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TWENTIETH CENTURY SEDIMENTOLOGICAL DEVELOPMENT OF BONEFISH POND, NEW PROVIDENCE ISLAND, BAHAMAS

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ABSTRACT

Changes in the sediments and microfaunas of Bonefish Pond during the past 100 years have been investigated by the analysis of surficial sediments, shallow cores, and map evidence. The aerial extent of the creek system has been reduced by about one-half during the past century. During this time there has been a major change in microfaunas and sediment types. Shallow cores indicate that the creek has changed from a predominately carbonate mud environment characterized by the bivalve *Polymesoda maritima*, with locally precipated gypsum zones, to the present carbonate sand environment dominated by macrophyte crusts and the bivalves *Gemma* and *Chione*. The development of macrophyte crusts as a major sediment component seems to have occurred as a result of the increasing industrial and agricultural development of southern New Providence Island. Protodolomite crusts are presently being formed throughout the creek system by the dolomitization of carbonate mud. This investigation presents evidence of a previously unreported marine environment of macrophyte crustal sediments, with associated protodolomite and gypsum, and documents the potential use of molluscan faunas in the interpretation of ancient Bahamian tidal creek environments.

INTRODUCTION

Bonefish Pond is a multi-inlet tidal creek system developed along the south-central coast of New Providence Island about 4 miles southeast of Nassau International Airport (Fig. 1). The creek system covers an area of approximately 2 1/2 square kms and has 3 inlets (here designated A, B, and C) connecting the creek with Bicardi Bay (Fig. 1). The sediments and fauna of this creek have not previously been investigated. In general, little is known about the sedimentology and faunas of the numerous tidal creeks occurring throughout the Bahama Archipelago. The only detailed, published study of a Bahamian tidal creek is one on Pigeon Creek, San Salvador Island (Mitchell, 1987a).

The use of modern tidal creeks as analogs for the interpretation of ancient tidal creek sediments has become increasingly important. The geologic mapping of Rum Cay (Mitchell, 1987b), New Providence Island (Garrett and Gould, 1984), Mayaguana and Great Inagua Islands (Mitchell, 1985a, 1985c; Pierson, 1982), Samana Cay (Mitchell and Sealey, in press), and San Salvador Island (Teeter, 1985; Thalman and Teeter, 1983; Titus, 1987) indicates that a significant portion of the surficial rocks of the Bahamas were formed in Pleistocene tidal creek environments when sea

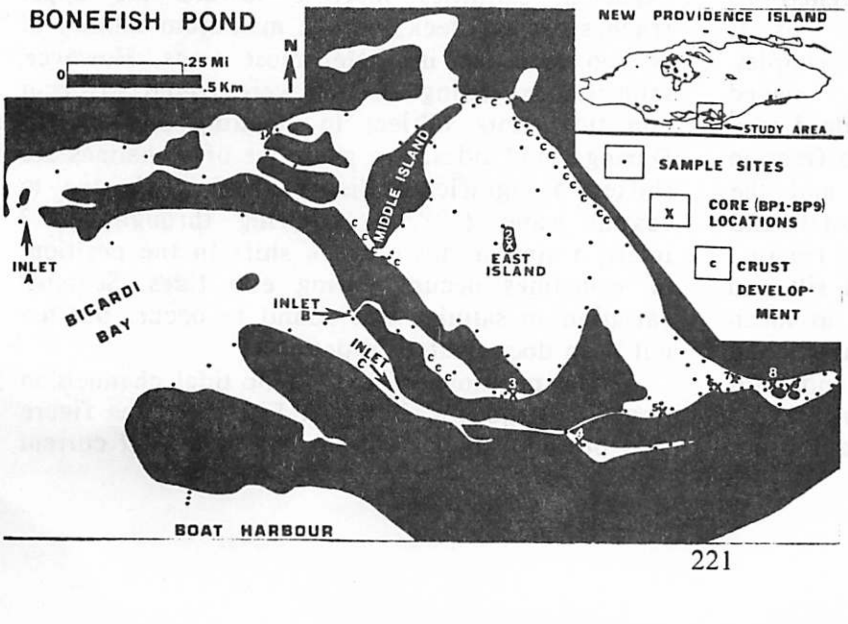

Fig. 1. Map of Bonefish Pond area showing major geographic features, sample locations, core sites, and areas of thin crust development; inset map indicates location of field area on New Providence Island.

level was higher than at present. On some islands (Great Inagua and Mayaguana Islands and Rum and Samana Cays) many interior Pleistocene rock units occurring at elevations up to 5m above present sea level can be assigned to tidal creek lithofacies (Mitchell, 1987b, p. 237; Mitchell and Sealey, in press).

The purpose of this study is to document the sedimentology and microfaunas of Bonefish Pond. The development of a previously unknown sedimentary environment is described and the first in depth investigation of the foraminiferal, ostracod, and molluscan biofacies of a Bahamian tidal creek is presented.

METHODS

A total of 200 surface sediment and alcohol-fixed/rose bengal stained microfaunal samples (upper 0-2cm), 100 water samples, and numerous current measurements were collected from 100 sampling stations in the Bonefish Pond area during 5 sampling periods: June-July 1982, July 1984, October 1985, December 1985, and June 1986 (Fig. 1). Water samples were collected in 10ml vials and analyzed for salinity using a Reichert automatic temperature compensated hand refractometer with an accuracy of $1^{0}/oo$. Current measurements were made using a neutral float suspended several centimeters below the water surface. Distances were determined using a compass and adjusted for the magnetic declination (4.5^{0} west) of the field area.

The sediment samples were collected using cores or small containers. In the laboratory each sample was treated with chlorox until all organic matter had been decomposed. Samples were then wet sieved through a U.S. Standard Series Sieve No. 230 (.06mm or 4ø diameter mesh). The silt-clay and sand subsamples were dried and weighed. To prevent loading on the sieves, the sand was, if necessary, split into 30 to 125 gram subsamples. Selected sand subsamples were then dry sieved through a 1/2ø interval set of U.S. Standard series sieves using a ro-tap for 15 minutes. The fraction retained on each sieve was weighed, and the percent each fraction made up of the total sand sample determined. The weight of the pan fraction was added to the weight of wet sieved silt and clay. Basic sedimentary parameters such as mean grain size, standard deviation, skewness, and kurtosis were then calculated. Visual and thin section identifications of the grain morphotypes occurring in the -2, -1, 0, 1, 2, and 3ø fractions of each sample were also undertaken. The results presented here are based on the silt-clay separation of 100 samples and the 1/2ø interval mechanical sieve analysis of 30 samples. Analyzed samples were selected in order to include all of the major subenvironments of the Bonefish Pond area.

Nine shallow cores were taken from various parts of the creek system. The locations of cores BP1-BP9 are shown in Figure 1. After extrusion, the cores were divided into units 1 to 7cms in thickness. Wherever possible, units were based on textural differences which suggested changes in the depositional environment. Each unit was wet sieved to separate silt-clay and sand, as described above. The dried sand subsamples were examined using a binocular microscope (X7 to X30 magnifications) for the identification of microfaunas and grain types.

A Phillips Norelco XRG-3000 powder X-ray diffractometer was used for the investigation of the bulk mineralogy of sediments. The silt-clay and sand fraction of the units from the 3 longest cores (BP2, BP6, BP8), surficial sediments and crusts, and samples of Pleistocene outcrops were analyzed to determine the relative abundances of low and high Mg-calcite, aragonite, protodolomite, gypsum, and low temperature quartz. Approximate mineral abundances were determined using a set of mixed standards as described by Blackmon (1962, p. 48).

PHYSICAL PARAMETERS

The major physical parameters related to sediment distribution in Bonefish Pond are: 1. salinity, 2. tidal currents, and 3. prevailing winds. The approximate distribution of maximum isohalines for the creek system, based on water samples from 70 stations, is shown in Figure 2. As expected, salinities increase toward the upper reaches of the creek, with a maximum salinity of $60^{0}/oo$ recorded in easternmost areas. However, salinities exceeding $80^{0}/oo$ were found to occur on tidal flats subject to flooding at high tide. During flood tides, the positions of isohalines are shifted a significant distance up creek due to coastal water ($37^{0}/oo$) entering through the 3 inlets; a similar down creek shift in the positions of isohalines occurs during ebb tides. Seasonal variation in salinity was found to occur, but has not been documented in detail.

The positions of the major tidal channels in Bonefish Pond are shown in Figure 3. The figure also presents the maximum recorded tidal current

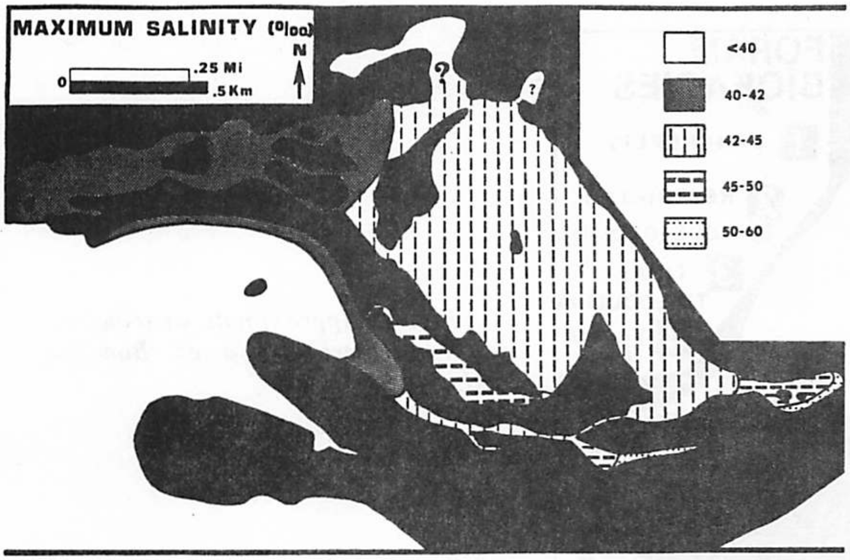

Fig. 2. Approximate distribution of isohalines, Bonefish Pond.

velocities (in meters per minute) for selected parts of the creek system. A maximum velocity of 22 meters/minute was recorded at the narrow channels connecting Inlets A, B, and C to the central and eastern parts of the creek system (Fig. 3).

SEDIMENTOLOGY

Sediment Sources

Five basic grain morphotypes occur in the sediments of Bonefish Pond: 1. aggregates; 2. lithoclasts; 3. skeletal remains; 4. macrophyte crusts; and 5. peloids. Ooids were not found to be present in the sediments of this creek system. Aggregates are broken pieces of thin, cemented sediment crusts containing high percentages of skeletal remains or macrophyte crusts. The locations where thin crusts are presently forming in Bonefish Pond are shown in Figure 1. The thin crusts are composed of protodolomite and varying levels of Mg-calcite and aragonite. Aggregates found in surficial sediments are presumably derived from one of these sources. The peloids are formed by the micritization of fecal pellets. Peloids are occasionally present in areas where sediment crusts are forming. Lithoclasts are eroded pieces of Pleistocene limestones (oosparitic eolianities) and thick Holocene crusts cropping out along the shores of Bonefish Pond or present beneath the unconsolidated tidal creek sediments. Pleistocene exposures are best developed along the southern margins of the creek; this area would be expected to have the highest concentrations of surficial lithoclasts with a low Mg-calcite mineralogy. Lithoclasts derived from thick Holocene crusts can be distinguished from those of Pleistocene origin by bulk mineralogicial analysis. The Holocene crusts are dolomitized carbonate

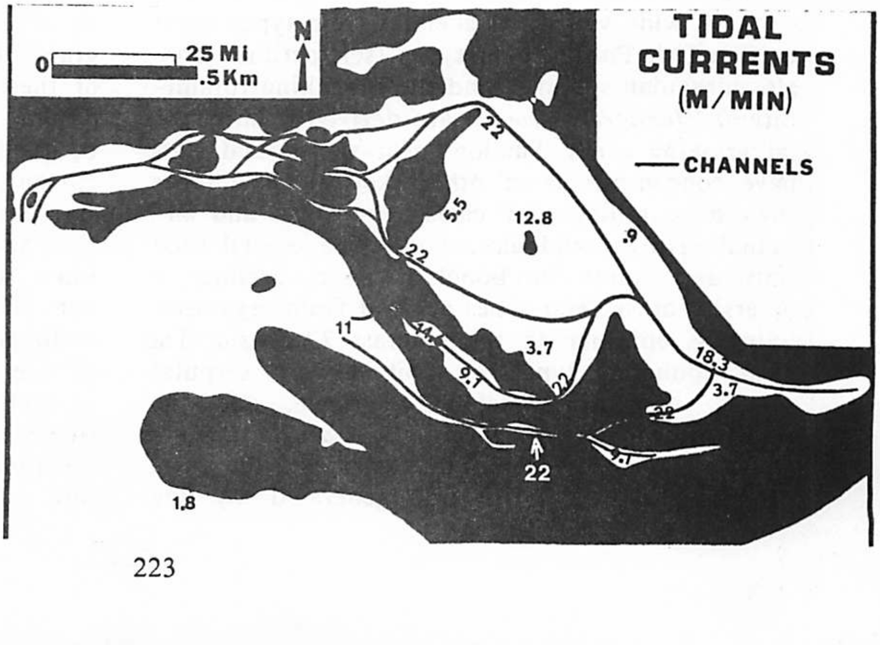

Fig. 3. Distribution of tidal channels and maximum recorded velocities of tidal currents in meters/minute, Bonefish Pond.

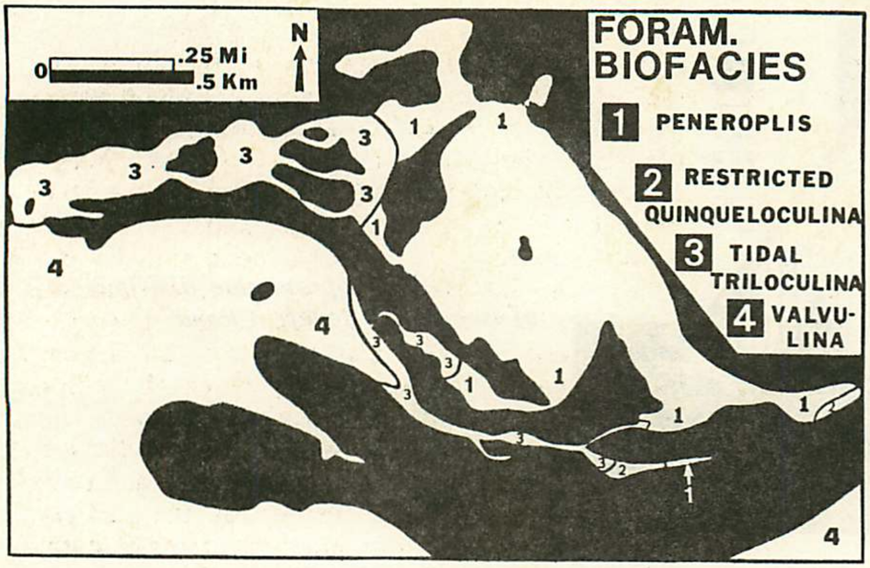

Fig. 4. Approximate distribution of foraminiferal biofacies, Bonefish Pond.

muds which are very finely crystalline and have few skeletal grains. Protodolomite and Mg-calcite are the dominant minerals present; aragonite is less common (under 15%) than it is in associated unconsolidated sediment. Very small amounts of gypsum may also be present. Macrophyte crusts are hollow tubular crusts formed by cyanophytes. Similar crusts, from a freshwater lake in Austria, have been described in detail by Schneider and Others (1983). Macrophyte crusts from Bonefish Pond are generally 0.2-0.4mm in diameter; broken crusts up to 4mm in length occur in the surficial sediments of the extreme southeastern part of the creek system. The crust exterior is usually covered by a network of microphyte crusts similar to those reported by Schneider and Others (1983). This is the first reported occurrence, in the marine environment, of macrophyte crusts as a significant contributor to the local sedimentary record.

A wide variety of skeletal grain types occur in Bonefish Pond. Some types (scleractinian corals, gorgonian spicules, and the branching foraminiferan *Homotrema rubra*) are derived from coastal fringing reefs. Shallow near-shore sand flats have concentrations of other skeletal grain types such as coralline and calcareous algae and infaunal bivalves and gastropods. The coastal sand flats and inlets to Bonefish Pond produce a diversity of skeletal types derived from organisms living as epibiota on the seagrass *Thalassia*. The most abundant types of epibiota are serpulid worms, encrusting melobesoid algae, and the foraminifera *Archaias*, *Cyclorbiculina*, *Quinqueloculina*, and *Sorites*. Within the creek the most common skeletal types are generated by the breakdown of calcareous algae (*Acetabularia*, *Halimeda*, and *Penicillus*) and by epibiota (for example, foraminifera and ostracods) occurring on these algae, *Thalassia*, and on mangrove roots and dead leaves. Infaunal, semi-infaunal, and epifaunal molluscs are other significant contributors to the skeletal sediments of Bonefish Pond. Skeletal grains derived from gastropods and bivalves were present at all sample stations. Shells of the gastropod genus *Caecum (C. cooperi* Smith and *C. pulchellum* Stimpson) are abundant in the sediments of the western and central parts of the creek system.

Transport Mechanisms

The various grain types occurring in Bonefish Pond may form by local current or wave effects on surficial crusts and exposed Pleistocene rocks (producing aggregates or lithoclasts) or by biological processes (producing skeletal grains, macrophyte crusts, and peloids). Once each of these grain types becomes a part of the creek system, there is the opportunity for transportation by tidal currents, waves, and bioturbation. Tidal currents are the chief mechanism of sediment transport within Bonefish Pond.

Sediments are transported up creek (from Inlets A, B, and C) during flood tides and settle out at slack high tide. This results in finer sediments being concentrated in the upper reaches of the creek system and in areas where tidal currents are low due to islands and embayments. However, the hollow tubular macrophyte crusts are preferentially transported down creek by ebb tide currents. Bioturbation mixes the sediment in a local area, moving some fine sediment to the sediment-water interface where it is likely to be transported by tidal currents or waves.

Silt and Clay

The percentages of silt and clay occurring in samples from 100 stations in the Bonefish Pond area are presented in Figure 5. Percents represent the total amount of wet and dry sieved particles less than 0.06mm in diameter. The silt-clay size component of the sediment is greatest in creek embayments and in the uppermost reaches of the creek, and is at its maximum in the extreme southeastern part of the creek system where values reach 55%. Mg-calcite and aragonite are the dominant components of the silt-clay mineralogy. Aragonite makes up 35-50% of the silt-clay sediment fraction in the coastal and western areas of Bonefish Pond. In the upper reaches of the eastern part of the creek, however, aragonite levels drop to 15-25%. The major source of this aragonite silt and clay is the physical and biological reduction of grains of thin-shelled molluscs and the calcified algae *Acetabularia, Halimeda*, and *Penicillus* (Neumann and Land, 1975; Stockman and Others, 1967). The sources of the Mg-calcite silt-clay are the macrophyte crusts and miliolinid foraminifera, such as *Peneroplis proteus*, which are abundant throughout the creek system (Gebelein and Others, 1980, p. 43).

One additional source contributes to the silt-clay sediment fraction occurring in Bonefish Pond. The Pleistocene eolianites cropping out along the margins of the creek are undergoing slow chemical and biological decomposition, producing low Mg-calcite grains and concentrations of terrigenous particles (primarily low temperature quartz). The terrigenous particles were incorporated in the eolianites after being transported by trade winds from northern Africa (Mitchell, 1984b). All surficial sediment samples from the interior of the creek system contain small amounts (under 1-2%) of terriginous silt-clay derived from the leaching of Pleistocene eolianites. Coastal sediments do not. The levels of terriginous silt-clay in surficial sediments are highest in the extreme southeastern part of the creek, where thick terriginous clay deposits have been leached from the underlying Pleistocene eolianites. In addition, small amounts of low Mg-calcite are present in the silt-clay fraction of the surficial sediments along the northern and extreme southeastern margins of Bonefish Pond. These are areas where Pleistocene limestones are exposed to surficial weathering.

Lithofacies

Based on the characteristic grain morphotypes present, 12 major lithofacies are recognized in the area of the Bonefish Pond tidal creek system. The 12 lithofacies are listed below along with a brief discussion of the physical and biological process responsible for their occurrence. The distributions of the lithofacies are presented in Figure 6.

1. <u>*Acetabularia-Batillaria*</u> Lithofacies. Dense patches of *Acetabularia crenulata* Lamouroux are developed in the narrow channels connecting Inlets A and B with central and eastern parts of the creek system. The channels have high tidal current velocities which encourage the development of *Acetabularia* and *Penicillus. Batillaria*

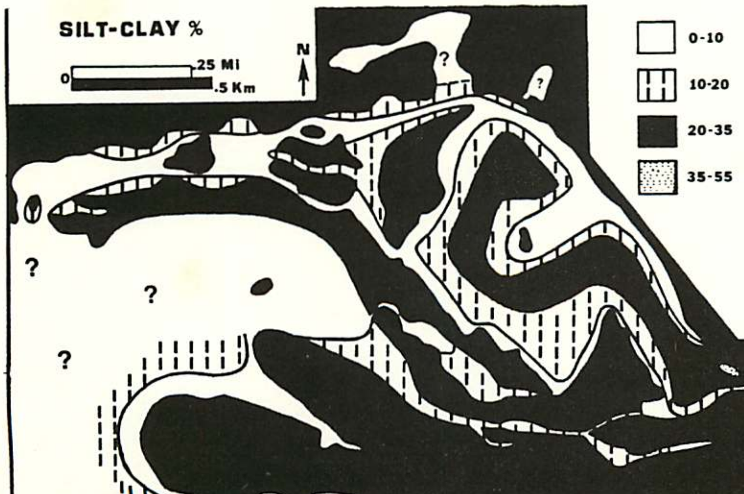

Fig. 5. Percent of silt and clay in surficial sediments, Bonefish Pond.

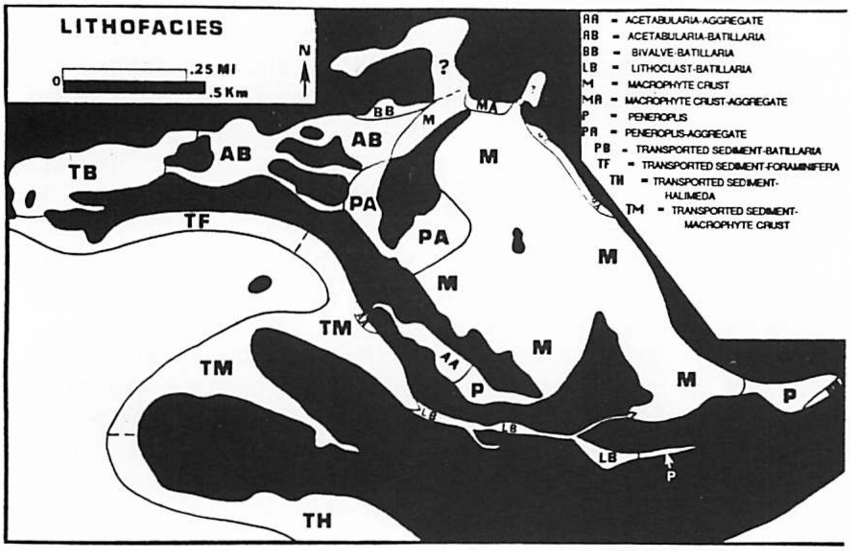

Fig. 6. Distribution of surficial sediment lithofacies, Bonefish Pond.

minima (Gmelin) is a herbivorous gastropod which is abundant in the creek system wherever algal development is significant.

2. Peneroplis Lithofacies. Large tests of *Peneroplis proteus* Orbigny are the dominant grain morphotype in shallow areas where salinities are high and a surface floc provides support for detached mangrove leaves, which are colonized by foraminifera (Mitchell, 1987a).

3. Macrophyte Crust Lithofacies. Macrophyte crusts are the dominant grain morphotype in the eastern part of the creek system. The

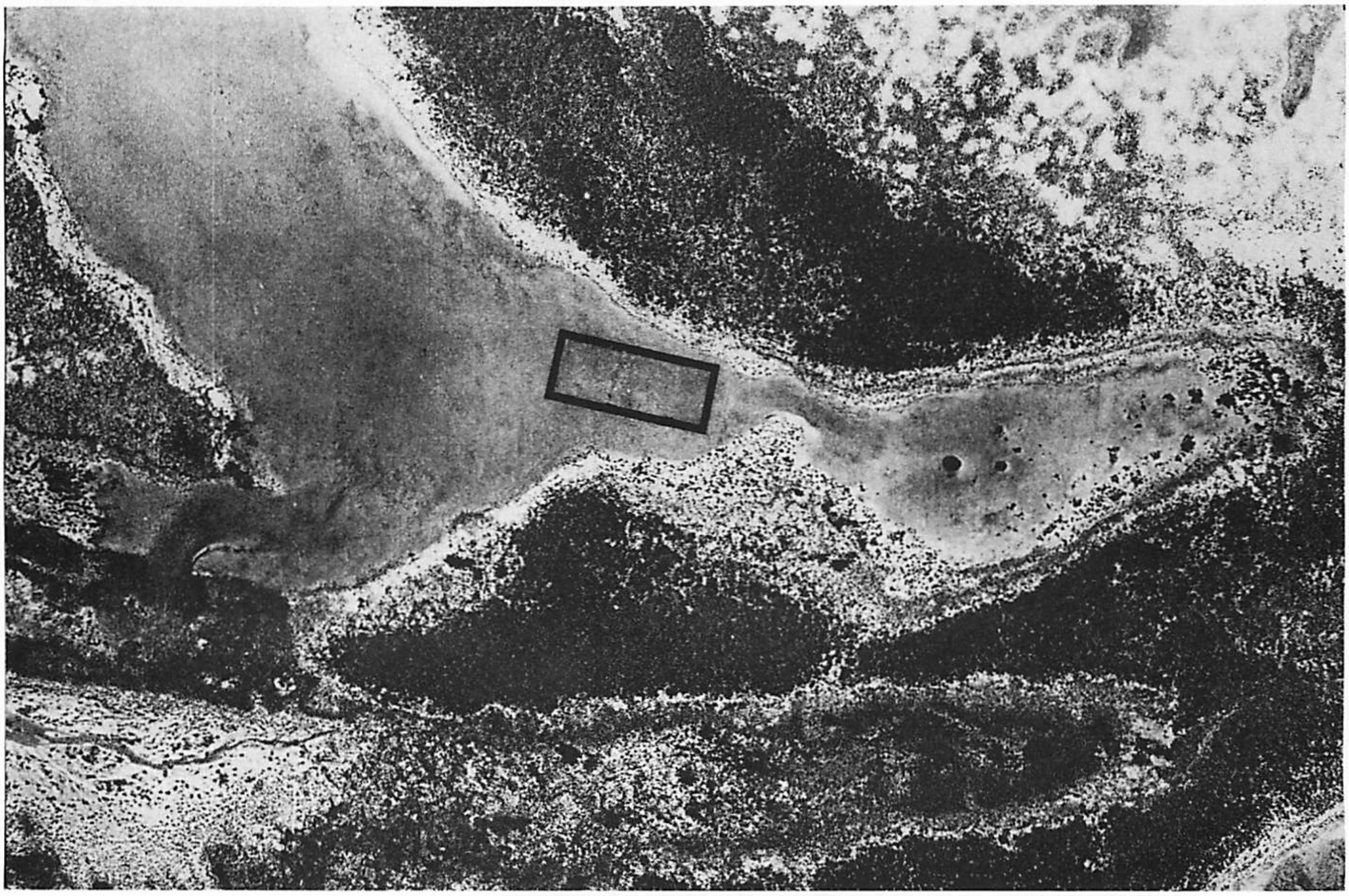

Fig. 7. Aerial photograph of southeastern Bonefish Pond; the occurrence of cyanophytes producing macrophyte crusts is indicated by the rectangle.

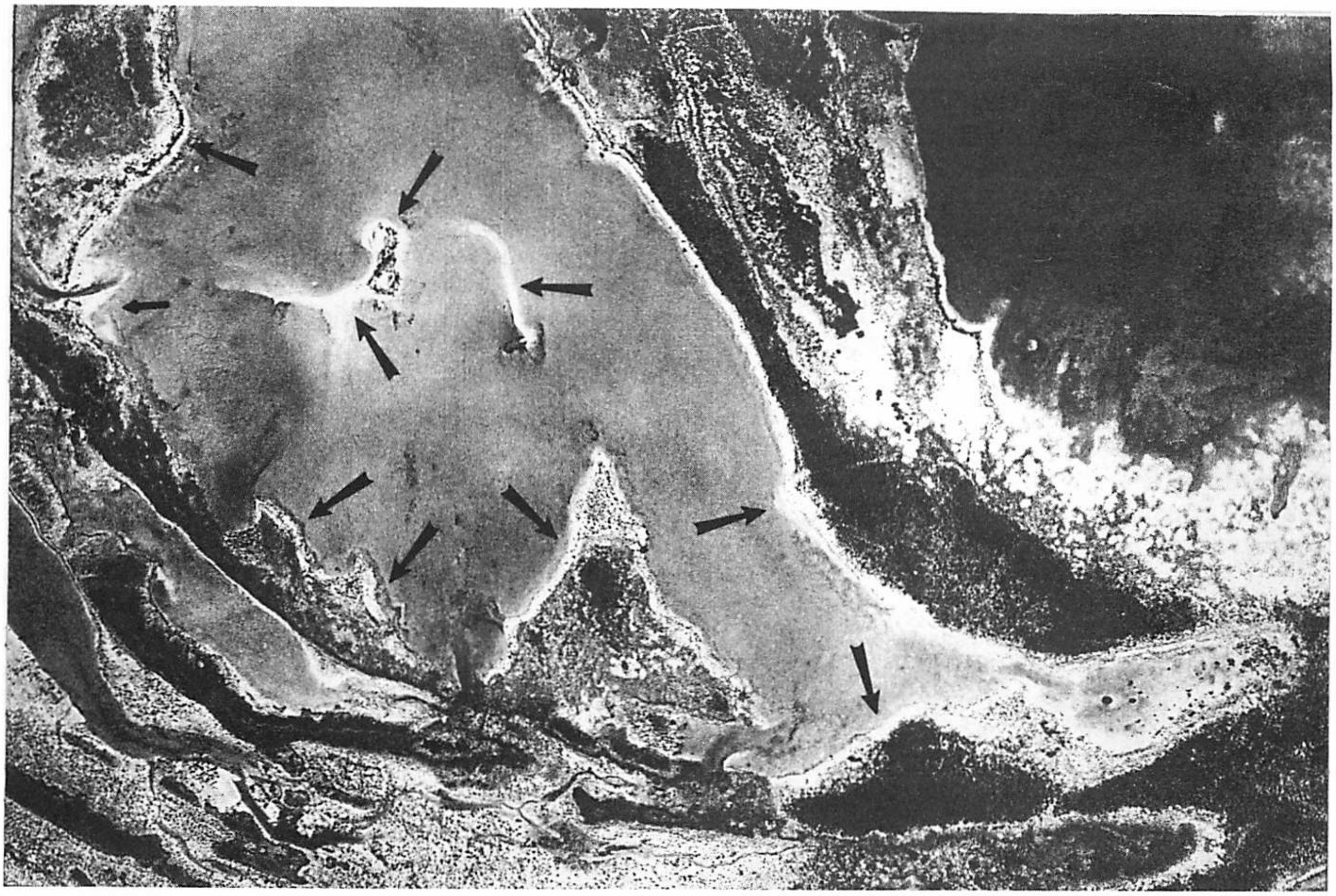

Fig. 8. Aerial photograph of eastern Bonefish Pond; arrows point to beaches, sand bars, and islands formed by the deposition of macrophyte crustal sediments.

field staining (with rose bengal) of sediment samples, and an associated organic floc, indicates that the cyanophytes producing the macrophyte crusts are living in an area of about 100 by 250 meters in the extreme southeastern part of the creek (Fig. 7). The hollow, cylindrical crusts are transported down creek by ebb tides, forming sand beaches, bars, and East Island (Fig. 8). The macrophyte crustal sediments become progressively finer northwest from the production area. They do not occur as significant grain types in sediments west of western Middle Island. However, macrophyte crusts have been transported through Inlet C to form an important component of surficial sediments in eastern Bicardi Bay.

4. *Acetabularia*-Aggregate Lithofacies.

5. *Peneroplis*-Aggregate Lithofacies.

6. Macrophyte Crust-Aggregate Lithofacies. A thin carbonate crust is formed below organic flocs up creek from Inlets A and B, along the edges of the creek channels north and south of Middle Island, and below an intertidal organic mat along the creek shore northwest of East Island (Fig. 1). The protodolomite crusts provide a source of aggregates for the three lithofacies, which are distinguished by the differences in types of grain morphotypes cemented into aggregates.

7. Bivalve-*Batillaria* Lithofacies. The sediments of two areas of the creek are characterized by a very fine sand fraction. These environments appear to be optimum for burrowing infaunal bivalves; most grain morphotypes are derived from the shells of the bivalves *Polymesoda* and *Anomalocardia*, as well as the associated gastropods *Batillaria minima* and *Cerithidea costata*.

8. Lithoclast-*Batillaria* Lithofacies. This lithofacies is limited to the narrow tidal channels connecting Inlet C with the southeastern part of the creek system. Due to high current velocities, a thick Holocene crust and Pleistocene bedrock is frequently exposed in the channels. The thin sediment covering consists of eroded lithoclasts and *Batillaria minima* shells; worn macrophyte crusts are also present in abundance.

9. Transported Sediment-*Batillaria* Lithofacies.

10. Transported Sediment-Foraminifera Lithofacies.

11. Transported Sediment-Macrophyte Crust Lithofacies.

12. Transported Sediment-*Halimeda* Lithofacies. The characteristic sediment of coastal areas adjacent to Bonefish Pond is a light to dark gray, reworked, and much transported skeletal sand. This transported sediment is combined with recently generated skeletal grains to produce four lithofacies. The Transported Sediment-*Batillaria* Lithofacies occurs in the lower reaches of the Inlet A entrance into the creek system, where *Batillaria minima* is abundant. This indicates that there is a net up creek movement of coastal transported sediments through Inlet A. Conversely, broken and abraded macrophyte crusts are a significant grain type along the coast adjacent to Inlet C. The resulting Transported Sediment-Macrophyte Crust Lithofacies occurs because there is an extensive net down-creek movement of sediment through Inlet C. The Transported Sediment-*Halimeda* Lithofacies occurs where *Halimeda* is abundant along the open coast of Boat Harbour. Finally, a Transported Sediment-Foraminifera Lithofacies is present along the coast between Inlets A and B west of the coastal occurrence of macrophyte crusts. The tests of abundant coastal foraminifera such as *Quinqueloculina* and *Triloculina* are combined with the gray transported sediment to form this lithofacies.

BIOFACIES

Mitchell (1984a, 1985b), Mitchell and Keegan (1987), and Mitchell and Sealey (In Press) have developed a classification of foraminiferal and ostracod biofacies based on the detailed analyses of the surface sediments of tidal creeks of Florida and the Bahamas. The foraminiferal and ostracod biofacies of Bonefish Pond are generally similar to those encountered in other Bahamian tidal creeks. The molluscan biofacies of Bahamian tidal creeks previously have not been investigated in detail. The ostracod and molluscan biofacies classification presented here for Bonefish Pond is based on the distribution of living individuals determined by rose bengal staining. The foraminiferal biofacies classification is based primarily on test preservation and abundance, since only dried microfaunal samples were analyzed; usually these samples did not provide adequate preservation of living, stained foraminifera. Consequently, the ostracod and molluscan biofacies distributions most accurately reflect the relationships between physical parameters and biofacies distributions in Bonefish Pond.

Foraminiferal Biofacies

The distribution of foraminiferal biofacies is presented in Figure 4. Four major foraminiferal biofacies are recognized in the Bonefish Pond area:

1. *Peneroplis* Biofacies. The sediments of most of the central and eastern portions of the creek system contain an abundance of large, very well preserved tests of *Peneroplis proteus* Orbigny. The fine sand fraction of the sediment contains numerous tests of *Miliolinella suborbicularis* (Orbigny). The optimum occurrence of these species appears to be limited to the areas of Bonefish Pond with the highest salinities and lowest dissolved oxygen levels and current velocities. The *Peneroplis* Biofacies is associated with lithofacies dominated by macrophyte crusts or aggregates.

2. Restricted *Quinqueloculina* Biofacies. The most extreme upper reaches of the southeastern part of the creek system are characterized by the foraminifera *Quinqueloculina bosciana* Orbigny and *Q. costata* Orbigny. These species are typically abundant in hypersaline to brackish lakes in the Bahamas (Mitchell, 1984 and 1985b). This suggests that tidal effects are minimal in these two restricted areas.

3. Tidal *Triloculina* Biofacies. The tidal channels connecting Inlets A, B, and C to the central and eastern parts of Bonefish Pond contain a limited foraminiferal fauna dominated by living specimens of *Triloculina bassensis* Parr and *T. bermudezi* Acosta. Tests of *Quinqueloculina bosciana* Orbigny, *Q. costata* Orbigny, *Q. tenagos* Parker, and *Q. poeyana* Orbigny are also abundant. The substrates in the three channels are largely composed of transported sediment (A), aggregates (B), or lithoclasts (C). Salinities vary considerably every several hours depending on whether the flow is an ebb or flood current.

4. *Valvulina* Biofacies. This biofacies is present in the coastal areas adjacent to Bonefish Pond. The most abundant species are the agglutinated foraminifera *Clavulina tricarinata* Orbigny, *Textularia agglutinans* Orbigny, and *Valvulina oviedoiana* Orbigny. Other common species include *Articulina mucronata* (Orbigny), *Peneroplis pertusus* (Forskal), *Pyrgo subsphaerica* (Orbigny), *Quinqueloculina lamarckiana* Orbigny, *Q.*

subpoeyana Cushman, *Sorites marginalis* (Lamarck), *Spiroloculina antillarum* Orbigny, *Triloculina carinata* Orbigny, *T. linneiana* Orbigny, and *T. rotunda* Orbigny. Abraded representatives of this biofacies are common throughout the western and central parts of the creek system, where they are transported by flood tide currents.

Ostracod Biofacies

Two major ostracod biofacies are recognized in the Bonefish Pond area: 1. an assemblage dominated by *Cyprideis americana*; and 2. an assemblage characterized by *Bairdia harpago* Kornicker. The distribution of these ostracod biofacies is presented in Figure 9. Virtually all sediment samples contained several living representatives of one or the other of these two taxa. In addition, living specimens of *Cytherella arostrata* Kornicker were often found associated with *Bairdia harpago*. The dead shells of other species were common throughout most of the creek system: *Actinocytheris subquadrata* Puri, *Aurila floridana* Benson and Coleman, *Dolerocypria inopinata* Klie, *Hemicyprideis setipunctata* (Brady), *Loxoconcha postdorsolata* Puri, *L. purisubrhomboidea* (Edwards), *Perissocytheridea bicelliforma* Swain, *Puriana floridana* Puri, *Reticulocytheris multicarinata* (Swain), and *Xestoleberis curassavica* Klie. Since none of these 10 species was found living in sediment samples, it is inferred that they occur on algal or rocky substrates. The *Cyprideis* Biofacies occurs in restricted areas where salinities are the highest. The *Bairdia* Biofacies occurs in coastal areas and where salinities are lowered by flood tide currents entering Inlets A, B, and C.

Molluscan Biofacies

The distribution of molluscan biofacies is presented in Figure 10. Four major molluscan biofacies are present:

1. Gemma Biofacies. This biofacies is characterized by the bivalves *Gemma gemma* (Totten) and *Laevicardium laevigatum* (Linnaeus). Well preserved dead shells of *Acteocina canaliculata* (Say) were usually found with the living *Gemma*, suggesting that the two species have a similar distribution. These species are abundant in the creek system southeast of Middle island. The *Gemma* Biofacies occurs where salinities are high, dissolved oxygen levels low, and the substrate is a fine to coarse sand composed of macrophyte crusts.

2. Polymesoda Biofacies. Sediments in two areas of Bonefish Pond are unusually fine-grained: (a) Along the shore north of Middle Island; and (b) in the extreme southeastern arm of the creek system. The two areas seem to provide an optimum substrate for the infaunal bivalves *Polymesoda maritima* (Orbigny) and *Anomalocardia brasiliana* (Gmelin) and the gastropod *Cerithidea costata* (Da Costa).

3. Chione Biofacies. A very small species of the bivalve genus *Chione* is very abundant throughout the western part of the creek system. The species occurring in Bonefish Pond seems to be most similar to *Chione pubera* (Bory Saint-Vincent). However, *C. pubera* is much larger and has different coloration. The *Chione* Biofacies is apparently dominated by an undescribed species of *Chione*. Living representatives of *Chione* and *Caecum nitidum* Stimpson were found together in most sediment samples from this area. The *Chione*

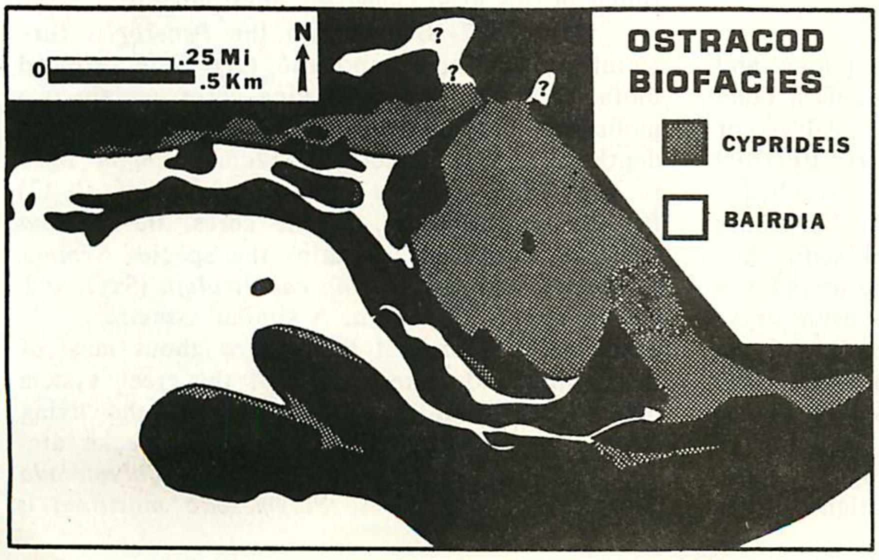

Fig. 9. Distribution of ostracod biofacies, Bonefish Pond.

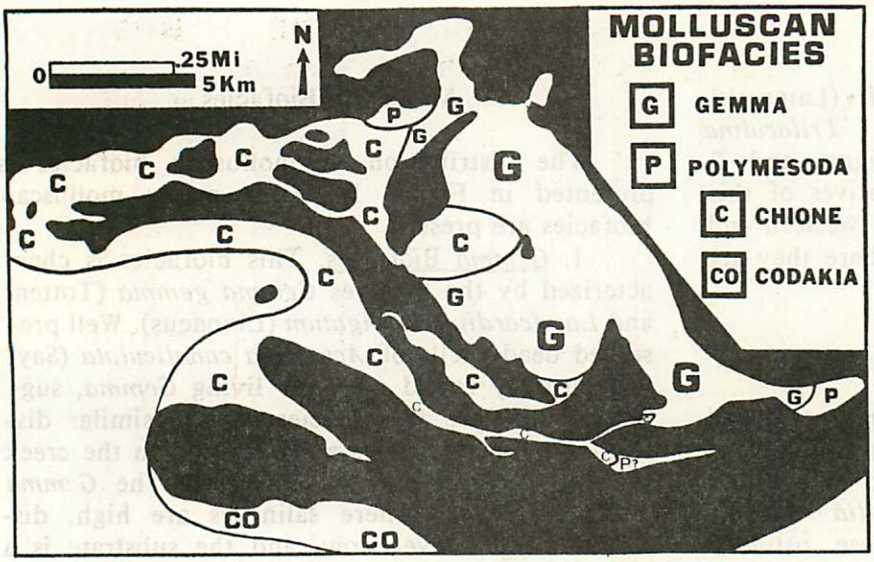

Fig. 10. Distribution of molluscan biofacies, Bonefish Pond.

Biofacies occurs where maximum salinities are about $45^{0}/oo$ and dissolved oxygen levels higher than those in the upper creek system. *Chione* sp. cf. *C. pubera* is most abundant in substrates consisting of the gray transported sediment and/or fine, broken aggregates or macrophyte crusts.

4. Codakia Biofacies. The bivalves *Codakia orbicularis* (Linnaeus) and *Codakia costata* (Orbigny) are typical of the diverse bivalve fauna occurring along the open coastal sand flats of Boat Harbour. Other living molluscs recovered from sediment samples include *Caecum plicatum* Carpenter, *C. nitidum* Stimpson, *Littorina angulifera* Lamarck, and *Brachiodontes exustus* (Linnaeus).

TWENTIETH CENTURY SEDIMENTOLOGICAL DEVELOPMENT

Core Analysis

Recent changes in the sedimentology and microfaunas of central and eastern Bonefish Pond have been investigated through the analysis of nine shallow cores (the locations of cores BP1-BP9 are given in Figure 1). All of the cores reached a thick Holocene crust or the Pleistocene limestones underlying the uncemented tidal creek sediments. Variations in the silt-clay percent, the abundance of selected grain types (aggregates, gypsum crystals, lithoclasts, and macrophyte crusts), and the biofacies present (foraminiferal, molluscan, and ostracod) in each core are summarized in Figure 11. All cores document considerable increases in silt-clay with increasing depth. During the sedimentary intervals representing the highest silt-clay deposition, gypsum crystals (disks) occur in cores BP1, BP2, BP5, and BP6. Lithoclasts are most abundant in the lowest and/or uppermost sediments of the cores; in most cases the lithoclasts contain significant levels of protodolomite. Macrophyte crusts are limited to the upper 8 1/2 to 13cms of the cores (Fig. 11).

The mineralogy of the silt-clay and sand fractions of each unit in cores BP2, BP6, and BP8 were determined by X-ray diffraction analysis. In general, dolomitization increases with depth, and there is a corresponding decrease in the amount of aragonite present. Low levels (less than 2%) of terrigenous quartz occur in all silt-clay fractions except those from the upper 5cms of core BP2. These sediments were deposited in a small hypersaline lake formed on East Island. It is unlikely that the terriginous silt-clay, leached from Pleistocene eolianites and transported through the creek by tidal currents, would be found in this local lacustrine environment.

Cores BP2-BP9 contain the *Peneroplis* foraminiferal biofacies and the *Cyprideis* ostracod biofacies at all levels. All nine cores contain two molluscan biofacies: 1. an upper (surface to a depth of approximately 10-12cm) *Gemma* Biofacies; and 2. a lower (below a depth of 10-12) *Polymesoda* Biofacies. In the cores, the *Gemma* Biofacies commonly contains the species *Gemma gemma* (Totten), *Acteocina canaliculata* (Say), and *Chione* sp. cf. *C. pubera*. A similar assemblage of dead shells is present today throughout most of the central and eastern parts of the creek system due to the tidal current mixing of the living *Gemma* and *Chione* Biofacies. These species are not present, or are rare, in the *Polymesoda* Biofacies of the cores. *Polymesoda maritima* is

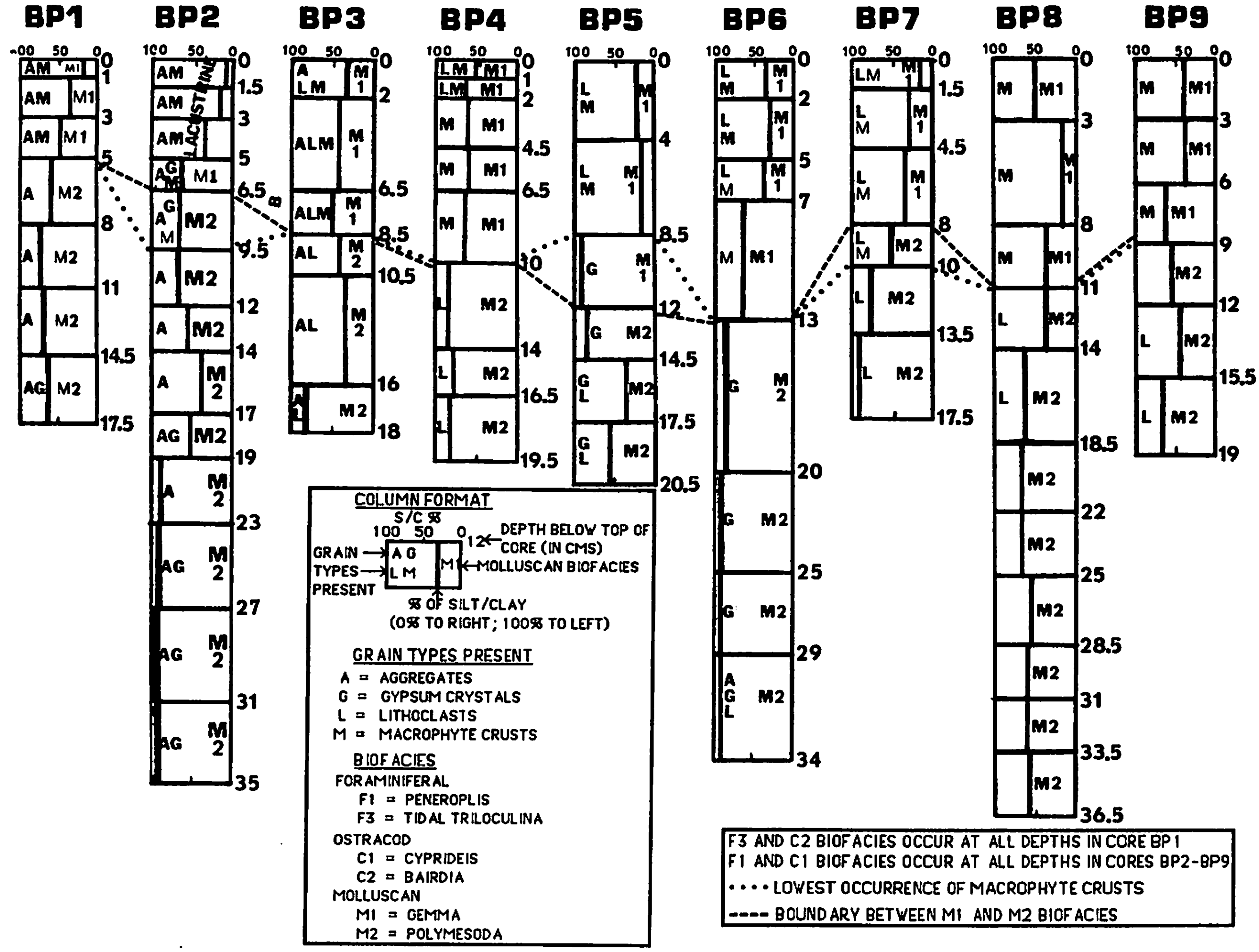

Fig. 11. Silt-clay variation, biofacies, and occurrence of selected grain morphotypes in shallow cores from Bonefish Pond. Units are given in cm intervals below the top of the core, which is the creek or lake sediment surface. Core locations are shown in Figure 1.

abundant in the lower parts of the cores; it is absent, or rare, in the upper 10-12cm (Fig. 11). The boundary between these biofacies coincides with a marked decrease in silt-clay percent in most cores. The change in molluscan biofacies seems attributable to a significant change in water turbidity, which would significantly affect these infaunal suspension feeding bivalves. At present, the *Polymesoda* Biofacies is limited to two small areas of the tidal creek system where the sand fraction of the sediment is very fine (Fig. 10). An increase in lithoclasts in the upper part of several cores (BP3-BP6) seems to reflect the heightened erosion and transport of Pleistocene limestones or Holocene crusts exposed along the margins of the creek system. This implies an increase in current velocities and is consistent with the corresponding decrease in silt-clay percents. The sand and silt-clay fractions at the base of two cores (BP2, BP6) contain significant levels (10-20%) of low Mg-calcite. This suggests that, in these areas, the cored sediment sequence directly overlies eroding Pleistocene limestones. Aggregates occur only in core BP3 which is located in an area where thin protodolomite crusts are presently forming. Since aggregates are common to abundant throughout core BP3, it appears that the conditions necessary for producing thin sediment crusts have continued in this area over a relatively long period of time.

Map Evidence

Map evidence of changes in the geography of the Bonefish Pond creek system during the past 100 years exists and indicates that much of the sedimentary sequence recorded in the upper portion of the cores was deposited in the Twentieth Century. An enlarged portion of an 1881 British survey map of southern New Providence

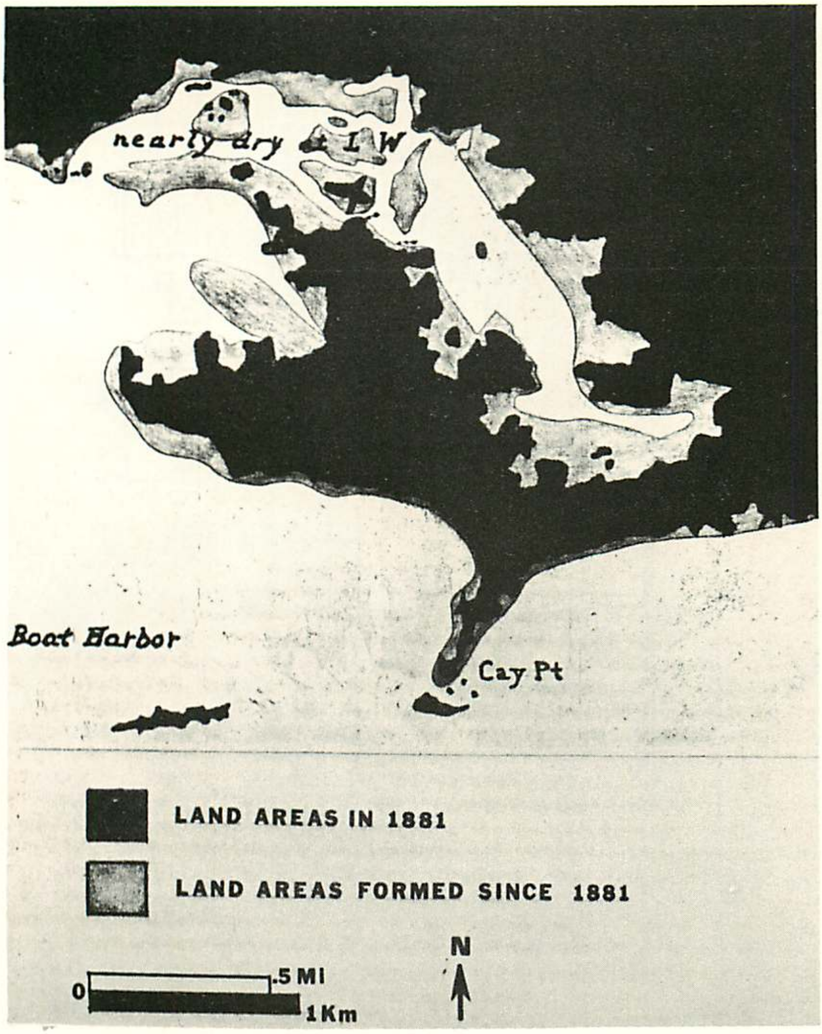

Fig. 12. Map of Bonefish Pond showing land areas in 1881 (black) and land areas formed within past 100 years (gray). Base map is from United States Hydrographic Office (1936).

island is presented in Figure 12. Land areas in 1881 are shown in black; land areas formed since 1881 (as determined from detailed aerial photographs and field surveys) are shown in gray. The map, aerial photograph, and field evidence documents that there have been very significant changes in the geography of Bonefish Pond over the past 100 years. The area covered by the tidal creek system has been reduced by about one-half. Coastline accretion has narrowed Inlet A to about one-sixth of its width in 1881. In addition, the islands restricting the western half of the creek have been developed during the past 100 years. Also, the shorelines of the eastern part of Bonefish Pond have been straightened and East Island has been formed by the deposition of sediments (Fig. 12).

DISCUSSION AND CONCLUSIONS

The evidence provided by present surficial sediment and biofacies distributions, shallow core analyses, and the evaluation of maps and aerial photographs supports a preliminary scenario for the development of Bonefish Pond over the past 100 years. In the Nineteenth Century, the creek system was a relatively extensive carbonate mud flat dominated by hypersaline foraminiferal, ostracod, and molluscan biofacies. The shallow mudflat ("nearly dry at low water" according to the 1881 British survey map) was geochemically suited for the widespread formation of protodolomite and gypsum crystals (disks). The protodolomite seems to have been precipitated in an unlithified carbonate mud, with the dissolution of aragonite taking place. A similar origin for protodolomite, occurring along western Andros Island, has been proposed by Gebelein and Others (1980). The gypsum disks are similar to ones discovered in shallow lakes on Rum Cay, Great Exuma Island, and northern Long Island (Mitchell, 1987b). The offshore area of Barcardi Bay seems to have been shallower than at present. The 1881 British survey map indicates that the Bay is "clear white sand [with] depth from 1 to 2 feet" (Fig. 12). Through the past 100 years, longshore transport and net up creek sediment transport have reconfigured the major entrance to the creek system, Inlet A, by narrowing the inlet and by developing islands in the inlet channel.

In the past few decades, the industrial development of south-central New Providence Island has modified Bonefish Pond in another way. Macrophyte crusts typically occur in the fresh water sublittoral environments of hardwater lakes rich in dissolved calcium carbonate. These environments may be subject to low levels of industrial pollution (Schneider and Others, 1983). It is hypothesized that the development and high level of productivity of the macrophyte crust-producing cyanophytes in Bonefish Pond are due to water chemistry changes caused by the increasing agricultural and industrial development of the area of southern New Providence Island adjacent to the creek system. The upper 10-12cms of all of the 9 shallow cores record the advent of major changes in the sedimentation and biofacies of Bonefish Pond, due apparently, to the explosive development of cyanophytes in the extreme southeastern part of the creek (Fig. 7). At present, thin protodolomite crusts are forming in several areas of central Bonefish Pond (Fig. 1). Much thicker Holocene protodolomite crusts occur along the margins of the central and eastern parts of the creek system. These thick crusts are largely composed of particles in the silt-clay size range. It is tentatively suggested that the thicker protodolomite crusts formed prior to the onset of macrophyte crust production. At present, 12 lithofacies, 4 foraminiferal biofacies, 2 ostracod biofacies, and 4 molluscan biofacies are recognized in the Bonefish Pond area. They have developed over the past few decades in response to shifting environments: one characterized by the widespread precipitation of protodolomite and gypsum has given way to one dominated by macrophyte crustal sediments.

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