the two species of *Mactra* is an *Arca* (quite possibly the "small, rather inflated, trigonal shell" mentioned by Davies) and a *Donax* together with fragmentary plant remains such as occur widely in the marine tuffs and marls of the Suva formation.

Subgenus COELOMACTRA Dall

Coelomactra Dall, Wagner Free Inst. Sci., Trans., vol. 3, pt. 4, p. 875, 1895.

Type (by original designation), *Mactra violacea* Gmelin. Recent, Indo-Pacific.

Mactra (Coelomactra) nasongoensis Ladd, new species (pl. 33, fig. 10; pl. 34, figs. 1, 2).

Shell small, subequilateral, subtriangular, rather strongly inflated, thin; beaks strongly incurved, located slightly anterior to the median line. Surface marked by fine incremental lines which merge abruptly into prominent grooves on the dorsal areas. Hinge of right valve consisting of 2 cardinals plus 2 anterior and 2 posterior laterals. The anterior cardinal is a broad, elongate, rectangular plate paralleling the shell margin; the posterior cardinal is shorter and is set almost at right angles to the other; the cardinals do not coalesce above; laterals long, thin, platelike. A deep triangular pit, the chondrophore, lies immediately behind the posterior cardinal; it is roofed over dorsally and separated from the scar of the ligament above by shelly matter. In the left valve two platy cardinals, coalescing above, form a right angle, the anterior arm being the larger, parallelling the shell margin and merging at its base with the anterior lateral; the single posterior lateral is wide and thin. Chondrophore and ligament scar as in right valve. Anterior sinuses well developed in both valves. Internal margins smooth.

The margins of the types are incomplete, but their measurements are given below. Holotype (B. P. Bishop Mus., Geol. no. 1179), a right valve: length 23.7 mm., height 21.7 mm., depth 10.2 mm. Paratype (B. P. Bishop Mus., Geol. no. 1180), a left valve: length 20.8 mm., height 20.5 mm., depth 8.3 mm.

Locality, Station 59.

The new Fijian species is considerably smaller than *M.* (*Coelomactra*) *violacea* Gmelin, the genotype, and there are many differences of specific rank. *M. nasongoensis* is very closely related to *M. bonneaui* Bernardi, a Recent Japanese species, which, however, is subcircular in outline and only moderately inflated. The new form is similar to *M. luzonica* Deshayes, a Recent species from the Philippine Islands, but that species is much less inflated and in its left valve the anterior cardinal is clearly separated from the anterior lateral by the anterior sinus. A degree of inflation fully equal to that of *M. nasongoensis* is encountered in *M. turgida* Gmelin, a much larger Recent species from Ceylon. *M. turgida,* however, shows obscure radial striations not observable on the fossils, and there are minor differences in the dentition which indicate that the two are specifically distinct. The right anterior cardinal in *M. turgida,* for example, is much shorter than that in *M. nasongoensis,* but the left anterior cardinal tends to merge with the anterior lateral much as in the fossil species. The two species are probably closely related.

Subfamily Lutrariinae

Genus LUTRARIA Lamarck

Lutraria Lamarck, Soc. Hist. Nat. Paris, Mem., p. 85, 1799.

Subgenus PSAMMOPHILA Leach

Psammophila Leach, Synop. Mollusca Great Britain, p. 274, 1852.

Type (by monotypy), *Lutraria solenoides* Lamarck [= *Lutraria oblonga* (Gmelin)]. Recent, seas of Europe.

Lutraria (Psammophila) species (pl. 34, fig. 3).

Represented by a single poorly preserved internal mold of a left valve. The shell was medium-sized, elongate-ovate, compressed, length nearly twice the height; inequilateral, the beak being located one third of the length from the anterior end. The dorsal margin slopes gently from beak to the anterior end, which is rather sharply rounded; ventral margin nearly straight; posterior end somewhat recurved dorsally, broadly rounded and noticeably gaping. Hinge plate consisting of a large obliquely triangular chondrophore, in front of which lies an A-shaped cardinal tooth and a short anterior lateral; posterior lateral apparently absent. Muscle scars and pallial line not preserved, the mold being marked only by a few indistinct concentric depressions near its margin. Measurements of the single specimen (B. P. Bishop Mus., Geol. no. 1143) are: length (almost complete) 68.0 mm., height 38.0 mm., thickness 8.1 mm.

Locality, Station 295.

The Fijian form is shorter, more compressed, and more sharply rounded anteriorly than the genotype. It likewise appears shorter than *L. philippinarum* Deshayes, a Recent species from the Sulu Sea. In *L. philippinarum* a small but distinct posterior lateral is present.

Family Teredinidae

Genus KUPHUS Guettard

Kuphus Guettard, Memoires sur differentes parties des sciences et arts, vol. 3, p. 139, 1770 (*fide* Sherborn).

Type (by subsequent designation, L. R. Cox, 1927), *Serpula polythalamia* Linnaeus. Recent, East Indies, Red Sea, East Africa, and Madagascar.

The genus *Kuphus* includes *Teredo*-like mollusks which bore in sand or mud. According to Cox (Paleont. Zanzibar Protect., p. 62, 1927), the valves of the adult animal are unknown, but the siphonal tubes are widely distributed in Recent seas and in the Tertiary rocks. Those from Fiji appear to differ from the material heretofore described, but the differences are of doubtful significance and, for the present, it seems best to withhold a specific name.

Kuphus species (pl. 34, figs. 4-7).

Tubes small, circular in section, generally straight, but some irregularly curved or twisted, gradually increasing in size anteriorly from a pointed posterior (upper) extremity to a diameter of about 15 mm. Walls composed of laminated calcium carbonate and showing considerable variation in thickness in any given cross section. Exterior smooth except for shallow constrictions at irregular intervals; interior surface smooth. The pointed posterior extremity is curved like a small horn and exhibits two minute circular openings, one at the apex, the other to one side. These are the siphonal openings and when traced inward are seen to become elliptical in section, each being encased in an inner wall which is distinct from the wall of the main tube. A short distance from the apex the inner walls disappear and the two openings coalesce to fill the entire tube.

The specimen reproduced as figure 7, plate 34 (B. P. Bishop Mus., Geol. no. 1190), shows the interior of the apex; figures 5 and 6, plate 34, show the posterior portion of another tube (B. P. Bishop Mus., Geol. no. 1191), and the specimen is unusual in that one of the siphonal openings has migrated some distance away from the apex, apparently by absorbing the shell and redepositing a series of 9 curved plates to fill the gap thus created. Figure 4 is a twisted section of a large tube (B. P. Bishop Mus., Geol. no. 1192) whose maximum diameter is 17 mm.

Locality, Station 374. Collected by the Hon. H. Marks.

The genotype is a very large shell with a rough, irregularly annulated outer surface. Its maximum diameter sometimes exceeds 50 mm. and its length reaches nearly a meter. Cox (Paleont. Zanzibar Protect., pp. 62-64, 1927) refers all the Tertiary tubes to this Recent species under the heading *K.* aff. *polythalamia* (Linnaeus). Included in the list is a tube from the upper Miocene of Java, described by Martin (Die Tertiärschichten auf Java, p. 79, pl. 14, fig. 17, *a,* 1879-80) under the name *Siliquaria bipartita.* The posterior end of this tube appears to taper more gradually than that of the Fijian tube and the internal septum persists for a greater distance. The Fijian tubes differ in the same way from those described by Gabb as *K. incrassatus,* from the Miocene of the West Indies. These features, however, may not be constant.

Class Scaphopoda

Order Solenoconchia

Family Dentaliidae

Genus DENTALIUM Linnaeus

Dentalium Linnaeus, Syst. Nat., 10th ed., p. 785, 1758.

Subgenus DENTALIUM sensu stricto

Type (by subsequent designation, Montfort, 1810), *Dentalium elephantinum* Linnaeus. Recent, Amboyna and Philippine Islands (*fide* Grant and Gale).

Dentalium (Dentalium) species (pl. 34, figs. 8, 9).

The subgenus *Dentalium* sensu stricto is represented by a single incomplete specimen. The shell is medium sized, thick, slightly curved, and gently tapering; sculpture consists of eight high, sharply rounded, longitudinal ribs separated by broad, flattened or slightly concave interspaces; each interspace with a low but distinct secondary median rib; some of the interspaces with faint indications of a third set of ribs, which are represented by very fine threads lying midway between the primary and secondary ribs; numerous growth lines encircle the shell, but are too fine to be seen with the naked eye. External ribbing not impressed on interior. Length of broken specimen (B. P. Bishop Mus., Geol. no. 1131), 7.8 mm.; greatest diameter at larger end 4.9 mm.; greatest diameter at smaller end 4.3 mm.; diameter of interior at larger end 2.9 mm.

Locality, Station 160.

The species apparently belongs to the group of *D. octangulatum* Donovan (Pilsbry, H. A., and Sharp, B., Scaphopoda: Man. Conch., ser. 1, vol. 17, pp. 1, 5, 16, 1897-98) which includes a number of Indo-Pacific, West American, and West Indian species. The Fijian form has sharper ridges and a thicker shell than *D. octangulatum,* however. It has fewer but more prominent ribs than the genotype, *D. elephantinum* Linnaeus. The Fijian species probably is new, but it seems best not to name it until better type material has been collected.

Subgenus **GRAPTACME** Pilsbry and Sharp

Graptacme Pilsbry and Sharp, Man. Conch., 1st ser., vol. 17, p. 85, 1897.

Type (by subsequent designation, Woodring, 1925), *Dentalium eboreum* Conrad. Recent, southeastern United States and the West Indies.

Dentalium (Graptacme) species (pl. 34, figs. 10-12).

Shell medium-sized, slender, slightly curved, circular in section, thick. Apical portion of shell marked by fine longitudinal riblets, but younger portions smooth and glossy. Measurements of one of figured specimens, B. P. Bishop Mus., Geol. no. 1132 (pl. 34, fig. 11), are: length (incomplete) 9.1 mm., diameter of larger end 2.7 mm., of smaller end 2.0 mm. The other figured specimen is cataloged as B. P. Bishop Mus., Geol. no. 1133.

Locality, Station 160.

Since the specimens at hand are all fragmentary they cannot be identified specifically. Only one specimen (B. P. Bishop Mus., Geol. no. 1132) retains enough of the apical portion of the shell to show the ribbing. The species is larger, has a thicker shell, and is more coarsely marked than the genotype, *D. eboreum* Conrad.

Family SIPHONODENTALIIDAE

Genus **CADULUS** Philippi

Cadulus Philippi, Enum. Moll. Sicil., vol. 2, p. 209, 1844.

Type (by monotypy), *Dentalium ovulum* Philippi. Recent, Mediterranean Sea (*fide* Woodring, 1925).

Cadulus? species.

A single specimen, broken at both ends, probably represents this genus. The fragment is small, elliptical in section, somewhat flattened on one side, and tapers in both directions. Surface smooth and glossy. Length (incomplete) 6.3 mm., maximum diameter at "equator" 3.2 mm., minimum diameter at "equator" 2.9 mm. Catalogued as B. P. Bishop Mus., Geol. no. 1186.

Locality, Station 296.

Class Amphineura

Order Polyplacophora

The chitons are represented in the Vitilevu collections by a single minute posterior valve obtained at Station 160. The plate is semicircular in outline and moderately arched; its apex is located slightly anterior to the middle and is marked by radiating striae. The margins are worn and this condition forestalls any attempt at accurate determination. The valve measures 1.5 mm. in length and is 2.0 mm. wide. Cataloged as B. P. Bishop Mus., Geol. no. 1205.

Class Gastropoda

Order Scutibranchiata

Superfamily Docoglossa

Family Patellidae

Genus HELCIONISCUS Dall

Helcioniscus Dall, Am. Jour. Conch., vol. 6, p. 277, 1871.

Type (by original designation), *Patella variegata* Reeve. Recent, Indo-Pacific seas.

Helcioniscus? species (pl. 34, figs. 13, 14).

The limpets are represented in the Fijian fossil collections by a single specimen, an internal mold which shows only the general form of the species and its muscle scars. As the classification of the Recent limpets is based largely on characters of the soft parts and the radula, it is usually impossible to identify fossils accurately, particularly imperfectly preserved ones such as the Fijian specimen. The genus *Helcioniscus* is widely distributed in the Indo-Pacific area to-day and contains a number of shells having the general appearance of the fossil described, but it is by no means certain that the fossil belongs to this genus.

Shell medium sized, conical, high, ovate in outline, a little narrower anteriorly; apex slightly anterior to the midpoint. Interior smooth, margin not noticeably crenulated; muscle scar horseshoe shaped, its knoblike ends directed forward.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1155), are: length 29.6 mm., width 22.2 mm., height 13.5 mm.

Locality, Station 305. Collected by Mr. J. B. Turner.

Superfamily RHIPIDOGLOSSA

Family TROCHIDAE

Genus TROCHUS Linnaeus

Trochus Linnaeus, Syst. Nat., 10th ed., p. 756, 1758.

Subgenus TROCHUS sensu stricto

Type (by subsequent designation, Thiele, 1924—preprints received by W. H. Dall on May 20, 1923), *Trochus maculatus* Linnaeus. Recent, Indo-Pacific seas; also reported from Pliocene of Java and Quaternary of Timor and Billiton (*fide* Van der Vlerk).

Trochus (Trochus) maculatus Linnaeus.

A single example of this widely distributed and variable species was collected in the marly deposits at Station 311. The shell, showing traces of its original color and luster, is identical with Recent examples from Vitilevu. The beds at Station 311 are not older than late Pleistocene.

Trochus (Trochus) species (pl. 34, figs. 15, 16).

Trochus species Mansfield, Carnegie Inst. Washington, vol. 23, p. 88, pl. 4, fig. 4, *a, b,* 1926.

Shell medium sized, high spired, conical, with a false umbilicus. Whorls five or more, somewhat flattened, and separated by a remarkably deep suture; base flattened. Sculpture consisting of four slightly beaded spiral threads. Interior lirate.

The figured specimen (B. P. Bishop Mus., Geol. no. 1158), is an incomplete internal and external mold. The height of the internal mold is 27.2 mm.; its diameter 32.9 mm.

The figured specimen is from Station 297. The species was also obtained from the conglomerate immediately below (Station 160). Mansfield's specimen came from the limestone in the same formation at Station 295 (Mansfield Station 4370).

The deep suture of this species appears to differentiate it from described species, but specimens good enough for type material have not yet been obtained.

Subgenus TECTUS Montfort

Tectus Montfort, Conchyl. Syst., vol. 2, p. 187, 1810.

Section ROCHIA Gray

Rochia Gray, Guide Syst. Distr. Mollusca Brit. Mus., pt. 1, p. 148, 1857.

Type (by subsequent designation, Thiele, 1924—preprints received by W. H. Dall on May 20, 1923), *Trochus acutangulus* Chemnitz. Recent, Indo-Pacific seas. Also reported from the Pliocene or Quaternary of Timor (*fide* Van der Vlerk).

Trochus (Rochia) niloticus Linnaeus.

A fragment which apparently belongs to this well-known species was found with the genotype, *T. maculata,* in the deposits at Station 311.

This species is the important "Trocas shell" widely used in the manufacture of "pearl" buttons. Fiji still exports several hundred tons annually, but, according to accounts of natives, the shell is not nearly so abundant on many of the reefs as it was formerly.

According to Van der Vlerk, the species has been reported from the Pliocene of Sumatra.

Subfamily GIBBULINAE

Genus MONILEA Swainson

Monilea Swainson, Shells and shellfish, p. 352, 1840.

Section MONILEA sensu stricto

Type (*fide* Cossmann, 1918), *Trochus calliferus* Lamarck. Recent, Indo-Pacific. Also reported from the Pliocene of Java (*fide* Van der Vlerk).

Monilea (Monilea) mateana Ladd, new species (pl. 35, figs. 1, 2).

Shell small, turbinate, very solid; whorls rounded, sutures impressed, base somewhat flattened. Aperture rounded-quadrangular, peristome incomplete; inner surface of outer lip with 10 lirations, its margin beveled; columella concave above, dentate below; umbilicus wide but with a broad ridge or funicle which spirals up its side to terminate against the dentate portion of the columella; funicle with a faint median groove. Sculpture consisting of strong spiral ribs beaded by axial striae. On the base the ribs are somewhat flattened and are well separated, but on the upper portions of the whorls they are rounded, close-set, and each third rib is more prominent than the others. Shell nacreous within and marked exteriorly by axial bands of reddish brown. The color pattern is particularly well shown by the paratype (B. P. Bishop Mus., Geol. no 1197).

Holotype (B. P. Bishop Mus., Geol. no. 1196): height 7.0 mm., diameter 8.0 mm. Topotype in U. S. National Museum (Cat. no. 372678).

Type locality, Station 160.

The genotype, *M. callifera,* has a lower spire, weaker sculpture, and a columella that is reflected over the funicle and part of the umbilicus. The fossils are more closely related to *M. lentiginosa* A. Adams, a larger Recent species from the southwest Pacific. On the Recent shell, however, the spiral ribs on the upper part of the whorls are not arranged in groups of three, as on the fossil shells, and the funicle shows no median depression.

Family TURBINIDAE

Genus TURBO Linnaeus

Turbo Linnaeus, Syst. Nat., 10th ed., p. 761, 1758.

Subgenus TURBO sensu stricto

Section TURBO sensu stricto

Type (by subsequent designatoin, Montfort, 1810), *Turbo petholatus* Linnaeus. Recent, Indo-Pacific (*fide* Woodring, 1928). Also reported from the upper Miocene and Pliocene of Java, the Pliocene and Quaternary of Timor, and the Quaternary of Celebes (*fide* Van der Vlerk).

Turbo (Turbo) petholatus thanus Ladd, new subspecies (pl. 35, fig. 3).

Shell medium in size, turbinate, imperforate, solid; whorls distinctly carinated at the suture and at a point a short distance below, the area intervening being flattened; a third carina, only faintly indicated, encircles the whorls immediately above the suture. Aperture circular, outer lip thin, inner lip heavily callused. Surface polished and marked by fine, close-set, regularly spaced axial lines; interior pearly.

Holotype (B. P. Bishop Mus., Geol. no. 1185): height (tip of spire broken away) 28.6 mm., diameter 27.5 mm.

Type locality, Station 160. The Recent *T. petholatus,* which is widely distributed in the Indo-Pacific area, is abundant on the present reefs of Vitilevu.

Only two fossil specimens were obtained, one of which is fragmentary, but both show the carinae as described above. A few specimens of the Recent *T. petholatus* have the middle carina even more strongly developed than do the fossils, but none of the Recent shells show the lowest carina nor do they have the suture as strongly carinated as do the fossils.

Subgenus SENECTUS ("Humphrey") Swainson

Senectus Swainson, Treatise on Malacol., pp. 206, 213, 215, 348, 1840.

Type (by subsequent designation, Herrmannsen, 1848), *Turbo chrysotomus* Linnaeus. Recent, tropical western Pacific (*fide* Woodring, 1928).

Turbo (Senectus) chrysotomus Linnaeus.

Fragmentary specimens of this species, which retain traces of their original color and luster, occur in the marly cave deposits at Station 311. These bedded deposits are not older than late Pleistocene. *T. chrysotomus* is a fairly common species on the shores of Vitilevu today.

Turbo (Senectus) crassus Wood.

Large heavy opercula, which almost certainly belong to this species, were found with the shells of *T. chrysotomus* at Station 311, and a single worn operculum was found embedded in the lithified beach sand at Station 157. The species is one of the common Turbos on Vitilevu's shores today.

Subgenus **OCANA** H. Adams

Ocana Adams, H., Zool. Soc. London, Proc., p. 143, 1861.

Type (*fide* Cossmann, 1918), *Turbo cidaris* Gmelin. Recent, South African coasts.

Turbo (Ocana) cf. gruneri Philippi (pl. 35, figs. 4, 5).

Turbo gruneri Philippi, Zeitschr. Malakozool., 3d ann. set, p. 98, 1846.

Turbo circularis Reeve, Conch. Icon., vol. 4, *Turbo*, pl. 10, no. 46, 1847. Pilsbry, Man. Conch., vol. 10, p. 214, pl. 41, fig. 24, 1888.

Turbo species *a* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 89, pl. 3, fig. 2, 1926.

Turbo species *b* Mansfield, Carnegie Inst. Washington, Pub. 344, p. 89, pl. 3, fig. 3, *a*, *b*.

Shell medium in size, spire moderately high, whorls convex, body whorl descending, aperture subcircular and somewhat expanded. Sculpture consisting of close-set spiral ridges. On the upper part of the whorls large rounded ridges alternate with finer granulated ridges; on the base the ridges are large, subequal in size, and all are granulose.

Measurements of the figured internal mold (B. P. Bishop Mus., Geol. no. 1228) from Station 158 are: length 40.4 mm., diameter 39.1 mm. Figure 5, plate 35, is a squeeze taken from an external mold from Station 295. The internal mold of this same specimen (B. P. Bishop Mus., Geol. no. 1229) measures: length (incomplete) 25.0 mm., diameter 23.2 mm.

Localities, Stations 160, 295, 297. Questionable specimens collected from Stations 158, 294, and 307.

The description of this species is based on a number of internal and external molds. If well-preserved shells are found the species may prove to be identical with *T. gruneri* Philippi, a Recent Australian species.

Genus **ASTRAEA** sensu lato

Astrea Roeding, Mus. Boltenianum, pt. 2, p. 79, 1798.

Type (by subsequent designation, Suter, 1913), *Trochus imperialis* Gmelin (= *Trochus heliotropium* Martyn). Recent, New Zealand (*fide* Woodring, 1928).

Astraea species (pl. 35, fig. 6).

Mansfield found two specimens, which apparently belong to this genus, in the collection from the limestone of Tamavua Quarry (Suva formation), on Walu Bay (Station 4370, Mansfield = Ladd Station 295). Mansfield's figure of one of these specimens (U. S. Nat. Mus., Cat. No. 352427) is reproduced in plate 35.

Subgenus CALCAR Montfort

Calcar Montfort, Conchyl. Syst., vol. 2, p. 135, 1810.

Type (by original designation and by absolute tautonymy), *Calcar sporio* Montfort (= *Turbo calcar* Linnaeus). Recent, Indo-Pacific.

Astraea (Calcar) species A (pl. 35, figs. 7, 8).

Shell medium in size, trochiform, thick, imperforate; aperture oval, very oblique, channeled at the periphery, nacreous within; columella with a distinct basal tubercle. Whorls flattened above the periphery and obliquely, radiately plicate, the nodular or spinose folds somewhat irregularly distributed, but those of one whorl tending to merge with those of the adjoining whorls; secondary axial ribs between the main folds trend at right angles to the oblique margin of the outer lip and are crossed by fine lines of growth; periphery obscurely bicarinate; base flattened and marked with concenrtic spinose ribs.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1226) are: height 15.6 mm., diameter 17.3 mm.

Locality, Station 160.

The Fijian specimens are too badly worn for accurate determination, but they appear to have fewer and more nodose folds than the genotype, *A. calcar* (Linnaeus). They are similar to specimens of *A. petrosum* (Martyn), a Recent Indo-Pacific species, but the Recent shell is distinctly bicarinate at the periphery and has a concave base.

Family DELPHINULIDAE

Genus DELPHINULA Lamarck

Delphinula Lamarck, Mus. Hist. Nat. (Paris), Ann., vol. 4 (20), p. 108, 1804. (*fide* Sherborn).

Type (by subsequent designation, Anton, 1839), *Delphinula laciniata* Lamarck (= *Turbo delphinus* Linnaeus). Also reported from the upper Miocene of Java and Nias, and from the Quaternary of Soemba (*fide* Van der Vlerk).

Delphinula distorta (Linnaeus) (pl. 35, fig. 9).

Turbo distortus Linnaeus, Syst. Nat., 10th ed., p. 764, 1758.

Delphinula distorta Lamarck, Animaux sans vertèbres découverts dans le bassin de Paris, vol. 6, pt. 2, p. 231, 1822. Reeve, Conch. Icon., vol. 1, *Delphinula,* pl. 2, no. 7, 1843. Pilsbry, Man. Conch., vol. 10, p. 268, pl. 65, fig. 8; pl. 68, figs. 12, 13, 1888.

The following description is based on a single fossil specimen.

Shell medium in size, turbinate, thick, upper part of spire flattened, later whorls angulated, descending, flattened above and on sides, body whorl rounded below, only slightly in contact with preceding whorl above. Interior of aperture round, smooth, nacreous; outer lip flaring, its margin angulated and crenulated; inner lip smooth with a sinuous margin; umbilicus moderately wide, deep, the wall adjoining the columella striated. Sculpture consisting of scaly spiral ribs, axial plications, and fine axial striae. The spiral ribs vary in size, the one on the shoulder being the largest and bearing numerous open spinelike processes. Two other unusually large spiny ribs occur near the base of the body whorl. Flattened upper surface of whorls with strong axial or radiating plications, about a dozen being present on the body whorl. Faint axial striae cross the ribs everywhere. Traces of reddish color preserved along the shoulder of the penult whorl and in the umbilical cavity.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1216) are: height 23. 5 mm., diameter 29.4 mm.

Locality, Station 160. The Recent shells have a wide distribution in the Indian Ocean and Australian and Japanese waters.

This species has the general form of the genotype, *D. delphinus* Linnaeus, but is a smaller species and is particularly characterized by the strong axial or radiating plications on the flattened upper surface of the whorls. Recent shells apparently show some variation in the height of spire and in the spiral sculpture, and the fossil appears to fall within this range.

Delphinula species (pl. 35, figs. 10-12).

Shell small, depressed, thick, body whorl angulated, descending, flattened above and somewhat at the sides, rounded below. Interior of aperture round, smooth, nacreous; inner lip smooth, its margin sinuous; umbilicus moderately wide, deep, the wall adjoining the columella striated. Sculpture consisting of spiral ribs, axial plications, and axial striae. The spiral ribs vary somewhat in size; those on the body whorl below the shoulder are very scaly. Upper surface of whorls with strong axial or radiating plications, seven present on the body whorl. Fine axial lines cross the shell everywhere and are responsible for the hollow spines or scales on the ribs of the lower part of the shell.

Measurements of the incomplete figured specimen (B. P. Bishop Mus., Geol. no 1217) are: height 17.8 mm., diameter 20.7 mm.

The specimen described was collected with *D. distorta* at Station 160 but probably represents a different species as it has a lower spire, is less sharply angulated below, is less spinose, and has fewer axial plications than *D. distorta.* If additional specimens show these differences to be constant, this form may be recognized as a new species.

Family NERITOPSIDAE

Genus **NERITOPSIS** Grateloup

Neritopsis Grateloup, Soc. Linn. Bordeaux, Actes, vol. 5, p. 129, 1832.

Type (by monotypy and original designation), *Neritopsis moniliformis* Grateloup. Miocene, southern France.

Neritopsis radula (Linnaeus), new subspecies? (pl. 35, fig. 13).

Shell large, subglobose, solid, imperforate, spire low, body whorl greatly expanded. Aperture large, broadly ovate, deeply channeled posteriorly; inner lip thickened by callus, flattened, with a broad, squarish notch near the center; outer lip thick, beveled, fluted within. Sculpture consisting of heavy, coarsely beaded spiral ribs separated by grooves which are pitted by the crossing of numerous fine axial lamellae.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1159) are: height (apex slightly broken), 31.8 mm., diameter 27.7 mm.

Locality, Station 160.

The fossil differs from Recent examples of *N. radula* in being unusually large and in having much coarser sculpture. Only one specimen of the fossil is at hand, however, and until more material has been obtained it is impossible to state whether the differences are persistent and, consequently, whether the fossil is a valid subspecies.

Family NERITIDAE

Subfamily NERITINAE

Genus NERITA Linnaeus

Nerita Linnaeus, Syst. Nat., 10th ed., p. 776, 1758.

Subgenus NERITA sensu stricto

Section AMPHINERITA von Martens

Type (*fide* H. B. Baker), *Nerita polita* Linnaeus (= *N. umlaasiana* Krauss). Recent, Indo-Pacific seas, Red Sea to Peru.

Nerita (Amphinerita) polita Linnaeus.

Represented by a number of specimens in the marly cave deposits at Station 311. Some of the shells are identical with Recent examples from the same area whereas others show some variation but are believed to belong to the same species. The shells still show traces of their original color pattern. Deposit not older than late Pleistocene.

Associated with the above specimens are two opercula of a species of *Nerita*. They apparently do not belong to *N. polita* or to any of the Recent species of this genus which I collected on the shores of Vitilevu.

Section THELIOSTYLA Mörch

Theliostyla Mörch, Cat. Conchyl. D. A. d'Aguirra et Gadea, Comes de Yoldi, p. 167, 1852.

Type (*fide* H. Burrington Baker), *Nerita albicilla* Linnaeus. Recent, Indo-Pacific.

Nerita (Theliostyla?) species (pl. 35, figs. 14, 15).

Shell small, subglobose, thick; spire very low, aperture semilunate, columellar lip slightly concave and covered with circular and oval pustules, its margin dentate, the rounded denticles widely spaced. Outer lip imperfecly preserved but apparently dentate within and bordered by a narrow groove, lip channeled posteriorly at its junction with the parietal wall. Surface worn but still showing traces of rounded spiral ribs and very minute zigzag lines of growth.

Measurements of the incomplete figured specimen (B. P. Bishop Mus., Geol. no. 1195) are: height 11.3 mm., diameter 12.8 mm.

Locality, Station 59.

The species is referred to *Theliostyla* because the observable characters of the lips suggest *N. albicilla,* type species of the section. The Fijian species, however, may quite possibly belong to another group of Neritas.

Genus THEODOXUS Montfort

Theodoxus Montfort, Conchyl. Syst., vol. 2, p. 351, 1810.

Subgenus THEODOXUS sensu stricto

Section THEODOXUS sensu stricto

Type (by original designation), *T. lutetianus* Montfort (= *Nerita fluviatilis* Linnaeus). Recent, rivers of Europe (*fide* H. Burrington Baker).

Subgenus CLITHON Montfort

Clithon Montfort, Conchyl. Syst., vol. 2, p. 327, 1810.

Section CLITHON sensu stricto

Type (by original designation), *Nerita corona* Linnaeus. Recent, rivers of Asia and the East Indies to Melanesia (*fide* H. Burrington Baker).

Theodoxus (Clithon) corona (Linnaeus) (pl. 35, fig. 16, pl. 36, fig. 1).

Nerita corona Linnaeus, Syst. Nat., 10th ed., p. 777, 1758.—Reeve, Conch. Icon., vol. 9, pl. 6, no. 27, 1856.

Niritina brevispina Lamarck, Animaux sans vertèbres découverts dans le bassin de Paris, vol. 6, pt. 2, p. 185, 1822.—Reeve, Conch. Icon., vol. 9, pl. 6, no. 28, 1856.—Pilsbry, Man. Conch., vol. 10, p. 65, pl. 23, figs. 16-18, pl. 24, figs. 19-28, 31-34, 1888.

Theodoxus corona Baker, Acad. Nat. Sci. Phila., Proc., vol. 75, p. 155, 1923.

The following description is based on the fossil specimen:

Shell medium-sized, globose, spire very low; whorls somewhat flattened on their upper surface, slightly angulated along a line some distance below the suture, broadly rounded below; spine bases present along the angle of the body whorl. At the suture the body whorl irregularly overlaps the preceding whorl. Aperture semicircular; callus area flattened, its margin irregular; columellar lip slightly concave in outline, its upper three quarters bearing a series of fine denticles, one of which, lying slightly above the middle, is much larger than the others. Outer lip channeled posteriorly at its junction with the parietal wall. Surface of whorls covered by irregular, rounded striae or wrinkles. Remnants of the original color pattern preserved as irregular spiral bands.

Measurements of the incomplete figured specimen (B. P. Bishop Mus., Geol. no. 1194) are: height 14.5 mm., diameter 15.1 mm.

The single worn specimen was collected at Station 160.

T. corona is a fluviatile species widely distributed in the Indo-Pacific area. Recent shells from Fiji and elsewhere show considerable variation in the development of the spiral ridge and its spines. The single fossil specimen clearly falls within the range of variation exhibited by the Recent shells.

Order PECTINIBRANCHIATA

Superfamily TAENIOGLOSSA

Family NATICIDAE

Genus NATICA Scopoli

Natica Scopoli, Introd. Hist. Nat., p. 392, 1777.

Subgenus NATICA sensu stricto

Type (by subsequent designation, Harris, 1897), *Nerita vitellus* Linnaeus (*"Natica rufa* Born" of authors). Recent, western Pacific (*fide* Woodring, 1928). Also reported from the Eocene and younger Tertiaries of Java and the upper Tertiary of nearby islands (*fide* Van der Vlerk).

Natica (Natica) marochiensis (Gmelin) (pl. 36, figs. 2, 3).

Nerita marochiensis Gmelin, Syst. Nat., vol. 6, p. 3673, no. 15, 1792.

Natica marochiensis Tryon, Man. Conch., vol. 8, p. 22, pl. 5, figs. 74-96, 1886.

The following description is based on the fossil material:

Shell small and globose, spire low, sutures distinct. Aperture semilunar, outer lip sharp, umbilicus almost completely filled by funicle, parietal callus moderately thick. Oblique wrinkles, extending backward from the sutures, are prominent on the upper portions of the whorls but merge into fine growth lines below.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1160) are: height 12.5 mm., diameter 10.9 mm.

Abundant in the conglomerate at Station 160. Also one of the commonest naticoids on the present-day tidal flats near Suva. The species is said to occur in various upper Tertiary horizons in Java (lower Miocene, upper Miocene, Pliocene), East Borneo (upper Miocene), Sumatra (Pliocene), Timor (Pliocene), Seran (Pliocene). In Celebes it occurs in Quaternary rocks (Van der Vlerk, Leidsche Geolog. Mededeel., vol. 5, p. 258, 1931), and Chapman has identified it from the upper Miocene to Pliocene rocks of New Guinea (Oil exploration work in Papua and New Guinea . . ., vol. 2, p. 59, 1931).

N. marochiensis has been reported living on the western coast of Africa, in the West Indies, Polynesia, and on the coast of Australia. Several varieties, based on differences in size and color, have been named. The Recent specimens from Vitilevu show considerable variation in color. The ground color is greenish gray with a narrow band of light gray or white near the suture, but some specimens show faint spiral bands darker than the ground color and axial bands that are lighter. The callus and the area surrounding the umbilicus are white or light gray. Interiors are dark brown. The exterior of the operculum has a single marginal rib.

The Fijian fossil specimens appear to have a slightly lower spire and a somewhat narrower aperture than the Recent specimens, but these features are variable, hence the fossils are referred to the Recent species.

Genus POLINICES Montfort

Polinices Montfort, Conchyl. Syst., vol. 2, p. 222, 1810.

Subgenus POLINICES sensu stricto

Type (by original designation), *Polinices albus* Montfort (= *Natica mammillaris* Lamarck = *Natica brunnea* Link). Recent, West Indies (*fide* Woodring, 1928).

Polinices (Polinices) mamilla (Linnaeus) (pl. 36, figs. 4, 5).

Nerita mammilla Linnaeus, Syst. Nat., 10th ed., p. 776, 1758.

Natica mamilla Reeve, Conch. Icon., vol. 9, pl. 7, no. 27, 1856.—Tryon, Man. Conch., vol. 8, p. 49, pl. 16, fig. 46, 1886.

The following description is based on the fossil material:

Shell small, pyriform, smooth, spire minute, outer lip thin, suture tangential. Aperture semilunate, parietal callus thick, entirely covering the umbilicus.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1162) are: height 16.1 mm., diameter 14.1 mm.

Localities: Station 160; the Recent shells have been collected widely in the southwest Pacific and, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 258, 1931), the species has been reported from the upper Miocene and Pliocene of Java, the Pliocene of Sumatra and Timor, the Quaternary of Celebes and Billiton.

Except for their smaller size the fossils cannot be distinguished from Recent examples of the species collected in Fiji, and in the collections of the

U. S. National Museum there are Recent shells from other areas that are as small as the fossils. The Recent shells are pure white, shining, and have a brown horny operculum with a narrow whitish border.

Polinices (Polinices) melanostoma Gmelin.

A single well-preserved specimen of this widespread Indo-Pacific species was collected from the marl at Station 311. It is smaller than the Recent specimens collected on the shores of Vitilevu by the writer, and the body whorl is only very faintly tinged with brown. The beds at Station 311 are not older than late Pleistocene. According to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 258, 1931), the species has also been reported from the upper Miocene and Pliocene of Java, the Pliocene of Sumatra, Timor, and Seran, and the Quaternary of Celebes.

Polinices (Polinices) species (pl. 36, fig. 6).

Shell medium-sized, ovate, thick, spire low and broadly pointed, suture tangential. Umbilicus large but almost completely filled by funicle, parietal callus thick, projecting slightly beyond funicle.

The figured specimen (B. P. Bishop Mus., Geol. no. 1161) lacks part of the outer lip. The specimen measures: height 19.4 mm., diameter 16.7 mm.

Locality, Station 160.

The species bears a general resemblance to Recent Fijian specimens in the U. S. National Museum which are assigned to *P. uber* (Valenciennes). The fossil, however, has a much stronger funicle and whorls that are less inflated.

Family AMPULLOSPIRIDAE

Genus GLOBULARIA Swainson

Globularia Swainson, Treatise on Malacol., p. 345, 1840.

Subgenus GLOBULARIA sensu stricto

Type (by subsequent designation, Herrmannsen, 1847), *Natica sigaretina* Lamarck (*fide* Stewart, 1926).

Subgenus WALUIA Ladd, new subgenus

Type, *Globularia edwardsi* Ladd, new species. Suva formation, Vitilevu, Fiji.

Shell very large, subhemispherical, very thick; spire very low, body whorl constituting most of the shell. Aperture lunate and very oblique, outer lip slightly flaring; umbilicus wide, lined with a thick callus whose outer margin terminates abruptly as a steep-sided wall or funicle that spirals around the umbilicus and curves downward to merge with the basal margin of the aperture. Body whorl very large, somewhat depressed below the suture.

The ampullinoids have recently been discussed by Stewart (Acad. Nat. Sci. Philadelphia, Proc., vol. 78, pp. 330-339, 1926), by Woodring (Carnegie Inst. Washington, Pub. 385, pp. 391-394, 1928), and by Cox (Geol. Survey India, Mem., new ser., vol. 15, pp. 170-177, 1930). During Tertiary time the group was represented by numerous genera and species in many parts of the world, but only a single species is found in the Recent fauna. As Stewart has suggested, therefore, "it seems better to recognize this all but extinct group as a separate family than to place it under the thriving Naticidae." This practice was followed by Cox and is adopted in the present paper.

The type of *Globularia* sensu stricto is a shell from the Eocene of Europe —type (by subsequent designation, Herrmannsen, 1847), *Natica sigaretina* Lamarck (*fide* Stewart, 1926). Closely related species are known from the Eocene of India and of both the eastern and western parts of North America. According to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 259, 1931), the genotype has been reported from the lower Tertiary of Borneo. In Aquitaine and in eastern North America the genus survived until the Miocene.

The single living species of *Globularia, G. fluctuosa* (Sowerby), is a Philippine species and is placed in the subgenus *Cernina*. Cossmann found this group very common in the Jurassic and Cretaceous of the Old World, but Stewart believes that this remarkable distribution needs further confirmation and suggests that *Cernina* developed from *Globularia* sensu stricto in the Miocene or later. The new subgenus *Waluia* appears to be more closely related to *Cernina* than to *Globularia* sensu stricto, but it is doubtful if the Recent *Cernina* developed from *Waluia*—it seems more probable that both developed in the southwest Pacific from a common ancestor in early Miocene or pre-Miocene time.

Globularia (Waluia) edwardsi Ladd, new species (pl. 36, figs. 7, 8; pl. 37, figs. 1, 2; pl. 38, fig. 1).

Shell very large, inflated, much wider than high, apical angle 143 degrees; whorls about five in number, the sutures impressed. Sculpture consisting of axial lines of growth, which are strongly retractive near the suture. Other features as given in the description of the subgenus.

Measurements of type specimens:	Height	Diameter
Holotype (B. P. Bishop Mus., Geol. no. 1231)	127 mm.	142 mm.
Paratype *a* (B. P. Bishop Mus., Geol. no. 1232)	135 mm.	215 mm.
Paratype *b* (B. P. Bishop Mus., Geol. no. 1233)	170 mm.	188 mm.

The outer lip is complete only in paratype *A*, which accounts for its diameter.

Localities: Holotype from Station 160; paratype *a* from Station 295; paratype *b* from Station 158. Paratype *a* collected by Mr. W. T. C. Edwards, of Suva.

The Fijian shell is much larger and thicker than *G. sigaretina* and its allies, has a lower spire, a more oblique aperture, and a proportionately larger body whorl. It also has an open umbilicus, whereas that of the genotype is filled with callus, though the coating is not thick enough completely to conceal the funicle. However, the comparative development of the umbilical callus is apparently not a feature of great systematic importance, because *G. patula* (Deshayes), from the Eocene of the Paris Basin, has an open umbilicus like the Fijian species yet is in all other respects very similar to *G. sigaretina*.

The single Recent representative of the genus, *G.* (*Cernina*) *fluctuata* (Sowerby), is larger than the Eocene genotype and its allies, but none of the shells of *Globularia* sensu stricto or *Cernina* even approach the Fijian specimens in size and thickness of shell. The aperture of *Cernina*, like that of *Globularia* sensu stricto, is less oblique than that of *Waluia* and the umbilicus of *Cernina* is usually filled by a thick pad of callus, but in an occasional shell it fails to hide the funicle completely. *Waluia* is the only one of the three subgeneric groups which possess a flaring aperture.

In *Cernina* and *Waluia* the whorls of the spire are but little inflated above the suture and the body whorl is distinctly depressed immediately below the suture. In these features both subgenera differ from *Globularia* sensu stricto. In view of the fact that *Globularia* sensu stricto is a group of older species it might be advisable to give *Cernina* generic rank, making *Waluia* a subgenus under it rather than under *Globularia*.

Family CALYPTRAEIDAE

Genus CHEILEA Modeer

Cheilea Modeer, K. Svenska Vet. Akad., Nya Handl., vol. 14, pp. 110, 111, 1793 (*fide* Woodring, 1928).

Type (by subsequent designation, Woodring, 1928), *Patella equestris* Linnaeus. Recent, Indian Ocean and elsewhere (?) in tropics. Also reported from the Pliocene of Java and the Quaternary of Timor (*fide* Van der Vlerk).

Cheilea species (pl. 36, fig. 1; pl. 37, fig. 3).

A single incomplete and apparently immature specimen represents this genus. It is a small, thick, broadly conical shell. The apex, lying posterior to the midpoint, is worn but shows a nucleus coiled at right angles to the main shell. Near the subcircular aperture the shell is abruptly deflected downward and becomes very thin. The outer surface is marked by coarse radial ribs. Internally, beneath the apex, there is a thick (broken) process, shaped like a half-funnel, which rises from a stout base and has its opening directed forward.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1153) are: length 6.7 mm., width 7.0 mm., convexity 3.1 mm.

Locality, Station 160.

The coarse radial ribs and other features of this species serve to distinguish it from the genotype and other Recent species with which it has been compared. However, until complete adult specimens have been found it seems advisable not to name it.

Family Hipponicidae

Genus HIPPONIX Defrance

Hipponix Defrance, Jour. de Phys., de Chimie, d'Hist. Nat. et des Arts, vol. 88, p. 217, 1819.

Type (by subsequent designation, Gray, 1847), *Patella cornucopia* Lamarck. Eocene, Paris Basin (*fide* Woodring, 1928).

Hipponix species (pl. 37, figs. 4-6).

Shell small, thick, broadly and obliquely conical, apex projecting beyond the posterior margin of the circular aperture. Nucleus (preserved in only one specimen) consisting of slightly more than one whorl, dextrally coiled at right angles to the axis of the adult shell. Sculpture consisting of coarse concentric frills marked with radiating riblets. Internally, the muscular impression is horseshoe shaped, its expanded ends directly forward.

The figured specimen (B. P. Bishop Mus., Geol. no. 1154) is slightly broken and above the average in size. Its measurements are: length 11.2 mm., width 11.9 mm., convexity 6.3 mm.

Locality, Station 160.

This specimen may prove to be identical with a Recent Pacific species usually identified as *H. antiquatus* (Linnaeus).

Family Architectonicidae

Genus ARCHITECTONICA ("Bolten") Roeding

Architectonica Roeding, Mus. Boltenianum, pt. 2, p. 78, 1798.

Subgenus ARCHITECTONICA sensu stricto

Type (by subsequent designation, Gray, 1847, *"Architectoma"*), *Trochus perspectivus* Linnaeus. Recent, Indo-Pacific (*fide* Woodring, 1928). Also reported from the lower Miocene and younger horizons in Java and elsewhere in the southwest Pacific (*fide* Van der Vlerk).

Architectonica (Architectonica) perspectiva (Linnaeus), new subspecies? (pl. 38, figs. 2-4).

Shell small, spire conical but very low, angular at the periphery. Aperture subquadrangular, umbilicus wide and deep. Sculpture consisting of crenulated spiral cords and bands, separated by grooves. On the base the arrangement from the umbilicus outward is as follows: umbilicus bordered by a strongly crenulated cord and separated from a smaller and less strongly crenulated cord by a groove; second cord also bordered by a groove, and latter followed by a broad, slightly convex band which is crossed by prominent axial ribs; a narrow crenulated cord followed by a deep groove separates the band from the peripheral cord. The periphery is formed by a strong cord which is only faintly crenulated. The upper surface of each whorl bears two crenulated marginal cords (in addition to the peripheral one) with a wide band between which is crossed by retractive axial grooves. The suture is laid in the groove between the peripheral cord and the outer narrow crenulated cord.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1163) are: height 5.9 mm., diameter 13.7 mm.

Locality, Station 165.

The spire of the fossil is much lower than that of *A. perspectiva* and its whorls are distinctly more convex below, but the small size of the fossil and the prominence of its sculpture, particularly the axial ribs, indicate that it is a young specimen. It therefore seems best not to name it until satisfactory type material has been collected.

Genus HELIACUS d'Orbigny

Heliacus d'Orbigny, Hist. Phys. Nat. de l'Île de Cuba, pt. 2, Mollusques, vol. 2, p. 68, 1842.

Type (by monotypy), *Solarium heberti* Deshayes (*fide* G. F. Harris). Recent, West Indies.

Heliacus species (pl. 38, figs. 5-7).

Shell small, solid, spire low and conical, its sides gently convex, sutures inconspicuous, base slightly rounded. Aperture subcircular, umbilicus deep, moderately wide, bearing a median crenulated cord and rimmed by a somewhat larger crenulated cord; 10 other crenulated spirals are present, the one on the periphery and the one immediately below it being more prominent than the others; 3 of the 10 cords lie above the periphery and 6 lie below it.

The single specimen (B. P. Bishop Mus., Geol. no. 1164) is worn. Its measurements are: height 4.2 mm., diameter 7.7 mm.

Locality, Station 160.

The Fijian specimen may represent *H. variegata planulatus* (Hanley), a low-spired variety of the widespread *H. variegata* Gmelin, but specimens from the Hawaiian islands invariably have only five spiral cords between the umbilical cord and the periphery, whereas the Fijian fossil has six. The fossil also resembles *H. implexus* (Mighels), a Recent Hawaiian species. It, however, usually shows four spiral cords above the periphery.

Family CERITHIIDAE

Genus PYRAZUS Montfort

Pyrazus Montfort, Conchyl. Syst., vol. 2, p. 459, 1810.

Subgenus PYRAZUS sensu stricto

Type (by original designation), *Pyrazus baudini* Montfort (= *Clava herculea* Martyn, = *Cerithium ebeninum* Bruguière). Recent, New South Wales (*fide* Marwick).

Pyrazus (Pyrazus) species (pl. 38, fig. 8).

Shell large, high-spired, imperforate, whorls slightly angulated. Aperture channeled both anteriorly and posteriorly; produced anteriorly into a canal and somewhat prolonged posteriorly. Inner lip callused. Sculpture consisting of axial plications and striations and 10 spiral ribs. The axial striae are indistinct over most of the shell, but near the aperture are strong enough to give the surface a cancellated appearance. Remnants of the original color pattern are preserved as narrow orange-colored axial bands.

Measurements of the incomplete figured specimen (B. P. Bishop Mus., Geol. no. 1187) are: height 78.4 mm., diameter 26.3 mm.

Locality, Station 160.

The single fossil specimen probably represents a new species, but the outer lip is almost entirely broken away and it seems inadvisable to give it a name until better type material is secured. The fossil species has fewer spiral ribs than the genotype, and its whorls are not nodose at the angles as are those of the Recent species.

Family STROMBIDAE

Genus STROMBUS Linnaeus

Strombus Linnaeus, Syst. Nat., 10th ed., p. 742, 1758.

Type (by subsequent designation, Montfort, 1810), *Strombus pugilis* Linnaeus. Recent, West Indies and Florida. Also reported from the Pliocene of Mexico (*fide* Grant and Gale).

Strombus floridus Lamarck.

This species is represented by numerous specimens in the sea cave deposits at Station 311, at a level 6 feet above present high tide. The material is well preserved, some of the specimens showing traces of the original color pattern. Deposit not older than late Pleistocene.

Ostergaard (B. P. Bishop Mus., Bull. 31, pp. 7, 27, 1928) found a few specimens of this species on the island of Oahu, Hawaii, in marine rocks which now lie a few feet above sea level. He also obtained it from a limestone dredged from the harbor of Honolulu. Both occurrences are thought to be no older than Pleistocene. The species lives today in Fiji, but it has not been taken alive in Hawaii.

Strombus urceus Linnaeus.

A single fragmentary specimen was collected with the shells of *S. floridus* at Station 311. The shell shows much of its original color and is identical with Recent shells from the same area. According to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 247, 1931), the species has also been reported from the Pliocene of Timor and the Quaternary of Celebes and Billiton.

Genus TIBIA ("Bolten") Roeding

Tibia Roeding, Mus. Boltenianum, pt. 2, p. 123, 1798.

Type (by subsequent designation, Dall, 1906), *Murex fusus* Linnaeus (*fide* M. A. Cox). Recent, western Pacific.

Tibia cf. **powisii modesta** (Martin) (pl. 39, figs. 1, 2).

Rostellaria powisii modesta Martin, Die Fossilien von Java: Reichs Geol.-Min. Mus. Leiden, Samml., new ser., vol. 1, pts. 6-8, p. 191, pl. 30, figs. 443, *a, b,* 444, 1899. Martin, K., and Icke, H.; Die fossilen Gastropoden von Trinil; in Selenka und Blanckenhorn, Die Pithecanthropus-Schlichten auf Java: Geol. u. Pal. Ergeb. der Trinil-Exped., Leipzig, p. 47, 1911 (*fide* Van der Vlerk).

Shell small, fusiform, thick, high-spired; whorls of spire gently convex, their diameter about twice their height; body whorl somewhat more inflated, its latter half with a prominent shoulder a short distance below the suture and with a pronounced axial swelling on the side opposite the outer lip; this swelling deflects the suture upward for a short distance. Aperture lenticular in outline, produced anteriorly into a long, thin, spinelike canal that is slightly curved backward; posteriorly the aperture is continued as a narrow, recurved channel resting on the penult whorl. Inner lip heavily callused, its margin distinct; outer lip greatly thickened, its outer margin produced into five pointed spines, its inner margin notched anteriorly and faintly dentate posterior to the notch. Sculpture consisting of numerous spiral ribs crossed by close-set axial lines, the two sets of markings being inconspicuous on the spire but very distinct on the body whorl. The spiral rib immediately below the suture is much larger than the others and is strongly developed on all whorls. A few of the ribs on the body whorl are grouped in pairs on some specimens; the shoulder on the latter half of the body whorl varies somewhat, being bounded anteriorly by a depression on some shells; a few specimens show low rounded varices on the whorls of the spire.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1221) are: length (incomplete) 39.1 mm., diameter 14.2 mm.

Localities, Stations 165, 304, and 306. Martin's type material was collected from the Pliocene (Sondé-beds) of Java.

T. powisii (Petit) is a species which lives today in Chinese and Japanese waters and, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 246, 1931), has been reported from the Pliocene of Timor. It differs from Martin's variety in that the shoulder of the body whorl is poorly developed, its sculpture is coarse and is uniformly developed on all whorls. The Fijian fossils are smaller than the Java specimens of *T. powisii modesta,* have a finer sculpture, and the body whorl near the aperture is not depressed below the suture of the penult whorl. They may represent a distinct species.

Family Cypraeidae

Genus CYPRAEA Linnaeus

Cypraea Linnaeus, Syst. Nat., 10th ed., p. 718, 1758.

Subgenus CYPRAEA sensu stricto

Section CYPRAEA sensu stricto

Type (by subsequent designation, Montfort, 1810), *Cypraea tigris* Linnaeus. Recent, Indo-Pacific (*fide* Woodring, 1928).

Cypraea (Cypraea) tigris Linnaeus.

A fragment which almost certainly belongs to the genotype was found in the sea cave deposits at Station 311. These deposits are not older than late Pleistocene. *C. tigris* is very abundant on the present reefs surrounding Vitilevu and, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 245, 1931), has been reported from the upper Miocene of Java and the Quaternary of Celebes.

Cypraea (Cypraea) species.

A fragmentary outer lip of a large species of *Cypraea* was collected from the conglomerate at Station 160. It bears a general resemblance to the Recent *C. tigris* but has more numerous teeth. It also resembles the rare *C. aurantia* Martyn, another large Recent species that occurs in Fiji, but the teeth on the fossil species are less sharply elevated than those on *C. aurantia.* The fossil, however, is somewhat worn, which may explain the apparent difference.

Section TALPARIA Troschel

Talparia Troschel, Das Gebiss der Schnecken zur Begründung einer natürlichen Classification, vol. 1, pp. 204, 206, 1863.

Type (by subsequent designation, following virtual tautonymy, Schilder, 1926), *Cypraea talpa* Linnaeus. Recent, Indo-Pacific (*fide* Woodring, 1928).

Cypraea (Talparia) isabella lekalekana Ladd, new subspecies (pl. 38, figs. 9-12).

Shell small to medium in size, moderately inflated, thick, smooth; flattened dorsally near the middle, thence sloping steeply to the posterior extremity and somewhat more gently to the anterior end; spire entirely covered. Aperture subcentral, narrow, and gently curved. Fossula deep, basal columellar fold heavy; teeth fine and exceedingly numerous, those on the inner lip not crossing the columellar furrow, though posteriorly the inner margin of the inner lip is dentate. The holotype shows 41 teeth on the outer lip and about the same number on the inner; the paratype, a smaller and less well-developed shell, has only 35 teeth on the outer lip and 34 on the inner.

Measurements of the holotype (B. P. Bishop Mus., Geol. no. 1148) are: length 37.0 mm., lateral diameter 23.5 mm., dorsoventral diameter 20.7 mm. Paratype (B. P. Bishop Mus., Geol., no. 1149) measures: length 24.0 mm., lateral diameter 14.0 mm., dorsoventral diameter 12.0 mm.

Type locality, Station 160.

This form is very closely related to *C. isabella* Linnaeus, which occurs in Fiji today, and which Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 244, 1931) states has also been reported from the Quaternary of Celebes; but the fossils are proportionately shorter and thicker, have more gently tapering extremities, and a less straightened aperture. The young shell more closely resembles *C. isabella* than does the larger and more fully developed holotype.

Subgenus EROSARIA Troschel

Erosaria Troschel, Das Gebiss der Schnecken zur Begründung einer natürlichen Classification, vol. 1, pp. 205, 210, 1863.

Section EROSARIA sensu stricto

Type (by virtual tautonymy), *Cypraea erosa* Linnaeus. Recent, Indo-Pacific. Also reported from lower Miocene and younger beds in Java and elsewhere in the southwest Pacific (*fide* Van der Vlerk).

Cypraea (Erosaria) agassizi Ladd, new species (pl. 39, figs. 3-5).

Shell small, globose, smooth; ventral surface gently convex as seen from the side; lips more strongly arched as seen from the anterior or posterior position; sides and dorsal surface of shell highly and rather uniformly arched. On the dorsal surface, immediately above the terminations of the outer lip, a series of shallow pits extends along the side of the shell. A similar series is barely recognizable on the opposite side, above the inner lip. Spire entirely concealed, a large lump of callus lying next to its place of concealment and immediately above the extremity of the outer lip. Fossula moderately wide and deep, somewhat constricted near its outer end, thence broadening and extending entirely across the inner lip. Columellar furrow broad and shallow anteriorly, becoming indistinct and finally disappearing posteriorly. Teeth widely spaced and strongly elevated, those near the center of the inner lip being shorter than those near the extremities; 18 teeth present on the outer lip, and on the inner lip 15 may be counted posterior to the fossula. On the inner lip the four teeth nearest to the fossula cross the columellar furrow though almost obliterated near the center of the depression; posterior to these the columella is smooth. Aperture narrow, noticeably curved, slightly wider anteriorly.

Holotype (B. P. Bishop Mus., Geol. no. 1152): length 13.9 mm., lateral diameter 9.5 mm., dorsoventral diameter 7.8 mm.

Type locality, Station 160.

The Fijian species bears a general resemblance to *C. staphylaea* Linnaeus, a Recent Indo-Pacific shell which, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 245, 1931), has also been reported from the Quaternary of Celebes, but is specifically distinct even from the smooth varieties of that highly variable species. The fossil is smaller, proportionately shorter, more highly inflated, and has a more strongly curved aperture than *C. staphylaea*. The series of marginal pits are much better developed on the Recent species, and the middle teeth of its inner lip are only half as long as those nearer the extremities, whereas on the fossil this difference in length, though noticeable, is not nearly so pronounced.

Section MONETARIA Troschel

Monetaria Troschel, Das Gebiss der Schnecken zur Begründung einer natürlichen Classification, vol. 1, pp. 205, 212, 1863.

Type (by virtual tautonymy), *Cypraea moneta* Linnaeus. Recent, Indo-Pacific.

Cypraea (Monetaria) annulus sosokoana Ladd, new subspecies (pl. 39, figs 6-8).

Shell small, broadly ovate in outline, moderately inflated, spire concealed; sides steep and thickened near the margin by a deposit of callus; aperture narrow, very slightly expanded anteriorly, nearly straight; teeth elongate, strong, and sharply elevated, about a dozen on each lip; columella smooth.

Holotype (B. P. Bishop Mus., Geol. no. 1147): length 16.0 mm. (incomplete), lateral diameter 12.6 mm., dorsoventral diameter 8.6 mm.

Type locality, Station 160.

This species is apparently very closely related to *C. annulus* Linnaeus, a widespread Indo-Pacific species that is very abundant on Vitilevu's reefs to-day. Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 243, 1931) states that *C. annulus* has also been reported from the Miocene of Java, the upper Miocene or Pliocene of Timor, and the Quaternary of Celebes. The chief points of difference are found in the aperture, which in the fossil form is very narrow, nearly straight, and but little expanded anteriorly.

Subfamily TRIVIINAE

Genus TRIVIA ("Gray") Broderip

Trivia Broderip, Penny Cycl., vol. 8, p. 256, 1837.

Subgenus TRIVIA sensu stricto

Type (by subsequent designation, Gray, 1847), *Cypraea europea* Montagu (= *Voluta jonensis* Pennant). Recent, seas of Europe (*fide* Woodring, 1928).

Trivia (Trivia) koroensis Ladd, new species (pl. 39, figs. 9, 10).

Shell small, ovate, moderately inflated; aperture narrow, slightly expanded anteriorly, straight except for slight bend near the concealed spire. Dorsal groove broad and shallow; threads strong and numerous without any tendency toward granulation.

Holotype (B. P. Bishop Mus., Geol. no. 1151): length 4.7 mm., lateral diameter 3.2 mm., dorsoventral diameter 2.9 mm. Paratype (deposited in U. S. Nat. Mus., Cat. no. 372674): length 3.9 mm., lateral diameter 2.7 mm., dorsoventral diameter 2.4 mm.

Type locality, Station 160.

T. koroensis is closely related to *T. oryza* Lamarck, a Recent Indo-Pacific species, but is smaller and has a narrower and straighter aperture.

The sides of the holotype of *T. koroensis* are slightly more straightened than those of the paratype, which are more nearly globose.

Family TONNIDAE ("DOLIIDAE")

Genus TONNA Brünnich

Tonna Brünnich, Zool. Fund., p. 248, 1771.

Type (*fide* Suter), *Buccinum galea* Linnaeus. Recent, Mediterranean Sea.

Tonna? species (pl. 39, fig. 11).

Shell small, spire moderately high, last whorl marked by about 16 broad spiral bands which are wider than the interspaces and are clearly distinguishable on the internal mold of the body whorl; columella incomplete but apparently long and only slightly twisted. Length 45.9 mm., diameter 35.1 mm.

This species is represented by a single imperfect specimen (Bishop Mus., Geol. no. 1118) in the collection from Station 158. The outer lip prominently lirate within, and apparently the inner lip was not strongly folded. These facts together with the general shape of the mold suggest that the species is a *Tonna* rather than a *Malea*. Unfortunately the outer lip is not preserved, so that this question can not be settled with certainty.

Family Cassididae

Genus **CASSIS** Scopoli

Cassis Scopoli, Introd. Hist. Nat., p. 393, 1777.

Type (by subsequent designation, Montfort, 1810), *Buccinum cornutum* Linnaeus (*fide* Grant and Gale). Recent, Indo-Pacific. Also reported from Miocene of Java by Martin (Die Tertiärschichten auf Java, p. 45, 1880).

Cassis species.

Shell large, heavy, conical, spire moderately low. Aperture long and narrow, emarginate below; margin of inner lip straightened, surface concave, heavily callused anteriorly but thinning above, columella plicate. Heavy varices at intervals.

The above remarks are based on a single internal mold on which the original shell of the columella and inner lip is preserved. Measurements: height 145 mm., diameter 116 mm.

Locality, limestone in the Suva formation at the head of Walu Bay (Station 295 of Ladd). Collected by Sir Henry Berkeley and presented to Prof. Alexander Agassiz.

The single specimen is too incomplete for specific determination. Its general appearance is that of the genotype, but the margin of its inner lip is straight or very slightly convex, whereas that of the genotype is distinctly concave along the anterior half of the aperture.

Genus **SEMICASSIS** Mörch

Semicassis Mörch, Cat. Conchyl. D. A. d'Aguirra et Gadea, Comes de Yoldi, p. 112, 1852.

Type (by subsequent designation, G. F. Harris, 1897), *Cassis japonica* Reeve. Recent, Japan (*fide* Woodring, 1928). Pliocene, Seran (*fide* Van der Vlerk).

Semicassis (Semicassis) vavakuana Ladd, new species (pl. 39, fig. 12).

Shell medium-sized, moderately inflated, spire low, shoulder strong; aperture elongate, narrowed posteriorly, wide anteriorly and reflected as a short, deep canal; siphonal fasciole much inflated. Inner lip thick and heavily callused, its margin detached from the body whorl below; inner margin of inner lip bearing a series of ridges which are long and irregular near the base, inconspicuous immediately above the base, and again prominent posteriorly. Outer lip greatly thickened, reflected, marked by long lirae within. Sculpture of body whorl below shoulder consisting of uniformly narrow, flattened, spiral bands crossed by a few fine axial striae; shoulder nodose or bordered by an elevated rim; above the shoulder on the body whorl the spiral bands are irregularly spaced and are beaded by axial striae; spire cancellated; suture carinated; 2 or 3 smooth, rounded varices present. The holotype retains some of its original color, the body whorl being brown, the lips yellowish.

Holotype (B. P. Bishop Mus., Geol. no. 1206): length 35.0 mm., diameter 22.9 mm. A paratype (B. P. Bishop Mus., Geol. no. 1207) is incomplete but compares favorably in size with the holotype.

Type locality, Station 59.

The fossil species is smaller, heavier, much less inflated, and has a stronger shoulder than *S. japonica,* the type of the genus. It is more closely related to *S. exarata* (Reeve), a larger Recent species, but has much finer sculpture.

Family Bursidae

Genus GYRINEUM Link

Gyrineum Link, Beschr. der Nat.-Samml. der Univ. Rostock, pt. 3, p 123, 1807.

Type (by subsequent designation following virtual tautonymy, Dall, 1904), *Murex gyrinus* Linnaeus (*fide* Stewart, 1926). Recent, southwest Pacific. Also reported from the Miocene of Java and the Quaternary of Celebes (*fide* Van der Vlerk).

Gyrineum species (pl. 39, fig. 13).

Shell small, spire elevated, pyramidally ovate in outline, with two rows of continuous lateral varices. Aperture subcircular, continued anteriorly as a short, slightly curved canal that is almost completely roofed over; inner lip callused, crenulated; outer lip with an elevated margin, crenulated within. Sculpture consisting of alternating spiral ribs and striae which override prominent axial ribs; fine axial striae are also present; on the earlier whorls the spiral ribs are somewhat beaded. The single shell at hand seems to show traces of a uniform brown coloration.

Measurements of the slightly broken figured specimen (B. P. Bishop Mus., Geol. no. 1222) are: length 18.2 mm., diameter 11.6 mm.

Locality, Station 304.

The fossil closely resembles the genotype, *G. gyrinus,* which is a common species on the shores of Vitilevu today. The single fossil is small and may represent a young individual, but its axial ribs are fewer than on specimens of the genotype and even the earlier whorls are not distinctly beaded; also, the anterior canal is straighter in the fossil shell.

The Fijian fossil appears to be identical with specimens of an unnamed (and apparently undescribed) species from the Philippine Islands (U. S. Nat. Mus., Cat. No. 283665), but accurate identification and complete description of the fossil must await additional material.

Family CYMATIIDAE

Genus SEPTA Perry

Septa Perry, Arcana, pl. 2, Jan. 1, 1810.

Type (by monotypy), *Septa scarlatina* Perry (= *Murex rubecula* Linnaeus) (*fide* Grant and Gale). Recent, south Pacific. Also reported from the Quaternary of Celebes (*fide* Van der Vlerk).

Septa rubecula (Linnaeus), new subspecies? (pl. 39, figs. 14, 15).

Shell medium in size, elongate, thick. Aperture ovate, contracted below into a short, open, slightly recurved canal; inner lip callused, the callus thick anteriorly with a series of sharp denticles that are not a reflection of the spiral sculpture; posteriorly the callus is thinner, its margin less distinct and its surface fails to obliterate the spiral ribs. Outer lip solid with a thickened margin, bearing eight prominent denticles on its inner surface. Body whorl moderately inflated with a strong axial varix opposite the outer lip. Sculpture consisting of sharply elevated spiral ribs beaded by axial lines. Between each 2 ribs there are 2 or more fine spiral striae, and each rib divides into 2 parts on the crests of the varices.

The figured specimen (B. P. Bishop Mus., Geol. no. 1210) shows only the body whorl. It measures 21.6 mm. in diameter.

Locality, Station 160.

The fossil shell agrees with Recent shells from Fiji in all important features but shows minor differences in sculpture. As only one incomplete fossil specimen was collected, these differences hardly justify the application of a new varietal name. The spiral ribs and striae of the fossil are much sharper and much more distinct than those of the Recent shells, and the beads on the ribs caused by the crossing of axial lines are more angular than on Recent shells.

Superfamily RACHIGLOSSA

Family THAIDIDAE

Genus THAIS sensu lato

Thais Roeding, Mus. Boltenianum, pt. 2, p. 54, 1798.

Type (by subsequent designation, Iredale, 1915), "*T. neritoides* = *M. fucus* Gmelin" (cited by Roeding as *Thais lena*) (*fide* Stewart, 1926). Recent, Cape Verde and Ascension Islands.

"Thais" species (pl. 40, figs. 1, 2).

The family Thaididae is represented by a single shell which is too badly worn to be accurately determined even generically. Important features still observable are as follows:

Shell small, spire moderately high, body whorl inflated. Aperture large, semiovate, produced anteriorly into a short canal; outer lip thick and apparently lirate within; inner lip wide and slightly concave; siphonal fasciole inflated. Sculpture consisting of strong spiral cords crossed by fine axial striae; large worn nodes are present on the body whorl. Length 19.7 mm., diameter 15.3 mm. Cataloged as B. P. Bishop Mus., Geol. no. 1224.

Locality, Station 59.

The subgenus *Thais* sensu stricto includes low-spired species with heavy tubercles. The Fijian fossil does not belong in *Thais* sensu stricto.

Family MURICIDAE

Genus MUREX Linnaeus

Murex Linnaeus, Syst. Nat., 10th ed., p. 746, 1758.

Subgenus MUREX sensu stricto

Type (by subsequent designation, Montfort, 1810), *Murex pecten* Montfort (= *M. tribulus* Linnaeus). Recent, Indo-Pacific (*fide* Woodring, 1928). Also reported from the Quaternary of Celebes (*fide* Van der Vlerk).

Murex (Murex) aff. **recurvirostris** Broderip (pl. 40, figs. 3-5).

(The citations for this species have been taken from Woodring, who states that they cover only the original publications, the records for Caribbean fossils, and the more accessible manuals.)

Murex recurvirostris Broderip, Zool. Soc. London, Proc., p. 174, 1832. Reeve, Conch. Icon., vol. 3, *Murex,* fig. 75, 1845. Sowerby, Thes. Conchyl., *Murex,* pl. 11, fig. 15, 1879. Gabb, Am. Philos. Soc., Trans., new ser., vol. 15, p. 201, 1873. Tryon, Man. Conch., vol. 2, pp. 80-82, pl. 11, fig. 193; pl. 12, figs. 124-125, 1880. Pilsbry, Acad. Nat. Sci. Phila., Proc., vol. 73, p. 353, 1922. Woodring, Carnegie Inst. Washington, Pub. 385, p. 288, 1928.

Murex nigrescens Sowerby, Conch. Illustr., *Murex,* fig. 113, 1834. Sowerby, Zool. Soc. London, Proc., p. 138, 1840. Reeve, Conch. Icon., vol. 3, *Murex,* fig. 92, 1845. Sowerby, Thes. Conchyl., *Murex,* pl. 11, fig. 18, 1879.

Murex messorius Sowerby, Conch. Illustr., *Murex,* fig. 93, 1834. Sowerby, Zool. Soc. London, Proc., pp. 137-138, 1840. Reeve, Conch. Icon., vol. 3, *Murex,* fig. 90, 1845. Sowerby, Thes. Conchyl., *Murex,* pl. 11, fig. 20, 1879. Dall, Mus. Comp. Zoology, Harvard, Bull., vol. 18, p. 196, 1889. Dall, Wagner Free Inst. Sci., Trans., vol. 3, pt. 1, p. 139,

1890. Dall and Simpson, U. S. Fish Comm., Bull., vol. 20, pt. 1, p. 407, 1901. Brown and Pilsbry, Acad. Nat. Sci. Phila., Proc., vol. 63, p. 353, 1911. Maury, Bull. Am. Paleont., vol. 5, p. 265, pl. 42, figs. 1-2, 1917. Maury, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Islands, vol. 3, pt. 1, pp. 63-64, 1920. Olsson, Bull. Am. Paleont., vol. 9, p. 303, 1922. Maury, Brasil Serv. Geol. e Min., Mon., vol. 4, pp. 136-139, pl. 6, fig. 5, 1925.

Murex domingensis Guppy (not Sowerby), Geol. Soc. London, Quart. Jour., vol. 22, p. 288, 1866. Guppy (part, not Sowerby), Geol. Mag., decade 2, vol. 1, p. 438 (list), 1874. Dall, Wagner Free Inst. Sci., Trans., vol. 3, pt. 6, p. 1584 (list), 1903.

?Murex sutilis White, Mus. Nac. Rio de Janeiro, Archiv., vol. 7, pp. 137-138, pl. 11, fig. 11, 1887. Maury, Brasil Serv. Geol. e Min., Mon., vol. 4, pl. 6, fig. 10, 1925.

Shell medium in size, ovate to fusiform, whorls moderately inflated. Aperture ovate, prolonged anteriorly as a narrow canal which is almost completely roofed over. Margins of inner and outer lips free, the inner margins of both bearing elongated denticles. Each whorl with three prominent varices which, on the body whorl, converge to the base of the anterior canal. Low, rounded axial ribs are present between the varices, their number increasing on the later whorls, 5 being present between each 2 varices on the body whorl. Varices and ribs overridden by alternating spiral cords and threads, the former in some cases producing short hollow spines on the varices, these spines being open on the older or last-formed side of each varix. There are 5 or 6 spiral cords on the penult whorl.

Measurements of the larger of the two figured specimens (B. P. Bishop Mus., Geol. no. 1208) are: length (anterior canal incomplete) 39.1 mm., diameter 30.7 mm. The smaller specimen (B. P. Bishop Mus., Geol. no. 1209) measures: length (anterior canal broken at tip) 30.1 mm., diameter 16.7 mm.

Localities, Stations 59 and 165.

The above description is based on three fossils that appear to be conspecific though exhibiting minor differences in size and sculpture. They belong to a small group of closely related species widely distributed in the Pacific and in the West Indies. The Fijian fossils appear to be most closely related to *M. recurvirostris* Broderip, a variable species which has lived in the West Indian region since the lower Miocene and which also occurs today on the Pacific side of Central America. The Fijian form is probably not identical with the American species, but it is impossible to say definitely because no one of the fossil specimens shows a complete anterior canal. As they do show some variation among themselves, additional specimens will be needed to determine the limits of this variation. The Fijian fossils have more numerous axial ribs than Miocene specimens of *M. recurvirostris* from Bowden, Jamaica. The single Fijian specimen which retains a fair portion of the columellar side of the anterior canal does not show the "drooping spines" which characterize the Bowden shells. In other respects, however, the two groups of shells are remarkably alike.

The Fijian specimens are probably identical with an unnamed Recent shell in the U. S. National Museum (one of the two specimens cataloged as No. 230422), from the Philippine Islands, though the Recent shell has axial ribs that are less well defined than those of the Fijian specimens.

The Fijian specimens strongly resemble *M. rectirostris* Sowerby, a Recent species reported from the Indo-Pacific area, but that species has strong, curved, closed spines on the varices and, of the several specimens examined, only one shows any trace of the denticles of the inner lip. *M. nodatus* Reeve is another closely related form, but it is strongly spinose, as is *M. rectirostris*, and the varix along the columellar side of its canal bears drooping spines. The Fijian fossils also find a close relative in *M. bantamensis* Martin, which is said to occur in the upper Miocene and Pliocene of Java and in the upper Miocene of Timor (Van der Vlerk, Leidsche Geolog. Mededeel., vol. 5, pp. 236, 288, 1931).

Family Nassaridae

Genus PHOS Montfort

Phos Montfort, Conchyl. Syst., vol. 2, p. 495, 1810.

Type (by monotypy), *Murex senticosus* Linnaeus (*fide* Stewart, 1926). Recent, southwest Pacific

Phos vitiensis Ladd, new species (pl. 40, fig. 6).

Shell small, solid, whorls but little inflated, spire moderately high, sutures impressed. Aperture narrow, slightly longer than half the length of the shell; inner lip with a heavy callus below which thins above, its margin becoming indistinct; columella with three prominent, subequal folds; outer lip strongly lirate within, its margin thin and slightly crenulated by the spiral sculpture of the body whorl; anterior canal short, basal notch moderate; siphonal fasciole weak. Sculpture consisting of numerous prominent axial ribs crossed by spiral bands and threads; three ribs on each whorl slightly larger than the others.

Holotype (B. P. Bishop Mus., Geol. no. 1165): length 18.0 mm., diameter 9.5 mm., length of aperture 9.9 mm. Topotype in U. S. National Museum (Cat. no. 372680).

Localities: holotype from Station 165; also found at Station 304.

The fossil differs greatly from the Recent genotype and should, perhaps, be placed in a separate subgenus. It has more prominent columellar folds, a shorter and less twisted anterior canal, a narrower aperture, and its whorls are not shouldered, as are those of the type.

Family Mitridae

Genus MITRA Martyn

Mitra Martyn, Universal Conchologist, vol. 1, explanatory table, pl. 19, 1784.

Subgenus TIARA Swainson

Tiara Swainson, Zool. Illustr., 2d ser., vol. 2, explanation of pl. 50 (Mitranae, pl. 5), 1831.

Type (by subsequent designation, Herrmannsen, 1849), *Tiara isabella* Swainson. Recent, China (*fide* Woodring, 1928).

Key to the Vitilevu Species

Axial threads not overriding spiral ribs.................................**M. (T.) fijiensis**
Axial threads overriding spiral ribs.................................**M. (T.) nasongoensis**

Mitra (Tiara) fijiensis Ladd, new species (pl. 40, fig. 7).

Shell small, slender, spindle-shaped, base of body whorl slightly constricted, whorls somewhat inflated immediately below the suture. Aperture narrow, elongate, its length exceeding half the total length of the shell, interior of outer lip smooth except for the margin, which is faintly crenulated. Siphonal notch narrow and deep, siphonal fasciole low. Columella with six oblique folds that become increasingly strong posteriorly. Inner lip covered by a layer of callus which thins posteriorly but has a fairly distinct margin. Sculpture consisting of strong spiral ribs and axial threads; 4 ribs are present on each whorl of the spire and 12 on the body whorl; traces of spiral threads—one between each pair of ribs—are recognizable on the posterior portion of the body whorl. Numerous fine axial threads occupy the spaces between the ribs.

Holotype (B. P. Bishop Mus., Geol. no. 1214): length 19.3 mm., diameter 6.4 mm.

Type locality, Station 165.

Mitra fijiensis is very closely related to *M.* (*Tiara*) *sokkohensis,* described by Martin from the lower Miocene (West-Progo beds) of Java (Die Altmiocäne Fauna des West-Progogebirges auf Java: Reichs. Geol.-Min. Mus. Leiden, Samml., new ser., vol. 2, pt. 6, p. 236, pl. 1, figs. 29, *a,* 30, 1916). The Java species has 5 spiral ribs on each whorl of the spire, the Fijian species only 4. *M. flammea* Quoy and Gaimard is a more robust shell, which lives today in the southwest Pacific and, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 225, 1931), has been reported from the upper Miocene and Pliocene of Java and several of the nearby islands. Specimens of the Recent *M. filaris gracilis* Philippi are larger, more slender, and have a much thinner callus on the inner lip.

Mitra (Tiara) nasongoensis Ladd, new species (pl. 40, fig. 8).

Shell small, slender, spindle-shaped, base of body whorl constricted. Aperture narrow, elongate, its length equal to half the total length of the shell; interior of outer lip smooth except for the margin, which is faintly crenulated. Siphonal notch narrow and deep. Columella with four (possibly more) oblique folds that become increasingly strong posteriorly. Inner lip covered by a layer of callus which thins posteriorly but has a fairly distinct margin. Sculpture consisting of spiral ribs—some of which are double—and axial threads; 4 ribs are present on each whorl of the spire, the upper 2 ribs being double; more than a dozen are present on the body whorl, the 2 posterior ones and 2 others near the middle of the whorl being double. Numerous fine axial threads occupy the space between the ribs and override the ribs.

Holotype (B. P. Bishop Mus., Geol. no. 1215): length 18.4 mm., diameter 5.9 mm.

Type locality, Station 165.

M. nasongoensis occurs with *M. fijiensis* Ladd, new species, but may be easily distinguished from it by its uninflated whorls, the greater constriction at the base of its body whorl, and its finer sculpture, particularly by the fact that its axial threads override the spiral ribs.

Genus VEXILLUM ("Bolten") Roeding

Vexillum Roeding, Mus. Boltenianum, pt. 2, p. 138, 1798.

Subgenus VEXILLUM sensu stricto

Type (by subsequent designation, Woodring, 1928), *Vexillum plicatum* ("Bolten") Roeding (= *Voluta plicaria* Linnaeus). Recent, Indo-Pacific.

Vexillum (Vexillum) gembacana (Martin) (pl. 40, fig. 9).

Mitra javana Martin (in part), Die Tertiärschichten auf Java, p. 27, pl. 6, fig. 2, *a*, 1879-1880.

Mitra (Turricula) gembacana Martin, Reichs. Geol.-Min. Mus. Leiden, Samml., 1st ser., vol. 3, p. 91, pl. 5, fig. 92, 1881-1889.

Turricula (Vulpecula) gembacana Martin, Die Fossilien von Java, new ser., vol. 1, pt. 1, p. 81, pl. 12, fig. 181, 1895, and vol. 1, pt. 2, no. 3, p. 454, pl. 58, figs. 24, 25, 1921.

Turricula gembacana Van der Vlerk, Leidsche Geolog. Mededeel., vol. 5, p. 227, 1931 (for additional references).

Shell small, slender, spindle-shaped; aperture narrow, elongate, less than half the total length, slightly channeled posteriorly, and produced into a short recurved canal anteriorly. Outer lip lirate within, inner lip covered by thick parietal callus, umbilical groove narrow, deep. Columella with three oblique folds which increase in strength and become more nearly horizontal posteriorly. Sculpture consisting of strong, rounded slightly curved axial ribs, about a dozen to each whorl, and fine spiral striae in the areas between the ribs.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1193) are: length (base slightly broken) 14.6 mm., diameter 4.8 mm.

Localities, Stations 59 and 165. In Java the species occurs in the lower Miocene (Rembang and Njalindoeng beds) and upper Miocene (Tjilanang beds). According to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, p. 227, 1931), it has also been reported from the upper Miocene (?) and Pliocene of Timor, the Pliocene of Seran, and the Quaternary of Celebes.

The species does not have a wide anal fascicle as does the genotype, and its columella has only three folds; hence, it probably does not belong in the section *Vexillum* sensu stricto.

Family Olividae

Genus OLIVA Martyn

Oliva Martyn, Universal Conchologist, vol. 3, explanatory table, pl. 3, 1786.

Type (by subsequent designation, Dall, 1905), *Oliva corticata* Martyn [= *Oliva incrassata* Solander (*O. angulata* Lamarck) ?]. Recent, "coasts of Guinea" (*fide* Woodring, 1928).

Key to Vitilevu Species

Spire moderately high...**O. carneola**
Spire low
  Sutural callus projecting above apex of spire......................**O. woolnoughi**
  Sutural callus not projecting above apex of spire................**O. makawana**

Oliva carneola (Gmelin) (pl. 40, fig. 10).

Voluta carneolus Gmelin, Syst. Nat., 12th ed., p. 3443, 1792.

Oliva carneola Lamarck, Mus. Hist. Nat. Paris, Ann., vol. 16, p. 321, 1811. Reeve, Conch. Icon., vol. 6, *Oliva,* pl. 22, no. 60, 1851. Marrat, Thes. Conchyl., *Oliva,* p. 20, pl. 342, figs. 333-335, 1871. Tryon, Man. Conch., vol. 5, p. 87, pl. 33, fig. 52, 1883.

Shell small, slender, cylindrical, sides gently convex, surface smooth and polished. Spire moderately elevated, aperture elongate, very narrow, channeled above, emarginate below; siphonal fasciole wide, bounded above by a faint ridge; parietal callus thick, plaits very strong.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1218) are: length 14.7 mm., diameter 6.9 mm.

Locality, Station 160. The Recent shells are widely distributed in Polynesia and Melanesia, being very abundant on the shores of Vitilevu. According to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, pp. 222, 288, 1931), the species was collected in Timor in rocks which Leupold believed to be "Jong-Neogeen" (Tertiary *f*-3 of Van der Vlerk-Umbgrove subdivisions). It is also said to occur in the Miocene-Pliocene rocks of New Guinea (Chapman, F., Oil exploration work in Papua and New Guina . . . , vol. 3, p. 48, 1931).

The single fossil is somewhat more slender than the average of the Recent shells.

Oliva woolnoughi Ladd, new species (pl. 41, fig. 1).

Shell medium in size, cylindrical, stout, rectangular in outline, surface smooth and glossy. Spire very low, covered by callus, suture between body whorl and spire deeply channeled, sutural callus exceedingly thick, projecting to a point higher than the apex of the spire; aperture elongate, base emarginate, outer lip thickened, siphonal fasciole wide, its upper margin distinct, parietal callus thick with numerous heavy plaits. Irregular blotches of yellowish-brown color are preserved on a few specimens.

Holotype (B. P. Bishop Mus., Geol. no. 1219): length 23.6 mm., diameter 13.0 mm. Topotype in U. S. National Museum (Cat. no. 372681).

Localities: holotype from Station 59; a single specimen was collected from Station 303.

The species resembles the specimens referred by Martin to *O. funebralis* Lamarck (Martin, K., Die Tertiärschichten auf Java, p. 16, pl. 2, fig. 14, *a*, 1879-80), but the Fijian shells are stouter, have more straightened sides, and a thicker sutural callus.

Oliva makawana Ladd, new species (pl. 40, fig. 11).

Shell small, cylindrical, rather stout, surface smooth and polished. Spire low, suture deeply channeled on all whorls, not filled by sutural callus; aperture elongate, channeled above, base emarginate, siphonal fasciole wide, parietal callus heavy, plaits strong.

Holotype (B. P. Bishop Mus., Geol. no. 1220): length 17.2 mm., diameter 8.8 mm.

Localities: holotype from Station 304; also represented at Stations 59 and 165.

This species is smaller than *O. woolnoughi* Ladd, new species, has a higher spire, a thinner sutural callus, and less straightened sides than that species.

Superfamily Toxoglossa

Family Cancellaridae

Genus CANCELLARIA sensu lato

Cancellaria Lamarck, Soc. Hist. Nat. Paris, Mem., p. 71, 1799.

Type (by monotypy), *Voluta reticulata* Linnaeus. Recent, Florida and West Indies (*fide* Woodring, 1928).

Cancellaria tholoensis Ladd, new species (pl. 41, fig. 2).

Shell medium in size, ovate, thick, whorls rather strongly inflated, sutures deep. Aperture lenticular in outline; outer lip flaring, directed obliquely backward and indented near the base by a broad, shallow sinus, lip margin beveled and strongly lirate within; columella with three strong subparallel primary folds and several obscure secondary ones between and above them. Inner lip heavily callused below where its surface is somewhat pustulose, callus thin above, failing to obliterate the sculpture of the shell; siphonal fasciole broad, a narrow umbilical groove lying between it and the detached margin of the inner lip. Sculpture consisting of two series of flat-topped spiral ribs with fine striae between them; the larger series are somewhat beaded by strongly retractive axial cords.

Holotype (B. P. Bishop Mus., Geol. no. 1213): length 28.4 mm., diameter 19.4 mm.

Type locality, Station 59.

The type of *Cancellaria* sensu stricto is an American shell and it is very doubtful that the Fijian species can be referred to the restricted group which it typifies. Of the various species available for comparison the fossil appears closest to the genotype, *C. reticulata*, but there are a number of differences:

1, the two upper columellar folds in the fossil are not distinctly bifid though they are paralleled by obscure secondary folds; 2, the internal lirae of the outer lip are not nodose near the edge of the lip; 3, the edge of the outer lip is flaring; and 4, the axial cords are more oblique or retractive than on the Recent species.

Family CONIDAE

Genus CONUS Linnaeus sensu lato

Conus Linnaeus, Syst. Nat., 10th ed., p. 712, 1758.

Type (by subsequent designation, Children, "1823"), *Conus marmoreus* Linnaeus. Recent, Indo-Pacific seas (*fide* Woodring, 1928). Also reported from the Quaternary of Billiton, in the Java Sea (*fide* Van der Vlerk).

Conus affinis Martin (pl. 41, fig. 3).

Conus affinis Martin, Die Tertiärschichten auf Java, p. 15, pl. 2, fig. 8, *a*, 1879-80.

Shell small, stout, inflated, spire high and deeply concave in outline, shoulder rounded, body whorl convex above, concave below. Aperture narrowed and channeled posteriorly, widening anteriorly; siphonal fasciole very slightly bulging. Anal notch shallow, anal fasciole flat, smooth. Sculpture of body whorl consisting of a series of deep spiral grooves near the base. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1212): length 16.9 mm., diameter 10.8 mm.

Locality, Station 59.

The specimens appear to be identical with the type material described and figured by Martin from the upper Miocene of Java. Both the Fiji and the Java specimens show traces of brown color.

Conus pertusus? Hwass.

Two perfectly preserved specimens, which probably may be referred to this Pacific species, were found in the marl beds at Station 311. The general form and coloration is that of *C. pertusus* and the shells are well striated, but the characteristic punctae are well developed only near the aperture—not over the entire body whorl. The beds at Station 311 are not older than late Pleistocene.

Conus pulicarius? Hwass (pl. 41, fig. 4).

Conus pulicarius Hwass, Encyclopédie méthodique, Histoire naturelle des vers, vol. 1, pt. 2, p. 622, 1792 (*fide* Reeve). Reeve, Conch. Icon., vol. 1, pl. 17, fig. 94, 1843. Tryon, Man. Conch., vol. 6, p. 19, pl. 5, fig. 69, 1884.

The following description is based on a single fossil specimen:

Shell medium-sized, thick, shoulders rounded and bearing a series of prominent nodes, sides gently convex, spire moderately high and slightly concave. Aperture narrow, widening anteriorly. Anal notch moderately deep, anal fasciole concave and spirally striate, two striae being more prominent than the others. Sculpture consisting of spiral grooves on the anterior third of the shell. Traces of the original color pattern indicate that the shell was white with regularly spaced spiral rows of red or brown elongate spots.

Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1167) are: height 26.9 mm., diameter 17.4 mm.

Locality, Station 160.

The single fossil specimen tentatively referred to *C. pulicarius* has an incomplete outer lip. It is smaller than the Recent forms collected from Vitilevu and has a slightly different color pattern, the spots on the fossil being more elongate and more regularly spaced. Also, the striae on the anal fasciole of the Recent shells are all nearly equal in size, whereas on the fossil two striae are larger than the others, the outermost one being the largest of all.

Conus species **A.**

The flattened spire of a large cone was found in the conglomerate at Station 160. It measures 48.9 mm. in diameter but is somewhat broken near the aperture. Its general form is that of *C. literatus* Linnaeus, a Recent Indo-Pacific shell that occurs on the reefs of Vitilevu today and has been reported from the upper Tertiary of Timor, according to Van der Vlerk (Leidsche Geolog. Mededeel., vol. 5, pp. 214, 288, 1931).

Conus species **B** (pl. 41, fig. 5).

Shell medium-sized, slender, biconic, the height of the spire being only slightly less than one third of the total height, shoulders strong and but little rounded, sides of spire straight, sides of body whorl straight or slightly concave. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1166) are: height 28.8 mm., diameter 12.3 mm., height of spire 8.8 mm.

Locality, Station 303.

The description is based on a single internal mold. This species differs from the other fossil cones from Vitilevu in its slenderness and in the remarkable height of its spire. Identification must await better material, but its general shape and proportions can be duplicated in Australian examples of *C. anemone* Lamarck (for example, Cat. No. 304459, U. S. Nat. Mus.).

Conus species **C** (pl. 41, figs. 6, 7).

Shell medium-sized, spire straight and moderately high, shoulder angular, sides of body whorl gently convex, aperture wide, expanding slightly anteriorly. Sculpture consisting of prominent nodose spiral ribs, alternate ribs being larger and more nodose than those intervening; depressions between ribs crossed by fine, close-set striae. Measurements of the figured internal mold are: height 39.5 mm., diameter 22.9 mm.

Localities: marl near the coast 3 miles east-southeast of Thuvu, at an elevation of 10 feet above high tide level (Station 379 of Ladd), collected by E. C. Andrews and the property of the Harvard College Museum of Comparative Zoology (loaned for study to the U. S. National Museum, where I had access to them); a badly crushed cone from Station 303 shows a similar sculpture and may represent the same species.

The description is based on an internal and external mold of a single specimen. The sculpture distinguishes it readily from the other fossil cones in the Vitilevu collections. The material is too poorly preserved to allow of specific identification, but its general form and sculpture seem to relate it to *C. granifer* Reeve and *C. sulcatus* Hwass, both of which are Recent shells from the southwest Pacific. (*C. sulcatus* has also been reported from the upper Tertiary of Java.)

Conus species **D** (pl. 41, fig. 8).

Shell small, slender, spire high and straight, shoulder subangular, sides very gently convex, aperture slightly wider anteriorly. Anal notch shallow, anal fasciole flattened or gently convex and marked with one or two spiral grooves. Sculpture of body whorl consisting of faint spiral threads that disappear on the posterior part of the whorl. Measurements of the figured specimen (B. P. Bishop Mus., Geol. no. 1211) are: length (incomplete) 24.4 mm., diameter 13.2 mm.

Locality, Station 59.

The single specimen is too badly worn for accurate determination. Its high spire suggests *C. herklotsi,* described by Martin from the Miocene of Java.

Family TEREBRIDAE

Genus TEREBRA Bruguière

Terebra Bruguière, Encyclopédie méthodique, Histoire naturelle des vers, vol. 1, p. xv, 1789 (genus without species).

Subgenus STRIOTEREBRUM Sacco

Strioterebrum Sacco, I molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 10, p. 33, 1891.

Type (by original designation), *Terebra basteroti* Nyst. Miocene, Mediterranean region (*fide* Woodring, 1928).

Terebra (Strioterebrum) species (pl. 41, fig. 9).

Shell medium-sized, slender, the sides of the spire slightly convex in outline. Aperture narrow, continued anteriorly as a moderately long canal; outer lip broken but, judging from the sculpture of the remainder of the whorl, only moderately inflected forward below the sutural band. Siphonal fasciole low; columella with two strong folds, the anterior one the wider; the area between the folds convex; inner lip thinly callused. Sculpture consisting of a sutural band and strong axial ribs, the sutural band being almost as wide as the remainder of the whorl. The figured specimen (B. P. Bishop Mus., Geol. no. 1223) was the only one found. It measures: length 26.6 mm., diameter 5.8 mm.

Locality, Station 59.

The specimen seems to be a *Strioterebrum,* as that subgenus was defined by Woodring (Carnegie Inst. Washington, Pub. 385, pp. 137, 138, 1928). The species probably is new, but the single specimen is not complete and I prefer to await more material before naming it.

Order Pteropoda

Family Cavolinidae

Key to Vitilevu Pteropods

Shell long and tubular...**Styliola acicula**
Shell in two parts, prolonged posteriorly into a short tube
  Subquadrate in outline
    Shell large..**Cavolina telemus rewaensis**
    Shell small
      Ventral part smooth
        Dorsal anterior margin not elevated............**Cavolina globulosa**
        Dorsal anterior margin elevated.........................**Cavolina** species
      Ventral part grooved...**Cavolina osoica**
  Triangular in outline...**Diacria mbaensis**

Genus STYLIOLA Lesueur

Styliola Lesueur, in Blainville, Man. de Malacol., p. 655, 1825.

Type (*fide* Dall, 1901), *Styliola recta* Lesueur. Recent, Atlantic Ocean; also reported from upper Miocene of Virginia.

Styliola acicula (Rang) (pl. 41, fig. 10).

Creseis acicula Rang, Notice sur quelques Mollusques nouveaux du genre *Cleodora*, etc., Ann. Sci. Nat., 1st ser., vol. 13, p. 318, pl. 17, fig. 6, 1828.

Cleodora acicula Souleyet, Voy. Bonite, Zool., vol. 2, p. 194, pl. 8, figs. 10-17, 1850.

Styliola recta Gray, Cat. Mollusca Brit. Mus., pt. 2, p. 18, 1850.

Clio (*Creseis*) *acicula* Pelseneer, Voy. Challenger, Zool., vol. 23, pt. 65, Pteropoda, pt. 2, pp. 51-53, 1888.

At Station 306 the Mba Valley marls contain numerous minute, needle-like, conical tubes. These tubes are straight or slightly bent, circular in section, and taper very gradually. They exhibit no sculpture except obscure lines of growth and apparently represent a *Styliola* which can not be distinguished from the Recent *S. acicula,* which occurs in warm seas the world over. The figured specimens (Bishop Mus., Geol. No. 1199) measure about 1 mm. in greatest diameter. Other specimens, in which the smaller portions of the tube are preserved, exceed 5 mm. in length. None of the fossils show the complete bulbous protoconch. The tubes are associated with numerous specimens of *Cavolina.*

Genus CAVOLINA Abilgaard

Cavolina Abilgaard, Skrivter of Naturhistorie-Selskabet, vol. 1, No. 2, pp. 174, 175, 1791.

Type (by monotypy), *Cavolina matans* Abilgaard (= *Monoculus telemus* Linnaeus). Recent, warm and temperate seas (*fide* Woodring, 1928). Also reported from Miocene and younger rocks in widely separated areas.

Cavolina telemus rewaensis Ladd, new subspecies (pl. 41, fig. 11; pl. 42, fig. 1).

Shell large, thin, globose; composed of two unequal parts, a dorsal one that is flattened and a ventral one that is greatly inflated. Dorsal part subquadrate in outline; pointed posteriorly, thence sloping rather steeply to the lateral angles; sides gently curved near the middle and deeply indented anterior to the middle; anterior margin sloping to a rounded point and reflected so as to project over the margin of the ventral part of the shell. Dorsal part marked by 3 radial ridges, the central one being only slightly more prominent than the other 2; anterior and lateral margins elevated; fine lines of growth present. Ventral part subtriangular in outline, truncated anteriorly and strongly inflated; marked only by very fine lines of growth.

The holotype (B. P. Bishop Mus., Geol. no. 1198) is a well-preserved internal mold, which measures: length (posterior spine incomplete) 14.4 mm., width 13.3 mm., height 8.0 mm. Topotype in U. S. National Museum (Cat. no. 372682).

Localities: holotype and two other molds from Station 158, in the Suva area; smaller specimens retaining the original shell from Station 306, on the opposite side of the island; internal molds which may represent the species collected by Ladd at Station 320 and by Agassiz on Walu Bay (Station 295 of Ladd).

The Cavolinas, being pelagic animals, are widely distributed and their shells vary greatly in size and to some extent in shape. The genotype, *C. telemus,* was originally described from the Mediterranean Sea, but it also occurs in the Atlantic and Pacific oceans and ranges geologically at least as far back as the Miocene. It is with some trepidation, therefore, that the writer suggests a new varietal name to a group that in the opinion of some workers is already overnamed. The Fijian fossils, however, have been compared with large collections of Recent shells and seem to show distinctive features that are worthy of recognition. Thus, the median ridge on the dorsal part of the fossil shells is much narrower and more sharply elevated than on any of the Recent shells; the fossils are proportionately wider, have steeper postero-lateral slopes, and their dorsal parts are much less inflated than the Recent shells.

Cavolina globulosa Rang (pl. 42, figs. 2, 3).

Cavolina globulosa Rang, MS., in Gray, Cat. Mollusca Brit. Mus., pt. 2, Pteropoda, p. 8, 1850 (name applied to figs. 20, 24, pl. 4, Atlas, Voy. Bonite).

Hyale globuleuse Rang, Bonite, Atlas, pl. 4, figs. 20-24, 1850.

Hyalaea globulosa Rang, in Souleyet, Voy. Bonite, Zool., vol. 2, pp. 142, 143, 1852.

Cavolina globulosa Pelseneer, Voy. H. M. S. Challenger, Zool., pt. 65, Pteropoda, pt. 2, pp. 81, 82, 1888. Meisenheimer, Deutschen Tiefsee-Expedition auf dem Dampfer Valdivia, 1898-1899: Wiss. Ergeb., vol. 9, pt. 1, p. 32, 1905.

The following description is based on the fossil material:

Shell very small, subquadrate in outline, divided into two parts, the dorsal part gently inflated, the ventral partly highly arched. Posterolateral angles about 90 degrees, posterior tube sharply recurved dorsally, lateral margins gently convex. Dorsal part elongate anteriorly, the rounded anterior margin not elevated, but strongly reflected ventrally so as to project over the truncated anterior margin of the ventral part of the shell; lateral margins of dorsal part elevated; dorsal part marked by three broad, low ridges. Ventral part marked by growth lines which are especially prominent near the base of the posterior spine and near the anterior margin. Holotype (B. P. Bishop Mus., Geol. no. 1204): length 3.6 mm., width 2.7 mm., height 2.7 mm.

Four specimens obtained from Station 306. Recent shells have been collected widely in the Indian Ocean and in the warmer parts of the Pacific.

Most Recent shells are nearly twice as large as the fossil specimens but there appear to be no other differences.

Cavolina osoica Ladd, new species (pl. 42, figs. 4, 5).

Shell small, subquadrate in outline, divided into two parts, the ventral part being much more inflated than the dorsal. Shell shouldered posteriorly, the median point being prolonged as a narrow curved tube; anterior margin of dorsal part broadly rounded and reflected ventrally so as to project over the truncated anterior margin of the ventral part of the shell. Dorsal part marked by five prominent ridges separated by grooves: the median ridge is prominent, the pair of ridges flanking it are broader and lower, the outermost pair high and narrow; some specimens show traces of an additional pair of ridges flanking those last mentioned. Ventral part with two prominent grooves diverging from the pointed posterior end and marked also by growth lines which are especially prominent anteriorly. Holotype (B. P. Bishop Mus., Geol. no. 1200); length (incomplete) 5.8 mm., width 5.4 mm., height 3.8 mm. Topotype in U. S. National Museum (Cat. no. 372683).

Localities: holotype from Station 304; also occurs at Station 306.

This species is unusual in that it shows the diverging ventral grooves that are characteristic of *Diacria*. In other respects it appears a typical *Cavolina*.

Cavolina species.

In the conglomeratic limestone at Station 158 are numerous molds of a small Cavolina which, except for their uniformly small size, strikingly resemble Recent specimens of *C. telemus,* the genotype. A typical specimen (B. P. Bishop Mus., Geol. no. 1203) measures: length (posterior spine incomplete) 5.7 mm., width 4.1 mm., height 3.0 mm. A single specimen from Station 298, in the type section of the Suva formation, probably represents the same species.

Genus DIACRIA Gray

Diacria Gray, Zool. Soc. London, Proc., pt. 15, p. 203, 1847.

Type (by original designation), *Hyalea trispinosa* Lesueur. Recent, warm and temperate seas (*fide* Woodring, 1928).

Diacria mbaensis Ladd, new species (pl. 42, figs. 6, 7).

Shell small, thin, shining, triangular in outline, divided into two parts, the ventral part being decidedly more inflated than the dorsal. Shell widest along a line anterior to the middle and produced on each side into a spiny point; posterolateral margins concave, the posterior end prolonged into a straight tube terminating in a nepionic bulb; anterior margin of dorsal part broadly rounded, thickened, and reflected ventrally so as to project over the truncated anterior margin of the ventral part of the shell. Dorsal part marked by five subequal rounded ribs which radiate from the pointed posterior end and by growth lines which are coarser on the thickened anterior margin than elsewhere. Ventral part of the shell marked only by growth lines.

Measurements of holotype, a specimen exposing the dorsal part, but with the posterior spine incomplete (B. P. Bishop Mus., Geol no. 1201), are: length 3.8 mm., width 3.0 mm. A paratype with the ventral part completely exposed (B. P. Bishop Mus., Geol. no. 1202) measures: length 4.6 mm., width 3.3 mm. Topotype in U. S. National Museum (Cat. no. 372684).

Localities: types from Station 306; also occurs at Station 304.

The outline and dorsal markings of this species indicate that it is a *Diacria,* though the smooth strongly inflated ventral part is suggestive of *Cavolina.* Apparently these two genera are very closely related.

FOSSIL DECAPOD CRUSTACEANS FROM VITILEVU, FIJI

By Mary J. Rathbun

This collection is of special interest as it is the first of its kind to be recorded from Fiji. The material is divided between two horizons. One is Neogene (Suva formation) and the other late Pleistocene or Recent. Of the 7 Neogene species, 4 are new, 1 is believed to be a native of Java, and 2 are Recent. The 4 species from the younger horizon are all Recent.

Order Decapoda

Family Majidae

Maja laddi Rathbun, new species (pl. 44, figs. 1-3).

Only the dorsal surface of the carapace is exposed; the fronto-orbital portion is lacking or obscure. Carapace subhexagonal, widest behind the middle; very convex from side to side, fairly level along two thirds of the median line, but sloping downward at either end; the gastric, hepatic, cardiac, and intestinal regions are indicated by shallow furrows; mesogastric region slightly sculptured; entire surface rough with unequal separated granules. Hepatic region small, bearing a large, pyramidal spine directed laterally and separated on the margin by a broad arcuate sinus from the branchial margin, which is furnished with a row of four subequal, equidistant spines (tips broken off). A smaller tubercle behind the last spine and above the carapace margin. Posterolateral margin in large part lacking; posterior margin narrow, prominent, and with indication of an ascending tooth or spine at the extremities. Front obscure; bearing at left of middle two small fragments of the rostrum curving downward; the position of the orbit is indicated only by a cross section not far from the hepatic spine.

Holotype (B. P. Bishop Mus., Geol. no. 1320): length of carapace approximately 34.8 mm., width 30 mm.

A left manus from the same place may belong to a larger specimen of the species. The extremities are incomplete; upper and lower margins thick and smoothly rounded. Outer layer of surface lacking; an inner layer is rough with distant linear tubercles, placed vertically for the most part. Palm highest at its distal two fifths. Length 29.4, height 11.9, thickness 7.8 mm. (B. P. Bishop Mus., Geol. no. 1321.)

Type locality, Station 158, abandoned quarry 6¼ miles from Suva, on Prince's Road to Nausori, conglomeratic limestone, Suva formation.

Family Parthenopidae

Parthenope (Platylambrus) fijiensis Rathbun, new species (pl. 44, figs. 4-7).

A left manus, small at proximal end, increasing in size toward distal end. Tips of spines or tubercles broken off. Upper surface (fig. 2) bordered on the inner edge with 4 unequal and equidistant spines, although a fifth spine may have been between the 2 distal ones; outer edge bordered with 4 spines of which 2 distal are near together, the others far apart; at proximal end of upper surface and nearer the outer edge, a large upstanding spine; at distal end a large spine directed obliquely inward and upward; a few small scattered spines or tubercles. On the lower margin but nearer the inner side a row of 4 small, equidistant tubercles; on outer surface (fig. 3) a row of 5 small tubercles through the middle, of which 3 on distal half are the larger and nearer together, and the other 2 are minute and distant.

Holotype (B. P. Bishop Mus., Geol. No. 1322): superior length of palm 14.7, distal width 4.4, proximal width 3.1 mm.

The specimen resembles *P.* (*Platylambrus*) *fraterculus*, a Recent species from the southeast coast of the United States, in which, however, the lower margin of the manus has a row of numerous tubercles.

Type locality, Station 158, abandoned quarry 6¼ miles from Suva, on Prince's Road to Nausori, conglomeratic limestone, Suva formation.

Family XANTHIDAE

Chlorodiella junghuhni? (K. Martin) (pl. 44, fig. 8).

Chlorodius junghuhni K. Martin, Die Tertiärschichten auf Java, p. 128, pl. 22, fig. 4, 1880.

It is with some hesitation that I give this name to the Fiji specimen. The carapace is exposed but is more than half lacking, the margin and the regions are partially delimited. As in Martin's figure the posterior and posterolateral margins are of subequal length, the cardiac region broad and well delimited, the lateral portion of the cervical groove deep; the mesogastric and protogastric regions are well marked and agree with the figure of the type specimen, but the anterior rim of the carapace is broken and bent downward, the four lateral lobes are not plainly seen. The surface is punctate, punctae shallow, irregularly placed and on the cardian region well separated; on the branchial region they are more numerous and toward the margin tend to run together.

The figured specimen (B. P. Bishop Mus., Geol. no. 1323) measures: estimated length of carapace 9, width 13.2 mm.

Locality, Station 165, on the right bank of Wailoa River about 1 mile above (west of) Nasongo, marl, Suva formation.

Etisus laevimanus Randall.

Etisus laevimanus Randall, Acad. Nat. Sci. Phila., Jour., 1839, p. 115.

Dactyl of left cheliped (B. P. Bishop Mus., Geol. no. 1328). Locality, Station 311, on the coast at Ravuka, 4¼ miles west of mouth of Na Singatoka River; elevation 5 to 6½ feet above high tide; late Pleistocene or Recent.

Family ATELECYCLIDAE

Montezumella lamiensis Rathbun, new species (pl. 44, fig. 9).

The greater part of a carapace lacking the margin excepting for a short distance on the front and anterolateral border. Specimen much broken, the different pieces overlapping and obscuring the regions. Surface covered with elongate, separated punctae each partially filled by an elongate tubercle. This tubercle is more plainly visible in the layer below the outermost. A broad, shallow sinus is visible to the right of the middle of the front margin. Anterolateral teeth broken off, the most posterior situated at about the anterior third of the lateral margin and considerably wider than the adjoining one; still farther forward and inward there is a cross section indicative of a tubular orbit.

Holotype (B. P. Bishop Mus., Geol. No. 1324): estimated length 60 mm., width 57 mm.

Type locality, Station 133, Lami quarry, on coast 3 miles northwest of Suva, conglomeratic limestone, Suva formation.

Family LEUCOSIIDAE

Myra? fijiensis Rathbun, new species (pl. 44, fig. 10).

A portion of a carapace showing the dorsal and left vertical surface. The dorsum is paved with small, flat, close-set granules, dotted at irregular intervals by slightly larger upstanding granules, and bordered laterally by a single row of still larger granules. The lateral portion of the carapace lacks the outer surface.

The fragment (B. P. Bishop Mus., Geol. No. 1325) is 17 mm. long by 11.8 wide.

Type locality, Station 133, Lami quarry, on coast 3 miles northwest of Suva, conglomeratic limestone, Suva formation.

Family CALAPPIDAE

Cycloes granulosa De Haan.

Cycloës granulosa De Haan, Fauna Japonica, p. 71, pl. 19, fig. 5, 1837.

Portion of carapace of small specimen (B. P. Bishop Mus., Geol. no. 1326). Locality, Station 320, along trail between Naivotho and Matainanu; 5-foot bed of tuffaceous and conglomeratic limestone, Suva formation.

Family COENOBITIDAE

Coenobita granulatus Bouvier.

Coenobita rugosus variety *granulatus* Bouvier, Soc. Philomath. Paris, Bull., 8th ser., vol. 2, p. 146, 1889-90.

Dactyl of second left leg (B. P. Bishop Mus., Geol. no. 1329). Locality, Station 311, marl on the coast at Ravuka, 4¼ miles west of mouth of Na Singatoka River, late Pleistocene or Recent.

Birgus latro (Linnaeus)

Cancer latro Linnaeus, Syst. Nat., 12th ed., vol. 2, p. 1049, 1767.

Piece of palm (B. P. Bishop Mus., Geol. no. 1327). Locality, Station 320, along trail between Naivotho and Matainanu; 5-foot bed of tuffaceous and conglomeratic limestone, Suva formation.

Family Paguridae

Dardanus gemmatus (Milne Edwards).

Pagurus gemmatus Milne Edwards, Ann. Sci. Nat., Zool., 3d ser., vol 10, p. 60, 1848.

Fragments of finger (B. P. Bishop Mus., Geol. no. 1330). Locality, Station 311, marl, on the coast at Ravuka, 4¼ miles west of mouth of Na Singatoka River, late Pleistocene or Recent.

Family Scyllaridae

Scyllarus vitiensis (Dana).

Arctus vitiensis Dana, Acad. Nat. Sci. Phila., Proc., vol. 6, p. 19, 1852.

One fragment of carapace (B. P. Bishop Mus., Geol. no. 1331). Locality, Station 311, marl, on the coast at Ravuka, 4¼ miles west of mouth of Na Singatoka River, late Pleistocene or Recent.

VERTEBRATA

Class PISCES

Subclass SELACHII

Order PLAGIOSTOMI

Family LAMNIDAE

Genus CARCHARODON A. Smith

Carcharodon Smith, A., in Müller (J.) and Henle, Mag. Nat. Hist., new ser., vol. 2, p. 37, 1838.

Type (*fide* Hay), *Squalus carcharias* Linnaeus. Recent in temperate and tropical seas; Pliocene of Europe; Miocene and Eocene of Carolinas (*fide* Hay).

Carcharodon megalodon (Agassiz) (pl. 42, fig. 8; pl. 43, fig. 4).

Carcharias megalodon Agassiz, Récherches sur les poissons fossiles, (atlas) vol. 3, pl. 29, 1835 (dates as given by Woodward and Sherborn, Cat. Brit. Fossil Vert., pp. xxv-xxix, 1890.) Charlesworth, Mag. Nat. Hist., new ser., vol. 1, p. 225, text-fig., 1837.

Carcharodon megalodon Agassiz, Récherches sur les poissons fossiles, vol. 3, (text) pp. 247-249, 1843. Emmons, North Carolina Geol. Surv. Rep., 1858, p. 227, fig. 50. Murray, Rep. Challenger Exped., Deep-sea deposits, p. 269, pl. 5, fig. 1, 1 *a*, 1891. Chapman, New Zealand Geol. Surv., Pal. Bull., No. 7, pp. 19-20, 1918. Ishiwara, Tôhoku Imp. Univ., Sci. Reps., 2d ser. (Geol.), vol. 5, no. 3, p. 65, pl. 10, fig. 33; pl. 11, figs. 1-8; pl. 12, figs. 1, 2, 1921. Mansfield, Carnegie Inst. Washington, Pub. 344, pp. 93-94, pl. 7, fig. 2, *a*, *b*, 1926.

Tooth very large; crown broadly triangular, subequilateral, thick; inner face convex; outer face flattened or very gently convex; tip slightly curved outward; serrated lateral edges concave, straightened or slightly convex; root thick. Measurements of the figured specimens (B. P. Bishop Mus., Geol. No. 1227) are: height of crown at middle of tooth, 63.9 mm., width of crown at base, 95.0 mm., thickness of crown at base, 18.8 mm., number of serrations on one side, 139 (tip of crown broken), thickness of root, 19.4 mm.

Localities: figured specimen from Station 158; also known from Station 295 (this is probably the locality from which Mansfield's specimen was obtained). Mr. W. T. C. Edwards, of Suva, has a number of specimens from Station 295, two of which he kindly presented to me.

Tertiary sharks' teeth from many parts of the world have been assigned to this species. Mansfield has cited references to occurrences in New Zealand, Australia, Java, Japan, Europe, and the United States and has pointed out that in nearly all instances it has been reported from the Miocene. In addition, I have seen specimens from two localities in northern Venezuela, in the State of Falcon, which were obtained from rocks believed to be upper Miocene in age. In the United States specimens have been collected from the Calvert formation (middle Miocene) and the Yorktown formation (upper Miocene).

In 1837 Charlesworth noted the occurrence of worn specimens of *C. megalodon* in the Red Crag of Suffolk, in England. The Red Crag, according to Neaverson (Strat. Paleont. pp. 466, 467, 1928), is Pliocene in age.

It is interesting to note that the *Challenger* dredged a specimen from the sea floor in the middle of the Pacific, at a depth of nearly 3 miles (2,385 fathoms). The specimen was in a red clay and only the hard enamel or dentine remained. It occurred with other sharks' teeth, most of which had a slight coating of manganese and some of which were deeply embedded in the same material. As the rate of sedimentation in the ocean depths must be infinitely slow, it seems quite possible that the teeth of *C. megalodon* may have been originally deposited on the ocean floor in late Tertiary time. Murray's figures show it to be remarkably like some of the Vitilevu specimens in size and shape and it has fully as many serrations.

There is considerable variation in the number of serrations possessed by teeth referred to *C. megalodon*, and detailed studies of large collections might show this character to be of specific value. Some of the specimens originally figured by Agassiz have only about 75 serrations on each side of the tooth, but others have nearly 120. One of the New Zealand specimens described by Chapman showed 75 denticles on the posterior side and 102 on the anterior; another had 123 posterior denticles and 150 on the anterior side; others fell between these two extremes. Fijian specimens from the same horizon and locality exhibit some variation in the number of denticles; however, it is possible that considerable variation exists between different teeth from the jaw of the same individual. The Pacific specimens, as a group, appear to have finer and more numerous denticles than those from other parts of the world, but pending more extensive studies I prefer to follow the usual practice and refer all the teeth to *C. megalodon*.

Family CARCHARINIDAE

Genus HEMIPRISTIS Agassiz

Hemipristis Agassiz, Récherches sur les poissons fossiles, vol. 3, pp. 237, 302, 1843.

Type (*fide* Hay), *Hemipristis serra* Agassiz. Tertiary of Europe, Carolinas; Miocene of Maryland, Virginia; upper Miocene of Java; Pliocene (?) of the Argentine.

Hemipristis serra Agassiz (pl. 43, figs. 1-3).

Hemipristis serra Agassiz, Récherches sur les poissons fossiles, vol. 3 (atlas), pl. 27, figs. 18-30, 1835; vol. 3 (text), pp. 237-238, 1843. Emmons, North Carolina Geol. Surv., Rep., 1858, p. 235, fig. 63. Eastman, Maryland Geol. Sur., Miocene, pp. 90-91, pl. 32, figs. 13, *a-b*, 14, *a-c*, 1904.

Lateral tooth large, obliquely triangular, apex curved backward and slightly outward, compressed; outer face gently inflated, inner face strongly convex; base broad. Posterior edge concave with 15 coarse oblique serrations; anterior edge slightly convex with 37 finer serrations; tip of tooth smooth. Measurements of the figured specimen (B. P. Bishop Mus., Geol. No. 1225) are: height of crown, 21.1 mm., width of crown at base, 21.8 mm., thickness of crown at base, 4.6 mm.

Collected by J. M. Ostergaard at Station 297. In Java this species has been reported from the upper Miocene (Martin, K., Reichs Geol.-Min. Mus. Leiden, Samml., Beilage Bd., p. 105, 1919); other localities and horizons as cited above.

Hay (U. S. Geol. Surv., Bull. 179, p. 313, 1902) gives additional references.

Undetermined Selachian Remains

Trygon or **Myliobatis** species? (pl. 42, fig. 9; pl. 43, fig. 5).

A well-preserved caudal spine of one of the rays was obtained from the Suva formation at Station 160. It can not be identified accurately as such spines are found in the sting-rays (Trygonidae) and in the eagle-rays (Myliobatidae). The spine is somewhat compressed dorsoventrally, more or less elliptical in section, and armed at each side with a row of recurved hooklets, about five to each centimeter. The dorsal surface is strongly arched from side to side and is marked by deep, irregular, longitudinal striae. The ventral surface is convex posteriorly but becomes concave anteriorly by the development of a broad median depression. Ventral surface finely striate, each row of hooklets bordered by a narrow groove (possibly a result of weathering). The incomplete figured specimen (B. P. Bishop Mus., Geol. no. 1189) measures: length 122 mm., maximum width 14 mm.

The fossil has been compared with a series of Recent ray spines obtained from the natives of Vitilevu, but the Recent specimens vary and may include more than one species. The fossil does not agree very well with any of them, but they show so much variation that it is impossible to say definitely that the fossil belongs to a distinct species. Fossils of this type have been obtained fom Tertiary rocks in many parts of the world. The Fijian specimen was collected by Mr. C. R. Harley-Nott, of Suva.

DIODONTIDAE

Genus DIODON Linnaeus

Diodon species?

Foye in 1918 (Am. Acad. Arts and Sci., Proc., vol. 54, p. 86) stated that he had obtained the tooth of an undescribed species of *Diodon* from the exposures on Walu Bay (Suva formation), at an elevation of 25 feet. The specimen was turned over to Dr. C. R. Eastman for description, but the study was not completed prior to Doctor Eastman's death. The writer did not find any specimens of *Diodon* in Vitilevu and his efforts to locate the specimen which Foye collected have not been successful.

Fossil Bird's Egg (pl. 43, figs. 6, 7).

Wood, Casey A., A fossil bird's egg from the post-Tertiary mud-rocks of Fiji: Auk, vol. 42, pp. 401-404, pl. 20, 1925. Wood, Casey A., A collection of birds from the Fiji Islands, pt. 3, Field observations, Ibis, ser. 12, vol. 2, pp. 105-106, 1926. Ladd, Harry S., The Fiji mud-rocks: Auk, vol. 43, pp. 408-409, 1926.

The small dark spots which are scattered over the shell are particularly abundant in an irregular band around the smaller end. As seen under the binoculars the spots are shallow pits and may represent the original color pattern, the colored areas weathering more easily. The larger end of the shell is broken away and the remainder is cracked but still remarkably well preserved. Length (incomplete) 43.7 mm., width 39.1 mm. Wood has suggested that the egg belongs to one of the rails.

Locality, marl in the Suva formation at Station 305. The rock at this station also yielded foraminifera, echinoids, mollusks, and a number of plant fossils. Collected by Mr. J. B. Turner and now in the possession of his son, Mr. Percy Turner, of Suva.

PLANT REMAINS

The plants have left a meager record in the Tertiary rocks of Vitilevu. Though fragmentary plant remains are widespread in the tuffs and marls and in some of the limestones, material sufficiently well preserved for identification is exceedingly rare. I am greatly indebted to Dr. W. A. Setchell, of the University of California, for examination of the poorly-preserved plant fossils. The following sketch has been prepared largely from his notes.

The impure limestone exposed at Station 158 contains many small nodular masses composed of concentrically banded calcium carbonate. A number of them have a well-rounded pebble of igneous rock as a nucleus. In 16 thin sections cut from the most promising specimens, Setchell found 2 or 3 crustaceous corallines, one of which he identified as *Lithoporella pacifica* Foslie, a species common in the tropical Pacific today. One of the others, a multistratose form, proved to be sterile, but its structure suggested *Lithothamnion,* close, perhaps, to *L. simulans* Foslie, a Recent species now living in the Pacific. The outcrop lies 555 feet above sea level and the fossils associated with the algae (Foraminifera, Mollusca, etc.) indicate that it is of approximately the same age as the type section of the Suva formation.

A number of corals in the limestone of Ravuka Quarry (Station 294), near Na Singatoka, are likewise encrusted with concentrically banded calcium carbonate, some of which probably is algal in origin. These limestones lie close to sea level and are placed in the Suva formation.

Whipple (written communication, June 19, 1932) identified *Lithothamnion* from the Viti limestone in several localities. This limestone is primarily foraminiferal and is certainly older than the type section of the Suva formation and its equivalents.

The marls at Station 374, in the town of Suva, yielded the stem of *Cyathea,* a tree fern, the species being very closely related to *C. affinis* (Forster), a Recent Polynesian species, the types of which were collected in Tahiti. This is an interesting occurrence for it shows that a part of Vitilevu was above water and supported vegetation at the time that the type section of the Suva formation was being deposited. Near Suva, at Station 305, Mr. J. B. Turner collected leaves, stems, and other plant remains from a foraminiferal marl exposed close to present sea level. The leaves are related to, or possibly identical with, forms now living in Fiji. The collection also included a fossilized nutmeg, the fruit with the mace.

The conglomerate exposed west of Nasongo (Station 59) contains plant stems, root casts, and a portion of a carbonized tree, probably a mangrove and possibly one of the species existing in Fiji to-day. The high-level tuffs of the section south of Nasongo (Station 362), from which Matley (83, p. 74) obtained dicotyledonous leaves, has also yielded broad, flattened, carbonized stems.

Bits of carbonaceous material are found in the bedded rocks at many other places, and thin carbonaceous films on many bedding planes. Thin seams of lignite also occur, but such material can not be identified. The absence of coal and the scarcity of fossil wood in the Tertiary rocks of Vitilevu is probably to be explained by the fact that most of the rocks are marine and under such conditions boring mollusks, such as the shipworm, destroy most dead wood before it can be incorporated into the accumulating sediments.

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PALEONTOLOGICAL INDEX

PLATE LEGENDS

PLATE 1.—TOPOGRAPHIC FEATURES.

A, Northern end of Mendrausuthu Range, Wainimala River in right foreground, joined by the Wainga in right middle ground. *B,* Rama, a volcanic neck in the Namosi-Rewa Range (photograph by R. W. Paine). *C,* Nasongo, a mountain village on the "wet side" of Vitilevu.

PLATE 2.—TOPOGRAPHIC FEATURES.

A, Southwest tip of the Thonoa Range, bordered by coastal plains. *B,* Namosi Hills from the top of the divide between Namuamua and the Wainikoroiluva crossing (photograph by R. W. Paine).

PLATE 3.—TOPOGRAPHIC FEATURES.

A, Embayed coast west at Ellington. *B,* Gorge of the upper Navua, marls and conglomerate. *C,* Rain forest on the Navua River.

PLATE 4.—TOPOGRAPHIC FEATURES.

A, Lake on the poorly drained surface of the Navosa Plateau. *B,* Open valley of the lower Na Singatoka, near Nakambuta. *C,* Reed-covered hills of Na Singatoka Valley, the leeward side of Vitilevu, trees only along rivers and in steep gullies.

PLATE 5.—BARRIER REEF.

A, Barrier reef east of entrance to Suva harbor, the line of breakers in foreground marks seaward edge of reef. *B,* Marginal zone of barrier reef east of entrance to Suva harbor. *C,* Coral pavement riddled with the borings of echinoids, barrier reef west of the entrance to Suva harbor. (Photographs by J. E. Hoffmeister.)

PLATE 6.—STRATIGRAPHIC FEATURES.

A, Supposed ripple marks in the Wainimala series, as exposed in a tributary to the Wainimala River (photograph by C. R. Harley-Nott). *B,* Conglomerate in the Suva formation at Station 144, near Rewasau, contains both limestone and igneous pebbles. *C,* Type exposure of Suva formation in an abandoned quarry near mouth of Walu Bay; main mass, coralliferous limestone resting on a thin, richly fossiliferous conglomerate; bedded marls above and below.

PLATE 7.—PHOTOMICROGRAPHS OF ROCK SECTIONS.

A, Specimen 7, from near Nandrau (21-N), Porphyritic basaltic glass from submarine flow (Suva formation), shows zeolite in the center with augite in a matrix of glass, × 32, nicols uncrossed; *B,* Specimen 12, from near Nairukuruku (31-Q), Viti limestone showing recrystallization of calcite in a matrix of calcite (light gray) and chlorite (dark gray), × 64, nicols uncrossed; *C,* Specimen 22, from near Nambauwanga (22-M) basaltic glass from ellipsoidal lava in the Suva formation showing zeolites (white) in a matrix of altered glass (black), × 64, nicols uncrossed; *D,* Specimen 28, from point 2 miles north of Namoli (21-P), basalt from the Wainimala series, shows chlorite (light gray bands) in a matrix of calcite, altered feldspar, and augite, × 64, nicols uncrossed; *E,* Specimen 35, from Nasinu Quarry (36-X), diabase showing iddingsite (black) surrounded by crystals of feldspar (light gray), × 64, nicols uncrossed. *F,* Specimen 61, from bank of Wainimala River (29-P), rhyolite tuff from the Sambeto series, rhyolite areas (light gray) are in a matrix of chlorite and altered feldspar, × 32, nicols uncrossed; *G,* Specimen 64, from near Lautoka (8-K), tuff from the Suva formation showing grains of augite (light gray), magnetite and limonite (black), in a matrix of altered glass (white), × 32, nicols uncrossed; *H,* Specimen 70, from Suva (35-Z), marl from the Suva formation showing sections of foraminifera (white) in a matrix composed of several minerals of which the chief one is calcite, × 64, nicols crossed.

PLATE 8.—PHOTOMICROGRAPHS OF ROCK SECTIONS.

A, Specimen 78, from near Nasimbitu (33-M), Viti limestone showing a fractured fossil (gray) cemented or healed by calcite (white), displacement in calcite vein, × 64, nicols uncrossed; *B,* Specimen 79, from the village of Nayavu (33-M), Viti limestone (gray) showing an inclusion of igneous material (white), × 32, nicols uncrossed; *C,* Specimen 82, from point 1 mile north of Nayavu (33-M), altered glass from the Sambeto series showing incipient crystallization of quartz (white) in a matrix of altered glass (black), × 32, nicols uncrossed; *D,* Specimen 84, from Tova Peak (36-J), olivine diabase from the Suva formation showing laths of feldspar (white), grains of augite (gray), and grains of magnetite (black), × 40, nicols uncrossed; *E,* Specimen 95, from Mboalu Creek (21-CC), inclusion of Wainimala basalt (fine grained) in Tholo granite (coarse grained), section cut from boulder, × 6, nicols crossed; *F,* Specimen 96, from boulder in Mboalu Creek (21-CC), compact sandstone (arkose) showing a mortar structure with large grains of feldspar and quartz, and finer-grained material in the interstices, × 64, nicols uncrossed; *G,* Specimen 105, from valley of Mbusa River (14-AA), Tholo granite showing crushing and hydrothermal alteration along cleavage cracks, × 16, nicols uncrossed; *H,* Specimen 107, from Vatuvula Point (12-AA), compact sandstone or quartzite from the Wainimala series, × 64, nicols uncrossed.

PLATE 9.—PHOTOMICROGRAPHS OF ROCK SECTIONS.

A, Specimen 109, from Tamunua River (13-Z), showing texture of quartzite of Wainimala series, section cut from boulder, × 64, nicols crossed; *B,* Specimen 117, from near Sovi Bay (12-AA), glassy basalt showing an amygdule filled with feldspar (white), with a border of palagonite (gray), in a matrix of glass (black), × 32, nicols uncrossed; *C,* Specimen 119, from near Na Singatoka (9-Z), limestone from the Na Singatoka formation showing fossils (dark gray) in a matrix of fine-grained calcite (light gray), × 64, nicols uncrossed; *D,* Specimen 121, from point 2 miles west of Nandele (10-N), andesite from the Sambeto series, showing feldspar phenocrysts (light gray), hornblende (gray), and magnetite (black), in a trachytic matrix, × 40, nicols uncrossed; *E,* Specimen 124, from the gorge on the upper Navua (20-Y), rhyolite from the Suva formation (or possibly from the Sambeto series), slide shows web of chlorite over mosaic of quartz and feldspar, × 48, nicols uncrossed; *F,* Specimen 132, from a pebble in the Nandi River (9-P), crushed Tholo granite showing large grains (altered) in a matrix of relatively smaller grains, × 16, nicols uncrossed; *G,* Specimen 49, from a boulder at Nasongo (25-L), porphyritic basaltic glass from the Suva formation showing an almost perfect cross section of augite, × 32; *H,* Specimen 25, from the upper Na Singatoka basin, half a mile below Nandrau (21-N), porphyritic basaltic obsidian from the Suva formation showing augite phenocrysts in a glassy matrix, × 32.

PLATE 10.—SMALLER FORAMINIFERA.

1, *Spiroplectammina parallela* Cushman: *a,* front view; *b,* apertural view; × 52. 2, *Textularia solita* (Schwager): *a,* front view; *b,* side view; × 40. 3, *Textularia* cf. *lythostrotum* (Schwager); × 20. 4, *Textularia* species?: *a,* front view; *b,* apertural view; × 20. 5, *Textularia* cf. *hauerii* d'Orbigny: *a,* front view; *b,* apertural view; × 14.4. 6, *Vulvulina nicobarica* (Schwager): *a,* front view; *b,* apertural view; × 40. 7, *Verneuilina bradyi* Cushman: *a,* front view; *b,* apertural view; × 40. 8, *Clavulina* *variabilis* Schwager: *a*, front view; *b*, apertural view; × 40. 9, *Gaudryina lacerata* (Schwager): *a*, front view; *b*, apertural view; × 14.4. 10, *Clavulina angularis* d'Orbigny (?): *a*, front view; *b*, apertural view; × 40.

PLATE 11.—SMALLER FORAMINIFERA.

1, *Robulus cushmani* Galloway and Wissler: *a*, side view; *b*, peripheral view; × 40. 2, *Robulus foliatus* (Stache): *a*, side view; *b*, peripheral view; × 6.4. 3, *Lenticulina echinata* (d'Orbigny): *a*, side view; *b*, peripheral view; × 20. 4, *Saracenaris acutauricularis* (Fichtel and Moll): *a*, side view; *b*, peripheral view; × 24. 5, *Planularia* species: *a*, side view; *b*, peripheral view; × 24. 6, *Planularia crepidula* (Fichtel and Moll): *a*, side view; *b*, peripheral view; × 24. 7, *Nodosaria arundinea* Schwager, × 16. 8, *Nodosaria brevicula* Schwager, × 16. 9, *Dentalina neugeboreni* (Schwager), × 24. 10, *Dentalina tauricornis* (Schwager), × 14.4.

PLATE 12.—SMALLER FORAMINIFERA.

1, *Dentalina spirostriolata* (Cushman), × 16. 2, 3, *Dentalina insecta* Schwager, × 22.4. 4, *Dentalina elegans* d'Orbigny, × 32. 5, *Dentalina perprocera* Schwager, × 32. 6, *Nodosaria equisetiformis* Schwager, × 22.4. 7, *Nodosaria stimulea* Schwager, × 32. 8, *Nodosaria koina* Schwager, × 32. 9, *Nodosaria glandigena* Schwager, × 32. 10, 11, *Vaginulina legumen* (Linné): 10, microspheric form; 11, megalospheric form; × 14.4. 12, *Pyrulina labiata* (Schwager), × 52. 13, *Pyrulina extensa* (Cushman), × 40. 14, *Nodosaria perversa* Schwager, × 52.

PLATE 13.—SMALLER FORAMINIFERA.

1, 6, *Lagena sulcata* Walker and Jacob, variety *alticostata* Cushman, × 72. 2, *Lagena punctulata* Sidebottom, × 72. 3, *Lagena marginata* (Montagu), × 72. 4, *Lagena striata* (d'Orbigny), variety *substriata* Williamson (?), × 72. 5, *Lagena gracilis* Williamson (?), × 72. 7, *Lagena striata* (d'Orbigny), variety *haidingeri* (Czjzek), × 72. 8, *Lagena plumigera* H. B. Brady, × 72. 9, *Lagena costata* Williamson, variety *amphora* Reuss, × 72. 10, *Lagena costata* Williamson, × 72. 11, *Lagena formosa* Schwager, × 72. 12, *Lagena alveolata* H. B. Brady, × 72. 13, *Lagena fimbriata* H. B. Brady, × 72. 14, 15, 17, *Lagena schwageriana* Cushman: 14, 15, × 72; 17, × 32. 16, *Lagena castrensis* Schwager, × 72. 18, 19, *Lagena orbignyana* (Seguenza), × 32.

PLATE 14.—SMALLER FORAMINIFERA.

1, *Lagena tubulata* Sidebottom, × 72. 2, *Lagena spiro-striolata* Cushman, × 72. 3, *Lagena spino-alata* Cushman, × 72. 4, *Lagena mucronulata* Reuss, × 52. 5, *Lagena staphylearia* Schwager, × 72. 6, *Lagena basi-striatula* Cushman, × 72. 7, *Nonion pacifica* Cushman: *a*, side view; *b*, peripheral view; × 52. 8, *Nonion galeata* Cushman: *a*, side view; *b*, peripheral view; × 40. 9, *Nonion stelligera* (d'Orbigny): *a*, side view; *b*, peripheral view; × 52. 10, *Nonionella limbato-striata* Cushman: *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 80. 11, *Nonionella clavata* Cushman: *a*, dorsal view; *b*, ventral view; *c*, apertural view; × 52. *Bolivinita quadrilatera* (Schwager): *a*, side view; *b*, apertural view; × 40. 13, *Nodogenerina protumida* (Schwager), × 16. 14, *Nodogenerina spinata* Cushman, new species, × 40. 15, 16, *Nodogenerina lepidula* (Schwager), × 40.

PLATE 15.—SMALLER FORAMINIFERA.

1, *Globobulimina pacifica* Cushman, × 52. 2, *Bolivina globigera* (Schwager), × 52. 3, *Virgulina* cf. *schreibersiana* Czjzek, × 72. 4, *Bolivina reticulata* Hantken (?), × 52. 5, *Bolivina hantkeniana* H. B. Brady, × 52. 6, *Uvigerina nitidula* Schwager, × 40.

7, *Uvigerina gemmaeformis* Schwager, × 40. 8, *Uvigerina crassicostata* Schwager, × 40. 9, *Uvigerina hispida* Schwager, × 72. 10, *Uvigerina proboscidea* Schwager, × 40. 11, *Trifarina bradyi* Cushman, × 72. 12, *Siphonodosaria fijiensis* Cushman, × 52. 13, *Pleurostomella brevis* Schwager, × 40. 14, *Pleurostomella sapperi* Schubert, × 72.

PLATE 16.—SMALLER FORAMINIFERA.

1, *Angulogerina fijiensis* Cushman, × 72. 2, 5, *Ellipsolagena fijiensis* Cushman, × 80. 3, 4, *Pleurostomella alternans* Schwager, *a*, *a*, front views; *b*, *b*, side views; 3, microspheric form; 4, megalospheric form; × 40. 6, *Pleurostomella alternans* Schwager, variety *telostoma* Schubert, × 40. 7, 8, *Nodosarella pacifica* Cushman: 7, megalospheric form; 8, microspheric form; × 14.4. 9, *Cassidulinoides bradyi* (Norman), × 52. 10, 11, *Ehrenbergina bicornis* H. B. Brady, × 32. 12, *Cassidulina delicata* Cushman, × 52. 13, *Cassidulina subglobosa* H. B. Brady, variety *ornata* Cushman, × 40. 14, *Ehrenbergina pacifica* Cushman, × 40.

PLATE 17.—SMALLER FORAMINIFERA.

1, *Eponides* species: *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 40. 2, *Allomorphina trigona* Reuss: *a*, front view; *b*, side view; × 72. 3, *Chilostomella oolina* Schwager: *a*, front view; *b*, side view; × 52. 4, *Eponides umbonata* (Reuss), variety *multisepta* Koch: *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 40. 5, *Globorotalia menardii* (d'Orbigny), variety *fijiensis* Cushman, new variety: *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 40. 6, *Pulvinulinella bengalensis* (Schwager): *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 24.

PLATE 18.—SMALLER FORAMINIFERA.

1, *Cibicides cicatricosa* (Schwager): *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 33.4. 2, *Laticarinina tenuimargo* (H. B. Brady): *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 53.4. 3, 5, *Planulina wuellerstorfi* (Schwager): *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 33.4. 4, *Planulina fijiensis* Cushman, new species: *a*, dorsal view; *b*, ventral view; *c*, peripheral view; × 26.7.

PLATE 19.—LARGER FORAMINIFERA.

1, *Cycloclypeus annulatus* Martin, surface view of specimen from Station 158, × 2. 2, *Cycloclypeus neglectus* Martin, horizontal section of specimen from Station 158, × 19. 3-6, *Lepidocyclina* (*Eulepidina*) *radiata* (Martin) H. Douvillé: 3, surface of microspheric form, × 2; 4, vertical section of macrospheric form, × 16; 5, horizontal section showing the embracing embryonic apparatus, × 19; 6, surface view of macrospheric form, × 5. All specimens from Station 158.

PLATE 20.—LARGER FORAMINIFERA.

1-8, *Lepidocyclina* (*Cyclolepidina*) *suvaensis* Whipple, new subgenus and new species: 1, horizontal section, × 10; 2, 3, surface, × 5; 4, vertical section, × 10; 5, horizontal section showing the embryonic chambers, × 16; 6, vertical section showing one aperture at the proximal end of the chamber, × 200; 7, horizontal section showing the system of interchamber communication, × 115; 8, vertical section showing the stoloniform passages at the distal end of the chamber, × 200. 1-4, specimens from Station 295; 5-8, specimens from Station 316. 9, *Lepidocyclina* (*Pliolepidina*) *tobleri* H. Douvillé, horizontal section showing the difference in the system of interchamber communication between *Pliolepidina* and *Cyclolepidina*, × 130. Specimen from Point Bontour, Trinidad.

PLATE 21.—LARGER FORAMINIFERA.

1, 3, *Lepidocyclina (Eulepidina) formosa* Schlumberger from Station 302: 1, vertical section, ×10; 3, horizontal section through the embryonic chambers, × 10. 2, *Lepidocyclina (Eulepidina) dilatata* (Michelotti) Lemoine and R. Douvillé, surface view of specimen from Station 158, × 2. 4, *Lepidocyclina flexuosa* Rutten, nearly vertical section of a specimen from Station 292, × 16. 5, *Lepidocyclina (Nephrolepidina) angulosa* Provale from Station 309, tangential section showing the large pillars, × 19. 6, *Lepidocyclina (Nephrolepidina)* species indeterminate, vertical section of a specimen from Station 292, × 16.

PLATE 22.—LARGER FORAMINIFERA.

1, *Lepidocyclina (Eulepidina) dilatata* (Michelotti) Lemoine and R. Douvillé, horizontal section showing arrangement of equatorial chambers and pillars, × 10. 2, 3, *Lepidocyclina (Eulepidina) dilatata laddi* Whipple, new variety: 2, surface view, × 2; 3, horizontal section showing polygonal arrangement of the equatorial chambers, × 16.

PLATE 23.—LARGER FORAMINIFERA.

1, *Lepidocyclina papulifera* H. Douvillé, surface view of specimen from Station 295, × 5. 2, *Miogypsina polymorpha* Rutten, vertical section of specimen from Station 292, × 19. 3, *Miogypsina thecideaeformis* Rutten, horizontal section of specimen from Station 309, × 28.

PLATE 24.—BRACHIOPODS AND PELECYPODS.

1-3, *Terebratulina waimanensis* Ladd, new species, holotype, × 2. 4-7, *Dallina vitilevensis* Ladd, new species, holotype, × 2. 8, 9, *Glycymeris (Glycymeris) fijiensis* Ladd, new species, holotype, × 1. 10, *Glycymeris (Glycymeris)* species *b*, right valve, × 3. 11-14, *Arca (Arca) thomasi* Ladd, new species: 11, 12, holotype, × 2; 13, 14, paratype, × 2. 15, 16, *Arca (Arca)* species *a:* 15, lateral, and 16, dorsal views, × 1 (U. S. Nat. Mus., Cat. No. 352413); 15, after Mansfield.

PLATE 25.—ARCIDAE.

1, *Arca (Arca)* species *A,* cast showing sculpture, × 4 (U. S. Nat. Mus., Cat. No. 352413); after Mansfield. 2, 3, *Arca (Arca)* species *B:* 2, lateral and 3, dorsal views, × 1 (U. S. Nat. Mus., Cat. No. 352414); after Mansfield. 4, 5, *Barbatia (Acar)* species, left valve, × 2. 6-8, *Barbatia (Obliquarca) javana* Martin: 6, right valve, × 1.5; 7, 8, left valve, × 1.5. 9, 10, *Navicula* species, right valve, × 2.

PLATE 26.—OSTREAS.

1, 2, *Ostrea* aff. *virleti* Deshayes, left valve, × 1. 3, 4, *Ostrea* species: 3, left valve, × 2; 4, right valve, × 2. 5, 6, *Ostrea* cf. *baribisiana* Martin, right valve, × 1.

PLATE 27.—PECTENS.

1-4, *Pecten (Pecten) suvaensis* Mansfield: 1, topotype, × 1; 2, sculpture of same specimen, × 4; 3, 4, homeotype, young specimen, × 1. 5-7, *Pecten (Chlamys) lamiensis* Ladd, new species: 5, paratype *b,* × 4; 6, holotype, × 1; 7, paratype *a,* × 1. 8, 9, *Pecten (Chlamys) nausorensis* Ladd, new species: 8, holotype, × 1; 9, paratype, × 4.

PLATE 28.—PECTENS.

1-3, *Pecten (Pallium) waluensis* Hertlein: 1, homeotype, × 1; 2, homeotype, × 1; 3, homeotype, showing sculpture, × 4. 4-9, *Pecten (Aequipecten) exaratus* Martin: 4, a right valve, × 2; 5, same specimen showing sculpture, × 4; 6, sculpture of a left valve, × 4; 7, same specimen, × 2; 8, interior of a right valve, × 2; 9, interior of a left valve, × 2.

PLATE 29.—PELECYPODS.

1, 2, *Pecten (Aequipecten) corymbiatus talicus* Ladd, new subspecies: 1, holotype, × 5; 2, paratype, × 5. 3, *Pecten (Aequipecten) corymbiatus* Hedley, right valve of a Recent shell from Australian waters, × 3. 4, *Pecten mirificus* Reeve, right valve, × 1. 5, *Pecten* species *b*, exterior, × 2. 6, *Plicatula* species, interior, × 2. 7, 8, *Lima (Lima) kavorica* Ladd, new species, holotype, × 2. 9, *Lima (Limatula) morioria?* Marwick, view of internal mold, × 2. 10-11, *Lithophaga* species: 10, dorsal, and 11, lateral views, × 1.5; after Mansfield. 12-14, *Coralliophaga laseona* Ladd, new species: 12, left valve of paratype, × 2; 13, 14, right valve of holotype, × 2.

PLATE 30.—PLEUROPHORIDAE, CHAMIDAE, AND CARDIIDAE.

1, *Coralliophaga laseona* Ladd, new species, left valve of paratype, × 2. 2-4, *Chama lazarus* Linnaeus, views of an internal mold, × 1. 5, 6, *Chama* species, right valve, × 2. 7, 8, *Cardium rewaense* Ladd, new species, holotype, × 3. 9, *Cardium* species *a*, internal mold, × 1; after Mansfield. 10, 11, *Cardium (Trachycardium) orbita* Broderip and Sowerby, new subspecies?: 10, sculpture, × 4; 11, internal mold of right valve, × 1.

PLATE 31.—PELECYPODS.

1, *Cardium (Laevicardium)* species *a*, internal mold, × 1; after Mansfield. 2, 3, *Tridacna mbalavuana* Ladd, new species, holotype, × 1. 4, 5 *Meiocardia* species *a*: 4, lateral, and 5, posterior views of internal mold of right valve, × 2; after Mansfield. 6, 7, *Meiocardia* species *b*: 6, lateral, and 7, posterior views of left valve, × 3. 8-11, *Antigona (Ventricola) vitiensis* Ladd, new species: 8, holotype, showing sculpture, × 4; 9, paratype, × 2; 10, exterior, and 11, interior of holotype, × 1. 12, *Dosinia wailoaense* Ladd, new species, paratype, × 2.

PLATE 32.—VENERIDAE AND TELLINIDAE.

1, 2, *Dosinia wailoaense* Ladd, new species, holotype, × 2. 3, *Dosinia?* species, left valve, × 1; after Mansfield. 4, *Antigona* species, right valve, × 1; after Mansfield. 5-7, *Antigona (Dosina) puerpera waluensis* Ladd, new subspecies: 5, internal mold, and 6, cast from external mold of holotype, × 1; 7, paratype, × 1; after Mansfield. 8, 9, *Irus mamaricus* Ladd, new species, holotype, × 4. 10, 11, *Tellina suvaensis* Mansfield, topotype, × 1.

PLATE 33.—PELECYPODS.

1, 2, *Tellina suvaensis* Mansfield: 1, cast of right valve of topotype, × 1; 2, left valve of Recent shell collected from tidal flat east of Ellington, × 1; 3, *Donax* species, right valve, × 2. 4, *Asaphis* species, left valve, × 1; after Mansfield. 5, *Solecurtus* species, right valve, × 1. 6-8, *Mactra (Mactrotoma) tholoensis* Ladd, new species: 6, holotype, × 1; 7, paratype *a*, × 3; 8, paratype *b*, × 2. 9, *Mactra (Mactrotoma?) vitiensis* (Davies), holotype, × 8/3; after Davies. 10, *Mactra (Coelomactra) nasongoensis* Ladd, new species, holotype, × 1.

PLATE 34.—PELECYPODS, SCAPHOPODS, AND GASTROPODS.

1, 2, *Mactra (Coelomactra) nasongoensis* Ladd, new species: 1, holotype, × 4; 2, paratype, × 4. 3, *Lutraria (Psammophila)* species, left valve, × 1. 4-7, *Kuphus* species: 4, section of large tube, × 1; 5, posterior part of a tube, showing unusual siphonal openings, × 1; 6, part of the same specimen, × 3; 7, interior of a tube, looking toward the siphonal openings, × 5. 8, 9, *Dentalium* (*Dentalium*) species: 8, section, and 9, side view of part of tube, × 3. 10-12, *Dentalium* (*Graptacme*) species: 10, side view, and 12, section of part of tube, × 4; 11, side view of part of another tube, showing sculpture, × 4. 13, 14, *Helcioniscus?* species, internal mold, × 1. 15, 16, *Trochus* (*Trochus*) species: 15, cast of part of external mold, × 1; 16, internal mold of same individual, × 1.

PLATE 35.—GASTROPODS.

1, 2, *Monilea* (*Monilea*) *mateana* Ladd, new species, holotype, × 4. 3, *Turbo* (*Turbo*) *petholatus thanus* Ladd, new subspecies, holotype, × 1. 4, 5, *Turbo* (*Ocana*) cf. *gruneri* Philippi: 4, internal mold, × 2; 5, cast from part of external mold, showing sculpture, × 2. 6, *Astraea* species, internal mold, × 2; after Mansfield. 7, 8, *Astraea* (*Calcar*) species *a*: 7, apertural, and 8, umbilical view, × 2. 9, *Delphinula distorta* (Linnaeus), side view, × 1. 10-12, *Delphinula* species: 10, apertural, 11, apical, and 12, umbilical views, × 1. 13, *Neritopsis radula* (Linnaeus), new subspecies? apertural view, × 1. 14, 15, *Nerita* (*Theliostyla?*) species: 14, apertural, and 15, apical views, × 3. 16, *Theodoxus* (*Clithon*) *corona* (Linnaeus), apertural view, × 2.

PLATE 36.—GASTROPODS.

1, *Theodoxus* (*Clithon*) *corona* (Linnaeus), apical view, × 2. 2, 3, *Natica* (*Natica*) *marochiensis* (Gmelin): 2, apertural, and 3, apical views, × 3. 4, 5, *Polinices* (*Polinices*) *mamilla* (Linnaeus): 4, apertural, and 5, apical views, × 2. 6, *Polinices* (*Polinices*) species, apertural view, × 2. 7, 8, *Globularia* (*Waluia*) *edwardsi* Ladd, new species, holotype, × 0.5. 9, *Cheilea* species, exterior, × 3.

PLATE 37.—AMPULLOSPIRIDAE, CALYPTRAEIDAE, AND HIPPONICIDAE.

1, 2, *Globularia* (*Waluia*) *edwardsi* Ladd, new species: 1, holotype, × 0.5; 2, paratype, *b*, × 0.5. 3, *Cheilea* species, interior, × 3. 4-6, *Hipponix* species, three views of same specimen, × 2.

PLATE 38.—GASTROPODS.

1, *Globularia* (*Waluia*) *edwardsi* Ladd, new species, paratype *a*, × 0.5. 2-4, *Architectonica* (*Architectonica*) *perspectiva* (Linnaeus), new subspecies?: 2, apical, 3, umbilical, and 4, apertural views, × 2. 5-7, *Heliacus* species: 5, apertural, 6, apical, and 7, umbilical views, × 3. 8, *Pyrazus* (*Pyrazus*) species, apertural view, × 1. 10-13, *Cypraea* (*Talparia*) *isabella lekalekana* Ladd, new subspecies: 10, 11, holotype, × 1; 12, 13, paratype, × 1.5.

PLATE 39.—GASTROPODS.

1, 2, *Tibia* cf. *powisii modesta* (Martin): 1, apertural, and 2, lateral views, × 2. 3-5, *Cypraea* (*Erosaria*) *agassizi* Ladd, new species, holotype, × 2. 6-8, *Cypraea* (*Monetaria*) *annulus sosokoana* Ladd, new subspecies, holotype, × 2. 9, 10, *Trivia* (*Trivia*) *koroensis* Ladd, new species, holotype, × 6. 11, *Tonna?* species, apertural view, × 1. 12, *Semicassis* (*Semicassis*) *vavakuana* Ladd, new species, holotype, × 1. 13, *Gyrinium* species, apertural view, × 2. 14, 15, *Septa rubecula* (Linnaeus), new subspecies?, two views of same specimen, × 1.

PLATE 40.—GASTROPODS.

1, 2, "*Thais*" species, two views of same specimen, × 2. 3-5, *Murex* (*Murex*) aff. *recurvirostris* Broderip: 3, 4, two views of same specimen, × 2; 5, apertural view of a smaller specimen, × 1. 6, *Phos vitiensis* Ladd, new species, holotype, × 2. 7, *Mitra (Tiara) fijiensis* Ladd, new species, holotype, × 3. 8, *Mitra (Tiara) nasongoensis* Ladd, new species, holotype, × 3. 9, *Vexillum (Vexillum) gembacana* (Martin), apertural view, × 3. 10, *Oliva carneola* (Gmelin), apertural view, × 2. 11, Oliva *makawana* Ladd, new species, holotype, × 2.

PLATE 41.—GASTROPODS.

1, *Oliva woolnoughi* Ladd, new species, holotype, × 2. 2, *Cancallaria tholoensis* Ladd, new species, holotype, × 1. 3, *Conus affinis* Martin, apertural view, × 2. 4, *Conus pulicarius?* Hwass, apertural view, × 1. 5, *Conus* species *b*, internal mold, × 2. 6, 7, *Conus* species *c*: 6, cast from part of external mold, showing sculpture, × 2; 7, internal mold of same individual, × 1. 8, *Conus* species *d*, apertural view, × 1. 9, *Terebra (Strioterebrum)* species, apertural view, × 2. 10, *Styliola acicula (Rang)*, a group of tubes, × 3. 11, *Cavolina telemus rewaensis* Ladd, new subspecies, holotype, × 3.5.

PLATE 42.—GASTROPODS AND PISCES.

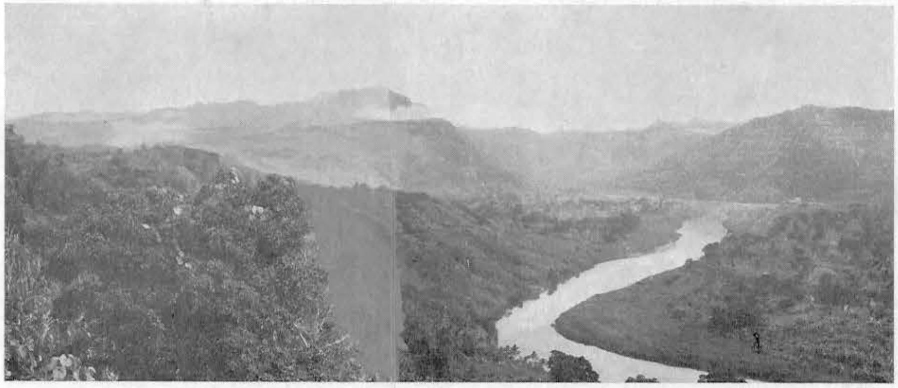
1, *Cavolina telemus rewaensis* Ladd, new subspecies, holotype, × 3.5. 2, 3, *Cavolina globulosa* Rang: 2, dorsal, and 3, lateral views, × 6. 4, 5, *Cavolina osoica* Ladd, new species, holotype, × 4. 6, 7, *Diacria mbaensis* Ladd, new species: 6, paratype, × 6; 7, holotype, × 6. 8, *Carcharodon megalodon* Agassiz, outer face, × 1. 9, *Trygon* or *Myliobatis* species?, dorsal view, × 1.

PLATE 43.—PISCES AND FOSSIL BIRD'S EGG.

1-3, *Hemipristis serra* Agassiz, three views of the same specimen, × 1. 4, *Carcharodon megalodon* Agassiz, inner face, × 1. 5, *Trygon* or *Myliobatis* species?, ventral view, × 1. 6, 7, Bird's egg, two views, × 1.

PLATE 44.—DECAPOD CRUSTACEANS.

1-3, *Maja laddi* Rathbun, new species: 1, holotype, a carapace, × 2; 2, left manus, outer side, × 2; 3, top view of same specimen, × 2. 4-7, *Parthenope (Platylambrus) fijiensis* Rathbun, new species: 4, holotype, left manus, upper view, × 3; 5, outer view, × 3; 6, upper inner view, × 3; 7, lower side, × 3. 8, *Chlorodiella junghuhni?* (K. Martin), view of carapace, × 3. 9, *Montezumella lamiensis* Rathbun, new species, holotype, a carapace, × 1 (sn = sinus; sp = spine). 10, *Myra? fijiensis* Rathbun, new species, holotype, part of carapace, × 3.



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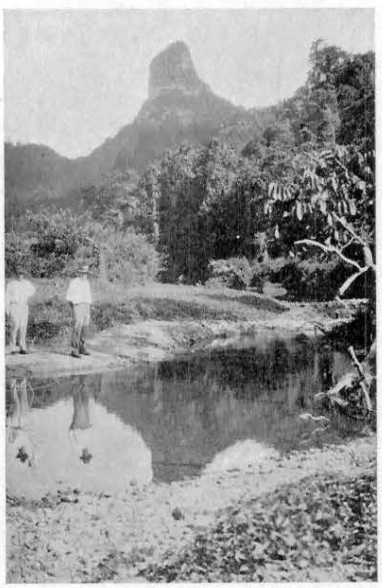

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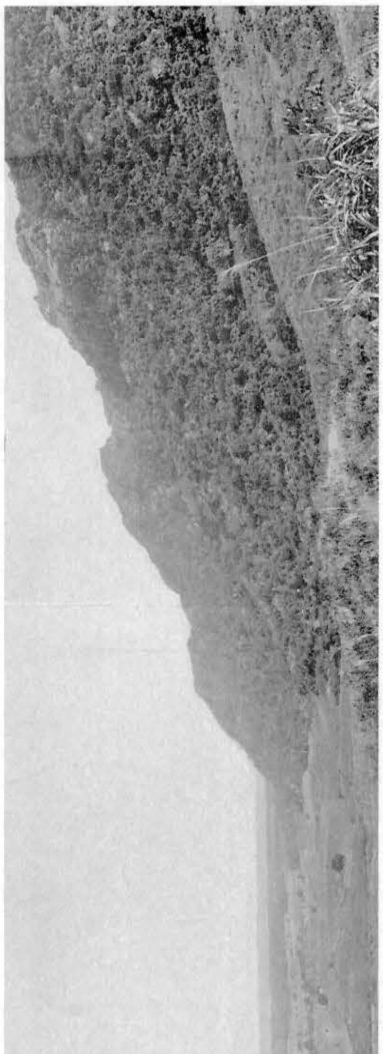

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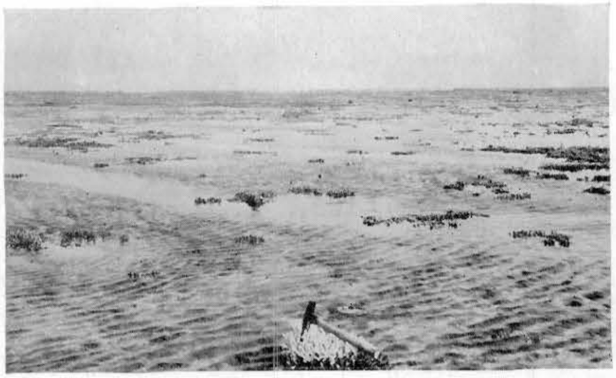

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BARRIER REEF.

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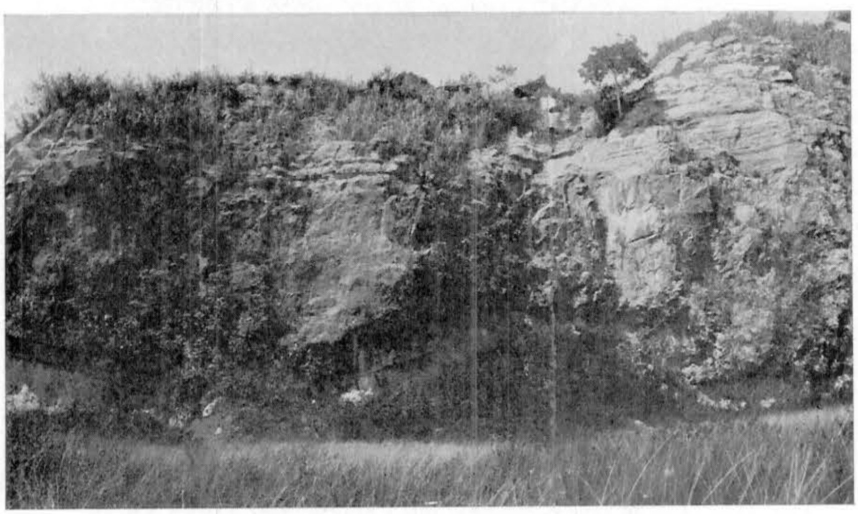
B



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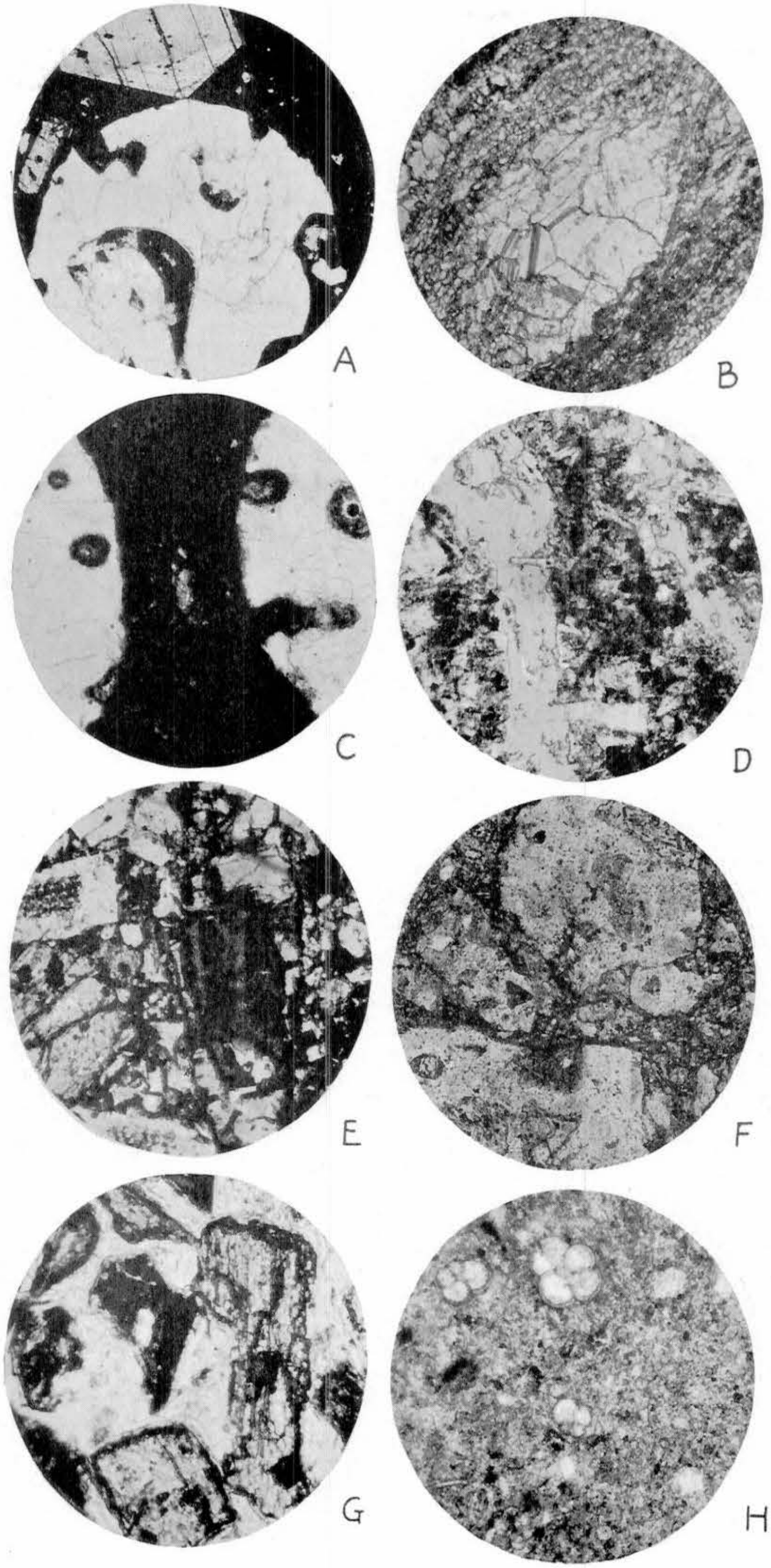
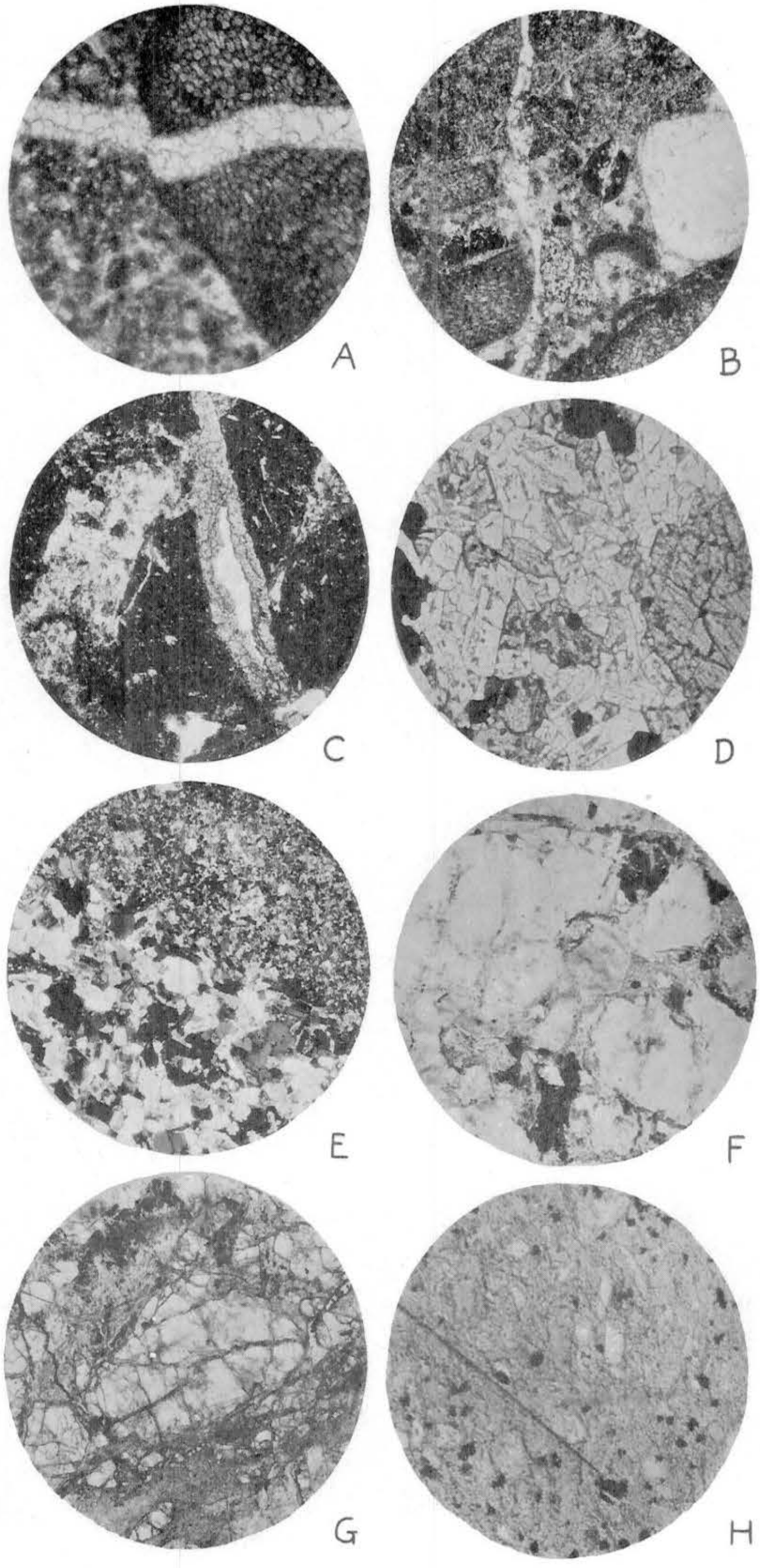


PHOTOMICROGRAPHS OF ROCK SECTIONS.



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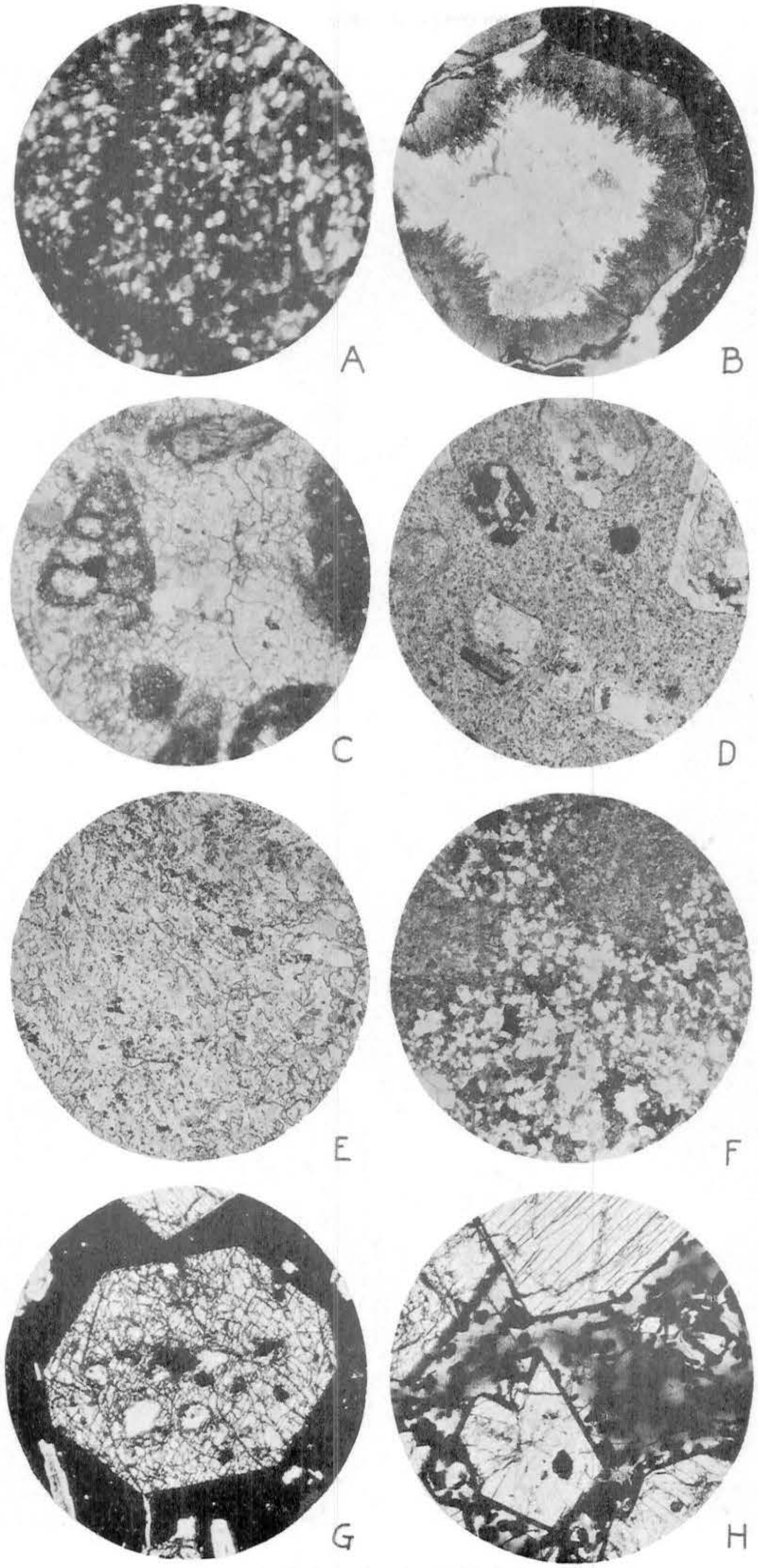

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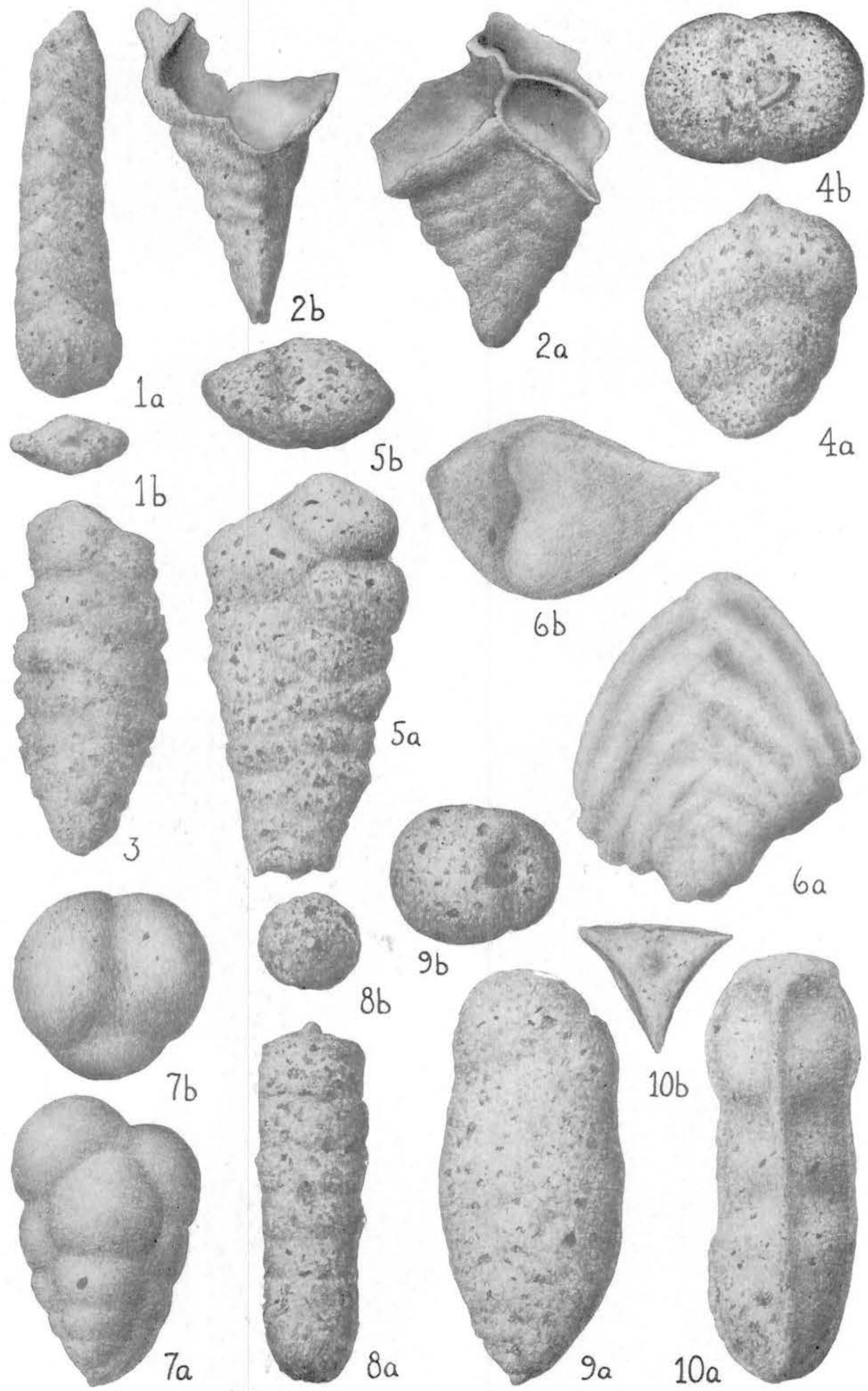
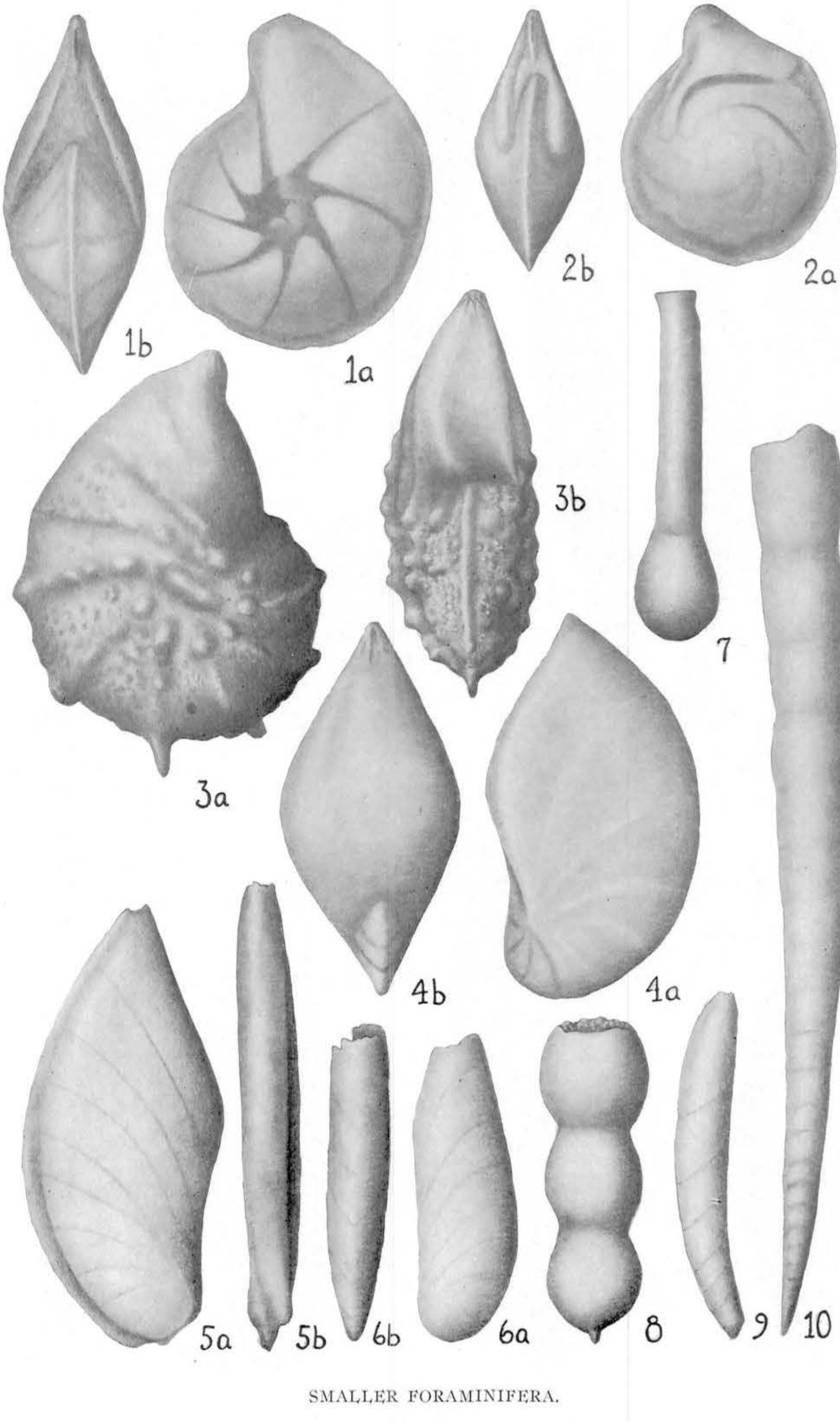


SMALLER FORAMINIFERA.



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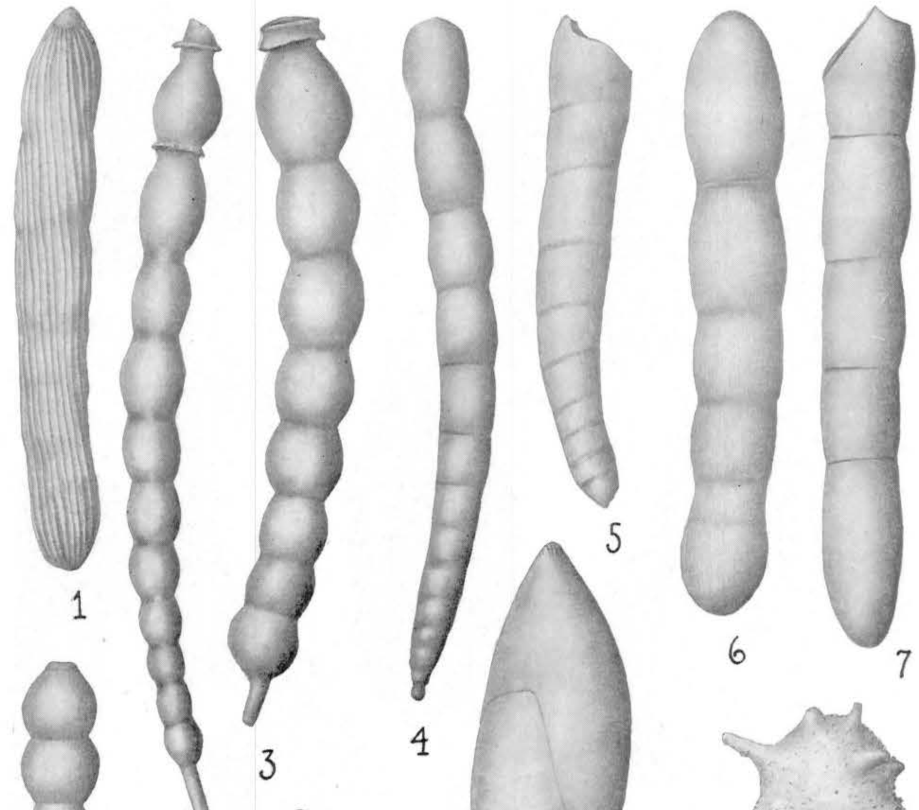

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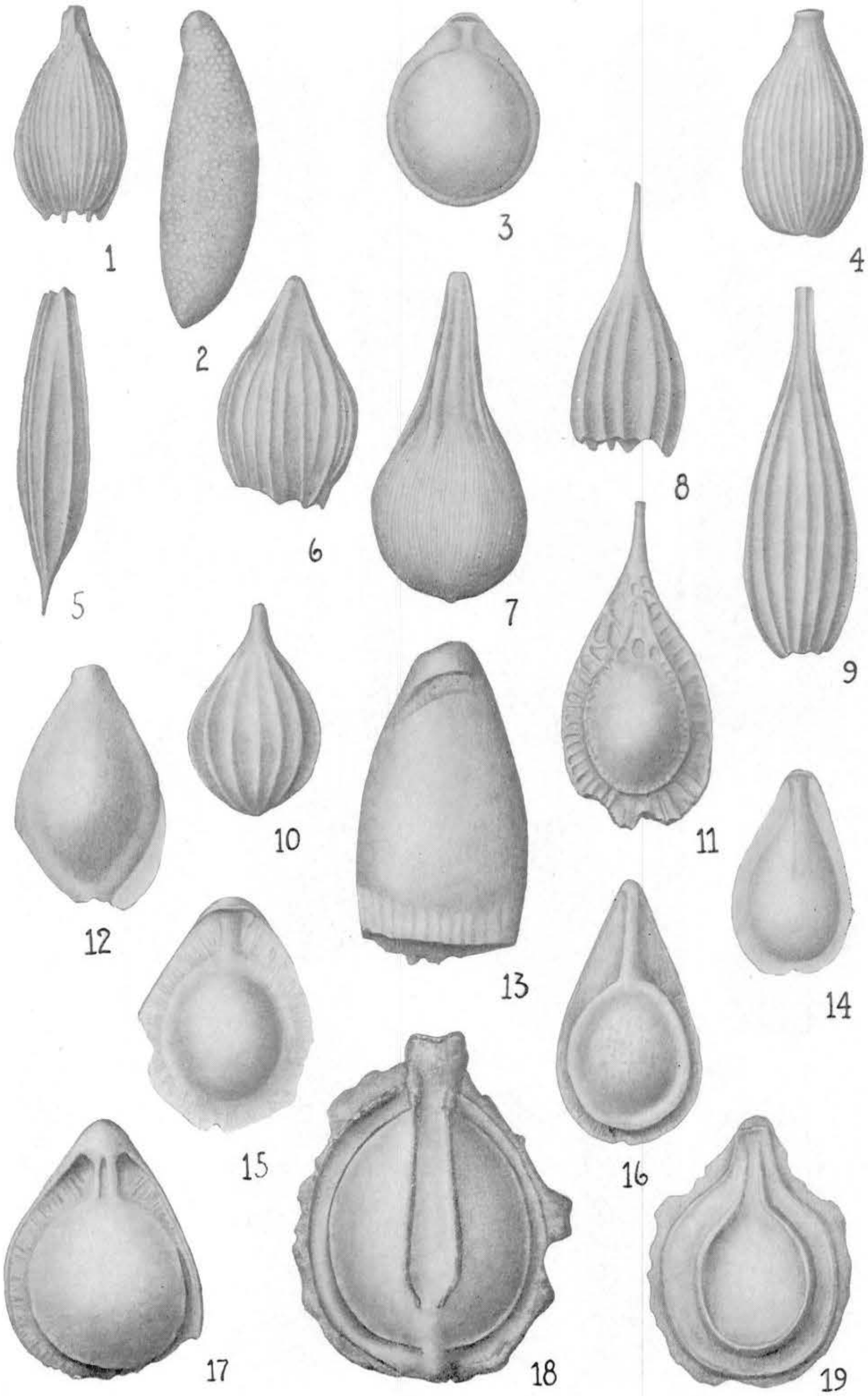

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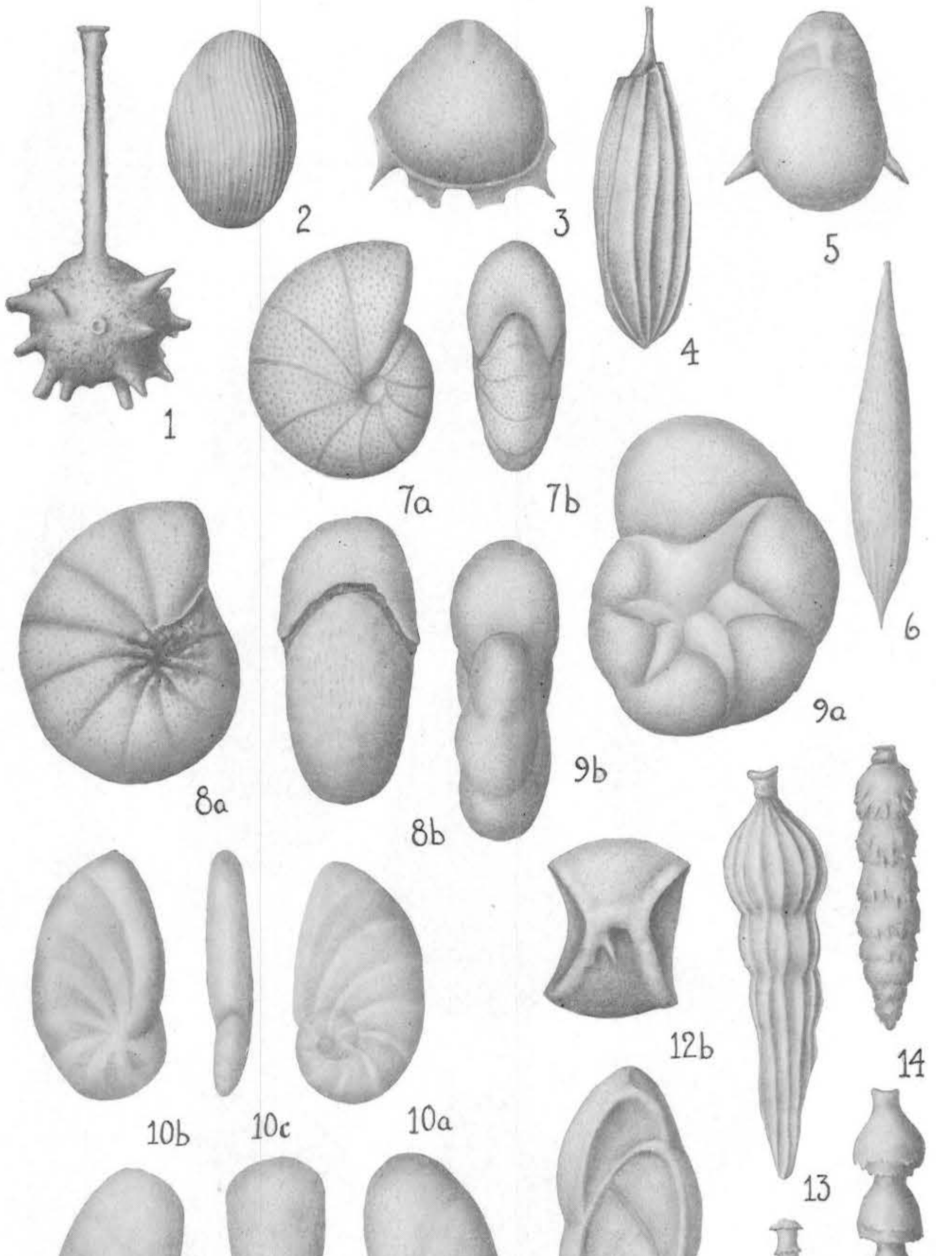

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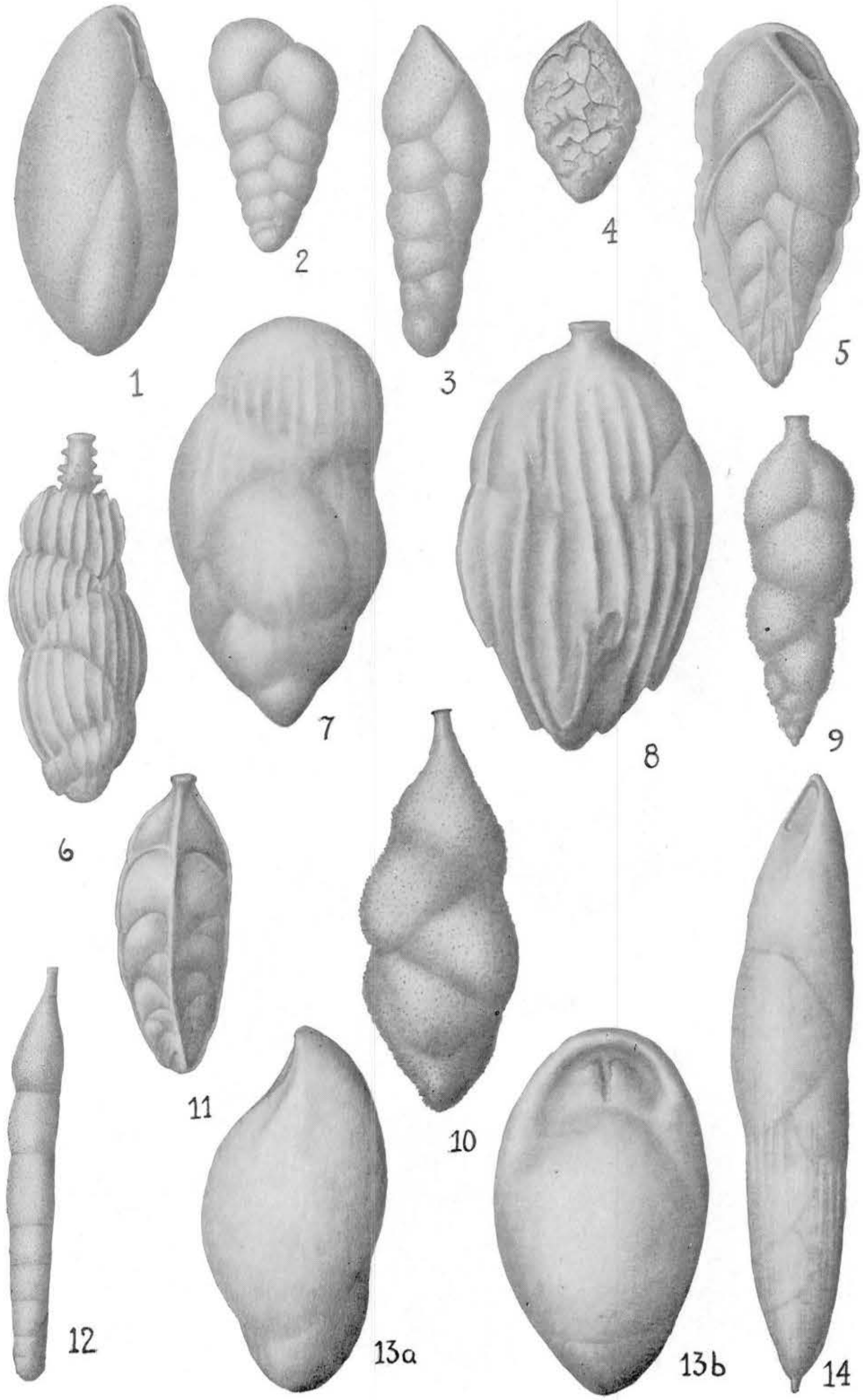

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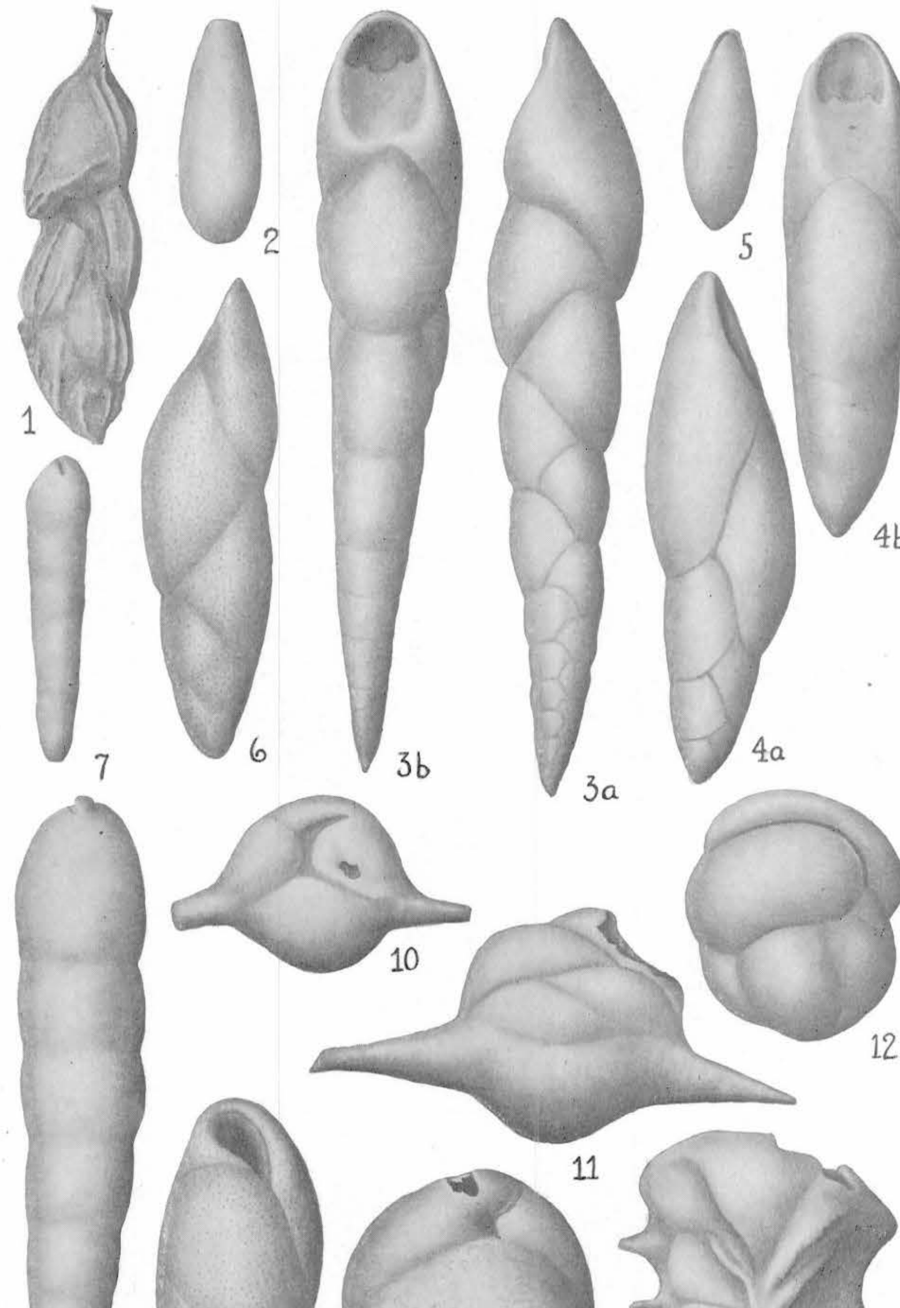

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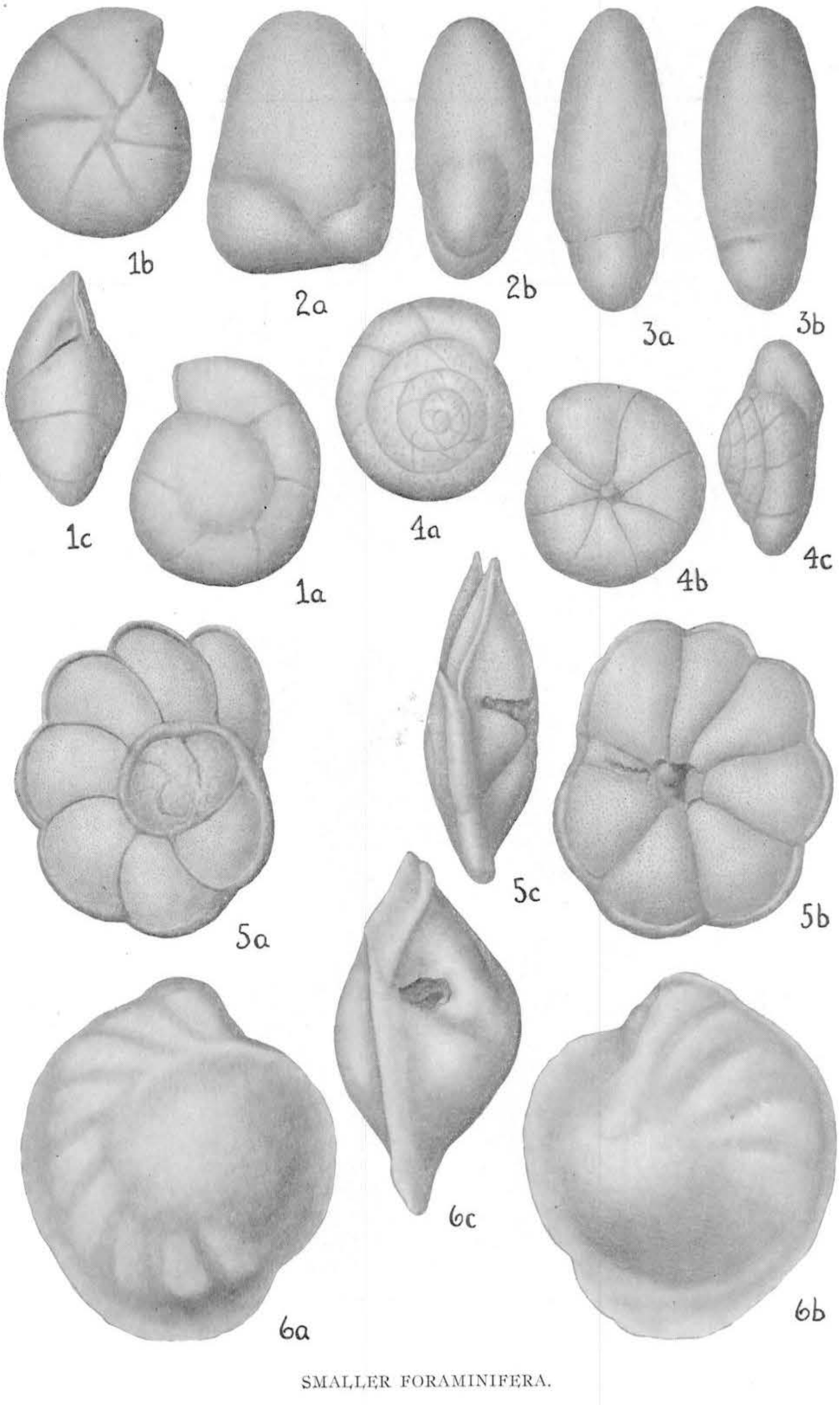

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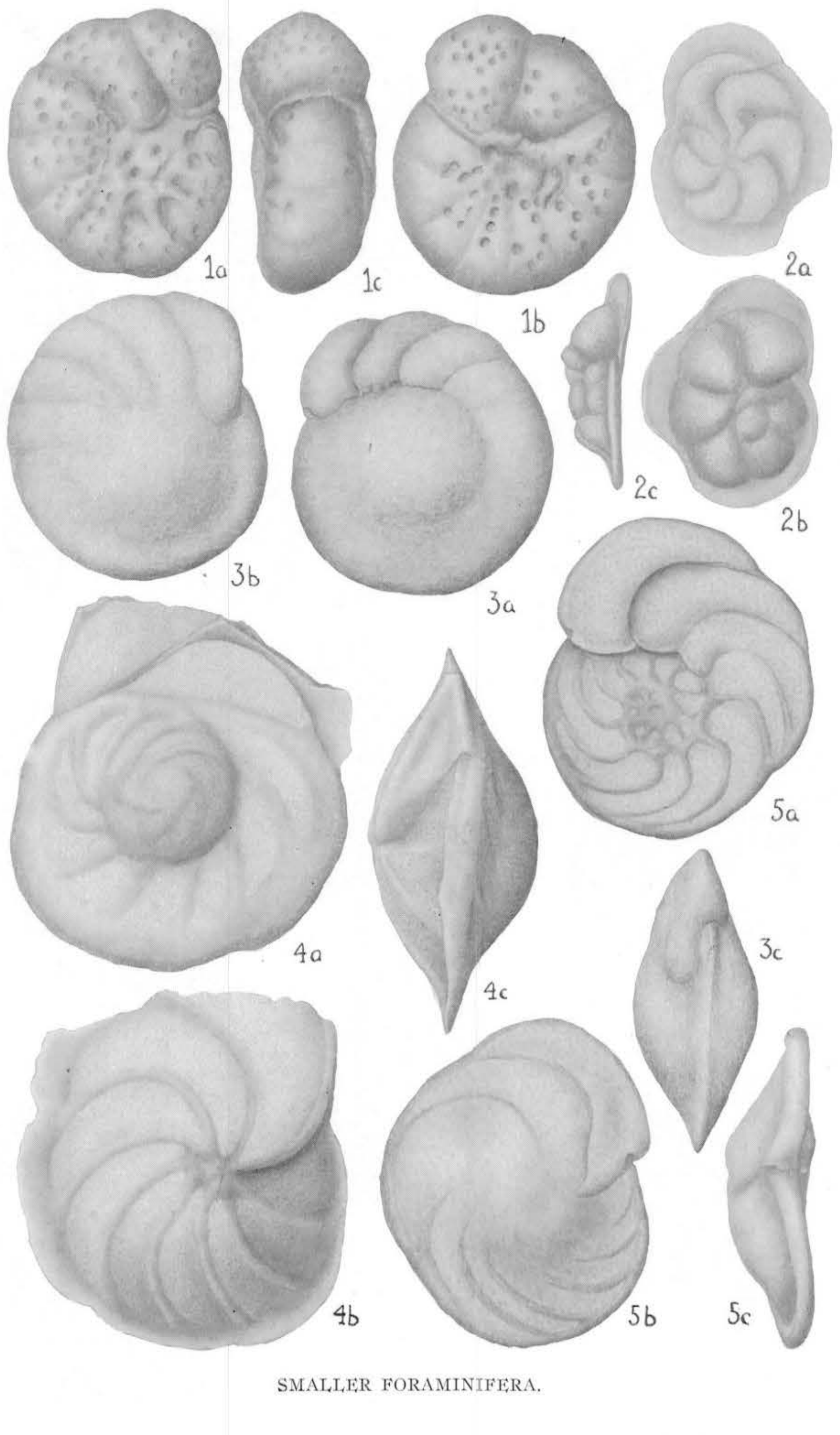

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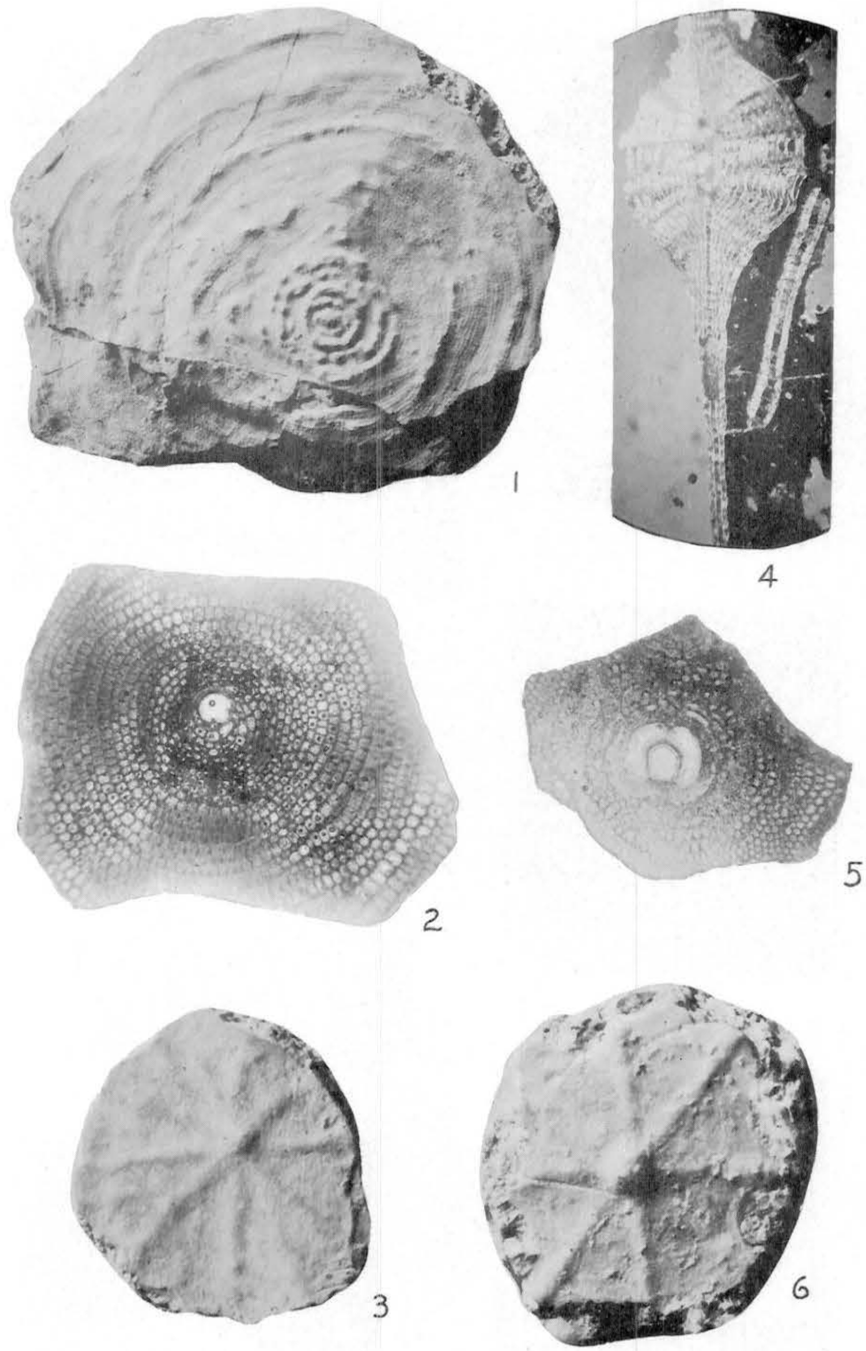
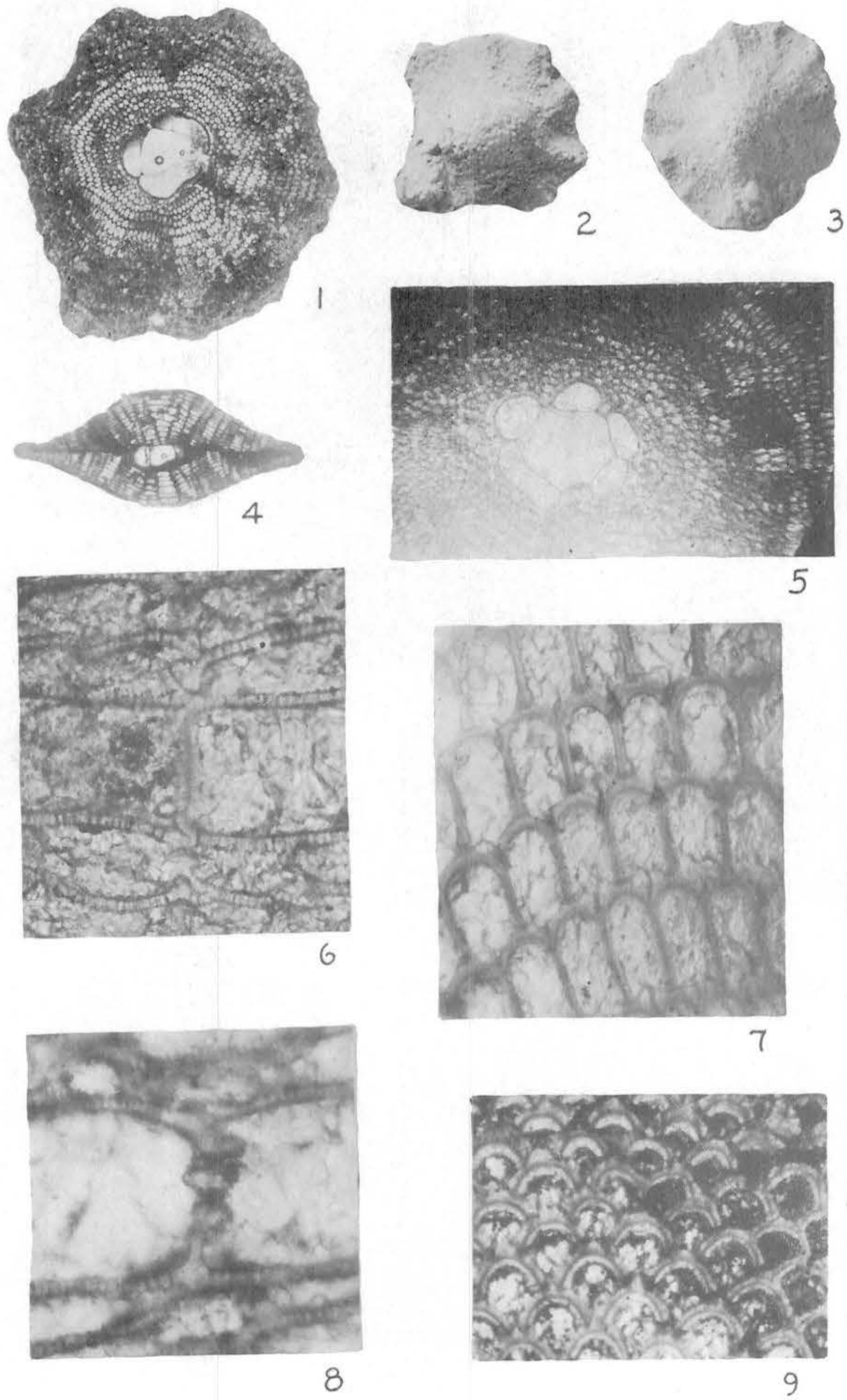


LARGER FORAMINIFERA.



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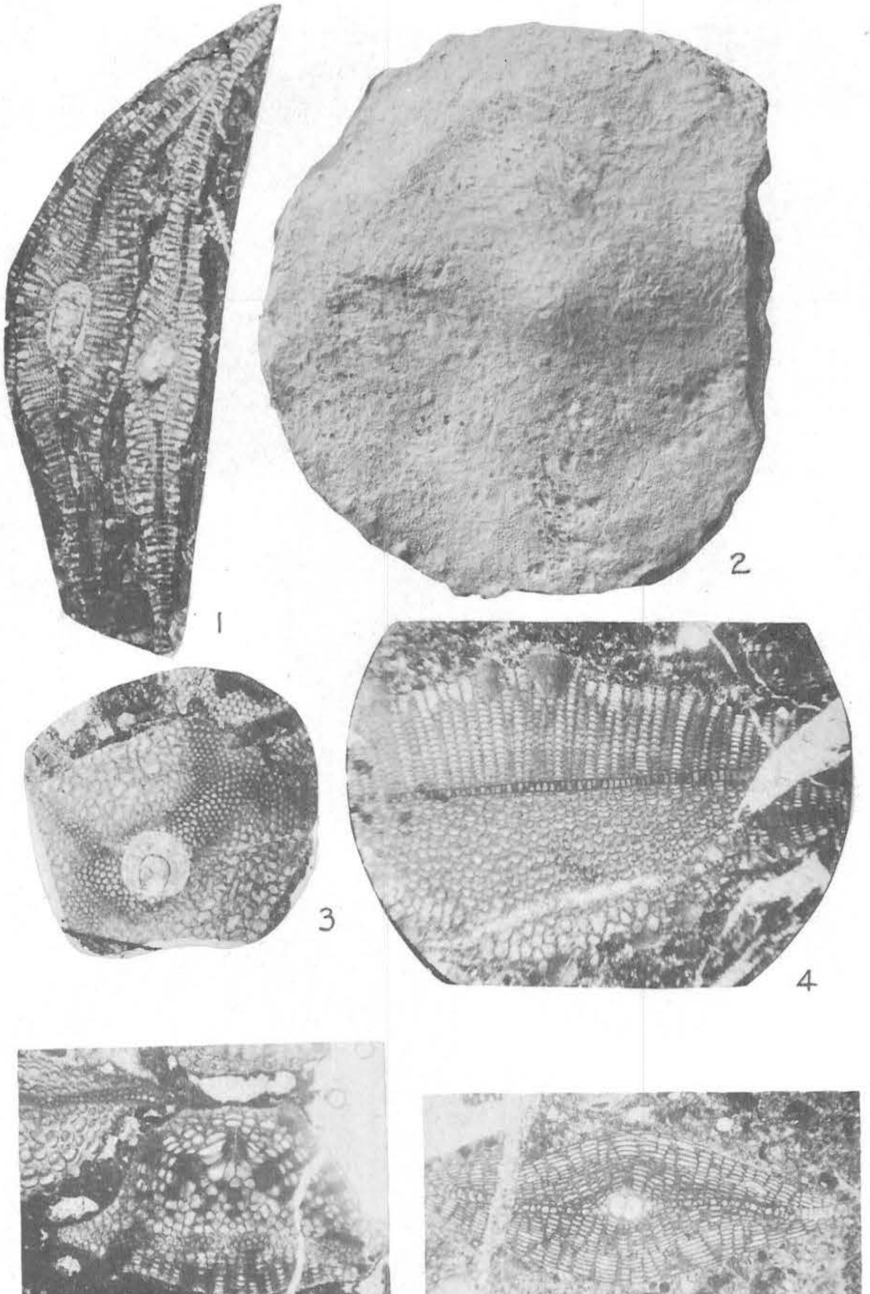

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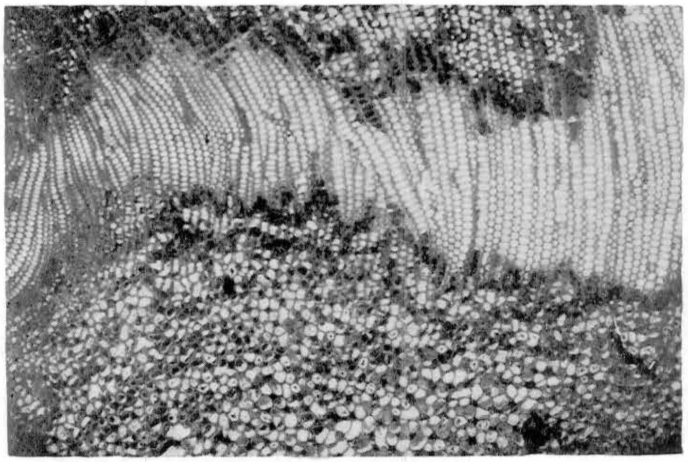

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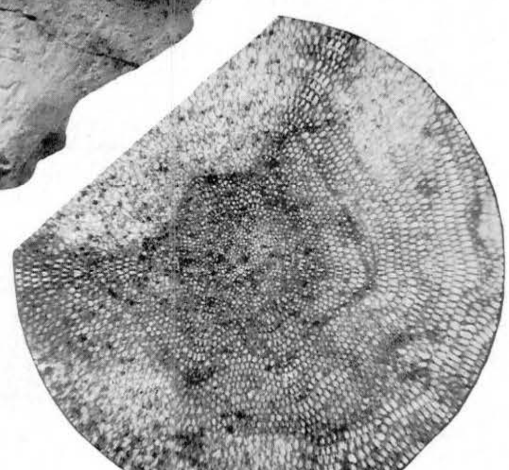

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LARGER FORAMINIFERA.

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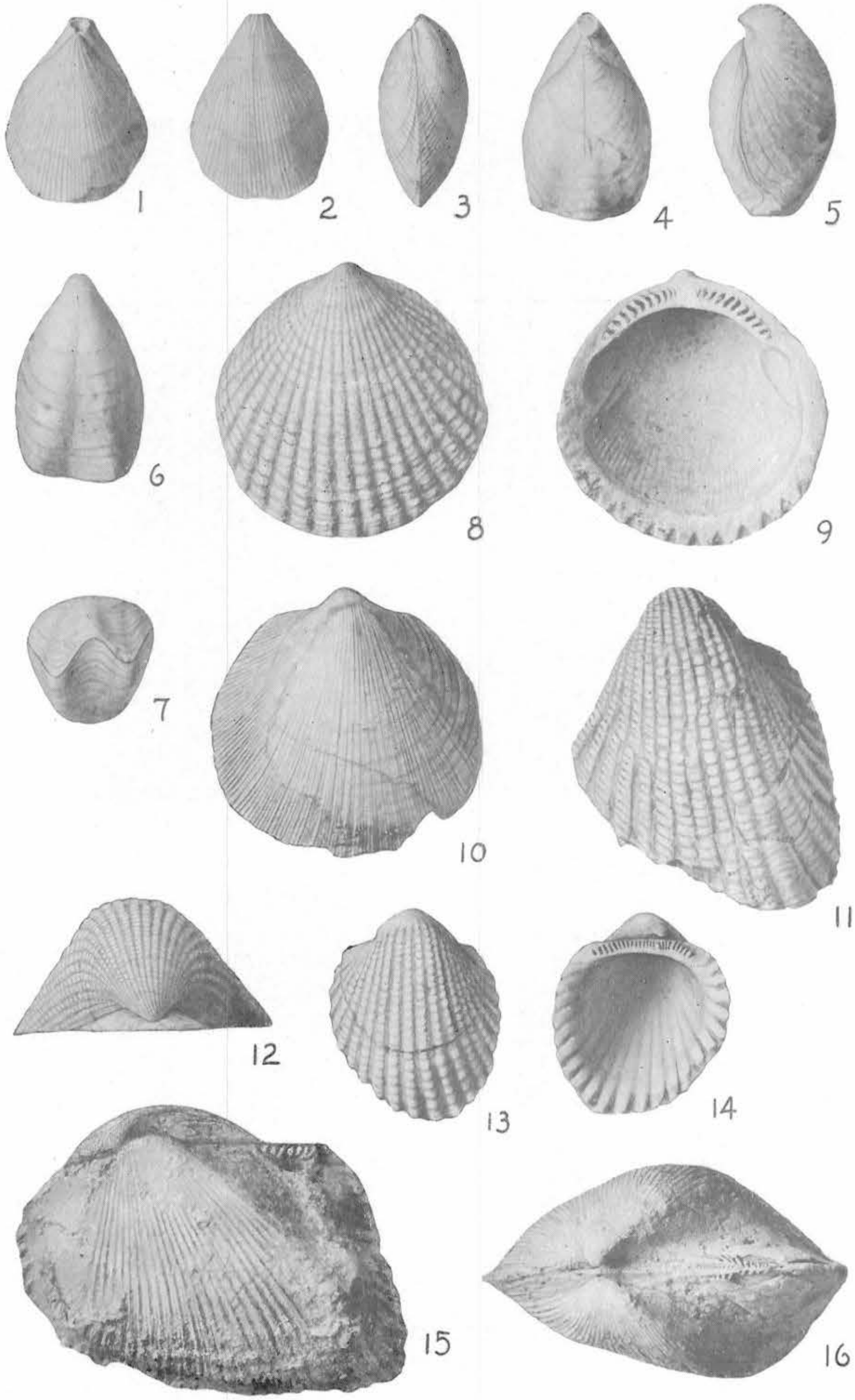
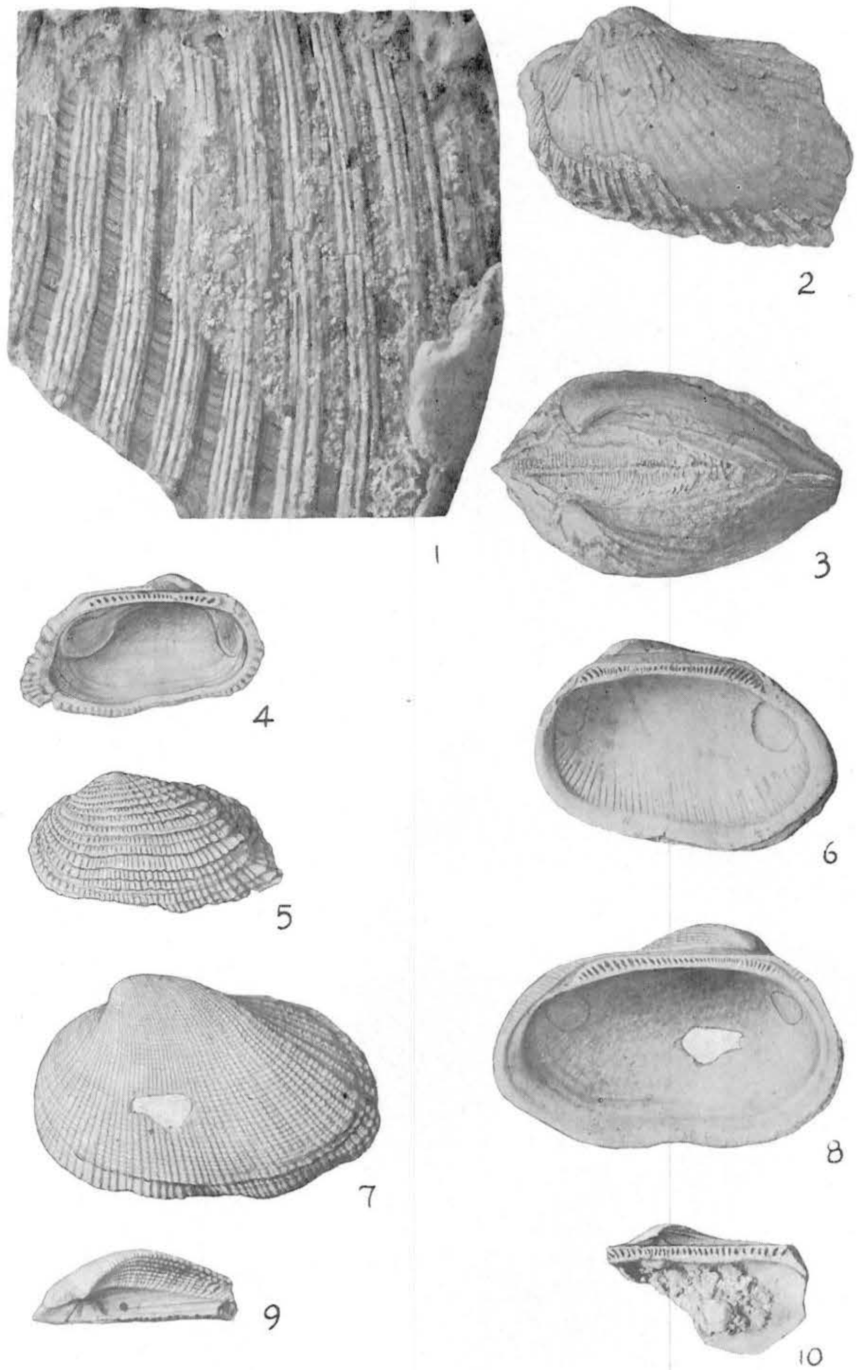
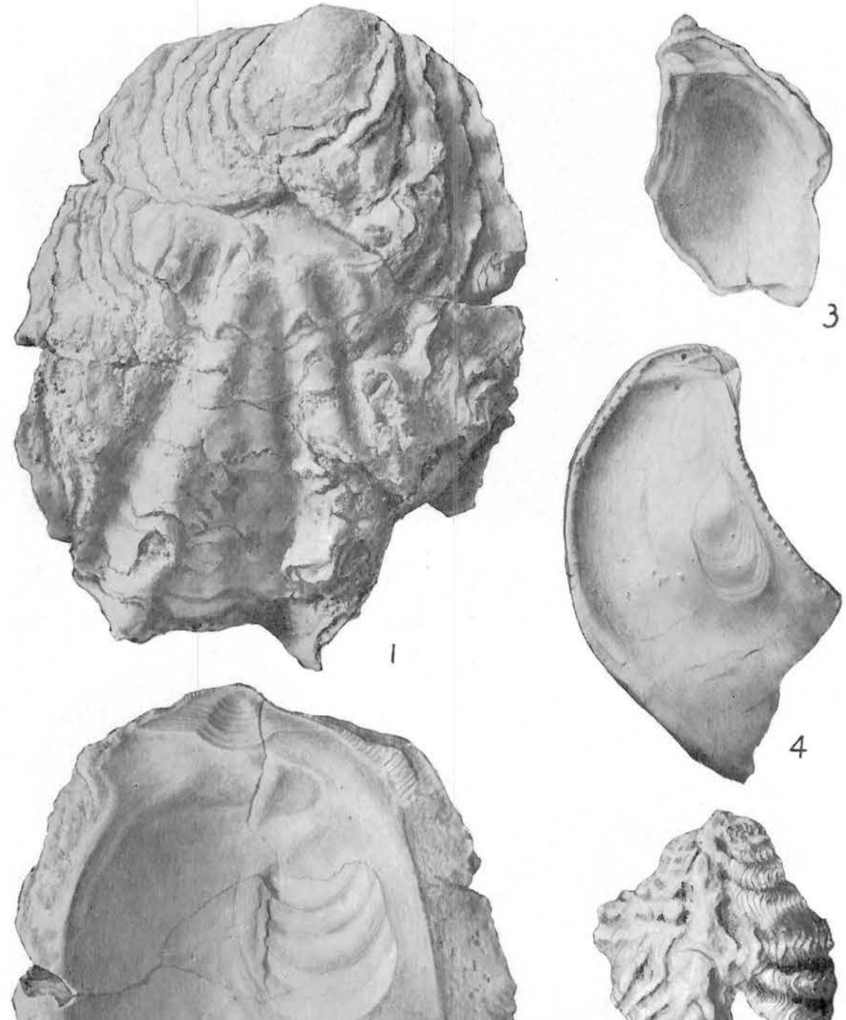
LARGER FORAMINIFERA.



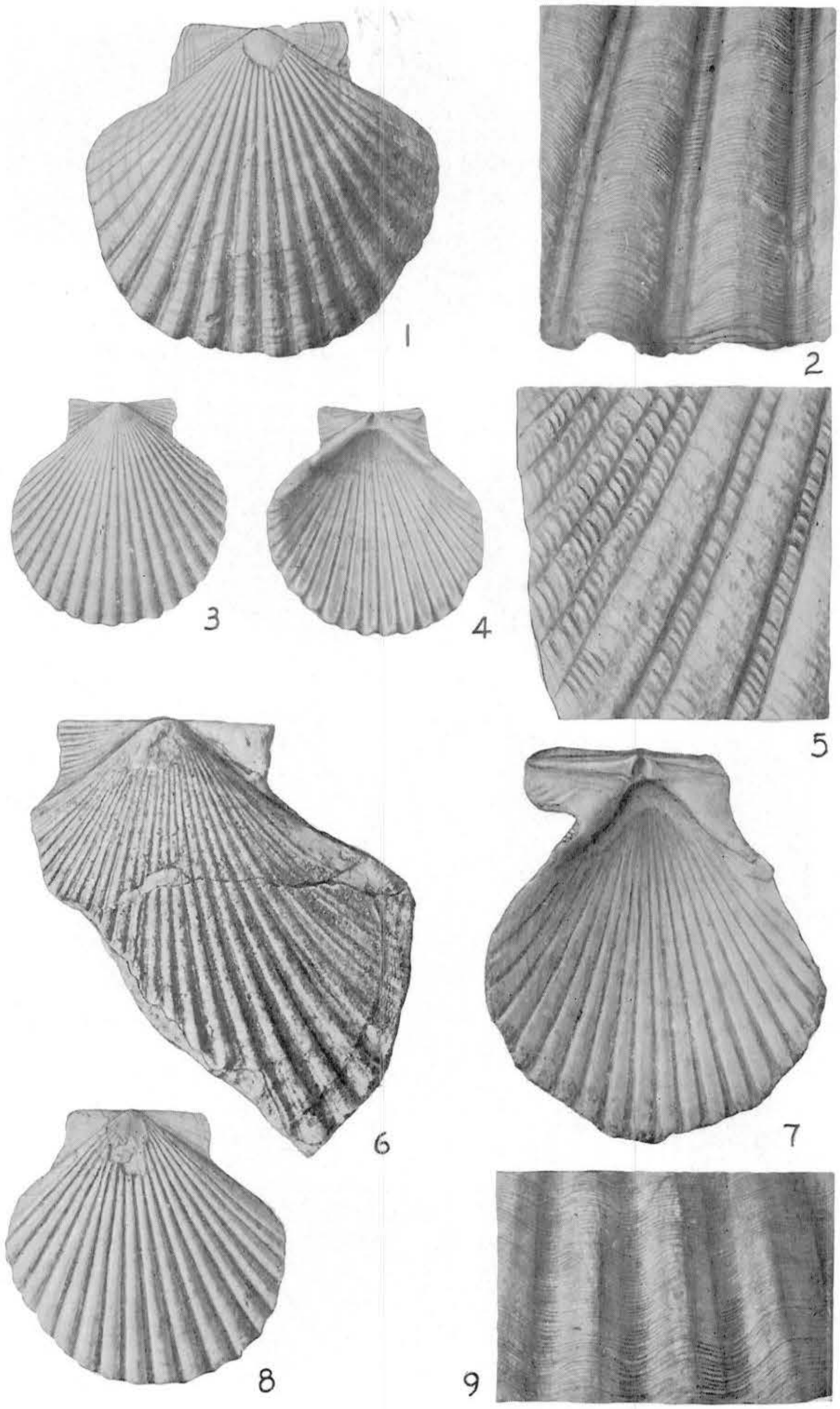
BRACHIOPODS AND PELECYPODS.



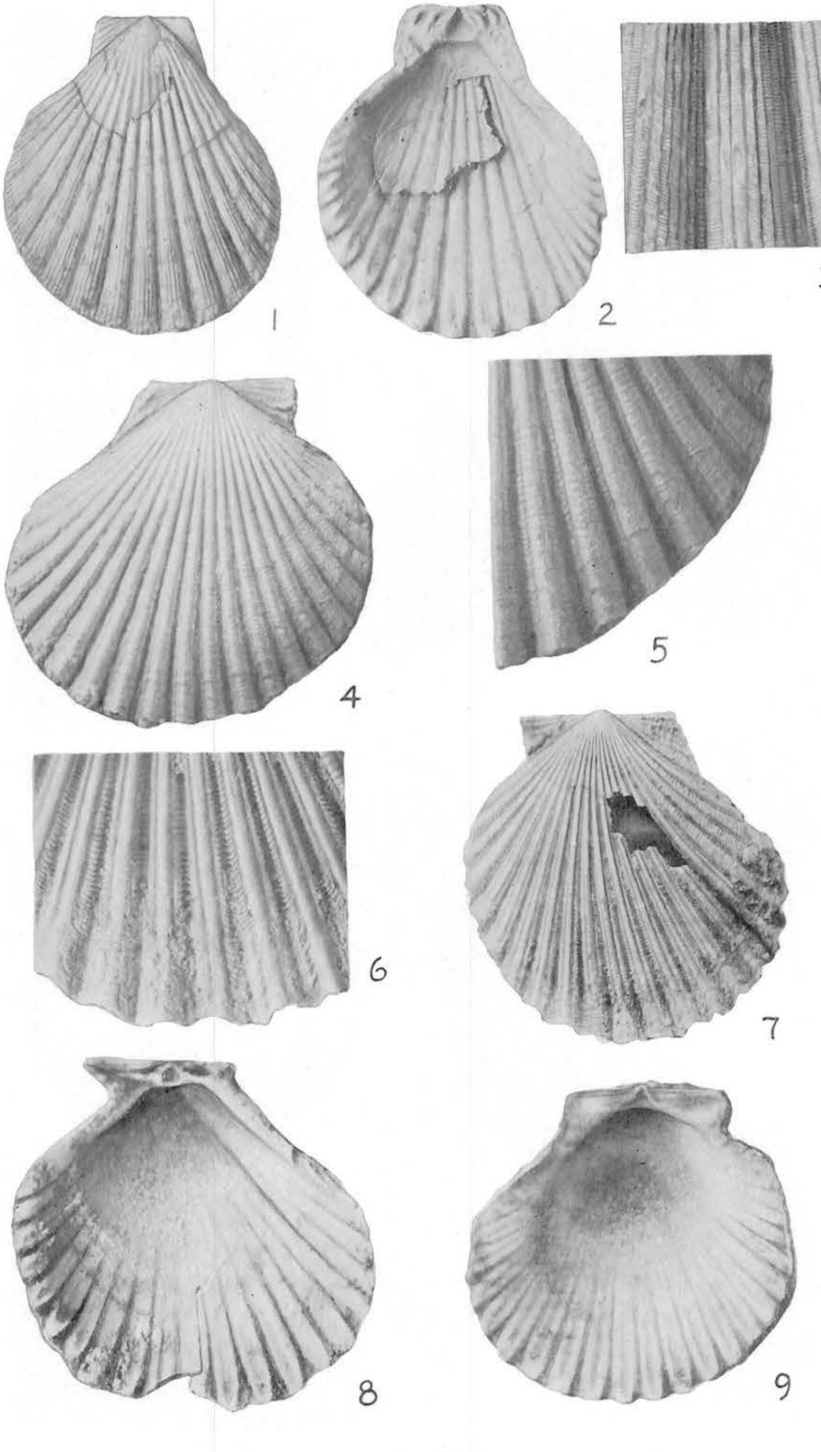
ARCIDAE.



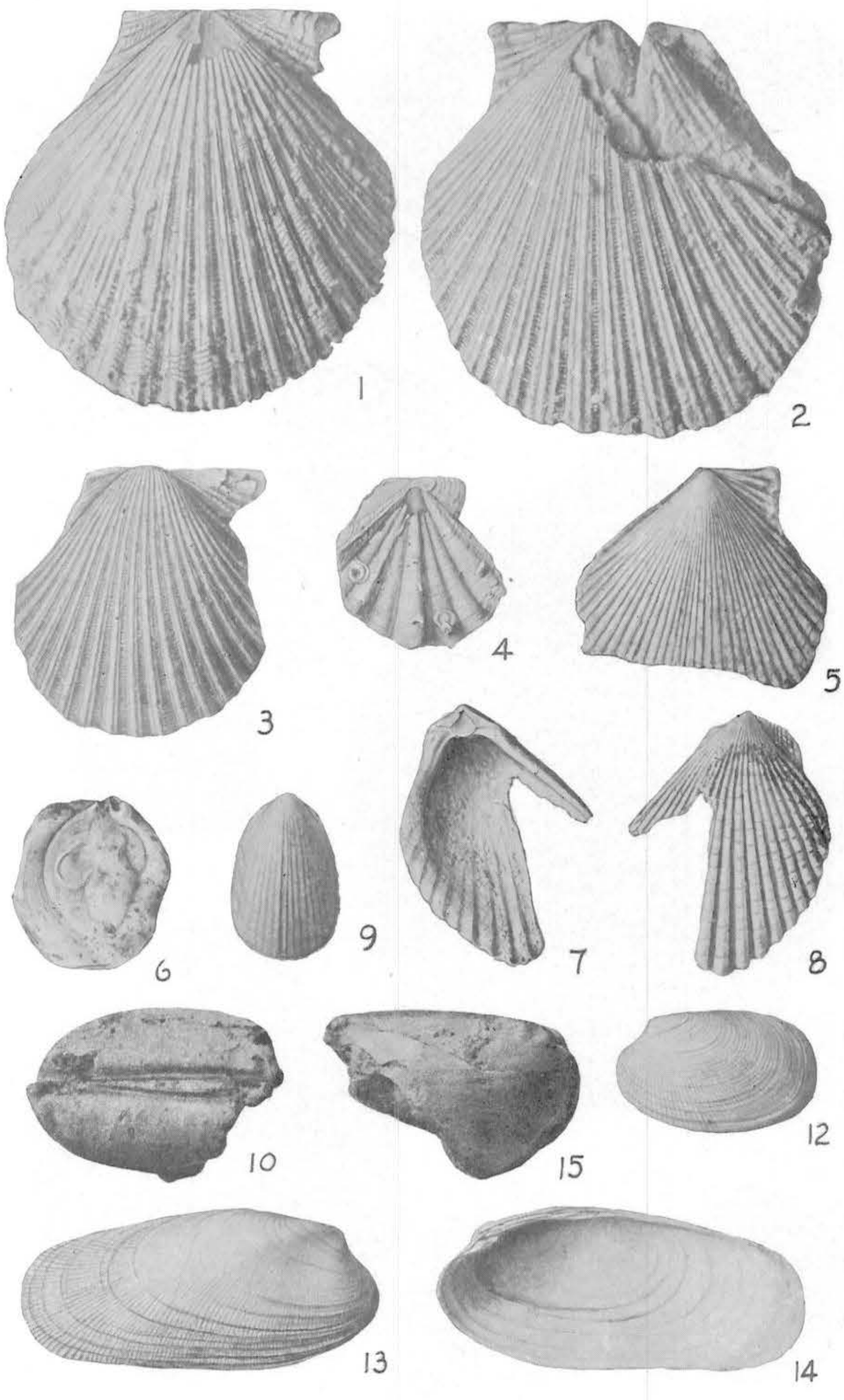
OSTREAS.



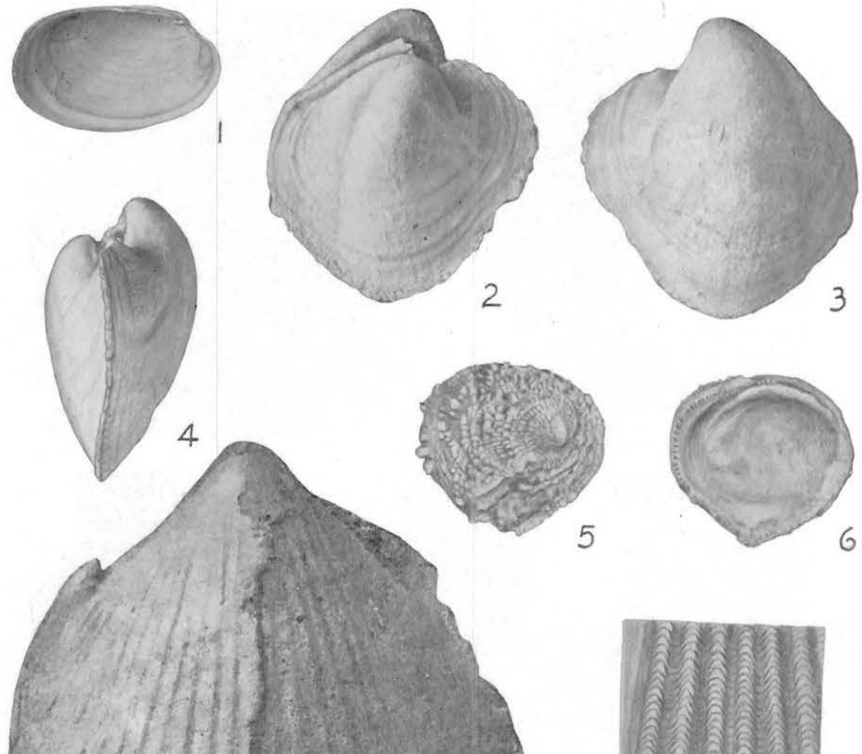
PECTENS.



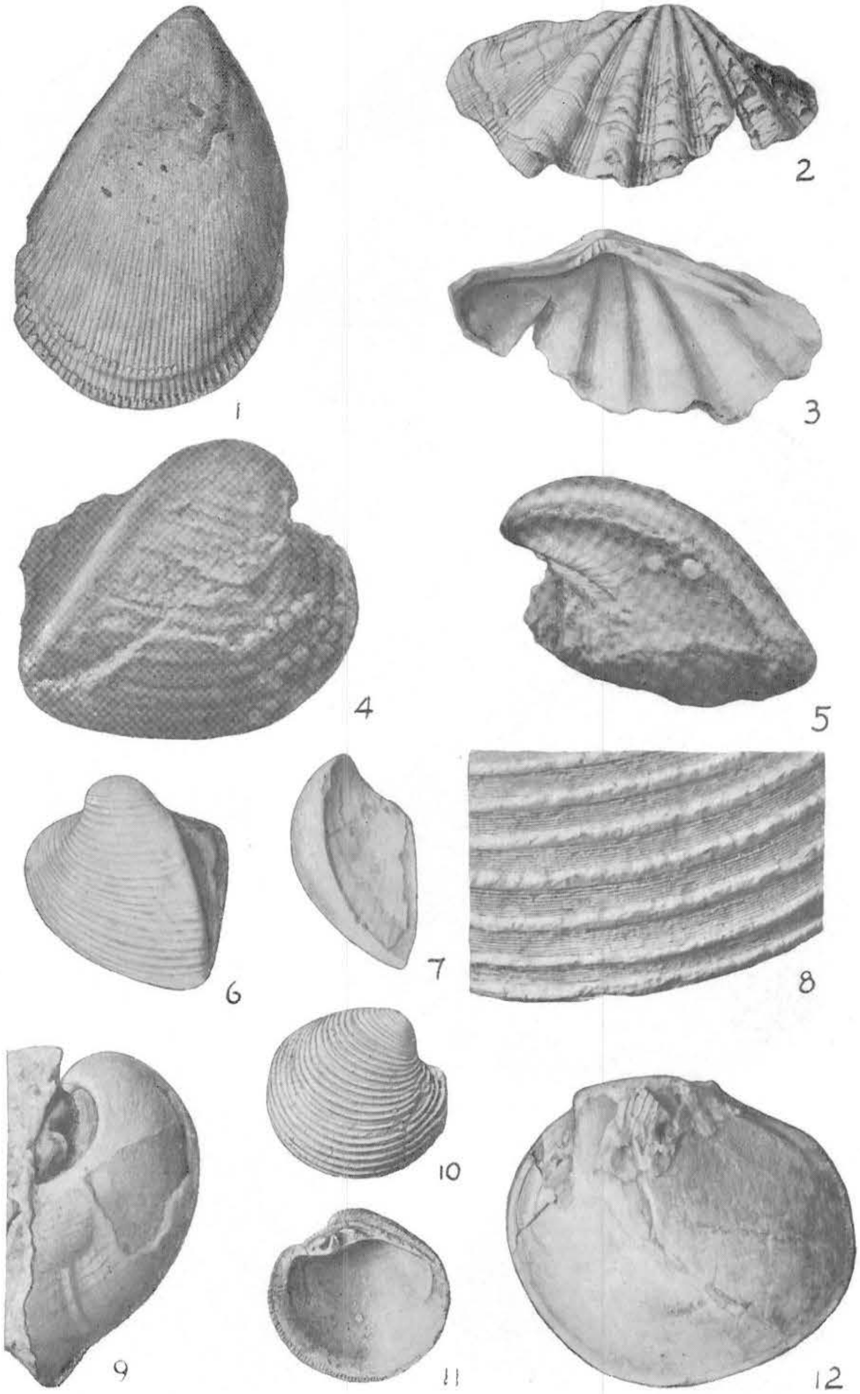
PECTENS.



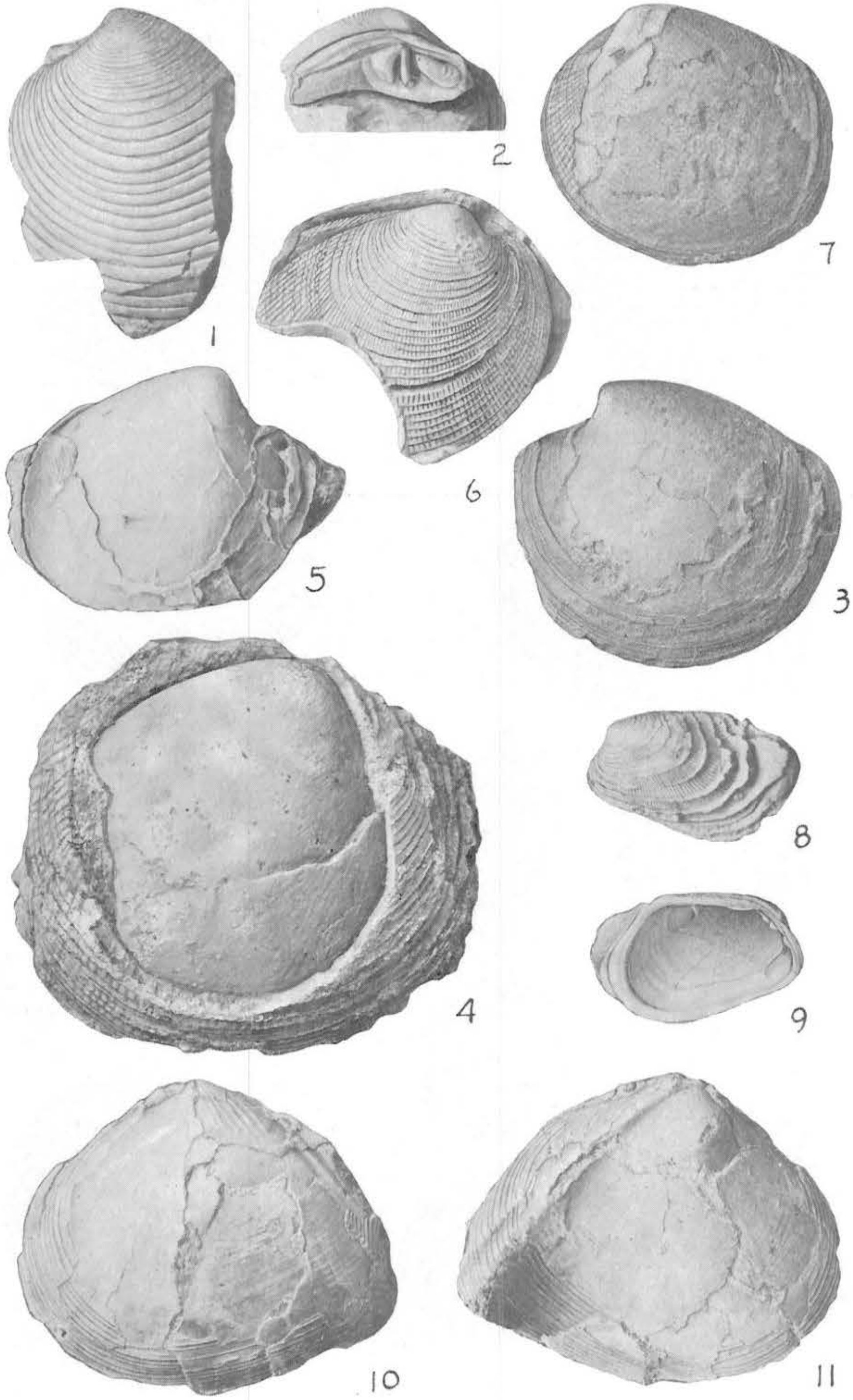
PELECYPODS.



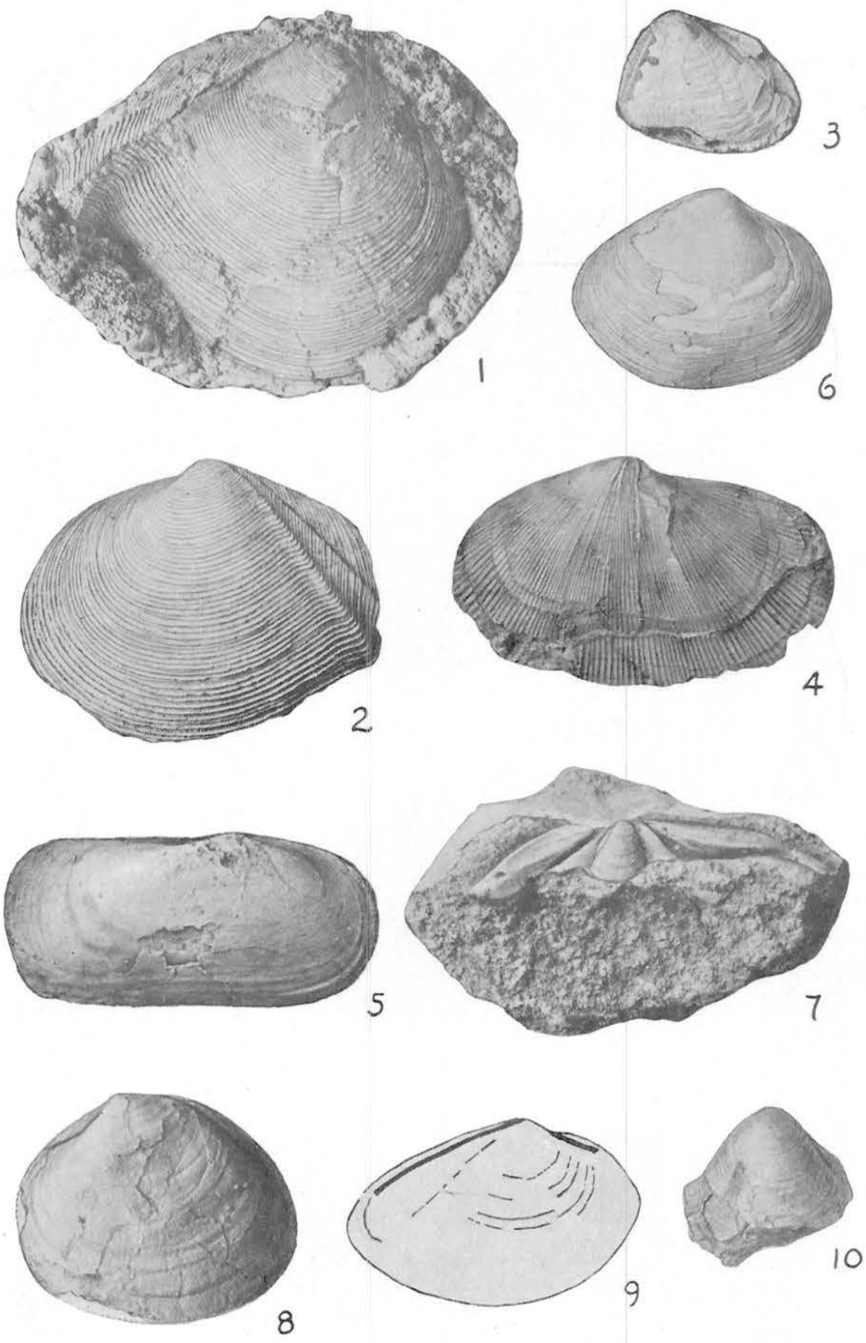
PLEUROPHORIDAE, CHAMIDAE, AND CARDIIDAE.



PELECYPODS.



VENERIDAE AND TELLINIDAE.



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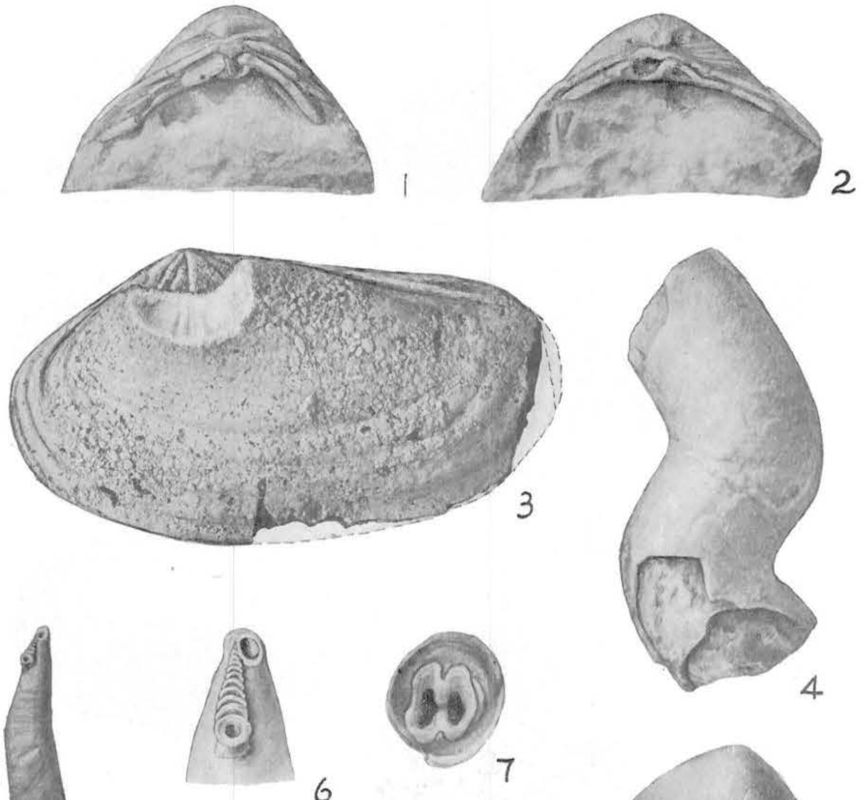
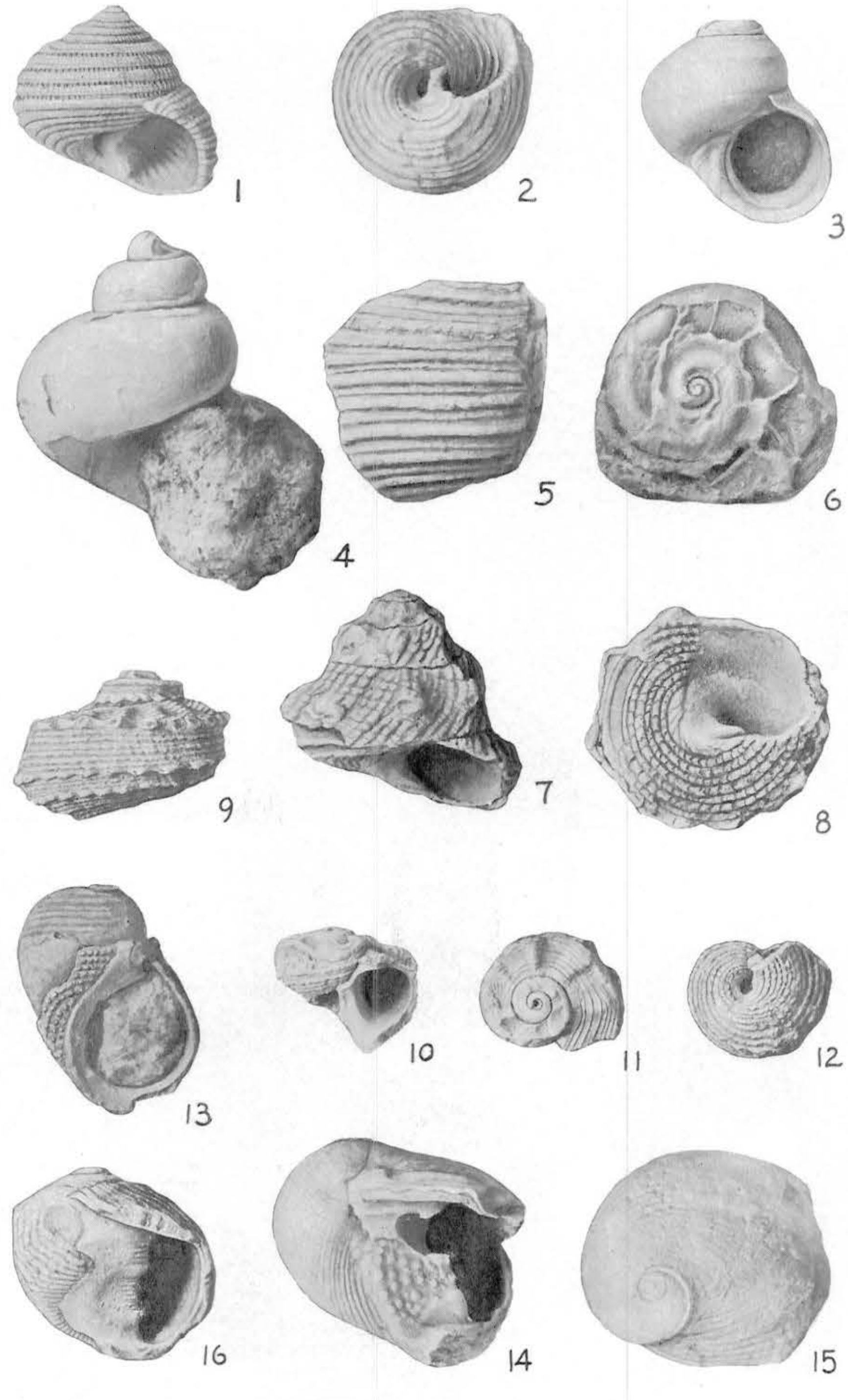
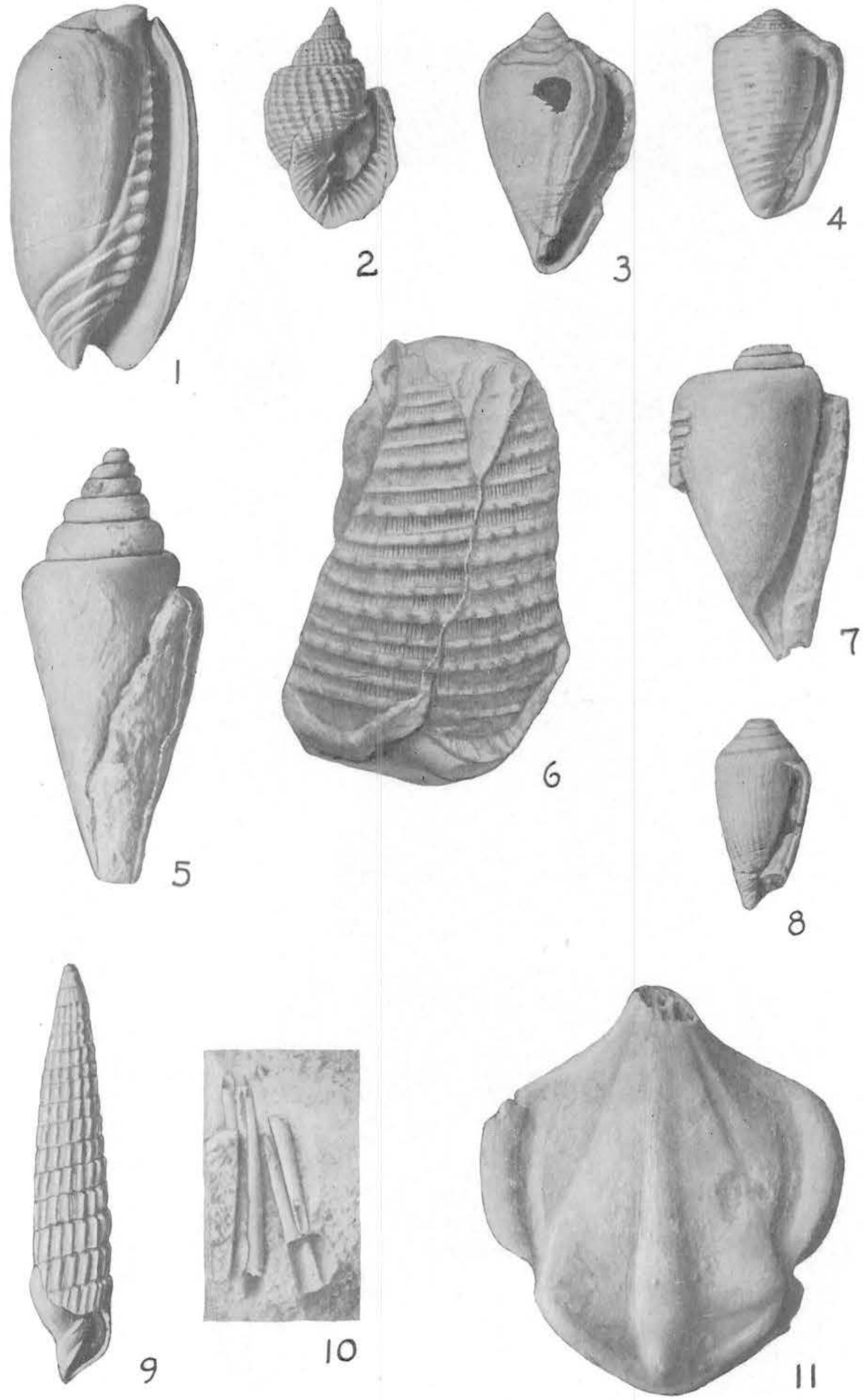


PELECYPODS, SCAPHOPODS, AND GASTROPODS.



GASTROPODS.

GASTROPODS.



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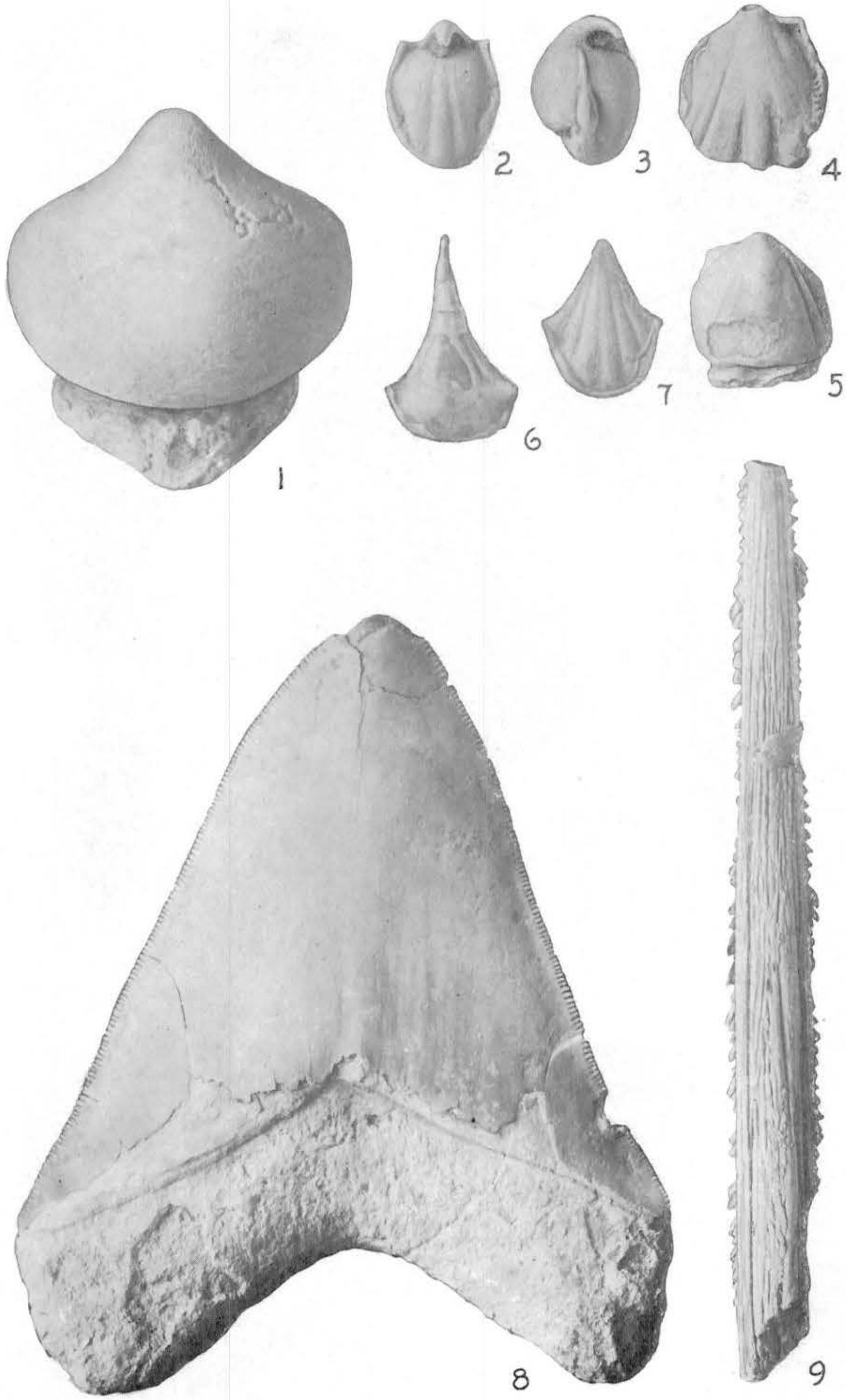
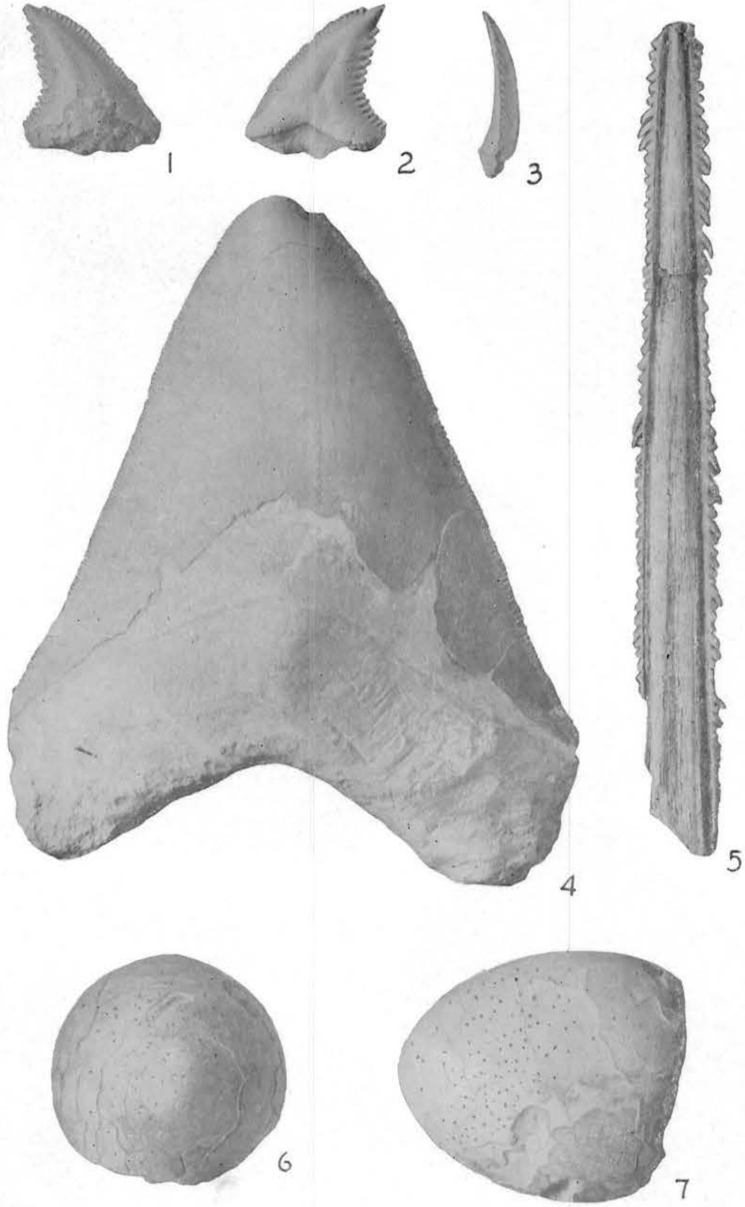
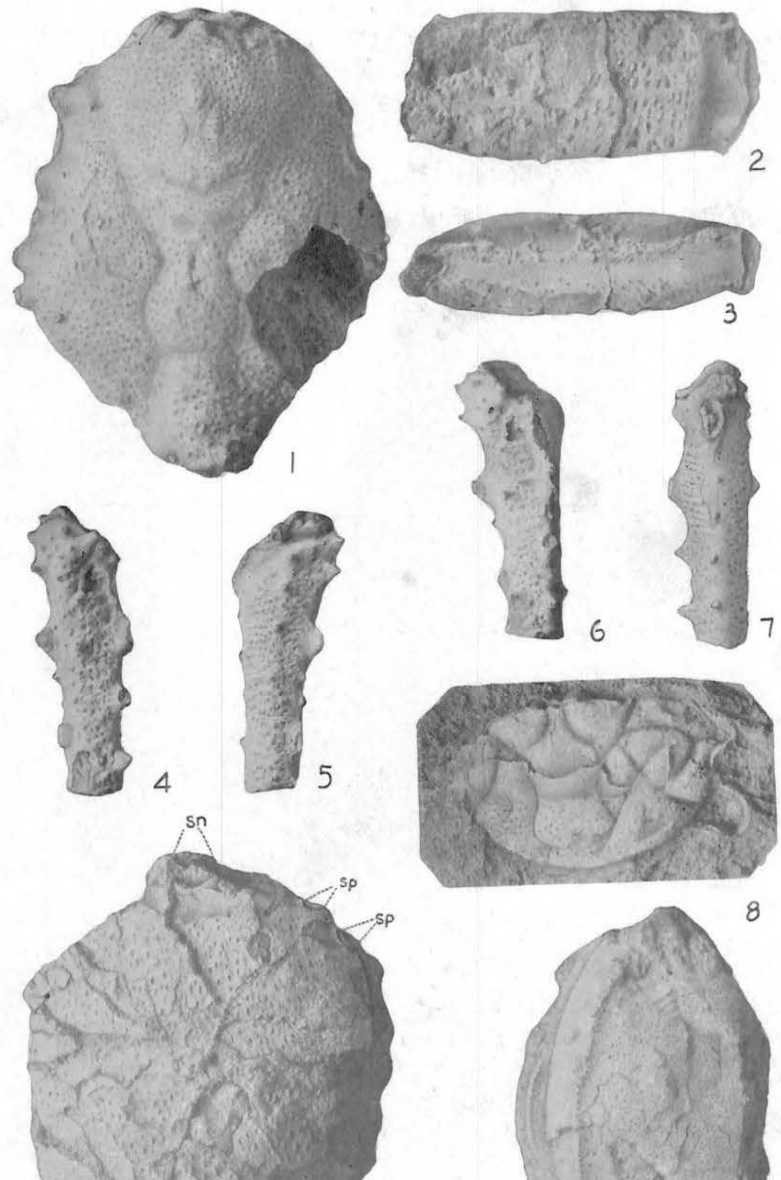


GASTROPODS AND PISCES.



PISCES AND FOSSIL BIRD'S EGG.



DECAPOD CRUSTACEANS.