Fossil Algae From Eniwetok, Funafuti and Kita-Daitō-Jima

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By J. HARLAN JOHNSON

BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

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A description of 90 species, including 4 new ones, belonging to 16 genera, and a discussion of the value of algae as paleoecological indicators and rock builders

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FOSSIL ALGAE FROM ENIWETOK, FUNAFUTI, AND KITA-DAITŌ-JIMA

By J. Harlan Johnson

ABSTRACT

Ninety species belonging to sixteen genera of calcareous algae are described and discussed. Four of the species are new. Most of the algae were obtained from holes drilled on Eniwetok, Funafuti, and Kita-Daitō-Jima; a few from outcrop samples. The several habitats occupied by algae on the existing reefs are briefly described. Algae are shown to have value as paleoecological indicators. They have contributed notably as rock builders.

The rocks containing the algae have been dated as: Recent and Pleistocene(?), Miocene, and Eocene. The algal floras from these units are quite distinct. Many of the species observed growing on the existing reefs occur in the Pleistocene(?) limestones along with some additional forms. With the exception of the highly variable form designated as *Lithoporella melobesioides* (Foslie) Foslie, the Recent-Pleistocene(?), Miocene, and Eocene floras have no species in common.

Charts show the known geographic and geologic distribution of species. Details of the stratigraphic distribution of the algae in the drill holes are appended at the end of the report.

INTRODUCTION

Since the end of World War II, geological studies of many of the Pacific Islands have been made by the U.S. Geological Survey. In connection with this work, the author visited a number of the islands and collected both living and fossil algae. He has also studied the large collections of algae made by the parties engaged in mapping the islands and has studied material from all the deep holes that have been drilled into Pacific island reefs.

Descriptions of the living and fossil algae from Bikini Atoll have been published by Taylor (1950) and Johnson (1954). Descriptions of fossil algae from Saipan have been published by Johnson (1957).

The present paper presents information obtained from studies of samples from deep holes drilled on Eniwetok, Funafuti, and Kita-Daitō-Jima and some comparisons with samples from Bikini. Drill holes on these four islands are the only ones that have penetrated deeply enough to give significant information as to the foundations of the atolls and their geologic history. Samples from all holes contain calcareous algae, and at certain levels such algae are extremely abundant. The four drilling localities are widely distributed geographically, and are separated by a considerable range of latitude (fig. 288). All but one of the holes penetrate rocks older than Pleistocene. The Eniwetok holes pass through 1,500 feet of Eocene rock. The present study indicates that algae have contributed notably to reef construction.

Insofar as possible, the data on the algae from the various islands has been synthesized, and the species descriptions have been arranged systematically.

SOURCE OF MATERIAL

This report is based on the limestone cores and cuttings obtained from the drill holes on Eniwetok, Funafuti, and Kita-Daitō-Jima.

ENIWETOK ATOLL, MARSHALL ISLANDS

Drilling on Eniwetok Atoll began in 1951 when several holes were drilled on the island of Engebi. One of these (K–1B) was carried to a depth of 1,285 feet. The following year two deep holes were drilled, each of which went to the underlying volcanic rock basement. The first, F–1 on Elugelab, struck the basement rock at a depth of 4,610 feet. The second, E–1 on Parry Island, reached a total depth of 4,222 feet, having penetrated 68 feet of basalt (fig. 289). Drill holes F–1 and E–1 are the deepest yet made in a coral reef, and are the only ones that have penetrated to the basement material. The holes passed through a relatively thin Quaternary section before entering a thick Tertiary section of shallow-water limestones.

Many of the beds penetrated by the drill were very fossiliferous. The most abundant fossils are Foraminifera, corals, mollusks, and algae. A detailed discussion of the stratigraphy and descriptions of the other groups of fossils are contained in other chapters of Professional Paper 260.

FUNAFUTI ATOLL, ELLICE ISLANDS

Drilling on Funafuti was done between 1896 and 1898. The final report on the project was published as an illustrated memoir by the Royal Society of London in 1904 and is recognized as a classic in geology. Members of the Royal Society who made the study discussed the petrography and alteration of the rocks, and described in detail most of the organisms found in cores and cuttings. One group not studied or described was the calcareous algae. They recognized the presence of these organisms, but no specialist was available for detailed study so they were lumped under the general term, *Lithothamnion*.

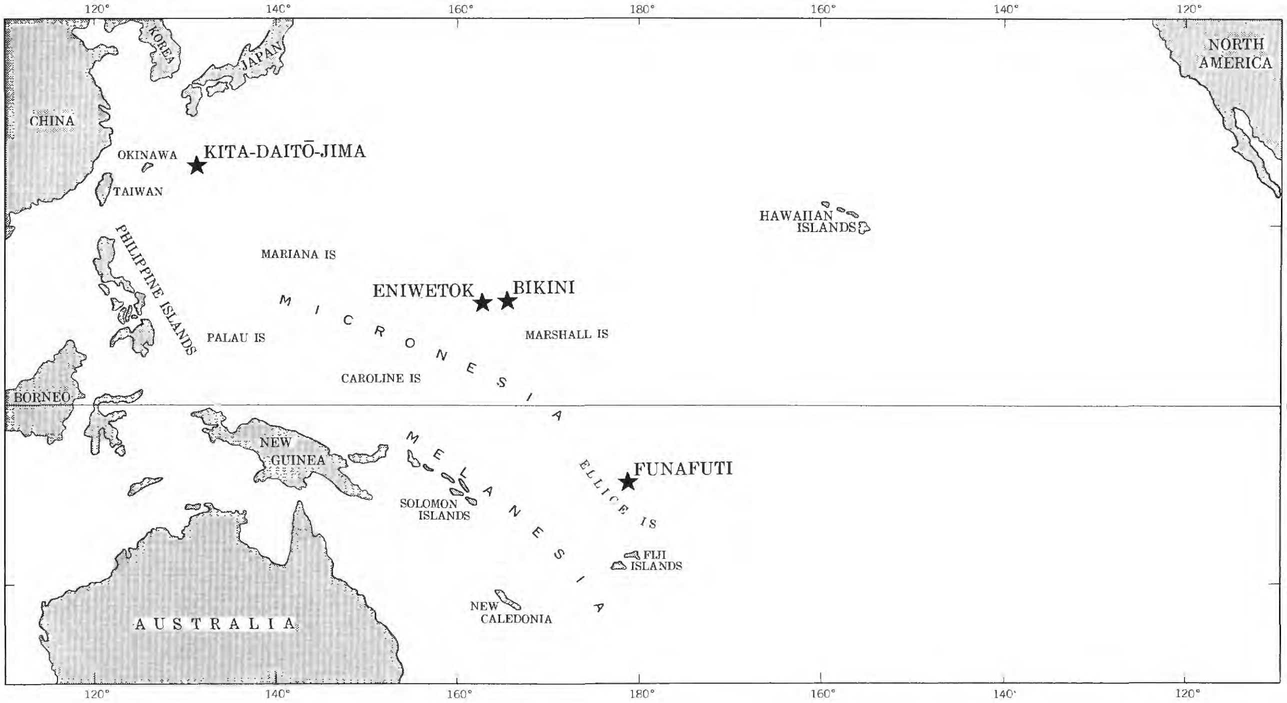

FIGURE 288.—Sites of deep drill holes—Eniwetok, Funafuti, and Kita-Daitō-Jima (position of Bikini also shown; algae described in Professional Paper 260–M).

After the deep drilling on Bikini had been completed, the authorities of the British Museum loaned the Funafuti cores to the writer for comparative studies, and he welcomed the opportunity to examine the algae.

The main boring at Funafuti (drilled in 1897–98) penetrated to a depth of 1,114 feet. Throughout its length the hole was in carbonate rocks: limestone, dolomitic limestone, and dolomite. No Tertiary sediments were reached. Considering the date at which the drilling was done and the type of equipment then available, the expedition made a remarkable recovery of cores. Most of the section was in hard rock, although some of the youngest beds were friable and incoherent "sands." In the deeper portions of the boring, the limestone was found to be recrystallized and highly dolomitized. Unfortunately, the alteration destroyed detailed structures of many fossils.

The abundance of algae found in the cores surprised all the geologists who took part in the investigation. Statements in the report regarding the importance of algae have been quoted in many later publications and have stimulated considerable work on calcareous algae.

KITA-DAITŌ-JIMA, PHILIPPINE SEA

A drilling project on Kita-Daitō-Jima was sponsored by Professor H. Yabe of Tōhoku University. The work began in March 1934 and continued for about 6 weeks, when a depth of 209.29 meters (687 feet) was reached. The project was resumed in January 1936 and the drilling continued to a total depth of 431.67 meters (1,416 feet). The work ended May 24, 1936. The section drilled first was mainly hard limestone, and core recovery was very good. In the second operation, the hole penetrated poorly consolidated material. The cores and cuttings were taken to Tōhoku University at Sendai, Japan, where they were studied. Reports on the petrology of the limestones have been published by Y. Ota in 1938, and S. Hanzawa described the Foraminifera in 1941. In these reports, repeated mention is made of the calcareous algae as important constituents of the calcareous sediments, but no species were described.

The authorities at Tōhoku University, through Professor Shoshiro Hanzawa, generously donated half of the entire core to the U.S. Geological Survey. This core is now on permanent deposit at the U.S. National Museum. The University authorities also loaned their thin sections. Numerous additional sections were prepared from parts of the core; the algae found in the sections are described in this report.

PROCEDURE

Genera of crustose coralline algae are differentiated on the basis of the character and structure of the hypothallus and perithallus and in the structure and arrangement of the sporangia and conceptacles. Species

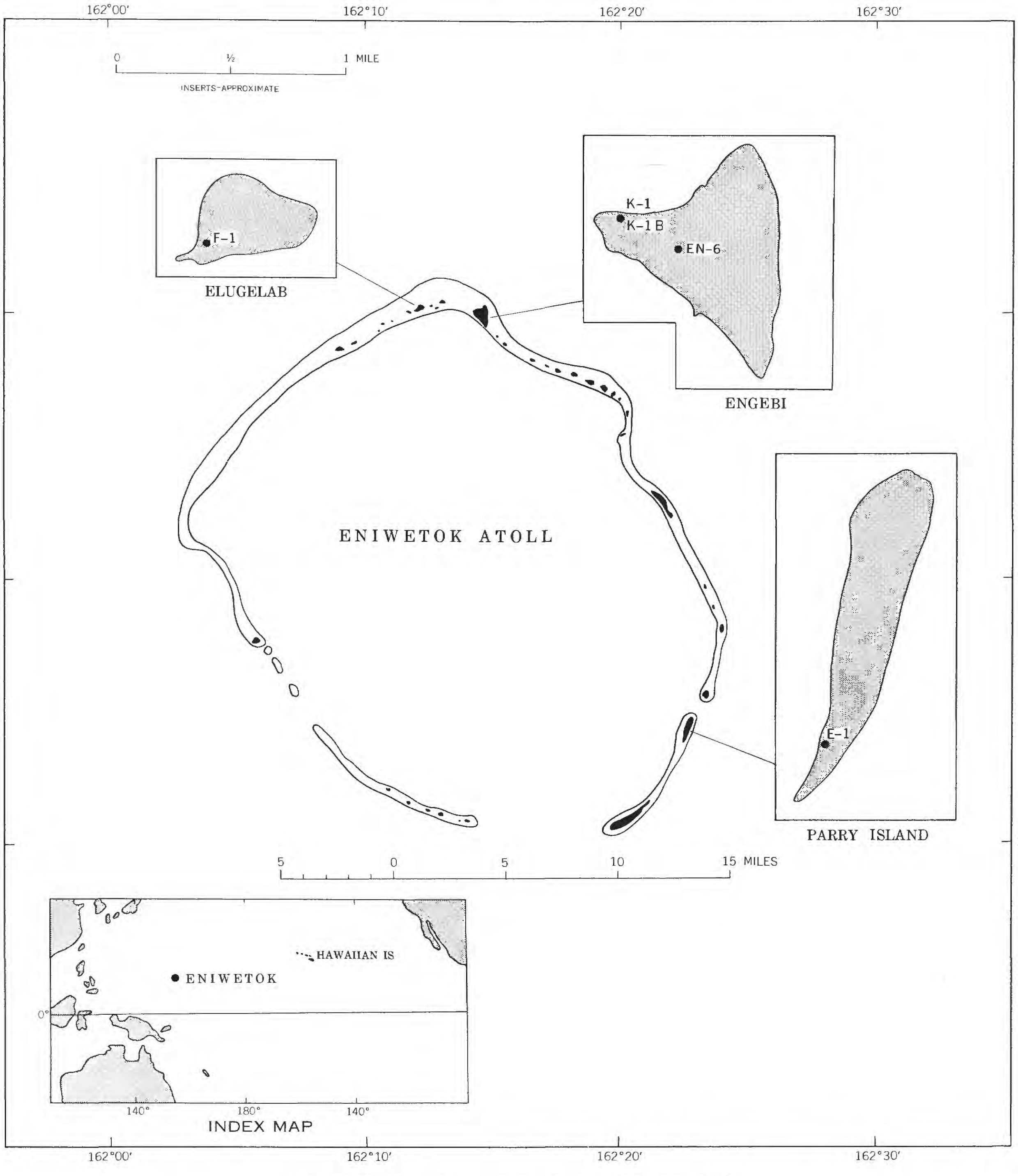

FIGURE 289.—Location of drill holes on Eniwetok Atoll.

are differentiated on dimensions of cells and conceptacles.

Numerous thin sections were prepared from various cores and from pieces of calcareous algae picked from drill cuttings. Each of the Eniwetok cores bears a letter designating the hole, followed by three numbers. The first number is that assigned to the hole, the second refers to the number of the core run, and the third the number of the core piece, counted from the top of the core. In the laboratory innumerable cell measurements were made and the thickness of the crusts, hypothallus, perithallus, and conceptacles measured. Many of the data obtained are summarized in tables.

ACKNOWLEDGMENTS

Thanks are due the authorities of the British Museum of Natural History for the arrangements which permitted a restudy of the Funafuti core and the original slides made from it. Miss L. M. Newton of that institution prepared a list of the Recent calcareous algae from Funafuti determined by M. H. Foslie, which are now in the collections of the British Museum.

Dr. Earling Siversten, Director, and Dr. Olav Gjaerevoll, Curator of Botany, at the Royal Norwegian Natural History Society's Museum at Trondheim, Norway greatly assisted the writer during a visit to the Museum in 1950. The Funafuti collections studied by M. H. Foslie, including a number of type specimens, were made available for examination and photography and small fragments were furnished for thin sectioning. Most of the photographic plates from which the illustrations for the Foslie and Prinz Memoir (1929) were prepared were also located.

In addition to arranging for loan of Kita-Daitō-Jima material, Dr. Shoshiro Hanzawa of the Institute of Geology and Paleontology of Tōhoku University, Sendai, Japan, personally assisted the writer most generously during several visits to Japan.

To Wataru Ishijima, Professor of Geology, Rikkyo (St. Paul's) University, Tokyo, Japan, and the foremost student of fossil coralline algae in Japan, the author is deeply grateful for many courtesies and kindnesses. His recent publication "Cenozoic Coralline Algae from the Western Pacific" (1954) has been frequently consulted.

CLASSIFICATION

Algae are classified into broad general divisions or phyla on the basis of the structure of the plants, and the chemical character of their normal pigments. The several phyla having fossil representatives are shown in the following table. All the rock-building algae described in the present report belong to 1 of 2 of the major divisions, the Rhodophyta (red algae) or the Chlorophyta (green algae). The classification of genera used is given in the table on classification. Generic identification keys are given later.

The important rock-building red algae belong to the family Corallinaceae, or coralline algae. These differ from the other calcareous algae in that the calcium carbonate is secreted within and between the cell walls as well as (in most specimens) being deposited around the plant tissues. For this reason, they make good fossils as they show recognizable and specifically identifiable microstructure such as the shape and arrangement of the cells.

Classification of fossil algae

Phylum	Family	Characteristic structures
Rhodophyta (Red algae).	Corallinaceae	Rows of closely packed cells, rectangular in section. Spore cases or conceptacles.
	Solenoporaceae	Rows of closely packed cells with polygonal cross section. Cross partitions present though frequently very thin.
Phaeophyta (Brown algae).	[Laminariales and others(?)]	Corded strands of parallel threads. Fronded types.
Chlorophyta (Green algae).	Dasycladaceae	A central stalk, preserved as a tube or bulb, surrounded by tufts of leaves or leaf bases, preserved as knobs or brushlike protuberances.
	Codiaceae	Small tubes loosely arranged so as to form segmented stems. Tubes round in cross section and branching.
	Charophyta	Highly developed small bushy plants. Fossils usually consist of calcified heavily ribbed spherical oogonia and the whorled branches which bear them.
Cyanophyta (Possibly Chlorophyta).	Porostromata	Small tubes loosely arranged; do not compress each other. No cross partitions visible.
Cyanophyta (Blue-green algae).	Spongiostromata	Cellular structure seldom preserved. The $CaCO_3$ is deposited as crusts on the outside of the colony or cell, or between the tissues, not in the cell wall. Classified on the basis of growth habit and form of the colony.

The calcareous green algae show varied degrees of calcification. Among the Dasycladaceae, the lime is deposited around the tissue forming molds of the plants and plant segments. The calcareous deposit may be sufficiently thick to envelope the entire plant, or it may be so thin as merely to coat the main stem and the primary branches. In *Halimeda*, on the other hand, the tissue itself is calcified, the process starting at the outer surface and working inward. In some cases the entire tissue is calcified; in others, only the outer part.

The red coralline algae is a difficult group to classify; several different classifications have been formulated for it. The features commonly used are: (a) Growth form; (b) arrangement of cells and differentiation of tissue; (c) features of the conceptacles, such as their shape, size, and position of the distribution of sporangia within them and the number of roof pores; (d) amount of calcification; (e) similarities of struc-

Classification used in present report

	Family	Subfamily	Genus
Rhodophyta (Red algae).	Corallinaceae	Melobesioideae (Crustose corallines).	*Archaeolithothamnium* *Dermatolithon* *Goniolithon* *Lithophyllum* *Lithoporella* *Lithothamnium* *Mesophyllum* *Paraporolithon* *Porolithon*
		Corallinoideae (Articulate corallines).	*Amphiroa* *Arthrocardia* *Corallina* *Jania*
	Dasycladaceae		*Dactylopora* *Acicularia*
Chlorophyta (Green algae).	Codiaceae		*Halimeda* *Microcodium*

tures; and (f) assumed relationships and evolution. Foslie and other students of Recent algae have tended to emphasize features a and c, while Lemoine and others who have been interested primarily in fossil algae have emphasized b, c, and d. In recent years, several students have emphasized features e and f.

The paleobotanist who works with algae is handicapped because commonly he has only fragments of the plants, pieces of the branches, in most cases broken from the basal crust, or small parts of the crust. Many of the fragments are sterile. When remains of the conceptacles are present, the chamber may be compressed, filled with foreign material, or covered with scar tissue that gives little indication of the roof structure. Rarely do the conceptacles show traces of the sporangia or indications of their distribution.

Some workers have considered the amount of calcification as an important feature in classification but the writer discounts this, as a number of external factors, including the age of the plant, appear to be involved; old plants are commonly much more calcified than young ones.

The use of similarities of structures in classification is hazardous. In many instances such similarities do mean close relationship but they may be developed in unrelated stocks as a result of parallel evolution or as a response to living in a similar, rather specialized, environment.

Lemoine (1911) has shown that it is possible to divide the Recent genera of the crustose corallines into two groups based on the arrangement of the cells. In the first group, represented today by *Lithothamnium*, the basic structure is a row of cells usually growing nearly vertically. In the second group, the basic structure is a layer of cells spreading horizontally or roughly parallel to the outer surface of the plant. Other features commonly fit in with these two subdivisions. For example, almost all of the plants showing the first type of tissue structure have conceptacles whose roof is pierced by multiple pores, while practically all of those having the second type of tissue structure have conceptacles pierced by a single pore.

The group that causes the most trouble, both in preparing the classification and in identifying the individual fossils, consists of extremely thin forms having a crustose thallus that is formed of one or, at most, of only a few layers of cells. It is not surprising that in this group there has been confusion in the definition of genera. In many cases, it is impossible to refer a specimen to a given genus unless conceptacles are present. It is not known if the thin crustose forms represent an original simple structural type or are highly simplified descendants of ancestors that originally had a much more complex thallus.

The author agrees with Lemoine that the character of the basal hypothallus should be considered as a very important feature in classification. He is not so sure as to the value in classification of the medullary hypothallus of branching forms, as there seems to be a tendency among all highly branching forms to develop a medullary hypothallus. This is true among *Lithothamnium*, *Lithophyllum*, and *Archaeolithothamnium*. The medullary hypothallus is also a prominent structure among the articulated coralline algae, all of which are branching forms.

KEYS TO THE TRIBES AND GENERA OF THE CRUSTOSE CORALLINE ALGAE

[Genera marked with asterisk (*) were found in Eniwetok drill holes]

I. Sporangia collected into conceptacles................ III
  Sporangia not collected into conceptacles.............. II
II. Tissue many layered with hypothallus and perithallus—*Archaeolithothamnium**
III. Conceptacles perforated by a few or many pores—Tribe Lithothamnieae.............................. IV
  Conceptacles perforated by a single pore—Tribe Lithophylleae.................................... V
IV. Roof of sporangial conceptacles perforated by few to many pores—Tribe Lithothamnieae..................... 1
  1. Thallus self-sustaining, not parasitic.............. 2
    2. Hypothallus a single layer of cells, at least in part; thallus epiphytic. Hypothallic cells in section, square or somewhat horizontally elongated—*Melobesia*
    2. Hypothallus of many layers of cells;
      3. Hypothallus of curved rows of cells.......... 3A
      3. Hypothallus coaxial (arched rows or layers of cells)—*Mesophyllum**
      3A. Sporangial conceptacles superficial or subimmersed—*Lithothamnium**
      3A. Sporangial conceptacles deeply immersed—*Clathromorphum*
V. Roof of sporangial conceptacles perforated by a single pore—Tribe Lithophylleae
  1. Megacells present............................. 2A
  1. Megacells absent.............................. 2B
    2A. Hypothallus consists of a single layer of cells.... 3
      3. Hypothallic cells vertically and obliquely elongated—*Hydrolithon*
      3. Hypothallic cells square or nearly so—*Fosliella*
    2A. Hypothallus of several to many layers of cells.... 3
      3. Megacells in lenses or horizontal clusters—*Porolithon* *
      3. Megacells singly or in vertical rows—*Goniolithon* *
      3. Megacells in both horizontal and vertical clusters—*Paraporolithon*
    2B. Hypothallus composed of cubic cells............ 3
      3. Thallus of several layers of cells—*Heteroderma*
      3. Thallus of many layers of cells, not epiphytic—*Lithophyllum* *
    2B. Hypothallus of one or two layers of obliquely elongated cells................................ 3

V. Roof of sporangial conceptacles perforated by a single pore—Tribe Lithophylleae—Continued
  2B. Hypothallus of one or two layers of obliquely elongated cells—Continued
    3. Thallus characteristically epiphytic or epizoic commonly expanding locally to two or more layers with cells nearly equidimensional—*Dermatolithon* *
    3. Thallus prostrate, epiphytic, or epizoic often superimposed—single layered except immediately around conceptacles, cells vertically elongated—*Lithoporella* *

KEYS TO THE GENERA OF THE ARTICULATE CORALLINE ALGAE

[Genera marked with asterisk (*) were found in Eniwetok drill holes]

I. Segments consist of several or many tiers of cells — II
  b. Segments consist of a single tier of long cells—*Lithotrix*

II. a. Each tier composed of regular cells with straight walls — III
  b. Tiers composed of irregular, sinuous and interlacing cells. (Conceptacles lateral. Nodes formed of a single tier of cells)—*Calliarthron*

III. a. Boundaries between tiers of cells essentially regular — IV
  b. Boundaries between tiers of cells irregular, commonly more or less stepped. Cells commonly wedge shaped. Segments small, slender, cylindrical. Conceptacles terminal—*Jania**

IV. a. Tiers of cells of principally the same length — V
  b. Commonly there are tiers of long and short cells variously alternating. Segments show considerable variation in size and some variation in shape. Commonly they are cylindrical or flattened cylindrical. Nodes rather inconspicuous, of one or several tiers of cells. Conceptacles lateral—*Amphiroa**

V. a. Tiers of cells gently but evenly arched — VI
  b. Tiers of cells flattened in central area, curving downward sometimes abruptly, toward the margins. Nodes of a single tier of cells. Branching regular, pinnate. Conceptacles are terminal—*Arthrocardia**

VI. a. Segments not of same shape in different areas of the same plant — VII
  b. Segments cylindrical or flattened cylindrical. In section, commonly wider at top than at base. Notes conspicuous with a single tier of very long cells. Branching commonly in a plane, pinnate. Conceptacles terminal—*Corallina**

VII. Segments commonly clavate, but may be oval, rounded, flattened or polygonal in section.
  1. Biforcating branching. Conceptacles on margins of upper lobes of segments—*Cheilosporum*
  2. Segments commonly cylindrical or nearly so near base of the frond becoming trapezoidal above. Branching pinnate. Conceptacles at the end of the lateral branches—*Joculator*
  3. Segments cylindrical or compressed cylindrical below, becoming flattened above with oval cross section. Branching dichotomous or alternating. Nodes consist of a single zone of cells. Conceptacles lateral—*Bossea*

DISTRIBUTION AND ABUNDANCE

The distribution of living calcareous algae is controlled, or at least strongly influenced, by a number of ecologic factors and, presumably, fossil species were similarly controlled. The most important factors are depth, salinity, temperature, intensity of light, turbidity, and, in the case of shallow-water forms, the character of the bottom. Each species adjusts itself to all of these factors.

The intensity of light seems to be the most important factor, with salinity ranking next. The depth range of a given species probably reflects the combined effects of light, salinity, agitation, and circulation. Experiments with some shallow-water forms have shown that they can tolerate a considerable variation in temperature and salinity for at least short times. Also, that they can stand abnormally high salinity better than a deficiency. Most of the coralline algae seem to require clear water, but some of the green algae are able to withstand appreciable amounts of mud or fine silt, although they too thrive best in clear water. The coralline algae commonly attach themselves to some hard substance, rock, coral, or fragments of hard organic debris, such as shells, fragments of coral, or other coralline algae. The green calcareous algae frequently spread over mud, lime mud, or even sandy bottoms.

CRUSTOSE CORALLINE ALGAE

The crustose coralline algae (subfamily Melobesioideae) are widely distributed both geographically and geologically. They are found in all the existing oceans, from the tropics to polar waters. Certain genera such as *Archaeolithothamnium*, *Goniolithon*, and *Porolithon* occur only in the tropical and warm temperate seas. *Lithothamnium* occurs in all seas but has its greatest development in the cold and cool temperate waters; *Lithophyllum* prefers the warmer waters, although some cool-water species are known.

Along rocky coasts in many places calcareous algae are found as thin white or pink crusts coating the rocks or forming shelves along the foreshore; they also occur in abundance immediately below low-tide level. Most branching forms develop in the zone between low-tide level and depths of 80 to 100 feet in the areas studied for this report; at greater depths the prevalent growth forms are crusts, which become smaller and thinner as the depths become greater. They are rare at depths below 400 feet, but specimens have been dredged from depths of 575 feet.

Each of the littoral and sublittoral zones is characterized by certain species. Along the English Channel, for example, of the 14 species of crustose corallines observed, 5 were found only in the littoral zone, and 3 occurred only in the sublittoral, while 6 occurred in both zones. Species characteristic of the littoral zone do not occur at depth. Similarly, forms characteristic of deeper waters seldom occur close to the surface. Observations made by Taylor (1950), Weber van Bosse (1904), and Dawson (1944, 1952, 1954) show a similar ecological distribution in the tropics.

Many Recent genera of the Melobesioidaea may be traced to Late Cretaceous times. A few, such as *Porolithon and Goniolithon*, did not become abundant until the Pleistocene.

ARTICULATE CORALLINE ALGAE

The articulate corallines (subfamily Corallinoideae) also have a fossil record dating back to Cretaceous times. Today, they occur in the shallow waters of warm and temperate seas. *Corallina* and *Jania* are the only genera that occur in cool and temperate waters. Along the European coast, *Corallina officinalis* has been found as far north as 71 degrees (Lemoine, 1940, pl. 114). *Amphiroa* reaches as far north as the Mediterranean Sea and the Gulf of California. In tropical areas, *Corallina* and *Jania* occur with *Amphiroa*. The other genera are relatively rare and are restricted to warm waters.

Around Pacific coral reefs, articulate corallines have been collected at depths ranging from low-tide level to more than 100 feet but they are most common in shallow water. Tufts and patches of them may be found in pools in the reef flat or on the undersides of masses of coral or beach rock. Locally they may be abundant in the lagoons close to the reefs or island beaches.

Away from the reefs they also occur along rocky coasts. Some species grow in abundance attached to the rocks at about tide level in areas of strongly agitated water. Other species grow in rock pools immediately below the level of low tide.

GREEN ALGAE

Recent Dasycladaceae live in warm marine waters. They attain their greatest abundance and variety in the tropics but extend into warm temperate seas. They occur as far north as the Mediterranean coasts of France and southern Europe; on the eastern side of the Pacific, they occur on the California coast.

They are generally found in shallow marine waters, although they have been observed in bays and estuaries where the water is slightly brackish, and in a few lagoons where the water has a salinity higher than normal. Their range is approximately from low-tide level to depths approaching 250 feet, but they occur abundantly only in depths of less than 30 feet and especially in 10- to 15-foot depths (Lemoine, 1940, p. 124).

The writer has collected them on the reef flats around the island of Guam where at low tide they can be found on the underside of rocks or masses of coral in shallow tidal pools where they are sheltered both from the violence of the waves and from strong sunlight. A few were also found on the reef flats of Okinawa in similar surroundings; in 1 or 2 localities, sizeable patches were found growing on a sand bottom 15 to 18 feet below sea level. Taylor (1950, p. 49–50) described *Neomeris* which he found on the tops of loose coral fragments on the reef flats and to depths of 25 feet. He also found a species of *Acetabularia*, which was obtained by divers at a depth of 30 feet.

Yamada (1934), in discussing the green algae of the Ryukyu Islands, described a number of species belonging to several genera from various places, all of which were found in tidal pools or at depths of a few meters.

Dasycladaceae commonly grow on sandy bottoms, on sandy clay bottoms, and on mud bottoms. They attach themselves to these relatively loose sediments with the aid of numerous fine hairlike growths. They also grow on loose pebbles, rock fragments, boulders, and on the underside of rocky masses and large corals in rock pools of the intertidal zone of reef flats and lagoons.

They range from Cambrian to Recent. Locally, from time to time they have been important limestone builders. They appear to have reached their zenith during the Late Triassic or Early Jurassic and to have been slowly declining since then. Dasycladacean limestone occurs abundantly in the Ordovician of Scandinavia, the Silurian of the Baltic region, the Permian of the southwestern United States, Japan, and the Adriatic region, and the Triassic of south-central Europe.

Halimeda is limited largely to the tropical and subtropical waters. It is common in the tropical Atlantic, tropical Pacific, and Indian Ocean, and is also found in the Mediterranean and in the Caribbean region. In the Pacific, it occurs as far south as 32° on the west coast of Australia and in the Atlantic, to 34° south on the east coast of South Africa. It extends northward in the western Pacific through the Ryukyu Islands and up to the southern coast of Japan. Specimens have been reported from numerous localities in Japan and even from Kamchatka. The latter appear to represent material carried north by the Japan current.

Specimens of fossil *Halimeda* have been reported from rocks as old as Late Cretaceous. They have been found in the Tertiary at many localities.

Species of *Halimeda* occur on both sandy and rocky bottoms and develop from areas exposed at low tides, down to depths more than 180 feet in the area studied for this report. Numerous species and forms have been described. They represent adaptations to a variety of environmental conditions. Some are found only in shallow water on sandy bottoms. Others grow attached to the rocks, particularly in crevices and holes in the rocks; still others seem to develop best in the depressions and holes on the reef flat. The most luxuriant growths have been recorded in lagoons adjacent to reefs. Taylor, in his report on the plants of the Bikini area (1950, p. 76–93) gave considerable data on the ecological occurrences of *Halimeda*. He described 14 species and 11 forms of subspecies. Of these, only one was collected from the outer slope of the reef where it occurred at depths of 150 to 275 feet. Three occurred along the marginal zone of the reef in holes or crevices between corals or in the reef rock. Eight were common on the reef flat, and 18 occurred in the deeper waters of the lagoons, mainly, at depths of 120 to as much as 180 feet.

ALGAE ON EXISTING REEFS

Existing atolls normally consist of: (*a*) An outer seaward slope, (*b*) a marginal zone, (*c*) a broad reef flat, and (*d*) the lagoon. Each of these areas (Emery, Tracey, and Ladd, 1954) has a characteristic assemblage of algae.

The seaward slope.—Crustose coralline algae occur along the outer slope, abundantly at the top but in decreasing amounts with depth. Large colonies of branching forms are abundant near low-tide level and are common to depths of 50 or 60 feet but are seldom found much deeper. In general, the colonies become smaller and the branches shorter and more widely spaced with depth. Thin encrusting forms are present at tide level but become more abundant with depth, with a maximum development at around 125 to 150 feet. At greater depths they become smaller, decrease in number, and have a darker color. Living specimens were dredged from depths as great as 1,100 feet at Bikini but they were small and scarce.

Locally, some articulated corallines develop on the upper parts of the reef slope, commonly at depths of from 10 to 50 feet, but they have been dredged from depths as great as 100 feet. *Halimeda* has about the same distribution as the articulated corallines.

The marginal zone.—Normally this is the area where the greatest development of calcareous algae occurs, culminating at times with the formation of the so-called *Lithothamnium* Ridge. This is probably the most spectacular development of coralline algae to be seen anywhere. Originally named the Nullipore Ridge by early writers, the term "Lithothamnium Ridge" is today somewhat a misnomer because the genus *Lithothamnium* has been broken up and, in the tropics, members of the genus, as now recognized, have little to do with building the ridge. For example the well-developed ridge at Bikini is built almost entirely by a few species of *Porolithon*. The term "algal ridge" used by some authors would be more correct.

On the windward side of the reefs, waves beat with force and along the reef margin there is a development of rounded algal heads, usually compact colonies of highly branching forms, such as *Porolithon gardineri*. At normal low tide, the outer part of the reef margin may be exposed a foot or two above low-tide level, but is always kept moist by spray from the surf. This belt, normally, is rather narrow. At exceptionally low tides it may appear as a strip 40 to 50 feet wide, sometimes more, but frequently less. Behind this ridge, in the area of less agitated waters, the reef margin grades into a nearly smooth algal pavement composed of crustose nonbranching algae such as *Porolithon onkodes*. The algal ridge may appear as a continuous strong outer reef margin or, if the surf is very heavy, it may be cut by numerous surge channels. Commonly, the calcareous algae are the only plants found along the algal ridge, but corals, mollusks, and echinoderms may be present in varying numbers particularly on the inner more protected areas.

The reef flat.—Behind the marginal zone, the reef flat normally extends toward the lagoon. In many places corals grow luxuriantly on the seaward part of the reef flat. Algae may grow with them, both crusts and small heads of branching types of the crustose corallines, tufts and clumps of articulated corallines, patches or tufts of *Halimeda*, and occasionally a few Dasycladaceae. In addition to these, noncalcareous algae may be common, especially various types of green algae and occasionally some brown or red algae may be present. In some places, where there is a wide reef flat along the shores of islands, wide stretches or patches of the otherwise barren inner reef flat may be covered with brown algae.

The lagoon.—This is another area where algae may be abundantly developed. In areas between islands the reef flat slopes gently into the lagoon. Commonly at depths of more than 10 to 25 feet the bottom may be carpeted with both calcareous and noncalcareous algae. Among the former, *Halimeda* may be abundant even down to depths of 150 to 175 feet. In such areas *Halimeda* segments are the main constituent of the deposits on the lagoon floor. Chapman (1901, p. 163–164) made an analysis of the organic content of 18 samples dredged at half-mile intervals across the Funafuti lagoon. Fifteen of these were at depths of 15½ to 26 fathoms and the percentage of *Halimeda* ranged from 75 to 99. In the final report on the Funafuti expeditions Halligan (1904, p. 160–164) reported on two holes drilled in the lagoon floor. The *Halimeda*-rich sediment that covered the bottom was found to continue virtually unchanged for a thickness of 70 feet or more. In 1955, V. J. Chapman discussed Recent Funafuti algae.

Along the shores of islands and in the shallower margins of the lagoons, besides *Halimeda*, tufts of articulated corallines and small crustose corallines occur. Dasycladeceae may be found growing under other algae and on corals in the shallow waters and more rarely may develop into sizable patches at depths of from 10 to 35 feet, especially on areas of fine sediment.

ALGAE IN DRILL HOLES

In all the samples studied coralline algae were abundant in the Recent and Pleistocene(?) deposits; *Halimeda* was also present, at some places in abundance. In the Miocene and Eocene deposits algae occur in considerable abundance but they are not uniformly distributed. At some levels they are common, at others rare or entirely absent. Data on the distribution of algae in the various drill holes are given in the section, "Geographic distribution and stratigraphic occurrences of algae" at the end of this report. Many of the gaps represent parts of the section from which neither cores nor cuttings were recovered. A discussion of drilling and recovery is given by Ladd and others (1953) and by Ladd and Schlanger (1960).

ALGAE AS LIMESTONE BUILDERS

Studies of the samples obtained from the Funafuti drill hole (Royal Society of London, 1904) showed that calcareous algae were present from the surface to the bottom of the hole at 1,114 feet and that at many horizons they contributed notably to the bulk of the reef. Recent studies in the Marshall Islands and in the Mariana Islands have shown that algae play a vital role in building the framework of the reef (Emery, Tracey, and Ladd, 1954; Johnson, 1954b, 1957). The drill samples from Eniwetok, Funafuti, and Kita-Daitō-Jima indicate that during much of Cenozoic time algae ranked next to Foraminifera in the volume of the material contributed to the reef. Only locally and temporarily were the corals as important as the algae in reef construction. Among the limestones studied, the percentage of algae by volume ranges from a low of 3 percent to a high of about 48 percent and averages about 17 percent. The crustose coralline algae and *Halimeda* are the important contributors with minor amounts of articulated corallines. A few Dasycladaceae were seen in the Eniwetok and Kita-Daitō-Jima drill samples, but were too rare to be of real importance as rock builders in these areas.

Today a number of species of *Halimeda* occur abundantly on and around the reefs, especially in the lagoons, and locally contribute considerably to the limestones. Some of the slides and specimens studied show that certain beds penetrated by the drill at Funafuti and Eniwetok were truly *Halimeda* limestones. These were quite common at Funafuti, occurring at intervals throughout the depth of the boring. They are not so abundant at Eniwetok but were especially well developed in the post-Tertiary beds.

In reef building, the coralline algae are the most important group. They assist in the formation of reefs in three ways: (a) By growing abundantly along the margin of the reef, particularly where the surf is strong, to form an algal ridge which breaks the force of the waves and protects the reef from erosion; (b) by acting as a binder to cement coral heads and fragments of other organisms into a more or less compact mass; and (c) by contributing to the volume of the reef mass. Taylor (1950, p. 28–30) gave a vivid description of the algal ridge at Bikini. Emery, Tracey, and Ladd (1954) and Johnson (1954 a, b) also discussed this feature and the importance of the work of the algae in reef construction.

ALGAE AS INDICATORS OF AGE

Studies made by Pia (1926, 1927) and by Mme. Lemoine (1939) in southern Europe and in the regions around the Mediterranean Sea showed that algae have considerable value as index fossils. Mme. Lemoine's work in Algeria revealed that the algal floras of each Epoch are quite distinct. Only a few Cretaceous species continue into the Eocene, whereas the Miocene floras are distinctly different from those of the Eocene and the Oligocene. Lemoine concluded that algal species have value in correlation as far as periods or epochs are concerned, but only in local areas can they be used for detailed stratigraphic correlation. She found, for example, that a species which occurs in the lower Eocene of Spain may occur in the middle Eocene in Libya or Morocco and be found even in the upper Eocene in Egypt or Persia, but very rarely does it extend into the Oligocene. The Mediterranean region is the only area in which sufficient work has been done on fossil algae to give us a knowledge of their time range. Until such work has been done in many other areas, the value of algae in correlation will be limited. The current studies of the geology of the Pacific Islands offer an opportunity to accumulate data for this purpose. Algae occur abundantly associated with Foraminifera whose time range is accurately known; consequently, the algae found in the various limestones can be dated with some assurance.

When studies of the algae and Foraminifera have been made from a larger number of islands, it will be possible to prepare a comprehensive chart showing the time range of the algal species in the Pacific region. A chart of this type presenting the data now available is given at the end of this paper. It will be noted that most of the species do not have a long time range.

ALGAE AS ECOLOGICAL INDICATORS

The algae can also be useful in interpreting the environment of deposition. Ecological studies in areas of the present seas have shown that the crustose types of coralline algae are found in abundance from the intertidal zone down to a depth of about 330 feet, and they occur sparingly to even greater depths. Those forming thin crusts or sheetlike masses seem to range from tide level down to the limit of light penetration, whereas those types that develop as masses of long branches seldom occur at depths greater than 30 feet. Articulated corallines grow from tide level to depths not exceeding 250 feet but do not appear to develop abundantly in depths greater than 75 feet. Algal distribution is affected not only by depth but by such factors as light, agitation of water, character of the bottom, the presence or absence of sediment, and the salinity of the water. The relation of these factors to the distribution of modern lime-secreting algae has been studied by a number of botanists, and the results were ably summarized by Lemoine in her 1940 paper and in a paper by Maxwell Doty on rocky intertidal surfaces (1957). Data on present-day distribution of many forms in the Marshall Islands are given by Taylor (1950) and Dawson (1957). Additional information on distribution is given under the generic descriptions in this paper.

Similar studies have been made regarding the distribution of the green algae. *Halimeda* thrives best in relatively shallow waters, from about tide level down to depths of about 50 or 60 feet, although specimens of some species have been found growing at depths of more than 250 feet. Luxuriant "*Halimeda* meadows" have developed over considerable areas of lagoon bottom at Bikini and Eniwetok. The author has observed similar developments in the shallow lagoon northwest of Peliliu in the Palau Islands, and over smaller areas at Ulithi Atoll and around Guam.

Pia (1927) has shown that the presence of abundant remains of Dasycladaceae always indicates shallow water and usually a muddy or silty bottom. In the present seas they are most abundant in depths down to 30 feet. They are rarely found at depths below 50 feet.

SYSTEMATIC DESCRIPTIONS

Phyllum **RHODOPHYTA (RED ALGAE)**
Class **RHODOPHYCEAE**
Order **CRYPTONEMIALES**
Family **CORALLINACEAE** (coralline algae)
Subfamily **MELOBESIOIDEAE** (crustose corallines)

Description.—Characteristically strongly calcified, showing a great variety of growth forms. Some are monostromatic, others form crusts more than a centimeter thick. Crusts may be smooth, covered by protuberances, or branched. Some species develop loose branches or aggregates of branches.

A key to the tribes and genera was given earlier in the section on "Classification."

Genus **ARCHAEOLITHOTHAMNIUM** Rothpletz, 1891

Description.—Hypothallus consists of rows of cells that start horizontally, then curve upward into perithallus. Normally in perithallus vertical (transverse) cell rows more prominent than horizontal (longitudinal) layers. In some species growth zones may be distinguished. Most characteristic feature of genus found in the sporangia, which are not collected into conceptacles but occur in lenses or layers in tissue. They may be packed closely together, or may be separated from one another by thin segments of tissue.

Today the genus is restricted to warm marine waters, with a known depth range of from 1 to 130 feet. It appears to be most common in depths from 25 to 65 feet. *Archaeolithothamnium* has a geologic range from the Early Cretaceous to Recent. It reached its greatest development during the Eocene.

For convenience in classification species are grouped into three divisions based on the growth form of the plant. The following table shows dimensions and distribution of species.

Nineteen forms recognized, three of these being new.

Measurements (in microns) and distribution of species of Archaeolithothamnium

Species	Hypothallus cells		Perithallus cells		Sporangia		Locality	Depth (feet)	Age
	Length	Width	Length	Width	Height	Diameter			
Division 1.—Simple crusts [Commonly thin; several layers may be superimposed]									
Archaeolithothamnium crustatum Johnson n. sp.	15-23(27)	9-13	11-19	9-12	85-115	41-50	Eniwetok F-1, Eniwetok E-1	12,000 2,662-2,681 1,718-1,740	Miocene.
lauense Johnson and Ferris	12-20	12-13	12-15	10-13	141-195	75-100	Eniwetok F-1	2,675±	Do.
marshallensum Johnson n. sp.	9-19	7-11	8-13	6-13	76-96	44-63	do	1,725-1,995	Do.
eniwetokensis Johnson n. sp.	15-28	10-15	14-18	10-13	41-50	25-30	do	1,978-2,003	Do.
oulianovi Pfender	9-21	8-12	9-12	7-10	56-76	32-49	do	3,655-3,988	Eocene.
puntiense Airoldi	5-8	10-14	8-14	7-12	62-96	30-59	Kita-Daitō-Jima	51- 513	Pleistocene (?)
schmidti Foslie	7-10	7-11	9-11	5-10	37-73	46-70	Funafuti	691- 698	Pleistocene or Recent.
cf. *A. sociabile* Lemoine	15-23	8-15	10-15	8-12	100-126	58-69	Eniwetok F-1	4,528-4,553	Eocene.
cf. *A. taiwanensis* Ishijima	11-15	6-9	11-13	7-11	75	50	do	1,718-1,740	Miocene.
sp. A	7-12	7-8	7-11	6-8	48-60	30-36	do	4,528-4,553	Eocene.
Division 2.—Crusts with warty protuberances, mammillae, or short stubby branches									
Archaeolithothamnium erythraeum (Rothpletz) Foslie.	10-40	9-12	14-20	8-10	75-90	45-55	Funafuti	748- 899	Pleistocene or Recent.
cf. *A. erythraeum* (Rothpletz) Foslie	12-40	10	13-19	8-10	95-119	70-90	do	867- 874	Pleistocene.
aff. *A. erythraeum* (Rothpletz) Foslie	----	----	12-16	8-12	63-86	30-50	Eniwetok E-1	2,340-2,660	Miocene.
aff. *A. saipanense* Johnson	----	11-13	12-14	9-14	145-165	96-100	Eniwetok F-1	4,528-4,553	Eocene.
nummuliticum (Gümbel) Rothpletz	----	----	13-23	9-14	100-131	55-90	Eniwetok E-1 Eniwetok F-1 do	2,802-2,808 3,655-3,665 4,197-4,202	Do. Do. Do.
cf. *A. hemchandri* Rao	----	----	11-19	8-12	48-65	43-45	do	3,655-3,665	Do.
sp. B	----	----	8-11	8-11	----	----	Eniwetok E-1	2,730-2,740	Do.
Division 3.—Strongly branching forms									
Archaeolithothamnium aff. *A. affine* Howe	16-27	11-14	11-16	9-10	90-120	34-36	Eniwetok E-1	2,350-2,360	Miocene.
dallonii Lemoine	----	----	20-24	9-12	90-136	54-75	do	2,802-2,808	Eocene.

Division 1—Simple crusts

Archaeolithothamnium crustatum Johnson, n. sp.

Plate 267, figures 1, 2

Description.—Thallus thin, crustose, frequently growing superimposed. Hypothallus 0.5–1.3 mm thick, composed of few layers of slightly curved nearly horizontal rows of cells 15μ–23μ (27μ) long and 9μ–13μ wide. Perithallic tissue quite regular, with well-defined transverse cell rows and fairly well marked longitudinal layers. Cells 11μ–19μ long and 9μ–12μ wide. Sporangia long, ovoid, measuring 85μ–115μ high and 41μ–50μ in diameter.

Remarks.—This form resembles *Archaeolithothamnium intermedium* Raineri but has larger sporangia and more regular perithallic tissue without alternations of layers of cells of different length. It is close to the Eocene species from Eniwetok, *A.* cf. *sociabile* Lemoine, in growth habit and cell size but has smaller and narrower sporangia and wider cells.

Age: Miocene.
Locality: Eniwetok F–1, depths 2,000 ft (core), 2,662–2,687 ft (core); E–1, 1,718–1,740 ft (cuttings).
Figured specimens: Holotype USNM 51424, 51425.

Archaeolithothamnium lauense Johnson and Ferris

Plate 267, figure 8

Archaeolithothamnion lauensum Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 11, pl. 1, figs. A, D.
Archaeolithothamnium lauense Johnson and Ferris. Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 218, pl. 46, fig. 7.

Description.—Thallus irregular crust as much as 15 mm thick. Hypothallus poorly developed consisting of few curved rows of cells that attain length of 20μ and width of 12μ–13μ. Perithallus forms compact tissue composed of well-defined vertical rows of cells with thin cross partitions. Cells 12μ–15μ by 10μ–13μ. Sporangia abundant, ovoid or elliptical, large, measuring 141μ–195μ high and 75μ–100μ in diameter.

Remarks.—In appearance, structure, and dimensions of cells and sporangia, the Eniwetok specimens agree with the type although they developed a slightly thicker crust.

Age: Miocene.
Locality: Eniwetok F–1, depth about 2,675 ft (core).
Figured specimen: M–5, USNM 51426.

Archaeolithothamnium marshallensum Johnson n. sp.

Plate 267, figure 5; plate 269, figure 3

Description.—Thallus crustose, normally thin. Hypothallus 1–1.3 mm thick composed of horizontal to curved rows of cells 9μ–19μ long and 7μ–11μ wide. Perithallic tissue fairly regular, transverse cell rows slightly more conspicuous than horizontal cells which are 8μ–13μ long and 6μ–13μ wide. Sporangia ovoid, 76μ–96μ high and 44μ–63μ wide.

Remarks.—In cell dimensions and size of sporangia this form closely resembles *A. kuboiensis* Ishijima, but differs in having regular instead of contorted perithallic tissue, and in shape and arrangement of sporangia.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,725–1,995 ft (core).
Figured specimens: F–1–5–1, holotype USNM 51427; F–1–5–35, USNM 51428.

Archaeolithothamnium eniwetokensis Johnson n. sp.

Plate 267, figure 6; plate 268, figure 1

Description.—Thallus thin, crustose, surface irregular. Hypothallus 100μ–135μ thick consisting of curved rows of rectangular cells 15μ–28μ long and 10μ–15μ wide. Perithallic tissue fairly regular. Vertical cell rows slightly more pronounced than horizontal, but cells so regularly arranged as to produce nearly reticulate pattern in vertical section. Cells 14μ–18μ by 10μ–13μ. Sporangia small, round ovoid, 41μ–51μ high and 25μ–30μ in diameter.

Remarks.—This species has smallest sporangia of any Miocene species yet described. In cell dimensions and size of sporangia it suggests *A. chamorrosum* Johnson from the Eocene of Saipan but has much more rounded sporangia and more regular perithallic tissue.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core).
Figured specimens: Holotype USNM 51429 (large); USNM 51430 (large).

Archaeolithothamnium oulianovi Pfender

Archaeolithothamnion oulianovi Pfender, 1926, Soc. española historia nat. Bol., v. 26, p. 325, pl. 10.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 218, pl. 38, fig. 5; pl. 39, figs. 4, 5.

Description.—Very thin crusts which may grow superimposed. Tissue irregular. Hypothallus poorly developed (50μ–90μ thick) consisting of few layers of irregular cells. Basal-layer cells commonly oblique. Cells measure 9μ–21μ by 8μ–12μ. Perithallus rather irregular. Cells in well-defined vertical rows but not regular horizontally. Cells 9μ–12μ by 7μ–10μ. Sporangia oval to circular in section, 56μ–76μ by 32μ–49μ, occurring in isolated clusters.

Remarks.—Distinctive features of this species are irregular perithallic tissue more suggestive of *Lithothamnium* than normal *Archaeolithamnium* and irregular arrangement of sporangia. Cells similar to those of type but show less range in size. They are similar to the material attributed to this species from Eocene of Saipan.

Age: Late Eocene.
Locality: Eniwetok F–1, depth 3,655–3,988 ft (core).
Specimens: F–1–9–9, F–1–10–1.

Archaeolithothamnium puntiense Airoldi

Archaeolithothamnion puntiense Airoldi, 1933, Palaeontographia Italica, Mem. Palaeont., v. 33, (new ser., v. 3), p. 83, pl. 7, fig. 1.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 218, pl. 53, figs. 3, 4.

Description.—Thallus irregular crusts from 0.5–15 mm thick. Hypothallus thin (0.03–0.1 mm thick), containing only a few curved layers of cells measuring 5μ–8μ by 10μ–14μ. Perithallus consists of fairly regular rows of cells, vertical partitions more conspicuous than horizontal. Cells rectangular, 8μ–14μ by 7μ–12μ. Suggestions of thin irregular growth zones. Sporangia abundant in well-defined layers, majority oval in section, some subquadrate with rounded corners. Sporangial cavities measure 62μ–96μ high and 30μ–59μ wide. One specimen shows slightly larger sporangia, 80μ–130μ high and 66μ–72μ wide.

Remarks.—In growth habit and dimensions of cells and sporangia, Kita-Daitō-Jima material closely resembles Airoldi's type material from Pleistocene of Somaliland. Ishijima's species *Archaeolithothamnium megamiensis* from Tertiary of Japan (Ishijima, 1933, p. 29) probably represents same species. Both papers were published about the same time (1933). Unfortunately, Ishijima's description was brief and generalized, being based on single fragment. It would be preferable to tie Kita-Daitō-Jima species with Japanese material because of its geographic proximity, but Airoldi's species has a more solid basis than Ishijima's; so his name is applied. Cell dimensions and size of sporangia mainly same as Recent *A. sibogae* Weber van Bosse and Foslie (1904, p. 41–42), but they differ greatly in structure and growth habit. *A. puntiense* develops as thin crust, whereas *A. sibogae* forms a cluster of thick branches with tissue differentiated into medial hypothallus and perithallus.

Age: Pleistocene(?).
Locality: Kita-Daitō-Jima, depth 16 ft (4.8 m) and 160 ft (48.7 m).
Specimens: Tōhoku University colln., slides 53 and 246.

Archaeolithothamnium schmidti Foslie

Archaeolithothamnion schmidti Foslie, 1901, Bot. Tidsskr., v. 24, p. 16
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 43, pl. 8, figs. 16–17

Description.—Thallus develops thin irregular crust, which forms rounded nodular mass 0.3—0.7 mm thick.

Hypothallus thin, composed of slightly curved rows of rectangular cells, many nearly square. Dimensions: 7μ–10μ long and 7μ–11μ wide (average 9μ by 8μ). Perithallus formed of fairly regular rows of cells; horizontal partitions of tissue much stronger than vertical. Cells 9μ–10.5μ long and 5μ–10μ wide (average 10μ by 8.5μ).

Sporangia circular to subelliptical; widely spaced in rows in tissue; size variable as shown by following dimensions in microns.

45 by 52	46 by 70
48 by 78	52 by 64
37 by 73	52 by 57

Remarks.—Growth habit and cell dimensions fit closely descriptions of Recent *A. schmidti* Foslie from Indochina and East Indies, except that conceptacles of Funafuti specimens are slightly wider than in type.

Age: Pleistocene or Recent.
Locality: Funafuti, main boring, depth 691–698 ft.

Archaeolithothamnium cf. A. sociabile Lemoine

Plate 267, figures 3, 4

Archaeolithothamnion sociabile Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont. no. 9, p. 53, figs. 16, 17.

Description.—Plants crustose, thin, some growing superimposed to form irregular crusts. Hypothallus 0.5–2 mm thick, formed of curved rows of cells 15μ–23μ long and 8μ–15μ high. Perithallus quite regular, horizontal layers almost as distinct as vertical rows. Cells rectangular, 10μ–15μ long and 8μ–12μ wide. Sporangia long ovoid, 100μ–126μ high and 58μ–69μ in diameter, closely packed, forming lenses in tissue.

Remarks.—In appearance, growth habit, and cell dimensions Eniwetok form closely resembles *A. sociabile* described by Lemoine from Algeria but has slightly larger sporangia and a somewhat greater development of the hypothallus.

Age: Late Eocene.
Locality: Eniwetok F–1, depth 4,528–4,555 ft (core).
Figured specimens: F–1–15–4 (1 and 2), USNM 51431, 51432.

Archaeolithothamnium cf. A. taiwanensis Ishijima

Plate 267, figure 7

Archaeolithothamnion taiwanensis Ishijima, 1942, Taiwan Tigaku Kizi, v. 13, no. 4, p. 120 (2), fig. 2.
Ishijima, 1954, Cenozoic and coralline algae western Pacific, p. 18, pl. 1, fig. 5.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 218, pl. 46, figs. 4–6.

Description.—Thallus rounded. Hypothallus 1–1.5 mm thick of curved rows of cells 11μ–15μ long and 6μ–9μ wide. Perithallus fairly regular with cells 11μ–13μ long and 7μ–11μ wide. Sporangia 72μ by 50μ

Remarks.—Represented by single fragment in Eniwetok collections. Closely agrees with Ishijima's type from Formosa but has better developed hypothallus.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,718–1,740 ft (core).
Figured specimen: F–1–4–8 (1), USNM 51433.

Archaeolithothamnium sp. A

Plate 267, figure 9

Description.—Thallus a thin irregular crust. Hypothallus 100μ–150μ thick composed of curved rows of small cells measuring 7μ–12μ by 7μ–8μ. Perithallus rather irregular, cells 7μ–11μ by 6μ–8μ. Sporangia 48μ–60μ high and 30μ–36μ in diameter.

Remarks.—Represented by a single specimen. Suggests *A. oulianovi* Pfender in growth habit and general character of tissue. Sporangia slightly smaller, cells smaller and square in section rather than oblong, as in *A. oulianovi.*

Age: Late Eocene.
Locality: Eniwetok F–1, depth 4,528–4,553 ft (core).
Figured specimen: CC–7, USNM 51434.

Division 2—Crusts with protuberances or short branches

Archaeolithothamnium erythraeum (Rothpletz) Foslie

Plate 268, figures 2, 3

Lithothamnium erythraeum Rothpletz, 1893, Bot. Centralbl., no. 14.
Archaeolithothamnion erythraeum Foslie, 1900, K. norske vidensk. selsk. Skr., no. 5, p. 8.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 38–41, pls. 5 and 6.

Description.—Thallus started as thin crust, then developed small mammillate protuberances. In 3 specimens in which thallus was observed, it measured 0.360 mm, 0.385 mm, and 0.246 mm in thickness. Hypothallus poorly developed, consisting of only a few nearly horizontal rows of cells, rather irregular, square to rectangular, mostly long and narrow. Size range from 10μ–40μ long and 9μ–12μ wide. Perithallus forms most of crust, composed of quite regular rows of cells from 14μ–20μ long and 8μ–10μ wide. Occasionally, a row of shorter cells sandwiched between rows of longer cells. Shorter cells nearly square and average 6μ–9μ by 7μ–10μ. Sporangia normally long and oval but some nearly spherical, others irregular. They measure 75μ–90μ by 45μ–55μ.

Remarks.—Specimens studied badly recrystallized, and it was difficult to measure cells except in few local patches. General appearance, growth habits, and dimensions of cells and sporangia are same as in Recent specimens of this species from tropical Pacific.

Age: Pleistocene or Recent.

Locality: Funafuti, slide 699, depth 748–763 ft; main boring, slide 703, depth 764 ft; slide 773, depth 891–899 ft.

Figured specimen: British Museum slide 773.

Archaeolithothamnium cf. A. erythraeum (Rothpletz) Foslie

Description.—Fragment of crust with mammilated surface about 0.5 cm thick. Hypothallus poorly developed. Exact measurement of cells impossible because of recrystallization, but they approximate 12μ–40μ by 10μ. Perithallus thick, layers of short approximately square cells alternate with several layers of long cells. Cells approximate 13μ–19μ by 8μ–10μ. Conceptacles elongate oval, in fairly regular rows in tissue; locally conceptacles are closely packed. Size 95μ–119μ by 70μ–90μ.

Remarks.—Represented by one badly recrystallized specimen. General appearance, growth habit, and cell dimensions fit modern *A. erythraeum*, but conceptacles somewhat larger, more regular, and more closely spaced.

Age: Pleistocene.

Locality: Funafuti, main boring, British Museum slide 757, depth 867–874 ft.

Archaeolithothamnium aff. A. erythraeum (Rothpletz) Foslie

Plate 268, figure 4

Archaeolithothamnion erythraeum, Weber van Bosse and Foslie, 1904. *Siboga* Expeditie Mon. 61, p. 39, pls. 5, 6.

Description.—Thallus crustose with rounded knobs or short stubby branches. Hypothallus not observed. Perithallic tissue compact, locally rather irregular, but in most cases with cells in fairly regular rows and layers. Cells rectangular 12μ–16μ by 8μ–12μ. Sporangia oval to almost cylindrical, 63μ–86μ by 30μ–50μ.

Remarks.—Represented by only few fragments. Material strongly resembles Recent *A. erythraeum*, cells in same size range, but conceptacles of Eniwetok specimens smaller. Ishijima described a species from the Tertiary of Japan (1933, p. 29) as *A. megamiensis* that almost corresponds in dimensions with present species except for growth form. It also resembles *A. taiwanensis* Ishijima. Ishijima's description so generalized that comparison is difficult. His species, however, appear to have smaller cells and conceptacles.

Age: Miocene.

Locality: Eniwetok, from cuttings collected from E–1 at depths of 2,340–2,660 ft but may have come from higher levels.

Figured specimen: 34, E–1, depth 2,650–2,660 ft, USNM 51435.

Archaeolithothamnium aff. A. saipanense Johnson

Archaeolithothamnium saipanense Johnson, 1957, U.S. Geol. Survey Prof. Paper, 280–E, p. 220, pl. 38, figs. 1–4, 6.

Description.—Thallus crustose, possibly with protuberances. Hypothallus about 120μ thick. Cell rows 11μ–13μ wide. Cell lengths could not be measured because of poor preservation. Perithallic tissue compact and fairly regular with cells 12μ–14μ by 9μ–14μ. Sporangia large, ovoid, 145μ–165μ high and 96μ–100μ wide.

Remarks.—Represented by single specimen. It closely resembles *A. saipanense* Johnson in growth habit and cell size but has appreciably larger sporangia. Sporangia largest observed in any Eocene *Archeolithothamnium*. It may represent new species, but until more and better material is available, it does not seem desirable to give it a new name.

Age: Late Eocene.

Locality: Eniwetok F–1, depth 4,528–4,553 ft (core).

Specimen: DD–5, USNM 51436.

Archaeolithothamnium nummuliticum (Gümbel) Rothpletz

Plate 268, figure 6; plate 269, figure 2

Lithothamnion nummuliticum Gümbel, 1861, Geognostische Beschreibung des bayerischen Alpengebirges und seines Vorlandes, p. 654.

Gümbel, 1871, Abhand. d. K. bay. Ak. Wiss., II Klasse, v. 11, pt. 1, p. 27, pl. 1, fig. 2b.

(Gümbel) Rothpletz, 1891, Deutsche geol. Gesell. Zeitschr., v. 43, p. 316, pl. 17, fig. 5.

Capeder, 1900, Contrib. allo studio der *Lithothamnium terziari*, Malpighia, p. 176, pl. 6, fig. 2.

Archaeolithothamnion nummuliticum (Gümbel) Lemoine, 1917, Bull. géol. Soc. France, ser. 4, v. 17, p. 247.

Lemoine, 1927, Mus. nat. histoire nat. Bull. (Nov. 1927), p. 546, fig. 1.

Lemoine, 1934, Vestni. stat. Geolog. ustavu csl. rep., v. 9, no. 5, p. 273.

Lemoine, 1939, Mat. carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 56.

Description.—Thallus crustose, developing protuberances or even short stubby branches. Hypothallus absent on specimens studied. Perithallus composed of rectangular cells 13μ–23μ by 9μ–14μ (commonly 16μ–23μ by 9μ–12μ). In some cases, tissue regularly arranged; in others irregular. In most areas vertical partitions more pronounced than horizontal. Sporangia large, ovoid to almost rectangular, measuring 100μ–131μ by 55μ–90μ.

Remarks.—Widely distributed species with long geological range. It has been described by many authors from western Europe, Mediterranean basin, and Near East. It is characterized by its unusual growth habit, relatively large rectangular perithallic cells, and large sporangia.

The several Eniwetok specimens have same growth habit, cell size, and length of sporangia. They differ in having somewhat wider sporangia (as much as 90μ instead of 65μ) and more pronounced vertical cell rows than in specimens attributed to this species in Mediterranean region.

Species suggests *A. saipanense* Johnson but has appreciably larger perithallic cells.

Age: Late Eocene.
Locality: Eniwetok E-1-2-3, depth, 2,802-2,808 ft (core); F-1, 3,655-3,665 ft, and 4,197-4,222 ft (cores).
Figured specimens: F-1-9-2 (4) (large), USNM 40813; E-1-2-3 (2) (large), USNM 40810.

Archaeolithothamnium cf. A. hemchandri Rao

Plate 268, figure 7

Archaeolithothamnion hemchandri Sripada Rao, 1943, Natl. Acad. Sci. India, Proc., v. 13, pt. 5, p. 275, pl. 1, fig. 7.

Description.—Thallus encrusted with mammiliform protuberances, hypothallus absent, perithallus of rectangular cells showing fairly pronounced recticulated pattern and measuring 11μ–19μ by 8μ–12μ. Sporangia rounded ovoid 43μ–45μ by 48μ–65μ.

Remarks.—Species represented by one specimen from Eniwetok material. It closely resembles type species described from lower Eocene of Assam but cells average larger and are slightly more irregularly arranged. *A. hemchandri* is distinguished from all other Eocene species of *Archaeolithothamnium* by its small cells and nearly spherical sporangia.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 3,655-3,665 ft (core).
Figured specimen: F-1-9-2 (2) (large), USNM 51437.

Archaeolithothamnium sp. B

Description.—Plant with short stubby branches, tissue of branches formed of rows of small nearly cubic cells so regularly arranged that they appear to be in layers. Cell walls forming both vertical and horizontal partitions are thin but clearly defined. Cells measure 8μ–11μ by 8μ–11μ. Conceptacles unknown.

Remarks.—Represented in Eniwetok collection by two worn fragments of branches.

Age: Late Eocene.
Locality: Eniwetok E-1, depth, 2,730-2,740 ft (cuttings).

Division 3—Strongly branching forms

Archaeolithothamnium aff. A. affine Howe

Plate 269, figure 1

Archaoelithothamnion affine Howe, 1919, Carnegie Inst. Washington Pub. 291, p. 11, pl. 4, fig. 1; pl. 5, figs. 1-2.
Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 60, fig. 25.
Lignac-Grutterink, 1943, Geol.-mijnb. genootsch. Nederland en Kolonien Verh., Geol. ser. jagu 113, p. 286, fig. 1.

Description.—Strongly branching form with distinct medullary hypothallus and marginal perithallus. Branches 2–3 mm in diameter. Medullary hypothallus forms most of branch; composed of curved layers of rectangular cells 16μ–27μ by 11μ–14μ. There are suggestions of growth zones. In these zones transverse upward-growing cell rows more conspicuous than layers. Marginal perithallus is 2–3 mm thick, composed of cells 11μ–16μ by 9μ–10μ.

Sporangia numerous, in regular rows in medullary hypothallus tissue; sporangia long and ovoid, some almost cylindrical; size 90μ–120μ by 34μ–36μ. Sporangia, in most cases, separated from one another by a few rows of tissue cells.

Remarks.—Very few branching species of *Archaeolithothamnium* with well-developed medullary hypothallus have been reported from Miocene. This form from Eniwetok most closely resembles *A. affine* described by Howe from Oligocene of West Indies, but has appreciably longer sporangia and more sharply separated hypothallus and perithallus.

Lignac-Grutterink reported material under this name from East Indies, but the Eniwetok specimen has longer sporangia and much more distinct marginal perithallus.

Specimen closely resembles the Recent *A. timorense* of tropical Pacific but has more nearly quadrate cells and longer sporangia. It probably represents an undescribed species but, with only one fragment available for study, it does not seem wise to describe it as such.

Age: Miocene.
Locality: Eniwetok E-1, depth 2,350-2,360 ft (cuttings).
Figured specimen: E-1, 2,350-2,360 ft, USNM 51438.

Archaeolithothamnium dallonii Lemoine

Plate 268, figure 5

Age: Miocene.
Locality: Eniwetok E-1, depth 2,350-2,360 ft (cuttings).
Figured specimens: F-1-9-2 (4) (large), USNM 40813.

Description.—Strongly branching form. Perithallic tissue regular with well-defined horizontal and vertical partitions. Cells 20μ–24μ by 9μ–12μ. Sporangia long oval to gourd shaped, 90μ–136μ by 54μ–75μ.

Remarks.—Represented by single well-preserved fragment from Eniwetok which resembles very closely Mme. Lemoine's type material from western Mediterranean. Only difference is that some of sporangia attain a slightly greater length in Eniwetok specimen.

This species closely resembles *A. nummuliticum* (Gümbel) Rothpletz except in growth form (strongly branching versus a crust with short stubby branches) and in having smaller sporangia.

Age: Late Eocene.
Locality: Eniwetok E-1, depth 2,802-2,808 ft (core).
Figured specimen: E-1-2-9 (large), USNM 51439.

Genus LITHOTHAMNIUM Philippi, 1837

The thallus may be crustose or with erect branches growing from a basal crust. The tissue consists of a hypothallus and a perithallus. A thin epithallus is present in living plants; it may or may not be preserved in fossils. Commonly, the hypothallus consists of loosely spaced horizontal rows of elongated cells that branch and curve upward at right angles to the substratum. The perithallus is composed of vertical infrequently branched cell rows, with the cells quadrate, rectangular, or ovate. Sporangial conceptacles have many openings or pores in the roof for the escape of spores.

This genus is represented by a number of species in the samples from Eniwetok, Kita-Daitō-Jima, and Funafuti.

For convenience in study the species are grouped in three divisions based on the growth form:

Division 1.—Simple crusts.

Division 2.—Crusts with warty protuberances or short stubby branches.

Division 3.—Strongly branching forms.

The following table summarizes the characteristic features of each species of *Lithothamnium* described.

Measurements (in microns) and distribution of species of Lithothamnium

Species	Hypothallus cells		Perithallus cells		Conceptacles		Locality	Depth (feet)	Age
	Length	Width	Length	Width	Diameter	Height			
Division 1.—Simple crusts [Commonly thin; several may be superimposed]									
Lithothamnium cf. *L. abrardi* Lemoine	16–26	9–12	12–15	9–12			Eniwetok F-1	4, 528–4, 553	Eocene.
crispithallus Johnson	11–21 (34)	8–13	7–14	6–11	550–590	190	do	4, 500–4, 553	Do.
cymbicrusta Johnson	15–27	10–15	10–15	10–12	304–537	185–200	do	4, 528–4, 553	Do.
leptum Johnson and Ferris	9–12	8–12	12–18	9–12	235–405	115–153	do	1, 718–2, 670	Miocene.
sp. A	14–23	10–13	12–13	11–14			do	1, 978–2, 003	Do.
sp. B	9–14	9–12	9–11	10–14			do	2, 662–2, 668	Do.
sp. C	22–42	8–16	8–19	9–14			do	1, 740–2, 670	Do.
Division 2.—Crusts with warty protuberances or short stubby branches									
Lithothamnium aff. *L. aucklandicum* Foslie	7–11	12–14	9–11	6–8	223–242	122–143	Kita-Daitō-Jima	0–173	Pleistocene.
funafutiense Foslie	10–24	10–12	6–14	6–11	500–750		Funafuti	0–800	Recent and Pleistocene
cf. *L. nitidum* Foslie	9–16	6–8	8–14	6–10	578–807	275–298	Kita-Daitō-Jima	0–16	Pleistocene.
cf. *L. mirabile* Conti	14–30	8–13	12–18	8–16			Eniwetok F-1	1, 978–2, 003	Miocene.
Division 3.—Strongly branching forms									
Lithothamnium sp. D	23–33	14–18	9–15	13–16			Eniwetok E-1	2, 003–2, 008	Miocene.

Division 1—Simple crusts

Lithothamnium cf. L. abrardi Lemoine

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

Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 67.

Lithothamnium cf. *L. abrardi* Lemoine. Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 221, pl. 41, figs. 6, 7; pl. 42, figs. 1, 5.

Description.—Thallus thin crust with well-developed hypothallus and poorly to moderately developed perithallus. Hypothallus consists of curved rows of cells 16μ–26μ by 9μ–12μ. Perithallus of rectangular cells 12μ–15μ by 9μ–12μ. No conceptacles present.

Remarks.—In general appearance and in cell dimensions Eniwetok material agrees with specimens described under this name from Eocene of Saipan.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 4,528–4,553 ft (core).
Specimen: DD-2.

Lithothamnium crispithallus Johnson

Lithothamnium crispithallus Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 223, pl. 42, figs. 6–8.

Description.—Thallus thin curving crusts, apparently originally attached but later growing free. Hypothallus well developed, 90μ–170μ thick, consisting of curved rows of cells 11μ–26μ (34μ) by 8μ–13μ. Perithallus thin, irregular, thickening greatly around conceptacles; cells 7μ–14μ by 6μ–11μ. Conceptacle chamber 550μ–590μ by 190μ.

Remarks.—Represented by a number of specimens. The Eniwetok specimens have longer perithallic cells than those described from Saipan.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 4,500–4,553 ft. (core).
Specimens: CC7; F-1-15-13 (2) large; F-1-15-3 (2) large F-1-14-29 large.

Lithothamnium cymbicrusta Johnson

Lithothamnium cymbicrusta Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 224, pl. 40, figs. 1, 6, 7; pl. 41, fig. 8.

Description.—Thallus thin regular crust about 300μ thick. Hypothallus well developed, forming most of crust. Hypothallus composed of rows of cells with fanlike arrangement, curving from center toward top and bottom; cells 15μ–27μ by 10μ–15μ. Perithallus thin, composed of regular rows of nearly square cells 10μ–15μ by 10μ–12μ. Clusters of conceptacles occur in little knobs raised above general level of crust. Conceptacle chambers 304μ–537μ by 185μ–200μ.

Remarks.—Eniwetok specimens agree with material described from Saipan except for larger size of some conceptacles. The large fanlike hypothallus and knobs of conceptacles seem to be very characteristic features of the species.

Age: Late Eocene.
Locality: Eniwetok F–1, depth 4,528–4,553 ft (core).
Specimen: DD–2.

Lithothamnium leptum Johnson and Ferris

Plate 270, figure 7

Lithothamnion leptum Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 13, pl. 2, fig. D.

Description.—Thallus thin irregular crust. Numerous thalli may grow superimposed to form an irregular mass. Hypothallus poorly developed or absent, at most only few rows of cells that measure 9μ–12μ by 8μ–12μ (14μ). Perithallus consists of rows of rectangular cells 12μ–18μ by 9μ–12μ. Conceptacle chambers 235μ–405μ by 115μ–153μ.

Remarks.—Eniwetok specimens closely agree with type material from Lau, Fiji. Also close to *L. araii* Ishijima from the Miocene of Japan.

Age: Miocene.
Locality: Eniwetok F–1 depths 1,718–2,670 ft (cores).
Figured specimen: F–1–6–12, USNM 40799.

Lithothamnium sp. A

Plate 269, figure 8

Description.—Thallus a thin irregular crust 200μ–350μ thick. Hypothallus plumose, 100μ–125μ thick; rectangular cells 14μ–23μ by 10μ–13μ. Perithallus 100μ–200μ thick; shows irregular growth zones of rows of rectangular cells 12μ–13μ by 11μ–14μ. Conceptacles unknown.

Remarks.—Form has about the same dimensions as *L. bikiniensum* Johnson from lower Miocene of Bikini but has well-developed rather plumy hypothallus and thicker crusts. Without knowledge of conceptacles of either species, they are considered as closely related but probably different.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core).
Figured specimen: F–1–5–12 (3), USNM 40800.

Lithothamnium sp. B

Plate 270, figure 2

Description.—Thallus an irregular crust 300μ–500μ thick. Hypothallus plumose, 175μ–200μ thick with local fanlike developments. Cells 9μ–14μ by 9μ–12μ. Perithallus relatively thin; cells 9μ–11μ by 10μ–14μ. Conceptacles unknown.

Remarks.—Species closely related to *L. araii* Ishijima and *L. leptum* Johnson and Ferris but has well-developed plumy hypothallus.

Age: Miocene.
Locality: Eniwetok F–1, depth 2,662–2,668 ft. (core).
Figured specimen: F–1–6–28 (3), USNM 40801.

Lithothamnium sp. C

Plate 269, figures 6, 7

Description.—Thallus an irregular crust 0.600—0.750 mm thick; well-developed hypothallus and perithallus. Hypothallus 150μ–250μ thick, composed of curved rows of cells 22μ–42μ by 8μ–16μ. Perithallus somewhat irregular, with noticeable growth zones; cells 8μ–19μ by 9μ–14μ. Conceptacles unknown.

Remarks.—This species differs from any previously described Miocene *Lithothamnium* in having unusually long hypothallic cells. Only *L. lauense* Johnson and Ferris has longer cells, but it has a poorly developed hypothallus in contrast to the thick conspicuous hypothallus of sp. C. Without a knowledge of the conceptacles, it does not seem desirable to give it a specific name.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,740–2,670 ft (cores).
Figured specimens: F–1–4–19 (1) large, USNM 40802; F–1–6–23 (4) large, USNM 40803.

Division 2—Crusts with warty protuberances or short stubby branches

Lithothamnium aff. L. aucklandicum Foslie

Plate 270, figure 6

Lithothamnion aucklandicum Foslie, 1907, K. norske vidensk. selsk. Skr., no. 6, p. 18.
Lithothamnium cf. *L. aucklandicum* Foslie. Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 224, pl. 53, fig. 9.

Description.—Thallus develops either as thick crust or more often as crust with warty protuberances. Hypothallus either poorly developed or only partly shown in the fragments observed. Hypothallic cells about 7μ–11μ by 12μ–14μ. Perithallus shows distinct irregular growth zones; cells 9μ–11μ by 6μ–8μ. Conceptacles small but numerous, 223μ–242μ by 122μ–143μ. Some show presence of sporangia (pl. 270, fig. 6).

Remarks.—The Kita-Daitō-Jima material belongs to the same species as the specimen described by the writer from the Pleistocene of Saipan as *L.* cf. *aucklandicum.* It closely resembles the Recent *L. notatum* Foslie from Japan but has slightly larger conceptacles. Unfortunately, Foslie's description is brief, rather vague, and based on external structure, so clear comparison cannot be made.

Age: Pleistocene (?).
Locality: Kita-Daitō-Jima core, depth 53 ft (16m).
Figured specimen: Tōhoku University colln., slide 124.

Lithothamnium funafutiense Foslie

Plate 270, figure 1

Lithothamnion funafutiense Foslie, 1900, K. norske vidensk. selsk. Skr., no. 1, p. 5–6.
Foslie and Printz, 1929, K. norske vidensk, selsk. Museet, Mon., p. 41, 56, pl. 12, fig. 3–4.

Description.—Thallus a thin irregular crust 0.125–0.600 mm thick. In some places several thalli superimposed to form crustose mass. Hypothallus moderately developed (often about 155μ thick); rows gently to strongly curved. Cells rectangular, some rounded, 24μ–35μ by 13μ–15μ. Perithallus thin to moderately developed (150μ–320μ thick). Cells square to slightly rectangular, 13μ–15μ by 10μ-15μ. Conceptacles not present.

Remarks.—Foslie discusses this form in two papers but does not give a clear description, particularly with regard to range in cell dimensions. These specimens fit perfectly his description as to growth habit and general appearance of tissue. They show greater size range of cells than given by Foslie, but closely approximate his measurements. In general, core specimens have somewhat longer hypothallus cells and slightly wider perithallus cells. This might result from slightly oblique section. This above description based on several fossil specimens in two British Museum slides (534 and 726) . Crusts similar in appearance observed in number of other slides but slides too thick or material too recrystallized to permit accurate cell measurement.

Age: Pleistocene.
Locality: Funafuti, main boring, depth 452–798 (possibly 880) ft.
Figured specimen: British Museum slide 534.

Lithothamnium cf. L. nitidum Foslie

Plate 270, figures 3, 4

Lithothamnion nitidum Foslie, 1901, K. norske. vidensk. selsk Skr., no. 3, p. 4.
Foslie and Printz, 1929, K. norske. vidensk. selsk. Museet. Mon., p. 44, 54, pl. 6, fig. 10.

Description.—Thallus crustose, thin, probably warty, 0.9–1.4 mm thick. Hypothallus absent or very poorly developed; when present, appears to consist of only few irregular cell rows; cells 6μ–8μ by 9μ–16μ. Perithallus of compact rectilinear rows of cells; cells rectangular 6μ–10μ by 8μ–14μ. Conceptacles large, flattened. Conceptacle cavities 578μ–807μ by 275μ–298μ.

Remarks.—In growth habit, character, and size of conceptacles and perithallic cells this form agrees with Foslie's description of *L. nitidum* from Japan. However, in Foslie's species the hypothallus better developed and contains larger cells. The Kita-Daitō-Jima specimens are closely related to *L. funafutiense* Foslie but have much smaller hypothallic cells.

This species was observed in a number of slides from Kita-Daitō-Jima. Most of the material is considerably recrystallized.

Age: Probably Pleistocene.
Locality: Kita-Daitō-Jima. Surface material and depth 16 ft (5 m).
Figured specimens: Tōhoku University colln., slide 53, and Aoki colln., slide 196 (1).

Lithothamnium cf. L. mirabile Conti

Lithothamnion mirabile Conti, 1943, Palaeontographia Italica Mem. Paleont., v. 41 (new ser. v. 11), p. 43–44, pl. 5, fig. 2; pl. 8, fig. 2.
Lithothamnium cf. *L. mirabile* Conti. Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 225, 48, fig. 3.

Description.—Thallus a thick irregular crust. Hypothallus well developed with curved rows of cells measuring 14μ–30μ by 8μ–13μ. Perithallus shows irregular growth zones; cells rectangular 12μ–18μ by 8μ–16μ. No conceptacles observed.

Remarks.—The Eniwetok specimens appear to belong to the same species as the material described from Saipan under this name. They agree with Conti's description except for having a slightly greater range in size of the hypothallic cells.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core).
Specimens: J–7 and K–3.

Division 3—Strongly branching forms

Lithothamnium sp. D

Plate 269, figures 4, 5

Description.—Long relatively slender branches formed of large medullary hypothallus surrounded by a narrow perithallus. Medullary hypothallus formed of well-defined rows of rounded cells; rows curve toward margins at first gently, then sharply, to merge into perithallus. Hypothallic cells 23μ–33μ by 14μ–18μ. Perithallus cells 9μ–15μ by 13μ–16μ. Conceptacles unknown.

Remarks.—Represented in Eniwetok material by several fragments of branches. Cell dimensions of this species differ appreciably from any branching *Lithothamnium* previously described from Miocene. However, without more material and knowledge of conceptacles, it does not seem wise to give it a specific name.

Age: Early Miocene.

Locality: Eniwetok E–1, depths 2,003–2,028 and 2,802–2,808 ft (core).

Figured specimens: E–1–1, USNM 40922; E–1–2, USNM 40804.

Genus **MESOPHYLLUM** Lemoine, 1928

Description.—Structurally this genus lies between *Lithothamnium* and *Lithophyllum*. Tissue resembles that of latter, with hypothallus commonly coaxial and a perithallus composed of well-defined layers of cells. In most cases, perithallus and tissue of branches show pronounced irregular growth zones. Conceptacles have numerous apertures similar to those of *Lithothamnium*.

Genus includes crustose and branching forms.

Known geologic range of *Mesophyllum* from Eocene to Recent, with greatest development during Miocene time.

Recent species live in littoral zone from just below tide level to depths as great as 175 feet; commonly found at depths of 30 to 100 feet.

For convenience in study, species arranged into three divisions based on growth habit.

Division 1.—Simple crusts.
2.—Short stubby branches.
3.—Strongly branching forms.

Following table gives dimensions and distribution of species identified.

Measurements (in microns) and distribution of species of Mesophyllum

Species	Hypothallus cells		Perithallus cells		Conceptacles		Locality	Depth (feet)	Age
	Length	Width	Length	Width	Diameter	Height			
Division 1.—Simple crusts [Commonly thin; several may be superimposed]									
Mesophyllum cf. *M. arakuraensis* Ishijima	15-24	7-9	7-9	8-9	315-360	180-210	Eniwetok F-1	2,662-2,687	Miocene.
eniwetoksensum Johnson n. sp.			10-11	9-11	647-780	200-210	do	1,978-2,003	Do.
sp. A	15-38	10-16	11-18	7-14			do	1,718-2,003	Do.
Division 2.—Crusts with short stubby branches									
Mesophyllum erubescens (Foslie)	20-26	7-9	13-17	7-12			Funafuti	20-30	Recent or Pleistocene
japonicum Ishijima	23-28	10-13	15-20	6-8			Eniwetok F-1	1,978-1,995	Miocene.
cf. *M. savornini* Lemoine			12-14	7-14	360-630	120-200	do	2,662-2,687	Do.
robustum Johnson n. sp.	13-27	7-12	8-16	9-10	238-356	140-180	do	3,052-3,055	Eocene.
Division 3.—Strongly branching forms									
Mesophyllum sp. B			12-22	9-14			Eniwetok F-1	1,718-1,740	Miocene.
cf. *M. australe* (Foslie)	13-25	5-8	12-22	5-8			Funafuti	20-30	Recent or Pleistocene.
pulchrum (Foslie)	12-25	8-12			290-350	175-190	do	736-748	Pleistocene.

Division 1—Simple crusts

Mesophyllum cf. M. arakuraensis Ishijima

Plate 270, figure 5; plate 271, figure 1

Mesophyllum arakuraensis Ishijima, 1954, Cenozoic coralline algae, western Pacific, p. 33, pl. 13, figs. 3–4.

Description.—Thallus small, irregular, crustose. Hypothallus coaxial, 150μ–400μ thick, of curved rows of rectangular cells 15μ–30μ by 7μ–13μ. Perithallus contains irregular zones of layers of nearly square cells 7μ–9μ by 8μ–9μ. Conceptacles small but high with multiple apertures. Size of conceptacle chambers 350μ–190μ, 350μ by 180μ, 479μ by 236μ.

Remarks.—Represented by one fairly well preserved specimen and a few badly recrystallized examples. Specimens closely resemble Ishijima's material from lower Miocene (Burdigalian) of Japan but differ in having slightly shorter hypothallic cells.

Age: Miocene.

Locality: Eniwetok F–1, depth 1,978–2,003 and 2,662–2,687 ft (core).

Figured specimens: F–1–5–11 (2) large, USNM 40805; F–1–6–18 (3), USNM 40806.

Mesophyllum eniwetokensum Johnson n. sp.

Plate 272, figure 4

Description.—Thallus a very thin irregular crust; many thalli may grow superimposed to develop nodular mass. Hypothallus absent or consisting of only few layers of cells. Perithallic cells rectangular, 10μ–14μ by 9μ–11μ. Conceptacle chambers large, 647μ–780μ by 200μ–210μ.

Remarks.—*Mesophyllum eniwetokensum* belongs to same group of genus as *M. koritzae* and *M. Sancti Dionysii*, which Lemoine (1939) found so abundantly developed in the Miocene of Algeria. It closely resembles *M. Sancti Dionysii* in growth habit, size of perithallic cells, and large size of conceptacles. It differs from that species, in however, that hypothallus is poorly developed or absent. Both species have large many apertured conceptacles but, whereas high and strongly arched in *M. Sancti Dionysii*, they are relatively low and flat topped in *M. eniwetokensum*.

Age: Miocene.
Locality: Eniwetok F-1 depth 1,978–2,003 ft (core).
Figured specimen: F-1-5-39 (3) holotype USNM 40807.

Mesophyllum sp. A

Plate 271, figure 3

Description.—Thallus an irregular crust or plate. Hypothallus moderately coaxial, 180μ–350μ thick; cells rectangular 15μ–38μ by 10μ–16μ. Perithallus shows irregular growth zones, 5 to 8 layers of cells in each zone. Cells rectangular, 11μ–18μ by 7μ–14μ. Conceptacles unknown.

Remarks.—A number of specimens of this species were observed. It differs in cell dimensions from previously decribed Miocene species. Without knowledge of conceptacles, it does not seem desirable to give it specific name.

Age: Miocene.
Locality: Eniwetok F-1, depths 1,718–2,003 ft (cores).
Figured specimen: F-1-5-12 (2), USNM 40808.

Division 2—Crusts with short stubby branches

Mesophyllum erubescens (Foslie)

Plate 272, figure 6

Lithothamnion erubescens Foslie, 1900, K. norske. vidensk. selsk. Skr., no. 5, p. 9.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 31–36, fig. 15–16, pl. 3, fig. 20.
Mesophyllum erubescens (Foslie) Lemoine, 1928, Soc. bot. France Bull. 5th ser. v. 75. P. 252.

Description.—Thallus a thin crust with thick stubby branches. Tissue of branches mainly medullary hypothallus though marginal hypothallus clearly developed. Tissue tends toward lenticular growth zones. Medullary hypothallus growth zones of 6–10 rows of rectangular cells; cells 20μ–26μ by 7μ–9μ Perithallus cells square to rectangular, 13μ–17μ by 7μ–12μ Conceptacles not present.

Remarks.—A widely distributed Recent species in the Pacific area. To judge by Foslie's several discussions it occurs in a number of growth forms and shows considerable range in cell dimensions.

The specimen studied agrees with Foslie's description.

Age: Pleistocene or Recent.
Locality: Funafuti, main boring, depth 20–30 ft.
Figured specimen: British Museum slide 615.

Mesophyllum japonicum Ishijima

Plate 271, figure 2

Mesophyllum japonicum Ishijima, 1954, Cenozoic coralline algae western Pacific, p. 32, pl. 12, figs. 1–5; pl. 13, fig. 1.

Description.—The plant forms an irregular crust from which arise short stubby branches. Hypothallus coaxial with cells 23μ–28μ by 10μ–13μ. Tissue of perithallus and branches shows strong irregular growth zones, each consisting of layers of rectangular cells 15μ–20μ by 6μ–8μ. No conceptacles present.

Remarks.—The structure, appearance, and cell dimensions agree closely with Ishijima's description and illustrations but the perithallis cells of the Eniwetok specimens average a little smaller.

Age: Miocene.
Locality: Eniwetok F-1, depth 1,978–1,985 ft (core).
Figured specimen: F-1-5-1, USNM 40809.

Mesophyllum cf. M. savornini Lemoine

Plate 271, figure 4

Mesophyllum savornini Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 83, figs. 43–46.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 227, pl. 52, fig. 8.

Description.—Thallus develops crust, bearing short stubby branches that show strong growth zones. Each composed of layers of rectangular cells. The cells measure 12μ–14μ by 7μ–14μ. Conceptacle chambers large, relatively low, and flat on top. Chambers 360μ–630μ by 120μ–200μ.

Remarks.—Represented by several fragments of branches. The character of tissue, cell dimensions, and large size of conceptacles agree with those of Lemoine's type, and with specimens described by author from the Miocene of Saipan.

Age: Miocene.
Locality: Eniwetok F-1, depth 2,662–2,687 ft (core).
Figured specimen: N-2, USNM 40944.

Mesophyllum robustum Johnson n. sp.

Plate 271, figure 6

Description.—Thallus a thick irregular crust, probably with rounded protuberances. Well-developed coaxial hypothallus 200μ–260μ thick. Hypothallic cells 13μ–27μ by 7μ–12μ. Perithallus consists of irregular growth bands, which may appear lenticular in section. Cells 8μ–16μ by 7μ–10μ. Conceptacles small but highly arched. They measure 356μ by 169μ, 301μ by 180μ, 238μ by 141μ. Some traces of sporangia in conceptacles. Sporangia show heights of 33μ–55μ and diameters of 26μ–40μ (30μ).

Remarks.—Species closely resembles *M. heteroclitum* Lemoine in cell dimensions and size of conceptacles but has better developed coaxial hypothallus; the hypothallus of *M. heteroclitum* consists of few horizontal layers of cells very regularly arranged. *M. robustum* also closely resembles *Lithothamnium camarasae* Pfender but differs from it also in character and development of hypothallus.

Age: Late Eocene.
Locality: Eniwetok F–1, depth 3,052–3,055 ft (core).
Figured specimen: F–1–7–7 (2) large, Holotype USNM 40812.

Division 3.—Strongly branching forms

Mesophyllum sp. B

Plate 272, figure 5

Description.—Plants with long narrow spines or branches that are composed of arched layers of rectangular cells arranged in pronounced growth zones; each zone with 6 to 12 layers of cells; cells measure 12μ–22μ by 9μ–14μ. Conceptacles unknown.

Remarks.—Represented by several worn fragments. They differ from any branching Miocene species hitherto described from Pacific. Nearest described species *M. commune* Lemoine from Miocene of Algeria. Eniwetok species has slightly larger cells. Better specimens and knowledge of conceptacles needed before naming species.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,718–1,740 ft (core).
Figured specimen: H2, USNM 40811.

Mesophyllum cf. M. australe (Foslie)

Lithothamnion coralloides f. *australis* Foslie, 1895, K. norske vidensk. selsk. Skr., no. 2, p. 9.
Lithothamnion australe Foslie, 1900, K. norske. vidensk. selsk. Skr., no. 5, p. 13.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 24–29, figs. 10–12, pl. 2, figs. 10–51.
Mesophyllum australe (Foslie) Lemoine, 1928, Soc. bot. France Bull. 5th ser. v. 75, p. 252.

Description.—Thallus crustose with short stubby branches. Hypothallus moderately developed coaxial; cells 13μ–25μ by 5μ–8μ. Perithallus composed of fairly regular rows of cells measuring 12μ–22μ by 5μ–8μ. Conceptacles absent.

Remarks.—Several fragments probably belonging to this species, or one closely related to it, were observed. Cells slightly longer than those of type but Foslie referred to *L. australe* as a highly variable form. Without conceptacles, an exact determination cannot be made.

Age: Pleistocene or Recent.
Locality: Funafuti, depths 20–23 ft and probably from depth 957 ft.
Specimens: British Museum slides 598, 611, 615.

Mesophyllum pulchrum (Foslie)

Plate 271, figure 5

Lithothamnion pulchrum Foslie, 1901, K. norske. vidensk. selsk. Skr., no. 3, p. 3.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 36–38, fig. 18, pl. 4,
Mesophyllum pulchrum (Foslie) Lemoine, 1928, Soc. bot. France Bull. 5th ser. v. 75, p. 252.

Description.—Thallus massive, branching, represented by fragments of thick branches. Basal hypothallus missing. Medullary hypothallus shows distinct rather regular cup-shaped growth zones. Cells appear rounded rectangular, longer than wide. Recrystallization prevents accurate cell measurements, but they are approximately 12μ–25μ by 8μ–12μ. Perithallus not observed around margins of branches. Three measured conceptacles gave diameters of 290μ–350μ and heights of 175μ–190μ.

Remarks.—Specimen badly recrystallized. Growth habit and general appearance of tissue suggest that dimensions of cells and conceptacles of this species fall within dimension range of Recent examples from East Indies.

Age: Pleistocene.
Locality: Funafuti, main boring, depth 736–748 ft.
Figured specimen: British Museum slide 688.

Genus LITHOPHYLLUM Philippi, 1837

In this genus thallus is polystromatic, forming a crust or crust-developing protuberances or erect branches; differentiated into hypothallus, perithallus, and epithallus. Hypothallus is several to many layers thick, commonly coaxial. Hypothallic cells are mostly horizontally elongated. The perithallus usually is thinner than the hypothallus with cells typically isodiametric but sometimes elongated. The epithallus is 1 to 4 layers thick, cells flattened parallel to the outer surface. It is seldom calcified; hence is rarely observed on fossil material. The conceptacles have a single large pore.

Lithophyllum is abundantly represented in the collections studied both in number of species and of individuals.

For convenience in study, the species are arranged into three divisions based on the growth habit.

Division 1.—Simple crusts.
2.—Crusts with warty proturbances or short stubby branches.
3.—Strongly branching forms.

The following table gives the dimensions and distribution of the species identified.

Measurements (in microns) and distribution of species of Lithophyllum

Species	Hypothallus cells		Perithallus cells		Conceptacles		Locality	Depth (feet)	Age
	Length	Width	Length	Width	Diameter	Height			
Division 1.—Simple crusts [Commonly thin; several may be superimposed]									
Lithophyllum acanthinum Foslie	18–25	8–14	8–15	7–14			Kita-Daitō	25–383	Pleistocene.
hanzawae Johnson n. sp.	12–30	9–12	7–11	7–10	125–170	36–55	do	180	Do.
johnsoni Ishijima	14–22	9–11	8–11	7–8			Eniwetok F-1	1,975–2,000	Miocene.
cf. *L. lingusticum* Airoldi	16–25	8–11	8–10	8–10			do	3,655–3,665	Eocene.
megacrustum Johnson and Ferris	10–18	15–76	9–17	27–83	225–447	67–102	Kita-Daitō	0–220	Pleistocene or Recent.
							Eniwetok K-1	400	Do.
							Funafuti	1,000	Do.
cf. *L. prelichenoides* Lemoine	14–18	8–9	10–12	7–11	185	81	Eniwetok F-1	1,978–2,003	Miocene.
quadratum Ishijima	10–14	27–43	9–12	17–30	208–246	101–109	Kita-Daitō-Jima	30	Pleistocene(?).
samoense Foslie	5–7	9–15	5–7	5–7	153–171	89–97	do	30	Do.
stefaninii Airoldi	9–11	9–26	8–16	13–25			do	23–396	Pliocene-Pleistocene.
thikombian Johnson and Ferris	15–20	24–33	12–14	16–27			do	393	Miocene(?).
Division 2.—Crusts with warty protuberances or short stubby branches									
Lithophyllum okamurae Foslie	12–16	30–45	12–22	8–10	161–235	60–78	Kita-Daitō-Jima	(1)	Pleistocene or Recent.
sp. A			11–14	8–10	195–210	90–160	Eniwetok E-1	2,655	Miocene.
Division 3.—Strongly branching forms									
Lithophyllum kladosum Johnson	28–65	10–17	10–23	9–17	315–375	160–250	Eniwetok F-1	1,720–2,000	Miocene.
							do	2,100–2,680	
cf. *L. kotschyanum* Unger	9–33	7–14	11–30	7–15			Kita-Daitō-Jima	37–347	Pleistocene.
profundum Johnson	20–41	9–15	8–16	9–13			Eniwetok F-1	1,978–2,003	Miocene.
							Eniwetok E-1	2,690–2,700	Do.
sp. B	30–36	15–18	9–15	10–15			Kita-Daitō-Jima	495	Do.

[1] Surface.

Division 1—Simple crusts

Lithophyllum acanthinum Foslie

Plate 273, figure 1

Lithophyllum acanthinum Foslie, 1907, K. norske. vidensk. selsk. Skr., no. 6, p. 26.

Description.—Thallus a crust 2–5 mm thick. Hypothallus coaxial; cells rectangular 18μ–25μ by 8μ–14μ Perithallus thin, cells rectangular, measuring 8μ–15μ by 7μ–14μ. No conceptacles present.

Remarks.—Represented in Kita-Daitō-Jima collection by number of poorly preserved fragments, all infertile. Growth habit and cell dimensions agree with Foslie's description of *L. acanthinum* from central Japan although some of perithallic cells attain greater length.

Age: Pleistocene and possibly late Pliocene.

Locality: Kita-Daitō-Jima core, depth 24 ft (7.5 m) and 380 ft (115 m).

Figured specimen: Tōhoku University colln., slide 656; slide 43, not figured.

Lithophyllum hanzawae Johnson n. sp.

Plate 272, figures 2, 3

Description.—Irregular crust 1.45–2.10 mm thick. Hypothallus composed of cell rows curving up and down from center. Walls of cell rows clearly defined; walls between cells in row thin and obscure. Cells 9μ–12μ by approximately 12μ–30μ. Perithallus of regularly arranged cell rows; cells 7μ–10μ by 7μ–11μ. Conceptacles abundant, small, cavities measuring 125μ–170μ by 36μ–55μ high. Tops slightly arched and perforated by one large pore.

Remarks.—This species belongs to small group of encrusting *Lithophyllum* characterized by unusually small size of perithallic cells and conceptacles. It is closely related to Foslie's highly variable *L. yendoi*, but differs by having a different type of hypothallus, which is more strongly developed, and in having smaller conceptacles and slightly larger cell dimensions.

The species is named for Dr. Shoshiro Hanzawa of the Institute of Geology and Paleontology of Tōhoku University who carefully studied the Kita-Daitō-Jima cores, described the Foraminifera (Hanzawa 1940–41), and assisted in the present restudy.

Age: Pleistocene(?).

Locality: Kita-Daitō-Jima core depth 53 ft (16 m).

Holotype: Tōhoku University, Aoki colln. slide 141.

Lithophyllum johnsoni Ishijima

Lithophyllum johnsoni Ishijima, 1954, Cenozoic coralline algae western Pacific, p. 42, pl. 25, fig. 4; pl. 26, figs. 1–3; pl. 27, fig. 3.

Description.—Thallus crustose, thin; well-developed coaxial hypothallus and moderately developed perithallus. Hypothallic cells 14μ–22μ by 9μ–11μ. Perithallic cells small, rectangular to square in section, measuring 8μ–11μ by 7μ–8μ. Conceptacles unknown.

Remarks.—The Eniwetok material fits Ishijima's species from the Miocene of Japan. Represented by a number of specimens in the Eniwetok collection.

Age: Miocene.
Locality: Eniwetok F–1, 1975–2,000 ft (core).

Lithophyllum cf. L. lingusticum Airoldi

Plate 272, figure 1

Lithophyllum lingusticum Airoldi, 1932, Paleontographia Italica Mem. Paleont., v. 33 (new ser., v. 3), p. 72–73, pl. 12, figs. 2–3.

Description.—Thallus a thin crust. Hypothallus coaxial, 160μ–250μ thick; cells 16μ–25μ by 8μ–11μ. Perithallus thin, 45μ–75μ thick, of nearly cubic cells measuring 8μ–10μ on a side. Conceptacles unknown.

Remarks.—No Eocene species of Lithophyllum with corresponding cell dimensions has been described previously. The closest described species is *L. lingusticum* Airoldi from the Oligocene of Somali which develops as a thin crust with short branches and has cell dimensions about the same as the Eniwetok specimens.

Age: Late Eocene.
Locality: Eniwetok F–1, 3,655–3,665 ft (core).
Figured specimen: F–1–9–9, USNM 40814.

Lithophyllum megacrustum Johnson and Ferris

Lithophyllum megacrustum Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 16, pl. 7, figs. D, E.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 228, pl. 54, fig. 8; pl. 55, fig. 1.

Description.—Plant has thick crust as much as or more than a centimeter thick. In some cases several superimposed thalli form crust. Hypothallus absent or slightly developed; commonly consists of single row of oblique cells, at most of only few rows of long cells; cells measure 6μ–18μ by 12μ–76μ, commonly 11μ–16μ by 28μ–48μ. Perithallus consists of regular rows of long rectangular cells with thick walls. Some areas are irregular, especially around conceptacles. In some rows, cells are arranged obliquely to row walls and there may be suggestion of alternation of rows of cells of slightly different length. Cell walls distinct and thick; cells show an unusual size range, measuring 8μ–18μ by 21μ–86μ, commonly 9μ–14μ by 31μ–54μ. Conceptacle chambers 300μ–447μ by 67μ–140μ.

Detailed measurements of a number of specimens studied from Kita-Daitō-Jima, Eniwetok, and Funafuti are as follows.

Sample	Depth (feet)	Hypothallus (microns)	Perithallus (microns)	Conceptacles (microns)
Kita-Daitō-Jima				
124	0	----------	10–14×41–68	----------
176	0	12–16×21–25	9–12×21–25	300–447× 81–98
176	0	10–14×40–62	9–12×37–82	425 × 92
25	18	11–18×39–80	9–14×27–42	320–403× 67–91
19	20	----------	11–14×22–36	278 × 92
59	29	8–9 ×29–47	9–12×34–42	385 ×109
60	29	10–14×31–76	8–12×30–61	302–374× 90–102
246	160	11–13×45–63	9–14×38–83	310 ×140
Aoki II	----------	----------	11–18×34–54	302–306× 76–93
Aoki II	----------	13–18×28–34	9–17×40–44	225–323× 73–89
272	----------	11–15×15–27	9–14×31–37	356–383× 86–88
361	217	----------	8–12×27–46	430 ×130
718	----------	14–15×27–47	14–15×31–48	328 × 81
Eniwetok				
K–1	400	7–14	7–14×40–50	Not present.
Funafuti				
Slide 774	1,000	----------	10–15×41–50	313–316× 82–84

Remarks.—Most abundant species in the Kita-Daitō-Jima cores. It resembles modern *Lithophyllum papillosum* (Zan.) Foslie of Mediterranean and tropical Pacific but differs in forming much thicker crust and, in most cases, has a more regular tissue.

Age: Pleistocene and probably Recent.
Locality: Kita-Daitō-Jima core, surface to depths of 220 ft (66 m). Funafuti core, depth 1,000 ft. Eniwetok core K–1, depth 400 ft.
Specimens: Tōhoku University colln., slides 25 and 176, and Aoki II.

Lithophyllum cf. L. prelichenoides Lemoine

Lithophyllum prelichenoides Lemoine, 1918, Soc. géol. France Bull., ser. 4, v. 17, p. 262, figs. 8, 9 [imprint date 1917].
Lemoine, 1939, Mat. Carte géol. de l'Algerie, ser. 1, Paléont., no. 9, p. 99, figs. 65–66, p. 107.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 229, pl. 49, figs. 1–2.

Description.—Thallus a thin crust or irregular plate consisting of well-developed coaxial hypothallus and thin perithallus. Hypothallic cells 14μ–18μ by 8μ–9μ. Perithallic cells nearly cubic, 10μ–12μ by 7μ–11μ. Conceptacle cavity 185μ by 81μ.

Remarks.—In growth habit, structure, and cell dimensions Eniwetok specimens resemble this widespread Miocene species. They differ from typical *L. prelichenoides* only in having slightly smaller average size of hypothallic cells.

Age: Miocene.
Locality: Eniwetok F–1, 1,978–2,003 ft (core).

Lithophyllum quadratum Ishijima

Plate 273, figure 2

Lithophyllum quadratum Ishijima, 1954, Cenozoic coralline algae western Pacific, p. 37–38, pl. 22, fig. 5a, b; pl. 23, fig. 1–4.

Description.—Thallus a thin crust commonly about 0.5 mm thick; several or many thalli may grow superimposed to form irregular flattened masses. Hypothallus thin and irregular; cells 10μ–14μ by 27μ–43μ. Perithallus shows rectilinear pattern in section. Tissue may show irregular growth zones. Cells measure 9μ–12μ by 17μ–30μ. Conceptacle cavities 208μ–246μ by 101μ–109μ.

Remarks.—Characteristic features of this species, rectilinear pattern of normal perithallic tissue, relatively large size of perithallic cells, diameter of the conceptacles, and irregularly zoned appearance of sections of crusts. Kita-Daitō-Jima specimens agree with Ishijima's description and illustrations except in having somewhat narrower perithallic cells. Species closely related to the Recent species *L. yessoense* Foslie, differing only in having longer hypothallic cells.

Age: Pleistocene (?).
Locality: Kita-Daitō-Jima, core depth 29 ft (8.97 m).
Figured specimen: Tōhoku University colln., slide 63.

Lithophyllum samosense Foslie

Plate 273, figures 5, 6

Lithophyllum samosense Foslie, 1906, K. norske vidensk. selsk. Skr., no. 2, p. 20.

Description.—Thallus a thin crust on other algae or objects. Crusts 0.3–0.6 mm thick. Hypothallus irregularly developed, apparently varying with irregularities in substratum; hypothallic cells 5μ–7μ by 9μ–15μ. Perithallus shows irregular growth zones, cells 5μ–7μ by 5μ–7μ. Conceptacles small, shaped like lima beans, in section 153μ–171μ by 89μ–97μ.

Remarks.—Foslie described two species of thin crustose *Lithophyllum* from Pacific, *L. samoense* and *L. yendoi.* These species differ only in cell dimensions and size of conceptacles. They appear to have much the same geographic range. Specimens from Kita-Daitō-Jima cores exactly fit Foslie's description of *L. samoense* but they are close to material from Saipan referred by writer to *L. yendoi*; the Kita-Daitō-Jima specimens have slightly larger conceptacles.

Age: Pleistocene (?).
Locality: Kita-Daitō-Jima, depth 29 ft (8.97 m).
Figured specimen: Tōhoku University colln., slides 61 and 256.

Lithophyllum stefaninii Airoldi

Plate 273, figures 3, 4

Lithophyllum stefaninii Airoldi, 1933, Palaeontographia Italica Men. Palaeont., v. 32, supp. 1, p. 90, pl. 8, fig. 2.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 228, pl. 54, fig. 4.

Description.—Thallus a thin crust with well-defined hypothallus and perithallus. Hypothallus moderately coaxial, cells oval to rectangular, measuring 9μ–11μ by 9μ–26μ. Perithallus quite regular, cells rectangular 8μ–16μ by 13μ–25μ. No conceptacles present.

Remarks.—Relatively common in Kita-Daitō-Jima material. In growth habit, appearance of tissue, and cell dimensions this form agrees with Airoldi's description of material from Pleistocene of Red Sea region.

Age: Probably Pliocene-Pleistocene.
Locality: Kita-Daitō-Jima core, depth 22 ft (7 m) and 396 ft (120 m).
Figured specimens: Tōhoku University colln., slides 62 and 661.

Lithophyllum thikombian Johnson and Ferris

Plate 273, figure 7

Lithophyllum thikombian Johnson and Ferris, 1950, B. P. Bishop Mus. Bull. 201, p. 17, pl. 6, figs. B and D.

Description.—Thallus crustose, consisting of well-developed coaxial hypothallus and some perithallic tissue. Hypothallus 0.29 mm thick, composed of rectangular cells 15μ–20μ by 24μ–33μ. Perithallus of regular layers of cells; cells 12μ–14μ by 16μ–27μ. Conceptacles not present.

Remarks.—This species is represented by several abraded fragments in core. In general appearance of tissue and in cell measurements it agrees closely with *L. thikombian* described from Miocene of Lau, Fiji.

Age: Probably Miocene.
Locality: Kita-Daitō-Jima core, depth 363 ft (110 m) and 389 ft. (119 m).
Figured specimen: Tōhoku University colln., slide 656.

Division 2—Crusts with warty protuberances

Lithophyllum okamurae Foslie

Plate 274, figure 1

Lithophyllum okamurae Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 30–31.

Description.—Thallus a thick crust from which develop warty protuberances. Hypothallus poorly to moderately developed; cells rectangular 12μ–16μ by 30μ–45μ. Perithallus thick, showing some growth zones; cells square to oblong in section, measuring 12μ–22μ by 8μ–10μ. Conceptacles abundant, small; cavities measure 161μ–235μ in diameter and 60μ–78μ high.

Remarks.—Foslie described this as a species with a variety of growth forms from Japan and East Indies. Forms include warty crusts and nodular crusts with short thick branches. Specimens studied fit description.

Age: Pleistocene or Recent.
Locality: Kita-Daitō-Jima, surface outcrops.
Figured specimen: Tōhoku University colln., slide 176.

Lithophyllum sp. A

Description.—Thallus a thick crust or mammillated mass. Hypothallus not observed. Perithallus of small rectangular cells in poorly defined layers. Cells measure 11μ–14μ long and 8μ–10μ wide. Conceptacles small gently arched to nearly flat on top. Conceptacle chambers measure 195μ–210μ in diameter and 90μ–160μ in height.

Remarks.—Represented in Eniwetok slides by two worn fragments. They differ from previously described Miocene species, but are too poorly preserved to use as base for a new species. The nearest described species is *Lithophyllum irregularis* Ishijima which, however, has much larger and flatter conceptacles.

Age: Miocene.
Locality: Eniwetok E–1, depth 2,650–2,660 ft (cuttings).

Division 3—Strongly branching forms

Lithophyllum kladosum Johnson

Plate 272, figure 7; plate 274, figures 4, 5

Lithophyllum kladosum Johnson, 1954, U.S. Geol. Survey Prof. Paper 260–M, p. 539, pl. 192.

Description.—Long slender branches composed of well-developed medullary hypothallus surrounded by a relatively thick marginal perithallus. Hypothallic cells oblong in section, arranged in arched layers. Cells show considerable range in size of different rows of same specimen, measuring 28μ–65μ high and 10μ–17μ wide. Perithallic cells cubic, in layers nearly perpendicular to the layers of the hypothallus; cells measure 10μ–23μ by 9μ–17μ. Conceptacles marginal, highly arched. Conceptacle chambers measure 315μ–375μ in diameter and 160μ–250μ in height.

Remarks.—In general appearance, cell measurements, and all structural features Eniwetok specimens agree with material described from beds of same age in Bikini drill hole. In addition several fertile specimens obtained.

This species is most abundantly represented of all species studied from Eniwetok material. It was found in both drill holes F–1 and E–1, in cores and in cuttings.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,720–2,000 ft (cores); E–1, depth 2,100–2,680 ft (cuttings).
Figured specimens: USNM 40815, and 40816, and 40924.

Lithophyllum cf. L. kotschyanum (Unger) Foslie

Plate 274, figures 2, 3

Lithophyllum kotschyanum (Unger) Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 34–36.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 230, pl. 57, fig. 1; pl. 58, fig. 1.

Description.—Thallus a crust with thick stubby branches that contain thick medullary hypothallus and moderately to well-developed marginal perithallus. Medullary hypothallus built of curved layers of rectangular cells; considerable range in cell size both in different layers and in same layer from center to edge. Cells measure 9μ–33μ by 7μ–14μ, commonly 12μ–15μ by 8μ–11μ. In some cases there appears a fairly regular alternation of several layers of long cells with several layers of short cells (plate 8, fig. 3). Marginal perithallus of well-defined cell layers, cells 11μ–30μ long and 7μ–15μ wide, commonly 11μ–20μ by 9μ–11μ. Conceptacles rather flattened on top with large central aperture; cavities 401μ–512μ in diameter and 93μ–180μ high.

Remarks.—Foslie's Recent species is very variable form. He named five forms, which grade one into another. There is corresponding variation in cell size and structural detail, some showing alternating layers of long and short cells, some not. The species has been reported from Red Sea to Samoa. The author has collected it around Guam and Saipan. The Kita-Daitō-Jima material agrees with Foslie's description except for having larger conceptacles. The type material has conceptacle diameters of 250μ–400μ, while our specimens show diameters from 401μ–512μ, commonly 401μ–440μ.

Numerous specimens attributed to this species were observed in the Kita-Daitō-Jima core at depths ranging from 10 to 100 meters (30 to 320 ft); all were worn branches or fragments.

Age: Pleistocene (?).
Locality: Kita-Daitō-Jima core, depth 35 ft (10.73 m) and 345 ft (105 m).
Figured specimen: Tōhoku University colln., silde 73.

Lithophyllum profundum Johnson

Plate 275, figure 5

Lithophyllum profundum Johnson, 1954, U.S. Geol. Survey Prof. Paper 260–M, p. 539–540, pl. 191, figs. 5–7.

Description.—Plant forms clusters of long relatively slender branches. Each branch consists of moderately wide medullary hypothallus and much narrower perithallus. Hypothallus of arched layers of rectangular cells 20μ–41μ long and 9μ–15μ wide. Perithallus formed of layers of small rectangular cells 8μ–16μ by 9μ–13μ. Perithallus shows growth zones. Conceptacle chambers 300μ–360μ in diameter and 190μ–225μ in height.

Remarks.—The structure, growth habit, and cell dimensions agree with species described from Bikini, based on fragments of infertile branches. Eniwetok collections contain larger pieces which give better idea of growth habit, and they include some with conceptacles.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core); E–1, 2,690–2,700 ft (cuttings).
Figured specimen: F–1–5–42, USNM 40913.

Lithophyllum sp. B

Description.—Worn fragment of branch with well-developed medullary hypothallus of gently arched layers of rectangular cells 30μ–36μ long and 15μ–18μ wide. Most of marginal perithallus worn off. Perithallic cells nearly square, 9μ–15μ by 10μ–15μ, averaging 10μ–11μ square in section. Conceptacles absent.

Remarks.—This form does not exactly fit description of any previously described Miocene species. Because no conceptacles are present and it is represented by only one specimen in Kita-Daitō-Jima collection, it does not seem desirable to name it as new species.

Specimen resembles fragment found in Bikini core at depth of 2,040 feet (Miocene). It was described (Johnson 1954b, p. 541) under name of *Goniolithon* cf. G. *frutescens* Foslie. Growth habit and cell dimensions are similar. Bikini specimen shows more pronounced growth zones than Kita-Daitō-Jima specimen.

Age: Miocene.
Locality: Kita-Daitō-Jima core, depth 492 ft (150 m).

Genus GONIOLITHON Foslie, 1900

The genus *Goniolithon* is closely related to *Lithophyllum*, having the same type of hypothallus and conceptacles. It resembles *Porolithon* in having numerous megacells in the perithallic tissue; however, these occur in small rows perpendicular to the outer surface, not in lenses parallel to the surface as in *Porolithon*. In many cases there are only 2 or 3 megacells in a group, one above the other. Today, the genus is represented in the tropical Pacific by a small number of widely distributed species.

Goniolithon frutescens Foslie

Goniolithon (*Cladolithon*) *frutescens* Foslie, 1900, K. norske vidensk. selsk. Skr., no. 1, p. 9–10.
Goniolithon frutescens Foslie, 1900, The fauna and geography of the Maldive and Laccadive Archipelagos, p. 468, pl. 35, figs. 5–6.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 53, pl. 10 figs. 10–11.
Foslie and Printz, 1929, K. norske vidensk. selsk. Museet. Mon., p. 30 pls. 48, 52.
Taylor, 1950, Mich. Univ. Studies, Sci. ser., v. 18, p. 123–124, pls. 58–60.
Johnson, 1954, U.S. Geol. Survey Prof. Paper 260–M, p. 541, pl. 195, figs. 1–2.
Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 231, pl. 59, fig. 4; pl. 60, fig. 3.

Description.—Fragments of long rather irregular branches. Medullary hypothallus and the marginal perithallus well developed. Medullary hypothallus thick; in section consists of slightly to strongly curved rows of rectangular cells 23μ–32μ long and 12μ–18μ wide. Perithallus composed of rows of cells that are fairly regular except around groups of megacells; cells measure 12μ–22μ long and 12μ–18μ wide; megacells 20μ–31μ in diameter, normally little longer or little shorter than wide. No conceptacles observed.

Remarks.—Foslie described this species originally from specimens collected on the Recent reefs at Funafuti. This species is most abundantly represented form recognized in the Funafuti cores. It also occurs in appreciable abundance on the Recent reefs and in surface and near-surface material at Eniwetok. It grows on corals and as small clusters of branches on the bottom in the more protected areas of the reef flat behind the algal ridge.

Age: Recent and Pleistocene.
Locality: Funafuti, on the Recent reefs and in the main drill hole down to depths of 950 ft; Eniwetok, Recent reefs and in K–1 from surface to depth of about 40 ft.

Goniolithon myriocarpon Foslie

Plate 275, figure 6

Goniolithon myriocarpon Foslie, 1904, Wiss. Meers., N. F. B. 7, abt. Helgoland, Heft 1, p. 23.
Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 45, pl. 9, fig. 6.
Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 9.

Description.—Thallus a thin crust. Hypothallus thin, poorly coaxial, or curved rows of cells. Cells 16μ–20μ long, 12μ–16μ wide. Perithallus moderately to well developed, cells 9μ–15μ long, 9μ–11μ wide. Megacells abundant in most area of perithallic tissue; 26μ–29μ high and 16μ–21μ wide. No conceptacles present.

Remarks.—In growth habit and cell dimensions the Eniwetok specimens agree with Foslie's descriptions of this widely distributed Recent species.

Age: Recent and Miocene.
Locality: F–1, Eniwetok 1,232–1,248 ft (core).
Figured specimen: F–1–3–3 (1), USNM 40820.

Goniolithon fosliei (Heydrich) Foslie

Plate 275, figure 7

Lithothamnion fosliei Heydrich, 1897, Deutsche, bot. Gesell., Ber. p. 15, 58.
Lithophyllum fosliei Heydrich, 1897, Deutsche bot. Gesell., Ber. p. 15, 140.

Goniolithon fosliei (Heydrich) Foslie, Weber van Bosse and and Foslie, 1904, *Siboga*-Expeditie, Mon. 61, p. 46–48, pl. 9, figs. 1–5.

Foslie and Printz, 1929, K. norske vidensk. selsk. Museet, Mon., p. 29, pl. 46, figs. 1–5.

Description.—Thallus a crust; superimposed thalli may form crustose masses over a centimeter thick. Thallus consists of well-developed coaxial hypothallus overlain by a perithallus that may be slightly or strongly developed. Hypothallic cells 20μ–38μ by 7μ–11μ; perithallic cells 12μ–20μ by 8μ–10μ. Megacells rare in some specimens, fairly abundant in others, commonly 3 to 5 in a vertical row. Conceptacles wide and low, 800μ–$1{,}000\mu$ in diameter.

Remarks.—This Recent species widely distributed over Indian Ocean and tropical Pacific. According to Foslie (1904) and Lignac-Grutterink (1943, p. 291), there is considerable range in cell dimensions in both same and in different specimens. Foslie, working only with Recent specimens, placed species in genus *Goniolithon.* Lignac-Grutterink, working with fossil material, considered it as a typical *Lithophyllum.*

A number of infertile fragments attributed to this species were observed in slides from the Funafuti cores.

Age: Recent and Pleistocene(?).
Locality: Funafuti, depth 526 ft.
Figured specimen: British Museum slide 665.

Genus POROLITHON Foslie

Description.—*Porolithon* resembles *Lithophyllum* in the structures of the hypothallus, perithallus, and conceptacles. It differs in having lenses of megacells in the perithallic tissue. These cells are much larger and commonly are more regularly arranged than the normal perithallic cells. A feature common to the genus is the presence of lateral pores connecting adjoining cells.

The genus contains both crustose and branching species. It occurs abundantly today in the tropical Pacific on and around the reefs. It is represented by a relatively small number of widely distributed species.

Members of this genus appear to develop most abundantly in relatively shallow well-circulated water. They are the most important builders of the algal ridge along the seaward margin of many reefs where their greatest development is from tide level down to 40 or 50 feet.

The genus is young, geologically. So far no specimens older than Pliocene have been found. *Porolithon* did not become abundant until the middle of the Pleistocene.

For convenience in classification the species are grouped into three divisions based on growth habit.

The following table shows the dimensions and distribution of the species studied.

Measurements (in microns) and distribution of species of Porolithon

Species	Hypothallus cells		Perithallus cells		Conceptacles		Megacells			Locality	Depth (feet)	Age
	Length	Width	Length	Width	Diameter	Height	Diameter	Height	Number in cluster			
Division 1.—Crusts												
Porolithon onkodes (Heydrich) Foslie.	--------	--------	6–12(20)	7–12	125–175	60–78	8–17	17–34	5–10	Eniwetok	En-1, 30–50	Recent and late Pleistocene(?).
										do	E-1, 10–30	Do.
										Funafuti	535 and 726	Do.
Division 2.—Large thick masses												
Porolithon craspedium (Foslie) Foslie.	--------	--------	9–14	9–11	200–270	100–125	13–18	20–30	7–12	Funafuti	Recent reef	Recent and Pleistocene(?).
										Eniwetok K-1	70, 110	Do.
										do	--------	Do.
Division 3.—Strongly branching forms												
Porolithon aequinoctiale (Foslie) Foslie.	--------	--------	12–18	9–13	135–216	72–108	11–18	27–41	7–9	Eniwetok	En-6, 35; E-1, 50–60.	Recent and Pleistocene(?).
gardineri (Foslie) Foslie.	9–13	9–30	8–9	10–11	--------	--------	10–18	28–35	4–6	Funafuti	10–30, 547–555	Recent or late Pleistocene(?).
marshallense Taylor	14–23	9–14	10–14(20)	8–11	135–144	81–90	11–18	25–45	8–12	Eniwetok E-1	10–80, 30–35, 60–70.	Recent.

Division 1—Crusts

Porolithon onkodes (Heydrich) Foslie

Lithothamnion onkodes Heydrich, 1897, Deutsche bot. Gesell. Ber., v. 15, p. 410.

Porolithon onkodes (Heydrich) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. ser., v. 18, p. 125, pls. 9, 61–63.

Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 232–233, pl. 55, figs. 6, 7; pl. 59, fig. 6.

Description.—Plant encrusting. Hypothallus thin, consisting of few layers of horizontally elongated cells. Perithallus tissue composed of rectangular cells 6μ–12μ (20μ) by 7μ–12μ arranged in vertical rows and poorly defined horizontal layers. Lenses of megacells occur at irregular intervals in perithallic tissue. In section they occur in clusters, commonly of 5 to 10. Megacells 17μ–34μ long, 8μ–17μ wide. Conceptacle chambers 125μ–175μ in diameter, 60μ—78μ high.

Remarks.—Fairly abundant in some near-surface samples. Specimens correspond with Recent material collected at Bikini Atoll.

Age: Recent and Pleistocene(?).

Locality: Eniwetok, Engebi Island, En–1, 30–50 ft; Parry Island E–1, depth 10–30 ft. Funafuti, main boring, 535 and 726 ft.

Division 2—Large thick masses

Porolithon craspedium (Foslie) Foslie

Lithophyllum craspedium Foslie, 1900, K. norske vidensk. selsk. Skr., no. 5, p. 26, 27.

Porolithon craspedium (Foslie) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. ser., v. 18, p. 126–128, pls. 64–65.

Johnson, 1954, U.S. Geol. Survey Prof. Paper 260–M, p. 541, pl. 193.

Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 232, pl. 56, figs. 4, 5; pl. 59, figs. 1–3.

Description.—Plant forms dense cushion-shaped masses with knobby or coarse fingerlike protuberances. Medullary hypothallus and marginal perithallus not sharply defined. Cells in rows and fairly distinct layers; perithallic cells 9μ–14μ by 9μ–11μ. Lenses of megacells abundant, which show a great range in size; the more conspicuous measure 20μ–30μ high, 13μ–18μ wide; commonly they are in clusters of 7 to 12. Conceptacle chambers 200μ–270μ in diameter, 100μ–125μ high.

Remarks.—A number of fragments were observed, all of which closely resemble Recent material collected at Bikini Atoll. Recent species grows in and just below the surf zone—particularly on lee side of reefs.

Age: Recent and Pleistocene(?).

Locality: Eniwetok K–1, depths 70–110 ~~ft; Engebi~~ Island, slides K–1–2 (2), K–1–2 (1); Funafuti, depth 40–70 ft.

Division 3—Strongly branching forms

Porolithon aequinoctiale (Foslie) Foslie

Plate 275, figures 1, 2

Lithophyllum aequinoctiale Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 46.

Porolithon aequinoctiale (Foslie) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. ser., v. 18, p. 132, pls. 68, 70.

Description.—Plants form masses of short wide branches. Eniwetok material consists of worn fragments mainly of perithallic tissue; perithallic cells 12μ–18μ by 9μ–13μ. Lenses of megacells abundant, showing as horizontal rows in section, commonly 7 to 9 in a row, but there may be many more. Megacells 27μ–41μ high and 11μ–18μ wide. Conceptacle chambers 135μ–216μ in diameter, 72μ–108μ high.

Remarks.—Eniwetok fragments attributed to this species largely on basis of abundance and size of megacells and size of conceptacle chambers. Perithallic cells fall within size range but average a little wider.

Species grows in shallow water on outer-reef platform and in lagoons.

Age: Recent and Pleistocene(?).

Locality: Eniwetok E–1, depth 50–60 ft. (cuttings) and En–6, 35 ft.

Figured specimens: En–6–29–2, USNM 40818; En–6–29–1, 40817.

Porolithon gardineri (Foslie) Foslie

Lithophyllum gardineri Foslie, 1907, K. norske vidensk. selsk. Skr., no. 8, p. 30.

Foslie, 1907, Linnean Soc. London Trans., ser. 2, Zoology, v. 12, pt. 2, p. 190.

Lithophyllum (*Porolithon*) *gardineri* Foslie, 1909, K. norske vidensk. selsk. Skr., no. 2, p. 44–45.

Porolithon gardineri (Foslie) Foslie. Taylor, 1950, Mich. Univ. Studies, Sci. ser., v. 18, p. 129–131, pls. 5–9; pl. 70, fig. 1; pls. 71–73; pl. 76, fig. 2, pl. 77.

Description.—Plants cushion shaped, as much as 30 cm in diameter and 20 cm high. Basal part crustose with long branches forming densely packed rounded heads. In section, heads show a regularly arranged medullary hypothallus with cells 9μ–30μ long, 9μ–13μ wide. Marginal perithallus moderately thick, rather loose texture, cells 8μ–19μ long and 9μ–11μ wide, arranged in radial rows but not in distinct layers. Megacells abundant in perithallic tissue, in clusters of 8 to more than 20, commonly 4 to 6 in a section. They measure 28μ–35μ high and 9μ–18μ wide. Conceptacles 110μ–152μ in diameter and 68μ–110μ high.

Remarks.—This Recent species is one of common forms in the algal ridge of many atolls. It was observed in a number of slides from Funafuti drilling.

Age: Recent and Pleistocene(?).

Locality: Recent species widespread in Red Sea, Indian Ocean, and tropical Pacific. Fossil material observed in Funafuti core at depths of 10–30 ft. and 547–555 ft.

Porolithon marshallense Taylor

Plate 275, figures 3, 4

Porolithon marshallense Taylor, 1950, Mich, Univ. Studies Sci. ser., v. 18, p. 128–129, pls. 67 and 76.
Johnson, 1954, U.S. Geol. Survey Prof. Paper 260–M, p. 542, pl. 197, fig. 1.

Description.—Plant compact mass of branches, each consisting of wide medullary hypothallus surrounded by relatively narrow marginal perithallus. Cells of hypothallus 14μ–23μ by 9μ–14μ, commonly about 16μ by 10μ. Perithallic cells 10μ–14μ (20μ) by 8μ–11μ, commonly about 12μ by 10μ. Megacells commonly 8 to 12 in cluster, size 25μ–45μ by 11μ–18μ, average 36μ by 12μ. Conceptacles 135μ–144μ in diameter, 81μ–90μ high.

Remarks.—This species closely fits Taylor's description in cell size and in having cells arranged in distinct layers. Few conceptacle chambers observed, somewhat smaller than in type material. It differs from *P. gardineri* in having larger megacells, and in having distinct layers of cells. Recent species frequently grow in surf zone, slightly behind outer edge of reefs.

Age: Recent.
Locality: Eniwetok E-1, depths 30–35 and 60–70 ft (cuttings).
Figured specimens: E-1 60–70 USNM 40819; E-1-30-35, USNM 40940.

Genus PARAPOROLITHON Johnson, 1957

The hypothallus and conceptacles are of the *Lithophyllum* type. The distinctive feature is that the perithallic tissue not only contains small lenticular clusters of large megacells such as characterize the genus *Porolithon*, but it also contains numerous smaller megacells which occur singly or in vertical groups as in *Goniolithon*. This genus is known only from the Miocene.

Paraporolithon saipanense Johnson

Paraporolithon saipanense Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 233, pl. 52, figs. 4, 5.

Description.—Thallus a warty crust 0.8–1.4 mm thick. Hypothallus poorly coaxial 75μ–225μ thick, composed of rectangular cells 12μ–25μ long and 11μ–15μ wide, averaging 13μ by 11μ. Perithallus of fairly regular rows of cells 13μ–17μ by 11μ–15μ. Partitions between cell rows clearly developed; lenses of large megacells sparingly distributed through tissue. Sections through these show 4 to 8 cells to a cluster, averaging 5; megacells measure 46μ–68μ high and 15μ–18μ wide. Smaller megacells, 15μ–18μ by 14μ–18μ scattered abundantly throughout tissue, singly or in pairs. No conceptacles present.

Remarks.—Only one fragment of this species was observed in the Kita-Daitō-Jima slides. In appearance and cell measurements it agrees with the specimen described from Saipan.

Age: Miocene.
Locality: Kita-Daitō-Jima core, depth 646 ft (197 m).
Specimen: Tōhoku Univerity colln., slide 876.

Genus LITHOPORELLA Foslie, 1909

Weber van Bosse, A., and Foslie, M. H., 1904. The Corallinaceae of the *Siboga* Expedition. Mon. 61, 110 pp., 16 pls.
Foslie, M. H., 1909. Algologiske Notiser VI. K. norske vidensk. selsk. Skr., no. 2, p. 1–63.
Lemoine, Mme. Paul, 1917. In F. Borgesen. Rhodophyta of the Danish West Indies. Dansk. Bot. Ark., v. 3, no. 1, p. 147–200.
Howe, M. A., 1919. Tertiary calcareous algae from the islands of St. Bartholomew, Antigua, and Angiulla. Carnegie Inst. Washington Pub. 291, p. 9–20, pls. 1–6.
Setchell, W. A., 1943. Mastorphora and the Mastophoreae: Genus and subfamily of Corallinaceae. Natl. Acad. Sci. Proc. v. 29, no. 5, p. 127–135.
Ishijima, W., 1954. Cenozoic coralline algae from the western Pacific: Private publ., Tokyo, Japan, 87 p., 49 pls.

The identification of thin crustose coralline algae whose thalli are built of one or only a few layers of cells is extremely difficult and unless conceptacles are present, specific identification is impossible.

The term *Lithoporella* was used by Foslie in 1904 (Weber van Bosse and Foslie, p. 73) as a subgenus under *Mastophora*, with *Mastophora melobesioides* Foslie as its type. Later Foslie (1909, p. 59) raised *Lithoporella* to full generic rank. This was accepted by American geologists without question for about 10 years. Marshall A. Howe in 1919 (p. 17) states, "Foslie's establishment of a genus *Lithoporella* to receive the monostromatic calcified forms that he had previously referred to *Mastophora* seems justified." However, a year or two earlier, Mme. Lemoine (1917, p. 174), apparently as a result of studies of modern algae from the West Indies, preferred to consider *Lithoporella* a subgenus under *Melobesia*. In recent years, American geologists have tended to follow Howe's example and consider *Lithoporella* as an independent genus, while most European geologists and botanists have followed Mme. Lemoine.

Lithoporella has very thin monostromatic crustose thalli except around the conceptacles. The cells are rectangular, vertically elongated, and form a palisade-like layer. Rhizoids are absent. The thalli commonly grow superimposed or alternating with other crustose algae or encrusting Foraminifera to form thick crusts. Conceptacles are large, with a single aperture.

Lithoporella closely resembles *Mastophora* Decaisne, but *Mastophora* has long rhizoids for attachment, and normally the thalli do not grow superimposed. Another closely related genus is *Heteroderma* Foslie which differs from *Lithoporella* in consisting of 1 or 2 layers of isodiametric cells which are not vertically elongated to form palisadelike layers. Adjacent thalli become confluent but never superimposed. *Melobesia* Lamouroux differs from *Lithoporella* by having horizontally elongated cells in the basal layer; the thallus may be several layers thick, and the conceptacles have a number of openings.

Lithoporella ranges from Eocene to Recent. In existing seas it is abundantly represented by a few widespread species. They grow on almost any sort of hard object and have been found attached to noncalcareous algae. They live from tide level to at least 50 meters. A number of Recent and fossil species have been named. All show a wide range of cell sizes, even in a single specimen.

The following table shows the measurements and distribution of species studied.

Measurements (in microns) and distribution of species of Lithoporella

Species	Cell dimensions		Conceptacles		Locality	Depth (feet)	Age
	Length	Width	Diameter	Height			
Lithoporella melobesioides (Foslie) Foslie	25–76	13–23	250–585	38–158	Funafuti, Recent reef cores	75–1,000	Pleistocene or Recent.
					Kita-Daitō-Jima	0–333	Pleistocene.
					Eniwetok	----	Eocene to Recent.
cf. *L. crassa* Ishijima	34–45	11–15	----	----	Eniwetok, K-1	350	Recent or Pleistocene(?).
longicella Johnson n. sp.	45–104	9–15	----	----	Eniwetok, E-1	260–270	Pleistocene(?).
antiquitas Johnson n. sp.	30–60	13–22	175–250	95–115	Eniwetok, E-1	2,003–2,028	Miocene.
sp. A	83–94	43–59	----	----	Eniwetok, F-1	2,675	Lower Miocene.
sp. B	23–46	16–23	----	----	Eniwetok, F-1	1,718–1,740	Upper Miocene.
sp. C	28–48	20–31	----	----	Kita-Daitō-Jima	380	Pliocene-Pleistocene.

Lithoporella melobesioides (Foslie) Foslie

Mastophora melobesioides Foslie, 1903, K. norske vidensk. selsk. Aarsber. 1902.

Mastophora (Lithoporella) melobesioides Foslie. Weber van Bosse and Foslie, 1904, *Siboga*-Expeditie Mon. 61, p. 73–75, figs. 30–32.

Foslie, 1908, Alg. Nat. 5, K. norske vidensk, selsk, Skr., no. 7, p. 19.

Lithoporella melobesioides (Foslie) Foslie. Foslie, 1909, Alg. Nat. 6, norske vidensk. selsk. Skr., 1909, no. 2, p. 58, 59.

Howe, 1918, U.S. Natl. Mus. Bull 103, p. 11.

Howe, 1919, Carnegie Inst. Washington Pub 291, p. 16–19, pl. 6.

Mastophora melobesioides Foslie. Pfender, 1926, Soc. española historia nat. Bol., v. 26, p. 327–328, pl. 15.

Melobesia (Lithoporella) melobesioides Foslie. Lemoine, 1928 (a). Mus. nat. histoire nat., Bull. 1927, p. 550.

Lemoine, 1928 (b). Inst. Catalonia Hist. Nat. Bull., ser. 2, v. 8, no. 5–6, p. 104.

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Description.—Thallus thin irregular crusts that consist of single layer of large vertically elongated rectangular cells; around conceptacles few additional layers of small cells may develop. Cell walls thick, showing great range in size even in same plant. Cells measure 25μ–76μ long and 13μ–23μ wide. Conceptacle chambers 250μ–485μ in diameter and 38μ–158μ in height.

Remarks.—Fossils attributed to this species were found abundantly in all material studied from Funafuti, Kita-Daitō-Jima, and Eniwetok.

Age: Eocene to Recent.

Lithoporella cf. L. crassa Ishijima

Plate 276, figure 6

Lithoporella crassa Ishijima, 1945, Cenozoic coralline algae western Pacific, p. 50, pl. 48, figs. 1–3; pl. 49, figs. 1–3.

Description.—Thallus a single layer of vertically elongated cells in palisadelike rows; cells 34μ–45μ high and 11μ–15μ wide with thick walls. Numerous thalli grow superimposed to form thick crusts. No conceptacles observed.

Remarks.—Represented by several infertile fragments. These closely resemble the material recently described by Ishijima from the Pleistocene of Formosa. In section they suggest *Lithophyllum megacrustum* Johnson and Ferris (1950) from the Pleistocene of Fiji but differ in the more irregular arrangement of the cell layers, which are interpreted as individual thalli. Without a knowledge of the conceptacles it seems wise only to indicate their resemblance to *Lithoporella crassa.*

Age: Recent or Pleistocene(?).
Locality: Eniwetok hole K-1, depth about 350 ft (cuttings).
Figured specimen: K-1-30-1, USNM 40821.

Lithoporella longicella Johnson, n. sp.

Plate 276, figures 3, 4

Description.—Thallus a single layer of long narrow palisade cells, which show a considerable range in size in a single thallus. Thalli may be irregular; numerous thalli growing superimposed to form thick nodular masses. Cells measure 45μ–104μ high and 9μ–15μ wide (commonly 70μ by 12μ). Cell walls distinct but not as thick as many species of the genus. Conceptacles unknown.

Remarks.—This species is closely related to Ishijima's species *L. australis* and *L. crassa* but has longer cells with thinner cell walls and in being strictly monostromatic.

Age: Recent or Pleistocene(?).
Locality: Eniwetok E-1, depth 260-270 ft (cuttings).
Figured specimen: Holotype, USNM 40822.

Lithoporella antiquitas Johnson, n. sp.

Plate 276, figures 1, 2

Description.—Thallus a single layer of vertically elongated cells 30μ–60μ long and 13μ–22μ (28μ) wide. Conceptacles small, 175μ by 95μ, to 250μ by 115μ. One shows an aperture with a neck about 40μ wide and 260μ long.

Remarks.—Cell size of this species within great size range of *Lithoporella melobesioides*, but below average size. Conceptacles of *L. melobesioides* measure 600μ–$1{,}000\mu$ in diameter, those of *L. antiquitas* smaller. Because type slide of *L. antiquitas* shows aperture clearly, including exit tube, without doubt it cuts conceptacle across center and shows maximum diameter.

Age: Miocene.
Locality: Eniwetok E-1, depth 2,003 and 2,028 ft (cores).
Figured specimen: E-1-1-4(1) large. Holotype USNM 40825.

Lithoporella sp. A

Plate 277, figure 14

Description.—Several fragments of *Lithoporella* in Miocene section showed large cells measuring 83μ–94μ by 43μ–59μ. These cells larger and much wider than most members of genus and probably represent an undescribed species; without knowledge of conceptacles it does not seem wise to name it.

Age: Miocene.
Locality: Eniwetok hole F-1, depth 2,675 ft (core).
Figured specimen: F-1-6-25 (2), USNM 40823.

Lithoporella sp. B

Plate 276, figure 5

Description.—Thallus a single layer of vertically elongated rectangular cells 23μ–46μ high and 16μ–23μ wide. Conceptacles unknown.

Remarks.—Represented by several infertile specimens.

Age: Miocene.
Locality: Eniwetok F-1, depth 1,718-1,740 ft (core).
Figured specimens: F-1-4-10 (2) and F-1-4-20, USNM 40824.

Lithoporella sp. C

Description.—Thallus monostromatic except around conceptacles. Cells elongated, often obliquely. Cells shown an appreciable range in size, as indicated below. Conceptacles unknown.

Slide No.	*Cell dimensions (microns)*	*Conceptacles*	*Age*
661(1)	32-44 by 20-31	Absent	Pliocene-Pleistocene
661(2)	28-34 by 25-28	do	Do.
661(2)	34-48 by 22-24	do	Do.

Remarks.—If the ratio of cell width and length is a basis for species differentiation in this genus, then this material belongs to different species than preceding ones. However it does not seem wise to give it a name without knowledge of conceptacles.

Locality: Kita-Daitō-Jima core, depth 115 m (380 ft).
Age: Pliocene-Pleistocene.
Specimen: Tōhoku University colln., slide 661.

Genus DERMATOLITHON Foslie, 1899

Algae in this genus develop small thin crusts characterized by a hypothallus formed of a single layer of large, obliquely elongated cells that may be contorted. The perithallus is formed of several to many layers of rectangular cells. The conceptacles are hemispherical to conical with a single aperture.

The genus is widely distributed today in tropical and temperate waters. The numerous species are commonly epiphytic but may grow, attached to shells, pebbles, and other objects. They are characteristic of the littoral zone, commonly just below low tide level but reaching to depths of as much as 80 meters.

Dermatolithon marshallensum Johnson, n. sp.

Plate 277, figure 13

Description.—Thallus normally monostromatic, consisting of single hypothallic layer. Cells obliquely elongated, measuring 40μ–63μ high and 18μ–27μ wide. Conceptacle hemispheric, 300μ in diameter and 125μ high.

Remarks.—*D. marshallensum* differs from *D. saipanensum* Johnson from the Miocene of Saipan in having shorter hypothallic cells, smaller conceptacles, and in lacking the well-developed perithallus found in *D. saipanensum*. It differs from the widely distributed Recent species *D. papillosum* (Zanardini) Foslie in having wider hypothallic cells and developing more regular thallus.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,725–1,985 ft (cores).
Figured specimen: F–1–5–18(3). Holotype USNM 40826.

Subfamily CORALLINOIDEAE (articulate corallines)

Fragments of articulate coralline algae were found in considerable numbers in the Eniwetok drill samples but were comparatively rare in the material from Funafuti and Kita-Daitō-Jima. In a few instances 2 or 3 segments were found connected by nodes but the majority of the fossils consist of single segments. The identification of such fragments is difficult, if not impossible, because many living species have been discriminated by using such features as size and shape of the plant or its fronds, character of the branching, or other features that cannot be recognized in fragments. The size, shape, and position of the conceptacles have also been used in separating Recent species. Because conceptacles are normally external and seldom are calcified, they are of little use in identifying fossils.

Attempts have been made to use features that can be determined from segments. These include: (a) The size and shape of the segments, (b) the dimensions of the cells along the axis of the frond, (c) the number of rows of cells in a segment, and (d) the range in size of cells. The first feature-listed above is useful in separating genera but is of questionable value in separating species because in a number of Recent species, the segments from different parts of the plant are known to differ considerably in size and shape and in the number of cell rows that form the segments. Measurements of the length of the cells along the axis also show appreciable variation, but it may be that for a given species the cell dimensions will fall within certain limits and thus be useful in characterizing the species. Such, indeed, is the case among the crustose corallines, but sufficient work has not yet been done with the articulate forms to decide the question. The author has, therefore, been reluctant to attach specific names to fossil articulates except where large numbers of specimens, including those showing joined segments, were available for study.

Representatives of three genera were found in the collections studied. *Corallina* and *Amphiroa* were the most abundant, with a few examples of *Jania*.

Genus JANIA Lamouroux, 1812

The plants consist of masses of slender dichotomously branching fronds arising from an inconspicuous disc. Each frond consists of a series of slender segments formed of tiers of hypothallic cells surrounded by a narrow perithallus, which is characteristically restricted to a single layer of small rectangular cells. The hypothallic cells tend to be wider in proportion to length than in most genera of articulate corallines. In many instances, they appear wedge shaped in section. Conceptacles usually occur singly in swollen terminal segments of branches.

Today this genus is widespread in the tropic and temperate seas where it is represented by many species. At least three species grow on the reefs at Eniwetok. The plants are fairly abundant locally on the undersides of rocks and in shallow pools on the reef flat. Fossil representatives are known from rocks as old as Late Cretaceous.

Jania miocenica Johnson n. sp.

Plate 278, figures 6, 7, 8

Description.—Slender segments with dimensions (in microns) as follows.

Slide	Size segment	Number of cell rows in segment	Number of cells in a row	Cells			
				Medullary, length	Hypothallus, width	Perithallic	
						Length	Width
F-1-4-8(2)	1.0×0.36						
	1.0× .25	20	16–18	38–47	13–15	[1]	[1]
F-1-4-10(2)	1.5× .3	43	18–21	31–47	12–16	[1]	[1]
F-1-5-2(2)		17+	20 22	41–47	12–15	10–13	11–16
F-1-5-18(3)	1.1× .25	24	18–22	32–41	16–19		
F-1-5-10(3)	1.7× .33	31	16+	41–47	17–23		
F-1-5-1(1)	1.3× .3	26+	13	37–46	16–23	19–28	21–28

[1] Absent.

A conceptacle chamber is shown on one specimen; it measures approximately 350μ in length and 100μ in width (pl. 278, fig. 8).

Remarks.—Numerous fragments were observed. Specimen showing conceptacle chamber believed to be first of Miocene age to be found.

Age: Miocene.
Locality: Eniwetok F-1, depth 1,718–1,980 ft (cores).
Figured specimen: F-1-4-8 (2), holotype USNM 40919; F-1-4-10 (2), USNM 40918.

Jania vetus Johnson

Jania vetus Johnson, 1957. U.S. Geol. Survey Prof. Paper 280-E, p. 237, pl. 52, fig. 2.

Remarks.—Several well-preserved segments belonging to this species found in one of Eniwetok cores.

Age: Miocene.
Locality: Eniwetok F-1, depth 1,232–1,248 ft (core).

Jania sp. A

Plate 278, figure 4

Description.—Long regular cylindrical segments about 2.0 by 0.37 mm. Segment contains 28 to 30 tiers of cells, 17 to 21 cells to a row. Hypothallic cells 59μ–73μ long, 16μ–20μ wide. Marginal cells 23μ–28μ long, 14μ–18μ wide.

Remarks.—Several well-preserved segments and pieces of segments found in the Eocene limestones of Eniwetok.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 4,320–4,340 ft (core).
Figured specimen: F-1-12-4(1) bottom, large, USNM 40916.

Genus AMPHIROA Lamouroux, 1812

Plants develop from a small basal disk. They consist of clusters of segmented fronds that branch dichotomously or trichotomously at regular intervals. Fronds formed of calcified segments alternating with uncalcified nodes. Segments cylindrical to flattened, in some cases having a thick midrib and thinner margins. Each segment contains a well-developed medullary hypothallus. In most Recent and Pleistocene species, the hypothallus is built of alternating tiers of long and short cells. Older species may have hypothalli with tiers of cells of equal or nearly equal length. The marginal perithallus is moderately well developed, built of layers of small rectangular cells. Conceptacles are lateral, more or less imbedded in the perithallic tissue, often projecting above the outer surface.

This genus occurs abundantly in the warm seas of today. Fossils are known from rocks as old as Late Cretaceous. A considerable number of fragments were observed in the Eniwetok material.

Amphiroa fortis Johnson, n. sp.

Plate 277, figures 8, 9

Description.—Segments 0.9–4.0 mm long and 0.3–0.75 mm wide. Cell rows of medullary hypothallus regularly arranged with tendency to alternation of length after the formula—3 long, 1 short. Cell lengths 63μ–71μ in the long rows, and 59μ–63μ in the short rows. Cell widths 6μ–11μ. Marginal cells 15μ–21μ long and 7μ–11μ wide. No conceptacles observed.

Remarks.—This species abundantly represented in core F-1-11. Characterized by the regularity of its cell rows and the length of their cells.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 4,197–4,222 ft (core).
Figured specimens: F-1-11-1, holotype USNM 40834; F-1-11-7, paratype USNM 40835.

Amphiroa sp. A

Plate 277, figure 6

Description.—Segments 1.8–2.5 mm long and 0.35–0.39 mm wide. Medullary hypothallus formed of layers of cells 54μ–81μ long and 11μ–18μ wide. Cell layers tend to follow pattern of 2 layers of long cells alternating with 1 of short cells. Cells in long layers 58μ–80μ long, 11μ–16μ wide. Cells in short layers 54μ–65μ long, 11μ–14μ wide. Marginal cells missing. No conceptacles observed.

Remarks.—Represented by about a dozen specimens in slides from F-1-15. This species has unusually long slender segments. Unfortunately, all are badly worn. Without a knowledge of marginal cells and conceptacles it does not seem desirable to give a specific name.

Age: Late Eocene.
Locality: Eniwetok F-1, depth approximately 4,540–4,550 ft (core).
Figured specimen: F-1-15-14, USNM 40945.

Amphiroa sp. B

Plate 277, figure 7

Description.—Segments composed of central hypothallus with layers of cells alternating—1 long and 1 short. Long cells 30μ–48μ long, 8μ–11μ wide; short cells 14μ–18μ long, 8μ–11μ wide. No marginal cells or conceptacles present.

Remarks.—Represented by two small badly worn fragments but of interest because of the pronounced and regular alternation of length of cell layers. This feature, while characteristic of most Recent and Pleistocene members of the genus, appears to be much less well developed in older species and is seldom noticeable in the early Tertiary forms seen by the writer.

Age: Late Eocene.
Locality: Eniwetok F-1, depth 4500–4525 ft (core).
Figured specimen: F-1-14-8(2) large, USNM 40914.

Amphiroa medians Johnson n. sp.

Plate 278, figures 1, 2, 3

Description.—Fronds consist of segments 1.2–1.6 mm long and 0.45–0.66 mm thick. Conceptacles unknown. Dimensional data in microns are given in the following table.

Slide	Size of segment	Number of cell rows in segment	Number of cells in a row	Formula	Medullary hypothallus		Marginal perithallus
					Long cells	Short cells	
F-1-5-1(1L)	1306×608	20	27-31	2-2, 2-1	63-71×13-16	53-63× 9-14	17-26(34)×12-25
F-1-5-1(4L)	1250×450	17+	24-29	1-1, 2-1	66-76×14-16	63-65× 9-14	Worn off.
F-1-5-2(2)	1550×540	31+	37-40	1-1, 2-1	52-62×14-18	47-55×13-17	Worn off.

Remarks.—A number of specimens found in core F-1-5. Cell dimensions and relatively slight difference in length between long and short cells appear to be most distinctive characteristics of this species.

Age: Miocene.

Locality: Eniwetok F-1, depth 1,978-2,000 ft (core).

Figured specimen: F-1-5(1L), holotype USNM 40923; F-1-5(1L), USNM 40809; and F-1-5-1(4L), USNM 40915.

Amphiroa sp. C

Plate 278, figure 5

Description.—Segments about five times as long as wide. Cell layers of central hypothallus of nearly equal length but show tendency for slightly longer cells to alternate with shorter cells. Detailed dimensions in microns are given in the following table.

Slide	Size of segment	Number of cell rows in segment	Number of cells in a row	Formula	Medullary hypothallus		Marginal perithallus
					Long cells	Short cells	
F-1-5-1(2)	----	34	16-22	1-1	48-60×14-18	45-56×11-17	Absent
F-1-5-3(1)	5.6×1.2	36	18-20	1-1	48-58×10-16	40-55×10-15	14-22×14-18

Age: Miocene.

Locality: Eniwetok F-1, depth 1,797-2,003 ft (core).

Figured specimen: F-1-5-3(1) small, USNM 40917.

Genus CORALLINA Linnaeus, 1758

The plants have a calcified crustose base from which arise numerous erect fronds that generally branch in a plane. The branching is commonly pinnate. The calcified segments are cylindrical or flattened, consisting of a medullary hypothallus surrounded by a thin cortical layer (perithallus). The medullary hypothallus consists of long narrow cells in layers of equal length. Nodes between the segments are normally not calcified. They are formed of a single layer of very long cells. Conceptacles are ovoid, terminal on short branches.

Corallina segments occur in considerable quantities at a number of levels in the Eniwetok drill holes. They represent a number of different species, several of which are described. Much of the material is too worn and frayed to permit specific identification.

Segments of articulate corallines attributed to this genus were observed in the loose and poorly consolidated material in the upper 70 feet of the main boring at Funafuti and in the upper 40 feet of the second boring. The material was not identified specifically.

Corallina prisca Johnson

Corallina prisca Johnson, 1957, U.S. Geol. Survey Prof. Paper 280-E, p. 239-240, pl. 37, fig. 4, pl. 40, fig. 10, pl. 44, figs. 1, 2, 7-11.

Description.—Segments flattened to nearly cylindrical. Cells of medullary hypothallus in center of tiers 68μ–104μ long, 7μ–10μ wide. Perithallic cells 16μ–21μ long, 9μ–11μ wide. No conceptacles observed.

Remarks.—A number of fragments were observed in slides of the Eniwetok cores which in appearance and dimensions correspond to this species described from the Eocene of Saipan.

Age: Late Eocene.

Locality: Eniwetok F-1, depth 4,500-4,550 ft (core).

Corallina eniwetokensis Johnson n. sp.

Plate 277, figures 10, 11, 12

Description.—Fronds composed of short slender segments, 0.5-0.8 mm long and 0.17-0.29 mm wide with rather small nodes. Cells of medullary hypothallus 62μ–120μ long and 8μ–12μ wide. Marginal cells 20μ–39μ by 13μ–24μ. Conceptacles unknown. Detailed dimensions (in microns) are given in the following table.

Slide	Size of segment		Size of node		Node cells		Hypothallic cells		Perithallic cells		Number of cells in row	Number of cell rows in segment
	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width		
F-1-3-10(4L)	640	290	175	187	24	10-13	70-110	8-10	31	13-19	18-20	6
	596	252	103	179	39	10-11	62-120	8-10	20-27	13-20	18	6
F-1-3-10(3L)	695	319	116	146	?	9-11	90-113	8-10	27	13	14-15	8
	654	194	----	----	----	----	97-110?	9-12	25-39	14-24	14-16	7
F-1-3-10(3L)	701	220	102	147	?	8-10	82-110	9-11	28-30	12-18	13-14	7
	687	173	----	----	----	----	87-112	9-11	24-27	13-18	13	6
F-1-3-10(4L)	680	267	101	217	?	?	98-123	10-12	----	----	20-22	5
	598	246	----	----	----	----	90-120	9-12	----	----	19-21	5
	536	352	100	210	----	----	90-108	----	15-21	10-15	18-21	5

Remarks.—In general appearance this suggests *Corallina neuschelorum* Johnson but differs in having more slender fronds and larger cells.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,230–1,248 ft (core).
Figured specimens: F–1–3–10(4) large, holotype, USNM 40828; F–1–3–10(3) large, paratype, USNM 40827.

Corallina neuschelorum Johnson

Corallina neuschelorum Johnson, 1957, U.S. Geol. Survey Prof. Paper 280–E, p. 239, pl. 37, fig. 3, pl. 50, figs. 1–4.

Description.—Small delicate species; fronds formed of many short segments. Hypothallic cells 65μ–105μ long, 7μ–10μ wide. Marginal cells 10μ–15μ by 9μ–11μ. Numerous measurements and illustrations given in original description.

Remarks.—Eniwetok specimens appear to be identical with species as described from the Miocene of Saipan. They occur abundantly in the F–1–5 core.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core).

Corallina marshallensis Johnson, n. sp.

Plate 277, figures 2, 3

Description.—Segments 0.8–1.2 mm long and 0.259–0.351 mm wide with 6 to 14 layers of cells. Top of layers flat or slightly depressed. Cells 99μ–140μ long and 9μ–12μ wide. Marginal cells 15μ–27μ wide and 9μ–13μ high. Node 200μ–250μ long. Conceptacles unknown.

Remarks.—This species has longer than average medullary cells and unusually wide marginal cells. Combination of cell dimensions differs considerably from that of any previously described Miocene species.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,978–2,003 ft (core).
Figured specimens: F–1–5–33(2), holotype USNM 40829; USNM 40830.

Corallina sp. A

Plate 277, figure 5

Description.—Segments about 0.75 mm long and 0.25 mm wide. Nodes 0.08–0.09 mm long and 0.25 mm wide. Medullary hypothallic cells attain lengths of 115μ–126μ and widths of 9μ–14μ. Marginal cells 20μ–21μ by 13μ–16μ. No conceptacles observed.

Remarks.—Represented by a number of worn pieces. Species is close to *C. otsukiensis* Ishijima in cell dimensions.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,232–1,240 ft (core).
Figured specimen: F–1–3–3(2), USNM 40831.

Corallina sp. B

Plate 277, figure 1

Description.—Frond consists of number of segments containing 8 to 10 layers of cells. Segments 750μ–1,000μ long; cells 42μ–64μ long, 8μ–11μ wide; nodes 110μ–140μ long. Conceptacles unknown.

Age: Miocene.
Locality: Eniwetok F–1, depth 1,718–1,740 ft (core).
Figured specimen: H–6, USNM 40832.

Corallina sp. C

Plate 277, figure 4

Description.—Segments cylindrical, 1.5–2.0 mm long and 0.3–0.4 mm in diameter with 16 to 18 gently arched layers of cells. Cells 63μ–81μ long, 11μ–13μ wide. Marginal cells 14μ–16μ long, 8μ–10μ wide. Nodes and conceptacles unknown.

Remarks.—In shape of segments and general appearance this species suggests *Corallina elliptica* Ishijima but has considerably shorter and wider cells. Represented by a number of fragments near base of F–1–5 core.

Age: Miocene.
Locality: Eniwetok F–1, depth 2,001–2,003 ft (core).
Figured specimen: F–1–5–40(5), USNM 40833.

CHLOROPHYTA (green algae)
Family DASYCLADACEAE
Genus DACTYLOPORA Lamarck, 1816

Dactylopora? sp.

Plate 278, figures 9–12; plate 279, figures 3, 4, 5

Description.—Horizontal segments 0.8–2.2 mm in diameter. Central stem 0.275–0.350 mm thick. Primary branches 26 to 28 in a whorl, with diameters of 40μ–50μ. No sporangia observed.

Remarks.—Represented by worn and poorly preserved horizontal segments that belong in or close to *Dactylopora* Lamarck.

Age: Late Eocene.
Locality: Eniwetok E–1, depth 2,802–2,808 ft (core).
Figured specimens: E–1–2–9 (2) large, USNM 40920; E–1–2–9 (3) large, USNM 40921; F–1, depth 2,805 ft, USNM 40942.

Genus ACICULARIA d'Archiac, 1943

Acicularia sp.

Plate 279, figures 6, 7

Numerous fragments of perforated calcareous plates appear to represent a member of this genus. They are too fragmentary to permit specific identification but are of interest as the first fossil representatives of this genus from the Pacific area.

Age: Late Eocene.
Locality: Eniwetok E-1, depth 2,802–2,808 ft (core).
Figured specimen: E-1-2-9, USNM 40944.

Dasycladaceae occurrences in cuttings from E-1, Eniwetok

Numerous specimens of Dasycladaceae were obtained from washed samples of well cuttings from Eniwetok hole E-1 in the interval between 2,780 and 3,100 feet. A superficial examination of the specimens yielded the following data:

Depth (feet)	*Specimen*
2780–2790	Dasycladaceae, probably *Cymopolia*? sp.
2830–2840	Dasycladaceae, probably *Cymopolia*? sp.
2850–2860	Dasycladaceae, genus uncertain without sectioning.
2890–2900	Dasycladaceae, *Larvaria*? sp.
2890–2900	Dasycladaceae, *Cymopolia*? sp.
2900–2910	Dasycladaceae, undet.
2910–2920	Dasycladaceae, *Cymopolia*? sp.
2930–2940	Dasycladaceae, uncertain, possibly *Larvaria*.
2950–2960	Dasycladaceae, several genera including *Cymopolia*, sp.
2960–2970	Dasycladaceae, *Cymopolia*? and another genus.
2970–2980	Dasycladaceae, undet.
2980–2990	Dasycladaceae, undet.
2990–3000	Dasycladaceae, undet.
3000–3010	Dasycladaceae, undet.
3030–3040	Dasycladaceae, undet.
3050–3060	Dasycladaceae, undet.
3060–3070	Dasycladaceae, undet.
3090–3100	Dasycladaceae, undet.

Family CODIACEAE

Genus HALIMEDA Lamouroux, 1812

Plate 279, figures 1, 2; plate 280, figures 1–4

These plants are bushy tufts of segmented branching stems or fronds. The segments may be subcylindrical, flattened, conical, or broad and leaflike. The young growing segments are bright green and uncalcified. Calcification occurs with age. It begins at the outer surface and is extended inward; the entire segment may eventually be calcified but commonly the process is incomplete.

Recent species of *Halimeda* are separated largely on the basis of the growth habit of the plant, structure of the nodes, and size and shape of the segments (Barton, 1901, p. 1–4). Because the fossils consist of loose segments it is seldom possible to assign them to species although the generic features are easily recognized.

Halimeda segments were numerous in all the Funafuti drill samples and were an important constituent in the lagoon drill holes (Halligan, 1904). A few were recognized in the Kita-Daitō-Jima hole from sediments thought to be of Pleistocene age. In the Eniwetok drill holes, they were particularly abundant in the younger beds but segments were recovered from a core in hole F-1 at a depth of 3,655–3,665 feet. *Halimeda* segments are so light and porous that they can travel almost indefinitely in heavy drilling mud. Some of the lowest occurrences from E-1 listed below may have been derived from younger horizons.

Figured specimens: From Eniwetok, USNM 40941; Kita Daitō Jima; Funafuti core.

Occurrences of HALIMEDA in cuttings from E-1, Eniwetok

Depth (feet)	*Species*	*Comments*
10–20	*Halimeda opuntia* (Linnaeus) Lamouroux	Abundant.
30–35	do	Do.
30–35	*Halimeda opuntia* f. *triloba* Barton	Do.
30–40	do	Do.
30–40	*Halimeda gracilis* Harvey	Do.
50–60	*Halimeda opuntia* f. *triloba* Barton	Do.
60–70	do	Do.
60–70	*Halimeda opuntia* (Linnaeus) Lamouroux	Do.
70–80	*Halimeda opuntia* f. *triloba* Barton	Do.
80–90	do	Do.
90–100	do	Do.
100–110	do	A few.
110–120	do	Do.
120–130	*Halimeda* sp	Do.
130–140	*Halimeda* cf. *opuntia* (Linnaeus) Lamouroux.	Do.
200–210	do	Do.
290–300	*Halimeda* sp	A few worn and broken pieces.
340–350	do	A few worn fragments.
380–390	do	A few segments.
400–410	do	A few shreds.
450–460	do	A few small segments.
460–470	do	Do.
480–490	do	A few fragments.
520–530	do	A few small segments.
530–540	do	Do.
950–960	do	Do.
970–980	do	Do.
990–1,000	do	A few broken segments.
1,100–1,110	do	A few small segments.
1,160–1,170	do	Do.
1,170–1,190	do	Do.

Genus MICROCODIUM Glück, 1912

Microcodium sp.

Description.—Thallus spherical, globular, or forming an irregular crust. In section usually elliptical, circular, or fan shaped. Consists of a circular or elongated central part or nucleus surrounded by large elongated petallike growths of "palisade cells." These fan out from the central portion of the circular or oval masses. The encrusting forms have a greatly elongated nucleus, from the sides of which the palisade cells grow out roughly parallel to one another.

The structure of the central part or nucleus is not preserved. The palisade cells appear as blades of clear or nearly clear crystalline calcite.

Some typical dimensions (in microns) are tabulated as follows.

Slide	Entire plant			Nucleus		Palisade cells	
	Shape	Length	Width	Length	Width	Length	Width
661	Rounded	500	400	142	135	110–180	35–65
	do	485	410	205	112	115–185	48–60
	Elongated	1160	600	330	122	98–182	35–62

Remarks.—Kita-Daitō-Jima material agrees with Glück's (1912) original description from Miocene of

Germany. It is identical with specimens found in Miocene of Saipan. Similar material was also observed in upper Miocene of Eniwetok. A discussion of this problematical organism has been published by Johnson (1953, p. 84–86).

Age: Miocene.
Locality: Kita-Daitō-Jima cores, depth 380 ft (115–118 m) and 630 ft (189 m). Eniwetok F–1, depth 1,232–1,248 ft (core).
Specimens: Tōhoku University colln., slides 661 and 821; Eniwetok F–1–3–3 and F–1–3–4.

GEOGRAPHIC DISTRIBUTION AND STRATIGRAPHIC OCCURRENCES OF ALGAE

The known geographical distribution and stratigraphic occurrences of species of algae described in the present report is given in the following tables.

Known geographical distribution of the species of coralline algae described in this report	Eniwetok	Bikini	Funafuti	Kita-Daitō-Jima	Saipan	Lau Fiji	Dutch East Indies	Japan	Tropical Pacific	Indian Ocean	Somaliland	Algeria	Spain	France	Italy	Yugoslavia
Recent and Pleistocene species																
Archaeolithothamnium erythraeum (Roth.) Foslie	--	--	X	--	--	X	X	--	X	X	--	--	--	--	--	--
schmidti Foslie	--	--	X	--	--	--	X	--	--	X	--	--	--	--	--	--
puntiense Airoldi	X	--	--	--	X	--	--	--	--	--	X	--	--	--	--	--
Goniolithon fosliei (Heydr.) Foslie	--	--	X	--	--	--	X	--	X	X	--	--	--	--	--	--
frutescens Foslie	X	X	X	--	X	X	X	--	X	X	--	--	--	--	--	--
myriocarpon Foslie	X	--	--	--	--	--	X	--	X	--	--	--	--	--	--	--
Lithophyllum acanthinum Foslie	--	--	--	X	--	--	--	X	--	--	--	--	--	--	--	--
hanzawae Johnson	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
kotschyanum Unger	--	--	--	X	X	--	X	--	X	--	--	--	--	--	--	--
megacrustum Johnson and Ferris	X	--	X	X	X	X	--	--	--	--	--	--	--	--	--	--
okamurae Foslie	--	--	--	X	--	--	X	X	--	--	--	--	--	--	--	--
quadratum Ishijima	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
samoense Foslie	--	--	--	X	--	--	--	--	X	--	--	--	--	--	--	--
stefaninii Airoldi	--	--	--	X	X	--	--	--	--	--	X	--	--	--	--	--
Lithoporella cf. *L. crassa* Ishijima	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
longicella Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
melobesioides (Foslie) Foslie	X	X	X	X	X	X	X	--	X	X	--	X	--	--	--	--
Lithothamnium aff. *L. aucklandicum* Foslie	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
cf. *L. nitidum* Foslie	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--
funafutiense Foslie	--	--	X	--	--	--	--	--	--	--	--	--	--	--	--	--

Known geographical distribution of the species of coralline algae described in this report—Continued	Eniwetok	Bikini	Funafuti	Kita-Daitō-Jima	Saipan	Lau Fiji	Dutch East Indies	Japan	Tropical Pacific	Indian Ocean	Somaliland	Algeria	Spain	France	Italy	Yugoslavia
Recent and Pleistocene species—Cont.																
Mesophyllum erubescens (Foslie)	--	--	X	--	--	--	--	--	X	X	--	--	--	--	--	--
pulchrum (Foslie)	--	--	X	--	--	--	X	--	X	--	--	--	--	--	--	--
Porolithon aequinoctiale (Foslie)	X	X	--	--	--	--	X	--	X	--	--	--	--	--	--	--
craspedium (Foslie) Foslie	X	X	X	--	X	X	X	--	X	X	--	--	--	--	--	--
gardineri (Foslie) Foslie	X	X	X	--	--	--	X	--	X	X	--	--	--	--	--	--
marshallense Taylor	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
onkodes (Heydr.) Foslie	X	X	X	--	X	X	X	--	X	X	--	--	--	--	--	--
Miocene species																
Archaeiolithothamnium aff. A. *affine* Howe	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
crustatum Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
eniwetokensis Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
aff. A. *erythraeum* (Roth.) Foslie	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
lauense Johnson & Ferris	X	--	--	--	X	X	--	X	--	--	--	--	--	--	--	--
marshallensum Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
cf. *A. taiwanensis* Ishijima	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Lithophyllum johnsoni Ishijima	X	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
kladosum Johnson	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
cf. *L. prelichenoides* Lemoine	X	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--
profundum Johnson	X	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--
thikombian Johnson & Ferris	--	--	--	X	--	X	--	--	--	--	--	--	--	--	--	--
Lithoporella antiquitas Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lithothamnium leptum Johnson & Ferris	X	--	--	--	--	X	--	--	--	--	--	--	--	--	--	--
cf. *L. mirabile* Conti	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Mesophyllum cf. *M. arakuaensis* Ishijima	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
eniwetokensum Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
japonicum Ishijima	X	--	--	--	--	--	--	X	--	--	--	--	--	--	--	--
cf. *M. savornini* Lemoine	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Paraporolithon saipanense Johnson	--	--	--	X	X	--	--	--	--	--	--	--	--	--	--	--
Amphiroa medians Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corallina eniwetokensis Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
marshallensis Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
neuschelorum Johnson	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Jania miocenica Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
vetus Johnson	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Eocene species																
Archaeolithothamnium dalloni Lemoine	X	--	--	--	--	--	--	--	--	--	--	X	--	--	--	--
cf. A. *hemchandri* Rao	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
nummuliticum (Gümbel) Rothpletz	X	--	--	--	--	--	--	--	--	--	X	X	--	--	X	X
oulianovi Pfender	X	--	--	--	X	--	--	--	--	--	--	X	X	--	--	--
aff. A. *saipanense* Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
cf. A. *sociabile* Lemoine	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lithophyllum cf. *lingusticum* Airoldi	X	--	--	--	--	--	--	--	--	--	X	--	--	--	--	--
Lithothamnium cf. L. *abrardi* Lemoine	X	--	--	--	X	--	--	--	--	--	--	X	--	--	--	X
crispithallus Johnson	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
cymbicrusta Johnson	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--
Mesophyllum robustum Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphiroa fortis Johnson	X	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corallina prisca Johnson	X	--	--	--	X	--	--	--	--	--	--	--	--	--	--	--

Occurrences of algae in drill holes F–1 and E–1

Depth (feet)	*Drill hole F–1*
0–45	*Porolithon* sp. and *Halimeda opuntia* (Linnaeus) Lamouroux.
45–110	*Porolithon*? sp., *Halimeda*? sp.
110–190	*Halimeda*? sp., *Lithothamnium*? sp.
190–280	*Halimeda* sp.
280–330	No determinable algae.
330–625	*Halimeda* sp.
625–975	No algae recognized except fragments of *Halimeda* sp.
975–1, 045	No samples.

Depth (feet)	*Drill hole E–1*
0–30	*Porolithon onkodes* (Heydrich) Foslie (10–30), *Porolithon marshallensie* Taylor (10), *Halimeda opuntia* (Linnaeus) Lamouroux.
30–90	*Porolithon marshallense* Taylor, *Porolithon aequinoctiale* (Foslie) Foslie (50–60), *Halimeda opuntia* (Linnaeus) Lamouroux, *Halimeda gracilis* Harvey.
90–145	*Halimeda opuntia* (Linnaeus) Lamouroux, *Halimeda*? sp.
145–300	*Lithoporella longicella* Johnson, n. sp. (260–270), *Halimeda* cf. *H. opuntia* (Linnaeus) Lamouroux.
300–530	*Halimeda* sp.
530–840	*Halimeda* sp.
840–1, 190	Occasional segments of *Halimeda* sp.

Depth (feet)	*Drill hole F-1*
1, 045–1, 060	No algae recognized.
1, 060–1, 080	No samples.
1, 080–1, 232	No algae recognized.
1, 232–1, 248	*Jania vetus* Johnson, *Corallina eniwetokensis* Johnson, *Corallina* sp., A, *Microcodium* sp., *Halimeda?* sp.
1, 248–1, 718	No samples.
1, 718–1, 740	*Archaeolithothamnium marshallensum* Johnson, n. sp., *Archaeolithothamnium* cf. *A. taiwanensis* Ishijima, *Lithothamnium leptum* Johnson and Ferris, *Lithothamnium* sp. C, *Mesophyllum* spp. A and B, *Lithophyllum kladosum* Johnson, *Lithoporella* sp. B, *Jania miocenica* Johnson, n. sp., *Corallina* sp. B.
1, 740–1, 975	No samples.
1, 975–1, 978	*Lithophyllum johnsoni* Ishijima, *Lithophyllum kladosum* Johnson.
1, 978–2, 003	*Archaeolithothamnium crustatum* Johnson, n. sp., *Archaeolithothamnium marshallensum* Johnson, n. sp., *Archaeolithothamnium eniwetokensis* Johnson, n. sp., *Lithothamnium* cf. *L. mirabile* Conti, *Lithothamnium* sp. A, *Mesophyllum* cf. *M. arakuraensis* Ishijima, *Mesophyllum eniwetokensum* Johnson, n. sp., *Mesophyllum japonicum* Ishijima, *Mesophyllum* sp. A, *Lithophyllum johnsoni* Ishijima, *Lithophyllum* cf. *L. prelichenoides* Lemoine, *Lithophyllum kladosum* Johnson, *Lithophyllum profundum* Johnson, *Lithoporella melobesioides* (Foslie) Foslie, *Jania mioceneium* Johnson, n. sp., *Amphiroa medians* Johnson, n. sp., *Amphiroa* sp. C, *Corallina neuschelorum* Johnson, *Corallina marshallensis* Johnson, n. sp., *Corallina* sp. C.
2, 003–2, 130	No algae recognized.
2, 130–2, 662	No samples.
2, 662–2, 687	*Archaeolithothamnium crustatum* Johnson, n. sp., *Archaeolithothamnium lauense* Johnson and Ferris, *Lithothamnium leptum* Johnson and Ferris, *Lithothamnium* sp. B, *Lithothamnium* sp. C, *Mesophyllum* cf. *M. arakuraenis* Ishijima, *Mesophyllum* cf. *M. savornini* Lemoine. *Lithoporella* sp. A, *Lithoporella melobesioides* (Foslie) Foslie.
2, 687–3, 052	No samples.
3, 052–3, 055	*Mesophyllum robustum* Johnson.
3, 055–3, 350	No samples.
3, 350–3, 353	*Lithophyllum? sp.*
3, 353–3, 655	No samples.
3, 655–3, 665	*Archaeolithothamnium oulianovi* Pfender, *Archaeolithothamnium nummuliticum* (Gümbel) Rothpletz, *Archaeolithothamnium* cf. *A. hemchandri* Rao, *Lithophyllum* cf. *L. lingusticum* Airoldi, *Lithoporella melobesioides* (Foslie) Foslie, *Halimeda* sp. (molds).

Depth (feet)	*Drill hole E-1*
1, 190–1, 230	No algae recognized.
1, 230–1, 715	No algae observed.
1, 715–1, 835	*Archaeolithothamnium crustatum* Johnson, n. sp. (1,718–1,740), *Lithophyllum kladosum* Johnson, *Lithophyllum?* sp., *Lithoporella melobesioides* (Foslie) Foslie.
1, 835–1, 993	*Lithophyllum? sp.*, *Lithoporella melobesioides* (Foslie) Foslie.
1, 993–2, 003	*Lithophyllum kladosum* Johnson.
2, 003–2, 028	*Lithopyhllum kladosum* Johnson, *Lithothamnium* sp. D, *Lithoporella antiquitas* Johnson, n. sp.
2, 028–2, 349	No algae observed.
2, 350–2, 355	*Archaeolithothamnium* aff. *A. erythraeum* (Rothpletz) Foslie, *Archaeolithothamnium* aff. *A. affine* Howe.
2, 355–2, 440	*Lithophyllum kladosum* Johnson, as rodlike branches.
2, 440–2, 600	*Lithophyllum kladosum* Johnson.
2, 600–2, 802	*Lithophyllum* sp. A (2,655), *Lithophyllum kladosum* Johnson (2,680), *Lithophyllum profundum* Johnson (2,690–2,700), *Archaeolithothamnium* sp. B (2,730–2,740), *Lithoporella melobesioides* (Foslie) Foslie.
2, 802–2, 808	*Archaeolithothamnium nummuliticum* (Gümbel) Rothpletz, *Archaeolithothamnium dallonii* Lemoine, *Lithoporella antiquitas* Johnson, n. sp., *Dactylopora?* sp., *Acicularia* sp.
2, 808–3, 127	No algae observed.
3, 127–4, 078	No samples.

Depth (feet)	*Drill hole F-1*	*Depth (feet)*	*Drill hole E-1*
3, 665–3, 963	No samples.		
3, 963–3, 988	*Lithophyllum*? sp., *Archaeolithothamnium eniwetokensis* Johnson, n. sp.		
3, 988–4, 197	No samples----------------------------------	4, 078–4, 100	Algal debris, but too recrystallized to identify.
		4, 100–4, 170	No samples.
		4, 170–4, 190	Probably all basalt.
		4, 190–4, 208	No samples.
4, 197–4, 222	*Lithophyllum*? sp., *Archaeolithothamnium nummuliticum* (Gümbel) Rothpletz, *Amphiroa fortis* Johnson, n. sp.	4, 208–4, 222	Olivene basalt.
		4, 222	Total depth.
4, 222–4, 316	No samples.		
4, 316–4, 341	*Lithophyllum*? sp., *Archaeolithothamnium*? *sp.*, *Jania* sp. A.		
4, 341–4, 406	No samples.		
4, 406–4, 431	*Lithothamnium*? sp., *Lithophyllum* sp.?		
4, 431–4, 500	No samples.		
4, 500–4, 525	*Lithothamnium crispithallus* Johnson, *Amphiroa* sp. B, *Corallina prisca* Johnson.		
4, 525–4, 528	No samples.		
4, 528–4, 553	*Archaeolithothamnium* cf. *A. sociabile* Lemoine, *Archaeolithothamnium* sp. A, *Archaeolithothamnium* aff. *A. saipanense* Johnson, *Lithothamnium* cf. *L. abrardi* Lemoine, *Lithothamnium crispithallus* Johnson, *Lithothamnium cymbicrusta* Johnson, *Amphiroa* sp. A, *Corallina prisca* Johnson.		
4, 553–4, 610	No samples; probably limestone.		
4, 610–4, 630	Probably basalt.		
4, 630	Total depth.		

DISTRIBUTION OF ALGAE IN BORING K–1, ENGEBI

Halimeda segments were observed at intervals throughout K–1 (total depth 433 ft, 6 in). Remains of coralline algae were found at irregular intervals but were only abundant at two zones. The first, from the surface to a depth of 33 feet, contained much algal debris, mainly belonging to *Porolithon onkodes* (Heydrich) Foslie, *Porolithon craspedium* (Foslie) Foslie, *Goniolithon frutescens* Foslie, *Goniolithon reinboldi* Foslie, *Goniolithon myriocarpon* Foslie. The second zone, from 396–422 feet, contained an abundance of *Lithoporella melobesioides* (Foslie) Foslie, and a few pieces of *Lithoporella crassa* Ishijima, *Lithophyllum megacrustum* Johnson and Ferris, and *Amphiroa?* sp.

DISTRIBUTION OF ALGAE IN FUNAFUTI BORING

Algae were found throughout the length of the main boring on Funafuti, but their distribution was not uniform. The distribution of the forms that were identified in the present study is given on page 946. Some zones were composed mostly of algae, but other zones contained only scattered fragments. At some levels the algae coated corals and other objects and appeared to be in position of growth. Elsewhere, they were represented by worn fragments which obviously had been transported some distance.

The abundance of algal remains in the Funafuti specimens seems to have been a surprise to those who made the original study, and their comments on the subject have been quoted many times in later works.

The slides originally prepared for the Funafuti study are excellent for Foraminifera and most other organisms, but are too thick to permit accurate cell measurements of the contained algae; consequently, much of the algal material present cannot be specifically determined. Also recrystallization occurred and this becomes pronounced in specimens from lower levels. In most specimens the presence of algae can be recognized and in many cases the genus to which they belong can be surmised, but recrystallization has so disturbed and destroyed the cellular structure that it is impossible to make specific determinations.

Remains of *Halimeda* were found throughout the drill holes. They were surprisingly abundant in the upper parts and in lagoonal deposits. Finckh, in discussing the biology of the atoll, said of *Halimeda:*

> This calcareous algae is abundant to an extraordinarily large extent in the lagoon and on the ocean slopes. In order to determine its bathymetrical distribution, systematic dredgings were carried on off the islets of Funamanu and Falefatu, with the result that it was invariably found to be present alive down to the 45-fathom limit. Beyond that depth it was never met with alive, except in the case of a specimen brought up in the tangles on one occasion off Tutanga islet from 80 fathoms. (Finckh, 1904, p. 135)

J. W. Judd, in discussing the materials from the lagoon of Funafuti, stated:

The dredgings in the lagoon showed that except where bosses of coral rock rise and form shoals, often with only a few feet of water upon them at high tide, the whole of the bottom of of the Funafuti lagoon is covered with a dense growth of the green calcareous algae *Halimeda opuntia* Lam., a well-known member of the order Siphoneae, group Chlorophyceae. This growth of *Halimeda* appears to be most vigorous in the shallower parts of the lagoon, but everywhere it forms a green living carpet down to depths of 120 feet, and is occasionally found alive at greater depths. The *Halimeda* fronds are often more or less covered with attached organisms, such as the Foraminifera *Sagenina, Polytrema*, etc., with *Spirorbis, Serpulae*, Polyzoa, etc., and other organisms. Intermingled with the living *Halimeda* and its broken tunicate spicules, as well as remains of Pteropoda, Gastropoda, Pelecypoda, Crustaceae and other forms of animal life, were several forms of *Lithothamnium.* In the central and deeper parts the number of Foraminifera is comparatively small, seldom exceeding 10 percent of the whole mass, and consisting only of species adherent to the fronds of *Halimeda*, with the free forms *Amphistegina* and *Heterostegina*. (Judd, 1904, p. 176–177)

Professor Hinde, reporting on the material from the borings, stated regarding the genus *Halimeda:*

Detached joints of this genus are present in all the borings; in some portions, as for example in the Lagoon Boring, for 60 feet below the lagoon floor, they form the greater part of the rock, and between 652–660 feet in the Main Boring they are the main constituents of the cores. As a rule their structure is well-preserved, so that they are readily recognized in microscopic sections. (Hinde, 1904, p. 331–332)

OCCURRENCES OF ALGAE IN FUNAFUTI BORING

Recent Reef and Lagoon	*Porolithon onkodes* (Heydrich) Foslie, *Porolithon craspedium* Foslie, *Porolithon gardineri* Foslie, *Goniolithon frutescens* Foslie, *Lithothamnium philippii* Foslie, *Lithophyllum subtilis* Foslie, *Halimeda opuntia* Lamarck, *Halimeda cunesta* Kutzling, *Halimeda tuna* Lamarck, *Halimeda gracilis* Harvey.
Depth (feet)	
0–10	*Halimeda*? sp.
10–20	*Porolithon gardineri* Foslie, *Porolithon onkodes* (Heydrich) Foslie, *Lithoporella melobesioides* (Foslie) Foslie, *Halimeda*? sp.
20–30	*Mesophyllum erubescens* (Foslie), *Porolithon gardineri* Foslie, *Mesophyllum* (*Lithophyllum*) *australe* Foslie, *Halimeda* sp.
60–70	*Lithoporella melobesioides* (Foslie) Foslie, *Corallina* sp., *Halimeda* sp.
80–90	*Halimeda*? sp.
110–120	*Lithothamnium*? sp., *Lithophyllum*? sp., *Halimeda*? sp.
210–220	*Lithophyllum* sp., *Lithoporella melobesioides* (Foslie) Foslie.
420–433	*Lithophyllum* sp?, *Halimeda*? sp.
452	*Lithothamnium funafutiense* Foslie, *Lithoporella melobesioides* (Foslie) Foslie.
500	*Goniolithon frutescens* Foslie.
526	*Goniolithon fosliei* (Heydrich) Foslie, *Goniolithon frutescens* Foslie, *Lithoporella melobesioides* (Foslie) Foslie, *Lithophyllum* sp., *Halimeda* sp.
547–555	*Porolithon gardineri* Foslie, *Lithophyllum* sp.
Depth (feet)	
643–652	*Lithophyllum*? sp., *Lithoporella*? sp., *Halimeda* sp.
691–698	*Archaeolithothamnium schmidti*, Foslie, *Lithophyllum* sp., *Halimeda* sp.
736–748	*Archaeolithothamnium erythraeum* (Rothpletz), *Mesophyllum pulchrum* (Foslie), *Goniolithon frutescens* Foslie, *Halimeda* sp.
764	*Archaeolithothamnium erythraeum* (Rothpletz) Foslie, *Lithothamnium* sp., *Halimeda* sp.
791–798	*Porolithon* cf. *P. onkodes* (Heydrich) Foslie, *Lithothamnium funafutiense* Foslie.
867–874	*Archaeolithothamnium erythraeum* (Rothpletz) Foslie, *Lithophyllum* sp., *Halimeda* sp.
880	*Lithothamnium funafutiense*? Foslie.
891–899	*Archaeolithothamnium erythraeum* (Rothpletz) Foslie, *Lithophyllum megacrustum* Johnson and Ferris, *Lithoporella melobesioides* (Foslie) Foslie.
950–957	*Goniolithon frutescens* Foslie, *Mesophyllum* cf. *M. australe* Foslie.
973	*Lithoporella melobesioides* (Foslie) Foslie.
1,006–1,015	*Lithothamnium* sp., *Lithophyllum* sp., *Halimeda* sp.
1,087–1,100	*Lithophyllum* sp., *Lithothamnium* sp., *Halimeda*? sp.
1,100–1,114	*Lithophyllum* sp., *Lithothamnium* sp.

OCCURRENCES OF ALGAE IN KITA-DAITŌ-JIMA BORING

Surface	*Jania* sp., *Corallina* sp., *Lithoporella melobesioides* (Foslie) Foslie, *Lithophyllum megacrustum* Johnson and Ferris, *Lithophyllum okamurae* Foslie.
17	*Archaeolithothamnium puntiense* Airoldi, *Lithothamnium* cf. *L. nitidum* Foslie.
23	*Lithophyllum* cf. *L. stefaninii* Airoldi, *Lithophyllum acanthinum* Foslie.
25	*Lithophyllum acanthinum* Foslie.
29–30	*Lithophyllum quadratum* Ishijima, *Lithophyllum samoense* Foslie, *Lithophyllum yessoense* Foslie.
37	*Lithophyllum* cf. *L. kotschyanum* Unger, *Lithoporella melobesioides* (Foslie) Foslie.
51	*Archaeolithothamnium puntiense* Airoldi, *Lithothamnium* aff. *L. aucklandicum* Foslie, *Lithophyllum hanzawae* Johnson n. sp.
60–78	*Lithophyllum megacrustum* Johnson and Ferris, *Lithophyllum okamurae* Foslie, *Halimeda* sp.
87	*Halimeda* sp.
115	*Lithoporella*?, sp. *Halimeda* sp.
130–135	*Halimeda*? sp.
160–165	*Lithophyllum megacrustum* Johnson and Ferris, *Halimeda* sp., *Archaeolithothamnium puntiense* Airoldi.
173	*Lithothamnium* aff. *L. aucklandicum* Foslie, *Halimeda* sp.
200	*Lithophyllum megacrustum* Johnson and Ferris, *Halimeda*? sp.
227–230	*Halimeda*? sp.
243	*Halimeda*? sp.
273	*Halimeda* sp.
283	*Halimeda*? sp.
333	*Lithoporella melobesioides* (Foslie) Foslie.
350	*Lithophyllum* cf. *L. kotschyanum* Unger.
367	*Lithoporella* sp. C, *Lithophyllum acanthinum* Foslie, *Lithophyllum stefaninii* Airoldi, *Lithophyllum thikombian* Johnson and Ferris.
380	*Lithophyllum acanthinum* Foslie, *Microcodium* sp.

393	*Lithophyllum thikombian* Johnson and Ferris, *Lithoporella melobesioides* (Foslie) Foslie, *Microcodium* sp.
500	*Lithophyllum* sp. B.
513	*Archaeolithothamnium puntiense* Airoldi, *Lithoporella melobesioides* (Foslie) Foslie.
563	*Dermatolithon?* sp.
630	*Microcodium* sp.
657	*Dermatolithon?* sp., *Jania?* sp., *Paraporolithon saipanense* Johnson.

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INDEX

[Italic numbers indicate description]

○

PLATES 267–280

PLATE 267

FIGURES 1–2. *Archaeolithothamnium crustatum* Johnson, n. sp. (p. 917).

1. A perpendicular section through the crust, × 95. Shows a narrow irregular hypothallus, a well-developed perithallus, and a number of sporangia. Miocene. Eniwetok. Holotype USNM 51424.
2. Specimen showing the irregular hypothallus at the base and a crust made of several superimposed thalli, × 48. Miocene. Eniwetok. USNM 51425.

3, 4. *Archaeolithothamnium* cf. *A. sociabile* Lemoine (p. 919).

3. A fragment showing part of the perithallus with numerous sporangia, × 48. Late Eocene. Eniwetok. USNM 51431.
4. Specimen giving details of the tissue and sporangia, × 48. Late Eocene. Eniwetok. USNM 51432.

5. *Archaeolithothamnium marshallensum* Johnson, n. sp. (p. 917).
A section of a crust showing a slightly developed hypothallus, and the perithallic tissue with a cluster of sporangia, × 48. Miocene. Eniwetok. Holotype. USNM 51427.

6. *Archaeolithothamnium eniwetokensis* Johnson, n. sp. (p. 918).
Section of crust, with a hypothallus consisting of a few curved rows of cells; fairly regular perithallic tissue and a row of sporangia, × 48. Miocene. Eniwetok. Holotype USNM 51429.

7. *Archaeolithothamnium* cf. *A. taiwanensis* Ishijima (p. 919).
Oblique section through a small fragment, × 95. Miocene. Eniwetok. USNM 51433.

8. *Archaeolithothamnium lauense* Johnson and Ferris (p. 917).
Section showing the relatively thick basal hypothallus, the regular well-developed perithallus, and two rows of sporangia, × 48. Miocene. Eniwetok. USNM 51426.

9. *Archaeolithothamnium* sp. A. (p. 919).
Oblique section of a thin slightly recrystallized crust with sporangia. Part of alga is growing around an encrusting foraminifer, × 48. Late Eocene. Eniwetok. USNM 51434.


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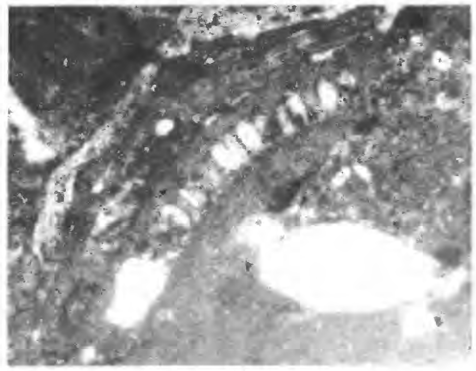
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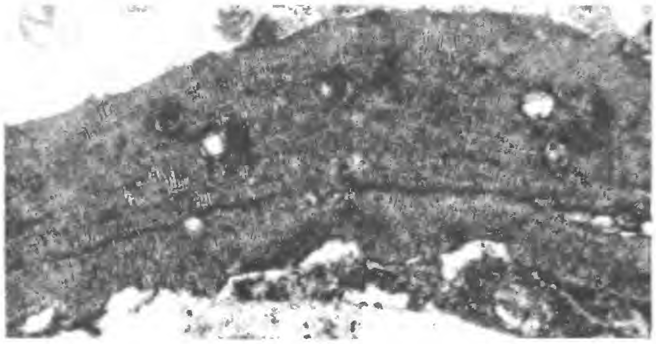
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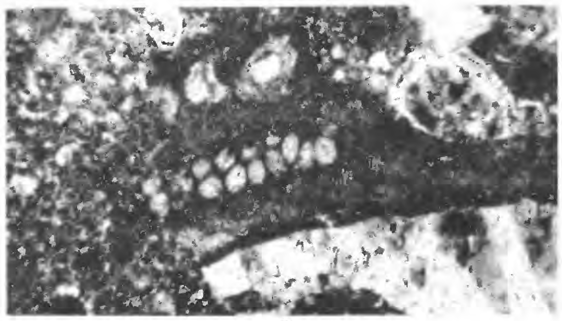
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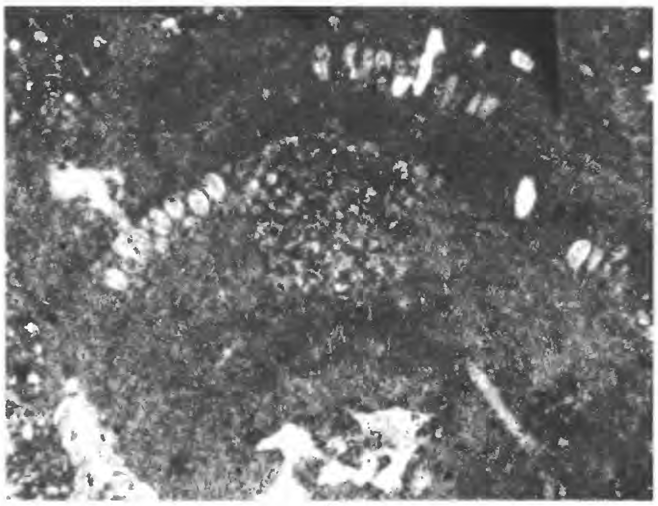
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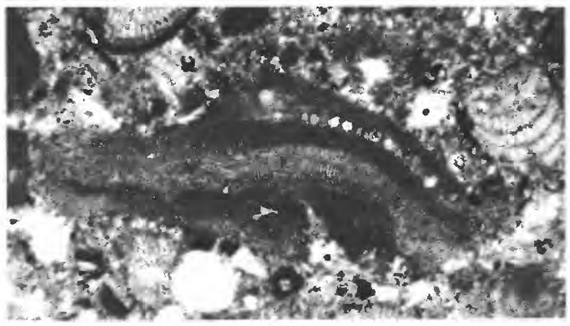
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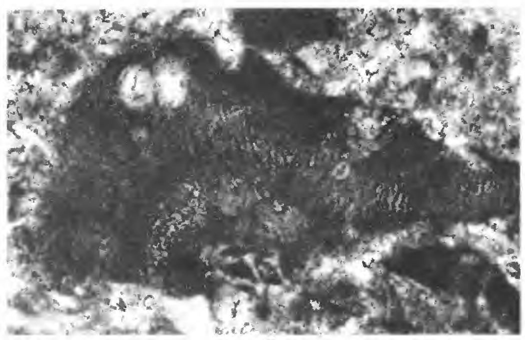
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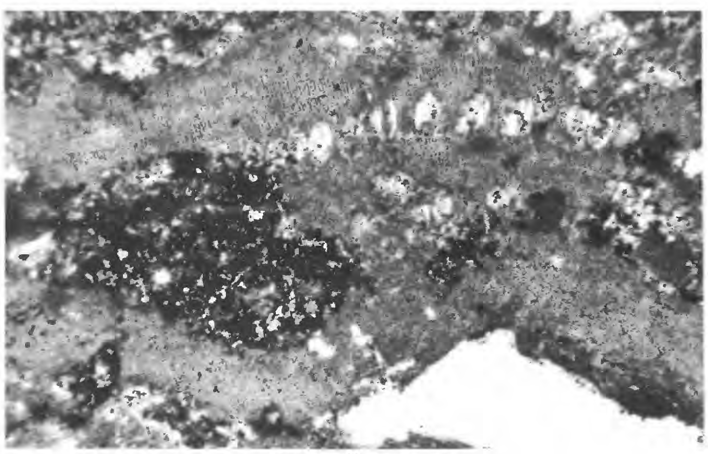
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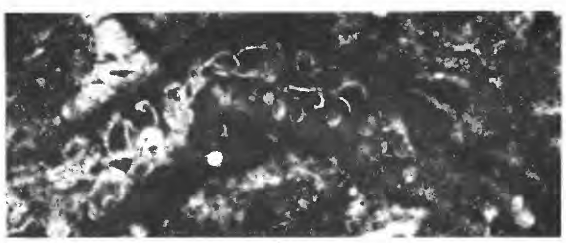
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ARCHAEOLITHOTHAMNIUM

PLATE 268

FIGURE 1. *Archaeolithothamnium eniwetokensis* Johnson, n. sp. (p. 918).
Detail of hypothallus and perithallus, × 95. Miocene. Eniwetok. USNM 51430.

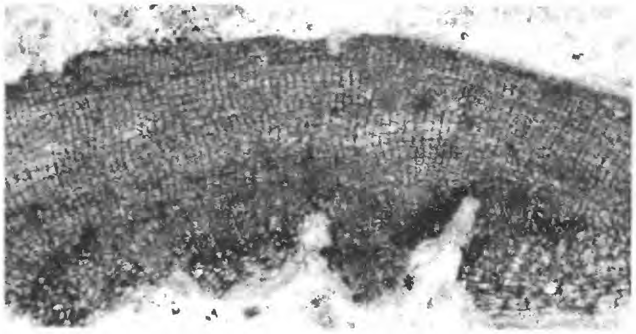
2, 3. *Archaeolithothamnium erythraeum* (Rothpletz) Foslie (p. 919).
2. Section of a considerably recrystallized specimen giving a general idea of the thallus and the sporangia, × 38. Pleistocene or Recent. Funafuti. British Museum slide 773.
3. Recrystallized specimen showing thin crust with numerous sporangia × 38. Pleistocene or Recent. Funafuti. British Museum slide 773.

4. *Archaeolithothamnium* aff. *A. erythraeum* (Rothpletz) Foslie (p. 920).
Detail of perithallic tissue and sporangial cavities, × 95. Miocene. Eniwetok. USNM 51435.

5. *Archaeolithothamnium dallonii* Lemoine (p. 921).
Slightly oblique longitudinal section of a branch showing the tissue and scattered sporangia, × 48. Late Eocene. Eniwetok. USNM 51439.

6. *Archaeolithothamnium nummuliticum* (Gümbel) Rothpletz (p. 920).
Section through a knobby crust, at the base is a fairly well developed hypothallus with curved cell rows, another patch of hypothallic tissue near the center probably represents scar tissue; a well-developed perithallus with sporangia is at the top, × 48. Late Eocene. Eniwetok. USNM 40813.

7. *Archaeolithothamnium* cf. *A. hemchandri* Rao (p. 921).
A vertical section of a fragment consisting of perithallic tissue containimg some sporangia, × 95. Late Eocene. Eniwetok. USNM 51437.



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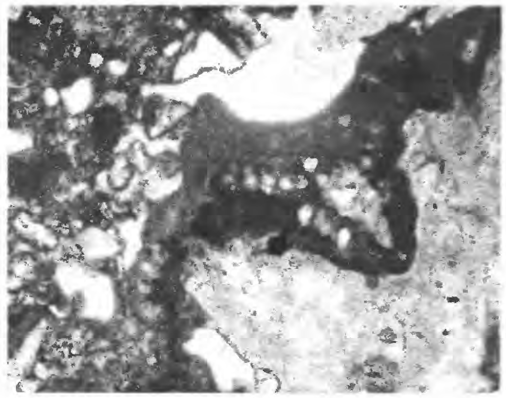

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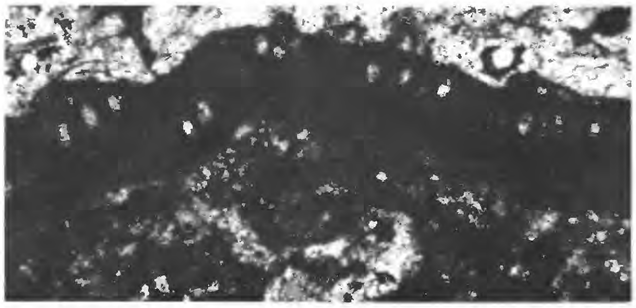

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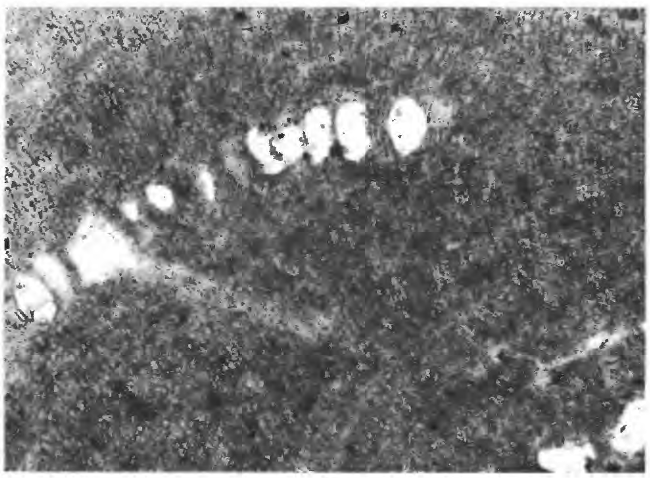

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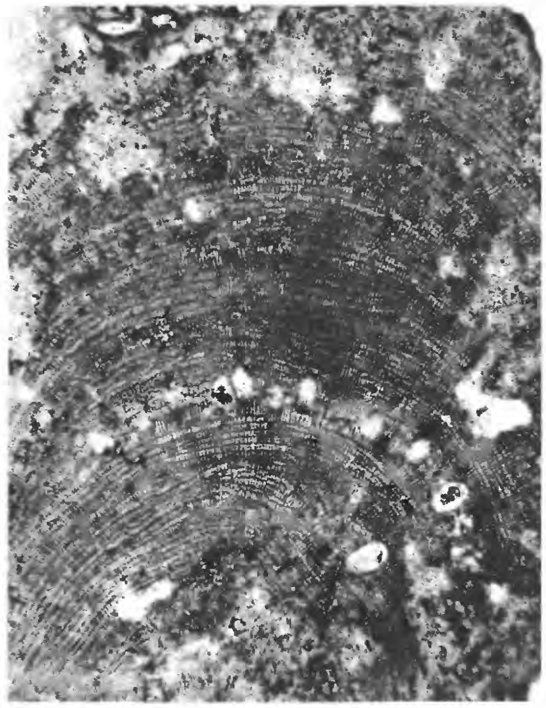

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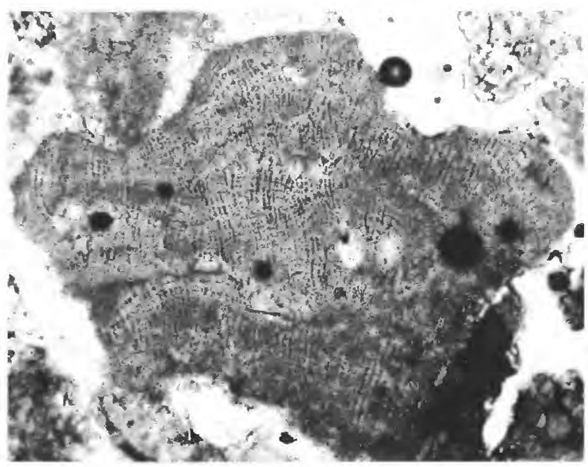


7

ARCHAEOLITHOTHAMNIUM

PLATE 269

FIGURE 1. *Archaeolithothamnium* aff. *A. affine* Howe (p. 921).
Part of a branch showing the vertical cell rows, the curved growth zones, and several layers of sporangia, × 38. Miocene. Eniwetok. USNM 51438.

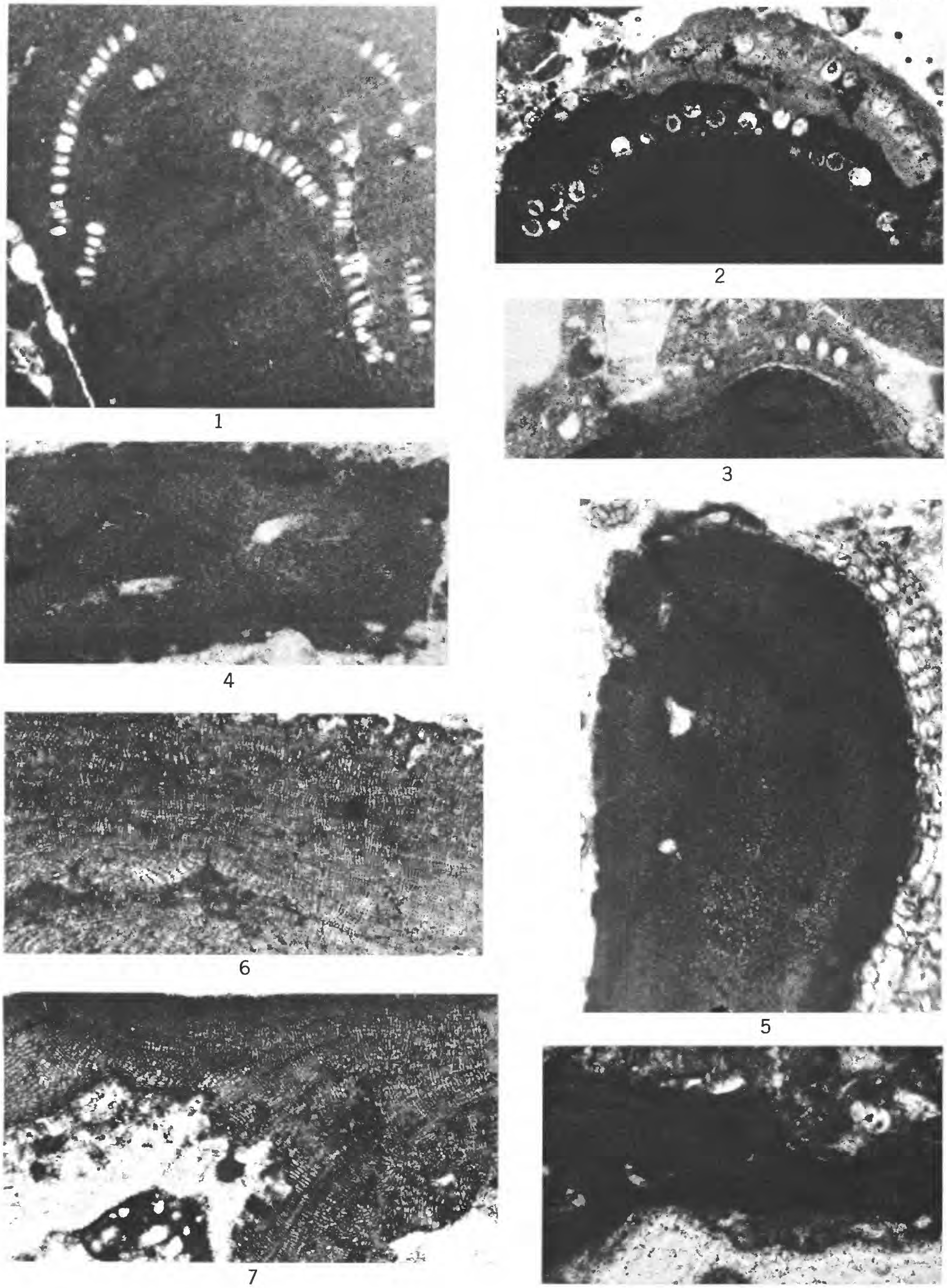
2. *Archaeolithothamnium nummuliticum* (Gümbel) Rothpletz (p. 920).
Section through a crust the bottom of which is badly recrystallized, × 48. Several layers of sproangia are visible and some details of the outer perithallic tissue. Late Eocene. Eniwetok. USNM 40810.

3. *Archaeolithothamnium marshallensum* Johnson, n. sp. (p. 917).
A thin crust, × 48. Consists almost entirely of perithallic tissue with a few sporangia. Miocene. Eniwetok. USNM 51428.

4, 5. *Lithothamnium* sp. D (p. 924).
4. Fragment of a slender branch with well-defined medullary hypothallus and a slender marginal perithallus, × 48. Miocene. Eniwetok. USNM 40922.
5. A slightly oblique section (× 48) of another branch showing more details of the marginal perithallus than fig. 4. Early Miocene. Eniwetok. USNM 40804.

6, 7. *Lithothamnium* sp. C (p. 923).
6. Section of a crust, × 48. Hypothallus thin and irregular with curved rows of cells with a thicker perithallus above. Miocene. Eniwetok. USNM 40802.
7. Specimen, × 48. Slightly oblique section showing details of hypothallus. Miocene. Eniwetok. USNM 40803.

8. *Lithothamnium* sp. A (p. 923).
Thin irregular crust, × 48. Miocene. Eniwetok. USNM 40800.



ARCHAEOLITHOTHAMNIUM AND *LITHOTHAMNIUM*

PLATE 270

FIGURE 1. *Lithothamnium funafutiense* Foslie (p. 924).
Thin crust showing the hypothallus and perithallus, × 38. Pleistocene. Funafuti. British Museum slide 534.

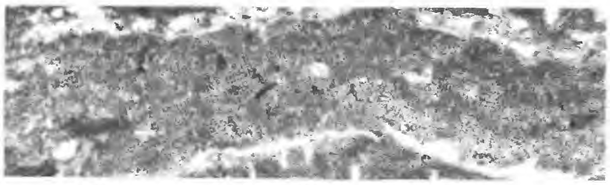
2. *Lithothamnium* sp. B (p. 923).
Shows the well-developed hypothallus and the relatively thin perithallus, × 95. Miocene. Eniwetok. USNM 40801.

3, 4. *Lithothamnium* cf. *L. nitidum* Foslie (p. 924).
3. Section of a crust with a thin hypothallus of curved rows of cells, a thick perithallus and a conceptacle chamber (near top) having indications of multiple openings in the roof of the conceptacle, × 38. Probably Pleistocene. Kita-Daitō-Jima. Tōhoku University, slide 53.
4. Specimen showing irregular growth zones and a conceptacle chamber with several apertures, × 95. Probably Pleistocene. Kita-Daitō-Jima. Tōhuko University, Aoki coll., slide 196.

5. *Mesophyllum* cf. *M. arakuraensis* Ishijima (p. 925).
Section of a large crust with well-developed coaxial hypothallus, a thick perithallus and a conceptacle chamber showing several apertures (upper left), × 48. Miocene. Eniwetok. USNM 40805.

6. *Lithothamnium* aff. *L. aucklandicum* Foslie (p. 923).
Shows irregular growth zones of the perithallic tissue and four conceptacles filled with sporangia, × 71. Pleistocene(?). Kita-Daitō-Jima. Tōhoku University, slide 124.

7. *Lithothamnium leptum* Johnson and Ferris (p. 923).
Crust with moderately developed hypothallus at the base, and a thicker perithallus above, × 48. Miocene. Eniwetok. USNM 40799.



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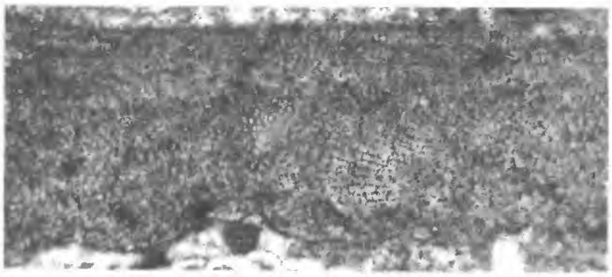

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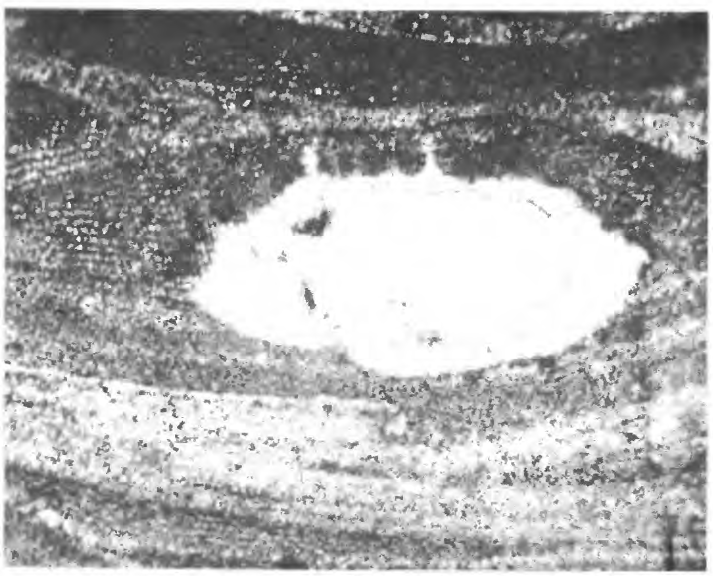

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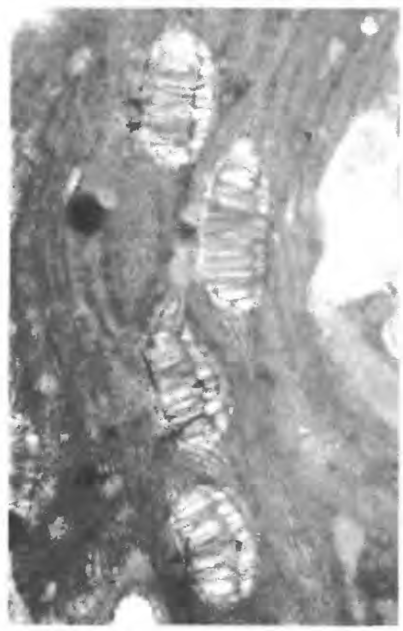

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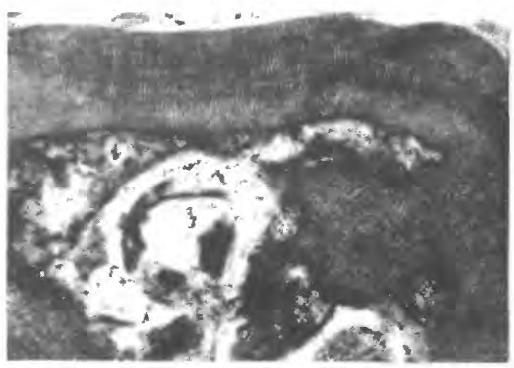

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LITHOTHAMNIUM AND *MESOPHYLLUM*

PLATE 271

FIGURE 1. *Mesophyllum* cf. *M. arakuraensis* Ishijima (p. 925).
Slightly recrystallized specimen showing hypothallus and perithallus, × 48. Miocene. Eniwetok. USNM 40806.

2. *Mesophyllum japonicum* Ishijima (p. 926).
Several specimens intergrown, × 48. A good basal hypothallus occurs near the bottom overlain by a thick perithallus with irregular growth zones. Miocene. Eniwetok. USNM 40809.

3. *Mesophyllum* sp. A (p. 926).
Slightly oblique section of a crust with a well-developed basal hypothallus and a thick perithallus composed of a number of irregular growth zones, × 48. Miocene. Eniwetok. USNM 40808.

4. *Mesophyllum* cf. *M. savornini* Lemoine (p. 926).
Section of a badly recrystallized branch containing three cavities of conceptacle chambers, × 48. Miocene. Eniwetok. USNM 40944.

5. *Mesophyllum pulchrum* (Foslie) Lemoine (p. 927).
Section of badly recrystallized branch with thick irregular growth zones and several conceptacle chambers, × 38. Pleistocene. Funafuti. British Museum slide 688.

6. *Mesophyllum robustum* Johnson, n. sp. (p. 926).
Section of a crust showing a well-developed coaxial hypothallus and a thick irregular perithallus with pronounced growth zones, × 95. Several conceptacles with traces of the sporangia are present. Late Eocene. Eniwetok. Holotype USNM 40812.

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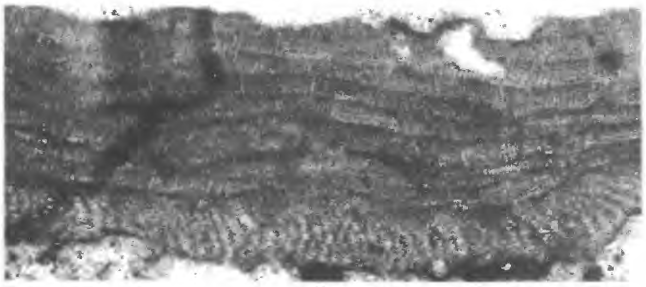

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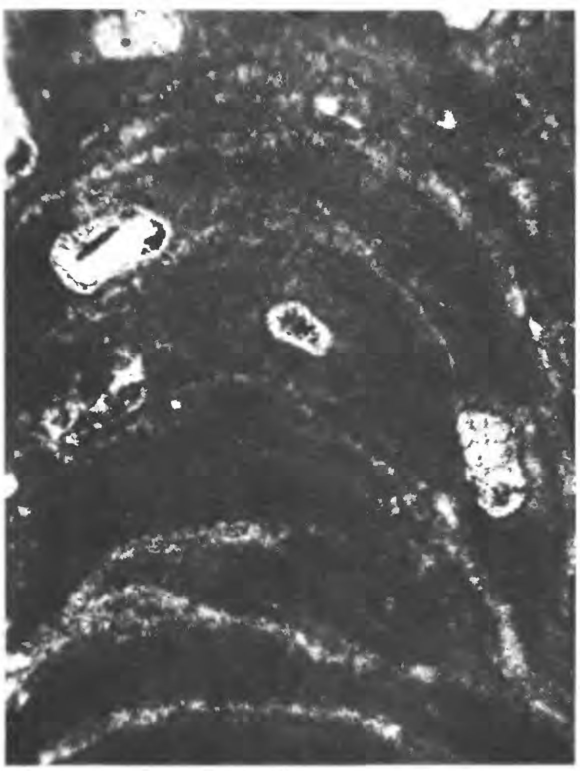

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MESOPHYLLUM

PLATE 272

FIGURE 1. *Lithophyllum cf. L. lingusticum* Airoldi (p. 929).
A thin crust (× 48) composed of a well-developed hypothallus with a thin perithallus. Late Eocene. Eniwetok. USNM 40814.

2, 3. *Lithophyllum hanzawae,* Johnson n. sp., (p. 928).
Pleistocene (?), Kita-Daitō-Jima. Holotype, Tōhoku University slide, Aoki colln. 141.
2. Detail of the hypothallus, perithallus, and conceptacle chambers, × 95.
3. General view showing the thick regular perithallic tissue and the numerous conceptacle chambers, × 38. The large single apertures of some of the conceptacles are plainly visible.

4. *Mesophyllum eniwetokensum* Johnson, n. sp. (p. 925).
Slightly oblique section of a crust formed of several superimposed thalli, × 48. Shows growth zones and several conceptacle chambers with traces of the sporangia. Miocene. Eniwetok. Holotype, USNM 40807.

5. *Mesophyllum* sp. B. (p. 927).
Section of a branch giving details of the tissue, × 48. Miocene. Eniwetok. USNM 40811.

6. *Mesophyllum erubescens* (Foslie) Lemoine (p. 926).
A part of the tissue of a branch, × 38. Pleistocene or Recent. Funafuti. British Museum slide 615.

7. *Lithophyllum kladosum* Johnson (p. 931).
Section showing branching, × 48. Miocene. Eniwetok. USNM 40924.

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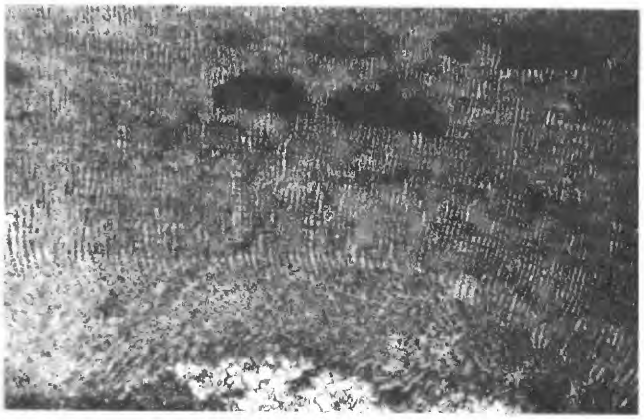

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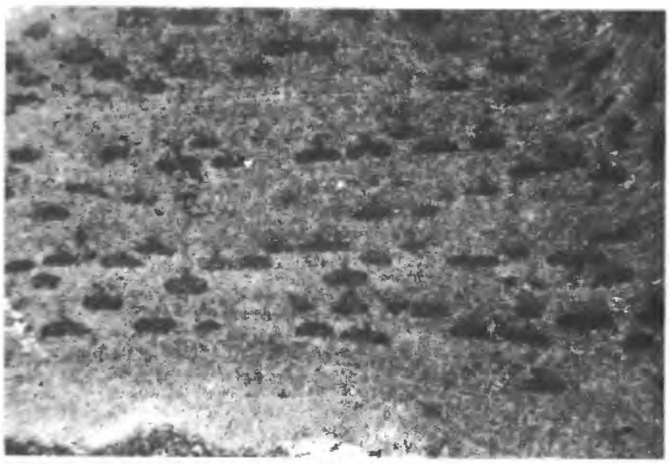

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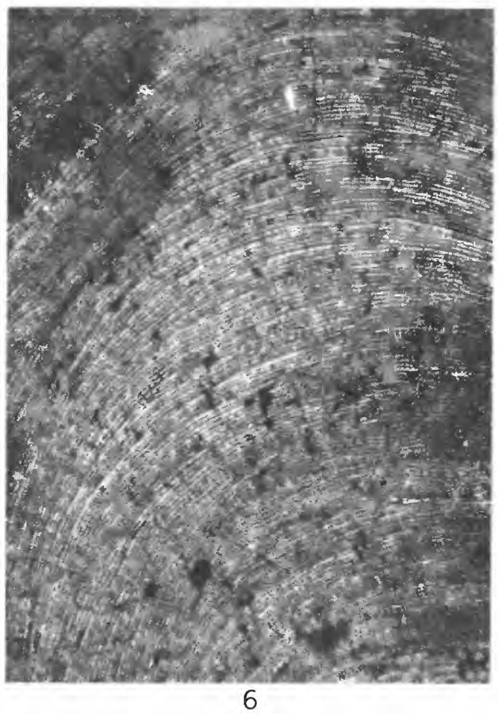

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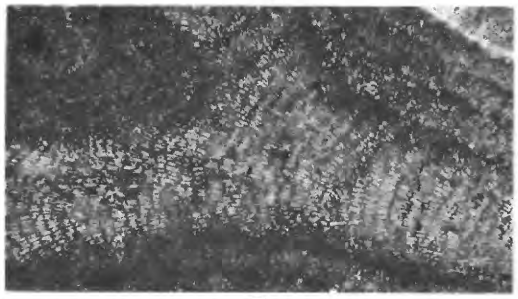

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LITHOPHYLLUM AND *MESOPHYLLUM*

PLATE 273

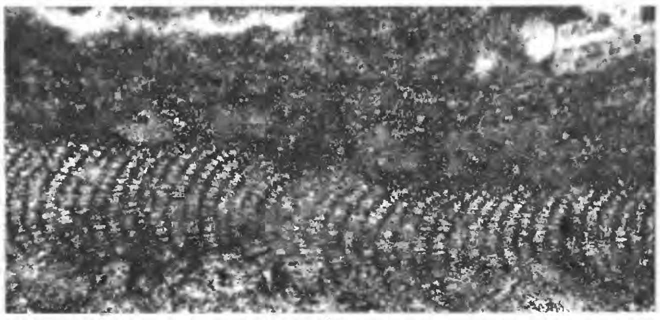
FIGURE 1. *Lithophyllum acanthinum* Foslie (p. 928).
Badly frayed crust showing well-developed hypothallus and perithallus, × 95. Pliocene or Pleistocene. Kita-Daitō-Jima. Tōhoku University slide 656.

2. *Lithophyllum quadratum* Ishijima (p. 930).
Section of a crust composed of several superimposed thalli, × 38. Each consists of a thin hypothallus and a thicker perithallus with regular tissue. Pleistocene(?). Kita-Daitō-Jima. Tōhoku University slide 63.

3, 4. *Lithophyllum stefaninii* Airoldi (p. 930).
Probably Pliocene-Pleistocene. Kita-Daitō-Jima. Tōhoku University slides 62 and 661.
3. Thin irregular crust showing the regular perithallic tissue and poorly developed hypothallus, × 38.
4. Slightly oblique section of crust with well-developed hypothallus, × 38.

5, 6. *Lithophyllum samoense* Foslie (p. 930).
Pleistocene (?). Kita-Daitō-Jima.
5. Section through a thick crust showing several conceptacle chambers, × 71. Tōhoku University slide 61.
6. Section of thin crust with a thin hypothallus at the base and a thick perithallus with several conceptacle chambers, × 38. Tōhoku University slide 256.

7. *Lithophyllum thikombian* Johnson and Ferris (p. 930).
Fragment showing well-developed coaxial hypothallus and parts of a narrow perithallus, × 95. Probably Miocene. Kita-Daitō-Jima. Tōhoku University slide 656.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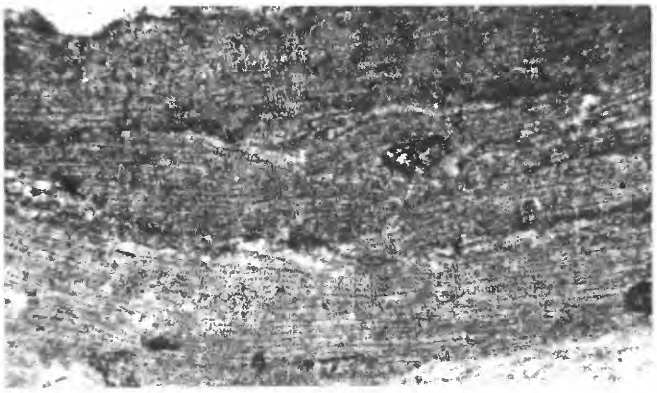
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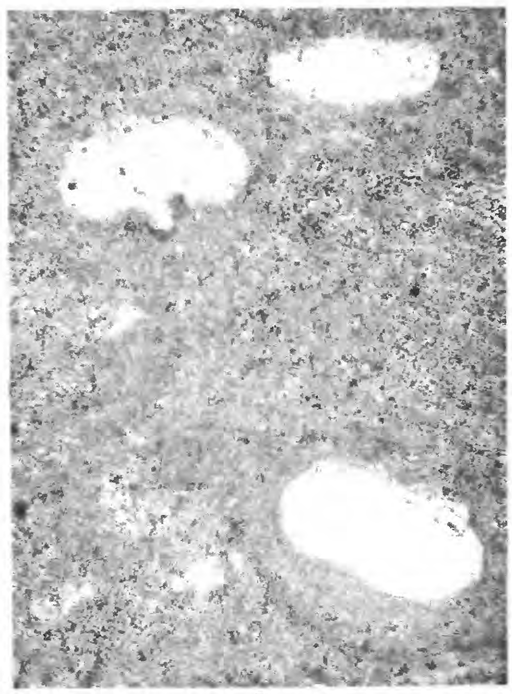
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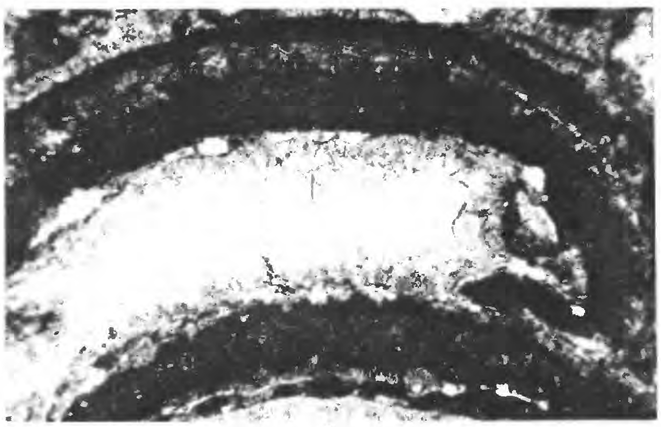
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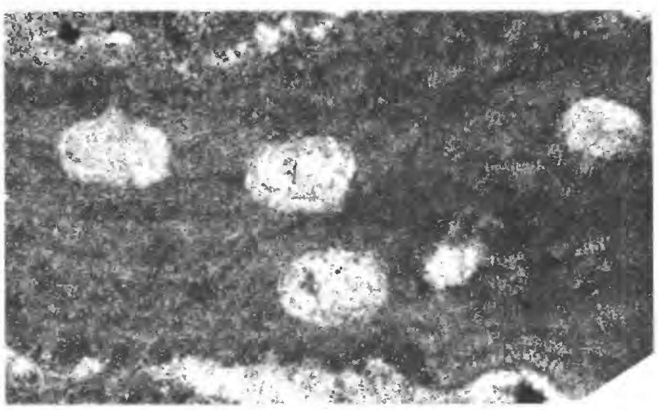
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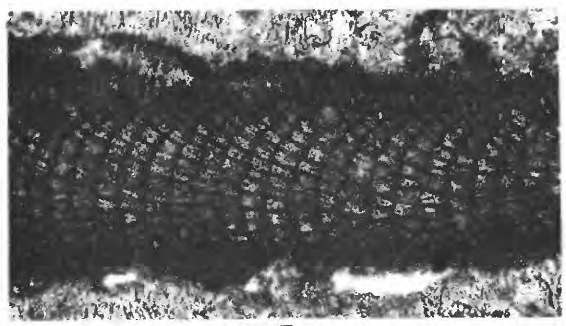
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LITHOPHYLLUM

PLATE 274

FIGURE 1. *Lithophyllum okamurae* Foslie (p. 930).

Section of a fertile crust with thick perithallic tissue and numerous small conceptacle chambers, × 38. Pleistocene or Recent. Kita-Daitō-Jima. Tōhoku University slide 176.

2, 3. *Lithophyllum* cf. *L. kotschyanum* Unger (p. 931).

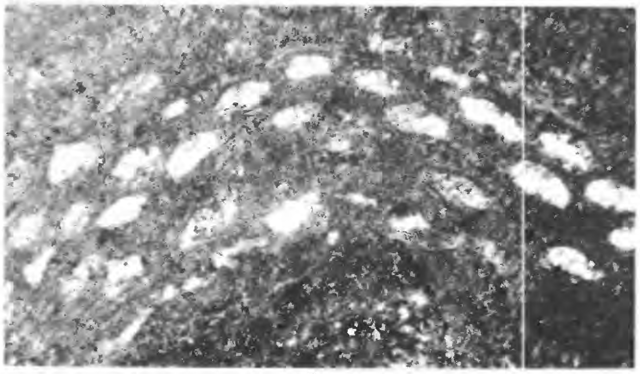
Pleistocene (?). Kita-Daitō-Jima. Tōhoku University slide 73.

2. Section of a large and partly recrystallized branch, × 38. Numerous growth zones and several conceptacle chambers are shown.
3. Slightly oblique section of branch showing transition from medullary hypothallus to marginal perithallus as well as pronounced growth zones and several small conceptacle chambers, × 38.

4, 5. *Lithophyllum kladosum* Johnson (p. 931).

Miocene. Eniwetok.

4. Section of a typical long slender branch bearing two conceptacles along the outer margin, × 48. USNM 40816.
5. Specimen showing the development of branches, × 48. USNM 40815.



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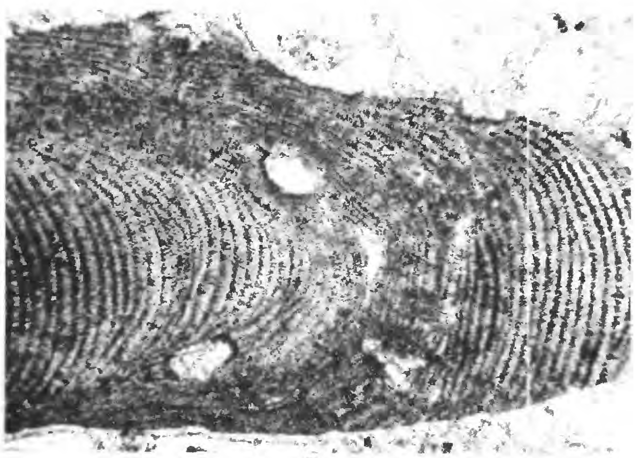

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LITHOPHYLLUM

PLATE 275

FIGURES 1, 2. *Porolithon aequinoctiale* (Foslie) Foslie (p. 934).

Pleistocene(?), and Recent. Eniwetok.

1. Section of perithallic tissue perpendicular to the cell layers showing the clusters of megacells, × 95. USNM 40817.
2. Section parallel to the cell layers showing the megacell clusters in ground plan, × 95. USNM 40818.

3, 4. *Porolithon marshallense* Taylor (p. 935).

Recent. Eniwetok.

3. Oblique section through the tip of a branch showing the medullary hypothallus, and the marginal perithallic tissue with numerous clusters of megacells, × 48. USNM 40819.
4. Section through branch showing details of tissue ×48. USNM 40940.

5. *Lithophyllum profundum* Johnson (p. 931).

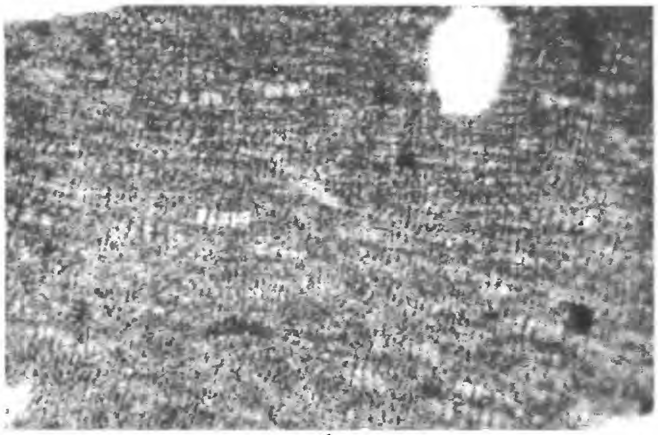
Branch with a marginal conceptacle, × 48. Miocene. Eniwetok. USNM 40913.

6. *Goniolithon myriocarpon* Foslie (p. 932).

Recent and Miocene. Eniwetok. Section of crust with a thin basal hypothallus and a thicker perithallus, × 48. Numerous megacells are distributed throughout penthallic tissue. USNM 40820.

7. *Goniolithon fosliei* (Heydrich) Foslie (p. 932).

Thin crust, somewhat recrystallized, with a well-developed coaxial hypothallus and a thicker perithallus, × 95. The small megacells are not clearly shown. Recent and Pleistocene(?). Funafuti. British Museum slide 665.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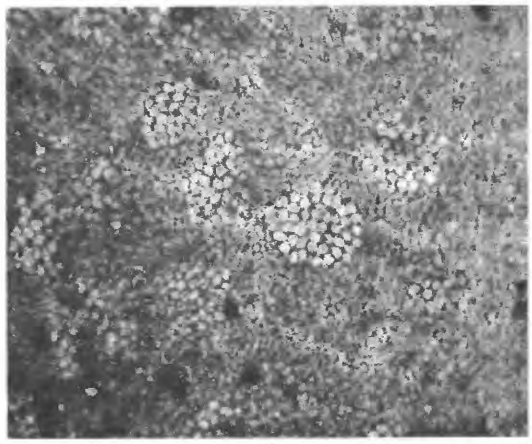
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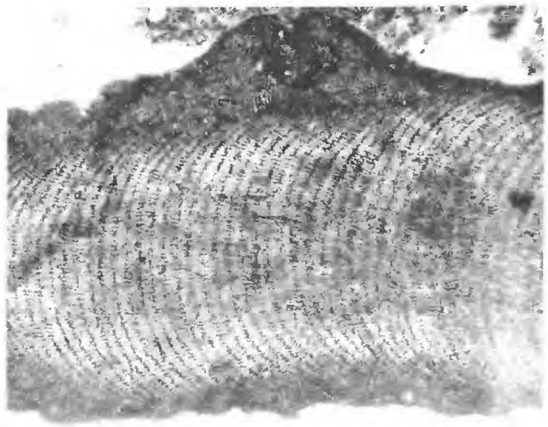
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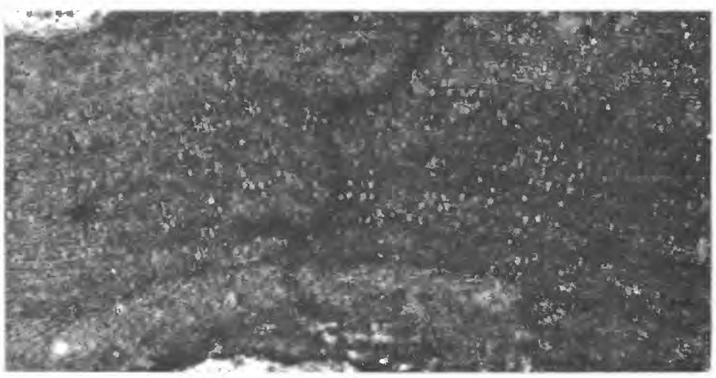
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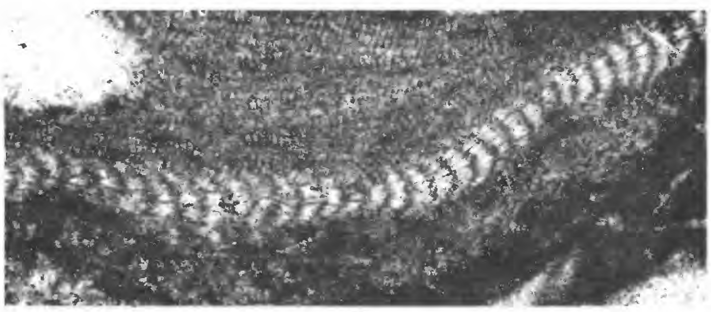
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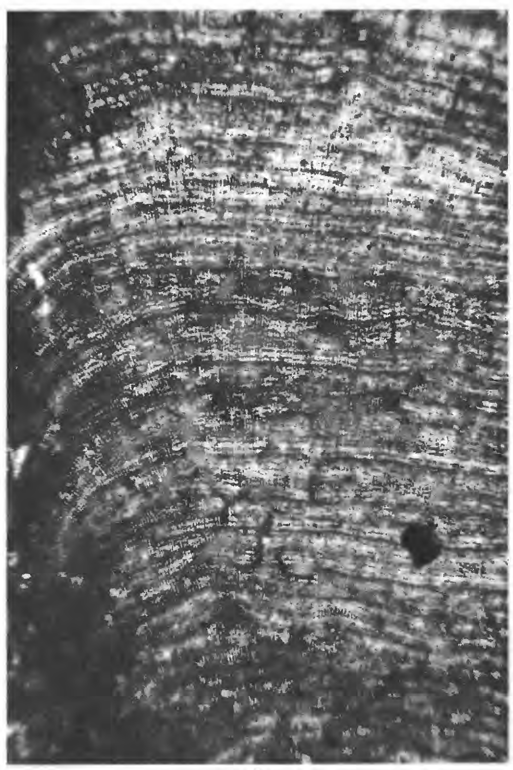
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POROLITHON, *GONIOLITHON,* AND *LITHOPHYLLUM*

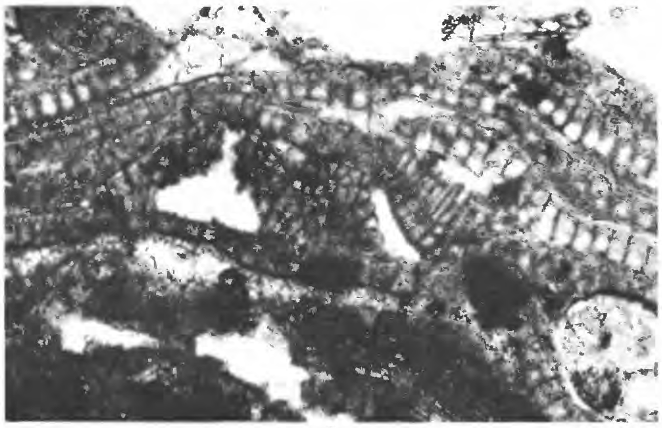
PLATE 276

FIGURES 1, 2. *Lithoporella antiquitas* Johnson, n. sp. (p. 937).
Vertical sections of fertile specimens showing the long canal leading to the conceptacle opening, × 95. Miocene. Eniwetok. Holotype USNM 40825.

3, 4. *Lithoporella longicella* Johnson n. sp. (p. 937).
Nearly vertical sections showing crusts formed of numerous thalli superimposed, × 48. Recent or Pleistocene(?). Eniwetok. Holotype USNM 40822.

5. *Lithoporella* sp. B (p. 937). Section, × 48. Miocene. Eniwetok. USNM 40824.

6. *Lithoporella* cf. *L. crassa* Ishijima (p. 936). The section cuts a number of superimposed thalli at various angles, × 48. Recent or Pleistocene(?) Eniwetok. USNM 40821.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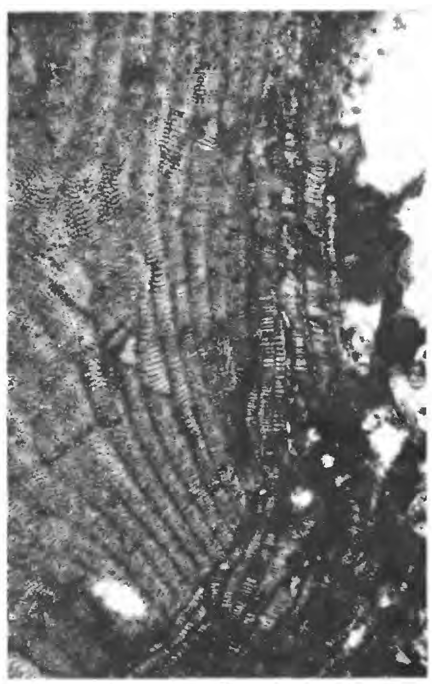
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LITHOPORELLA

PLATE 277

FIGURE 1. *Corallina* sp. B (p. 941).
Two segments, × 48. Miocene. Eniwetok. USNM 40832.

2, 3. *Corallina marshallensis* Johnson, n. sp. (p. 941).
Miocene. Eniwetok.
2. Two segments with a node between, × 48. Holotype USNM 40829.
3. A single segment, × 48. USNM 40830.

4. *Corallina* sp. C (p. 941).
Nearly complete segment, × 48. Miocene. Eniwetok. USNM 40833.

5. *Corallina* sp. A (p. 941).
Worn segment, × 48. Miocene. Eniwetok. USNM 40831.

6. *Amphiroa* sp. A (p. 939).
Long segment somewhat abraded, × 38. Late Eocene. Eniwetok. USNM 40945.

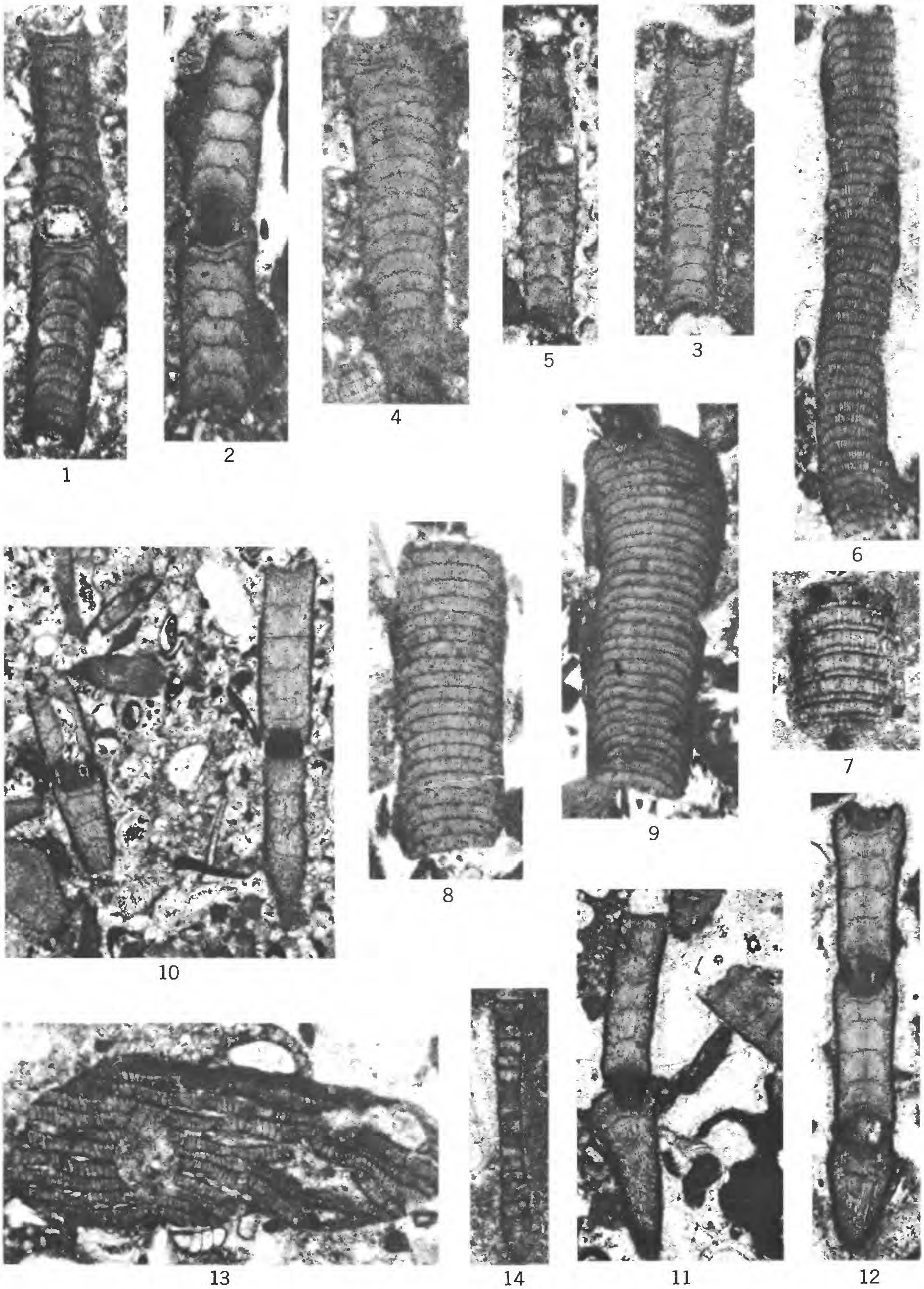
7. *Amphiroa* sp. B (p. 939).
Fragment showing alternating layers of long and short cells, × 95. Late Eocene. Eniwetok. USNM 40914.

8, 9. *Amphiroa fortis* Johnson, n. sp. (p. 939).
Late Eocene. Eniwetok.
8. Worn piece of a large segment, × 48. Paratype, USNM 40835.
9. Nearly complete segment showing a little of the marginal perithallus as well as the thick medullary hypothallus, × 38. Holotype USNM 40834.

10–12. *Corallina eniwetokensis* Johnson, n. sp. (p. 940).
Miocene. Eniwetok.
10. Several worn fragments cut at various angles, × 48. Paratype USNM 40827.
11. Several pieces, one shows a complete segment, a node, and character of the branching, × 48. Paratype USNM 40827.
12. Three segments with the intervening nodes, × 48. Holotype USNM 40828.

13. *Dermatolithon marshallensum* Johnson, n. sp. (p. 938).
Several specimens, one bearing a conceptacle, × 48. Miocene. Eniwetok. Holotype USNM 40826.

14. *Lithoporella* sp. A (p. 937).
Small piece of a young plant, × 48. Miocene. Eniwetok. USNM 40823



CORALLINA, *AMPHIROA*, *DERMATOLITHON*, AND *LITHOPORELLA*

PLATE 278

FIGURES 1–3. *Amphiroa medians* Johnson, n. sp. (p. 939). Miocene. Eniwetok.

1. Segment showing character of branching, × 48. USNM 40915.
2. A larger segment with branch, × 48. Holotype USNM 40923.
3. Several worn fragments, × 48. USNM 40809.

4. *Jania* sp. A (p. 939).
A nearly complete segment, × 48.
Late Eocene. Eniwetok. USNM 40916.

5. *Amphiroa* sp. C (p. 940).
A branching segment, × 48. Miocene. Eniwetok. USNM 40917.

6–8. *Jania miocenica* Johnson, n. sp. (p. 938).
Miocene. Eniwetok.

6. A long segment, × 48. USNM 40918.
7. A slightly oblique section of a small segment, × 48. Holotype USNM 40919.
8. A fragment of a terminal segment showing a conceptacle chamber, × 48. Holotype USNM 40919.

9–12. *Dactylopora*? sp. (p. 941).
Random sections of worn fragments, × 24. Late Eocene. Eniwetok. USNM 40920 (figs. 10, 11, 12) and USNM 40921 (fig. 9).

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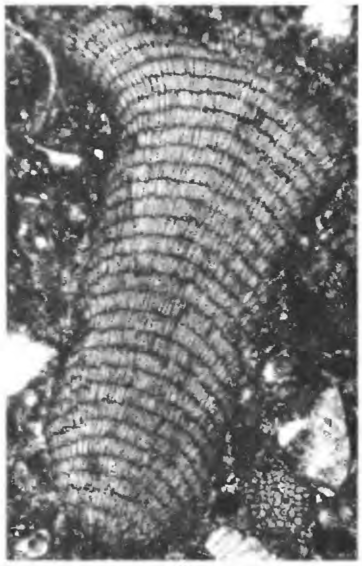

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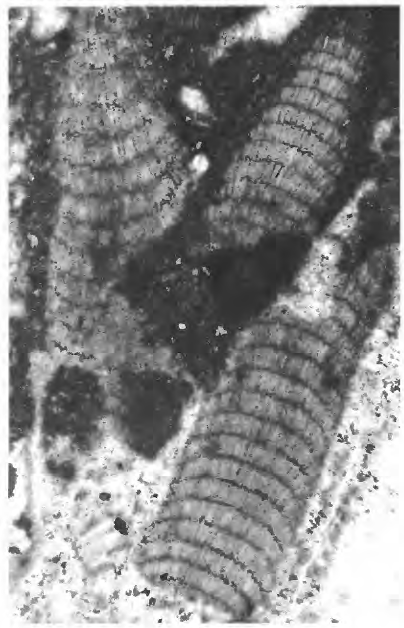

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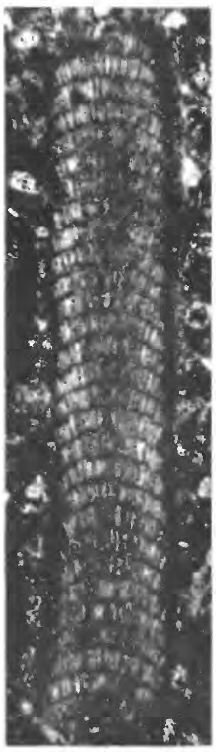

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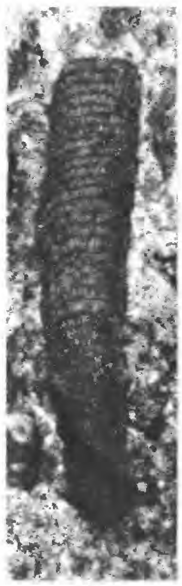

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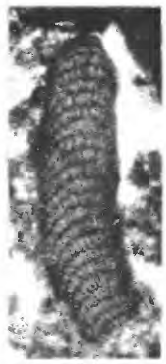

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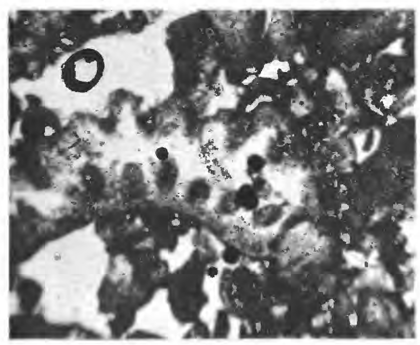

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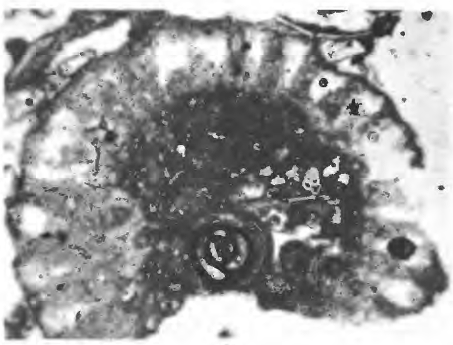

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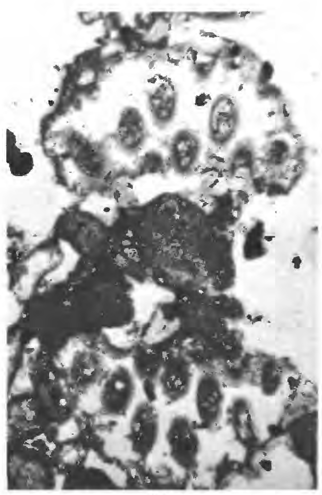

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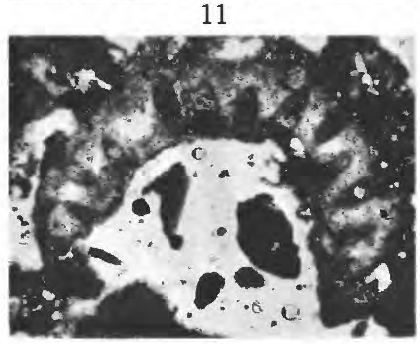


12

AMPHIROA, *JANIA*, AND *DACTYLOPORA*

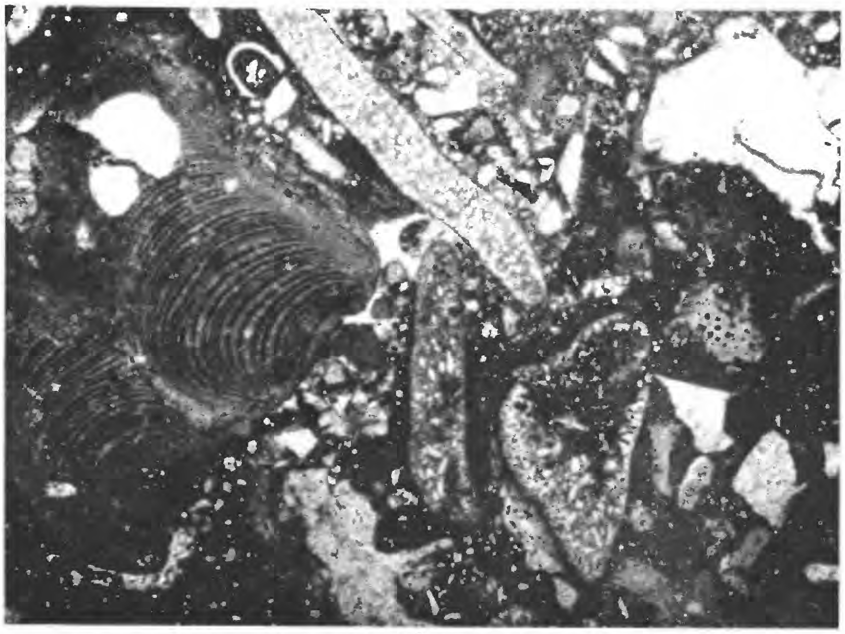
PLATE 279

FIGURE 1. *Halimeda* segments and coralline algae, × 14. (p. 942).
Pleistocene(?). Kita-Daitō-Jima.

2. *Halimeda* segments in limestone, × 1. (p. 942).
Pleistocene(?). Eniwetok. USNM 40941.

3–5. *Dactylopora*? sp. (p. 941).
Late Eocene. Eniwetok.
3, 4. Nearly tangential sections, × 24. USNM 40942.
5. A longitudinal section near the outer margin, × 24.
USNM 40921.

6, 7. *Acicularia* sp. (p. 941).
Numerous unoriented fragments scattered over the slides, × 14. Late Eocene.
Eniwetok. USNM 40944.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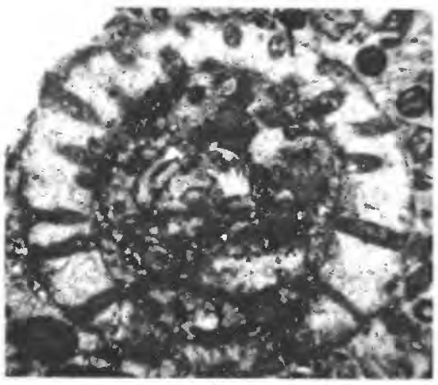
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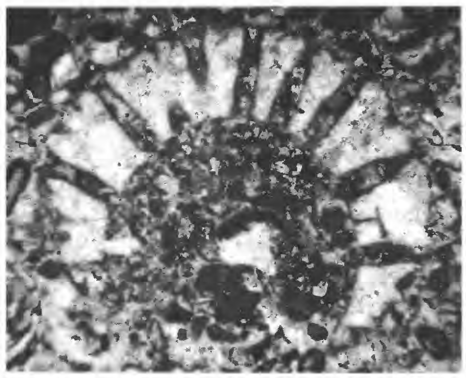
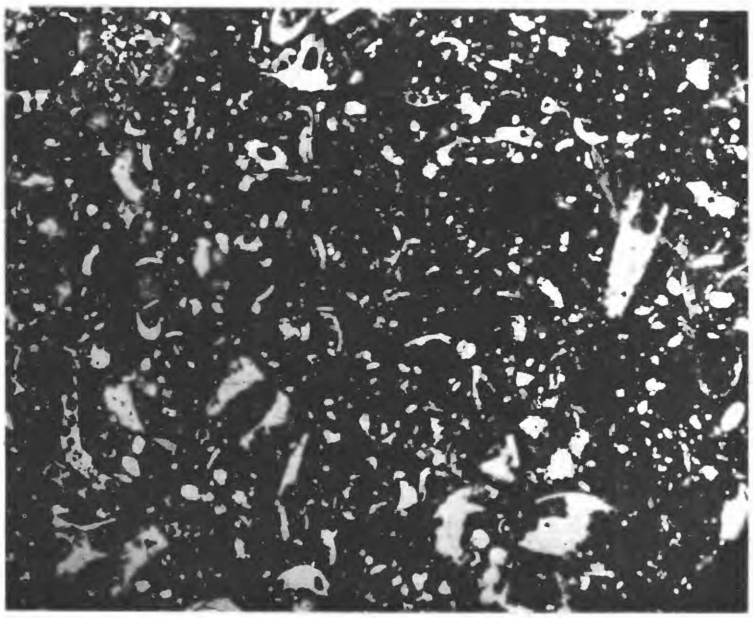

4


5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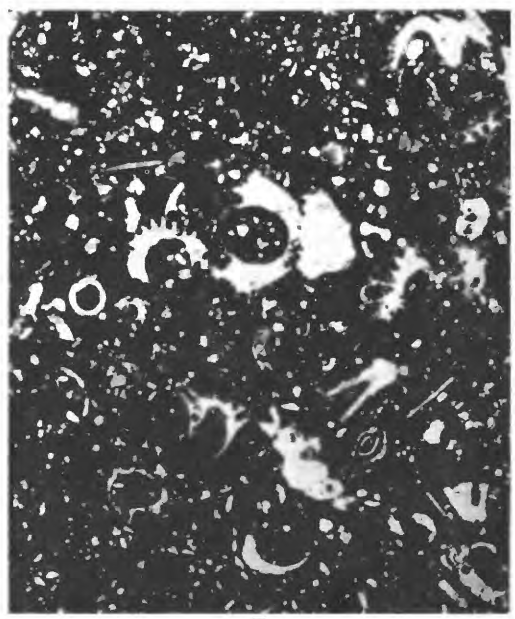
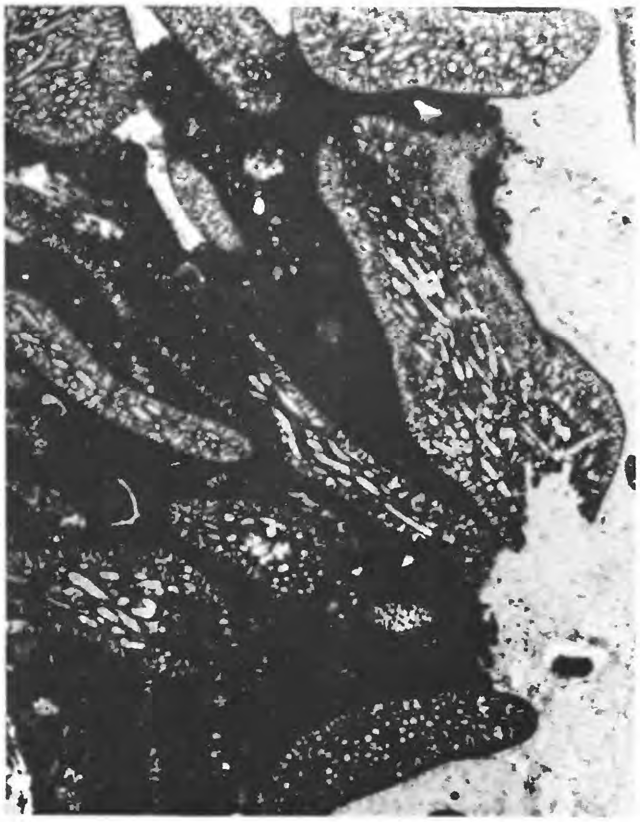

7

HALIMEDA, *DACTYLOPORA*, AND *ACICULARIA*

PLATE 280

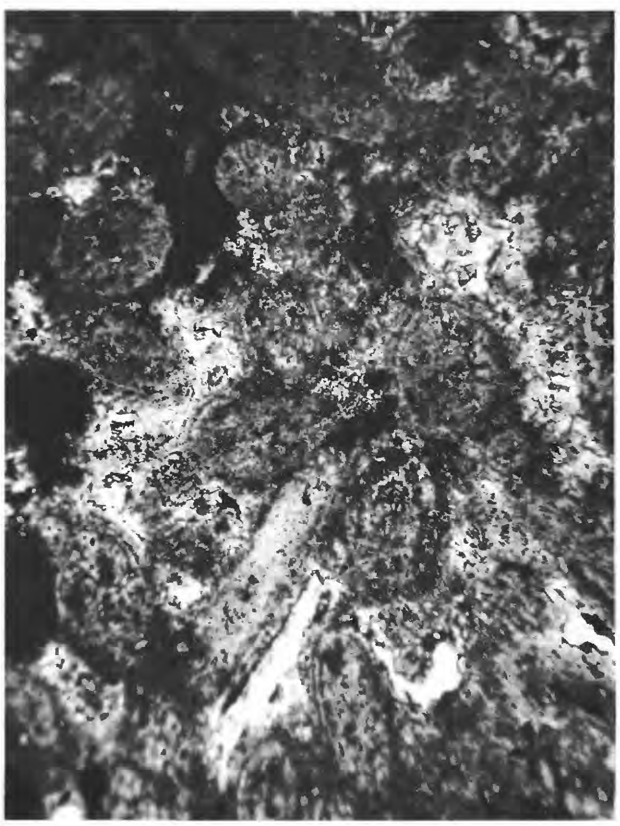
FIGURES 1–2. Numerous segments of *Halimeda* cut at various angles, × 14. (p. 942). Pleistocene(?). Kita-Daitō-Jima.

3–4. Segments of *Halimeda* badly recrystallized, × 38. (p. 942). Pleistocene or Recent. Funafuti core.

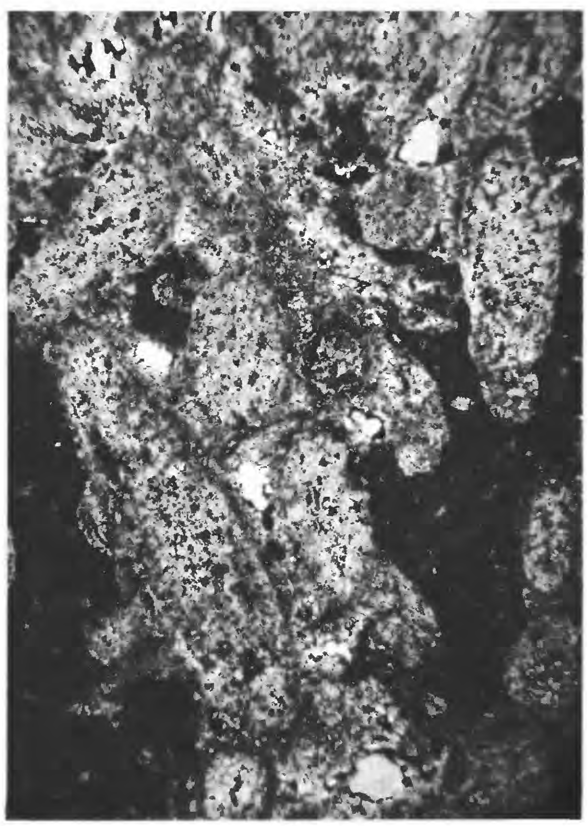


1

2



3



4

HALIMEDA