Modern and Ancient Carbonate Beach-Dune Systems on the Windward Side of San Salvador Island, the Bahamas

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INTRODUCTION

Despite its identification as one of the more thoroughly studied islands in the Bahamas, San Salvador Island's beaches have received relatively little attention from sedimentologists. Only the most general of surveys have been conducted; these have shown the beaches to be as varied as the island itself (Clark, Mylroie and Carew, 1988). Inattention to San Salvador's beaches is part of a larger pattern of ignorance concerning modern carbonate beach sediments worldwide. Because of this, there are relatively few identified examples of carbonate beach deposits in the rock record (Inden and Moore, 1983). These fossil strandlines are known to harbor oil and thus warrant detailed study.

In June, 1990, a one kilometer section of East Beach, near the United Estates settlement at the northeast corner of the island, was chosen as representative of windward beaches on San Salvador and elsewhere in the Bahamas. A baseline was surveyed, and data were collected along nine transects. Work at the nearby Hanna Bay Cliffs served to identify them as a Holocene analogue to the modern windward beaches. The beach was resurveyed on December 30, 1990 to assess changes over the preceding six months. Data indicate that East Beach is actively prograding, despite what is probably seasonal erosion of the foreshore and berm. Mean grain sizes and standard deviations follow a pattern decreasing from the dunes to the ocean. This interesting result could be the product of rapid lithification and the formation of micrite crusts and particle rims in backshore and dune areas. Eventually, if the present trend continues, the present East Beach system will lithify and be exposed as a progradational sequence, much as the Hanna Bay member of the Rice Bay Formation is today.

FIELD AREA AND METHODS

East Beach faces the open Atlantic over a shallow shelf and intermittent reefs, and is characterized by a shallowly dipping, broad expanse of fine to very fine biogenic sand. The beach lies seaward of a large field of vegetated ridges interpreted by Titus (1986) to represent progressive stages of accreting beach and dune sands. Steady trade winds from the east and southeast produce generally rough waters, which have shaped the beach into a series of large, curving bays and sandy headlands. The wavelength of this rhythmic topography is about 500 meters, but higher order harmonics also produce an intermittent smaller cusp and horn system. Gentle wind induced onshore and alongshore currents cause a rippled bottom and onshore transport of the sediments produced by flourishing patch reefs offshore (Marrack, 1989).

On June 12, a baseline was surveyed at the base of the primary dune along the kilometer section, and nine parallel transects were taken at 125-meter intervals along this baseline. Stake and horizon profiles were made along each transect from the slope of the secondary dune to 1.5 meters water depth. These were used to produce a topographic map of the beach (fig. 1). Six sediment samples were taken along each transect. Ten large trenches were dug in the foreshore and dune areas to investigate the erosive or depositional nature of the beach at each site. To assess sediment transport potential, nearshore currents were measured with a flowmeter at each transect and through a full tidal cycle. Burrows and other features of the beach thought likely to be preserved were photographed and sketched. On December 30, the transects were re-profiled and plotted. The data from the two trips were combined to produce a map of erosion and deposition over the six months between June and December (fig. 2).

To the north of East Beach lie the sea cliffs of Hanna Bay. These low bluffs compose the Hanna Bay Member of the Holocene Rice Bay formation. Structure revealed in the cliffs is mostly sweeping eolian crossbedding, but at the base of the cliffs lies a zone of fine, seaward dipping foreshore lamination. Burrows and other indicators of the beach environment also fill this zone. At this site, two detailed stratigraphic sections were drafted, and the rock was sampled in eight locations above a baseline.

In the lab, sand samples were sieved for ten minutes each using a Ro-Tap, and sediment grain-size analysis carried out with the help of the IBM PC programs PROBSPL.5 and SIEVE. Topographic maps of mean grain size and standard deviation can be seen in figures 3 and 4. Rock samples from the Hanna Bay Cliffs were thin sectioned, and are to be examined for composition and evidence of micrite crust or rim formation. This thin section work is continuing.

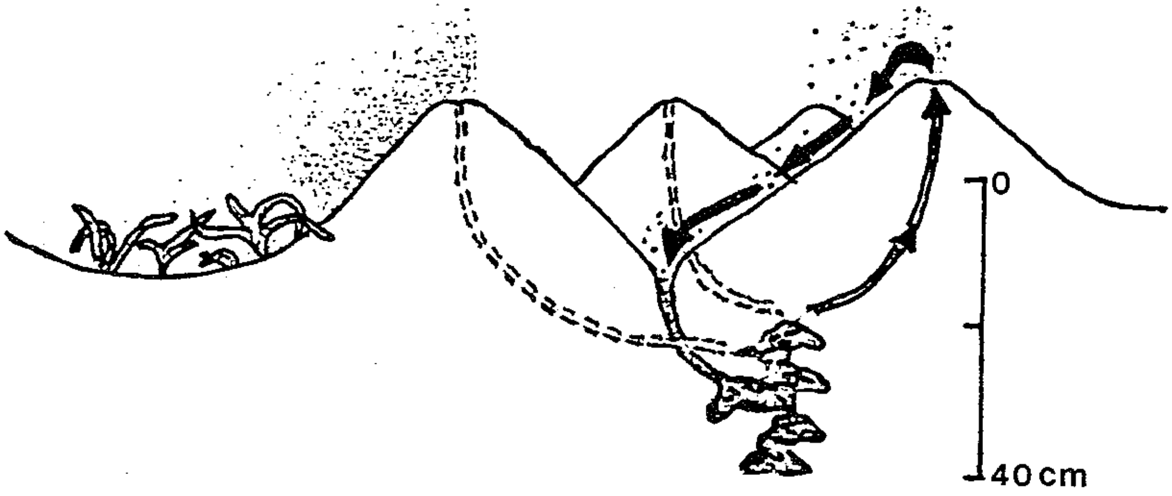

Figure 2. Cross sectional view of a callianassid mound and burrow complex, with surrounding turtle grass (*Thalassia testudinum*) (after Suchanek, 1983).

cm (Fig 2.). The smaller *Upogebia pusilla* leaves surface sedimentary features that can be recognized as four small holes found together on a mound. The large fiddler crab leaves a distinctive 2 -3 cm hole on top of a mound and is characteristically surrounded by fecal pellets. The small holes of the small fiddler crabs can be distinguished from the *Upogebia pusilla* burrows by the characteristic mounds of fecal pellets surrounding the crab burrows.

SEDIMENTS

Sediment analyses showed that the substrate is a calcareous, fine-medium grained, shelly, pelloidal sand. The main categories of the sand fraction were found to be: fecal pellets, foraminifera, gastropods, bivalves, ostracodes, and grain aggregates. Samples taken in the subtidal zone were found to be more fine-grained and better sorted than samples from the heavily bioturbated zone of the callianassids.

CONCLUSIONS

A thorough understanding of the characteristics of the modern carbonate tidal flat at Pigeon Creek should enhance the capability for recognition of similar settings preserved in the carbonate rock record. Several interrelationships between the substrate, burrowers, and vegetation exist that are important both ecologically and geologically. Specifically, the continual reworking of the sediment by the burrowing organisms of the tidal flat environment contributes significantly to the understanding of the distinct zonation of the flora and the sedimentary features of the flat.

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DISCUSSION

From the topographic map of the June profiles (Fig. 1) one can identify many of the important features of the beach. The foreshore, evidenced by the generally broad, evenly spaced contours near and just below Mean Low Water, shows well the gently undulating topography of the beach. This feature is less evident on the maps than in the field; it also appears less periodic than one might expect such topography to be. The various embayments and prominences on the beach do not necessarily correspond to the two larger cove-point cycles on which the baseline was surveyed, though there are protuberances at sites one and five. This difference between the course of the primary dune and the topography of the beach sand itself may indicate the rhythmic topography to be unstable.

Farther up the beach lie the more closely spaced contour lines of the berm. These again do not follow the periodicity of the primary dune, and in fact may be seen as almost completely out of phase, with points at three and seven. Between the berm and the baseline lies the backshore, evidenced by the wide space between the 1.5 and 2 meter contour lines. It is here that thick mats of drifting weed, mostly Sargassum, wash up along with trash from over 18 countries and are entombed within the mobile sand. The backshore is also home to several animal indicators of the beach environment, notably the burrowing ghost crab, Ocypode Quadrata,and the wandering traces of rove beetles.

Still farther up the beach, beyond the baseline, lies the primary dune crest and the swale behind it. This dune is characterized by its low, broken appearance. Vegetation such as sea oats, Uniola Paniculata, and bay geranium, Ambrosia Hispida, heavily covers parts of it, holding the sand against the wind. Finally, beyond the swale lie the closely spaced and fairly straight contours indicating the rise of the secondary dune ridge, which is heavily vegetated with many species of woody plants, largely the bay grape, Coccoloba Uvifera.

Figure 2 is an isopach map showing areas and amounts of erosion and deposition that took place on the beach between June and December. Immediately noticeable is the lack of change in backdune areas and the general erosion of the berm, especially at sites 2-3 and 6-7. Obvious also are the two bands of deposition on what corresponds to the primary dune area and the bottom of the foreshore. Erosion of the berm and backshore can be accounted for by seasonal retreat of the berm and the formation of a steep winter foreshore from the broad, gently sloped summer example. Erosion (up to 0.50 meter) at the sites mentioned above could relate to their appearance as protuberances on the June topographic map (fig. 1), thus representing a smoothing of the shoreline in reaction to differing winter wave patterns. The seaward depositional band (see fig. 2) indicates that sand may be moving to offshore bars. Lost sediments would return to the shoreline in a winter erosion / summer accretion pattern. Trench data gathered in June showed this expected accretionary beach in all but one case. Observations indicate only weak, wind-influenced longshore current. This current generally would flow to the north, given prevailing wind directions. The shoreline is protected from storm winds, generally out of the northwest. Littoral drift is therefore probably only a minor addition to general onshore-offshore seasonal sediment transport patterns.

The band of deposition along the primary dune is most interesting. It represents an accretion of the dune system, and ultimately the whole shoreline. This hypothesis corresponds extremely well to Titus' theory of past island growth to the east (fig. 5). Further support for this theory can be found in the deposition of a new "pre-primary dune" observed as a vegetated and growing 30-cm high lump on the backshore at site 2. This lump formed in its entirety between June and December and may represent a new dune line, the next step to the east.

The final two diagrams, figures 3 and 4, are plots of mean grain size and standard deviation (graphic method), respectively. They correlate very well in showing the expected changes in areas of erosion and deposition. For instance, the two lighter spots on the foreshore of figure 3 correspond to the areas of moderate sorting in figure 4 as well as to protuberances at the same sites visible in fig. 1, and to the areas of high erosion in figure 2. Coarser sediment may represent the addition of a shell lag from eroded material, or could reflect higher energy at those two spots where samples came from the surf line.

One interesting and somewhat mystifying feature of these last two diagrams is the apparent coarsening of the sediments toward the backshore and dune. This is not to be expected, especially if the sediments are produced just offshore (as Marrack, 1989, proposed). Instead, the sand should become finer and better sorted farther onshore, as this would represent increasing distance from its immediate source, the ocean. One hypothesis that could be investigated in future work is the nature of the surface crust observed forming in dune areas. Perhaps coarsening of sediments away from the beach represents thicker buildup of rims or crusts on individual sand particles, or more aggregation of grains by this process. This would effectively increase grain sizes, act as a cement to further stabilize the dunes, and could perhaps be a mechanism for the progradation of the East Beach shoreline.

CONCLUSIONS

East Beach, near the settlement of United Estates, is typical of the windward beaches of San Salvador. The beach is characterized by generally fine, very well to moderately sorted skeletal carbonate sand, and is in a state of flux. Over the months between June, 1990 and December of the same year, East Beach suffered a net erosion. The foreshore became steeper and the berm retreated as sand was carried offshore, probably due to seasonal increase in wave energy. Despite this change, however, the primary dune showed evidence for accretion. This localized accretion may be an indication that the beach-dune system, and thus the island, is in fact prograding to the east as proposed by Titus (1986). If this trend continues, eventually the body of sand that is now East Beach will be preserved in the rock record as a regressional sequence, much the same as is exposed in the Hanna Bay Cliffs today.

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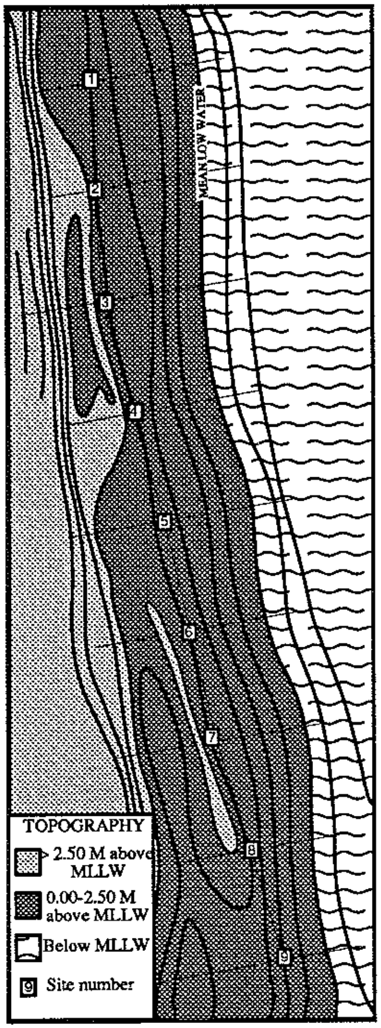
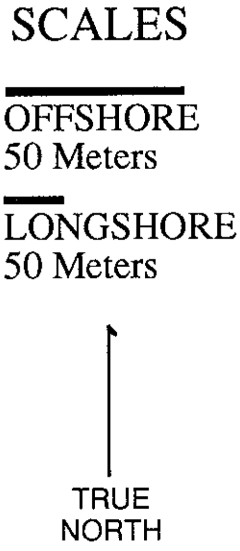


FIGURE 1. A contour map of topography for East Beach as of June 16, 1990. Contour interval 0.50 meters.



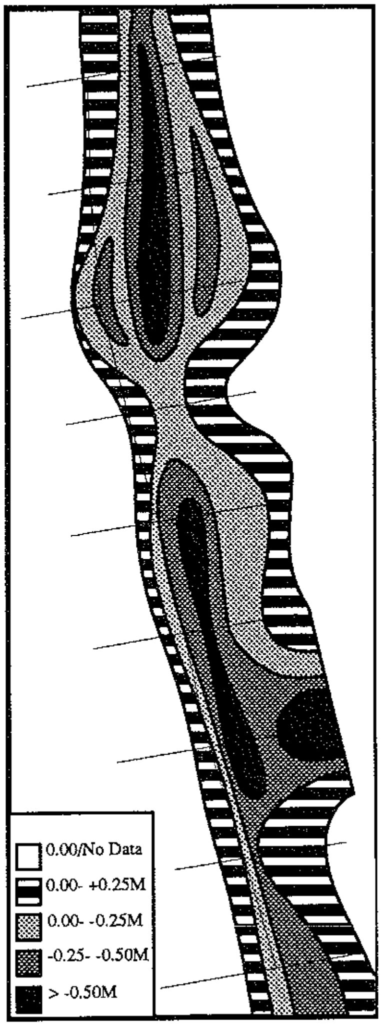


FIGURE 2. Erosion and deposition over the months between June 16 and December 29, 1990. Contour interval 0.25 meters.

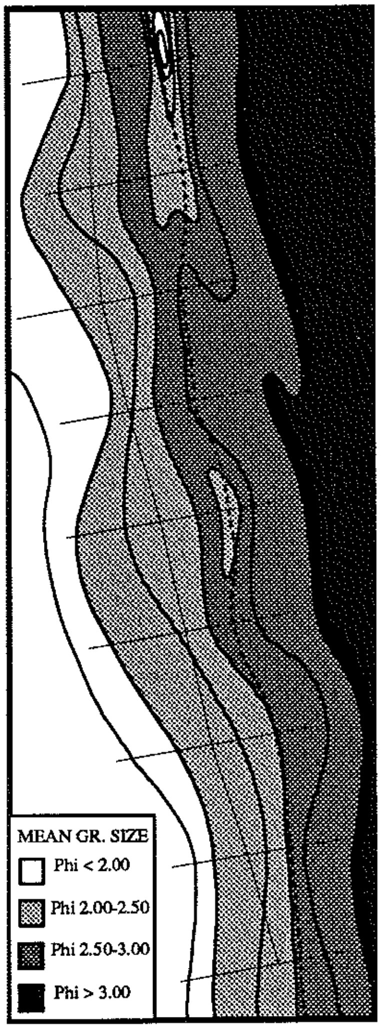
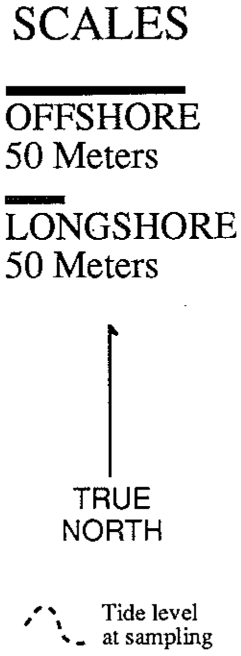


FIGURE 3. A contour map of mean grain size (graphic method) for East Beach on June 16, 1990.
Contour interval 0.50 Phi units.



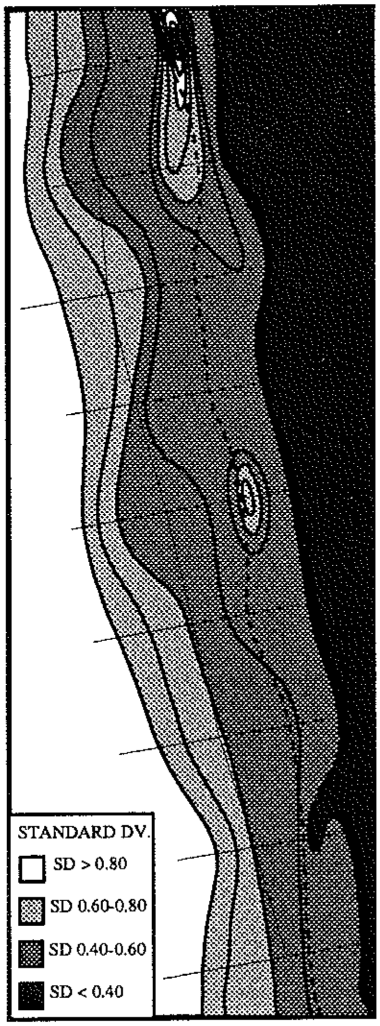


FIGURE 4. A contour map of standard deviation (graphic method) for East Beach on June 16, 1990.
Contour interval 0.10 Phi units.

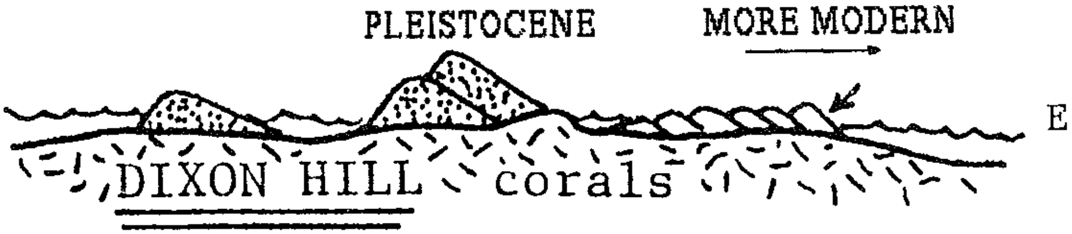


FIGURE 5. Diagram from Titus (1986) showing modern and Holocene dune ridges accreting to the east. Arrow denotes present East Beach, scale approximately 7 cm per kilometer.

A PETROGRAPHIC STUDY OF A PLEISTOCENE SHALLOW SUBTIDAL TO EOLIAN SEQUENCE, "THE GULF", SAN SALVADOR ISLAND, BAHAMAS

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INTRODUCTION

The purpose of this study was to unravel the effects of relative sea-level changes on the depositional and diagenetic history of the sedimentary units in one area of the southern coast of San Salvador Island. Four weeks were spent in the field measuring stratigraphic section, drawing scale diagrams of eolian crossbeds and other important geologic features, and taking both cores and hand samples for further laboratory study. Petrographic study and SEM work were completed on these samples. A detailed analysis of the sedimentary facies revealed a complex depositional history marked by pronounced sea-level changes during the late Pleistocene. The following is a description of the facies and a discussion regarding sea-level changes and paleoenvironments.

FACIES DESCRIPTION

Coral Rubble Facies:

This facies is composed primarily of large coral heads set in a peloidal grainstone matrix. The overall rubble zone is poorly stratified as well as relatively poorly cemented. The coral species identified from this facies include: *Diploria strigosa, Monastrea annularis, Acropora cervicornis, Acropora palmata,* and *Porites*. The size of individual coral heads range from 5 to 20 cm diameter and they are oriented randomly relative to their original growth position.

The matrix surrounding the large coral heads is composed of peloidal grains and superficial ooids, as well as fragments of coral, halimeda, molluscs, gastropods, coralline algae, and various foraminifera. Quantitatively, the matrix is made up of 70% peloids, 22% bioclasts, and 8% ooids. Coralline algae are found as encrustations on fragments of corals, forams, and other shell fragments. The forams are abundant and include such species as: *peneroplid, homatrima, milliolid,* and *gypsenid.*

Micritic cements and geopetal structures are primarily found within coralites. Radiating crystals of aragonite coat the inside of only a small proportion of the corals sampled. Forams that are not encrusted by coralline algae are filled with radiating, acicular crystals of aragonite.

Aragonitic meniscus cements predominate between the matrix grains. Brown, micritic cements form thin rinds or envelopes around the ooids and peloids. There is also micritization of the edges of coral and mollusc fragments due to marine micro-borers. These cements are diagnostic of marine phreatic diagenetic environments.

Beach Transition Zone:

This facies is found at the contact between the Coral Rubble facies and the Eolian facies (Fig. 1). It consists of yellowish tan, fine-grained ooids (0.6mm) and bioclast fragments. The ooids form a rather homogenous unstratified bed that is approximately 25cm thick, and is interrupted by a single 2.5cm-thick division of bioclast fragments. The bioclast fragments include molluscs, foraminifera, gastropods, and the West Indies top shell.

The ooids in the facies are poorly cemented so that pore space occupies nearly 40% of the bed. The cements are meniscus and aragonitic in composition. These cements are diagnostic of marine phreatic diagenetic environments.