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Fig. 1, September 1976

THE DEVELOPMENT OF RODRIGUEZ BANK, A HOLOCENE MUDBANK IN THE FLORIDA REEF TRACT[1]

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Abstract: Rodriguez Bank is a Recent mound of unconsolidated calcareous sediments deposited during a relative rise in sea level in the absence of vigorous wave action. This mound, unlike modern coral-algal reefs, has no rigid organic framework and plants are directly and indirectly responsible for the accumulation. The principal sediment contributors to the bank are algae. An embayment in the Pleistocene rock floor localized the initial deposition of sediment that provided the nucleus for bank development. Although the hydrography and biotic assemblages changed, the bank maintained itself as a topographic feature.

INTRODUCTION

This report describes the development of a Holocene mound of lime mud sediments in the inshore zone of the Florida reef tract. The investigation of Rodriguez Bank was undertaken in 1958 to study Holocene sediment buildups in south Florida after a reconnaissance of Tavernier Bank and Rodriguez Bank (Fig. 2) revealed an appreciable thickness of Recent sediment. These areas were previously thought to have been Pleistocene topographic knobs.

A company report on Rodriguez Bank was submitted in 1965. Since 1964, selective data has been released for field guidebooks (Ginsburg, 1964, Multer, 1969, Ahr and Shinn, 1975). Peat dates released to Scholl, *et al.* (1969) enabled them to revise their submergence curve for south Florida.

In view of the continuing interest by study groups, data on the Rodriguez Bank area was reviewed and the original report was updated. The report is here presented in its entirety.

Cores were impregnated with polyester resin (Ginsburg, *et al.*, 1966), a technique that preserves depositional fabrics and sedimentary structures in unconsolidated sediment. Figure 23 is an index of probings, cores, and control stations used in this study.

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SETTING AND ENVIRONMENT

The Florida Peninsula and its submarine extension, the Floridian Plateau (Agassiz, 1888), are part of a vast region of carbonate deposition that includes the Bahama Banks and the northern coast of Cuba (Fig. 1). Since Jurassic time, shallow-water carbonate sedimentation has been dominant over the entire region from Cuba to central Florida and from the Gulf of Mexico to the easternmost Bahama Islands. The total section is in excess of 14,000 ft (4,267 m) (Goodell and Garman, 1969).

The present topography of the southeastern margin of the Floridian Plateau is dominated by linear coral-algal reefs, both Recent and Pleistocene. The Pleistocene coral reef, Key Largo limestone (Hoffmeister and Multer, 1964) forms a chain of islands curving from Soldiers Key (just south of Miami) southwestward to Bahia Hondo Key, a distance of approximately 94 miles (174 km). Only a part of this area is shown in Fig. 2. This chain of islands separates the reef tract from Florida Bay, a large triangular area of intermittently exposed mud banks and semi-isolated areas of deeper water. Seaward of the Pleistocene reef islands and paralleling them is an arcuate band of living reefs, linear shoals, and depressions termed the Florida Reef Tract by Vaughan (1916). Living reefs that locally reach the low water mark are concentrated on the seaward side of this band to form a discontinuous barrier (Fig. 2). These reefs are termed outer reefs by Ginsburg (1956), and the area between them and the exposed Key Largo limestone, which is 3 to 7 miles (2.6 to 13 km) wide, is the back

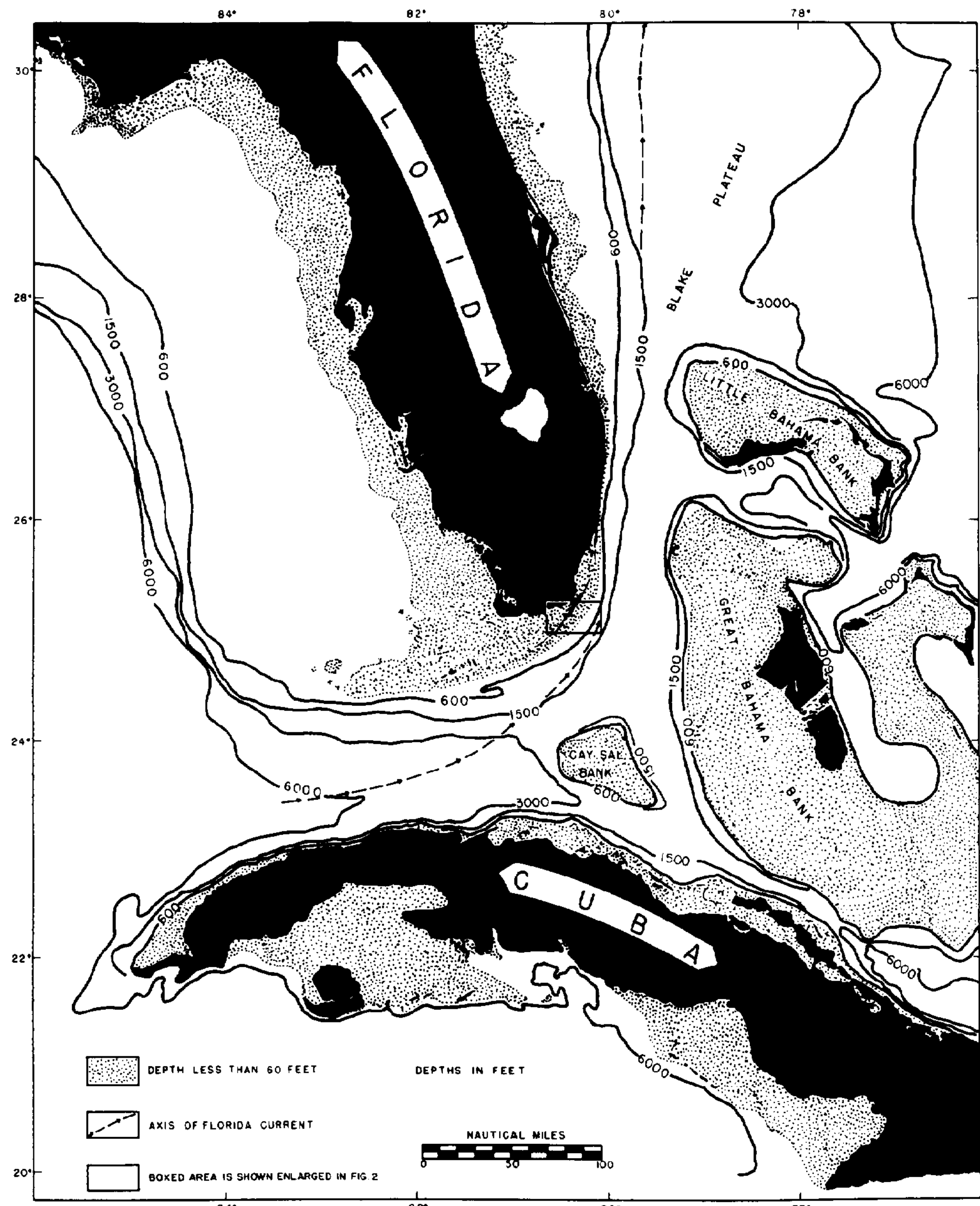

FIG. 1.—Bathymetry of Florida, Cuba and the Bahamas.

reef. This area is characterized by a prominent linear shoal, White Bank, and reef knolls (Mosquito Bank, Hen and Chickens, etc.). Areas of deeper water, exceeding 18 ft (5.5 m) surround these features. Toward Key Largo the water shallows, and it is in this inshore zone that Rodriguez Bank is located.

Rodriguez Bank is an elongate mound (Fig. 3) 8,700 ft (2,654 m) long and 2,800 ft (854 m) wide, bounded on all sides by deeper water. Water depth on the bank ranges from 0 to 3 ft (1 m), whereas water depth surrounding the bank ranges from 5 to 13 ft (1.5 to 4 m). A number of traverses from the key south to the

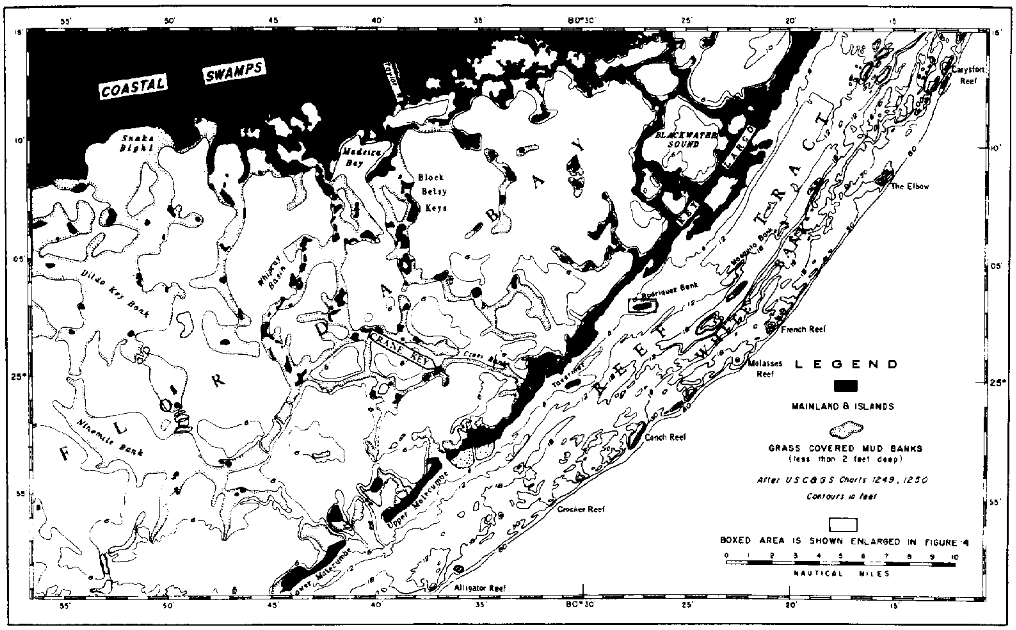

FIG. 2.—Bathymetry and physiography of a portion of the Florida Reef Tract, the Florida Keys, and Florida Bay.

windward bank margin have shown the bank margin to be about 6″ (.15 m) shallower than the bank itself. Rodriguez Key stands approximately 4″ to 1 ft (.1 to .3 m) above mean low water.

The tide data from nearby Mosquito Bank and Tavernier Key (Fig. 2) were used to adjust all depths to mean low water level. The mean tidal range is 2.2 ft (.66 m) and the spring range is 2.6 ft (.8 m) (U.S. Coast and Geodetic Survey, 1959). During spring tides the bank is subaerially exposed for short periods of time.

Circulation is due to currents generated by semidiurnal tidal exchange and winds. The general tidal movement of water on the bank has been observed to be from east to west. During ebb tide, the brownish colored water which drains from the surface peats on Rodriguez Key flows southwest across the bank.

In the Rodriguez Bank area swells are absent and only wind-generated waves are present. The prevailing winds are easterly (Fig. 4); they are predominantly from the southeast during the summer months and from the northeast during the winter months. Because of these wind directions, only the windward bank margin receives frequent wave agitation. Rodriguez Bank is well protected from high winds by a proximate land area to the north and west and by the numerous shoals on the south and east which characterize the back reef of the Florida Reef Tract (Fig. 2).

Temperature and salinity variations for the area are expected to be generally similar to those of the reef tract. The temperature range for the reef tract is 15°–33°C, and the range in salinity is 32–38‰ (Ginsburg, 1956).

The east end of Rodriguez Bank is within the John Pennekamp Coral Reef State Park.

ECOLOGIC ZONES

The surface of Rodriguez Bank and continuous sea floor support a large population of sedentary marine plants and animals. Many of these organisms have calcareous skeletons, but only green algae, red algae, and corals are major contributors to the marine sediments. Mangroves and marine grasses do not calcify; Mangroves contribute organic sediment whereas marine grasses do not. The observed growth density of the principal living organisms is related to water depth and movement, and their distribution defines four distinct ecologic zones: *Porites* (coral) zone, *Goniolithon* (red algae) zone, grass and green algae zone, and mangrove zone (Figs. 3 and 5).

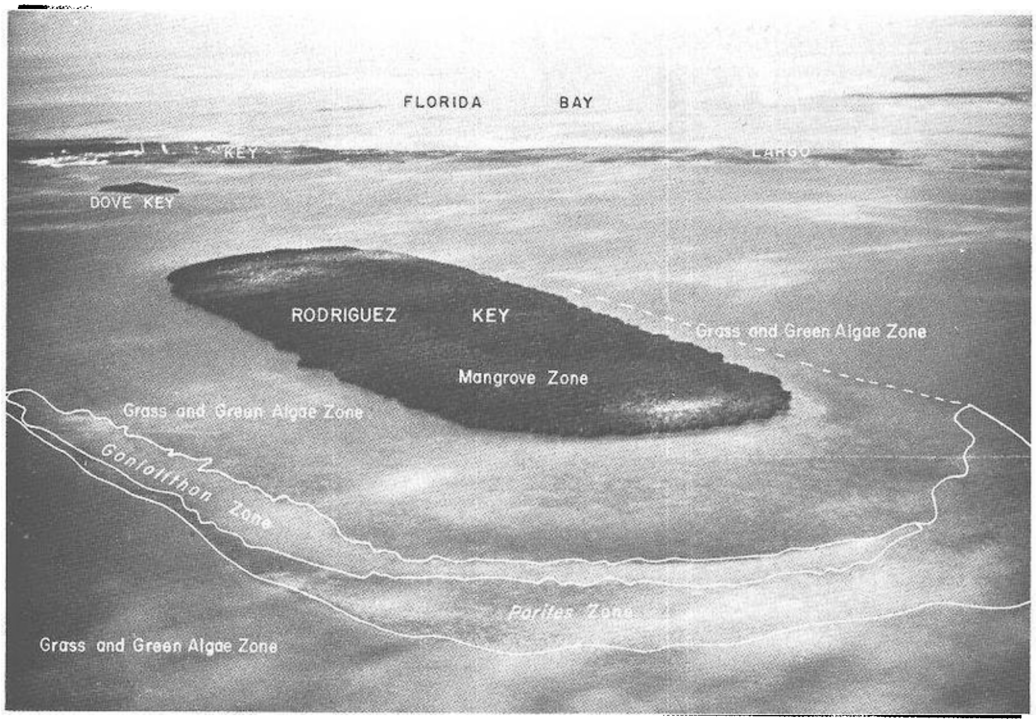

FIG. 3.—Aerial photograph of Rodriguez Bank.

Porites Zone.—The branching small finger coral *Porites divaricata* (Fig. 6) is the dominant organism of a well-defined zone at the windward bank margin.

The depth of this zone is 1 to 4 ft (.3 to 1.2 m). The upper limit of living *Porites* is coincident with the low water spring tide level of 0.9-ft (.27 m) below mean low water. The reason for the lower depth limit is not known. Possibly *Porites* is being crowded out by cushions of the green alga *Halimeda opuntia.*

Porites is not cemented to the bottom but the branched colonies are wedged against each other or held in place by the intergrowth of sponges and green algae. The branches range from 6 to 13 mm in diameter and are stick-like in form. They are fragmented by organisms and easily broken by wave agitation to sand and gravel size particles. Fragments less than 200 μ are rare.

Goniolithon Zone.—*Goniolithon* sp., a branching calcareous form (Fig. 7) is the only calcified red alga in this area. It inhabits the shallowest water at the windward margin of the bank forming a well-defined zone (Fig. 5). Branched growths of *Goniolithon* entwine to form a dense, forestlike growth that completely covers the bottom. Nevertheless, individual clumps are easily picked up. The branches range in size from 1.3 to 4.5 mm in diameter and are broken to sand and granule size fragments by wave surge and by organisms. Fragments less than 1 mm in size are rarely seen in sediments.

Grass and Green Algae Zone.—Marine grass, *Thallassia testudinum,* (Fig. 8) and green algae (Fig. 9) are the dominant organisms of this zone. These plants live throughout the reef tract and Florida Bay from the intertidal zone to depths of 40 ft (12 m) or more. In the Rodriguez Bank area, marine grasses and green algae are common and locally abundant from the bank environment, which is partially exposed at low water, to the off-bank environment where the water is deeper and conditions more uniform.

Marine grasses are not calcified but are important in sedimentation because: (1) their long leaves coated with organic slime trap fine sediment on contact and allow suspended sediment to settle to the bottom (Fig. 8); (2) these leaves provide surfaces for attachment or food

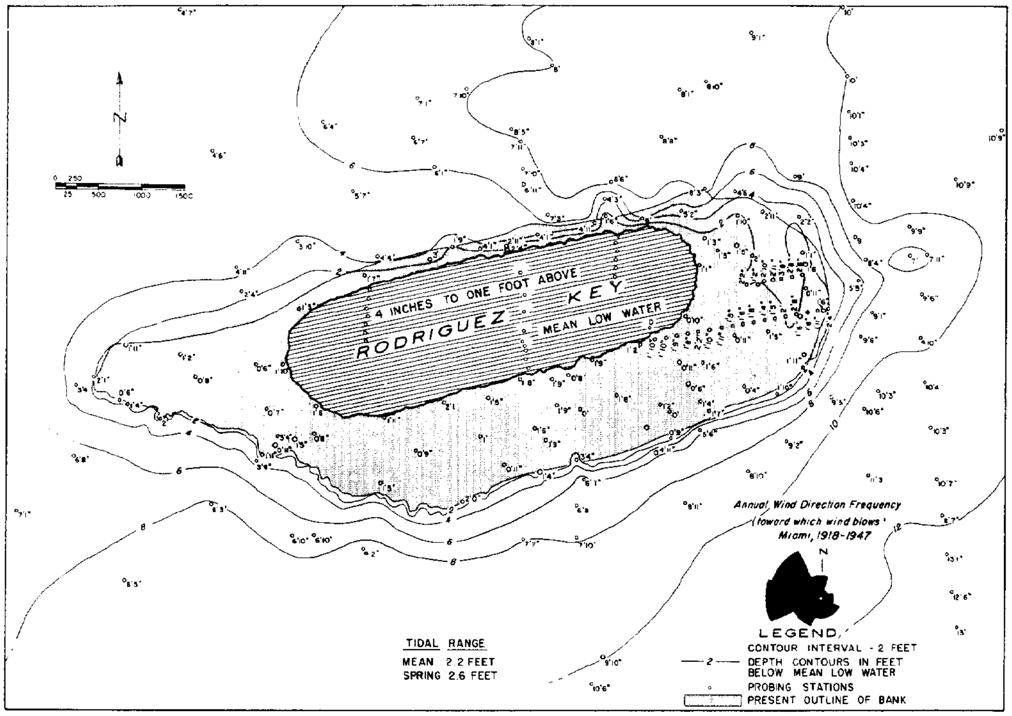

FIG. 4.—Top of Recent sediment surface (bathymetry).

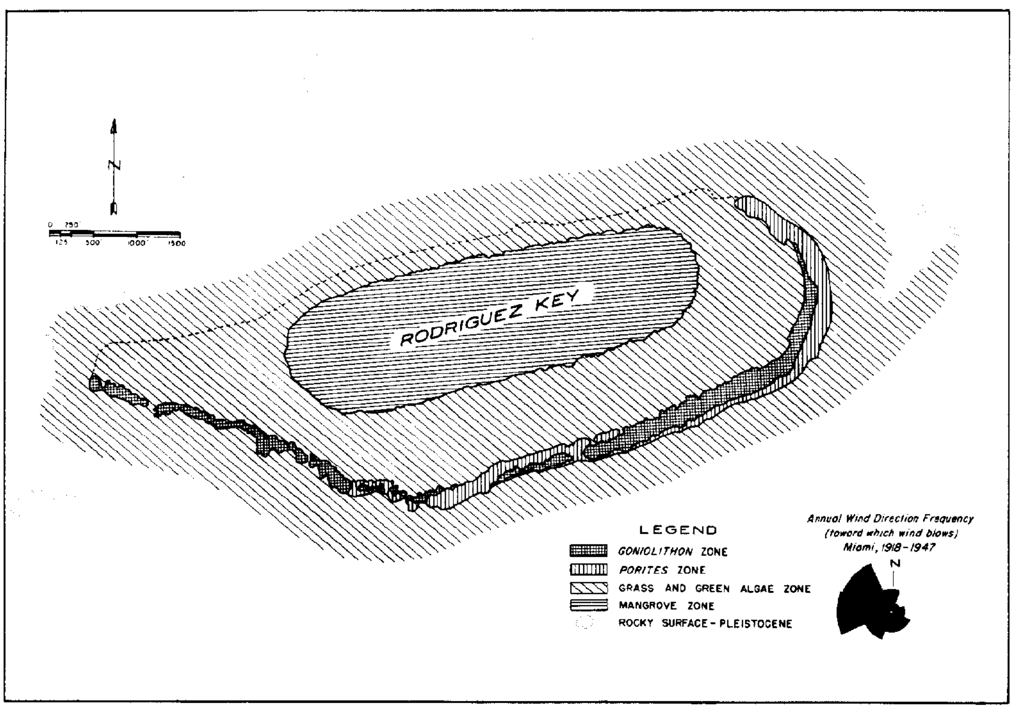

FIG. 5.—Surface zonation of dominant living organisms.

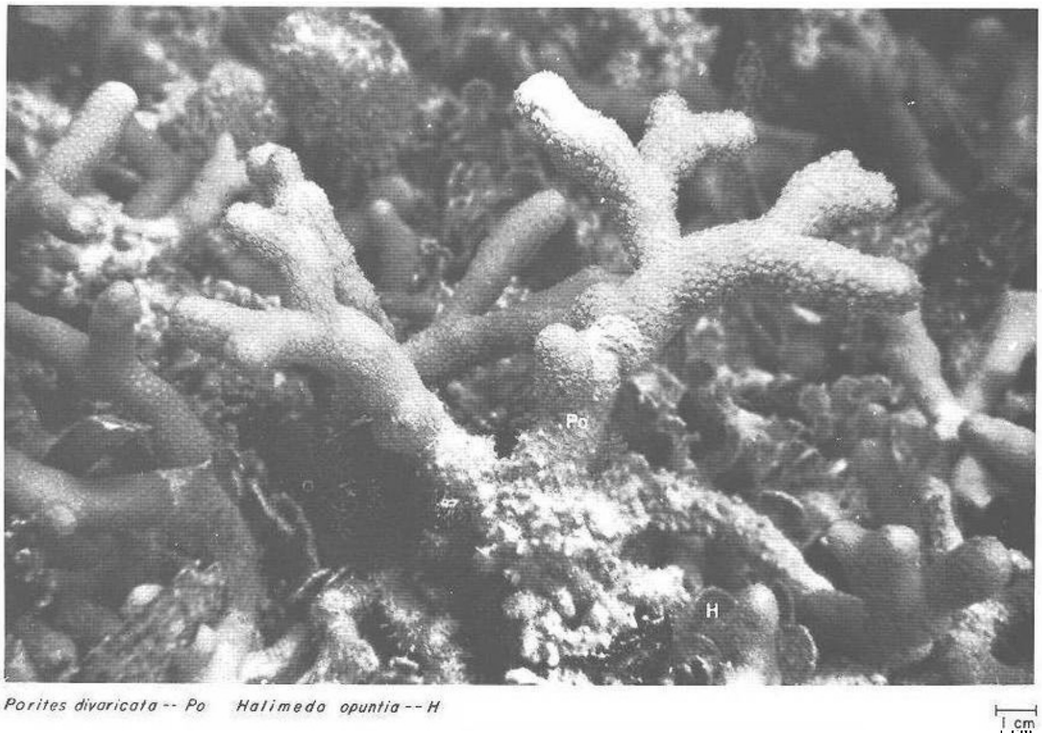

FIG. 6.—Underwater photograph of *Porites* zone, Rodriguez Bank.

gathering and a habitat for benthonic organisms, and (3) the meshlike system of roots and rhizomes stabilizes the sediment as soon as it is deposited (Station 8162.1, Fig. 14).

The skeletons of calcareous green algae produce sand, silt, and clay size particles. *Halimeda tridens* and *Halimeda opuntia* (Fig. 9) are segmented, heavily calcified forms which disintegrate postmortem. *Halimeda tridens* is an erect branching type, whereas *Halimeda opuntia* forms cushionlike masses. *Halimeda* plates have abundant unoriented pores and the segments are easily broken by organisms as they nibble on them in the uncalcified portion that serves as food.

Penicillus sp., *Rhipocephalus* sp., and *Udotea* sp. (Fig. 9) are other calcified green algae present in this zone. Their stems and filaments disintegrate to clay size crystalline particles (Stockman, *et al.*, 1967).

Mangrove Zone.—Rodriguez Key is a dense forest of red mangroves (*Rhizophora mangle*) (Fig. 10). The surface of the key is subaerially exposed at low tide and inundated at high tide. Mangroves contribute peat sediments.

SURFACE SEDIMENTS, THEIR ORIGIN AND DISTRIBUTION

Surface sediments in the Rodriguez Bank area vary from skeletal sands and gravels to variable mixtures of lime mud and skeletal sand (Fig. 11). Over half of the total sediment is greater than 1/16 mm in particle size, and these particles are of recognizable skeletal origin. *Halimeda* is the most abundant recognizable skeletal constituent (Fig. 12). Other constituents are fragments of *Goniolithon*, *Porites*, mollusks and foraminifers. Skeletal constituents comprising less than 5% are not included.

The distribution of the textural sediment types in the Rodriguez Bank area is determined by the density and relative production of the individual skeletal contributors, the size and nature of the skeleton, and its susceptibility to fragmentation. Burrowing organisms frequently mix sedimentary particles across facies boundaries. Locally, sorting by wave action modifies the sedimentary textures, but for the area as a whole it has little effect.

The surface sediment distribution (Fig. 11) is based on the visual examination of the entire bank and the binocular examination of the up-

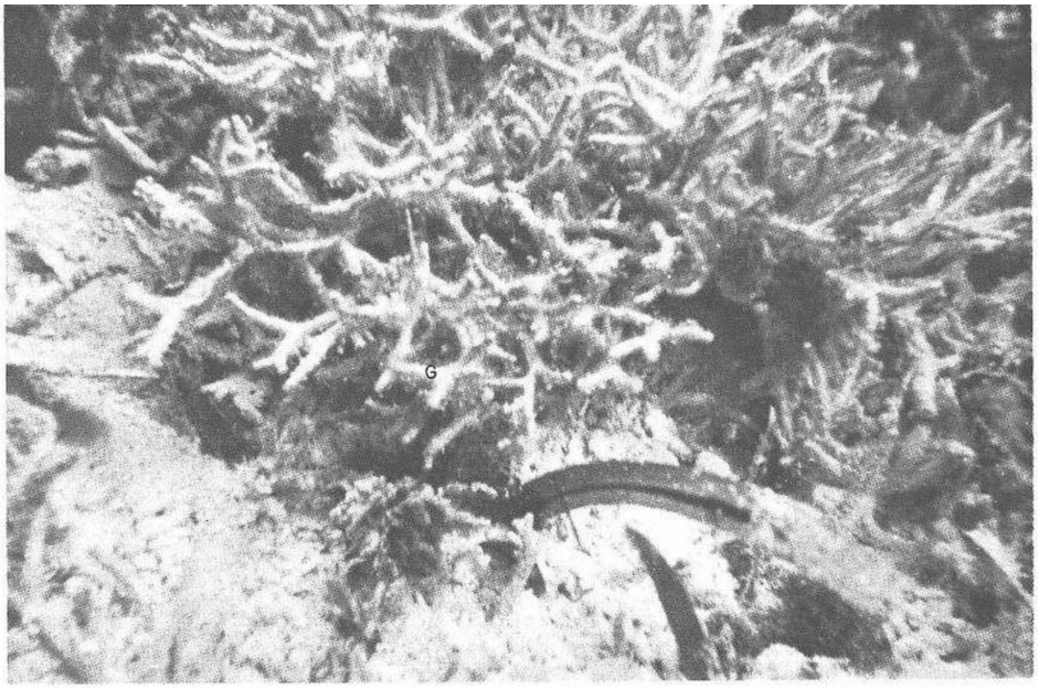

FIG. 7.—Underwater photograph of *Goniolithon* zone, Rodriguez Bank.

permost foot of sediment from 32 cores. These sediments are related to the bank, windward bank margin, off-bank, and Rodriguez Key environments in which they occur. The bank environment is defined as an area of very shallow water which is partially exposed at low water. On the north side of Rodriguez Key the seaward edge of the bank is roughly coincident with the 4-ft bathymetric contour line. The windward bank margin environment is a belt which is continuously agitated and wet by waves even at low water. The off-bank environment is the area of deeper water where more uniform conditions prevail. The Rodriguez Key environment is subaerially exposed at low tide and inundated at high tide.

Windward Bank Margin Sediments.—Goniolithon and *Porites* are the predominant constituents of the skeletal sands and gravels at the windward bank margin (Fig. 13). Other than these constituents, the green alga *Halimeda* is the most abundant. It occurs as gravel, sand, and silt size fragments.

Other less common constituents are mollusks and foraminifers, fecal pellets, calcispheres, echinoid spines, and worm tubes measuring 600 μ in diameter. The mollusks and foraminifers occur as whole forms and sand size fragments. The fecal pellets are of sand size and are composed of lime mud. The calcispheres are spherical and hollow with a diameter ranging from 150 to 200 μ and have a wall thickness of 20 μ. A. W. Rupp (1967) and D. S. Marszalek (1975) describe Rodriguez Bank as providing an optimum environment for the growth of *Chalmasia*, a calcareous green dasycladacean algae that forms reproductive cysts known as calcispheres.

The scarcity of lime mud at the windward bank margin is attributed to the relatively sparse distribution of *Penicillus*, *Rhipocephalus*, and *Udotea* which contribute clay and silt size lime particles, the low-energy wave action and water movement which inhibit settling of these fine particles, and the sparsity of marine grass as a trapping agent.

Bank and Off-Bank Sediments.—In contrast with the skeletal sands and gravels which characterize the windward bank margin, the bank

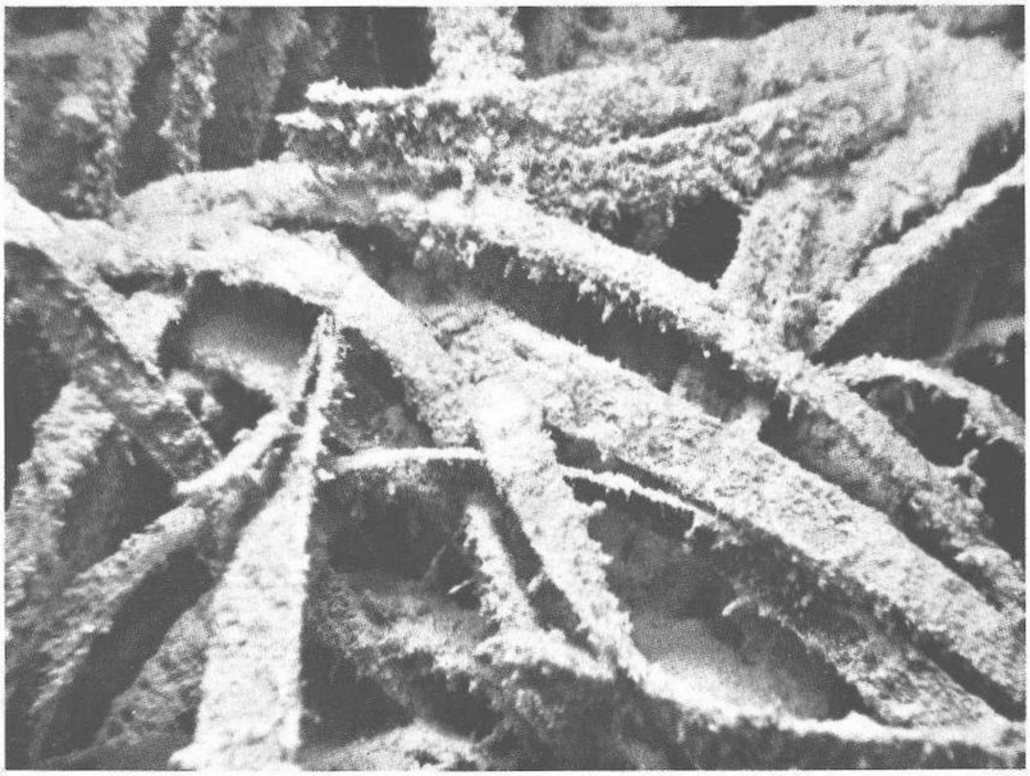

FIG. 8.—Underwater photograph of "fine" lime sediment trapped by organic slime on marine grass, *Thallasia testudinum,* Rodriguez Bank.

and off-bank sediments are mixtures of lime mud and skeletal sand (Fig. 14) that vary from predominantly skeletal sand with minor amounts of lime mud to lime mud with floating skeletal sand and gravel. A volumetric estimate of lime mud in surface sediments was computed by point-counting eight thin sections from the bank environment and one thin section from the off-bank environment plus low power microscopic particle percentage estimates of core slabs. The results showed that the amount of lime mud ranged from 40 to 68% with an average of 57%.

Halimeda is the dominant recognizable constituent of both the coarse and fine sand fraction (Fig. 12). Sand and gravel size tests and fragments of mollusks and foraminifers are common. Other sparse constituents are fragments of *Porites,* silt size spicules, and calcispheres. Locally, in bank sediments, calcispheres constitute 5% of the sediment. Colonial corals other than *Porites,* solitary corals, and echinoid spines are sparse in off-bank sediments and are absent in bank sediments.

The sand size fraction is coarser adjoining the bank north of the key and adjoining the windward bank margin and becomes finer grained with increasing water depth. At a depth of 8 to 10 ft (2.4 to 3 m) the sand size fraction is very fine to fine.

On the seaward side of the windward bank margin, where the water depth is 4 to 6 ft (1.2 to 1.8 m), the sediments are skeletal sands (Fig. 11) composed almost entirely of *Halimeda* with minor amounts of lime mud.

There are four possible sources for the lime mud (particle size less than $\frac{1}{16}$ mm) in the bank and off-bank sediments.

(1) The green algae *Penicillus, Rhipocephalus,* and *Udotea* disaggregate postmortem to clay size aragonite (Stockman, *et al.,* 1967). These algae grow abundantly in the bank and off-bank environments.

(2) Lime mud is produced by organic and

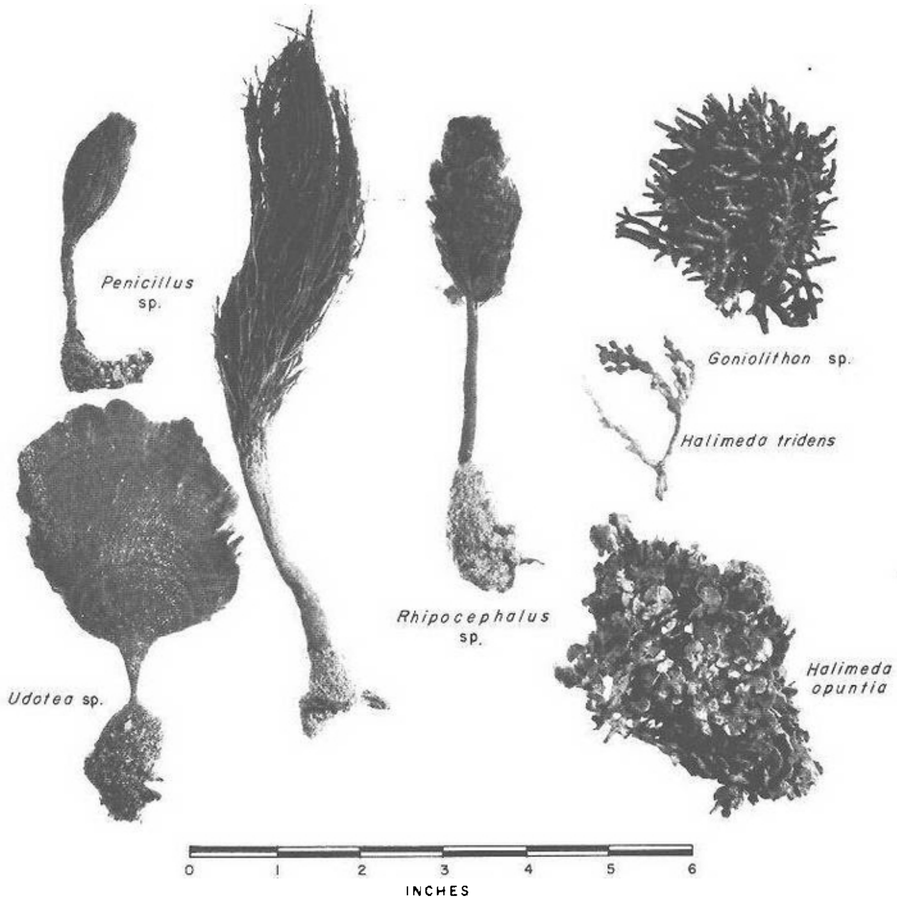

FIG. 9.—Sediment-contributing green and red algae, Rodriguez Bank area.

mechanical breakdown of larger skeletal debris. Mechanical attrition of skeletal particles in this area is insignificant because of the low-energy wave action. Therefore, the agent responsible for the majority of skeletal breakdown is believed to be the activity of organisms in their burrowing and feeding habits. All skeletons are fragmented, but *Halimeda* is most susceptible to organic breakdown because of its thin, brittle, porous plates. In thin sections, recognizable *Halimeda* ranges in size from whole segments (up to 2.5 cm long) to particles of finest sand size, and it seems reasonable that organic breakdown produces even finer particles. This kind of breakdown produces particles down to silt size fraction rather than clay size particles.

(3) Fine sediment stirred up from the bottom in the back reef by sustained winds of 15 mph or more (Ginsburg, 1956, p. 2398) may possibly be transported onto the bank, where it is trapped by marine grass.

(4) Physiochemical precipitation of fine aragonite mud is another possible source.

Considering these sources, the coincident position of the ecologic zones with their remains in the sediment as shown in Fig. 5, and the results by Stockman, *et al.* (1967), we conclude that *in situ* production by algae is favored as the dominant contributor of lime mud.

Rodriguez Key Sediments.—The only sediments which have been observed on Rodriguez Key are mangrove peats (Fig. 13). These peats are devoid of the remains of other organisms occurring in the area.

STAGES OF SEDIMENTATION

In order to study the three dimensional distribution of these sediments on Rodriguez Bank,

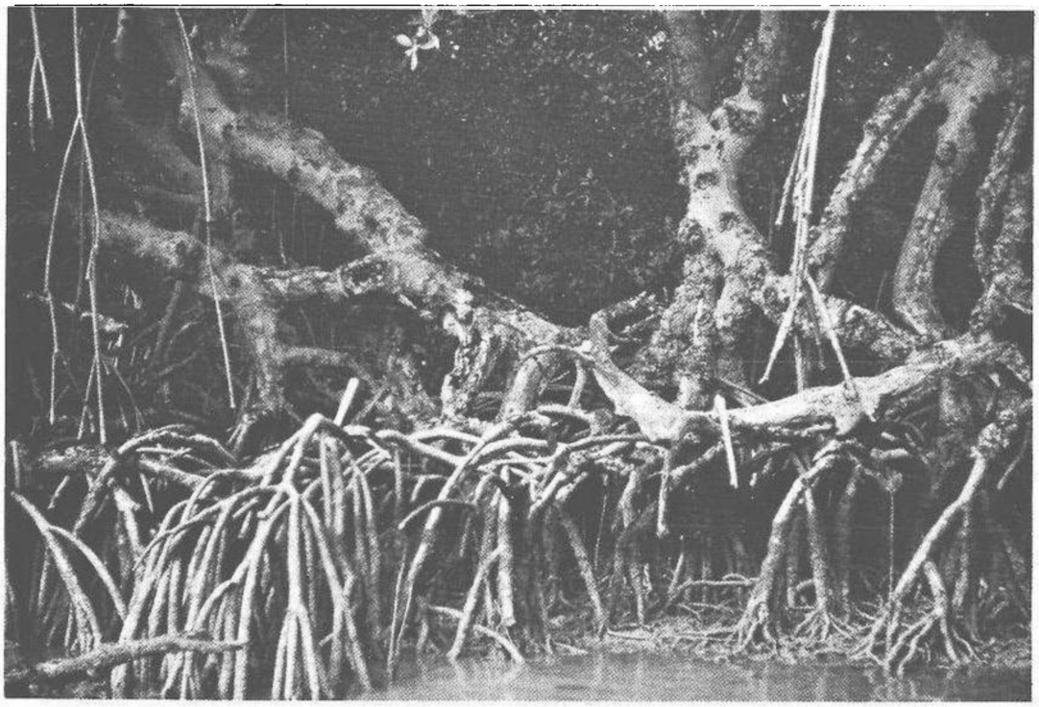

FIG. 10.—Mangrove forest on Rodriguez Key.

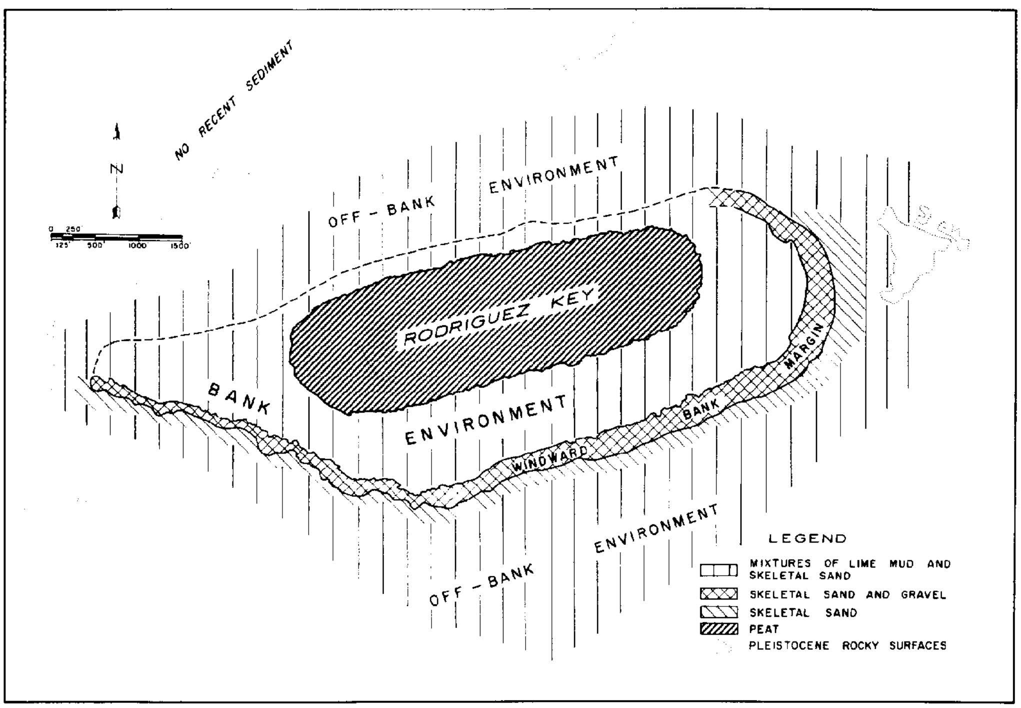

FIG. 11.—Surface sediments and environments.

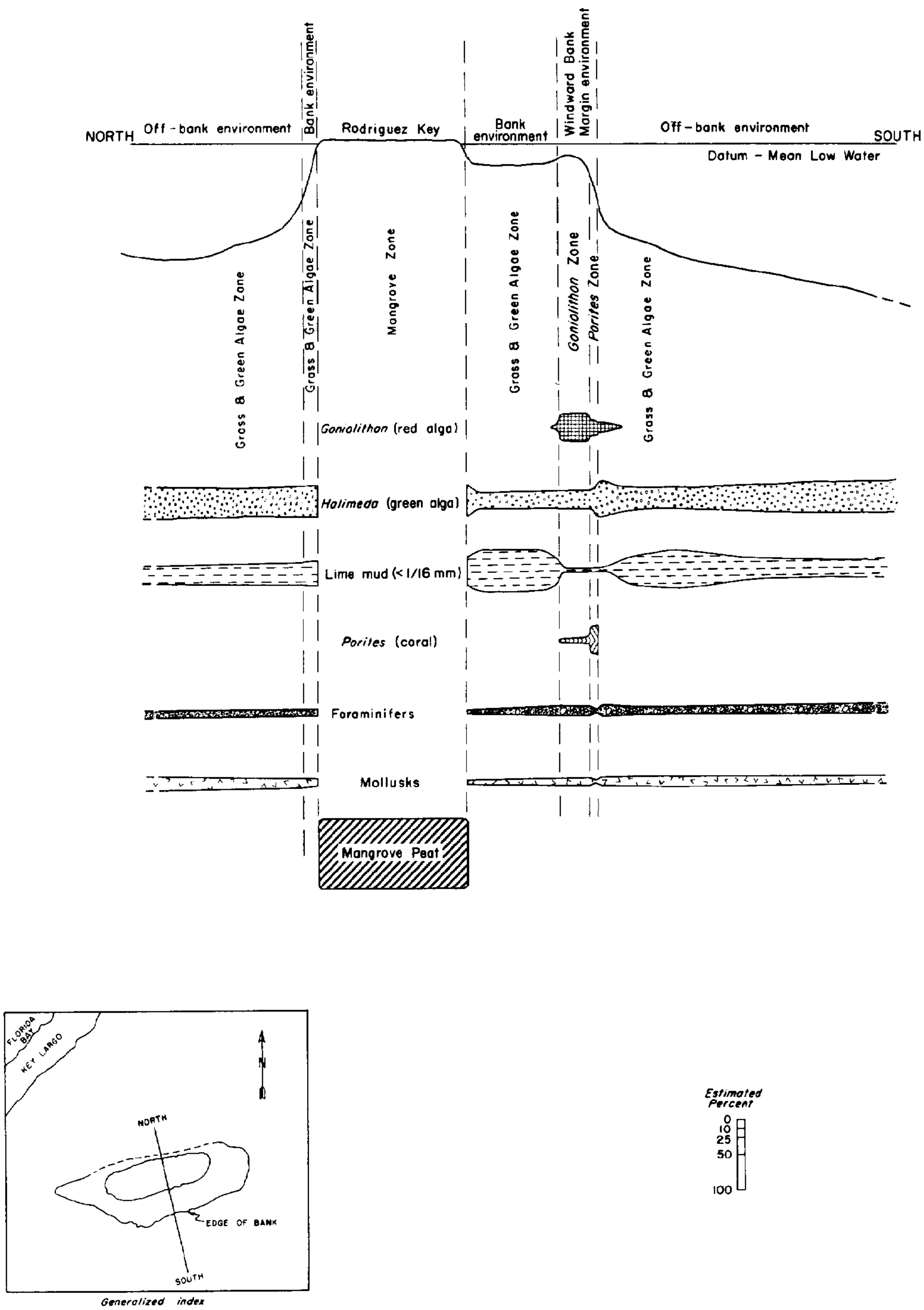

FIG. 12.—Generalized variations of the major constituents in surface sediments.

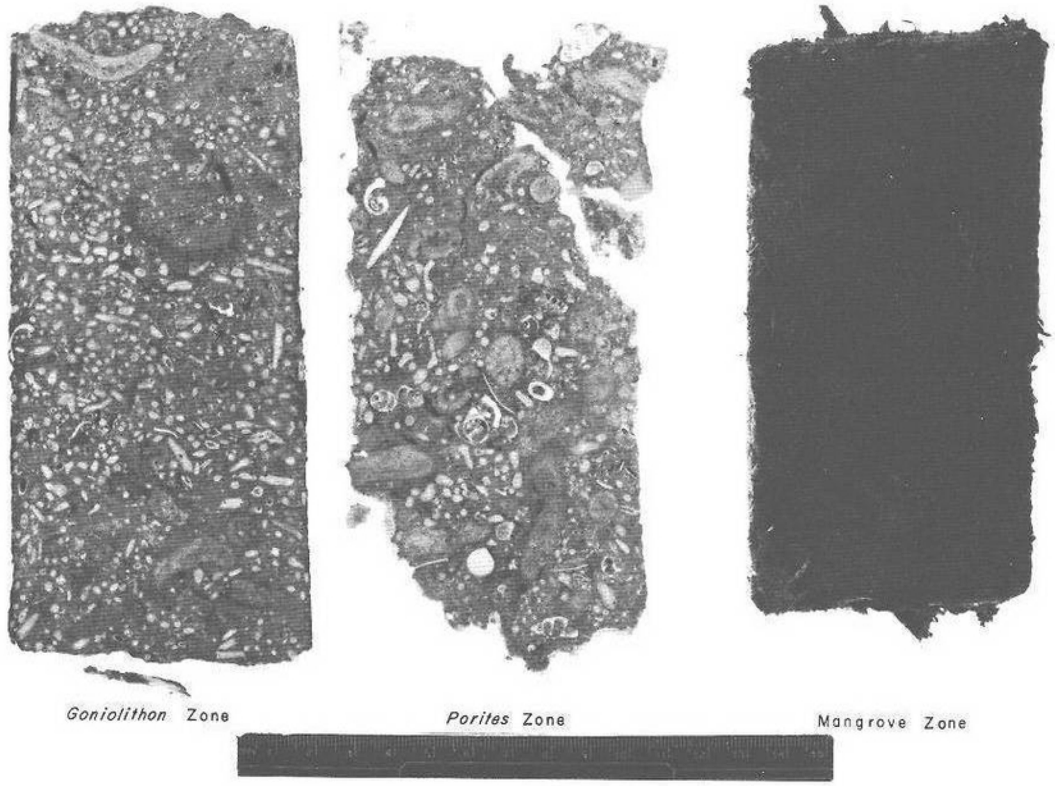

FIG. 13.—Slabs of plastic-impregnated cores of surface sediments in *Goniolithon*, *Porites*, and mangrove zones, Rodriguez Bank.

the area was probed and a series of cores were taken across the bank (Fig. 23). The results of this core examination are portrayed in the North-South and West-East cross sections, Figs. 16 and 17, respectively.

Sedimentation in the Rodriguez Bank area is divided into three stages based on differences in the lime sediments. The sedimentary environments of the subsurface sediments representing these stages are analogous to present-day conditions and related surface sediment in the Rodriguez Bank area and Florida Bay. An isopach map of these Recent sediments is shown in Fig. 15.

Stage I

Stage I is represented by lime mud sediments deposited during a relative rise in sea level to a present subsea of 17 ft (5.2 m). These sediments are confined to the re-entrant and the area seaward of this re-entrant (Fig. 18). The lime muds contain scattered delicate mollusk fragments and miliolid foraminifers. Silt size siliceous spicules are sparse to common. At station 9003 (Figs. 16 and 19), the lime muds are thinly laminated. At station 8174 (Figs. 17 and 19) which is located in the re-entrant, the thinly laminated lime muds contain common mangrove roots and abundant mangrove root hairs. Locally, mangrove peats may have accumulated and been preserved. Immediately overlying the rock floor and underlying the lime muds, the sediment is a mixture of lime mud and skeletal sand rich in mollusk fragments with scattered sand size fragments of Pleistocene rock. Similar mollusk-rich sediments overlie the rock floor in Florida Bay.

Stage II

Stage II is represented by lime mud sediments deposited from a present subsea of 17 ft (5.2 m) to a subsea of 6 ft (1.8 m) (Figs. 16 and 17) during a relative rise in sea level. Between a subsea of 17 ft (5.2 m) and 12 ft (3.7

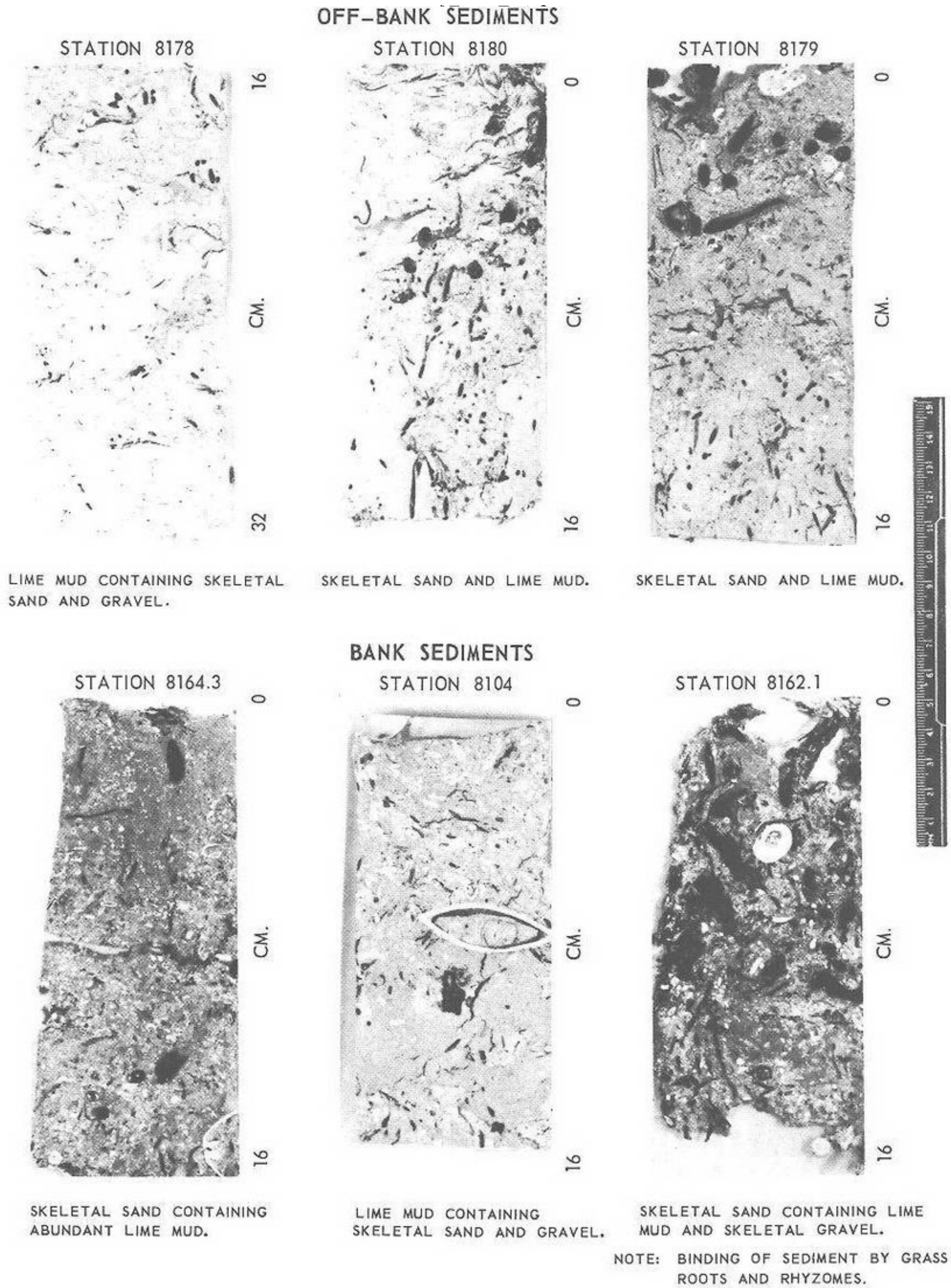

FIG. 14.—Slabs of plastic-impregnated cores of surface sediments in Bank and Off-Bank Environments, Rodriguez Bank.

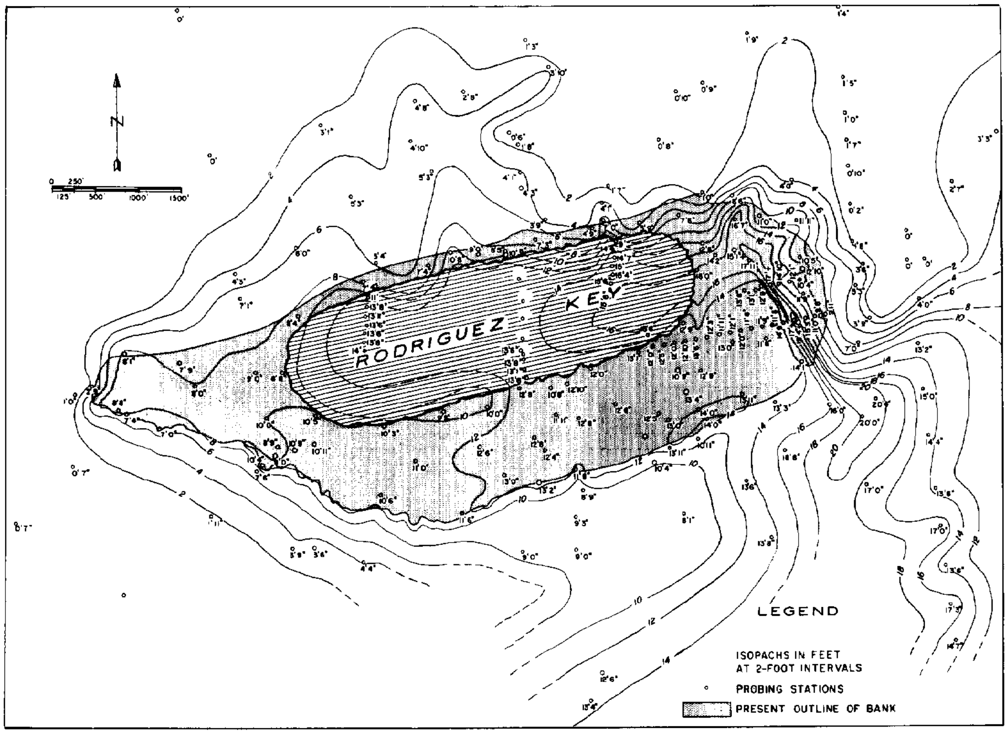

FIG. 15.—Isopach of Recent sediment.

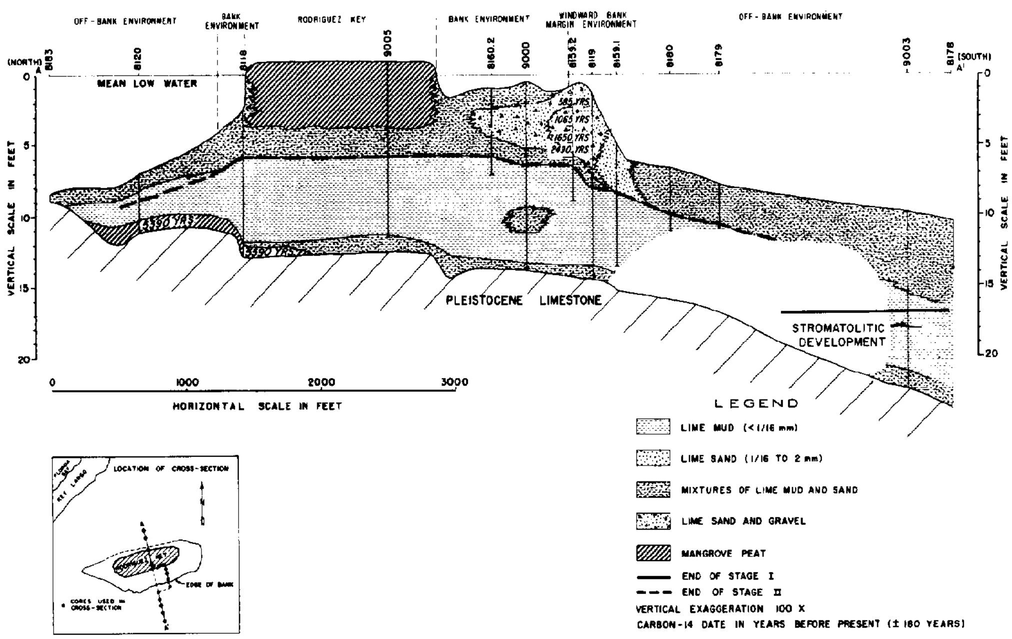

FIG. 16.—North-south cross section, Rodriguez Bank.

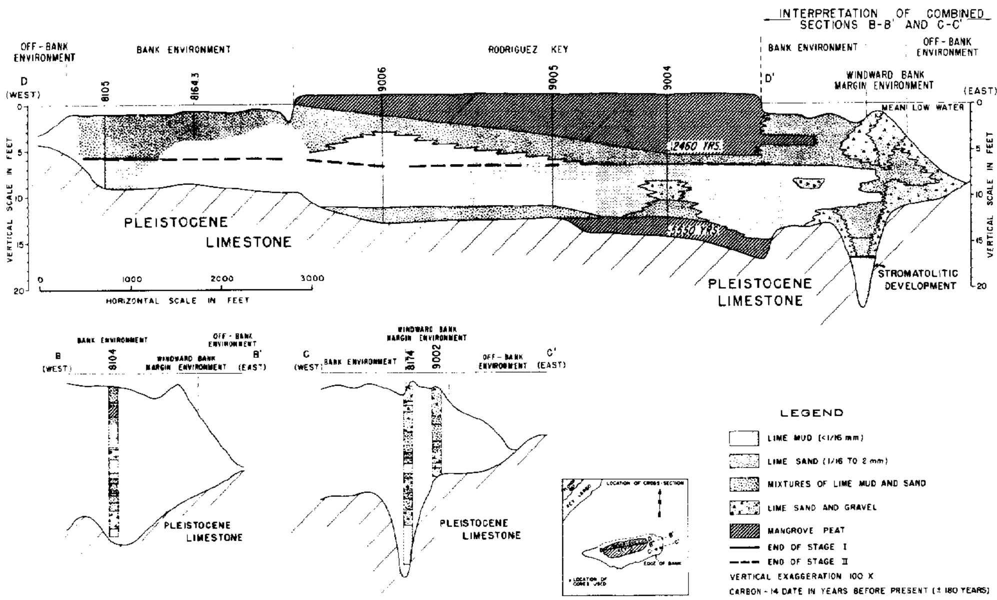

FIG. 17.—West-east cross section, Rodriguez Bank.

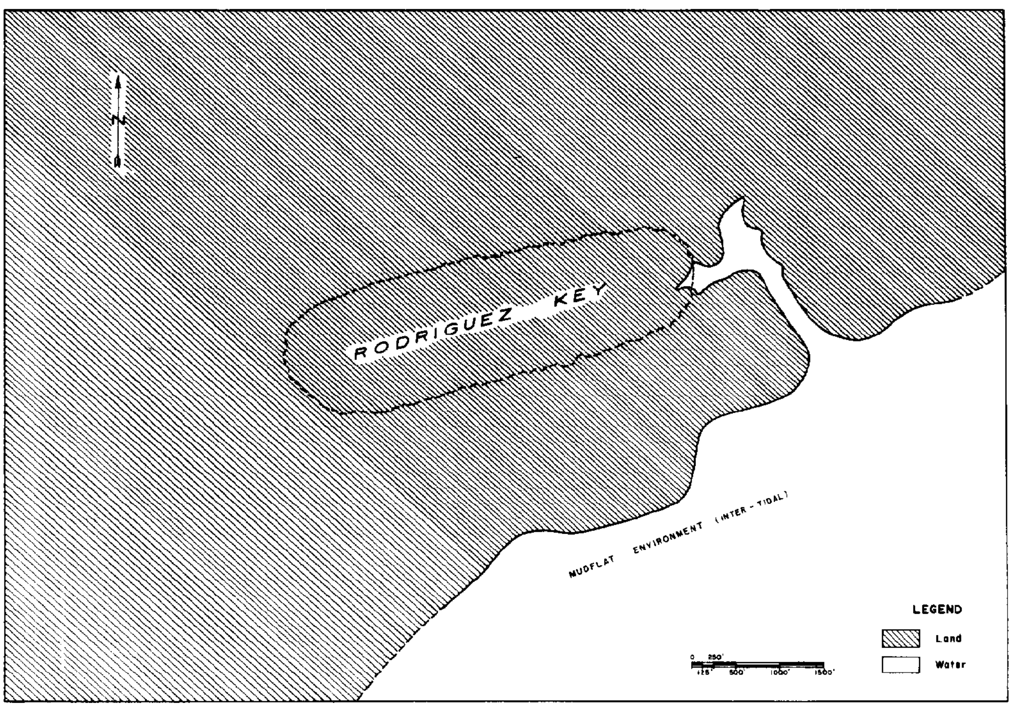

FIG. 18.—Paleogeology at a subsea of 17 ft.

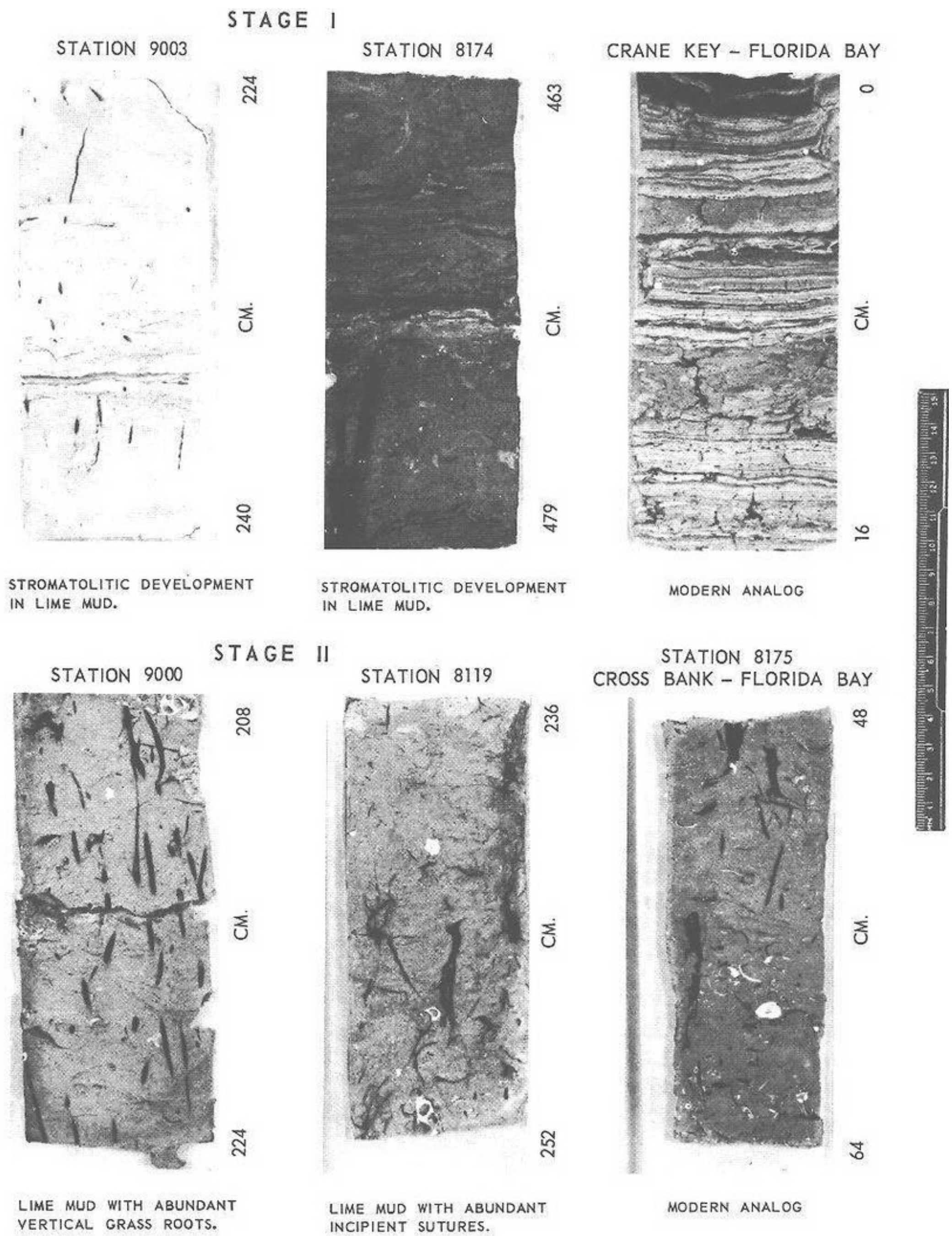

Fig. 19.—Slabs of plastic-impregnated cores of subsurface sediments, stages I and II, Rodriguez Bank, compared with modern analogs.

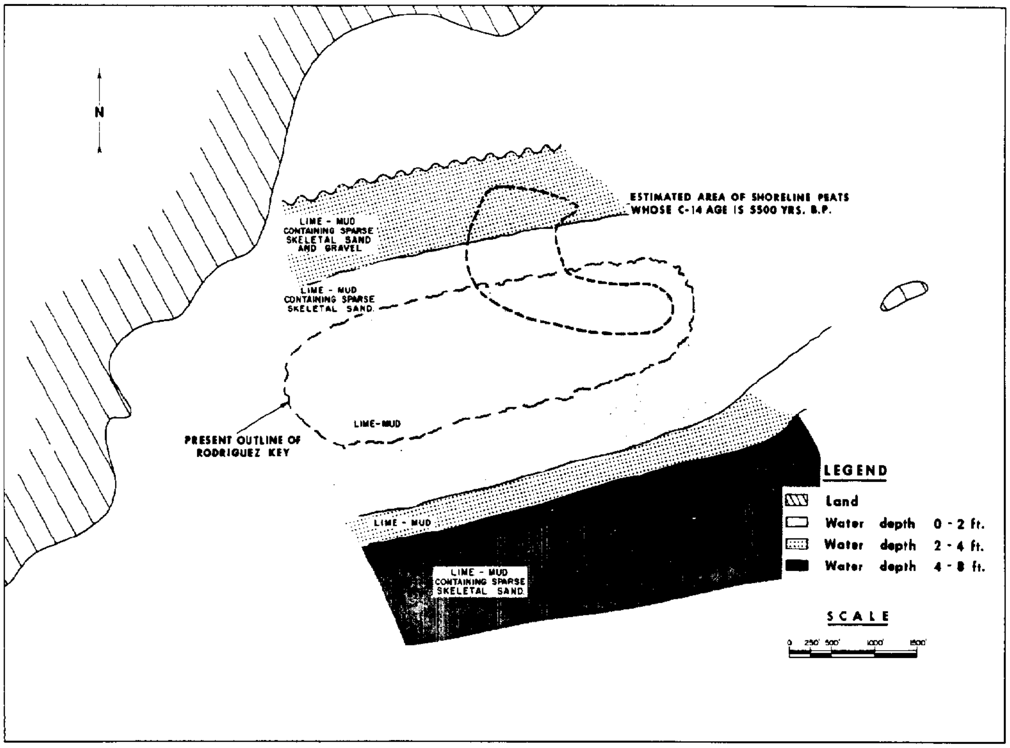

FIG. 20.—Paleogeology and sediment distribution at a subsea of 8 ft.

m) the sediments were confined to the re-entrant, the embayment underlying Rodriguez Bank, and the area seaward of the re-entrant. From a subsea of 12 ft (3.7 m) to 6 ft (1.8 m), lime mud sediments were deposited in the area now occupied by the bank. Lime muds are the predominant sediments of stage II. Figure 20 shows that Rodriguez was already well established as a mud bank at a present day subsea of 8 ft.

Locally, there are three areas where the sediments differ: (1) the area overlying the Pleistocene rock floor; (2) the re-entrant and the channels which incise the mud bank, and (3) the area seaward from the mud bank.

Mud bank sediments are lime muds containing sparse skeletal fragments of miliolid foraminifers, thin-shelled mollusks, and *Halimeda* (Fig. 19). Peneroplid foraminifers and silt size siliceous spicules are scattered. Grass roots and grass fragments are commonly observed in the lime muds. These mud bank sediments are compared with a core slab from Cross Bank, a Holocene mud bank in Florida Bay (Fig. 19).

The sediments immediately overlying the Pleistocene rock floor during this stage are mollusk-rich mixtures of lime mud and sand, and shore line peats (Figs. 16 and 17). The mollusk-rich sediment measures up to 1 ft (30 cm) in thickness and is very similar to the sediments which overlie the rock floor at the beginning of state I. The shoreline peats (Fig. 20) range in thickness from one centimeter to 46 centimeters (1½ ft).

During the relative rise in sea level following stage I, the re-entrant shown in Fig. 17 was filled with two distinct sediment types. At the margins, it appears that a shoulderlike *Porites* zone (see "Ecologic Zones") existed. The resulting sediments are skeletal sands and gravels composed predominantly of *Porites* fragments. Other than *Porites,* the most significant constituent is the green alga *Halimeda. Goniolithon,* foraminifers, mollusk fragments, and colonial corals other than *Porites* are common to sparse.

The first sediments of this stage in the central part of the re-entrant are skeletal sands composed predominantly of *Halimeda* fragments. Scattered occurrences of mollusks, foraminifers, fragments of *Porites,* other colonial corals, and *Goniolithon* are seen in the cores.

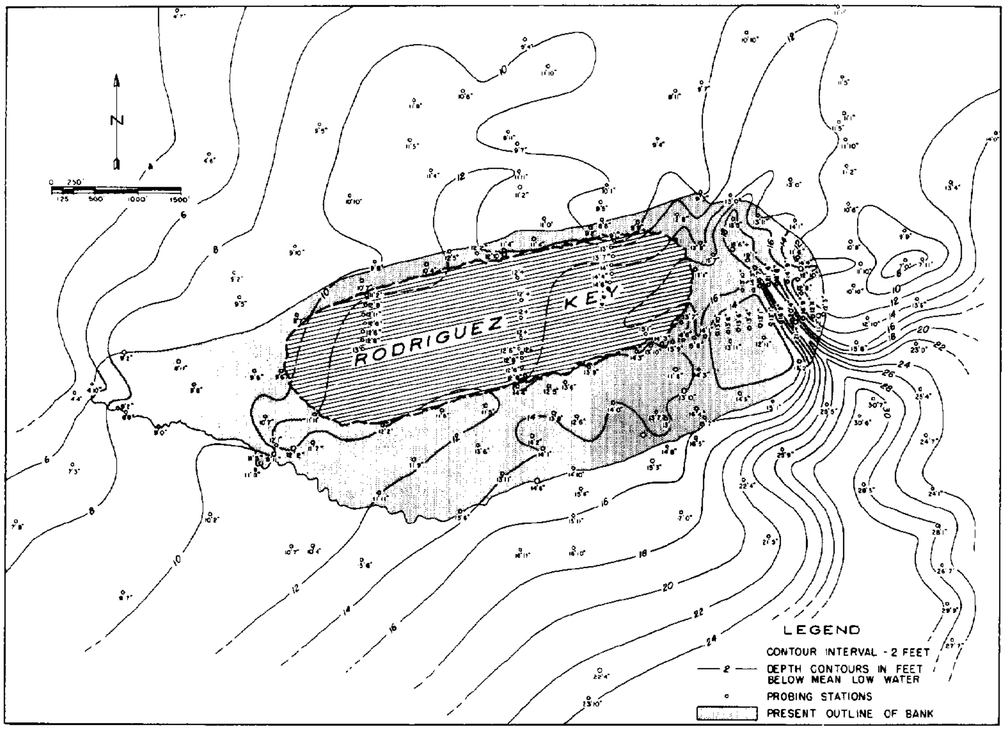

FIG. 21.—Top of Pleistocene bedrock.

This skeletal sand grades upward into lime muds.

During its development the mud bank was locally incised by channels or passes. One of these is recognized at station 9004 (Fig. 17). The lower sediments in this channel are mixtures of lime mud and sand. *Halimeda* is recognized as the dominant sand size constituent with whole forms and fragments of mollusks, foraminifers, *Goniolithon* and *Porites*. Common plant residues include grass, mangrove roots, and mangrove root hairs. The upper sediment in this channel is skeletal sand containing gravel size skeletal fragments. *Halimeda* is again the dominant sediment constituent.

The contemporaneous sediments which accumulated in deeper water outside of the periphery of the mud bank are lime muds containing whole forms and fragments of peneroplid and miliolid foraminifers, mollusks, and colonial corals. North of the mud bank at station 8120 (Fig. 16) the contact between the sediments of stage II and stage III is recognizable, whereas at station 9003 seaward from the mud bank this contact is not easily discernible.

Stage III

Stage III represents the deposition of lime sediments from a present subsea of 6 ft (1.8 m) to the present level during a relative rise in sea level (Figs. 16 and 17). These particulate sediments differ markedly from those of stage II by being coarser. The organisms and sediments which characterize this stage are identical with the ecologic zones and related sediment distribution on present-day Rodriguez Bank.

INITIATION AND DEVELOPMENT OF RODRIGUEZ BANK

Sea level was at least 20 ft lower than at present some 10,000 years ago (Shepard and Suess, 1956, pp. 1082–1083). At that time the rock floor in the area of Rodriguez Bank was subaerially exposed. The oldest peat dates which overlie the rock floor are 5,500 YBP (Figs. 16 and 17). The Pleistocene rock floor beneath Rodriguez Bank has two major features as shown in Fig. 21: (1) a narrow re-entrant up to 8 ft below the surrounding rock floor, and (2) a large embayment (12-ft contour)

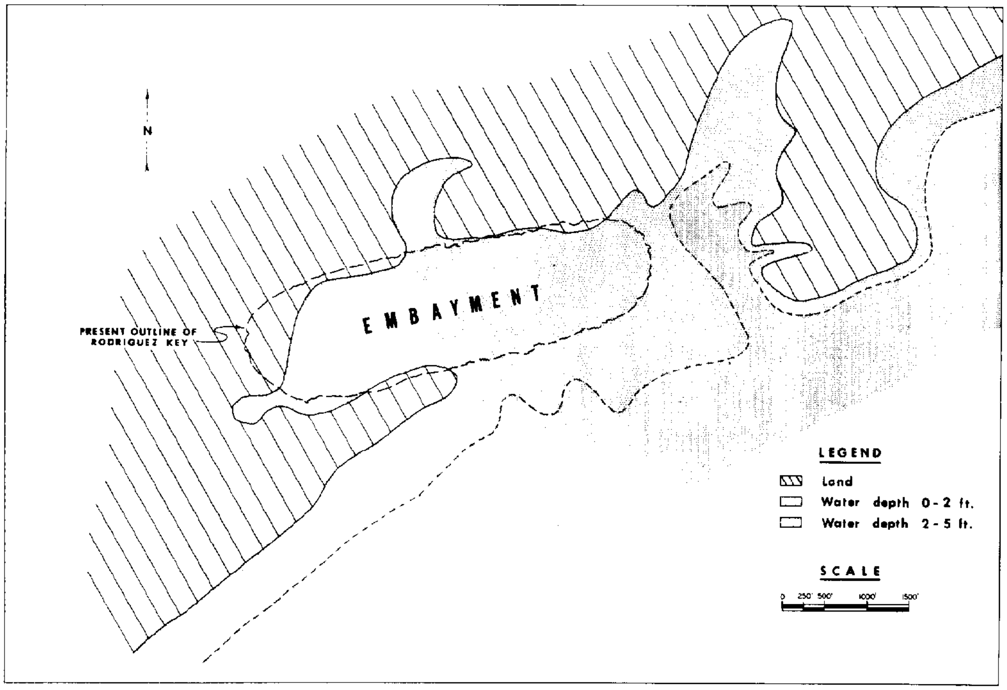

FIG. 22.—Paleogeology at a subsea of 12 ft.

which was the site where Rodriguez Bank was initiated. A subsidiary feature is the rocky knob east of the re-entrant. The trend of this irregular Pleistocene rock floor is northeast-southwest paralleling the present-day Florida Keys. The origin of the features which characterize this rock floor is not well established—they may be in part depositional if the limestone is Key Largo limestone, or they may be entirely or partly erosional.

The regional topography when sea level was 20 feet lower than at present is not known, particularly on the seaward side of Rodriguez Bank. The linear shoal White Bank, which is located approximately 3 miles seaward from Rodriguez Bank (Fig. 2), was previously thought to be Pleistocene rock, but probings show that there is 10 to 15 ft (3 to 4.8 m) of unconsolidated sediment over the rock floor. Thus, in all probability, White Bank did not exist at this time, and the rock floor was more or less uniform.

During the relative rise in sea level the first areas to be flooded were the deeper areas seaward of the present-day bank and the narrow re-entrant (Fig. 18). These early lime mud sediments were deposited during stage I. That similar conditions prevailed throughout the Rodriguez Bank area at this time is indicated by the stromatolitic development occurring at a subsea of 18 ft at both stations 9003 and 8174. These are compared with Recent stromatolites accumulating on the intertidal mud flats of Crane Key in Florida Bay (Fig. 19). Perhaps the bare rock floor was flat enough and far enough from the edge of the platform to allow these intertidal sediments to be deposited, or that sediment was accumulating on White Bank restricting circulation in the Rodriguez Bank area.

At a present subsea of 17 ft (5.2 m), there is a change in the sediments which separates stage I from stage II (Figs. 16 and 17). The core at station 9003, seaward of present-day Rodriguez Bank, suggests that upward of 17 ft (5.2 m) subsea conditions were continuously changing in this area because the lime muds contain progressively more skeletal debris.

During early stage II, skeletal sands and gravels were accumulating at the margins of the re-entrant while skeletal sands were being deposited in the re-entrant (Fig. 17, C-C′). These sediments suggest that the flow of water in the re-entrant was concentrated and provided more agitation and ecologic conditions favorable to organisms producing skeletal sand and gravel. The grading upward from skeletal

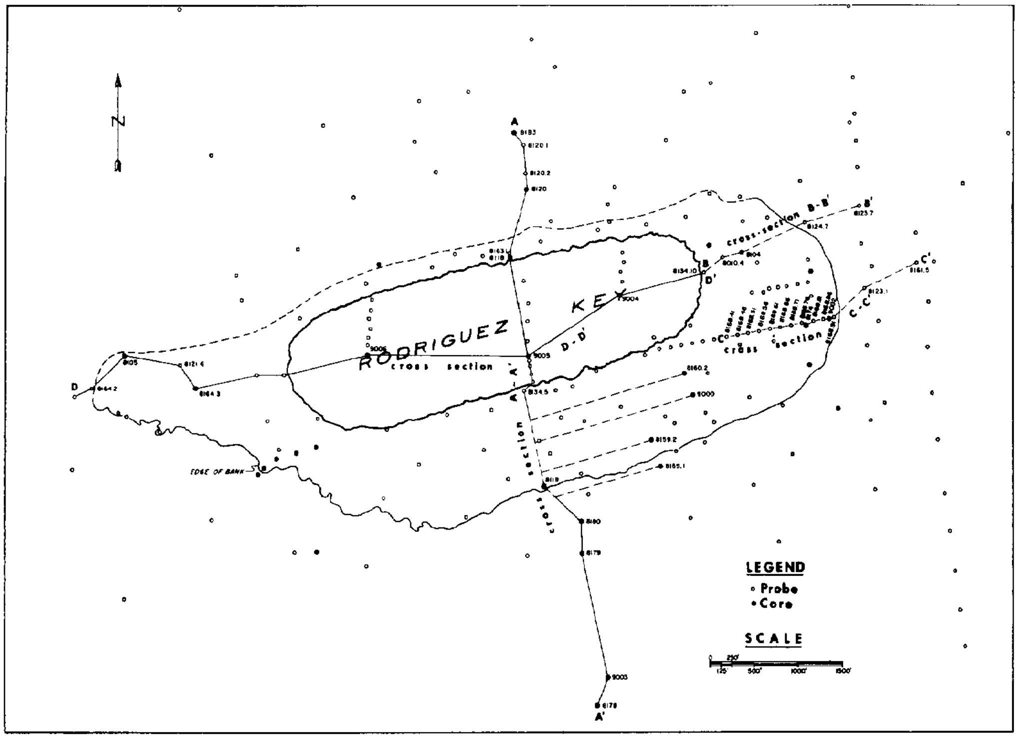

FIG. 23.—Index of probings, cores, and control stations used in the cross sections.

sands to lime muds shows that as the re-entrant was being filled, there was less agitation.

At a present subsea of about 12 ft (3.7 m) the area beneath the mud bank was flooded. This area is shown in Figure 22 as a shallow platform embayed by a shoreline. This embayment apparently acted as a trap for transported "fine" sediment. As soon as a thin veneer of fine sediment was deposited, marine grasses began to grow. Once established, these marine grasses stabilized the sediment, provided a habitat for other plants and animals, and, with their ability to trap and bind sediment, produced the mud bank of stage II. Rocky surfaces, bare of sediment, characterize present-day straight shorelines seaward along the Florida Keys, but within any sizable embayment or in the lee of projecting points or rocky islands, fine sediment is accumulating in shallow areas that are sparsely to thickly covered by marine grasses. The mangrove peats which overlie the rock floor may have provided a "rich soil" for the initial growth of the marine grasses.

The low-relief lime mud mound of stage II developed as a near surface accumulation as sea level continued to rise due to grass stabilization and because organic activity is more intense in very shallow water (a few feet) than in deeper water.

The sediments which accumulated during this stage are not presently being deposited on Rodriguez Bank but are similar in many respects to the marginal mud banks in Florida Bay. Both are dominantly lime muds containing skeletal fragments of foraminifers and thin-shelled mollusks (Fig. 19).

Ginsburg and Lowenstam (1958, p. 312) suggested that trapping and binding by marine grass is the major process that has produced the mud banks in Florida Bay. These grasses trap fine sediment from suspension in a manner analogous to flypaper (Fig. 8). They allow locally derived clay and silt lime particles and crystals to settle to the bottom by reducing wave action and diminishing current flow. The grass leaves extend up to a height of about 1 ft (30 cm) above the sediment and provide a habitat for many animals and plants. Worm tubes, foraminifers, and bryozoa have been observed on these grass leaves. As soon as deposited, the sediment is "fixed" by grass roots and rhizomes.

Live roots have been observed to extend 38 cm (15″) into the sediment.

Marginal mud banks in Florida Bay have *Porites* and *Halimeda* living in channels that cut into the mud bank on the seaward side. These channels appear to be similar to those which incised the low-relief mud bank at Rodriguez. The skeletal sands and gravels which occur in these channels and in the re-entrant suggest that the flow of water in these areas is concentrated and provides more agitation and ecologic conditions favorable for organisms producing skeletal sand and gravel.

The origin of sand and gravel size skeletal debris in the sediments can be related directly to the organisms. The origin of the lime mud is considered to be mainly *in situ* production by green algae contributing clay size aragonite crystals.

The mud bank was isolated at a subsea of 8 ft (24 m) as the sea continued to transgress the Pleistocene surface and the shoreline straightened. In spite of its isolation, the bank continued to develop relief and maintain itself. Figure 20 shows the paleogeology, the interpreted bathymetry over the bank, and the sediment distribution at this time.

At a present subsea of about 6 ft (1.8 m) the sediments on the bank changed abruptly from the lime muds of stage II to coarser lime sediments of stage III. Environmentally, this means going from restricted water circulation, which was not ecologically favorable for sand and gravel size skeletal producers, to open-water circulation such as that of the present, where ecologic conditions favored a greater population of skeletal sand and gravel producers.

This abrupt change in sediments is due to increased circulation in the back reef and flooding over White Bank (Fig. 2). The age and nature of White Bank are not known, except that it is sediment and not rock. It seems reasonable to assume that, like Rodriguez Bank, White Bank also developed during the relative rise in sea level and that by keeping pace with sea level, it formed a barrier to water circulation for Rodriguez Bank during stage II. Wind-generated waves are assumed to have been easterly as they are today. Then, at a subsea of about 6 ft (1.8 m) it was drowned by water flooding over and around it, and this permitted open circulation to extend to Rodriguez Bank.

With the advent of open-water circulation, a *Goniolithon* and *Porites* zone was established at the windward margin of Rodriguez Bank (Fig. 16). Because of the initial gentle slope, waves were able to wet continuously a wider area, which resulted in a very wide *Goniolithon* zone. The great production by skeletal sediment producers modified the slope to its present narrow zone that can be effectively wet by waves. During this stage the bank prograded seaward a distance of about 200 ft (61 m).

The westward thinning of mangrove peat (Fig. 17) suggests that the mangroves were first established at the east end of the bank and migrated westward over the bank. The effective dispersal of the mangrove seedlings likely occurred after stage III was established. According to Davis (1940, pp. 370–381), tides, local currents, and winds distribute the seedlings, and that *Rhizophora* communities begin in water less than 2 ft (.6 m) deep and are easily established in sediments with thick growths of turtle grass and algae.

The accumulation of lime mud on the bank surface is interpreted not to be altogether biogenic but is influenced by surface currents that transport loose mud size particles westerly across the bank to form a spit-like accretion.

CONCLUSION

Rodriguez Bank is a Recent mound of unconsolidated calcareous sediments deposited during a relative rise in sea level in the absence of vigorous wave action. The bank was initiated because an embayment in the Pleistocene rock floor acted as a trap for "fine" sediment. Once established, the mudbank developed as a near surface accumulation. Unlike modern coral-algal reefs, it has no rigid organic framework and plants are directly and indirectly responsible for the accumulation. During its early stages, the bank developed in an environment of quiet water where circulation was restricted but at a present day subsea of 1.8 m (6 ft) conditions changed to open water circulation. Although the hydrography and the density and relative production of the individual skeletal contributors changed, Rodriguez Bank maintained itself as a topographic feature.

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