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TEXTURE AND COMPOSITION OF HOLOCENE BEACH SEDIMENT, SAN SALVADOR ISLAND, BAHAMAS

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ABSTRACT

Sedimentation on San Salvador may be seen as a model for that of many other Bahamian islands. Because of its location on a small, isolated, carbonate bank, there are constraints on beach development and sediment supply. To determine the nature of the beach sediment, samples were collected along transects across the subaerial portions of 18 selected beach sites along the island periphery. These beaches provided a total of 71 samples that were dry sieved to determine texture. Sixty-five samples were impregnated and cut into thin sections for petrographic study.

The results of dry sieving show a majority of the beach environments (60 out of 71 sampled) are moderately well to well sorted. In a beach by beach comparison however, grain sizes are more diverse. Beaches along the eastern margin are predominantly fine to medium grained while western beaches, though mostly well sorted, show a high degree of variability in grain size. Preliminary interpretations indicated that textural findings may be related to the strength and consistency of active physical processes such as wind, wave and current activity and also to antecedent topography and platform morphology. Analysis of thin sections show a mostly bioclastic composition for San Salvador beaches. Comparisons of fine and medium grained eastern beaches with their western counterparts show that percentages of red algae, lithoclasts, peloids, foraminifera and minor constituents vary significantly. This indicates that composition is not a controlling factor for grain size and sorting or vice versa.

INTRODUCTION

General Setting

San Salvador Island is a small island situated on a shallow, isolated carbonate bank on the eastern edge of the northwest Bahamas. The island measures eleven kilometers in width (E-W) and nineteen kilometers in length (N-S). Surrounding San Salvador is a narrow shelf, which drops almost vertically from the shallow bank to deep ocean on the western and southern margins. On the eastern and northern sides, the transition from shallow bank to deep ocean is gradual and the slope more gentle. Numerous bank/barrier and fringing reefs are found offshore.

The topography is highlighted by Pleistocene and Holocene eolian ridges. Many of these ridges form headland cliffs along the shoreline, and between them beach sediments are deposited. Like other Bahamian islands, San Salvador beaches are associated with a high energy carbonate shelf environment (Inden and Moore, 1983) in which wind, waves and currents play a dominant role in the sedimentation.

Purpose

Most previous research in the Bahamas and on San Salvador has been concentrated on shallow bank margins rather than beaches. Studies of the Little Bahama Bank carbonate margins (Hine and others, 1981; Hine and Neumann, 1977; Hine, 1983) resulted in classifications and models for sedimentation onto the shallow water banks. These classifications generally indicate that platform morphology, physical energy and antecedent topography are controlling factors on sedimentation.

There have been a few general descriptions of beaches on San Salvador: at French Bay (Bain, 1986), and a grain size distribution study along selected lower beachfaces (Lee and others, 1986) around the island.

The purpose of this study was to analyze the texture (grain size and grain sorting) of modern carbonate beach sediments, identify the allochems which comprise these sediments and determine the relationship of sediment properties to energy (wind, wave and currents) and physiographic features like platform morphology, beach slope and antecedent topography.

METHODS

Field Methods

Between May 17 and June 8, 1987, eighteen beach sites on San Salvador were selected for a textural analysis (Fig. 1). At each site, sediment samples were gathered from each of the subaerial facies (lower beachface, upper beachface, back beach and dune), if all were present, along a measured transect across the beach environment (Fig. 2). Clinometer reading were taken from the lower beachface to the highest topographic feature adjacent to the shoreline in order to measure the beach slope.

Only the subaerial beach environments were included in order to allow comparison between the composition of modern beach sands and dunes, and lithified eolianites of both Pleistocene and Holocene age. A total of 71 individual samples were collected.

Laboratory Methods

Approximately 50 grams of sediment from each of the 71 samples were washed and dried in preparation for sieving. Sieve sizes -1.5, -1.0,-0.5, 0, .05, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 were used. Samples were rotapped for 15 minutes. The contents of each sieve was weighed using a

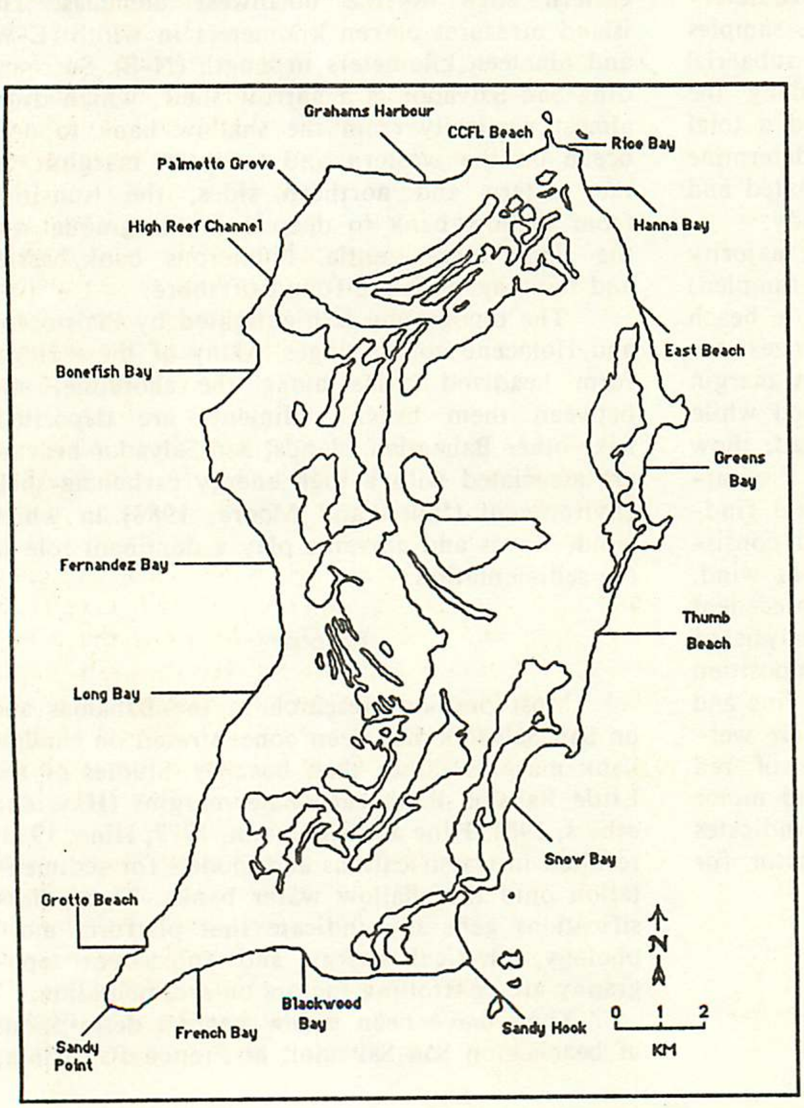


Fig. 1. Map showing transect and sampling locations of study area.

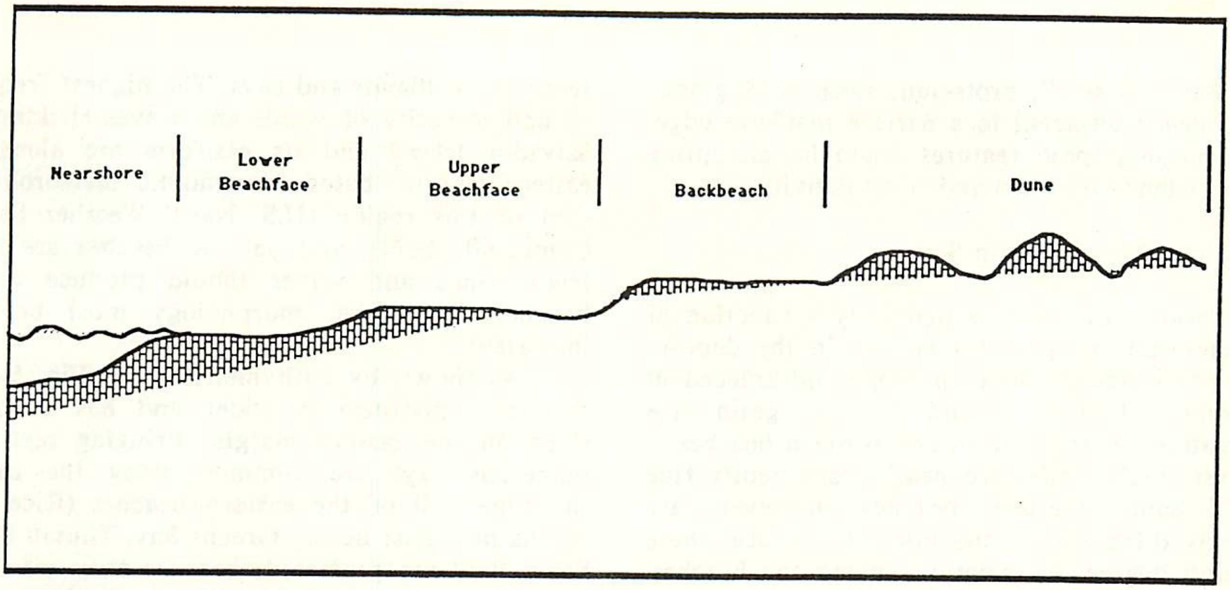


Fig. 2. General profile of beach environment transect.

Fisher scientific balance. All textural data was then calculated and determined using the Folk classification method (Folk, 1974) and the Udden-Wentworth grain size scale.

Samples from 16 of the 18 beaches (a total of 64 samples) were chosen for compositional analyses. Sediments were impregnated with clear epoxy, then mounted and cut into thin sections. These sections were studied using a petrographic microscope at 10X magnification. Allochems were identified by comparison to figures in Adams and others (1984) and Scholle (1978). To determine the percent of each allochem type, 150 points were counted on each thin section.

SIEVE RESULTS

Grain Sorting

A majority of the samples collected (60 out of 71) show a uniformity in grain sorting, ranging from moderately well to well sorted. Only the sieve results of the lower beachface and dune environments for the eastern and western beaches are presented in this paper (Figs. 3 and 4). These environments represent the transect end members and thereby offer a comparison of textural data from mean sea level and the dune area. The eastern and western shorelines, because of their length, differing platform morphology and varying magnitudes of physical energy offer interesting comparisons.

Textural data from the lower beachface were similar to those obtained by Lee and others (1986) in their study of grain size distribution at these same beaches. The consistency of the textural characteristics over a period of four years (their samples were collected in 1983 and 1984) indicates that the results of this study may be regarded as representative of the beaches and not simply anomalous examples.

The lower beachfaces along both eastern and western beaches are predominately well sorted. This indicates that the factors most influential for sorting: consistency of energy levels from wind, waves, currents and storms in the depositional area, are yielding well sorted beaches on the island. As expected, the dune sediments are well sorted as a result of the winnowing effect of consistent winds that average 10 knots in the San Salvador platform region (U.S. Naval Weather Service Command, 1974).

A combination of high wind (75% frequency and 25% calm averaging 12 knots) and wave (77% frequency and 23% calm) activity along the windward eastern side may account for the well sorted lower beachface, while on the western edge, the consistency of lower winds (9% frequency, 10 knot average) and waves (9% of all waves) are a major factor of beachface sorting (U.S. Naval Weather Service Command, 1974).

Deviations from the predominately well sorted texture may be the result of localized disruptions in the normally consistent energy processes. For example, at Grotto Beach, the steepness of the beach slope (33.8% grade) and its location in a cove may result in more varied wave and current action, causing its moderate sorting.

Snow Bay is a small, protected, steep (22% grade) pocket beach adjacent to a narrow platform edge. These physiographic features could be disrupting the consistency of wave and wind activity.

Grain Size

Average grain size is primarily a function of the magnitude of physical energy in the depositional environment, platform slope and antecedent topography. Figures 3 and 4 show grain size information for the eastern and western beaches.

East side beaches are nearly consistently fine grained sand. Western beaches, however, are markedly different. In the lower beachface, there is a high degree of variation among the beaches. The dune environments are somewhat less variable and are predominately medium sand.

Explanations for the contrast in beach sediments in the east and west must be attributed to the differing platform morphology and the presence of headlands and cays. The highest frequency and intensity of winds and waves striking San Salvador Island and its platform are along the eastern margin, based on synoptic meteorological data of this region (U.S. Naval Weather Service Command, 1974), and yet the beaches are finer. High winds and waves should produce coarser beaches. Therefore, morphology must be very important.

As shown by bathymetric data (Fig. 5), the carbonate platform is wider and has a gentler slope on the eastern margin. Fringing reefs and numerous cays are common along the eastern shoreline. All of the eastern beaches (Rice Bay, Hanna Bay, East Beach, Greens Bay, Thumb Beach, Snow Bay) are protected, because they are developed between headland cliffs and ridges. The combined factors of shelf slope, reefs and cays act as barriers to wind and wave action, thus reducing energy levels. Wave energy is further reduced at the shoreline by headland cliffs which

Location of Sample Area	Grain Size			Sorting			Skewness			Kurtosis			
	fine	med	coarse	poor	mod	well	fine	symm	coarse	m	l	sym	p
Rice Bay	X					X		X		X			
Hanna Bay	X					X			X	X			
East Beach	X					X		X		X			
Green Bay	X					X		X		X			
Thumb Beach		X				X			X	X			
Snow Bay		X			X				X				X

Location of Sample Area	Grain Size			Sorting			Skewness			Kurtosis			
	fine	med	coarse	poor	mod	well	fine	symm	coarse	m	l	sym	p
Rice Bay	X					X		X			X		
Hanna Bay	X					X			X		X		
East Beach	X					X			X	X			
Green Bay	X					X		X		X			
Thumb Beach	X					X			X		X		
Snow Bay		X				X		X		X			

Fig. 3. Sieve results of lower beachface (top) and dune environment (bottom) for eastern beaches.

Location of Sample Area	Grain Size			Sorting			Skewness			Kurtosis			
	fine	med	coarse	poor	mod	well	fine	symm	coarse	m	l	sym	p
Palmetto Grove		X				X	X				X		
High Reef Channel			X			X	X				X		
Bonefish Bay	X					X			X		X		
Fernandez Bay			X			X			X				X
Long Bay	X					X			X	X			
Grotto Beach			X		X				X		X		

Location of Sample Area	Grain Size			Sorting			Skewness			Kurtosis			
	fine	med	coarse	poor	mod	well	fine	symm	coarse	m	l	sym	p
Palmetto Grove		X				X		X		X			
High Reef Channel			X			X		X			X		
Bonefish Bay	X					X	X				X		
Fernandez Bay		X				X		X		X			
Long Bay		X				X		X		X			
Grotto Beach		X				X		X		X			

Fig. 4. Sieve results of lower beachface (top) and dune environment (bottom) for western beaches.

refract and dissipate incoming waves. The lowered energy levels are allowing only the finer particles to reach the beaches.

An exception to the fine grained characteristics of the eastern beaches are Snow Bay and Thumb Beach, which are predominately medium grained. Both have slightly narrower platform widths than the other eastern beaches. Transport distance is shorter and energy dissipation is less as a result. Discontinuous offshore reefs and headland cliffs, however, act as wave barriers, thereby allowing medium sized rather than coarse particles to reach the beaches.

On the western side, an equal amount of fine, medium and coarse grained environments are found. The frequency of high wind and waves is lower along the western margin (U.S. Naval Weather Service Command, 1974), but the variations of platform width, beach orientation, presence of headlands and storm activity may be the main contributors to the wide grain size distribution. Storms frequently blow in from the northwest side of San Salvador during the winter and spring for short durations. Beaches in this area, therefore, are subjected to high intensity short duration storm waves and winds that deposit coarse material onto the shore at the less protected sites.

At coarse beaches like Fernandez Bay and Grotto Beach, their steep grade (37% and 34% respectively) and narrow platform allow the full brunt of waves and currents to hit the shores with little wave dissipation. Offshore reefs act as only slight barriers to the waves.

The coarse and medium sediment within High Reef Channel and Palmetto Grove beaches must be related to beach orientation and storm activity since the shelf is relatively broad along these beaches. A lack of barriers (no protruding cliffs and discontinuous reef development) to reduce wave energy and northwesterly storm activity must account for the coarse sediment.

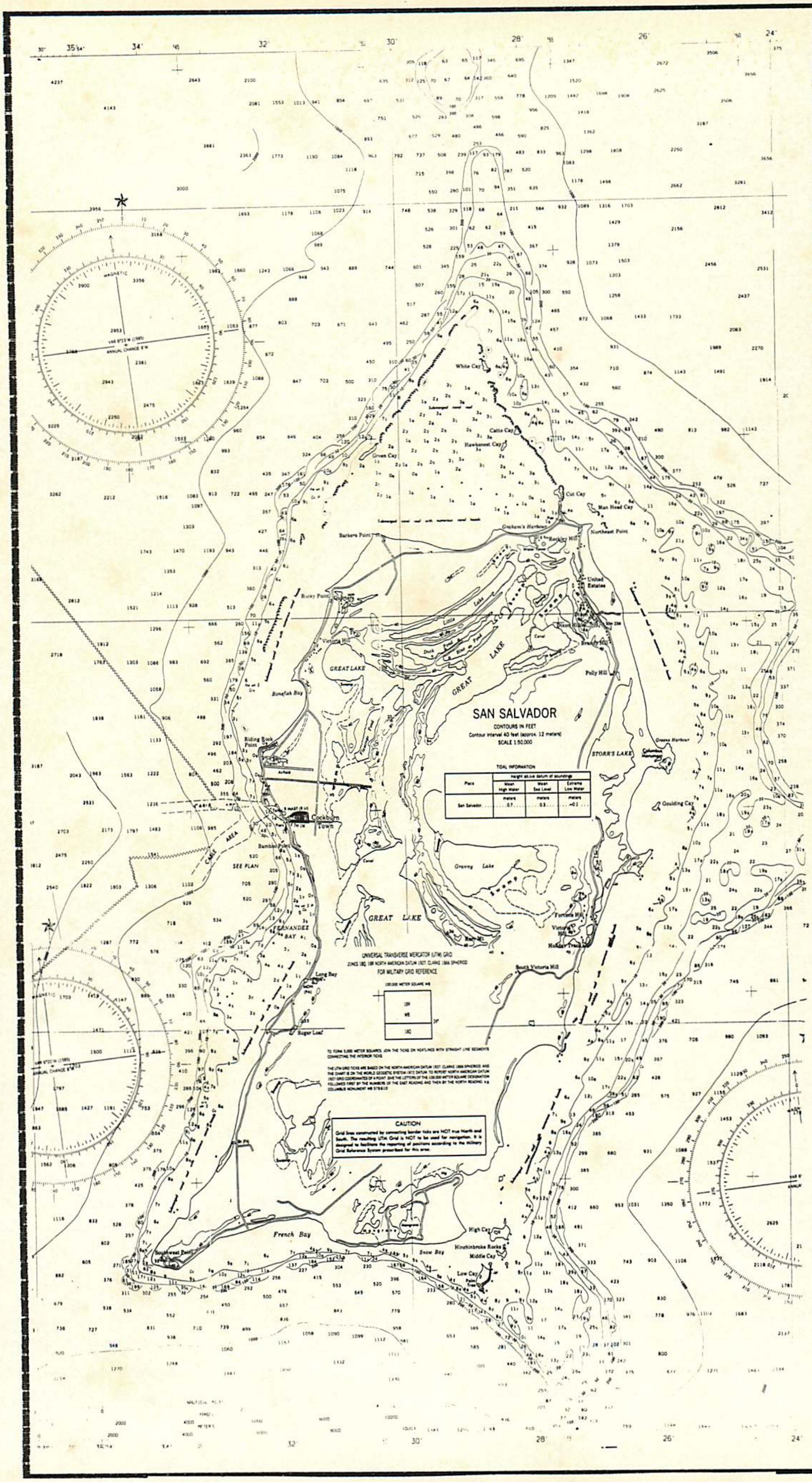


Fig. 5. Bathymetric map of San Salvador Island.

Bonefish Bay, located in the northwest part of San Salvador, is a very fine grained beach. An important distinction of this beach is its location between two headlands, unlike any other western beach studied here and a fringing reef that stretches across the bay very close to shore. Except for the narrower platform, these characteristics are similar to many of the fine-grained eastern beaches. Long Bay has the widest shelf among the western beaches and is protected by discontinuous coral reef development along the bank margin. The broader shelf dissipates much of the wave energy and results in fine and medium grained sediment reaching the shore. The medium grain size reported for the Long Bay dune is unusual as dune areas are typically finer than the other beach environments. One explanation is that erroneous calculations of grain size data were made. Another possible reason is that the dune is relict, and not in equilibrium with the current beach.

COMPOSITION RESULTS

No attempt was made to determine where the allochemical grains were created or the type of biota within the reef ecosystem. The intent was only to report the type and percent of allochemical constituents which make up the beaches. Petrographic analysis of 64 samples from 16 of the 18 beaches reveal that the sediments are predominantly bioclastic. Figures 6 through 11 show the results of the composition study. The most common constituents are foraminifera, red algae, green algae, mollusk fragments, lithoclasts and peloids. The term lithoclast is used to describe grains that have been welded or cemented together. This includes grapestones and beachrock fragments. Peloids is an inclusive term for micritized grains, pellets and grains too small to identify the shape or internal structure. Minor percentages of bryozoans, sponge spicules, coral fragments, annelid tubes, echinoderms and ostracods were also counted.

Eastern beaches were looked at to determine if allochemical amounts differed in a beach by beach comparison. Most allochemical percentages were found to be very similar for all environments. The only major exception was red algae, whose percentages varied in the lower beachface, upper beachface and backbeach environments of all eastern beaches. For western beaches, only the lithoclast and peloidal sands showed percentage variations in beach by beach comparisons. An analysis of this variation indicates that lithoclast content increases with increasing grain size, and peloid content decreases.

A comparison of the eastern versus western beach environments shows that foraminifera and red algae percentages are higher on the eastern beaches, while lithoclast and peloid sediment predominate on western beaches. Eastern beaches also contain a wider variety of minor constituents.

The fine and medium grained eastern beaches were also compared with their western counterparts. Results of the comparison show that the percentages of red algae, lithoclasts, peloids, minor constituents and to some extent foraminifera vary significantly. Therefore, composition is not seen as a controlling factor for grain size and sorting or vice versa. It is more probable

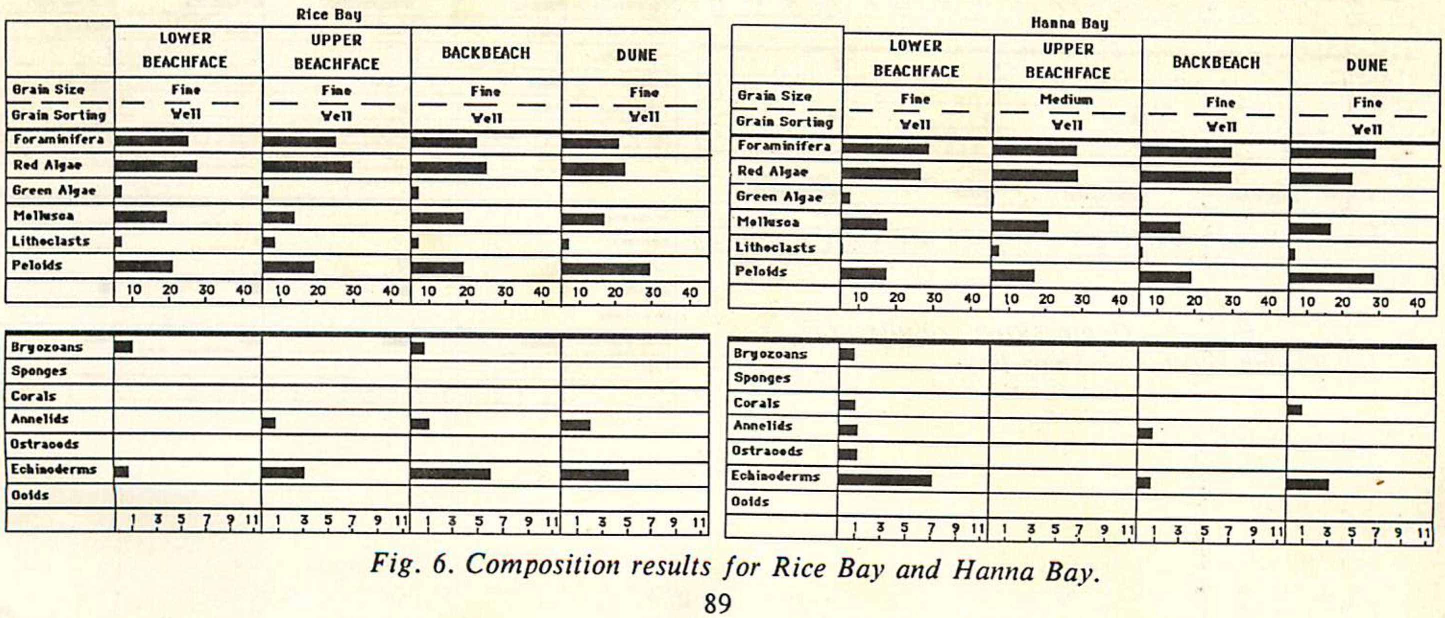
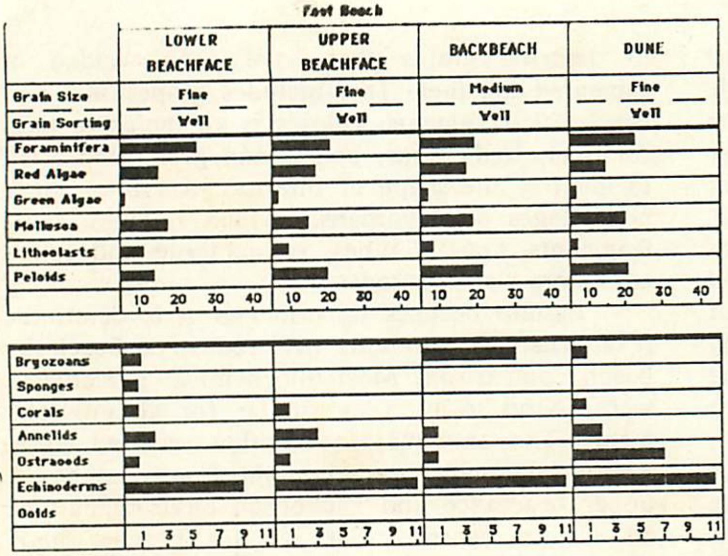


Fig. 6. Composition results for Rice Bay and Hanna Bay.



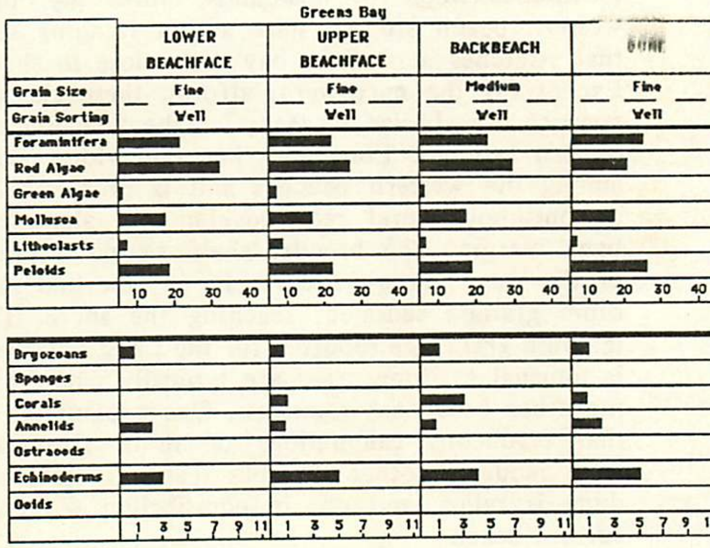
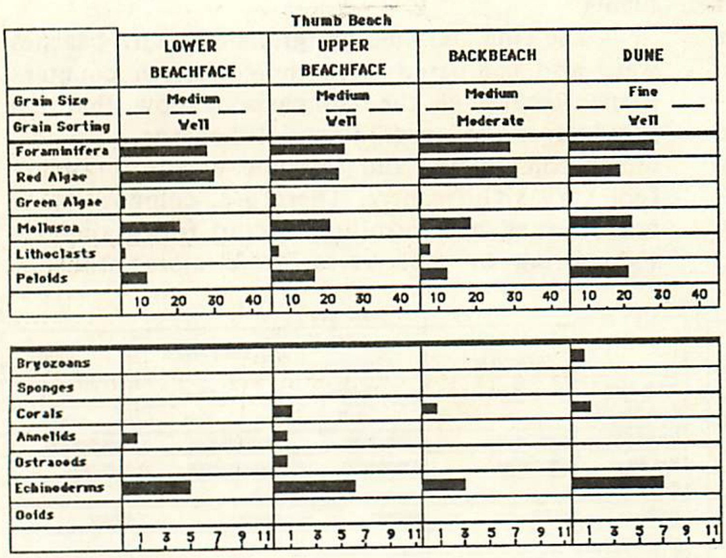


Fig. 7. Composition results for East Beach and Greens Bay.



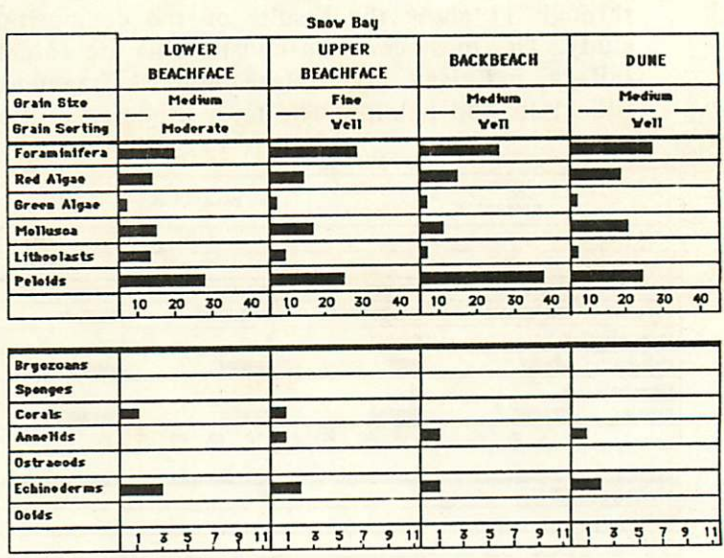
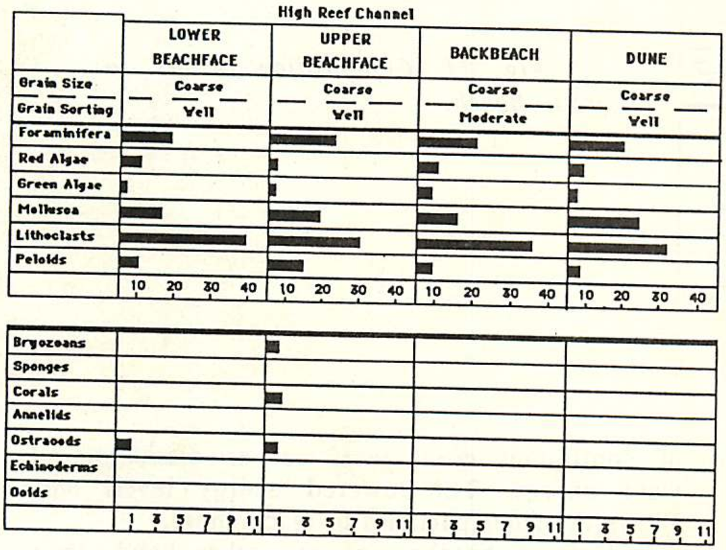


Fig. 8. Composition results for Thumb beach and Snow Bay.



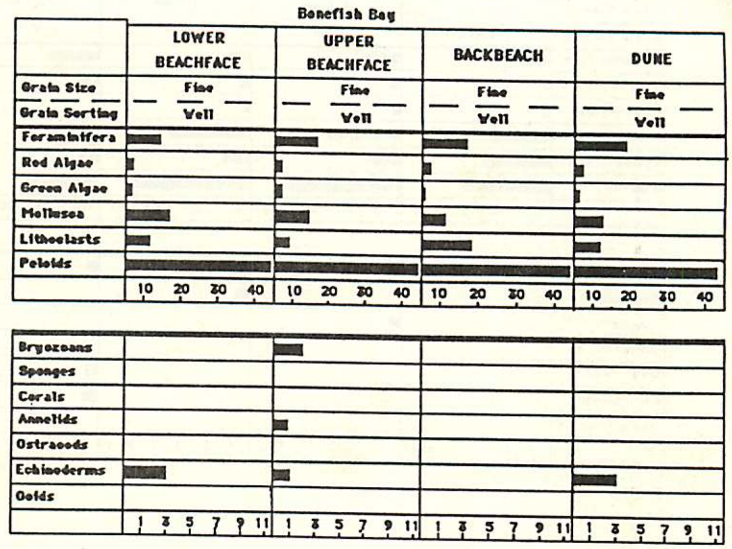
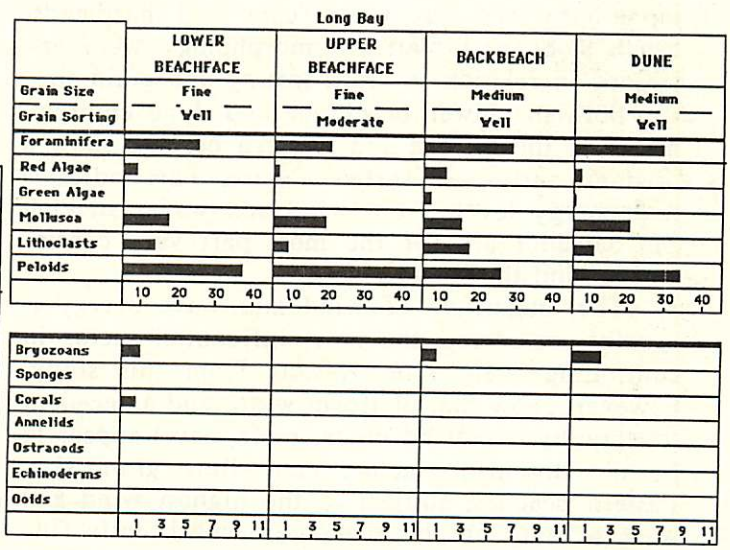


Fig. 9. Composition results for High Reef Channel and Bonefish Bay



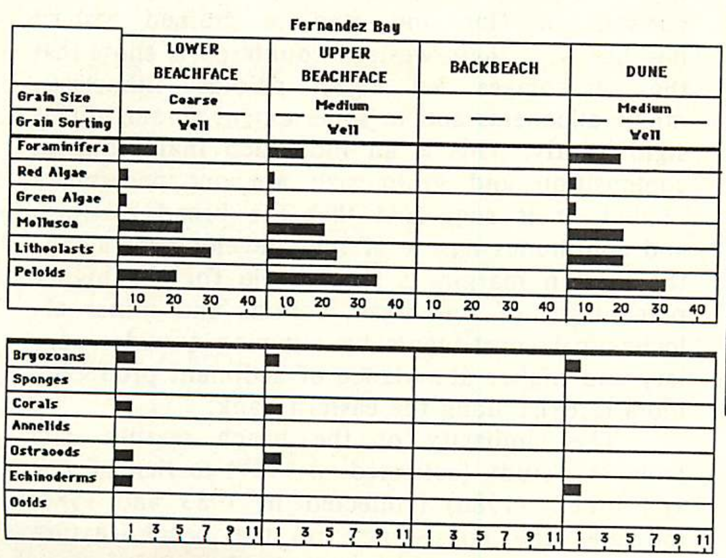


Fig. 10. Composition results for Fernandez Bay and Long Bay.

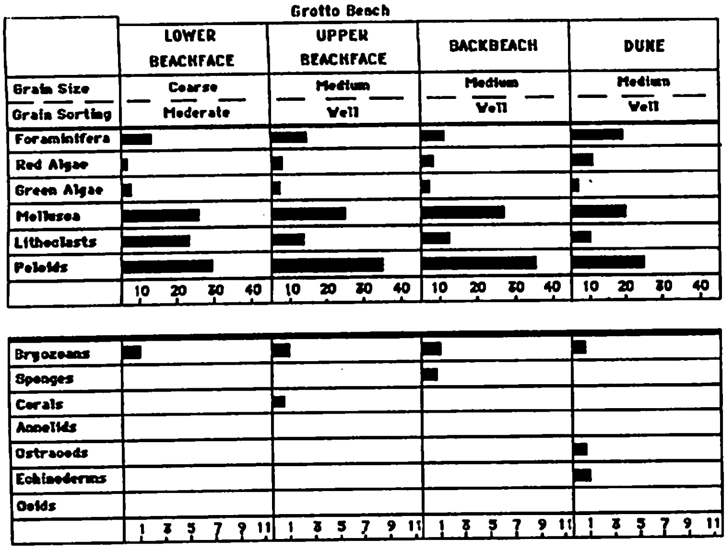


Fig. 11. Composition results for Grotto Beach.

that platform slope and the presence or absence of offshore reefs are the major reasons for the composition differences. A broader platform and the continuous nature of reefs may be allowing a larger abundance and variety of biota to exist on the eastern bank than on the narrower western bank.

SUMMARY

Sedimentation onto the beaches of San Salvador is controlled by a number of factors. Wind and wave activity, the presence of antecedent topography such as reefs, cays and headlands, beach slope and platform morphology were examined in relation to grain sorting and grain size.

Both the lower beachface and dune environments of the eastern and western beaches show a predominantly well sorted texture. This indicates that energy levels from wind and waves striking San Salvador are for the most part very consistent around the island.

The magnitude of wind and wave energy is usually considered the most influential factor in controlling grain size. Results from this study, however, show that platform width and antecedent topography (headland cliffs, reefs, cays) appear to be the dominant factors controlling grain size. Eastern beaches, subject to the highest wind and wave activity on the island, are consistently fine grained sand. This is unlike the coarse grained sand that is expected in a very high energy environment. It is concluded here that the broad, gently sloping nature of the platform, development of prominent headlands between beaches (characteristics of all eastern beaches) and the presence of continuous coral reefs act as dissipators of wave energy. The lowered energy levels only allows the finer particles to reach shore.

Western beaches, on the other hand, show wide variations in grade, platform width, orientation, development of reefs, cays and headlands. Seasonal storm activity also plays an important sedimentation role. Therefore, grain size differences exist among the beaches, which range from very fine to coarse.

Beach sediments are bioclastic sands in which the major constituents are foraminifera, red and green algae, mollusk fragments, lithoclasts and peloids. Eastern beaches show a higher percentage of forams, red algae and minor constituents, while lithoclasts and peloids are found in higher amounts on the western beaches. Comparisons of fine and medium grained eastern beaches with their western counterparts show that the percentages red algae, peloids, lithoclasts, minor allochems and to some extent forams differ significantly. This is an indication that sediment composition and grain size are not necessarily related. It is suggested that the broad platform and continuous nature of reef development along-the eastern margin is responsible for the higher percentages of red algae, forams and minor allochemical constituents by allowing a wider variety and higher abundance of sediment producing biota to exist along the eastern bank.

The similarity of the beach texture data from this study (collected in 1987) to that of Lee and others (1986) (collected in 1983 and 1984) indicates the consistency of the beach texture over a four-year time period. This consistency demonstrates that synoptic sampling of beaches can provide a meaningful measure of beach texture for relatively long time periods, despite daily to seasonal variations in conditions.

The beaches of San Salvador are conspicuous in their lack of ooids. This peloidal bioclastic beach composition is consistent with modern dune deposits and with the lithified Holocene marine and eolian rocks of the Rice Bay Formation (Carew and Mylroie, 1985). The contrast of these modern beaches with the ooid-dominated Pleistocene Grotto Beach formation is striking, indicating that the beach source areas in Grotto Beach time were very different from today. It is interesting to note that the modern beach sediments, although very different from rocks of the Grotto Beach Formation, are quite similar to those of the older Owl's Hole Formation.

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REFERENCES CITED

Adams, A.E., Mackenzie, W.S., Guilford, 1984, Atlas of Sedimentary Rocks Under the Microscope: Wiley and Sons, New York, p. 104.

Bain, R.J., 1986, Beach Rock, French Bay: in Curran, A.E., ed., Pleistocene and Holocene Carbonate Environments on San Salvador Island, Bahamas: Georgia Geological Society Field Trip Guidebook and College Center of the Finger Lakes Bahamian Field Station, p. 121-128.

Carew, J.L. and Mylroie, J.E., 1985, The Pleistocene and Holocene stratigraphy of San Salvador Island, Bahamas, with reference to marine and terrestrial lithofacies at French Bay, in Curran, H.A., ed., Pleistocene and Holocene carbonate environments on San Salvador Island, Bahamas - Guidebook for Geological Society of America, Orlando annual meeting field trip #2: Ft. Lauderdale, Florida, C.C.F.L. Bahamian Field Station, p. 11-61.

Folk, R.L., 1974, Petrology of sedimentary rocks: Hemphills Publishing Company, Austin, Texas, p. 179.

Hine, A.C. and Neumann, A.C., 1977, Shallow carbonate bank margin growth and structure, Little Bahama Banks, Bahamas: American Association of Petroleum Geologists Bulletin, v. 61, no. 3, p. 376-406.

Hine, A.C., Wilbur, R.J., and Neumann, A.C., 1981, Carbonate sand bodies along contrasting shallow bank margins facing open seaways in northern Bahamas: American Association of Petroleum Geologists Bulletin, v. 65, no. 2, p. 261-290.

Hine, A.C., 1983, Modern shallow water carbonate platform margins, in Cook, H.E., Hines, A.C., and Mullins, H.T., eds., Platform Margin and Deep Water Carbonates: Society of Economic Paleontologists and Mineralogists Short Course No. 12, p. 3-34.

Inden, R.F. and Moore, C.H., 1983, Beaches in Scholle, P.A., Bebout, D.G., and Moore, C.H., eds., Carbonate Depositional Environments: American Association of Petroleum Geologists Memoirs #33, p. 218-256.

Lee, Y.I., Lindsey, B., May, T., and Mann, C.J., 1986, Grain size distribution of calcareous beach sands, San Salvador Island, Bahamas: College Center of the Finger Lakes Bahamian Field Station Occasional Paper, no. 1, 12p.

Scholle, P. A., 1978, A color illustrated guide to carbonate rock constituents, textures, cements and porosities: American Association of Petroleum Geologists Memoir #27, 241 p.

United States Naval Weather Service Command, 1974, Summary of synoptic meteorological observations: Caribbean and nearby island coastal marine areas, vol. 3: Asheville, N.C., National Climatic Center, p. 317-395.