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GEOLOGICAL SURVEY

Hoffa Reef: a shelfedge calcareous prominence in the northern Gulf of Mexico

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TABLE OF CONTENTS

INTRODUCTION

Hoffa Reef is a hard-rock, calcareous bank located about 50 km southwest of the Mississippi Delta on the Louisiana Continental Shelf edge (Fig. 1). The reef, which is part of a discontinuous belt of similiar features, forms a boundary between two major marine sedimentary provinces, the Continental Shelf and Slope. These shelfbreak features are important to the sedimentological, geotechnical, and geochemical dynamics of the Gulf of Mexico Continental Margin.

The northern Gulf of Mexico shelfbreak probably formed during the late Pleistocene epoch when eustatic sea level was lowered. During the last major regression of the late Wisconsin age, sea level in the Gulf of Mexico was about -140 m (Fisk, 1944) and the continental shoreline was approximately at the present day shelfbreak. Subsequently, the surficial strata of the exposed shelf were subjected to erosion, desiccation, leaching, and oxidation to form the most recent lithified weathered horizon encountered in test borings across the northern Gulf Shelf (Fisk and McClelland, 1959). These weathered fluvial and littoral sediments were submerged during the Holocene transgression and, because of their lithified nature, were often preserved. A few of these weathered deposits off the northern Gulf Coast are not covered by the mantle of Recent sediments. The purpose of this report is to describe the geology, mineralogy, and fauna of one of these submarine calcareous prominences, locally known as Hoffa Reef.

Modern carbonate shelfbreak features, such as the one described in this report, are morphologically distinct from their siliciclastic counterparts because of the dominance of *in situ* organic sediment production and early diagenesis (Hine and Mullins, 1983). These prominences, whose tops have been swept free of finer detritus by tides and storm-induced wave and current action, are generally interpreted to be the surface expressions of salt domes (Shepard, 1937; Parker and Curray, 1956; Lankford and Curray, 1957; Nettleton, 1957; Neuman, 1958; and Curray, 1960). However other authors have identified these features as bioherms without structural control (Ludwick and Walton, 1957), igneous intrusions (Carsey, 1950), or erosion by wave and current action (Thayer and others, 1974).

Several earlier reports have described other calcareous banks which form the belt of topographic highs that extends along the shelfedge of the northern Gulf of Mexico. In the northeastern Gulf, Ludwick and Walton (1957) reported a narrow zone of reeflike features of porous, rigidly cemented calcite, and Moore and Bullis (1960) described a deep-water (466 m) coral reef 64 km east of the Mississippi River mouth. In the northwestern Gulf, Williams (1951), Stetson (1953), Gealy (1955), Goedicke (1955), Curray (1960), and Thayer and others (1974) have reported steep-sided, flat-topped domes covered with various combinations of shell fragments, living and dead corals and calcareous algae, bryozoans, iron and manganese crusts, and limestone.

METHODS

During May 1981 aboard the R/V Gyre, the U.S. Geological Survey collected a rock dredge sample from Hoffa Reef. Fifteen kilometers of high-resolution seismic-reflection profiles (12.5 kHz) were run to determine the relief and extent of the feature.

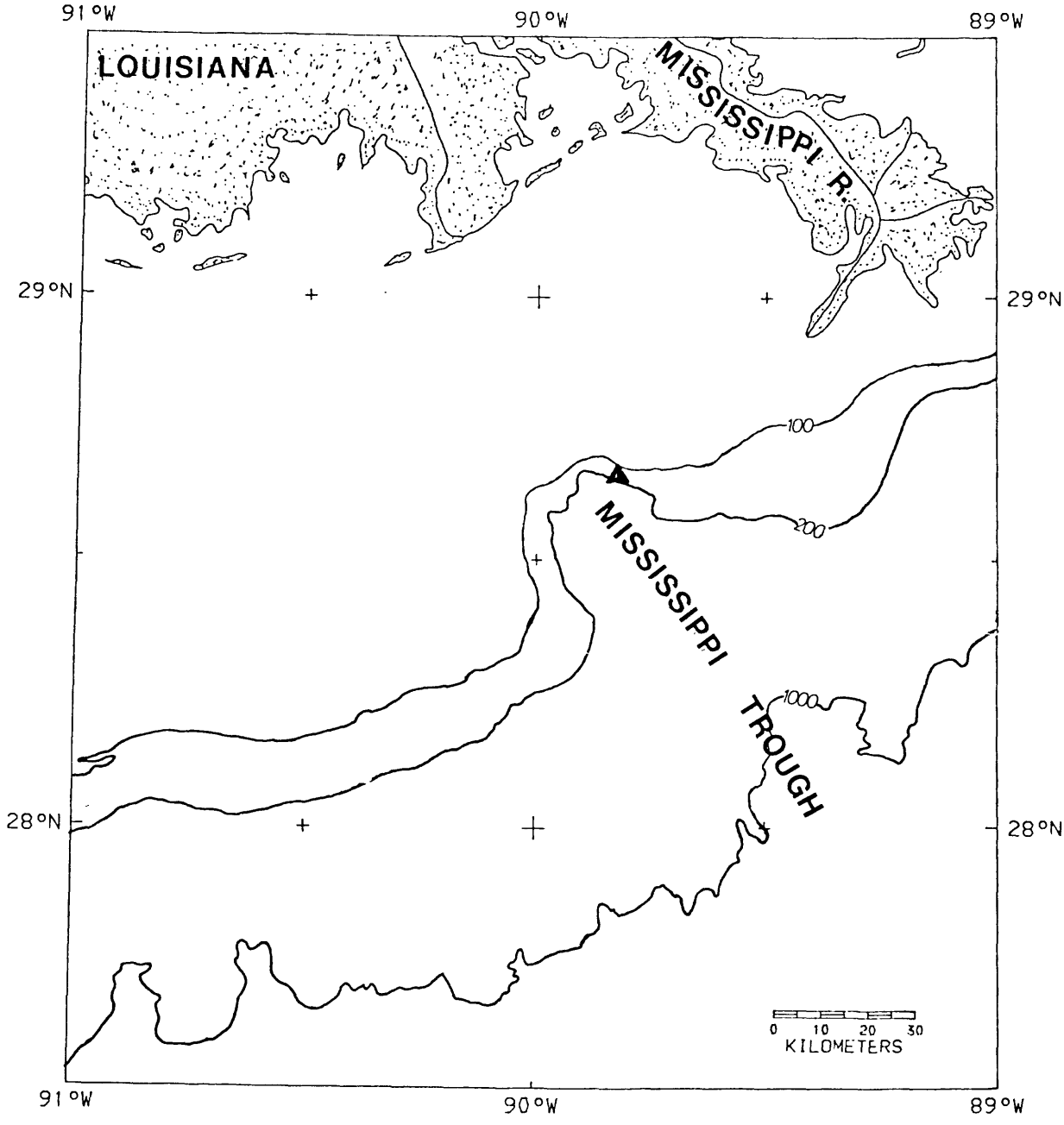

Figure 1. Map showing the location of Hoffa Reef (solid triangle).

Samples of the foundation and faunal remains were thin sectioned and examined under a petrographic microscope. The carbonate in a few of the thin sections was stained according to methods described by Friedman (1959) to aid in the recognition of textural and compositional differences. X-ray diffraction analyses were performed on both randomly oriented aggregate and oriented aggregate mounts. The oriented aggregate mounts were suction mounted on silver filters and subjected to four treatments: air-drying, glycolation, heating to 400° C, and reheating to 550° C. The oriented aggregate mounts were X-rayed after each treatment. Semiquantitative estimates of the minerals present were made by comparison of peak intensities with X-ray patterns from a collection of mineral standards. Relative percents of the clay minerals were estimated by a method described by Biscaye (1965).

RESULTS

Hoffa Reef is a west-northwest-trending, elongate, calcareous prominence located on the shelf northeast of the Mississippi Trough. High-resolution seismic-reflection profiles (Fig. 2) show that the exposed bank is narrow (70-100 m wide), about 2.6 km long, and of low relief (5-10 m), and 95-105 m deep.

The reef is composed of two lithofacies; a dolostone substrate and a macro-faunal component of calcium-carbonate-secreting organisms. The dolostone substrate (Table 1) is dense, light gray (5Y 6/1), micritic, foraminiferal-bearing, and contains substantial iron; it is ankerite rather than true dolomite (Fig. 3). Few silt-sized euhedral ankerite rhombs and no internal sedimentary structures or detrital sediment coarser than silt are present in the dolostone. Almost all of the ankerite crystals in this micrite are very fine grained (<5 microns). Most of the dolostone sampled was in the form of oblate nodules, which varied in size from 1.5-9 cm in thickness and 7-50 cm in diameter. However, some of the samples had fresh angular faces, which suggests they were broken off larger pieces. Framboidal pyrite and siderite, which indicate a reducing depositional environment, are common authigenic minerals in the unweathered parts of the dolostone. The pyrite is concentrated around worm borings but is also found dispersed throughout the matrix. These authigenic minerals, in conjunction with a detrital fraction of quartz, feldspar, and layered silicates, make up less than 20 percent of the rock. The detrital quartz and feldspar grains are rounded to subrounded. A clay mineral assemblage consisting of smectite, mixed-layer illite/smectite, chlorite, illite and/or mica, and kaolinite was found in the reef substrate.

The dolostone contains a shallow-water marine foraminifera assemblage (C.W. Poag, oral commun., 1983). The foraminifera are unaltered and are composed of high magnesium calcite. This assemblage is Pleistocene or Holocene in age, contains both benthonic and planktonic forms, and includes: Globorotalia truncatulinoides, Chiloguembelina sp., Globergerina sp., and Brizalina sp. Echinoderm spines composed of high-magnesium calcite are the only other biogenic calcite represented in the dolostone.

The surfaces of the dolostone clasts have been weathered and are covered by an oxidized, dark reddish-brown (5YR 3/2) rind. The rind is goethite- and siderite-rich, ranges from 2-10 mm thick, and suggests that this surface of the dolostone was subjected to subaerial erosion. Patches of a thin, black ferromanganese stain covered some surfaces of the weathered rind.

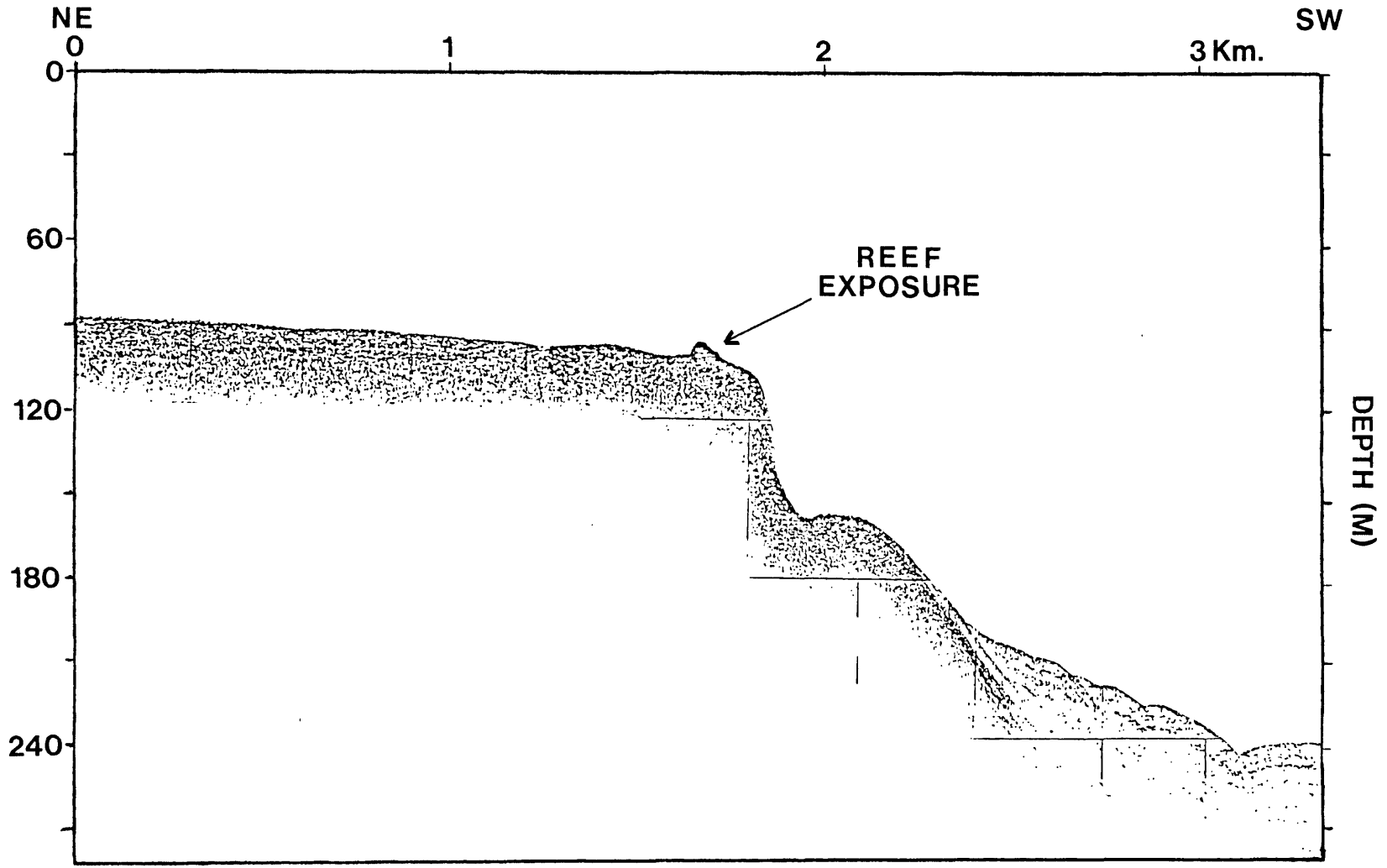

Figure 2. High-resolution seismic-reflection profile (12 kHz) Hoffa Reef. Figure shows bathymetry of reef exposure, shelfbreak, and bottom dipping steeply toward the axis of the Mississippi Trough.

SAMPLE	SMC	M/L	CHL	I/M	KAO	QTZ	FELD	CALC	ARAG	PYR	SID	GOE	D/A	COMMENTS
HR-1	1	1	T	9	3	3				1	T		81	DOLOSTONE
HR-2	2	3	T	3	2	2					1	6	81	DOLOSTONE RIND
HR-3	T		T	T	T			56	41	T	T			LITHOTHAMNOID
HR-4	2	T	T	1	1	3		52	20		T	6	14	LITHOTHAMNOID
HR-6	2	T	2	5	2	3	T	T		T			85	DOLOSTONE
HR-7	2	2	1	5	2	3	T	3		T	T		81	LIGHT GRAY WORM TUBE
HR-8A	T	2	2	4	2	3	T	T		T			86	DK WORM TUBE/GRAY INTERIOR
HR-8B	T	1	T	2	T	2	T	T			T	9	83	DK WORM TUBE/RIND
HR-9	2		T	2	1	T		40	T		T	10	36	BRYOZOAN
HR-10A	2	T	T	1	1	T		55	38		T		1	LITHOTHAMNOID
HR-10B	1			T	T	T		84	14					GRAY LITHOTHAMNOID INTERIOR
HR-11A	4	T	T	3	2	3		T			T	T	86	WORM TUBE/GRAY INTERIOR
HR-11B	T	T	T	T	T	2	T	T			T	15	75	WORM TUBE/RIND

Table 1. Estimated mineral modes, in relative percent, determined from X-ray powder diffraction for samples dredged from Hoffa Reef in the northern Gulf of Mexico. SMC: smectites; M/L: mixed-layer clay minerals; CHL: chlorite; I/M: illite/mica; KAO: kaolinite; QTZ: quartz; FELD: feldspars; CALC: high- and low-magnesium calcite; ARAG: aragonite; PYR: pyrite; SID: siderite; GOE: goethite; D/A: dolomite/ankerite.

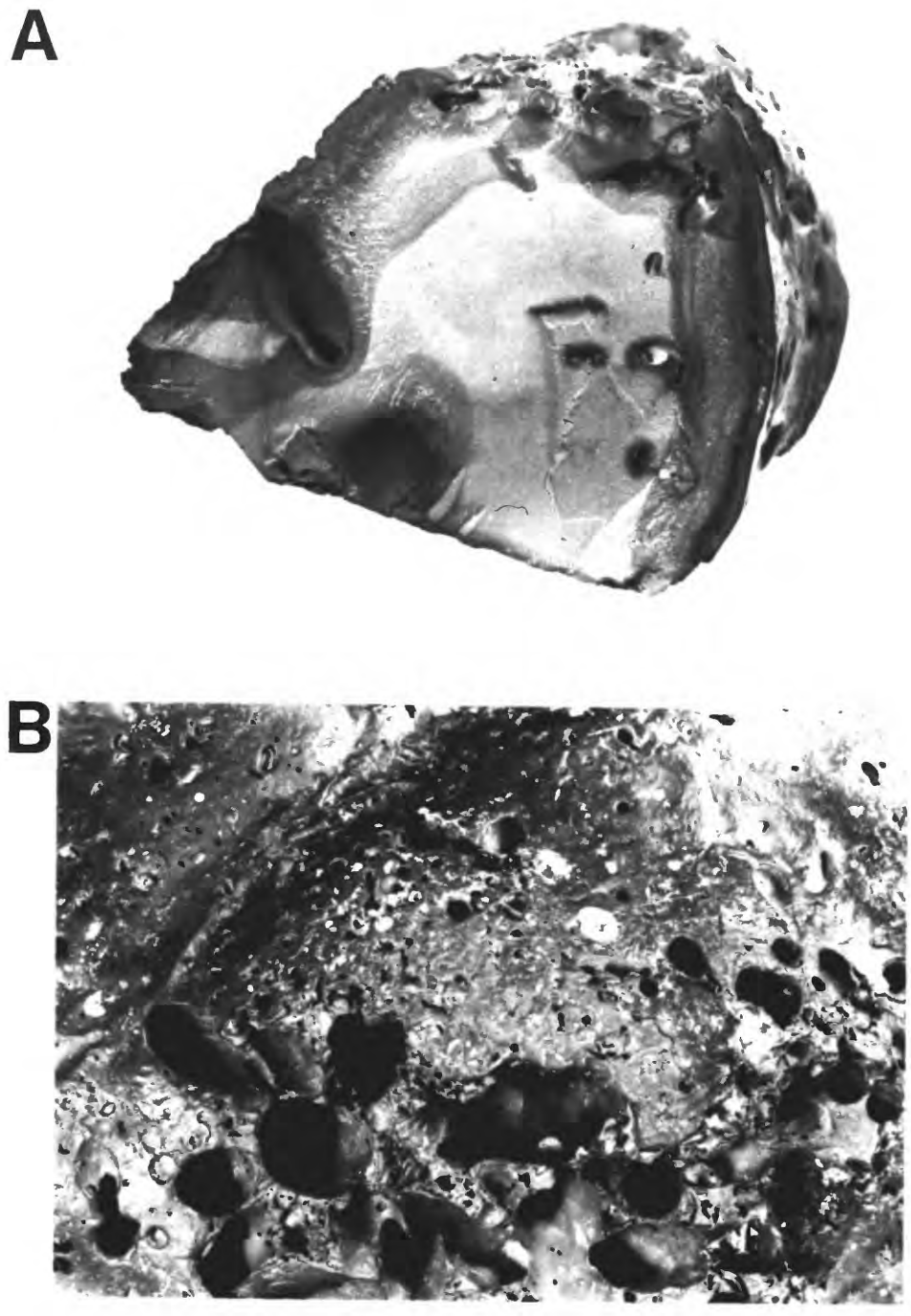

Figure 3. Dolostone substrate of Hoffa Reef. A. Cross section of dolostone showing oxidized goethite rind, unaltered dolostone, and pyritized worm borings. B. Weathered surface of dolostone showing lithophaga borings.

The surface of the dolostone has been heavily bored by lithophaga. Because the oxidized rind lines the lithophaga borings, these organisms lived on the substrate prior to subaerial exposure. No living lithophaga were found in the borings. Foraminifera found in the lithophaga borings were from a shallower environment than the foraminifera in the matrix of the dolostone (C.W. Poag, oral commun., 1983).

The selective dolomitization has also preserved casts and molds of what appears to be worm tubes or shrimp borrows (Fig. 4). Most, but not all, of these casts are surrounded by the goethite rind.

The macro-organisms collected from the bank are different from those living in the surrounding soft, Recent, shelf sediments (Parker and Curray, 1956). Calcareous algal nodules (lithothamnion) dominated the macro-faunal component of the reef. These nodules (Fig. 5) average about 7 cm in diameter; no living specimens were collected in the dredge. Foraminifera (including specimens of Amphistegina, Hoeglundina, and Globergerina), echinoderm spines, shell fragments, and bryozoans were commonly observed within the algal nodules. The nodules, which have been bored by lithophaga, are composed mainly of high-magnesium calcite. About 15-40 percent of the algal nodules are aragonite, which is confined to thin layers between the concentric growth rings of the lithothamnion. The surface and a large part of the interior of these nodules is typically a very pale brown (10YR 7/3-8/3). However, their centers are dense, light gray, and composed of a greater percentage of high-magnesium calcite.

Encrusting bryozoans are commonly found on the dolostone substrate. One species, which occurred in nodular masses (Fig. 6) about 7 cm in diameter, was composed of high-magnesium calcite. Small corals and encrusting foraminifera were observed on the surface of these nodular bryozoans. Fragments of the dolostone substrate imbedded in the basal part of this bryozoan are responsible for the ankerite detected in the X-ray diffraction analysis sample HR-9.

Sponges, small ahermatypic corals, and encrusting foraminifera are the only organisms presently living on the reef.

DISCUSSION

Based on the color, density, mineralogy, and biogenic assemblage, we believe the sediments of the bank substrate were deposited under reducing, shallow-water marine conditions. The dolostone contains no internal textural structure, laminae, or detrital sediment coarser than silt and therefore was probably deposited as an aragonite mud in a low energy environment. Dolomite and ankerite usually form in evaporite sequences or as a replacement of calcite or aragonite in limestones (Fischer and Rodda, 1969). Because the Hoffa Reef dolostone was put down under shallow-water marine conditions, the ankerite must have formed by replacement. Therefore, the aragonite probably was selectively recrystallized during early diagenesis to form the dolostone. Subsequent mixing of marine and meteoric waters during the late Pleistocene regression could have allowed enough fresh water to flush through the system to permit dolomitization (Land, 1973).

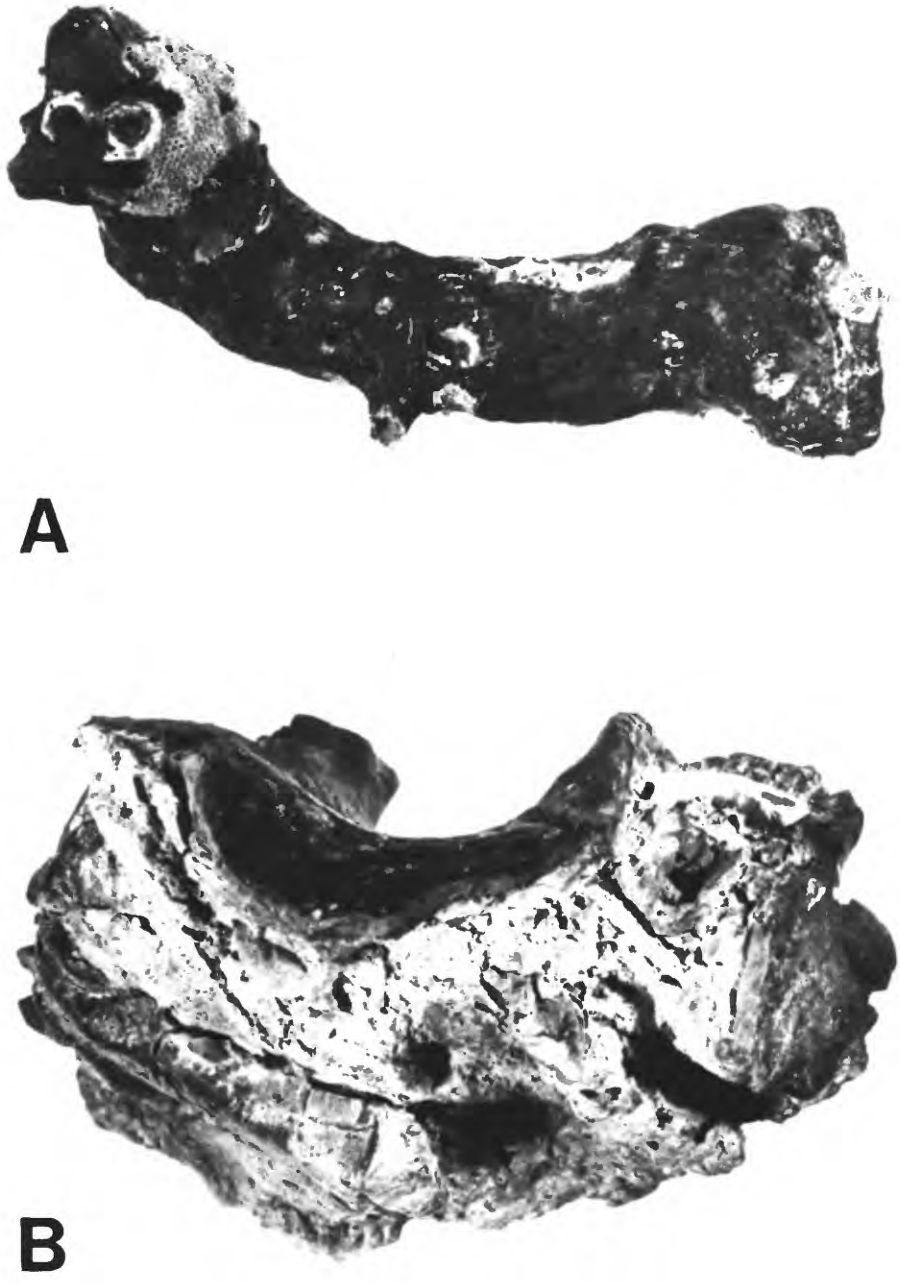

Figure 4. A. Dolostone worm tube or shrimp burrow cast showing encrusting bryozoan and ahermatypic corals. X-ray diffraction analysis samples HR-8a and HR-8b in Table 1 were taken from this cast. B. Dolostone worm tube or shrimp burrow mold. X-ray diffraction analysis samples HR-11a and HR-11b were taken from this mold.

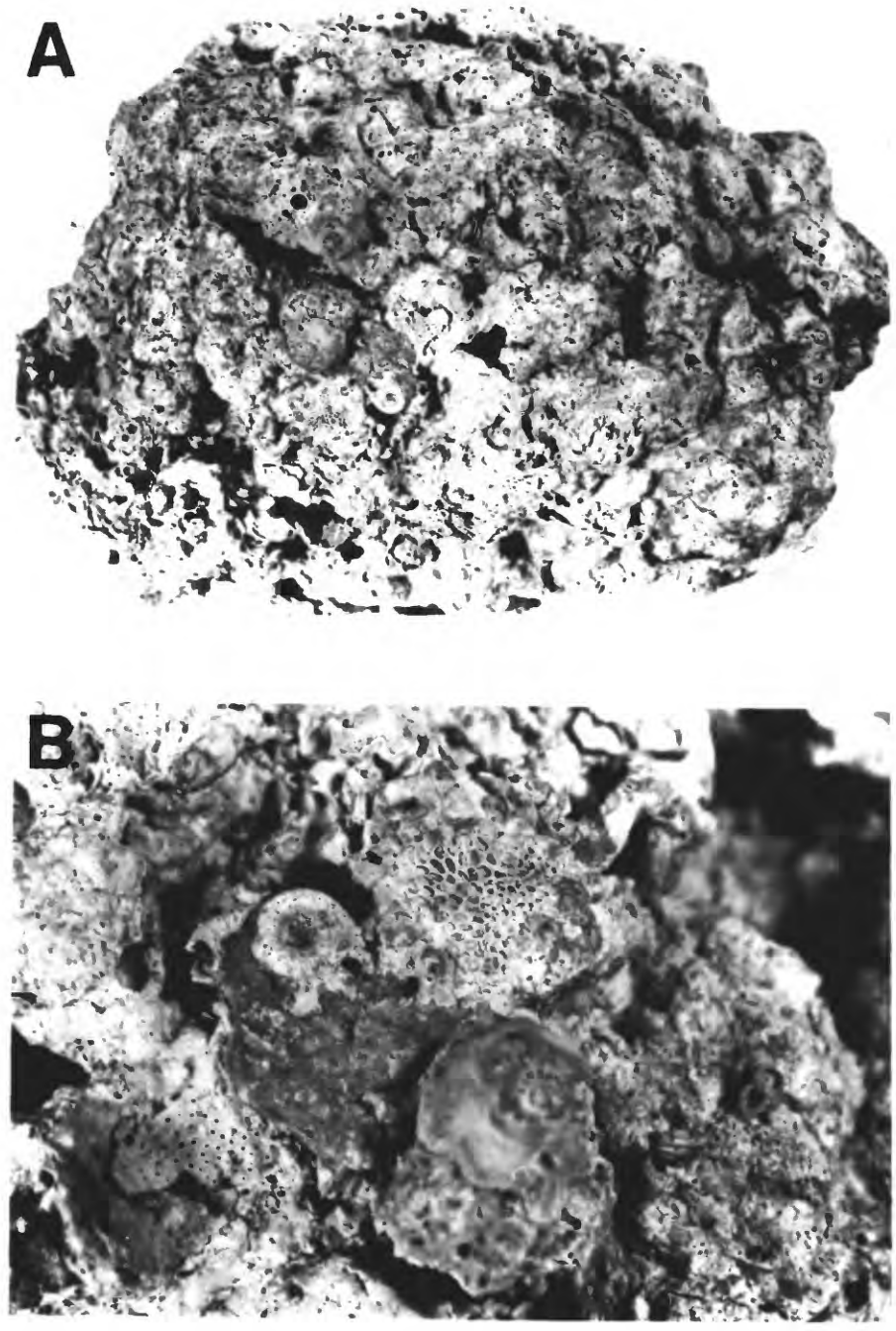

Figure 5. A. Calcareous algal nodule (lithothamnion). X-ray diffraction analysis sample HR-3 in Table 1 was taken from this sample. B. Close-up of algal nodule showing encrusting foraminifera and bryozoans.

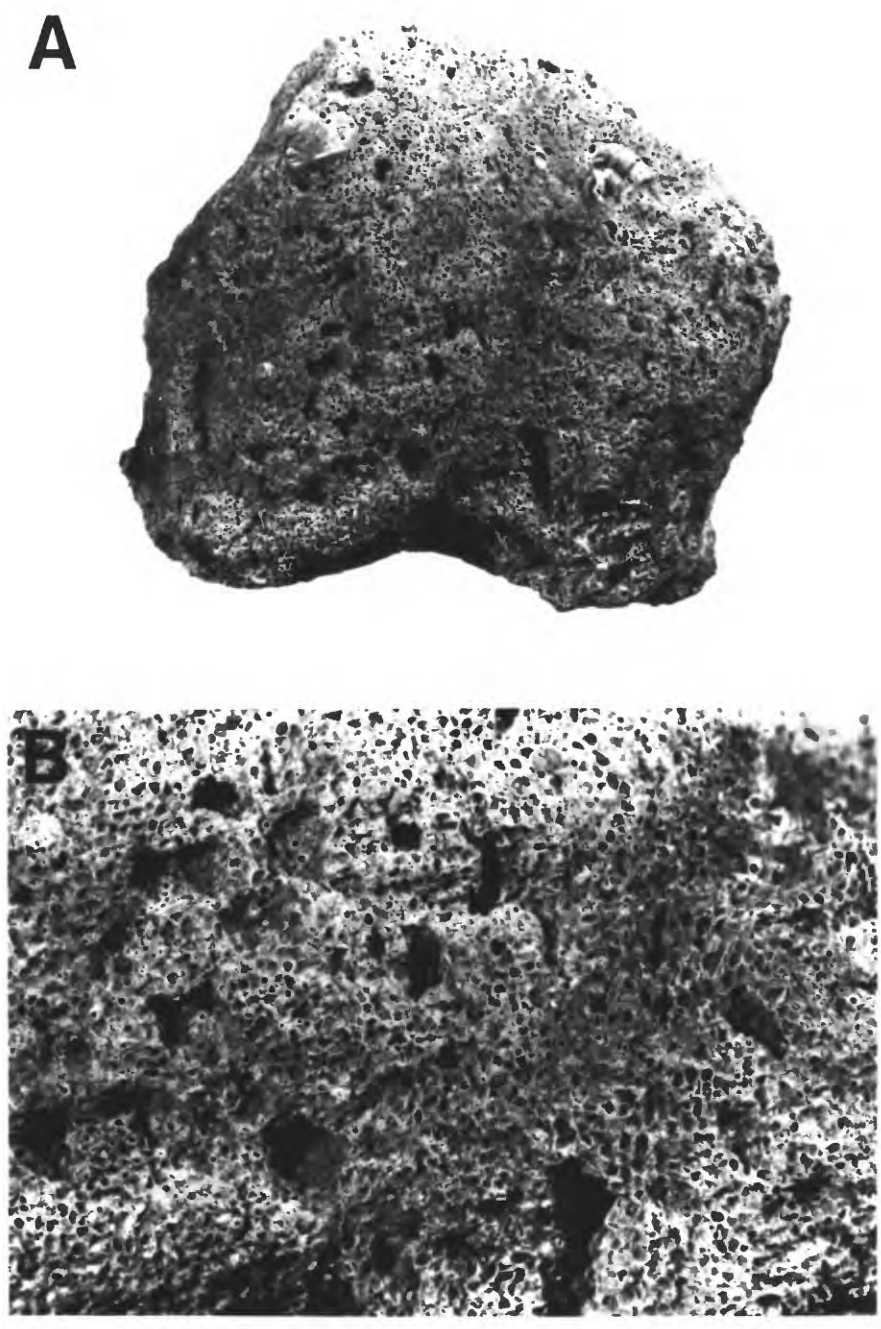

Figure 6. A. Encrusting nodular bryozoan. X-ray diffraction analysis sample HR-9 in Table 1 was taken from this sample. B. Close-up of nodular bryozoan showing weathered zoaria.

Several lines of evidence (Fisher and Rodda, 1969) suggest that the ankerite was formed prior to lithification: 1) very fine grain size and dense fabric result from replacement in a non-supported mud; 2) non-dolomitization of the foraminifera tests and echinodern spines; and 3) mudstone lithology of the substrate, a rock of low permeability. According to Fischer and Rodda (1969), lithified mudstone is usually not dolomitized by refluxing brines.

All of the calcite of Hoffa Reef was allochemical and high-magnesium. The presence of high-magnesium calcite is typical of Recent carbonates and may be indicative of the high water temperature within which the calcite formed (Chave, 1954), the types of organisms which secreted the calcite (Scholle and others, 1983), or the weathering of aragonite to high-magnesium calcite under freshwater conditions during the last regression. We believe the latter case is the most probable because of the absence and/or depletion of aragonite in the bryozoan and lithothamnion samples.

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