Kuhlman, H. H. 1961. Studies on the morphology and growth rate of the cestode *Hymenolepis microstoma* after gamma irradiation of the cysticercoids and eggs. (unpublished) Ph.D. Thesis, Department of Zoology and Entomology, University of Tennessee, Knoxville.

Ogren, 1953. Concepts of early development derived from comparative embryology of oncospheres. (unpublished) Ph.D. Thesis, University of Illinois Graduate School, Urbana.

Oswald, Vernon H. 1957. A redescription of *Pseudodiorchis reynoldsi* (Jones, 1944) (Cestoda, Hymenolepididae), a parasite of the short-tailed shrew. *J. Parasit.* 43:464-469.

Palais, Mireille 1933. Les anomalies des cestodes. Recherches experimentales sur *Hymenolepis diminuta* (Rud.) *Ann. Fac. Sc. Marseille* 6:109-163.

Schiller, 1957. Investigations on the use of x-irradiations as a mechanism for facilitating the study of morphological variation in *Hymenolepis nana. J. Parasitol.* 43 (Suppl.) :5.

1959. Experimental studies on morophological variation in the cestode genus *Hymenolepis.* II. Morphology and development of the strobilate phase of *Hymenolepis nana* in different mammalian host spcies. *Exptl. Parasit.* 8: 225-235.

Wardle R. A. and McLeod, J. A. 1952. The Zoology of Tapeworms. University of Minnesota Press, Minneapolis.

OBSERVATIONS OF PRESENT-DAY CARBONATE ENVIRONMENTS IN THE BAHAMA ISLANDS

R. L. Wilson
University of Chattanooga, Chattanooga, Tennessee
R. E. Bergenback
The Pennsylvania State University
State College, Pennsylvania

Introduction

During the fall and winter of 1958 the writers began a detailed study of the limestones of Mississippian age on Lookout Mountain near Chattanooga, Tennessee. Marked lateral and vertical changes were noted in these ancient oolitic limestones. In order to better understand the environments and sedimentary processes responsible, it was believed advantageous to visit an area of recent carbonate formation.

The Bahama Islands, located south and east of Miami, Florida (Fig. 1), are considered to be one of the classic areas for the study of marine carbonate deposition. Since Louis Agassiz's study of 1851, this outdoor laboratory has been of major importance to geolgists.

Acknowledgements

The writers wish to thank Mr. George Clark, Chairman of the Board of Pioneer Bank, Chattanooga, for his interest in this study. Mr. Clark made available the necessary funds and volunteered the use of his yacht, Pioneer, which served as the main base of operations in the Bahamas.

Sincere appreciation goes to Dr. Leon Johnson, of the Pennsylvania State University, who provided X-ray analyses of carbonate mud samples. The assistance and advice of Dr. Cesare Emiliani of the International Oceanographic Foundation of Miami and Rear Admiral Karo, Director of the U.S. Coast and Geodetic Survey, also is gratefully acknowledged.

Local assistance was provided by Col. Peter Wilson, retired British army officer of Fresh Creek, Andros Town, Bahama Islands. The crew of the yacht, Captain Bob Lackey and Sam Lowe, helped in collecting samples and taking photographs.

Methods of Study

Owing to the limiting time factor, a relatively small number of rock and sediment samples were taken. The unconsolidated sands and muds on beaches, lagoon floors, and river bottoms were spot-sampled for mechanical, X-ray, and spectrographic analyses.

These field samples were supplemented by numerous photographs and brief field descriptions. Airplane flights over the Fresh Creek vicinity provided additional data.

Areas of Study

The areas studied during the 8-day period in December 1959, included: (1) the region around the mouth of Fresh Creek on Andros Island, (2) Big Wood Cay in the vicinity of Middle Bight, and (3) North Cat Cay on the western margin of the Bahama Island group (Fig. 1).

The major portion of this brief investigation centered about Andros Town on Fresh Creek (Fig. 2) because of the relatively large number of closely-spaced environments of carbonate formation and accumulation. These environments include: (1) reef, (2) cay (island), (3) lagoon, (4) beach, and (5) stream. The Middle Bight area displayed characteristics of (1) beach and (2) lagoon. North Cat Cay showed (1) beach and (2) lagoonal environments to advantage.

Fresh Creek Area

The narrow barrier reef off the eastern coast of Andros Island extends a short distance seaward (toward the Tongue of the Ocean) from the exposed cays. It is not continuous and through one of the breaks it is possible to gain access to the Andros Town harbor. The area visited is located off the northernmost island of the Goat Cay group (Fig. 2).

This reef is a living community covered by 7 to 10 feet of water at high tide and only 4 to 5 feet at low tide. The water was very clear and had a temperature of 71° to 75°F. The "rock" consists principally of sand-sized skeletal material held in place by growing coral colonies. Sea fans are the most common. Others include: (1) *Acropora palmata* (Elkhorn coral), (2) *Acropora cervicornis* (Staghorn coral), (3) *Goniolithon strictum,* and (4) several species of *Porites.* Sharp-spined sea urchins were abundant.

Of the many islands in the area, Long Cay was chosen primarily because of its accessibility. It is

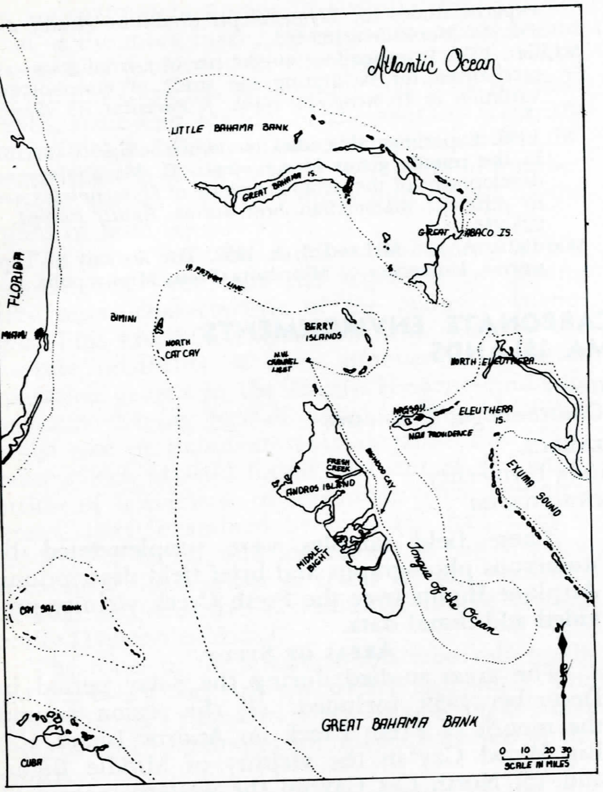

Figure 1. Index Map, Great Bahama Bank

located about 6,000 feet northeast from the mouth of Fresh Creek (Fig. 2). The northern tip, ranging from 150 to 200 feet in width, was the portion studied. On the seaward (Tongue of the Ocean) side there is very little beach and a generally rocky surface is exposed at low tide. On the lagoonward (western) side a gently sloping skeletal-sand beach ranges from 5 to 20 feet in width. The relief at low tide is about 15 feet above sea level.

Perhaps the most spectacular feature of Long Cay is the surface of the oolitic rock. Much of it is so intricately and deeply pitted (1 to 2 feet) that walking is difficult. Presumably the pitting is due to: (1) subaerial leaching, (2) marine organisms, (3) chemical reaction with sea water, or (4) some combination thereof. Abraded pebble- and cobble-sized fragments of more recent coral and gastropod shells are found in many of these pits. Some have become cemented to the sides and bottoms and can only be pried loose with difficulty.

Adhering to the island rock in the littoral zone are numerous small marine gastropods (as much as 1 inch in diameter) and, in addition, on the lagoonal side, many chitons (3 to 4 inches long). Both the gastropods and chitons make shallow depressions where they are attached. On the southern beach small ramifying holes are made by the *Teredo*, a boring organism.

It appears that organisms such as the chiton, gastropods and *Teredo* play a significant role in the destruction of carbonate rock. Recent small-scale cementation is proven by the bonding of t[h] fragmental material in the bedrock pits.

The portion of the windward lagoon studied [is] situated between Long Cay and Andros Island. T[he] lagoon is almost a mile wide at this point.

About 500 to 800 feet offshore of Long Cay [a] channel in the lagoon roughly parallels the li[ne] of cays. This channel is as much as 300 feet wi[de] and at low tide is from 7 to 12 feet deep. Relativ[ely] little sea grass grows on the bottom, and some [of] the largest starfish and conch shells in the lago[on] are found here.

In the remainder of the lagoon are extensi[ve] patches of sea grass, *Thallasia,* which has a reti[cu]lated root pattern effective in stabilizing the bott[om] sediments. Near the seaward edge of the lago[on] are isolated growths of brain corals, *Diplora* s[p.] and species of *Porites* as well as sea anemones a[nd] echinoids. The skeletal sand in this area of [the] lagoon floor is difficult to distinguish visually fr[om] that of the southern beach on Long Cay.

Several unsuccessful attempts to take core sa[m]ples of the lagoon bottom revealed a thin ven[eer] (about 10 inches) of lagoonal sediment underl[ain] by bedrock.

Three spot samples of bottom sediments w[ere] taken from the lagoon (Fig. 2), and mechani[cal] analyses were performed (Fig. 3, Samples 1, 2, a[nd] 3). It is worthy of note that the sample taken fr[om] the channel within the lagoon (sample 1) is diff[er]ent both in sorting and grain-size distribution fr[om] the other two samples. Generalizations based [on] only three samples from such a large area wo[uld] be hazardous.

The lagoon exhibits subenvironments consist[ing] of the channel and the marine grass patches. [On] the basis of visual observation of texture, the [dis]tinction between the beach and the lagoon fl[oor] near the beach is difficult. Inasmuch as the s[edi]ments of the floor form only a thin veneer, i[t is] likely that the bedrock of the lagoon and of An[dros] Island are continuous. The lagoon is probabl[y] located because of local subsidence of a portio[n of] the bedrock.

Along the beach on the northeastern shor[e of] Andros Island, several trips were made both n[orth] and south of Andros Town. At low tide the be[ach] ranges from 50 to 80 feet in width. Much of [the] surface is covered by skeletal sand and gravel si[mi]lar to that reported by Illing (1954).

Although no detailed analysis of the com[po]sition of the beach sand was made, a visual exa[mi]nation indicated that foraminifera, mollusks, [and] corralline algae fragments are of major importa[nce] in the Fresh Creek area. Much of the beach sur[face] is composed chiefly of sand-sized material; howe[ver,] in a few places oolitic bedrock contributes to [the] beach sediment. Bach rock, as reported by Ginsb[urg] (1953) on the Dry Tortugas off Florida, was [not] observed in this area.

The beach sand, for the most part, is unconsolidated, fine- to medium-grained, ske[letal]

TABLE I

Contents of Bahamian Shelf Lagoon Sand (After Illing, 1954)

Type	Percentage
Country rock	2
Faecal rock	½
Other grains	10½
	13
Calcareous algae	39
Corals	12
Foraminifera	18
Other organisms	4
	87

sand (Fig. 3, Samples 4 and 7). Near headlands the concentration of wave energy results in a significantly coarser and less well-sorted sand (Fig. 3, Sample 8). Some of the headlands also show pebble- and cobble-sized fragments of coral and whole shells of conchs and pelecypods.

Of significant concern are the marked textural changes that occur laterally in the relatively restricted environment. Apparently, the configuration of the sea bottom in front and the dissipation of wave energy are major controlling factors in textural distribution on the beach.

Along the northeastern side of Andros Island are several shallow, brackish streams (usually less than 10 feet in depth). Fresh Creek (Fig. 2) is one of these. At its mouth Andros Town is located.

Aerial reconnaissance of the area disclosed at least two areas of deeper water: (1) the present channel off the mouth of Fresh Creek which flows into an ever smaller and deeper submarine trench as it crosses the margin of the platform into the Tongue of the Ocean, and (2) several large drowned sinkholes in the bedrock located as much as 1 mile inland from Andros Town. Other observers (Agassiz, 1894; Vaughn, 1914; and Duran, 1955) also noted these phenomena and measured sinkholes at least 200 feet deep. These areas of deeper water within the generally shallow banks indicate, in the opinion of the writers, that Andros Island probably stood at least 100 feet above sea level during the Pleistocene or post-Pleistocene period. Newell and Rigby (1957) noted a series of marine terraces just beyond the edge of the outer platform off the

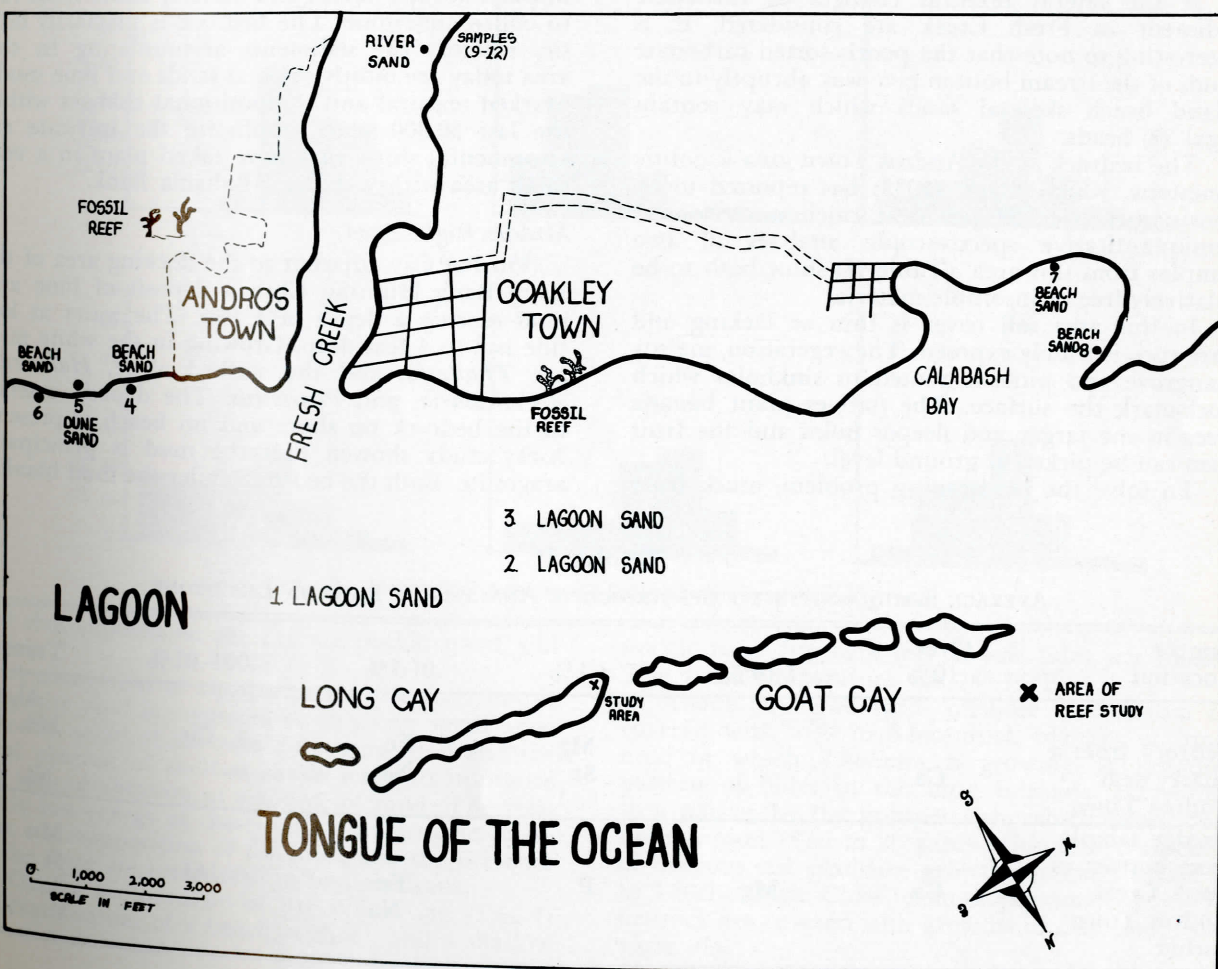

Figure 2. **Sample Localities, Fresh Creek Area**

mouth of Fresh Creek which resemble wave-cut benches and are interpreted by them as submerged strand lines produced during the Wisconsin stage of Pleistocene.

In an area of 1 to 5 miles upstream from the mouth of the creek the bottom sediment generally is poorly sorted and ranges from zero to 3 feet in thickness (Fig. 3, Histograms 9-12). X-ray analysis indicates that the clay-sized fraction is principally calcite. Where there is no sediment, pitted oolitic bedrock is visible. Probably this bedrock was pitted during the "Pleistocene depresssion of sea level" (Newell and Rigby, 1957).

Along the intertidal zones of the islands in Fresh Creek are found laminated algal (?) limestone "heads." They occur as encrustation on oolite bedrock and consist of alternating laminae (as much as ⅛ inch thick) of dark to very light brown, hard, somewhat porous limestone. In other areas of these zones the oolitic bedrock is covered by growths of *Dasycladacean* algae, which seemingly are associated with calcium carbonate deposition. Oolite rock as much as 6 feet above high tide is encrusted with this algal (?) limestone, but the pitted nature of this surface shows evidence of solution rather than deposition.

If the lateral textural changes of carbonate sediment in Fresh Creek are considered, it is interesting to note that the poorly-sorted carbonate muds of the stream bottom give way abruptly to the island beach skeletal sands which may contain algal (?) heads.

The bedrock of the Andros Town area is oolitic limestone, which Black (1933) has reported to be consistently over 98 per cent calcium carbonate. Semiquantitative spectroscopic analyses of two samples from this area (Table II) show both to be relatively free of insoluble material

In this area soil cover is thin or lacking and bare rock is widely exposed. The vegetation, mainly mangrove and pine, is rooted in sinkholes which pock-mark the surface. The natives plant banana trees in the larger and deeper holes and the fruit then can be picked at ground level.

To solve the landscaping problem, muck from nearby coastal swamps is used as a base for pla growth. To plant larger trees a narrow trench to 4 feet deep is dug and filled with materi dredged from the swamps.

Along the landward side of the lagoon just we of Coakley Town and underlying what appears be a low ridge of oolitic limestone is a striki exposure of an ancient reef. Newell and Rig (1957) in their description of the reef cite a C age determination of 30,000 years made by t Lamont Geological Observatory.

This dome-shaped reef extends above the lagoo floor to a maximum height of 15 feet and di laterally into the bedrock underlying the lagoo Its material is less resistant than the overlyi oolite limestone, making the reef outline eas discernible. More than 30 species of corals a mollusks have been described from this reef (N well and Rigby, 1957). The preservation of t fossils is excellent and the friable nature of t rock renders collecting easy. At the western end small patch of breccia is present. Wilson and othe (1961) noted additional areas of fossil patch re as much as half a mile inland from the prese shore of the lagoon.

It is significant that the bedrock of this ar displays abrupt lateral and vertical facies from re to oolitic limestone. The bedrock is primarily oo tic, whereas the sediments accumulating in th area today are mostly skeletal sands and lime mu Marked textural and compositional changes with the last 30,000 years emphasize the intricate e vironmental shifts that have taken place in a ve small area within the vast Bahama Bank.

Middle Bight Area

On Pot Cay adjacent to the docking area of t Bang Bang Hunting Club a deposit of lime a mud reaches a depth of 4 feet. The water at lo tide is 3 to 4 feet deep. Growing in the white m are *Thallasia,* and the stalked algae, *Halime Acetabularia,* and *Penicillus.* The deposit exte to the bedrock on shore and no beach is prese X-ray study showed that the mud is principa aragonite. Both the bedrock under the mud blan

TABLE II

Average Semiquantitative Spectroscopic Analysis of Bahama Limestone

Sample Location	Over 10%	1-10%	.1-1%	.01-1%	.001-.01%	Tra
Bedrock from a quarry near Andros Town	Ca		Mg Sr	Fe Na	Cu	Al Mn Ni
Dredge sample from bottom of Fresh Creek Andros Town harbor	Ca	Mg	P	Fe Na	Al Ni	Mn Si Sn V

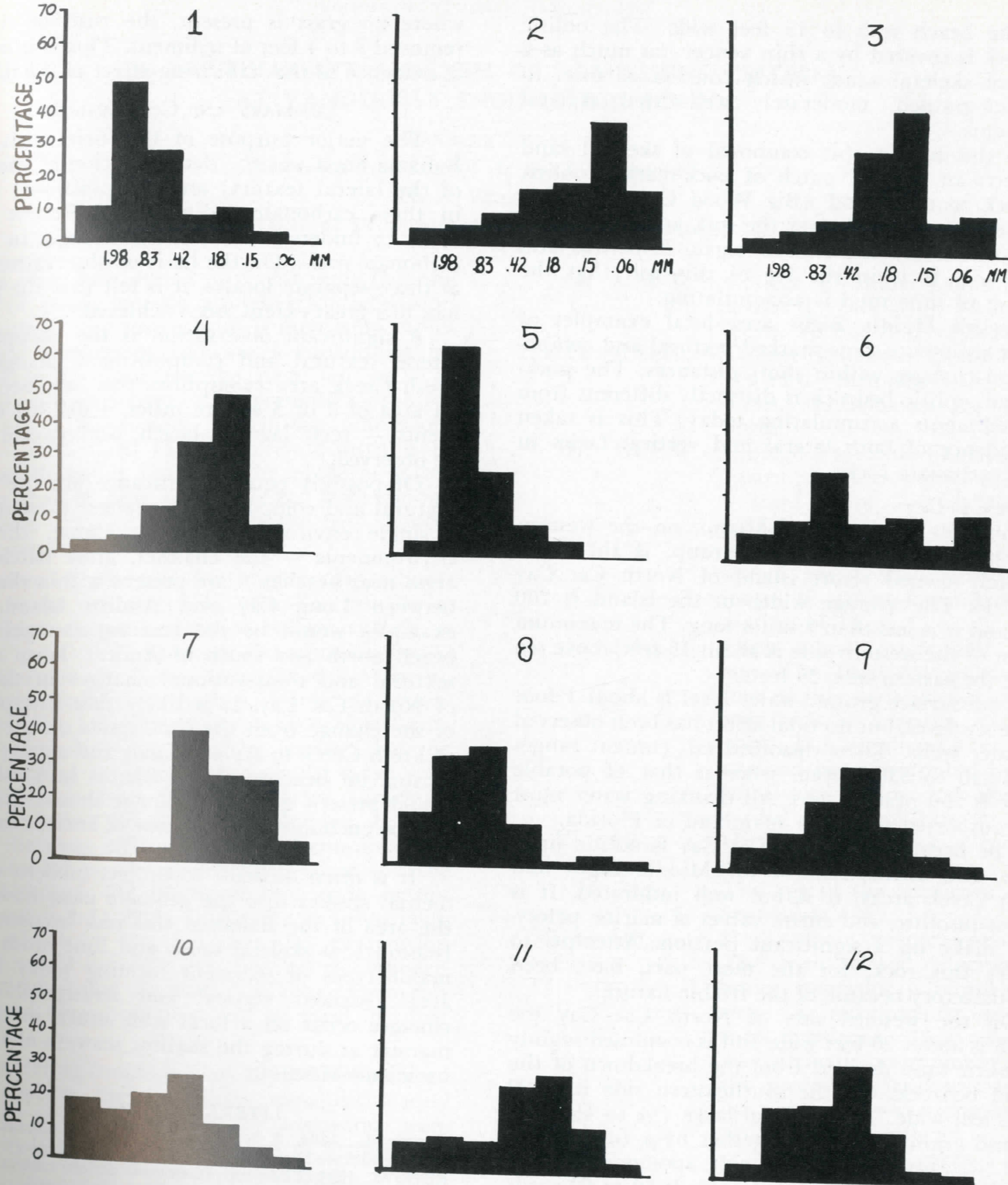

Figure 3. Mechanical Analyses of Sediments in Fresh Creek Area.

and that exposed on the cay are pock-marked and oolitic.

A connection of algae with the precipitation of aragonite mud is suggested in this very small area. The low relief of the whole Bahama Shelf and the local absence of skeletal sands seem to minimize the idea of abrasion as a source of mud. The relatively low energy of these harbor waters, the thickness and composition of the mud, and the presence of the algae are considered to be significant.

On the southern tip of Big Wood Cay (Fig. 1) an examination of a beach, a shoal, and a shallow neritic zone (up to 4 feet at low tide) was made. The water temperature was 73°-74°F.

About 50 to 60 yards offshore the bottom is covered with a 2- to 3-foot-thick blanket of lime mud in which *Thallasia* is growing. A random pattern of holes in the mud is made, according to a native, by the grouper fish, which ingest the bottom mud. Ten to 20 yards offshore are patches of bulbous red plantlike growths (algae?) about 2 to 3 inches high. Close to shore exposures of oolitic bedrock are covered with growths of *Dasycladacean* algae (?).

The beach is 5 to 15 feet wide. The oolitic bedrock is covered by a thin veneer (as much as 2 feet) of skeletal sand, which consists of fine- to medium-grained, moderately well-sorted skeletal fragments.

In this area a spit composed of skeletal sand connects an isolated patch of pock-marked oolitic bedrock to the island (Big Wood Cay). Shoaling agitated waters break over the spit, and growing in these waters are the stalked algae, *Penicillus* and *Halimeda*. It is in the lee of this spit that the blanket of lime mud is accumulating.

In this Middle Bight area local examples of recent sediments show marked textural and compositional changes within short distances. The pock-marked, oolitic bedrock is distinctly different from the sediments accumulating today. This is taken as evidence of both lateral and vertical facies in these carbonate rocks.

North Cat Cay

Some 50 miles east of Miami, on the western edge of the Bahama Island group, is the small privately owned resort island of North Cat Cay (Fig. 1). The average width of the island is 200 feet, and it is less than 3 miles long. The maximum height of the western side is about 15 feet above sea level; the eastern side, 25 feet.

A subsurface ground-water level is about 1 foot above sea level, but no tidal effect has been observed in water wells. Their dissolved salt content ranges from 350 to 5,050 ppm, whereas that of potable water is 250 ppm or less. All drinking water must be transported from the mainland of Florida.

The bedrock of North Cat Cay is oolitic limestone, but, unlike that of the Middle Bight and Fresh Creek areas, it is not well indurated. It is almost pisolitic, and entire valves of marine pelecypods make up a significant portion. Attempts to quarry this rock, for the most part, have been unsatisfactory because of the friable nature.

On the western side of North Cat Cay the beach is about 20 feet wide and is composed mainly of oolitic sand derived from the breakdown of the island bedrock. On the southeastern side it is 20 to 30 feet wide. The surficial layer (¼ to ½ inch) of sand grains is bound together by a filamentous algal (?) growth to form a soft, spongy mat. It is as much as 10 feet wide and extends 50 to 60 yards along the beach. Presumably this mat controls sedimentation, because the sediment in front of and behind it is slightly coarser than the material within the mat.

The beach features of North Cat Cay have significance in that this recent beach on a small island shows oolitic sand in one area and skeletal sand with an algal (?) mat in an adjacent area. The oolite stems from a pre-existing source, and the skeletal sand and algal (?) mat are results of recent processes.

On the southeastern side of North Cay Cay, in a small tidal lagoon, the sandy bottom has been partially stabilized by *Thallasia*. In the places where no grass is present, the rush of tides removed 3 to 4 feet of sediment. This is interpre as evidence of the stabilizing effect of *Thallasia*

Summary and Conclusions

The major purpose of this brief visit to Bahama Shelf was the determination of the nat of the lateral textural and compositional char in these carbonate sediments of Recent age order to understand the facies changes in anci carbonate rocks. On the basis of observations m at three separate locales, it is felt that the purp has, to a great extent, been achieved.

A significant observation is the abruptness lateral textural and compositional changes. T Fresh Creek area exemplifies this best because, an area of 2 or 3 square miles, 4 distinct envir ments — reef, lagoon, beach, and stream — be observed.

Of possibly equal significance are the mark textural and compositional changes present with a single environment. For example, three s environments — the channel, grass patches, a areas near beaches — are present within the lago between Long Cay and Andros Island. Ot examples would be the textural changes on beach north and south of Andros Town and textural and compositional changes in the bea of North Cat Cay. It is likely that interpretati of the change from the lime muds on the botto of Fresh Creek to skeletal sands and algal (?) hea located on beaches of the islands in Fresh Cre would present quite a challenge should this con tion be encountered in a study of ancient carbona rocks.

It is often difficult to project modern enviro mental studies into the geologic past; however, the area of the Bahamas this task becomes easi Inasmuch as skeletal sands and lime muds are t major types of sediment forming today in th areas, marked vertical and stratigraphic fac changes occur on a local scale much in the sa manner as during the shallow seaways of the Pa ozoic and Mesozoic.

LITERATURE CITED

Agassiz, L., 1894. A reconnaissance of the Bahamas and the elevated reefs of Cuba. *Mus. Comp. Zoology*. 26: 1-2

Black, M., 1933. The precipitation of calcium carbonate on t Great Bahama Bank. *Geol. Mag*. 70: 455-466.

Doran, E., Jr., 1955. Land forms of the southeast Baham *Univ. of Texas*. 5509: 1-38.

Ginsburg, R. N., 1953. Beachrock in south Florida. *Jour. S Petrol*. 23: 85-92.

Illing, L. V., 1954. Bahama calcareous sands. *Bull. Am Assoc. Petrol. Geol*. 38: 1-95.

Newell, N. D., and J. K. Rigby, 1957. Geological structu on the Great Bahama Bank. Symposium: Regional asp of carbonate deposition. *Soc. Econ. Paleo. and M* Spec. pub. 5: 15-72.

Vaughn, T. W., 1914. Preliminary remarks on the geolog the Bahamas with special reference to the origin Bahaman and Floridian oolites. *Pap. Tortugas L* 5: 47-54.

Wilson, R. L., R. E. Bergenback, and C. P. Finlayson, 19 Fossil coral reefs, Fresh Creek, Andros Island, Baham (abs.) *Special Paper No. 68. Geol. Soc. of Amer*. :82