Morphodynamics of Two Modern Carbonate Beach-Dune Systems on San Salvador Island, Bahamas

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INTRODUCTION

An understanding of the dynamic processes in the coastal zone is vital to developing a clear picture of the effects that small and large scale change can have on this system. Modern sediment dynamics can be detailed by following a series of profiles with baseline data. Two beaches on opposite ends of the island of San Salvador were chosen for comparison. East Beach and Sandy Point Beach are representative windward and leeward beaches with unique characteristics. Seasonal patterns are responsible for annual changes in East beach, but storm events provide the largest elements of change for these modern carbonate beach-dune systems at Sandy Point.

FIELD AREAS AND METHODS

East Beach is a windward beach located on the northeastern side of the island. It has a smooth undulating foreshore with a well-developed sequence of secondary dunes to the west. A 1 kilometer baseline was laid out in the primary dune and marked at 125 meter intervals in a series of nine profiles in June 1990 (Brill, 1991). In June 1992, these stations were located, and all nine profiles were surveyed by the stake and horizon method of profiling. All profiles originated in the primary dune and extended to 1.5 meters depth where possible (Figure 2). The time and date of all profiles were carefully recorded to allow for adjustment of all profiles to the Mean Level of Low Water (MLLW). Six profiles were extended to at least 50 meters offshore to better quantify the movement of sediment along East Beach. Depths offshore were measured with a weighted line and corrected to MLLW. All profiles from East Beach were reprofiled in January 1993. Elevations of the nine profiles were used to contour a topographic map of East Beach for June 1992 and January 1993 (Figures 1a and 1b). Sediment samples were collected along these six offshore profiles. All sediment samples were sieved and characterized according to the mathematic parameters of Folk and Ward (1957). Three carbonate sediment samples were collected for radiocarbon dating analysis. One sample from the foreshore will be used to provide baseline data for understanding the dates provided by samples collected from the secondary dune ridges behind East Beach. These dates will be used with their distance from the present foreshore to give an estimate for the rate of progradation of East Beach.

On the opposite corner of San Salvador, Sandy Point Beach comprises the southwestern point of the island. This leeward beach is free from most of the flotsam and jetsam that clutters the foreshore of East Beach and provides a remarkable contrast to East Beach. From rock headlands to the east, Sandy Point Beach wraps around the southwestern corner of the island and continues north until it ends at the cliffs at Grotto Bay. A 1.925 kilometer baseline was laid out in the dunes parallel to the shore in June 1990 (Loizeaux, 1991). Ten profile stakes were marked every 200 meters. This study area was expanded by the addition of seven more profile locations to better quantify the migration of sediment along this large area of beach. Two profiles were added to the southeastern portion of Sandy Point Beach to extend this study area 400 meters to the rock headlands to the east. Three profiles were positioned in the southwest on Sandy Point to allow for better control of the migration of the lobe of sand that comprises this point. Two profiles were added to the northern section in Grotto Bay to bring the total length of beach profiled to 2.4 km. Six offshore profiles were also completed on the northern section during June 1992 and January 1993. A swift current flowing around Sandy Point prevented completion of any profiles in the southernmost portion of the study area. All stations were profiled during June 1992 and January 1993. Unlike East Beach, the amount of change observed at Sandy Point after a southwesterly storm on June 21, 1992, did warrant another series of profiles on June 23, 1992. All profiles were performed using the same methods mentioned for East Beach and were also corrected to MLLW. Topographic maps were contoured for Sandy Point Beach for the beginning of June 1992, June 23, 1992, and January 1993 (Figures 3a, 3b, and 3c). Sediment samples were collected during the offshore profiling and later sieved in the lab. A sediment sample from the foreshore was also obtained from Sandy Point Beach to compare with the radiocarbon age obtained from the foreshore sample from East Beach. During all visits to each beach, careful field notes and pictures were taken to further document the change in these beaches.

In January, 1993, Becca Beavers, Lisa Greer, Heather Moffat, and Al Curran returned to San Salvador for an eight-day mini-workshop designed to collect seasonal data for the three student projects. Becca had some problems finding San Salvador (if you ask her very nicely, she *may* tell), but once that was resolved, we had an excellent week of further field work to finish successfully the data gathering for these projects.

Our research group is grateful to the Bahamian Field Station and its staff on San Salvador Island for full logistical support during the period of summer field work. We also thank the Keck Foundation for providing funding to the Keck Geology Consortium which sponsored this project.

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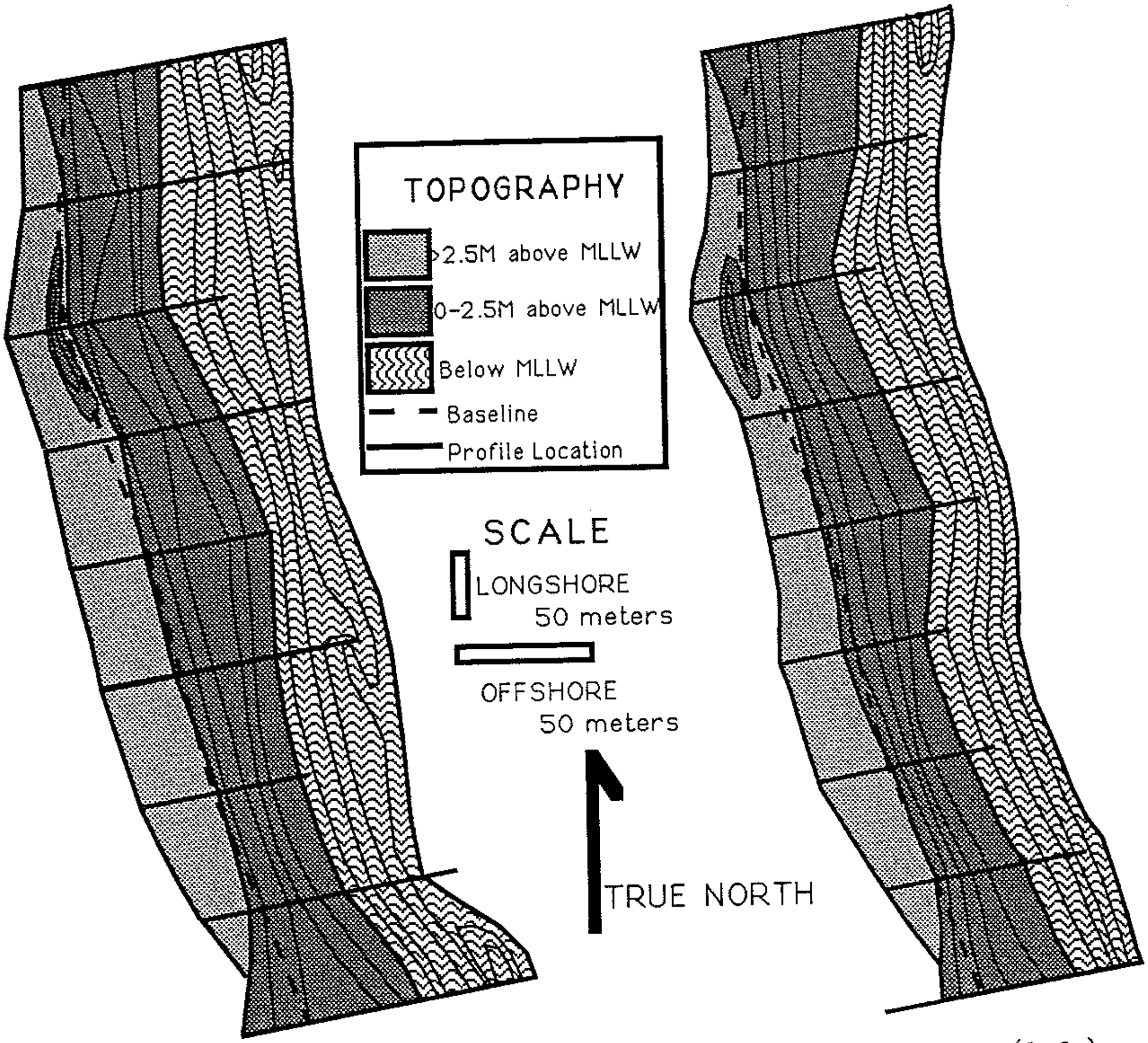

Figures 1a and 1b. Topographic maps for East Beach for June 1992 (left) and January 1993 (right). Contour interval 0.5 meter.

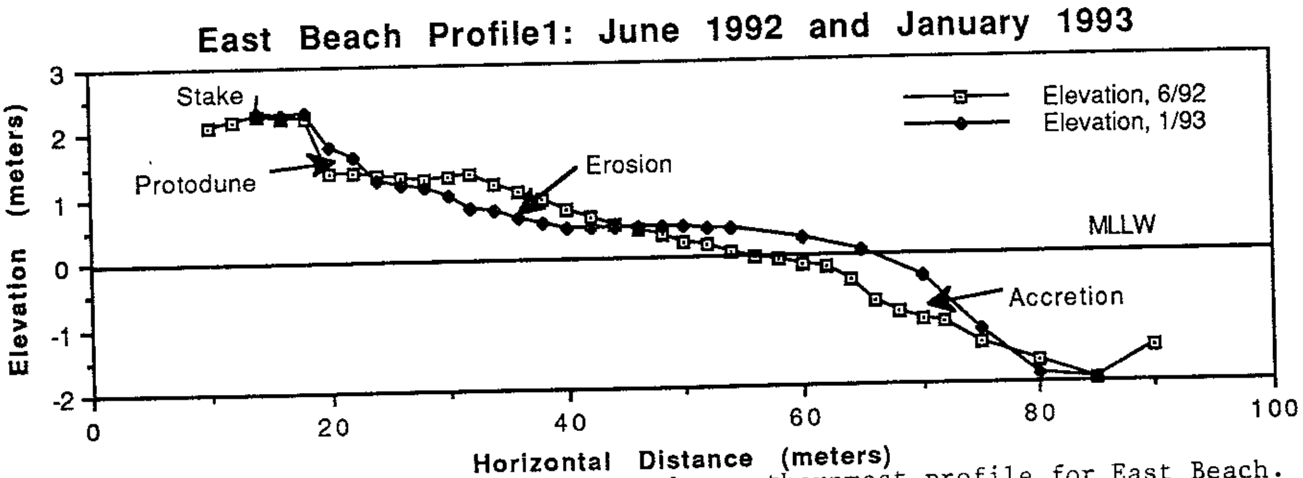

Figure 2. Erosion and accretion on the northernmost profile for East Beach.

DISCUSSION

East Beach is a generally assumed to be prograding. The large amounts of dune material (Titus, 1984) which characterize the backshore of East Beach are remarkably stable. The rhythmic topography along East Beach is manifested by the undulating shoreline (Figure 1a and 1b). The profile in Figure 2 represents the northernmost profile surveyed along this section of beach. The addition of the offshore profiles for this study allowed for observation of this profile to a depth of 2 meters below MLLW. Beyond 2 meters depth, this profiles begis to shallow when it encounters a grass bed offshore. Grass beds and patch reefs offshore of the beach can help to disperse wave energy before the waves reach the shore. This profile indicates the prograding protodune which is common along most of East Beach. Many succulent plants such as *Sesuvium portalacastrum* and *Ernodea littoralis* are rapidly colonizing this protodune area and dense wracklines that are common on windward beaches in the Bahamas. Further analysis of this profile indicates erosion of the foreshore since June 1992 but deposition further offshore. This profile helps to evidence that a net loss from the East Beach system may not be occurring even if erosion is observed on the foreshore. The sediment may merely be reworked and stored offshore.

The lobe of sand that comprises Sandy Point is highly mobile. During the month of June as northward migration of this carbonate sand was observed, significant erosion at the southeastern portion of the beach was also observed. Erosion after the storm on June 21, 1992, exposed lithified Holocene dunes that were further exposed by January 1993. Comparison of Figures 3a-3c will evidence this change most noticeable as enlargement of this lobe on the western side of the island. A large ridge and runnel system on this lobe dramatically changed from summer to winter. By January 1993, sediment continued to accumulate and formed a pronounced ridge in the northernmost portion of this lobe of sand (Figure 3c). Although the largest movement of sand around Sandy Point seems to have occurred during the storm in June, reworking of the drainage patterns on Sandy Point continued to occur throughout the year. The largest element of change in the Sandy Point beach-dune system appears to be the storm patterns that cause this system to be driven by events rather than seasonal differences.

CONCLUSIONS

Continued monitoring of the profiles at East Beach combined with offshore measurements establishes a pattern of stability for East Beach. Although the sediment may move offshore and seem to disappear from the beach, no net loss from the system is occurring. Changes in annual sand storage patterns are significantly different from net loss from a system. Like East Beach, the profiles at Sandy Point Beach were surveyed a few times in the past two years. This continuation of the study of the morphodynamics of two carbonate beach-dune systems is a valuable resource for understanding the dynamics of this system. As evidenced by the effects of a single storm, the Sandy Point Beach system appears to follow an event driven model. Natural trajectory experiment like this one can provide valuable information on the recovery and seasonal patterns of dynamic systems. Further research and monitoring of the beaches can only serve to enhance the understanding of this dynamic system. Additional work offshore and in adjacent areas is necessary if we are to fully understand the sediment generation, accumulation, and dispersal patterns surrounding East Beach and Sandy Point.

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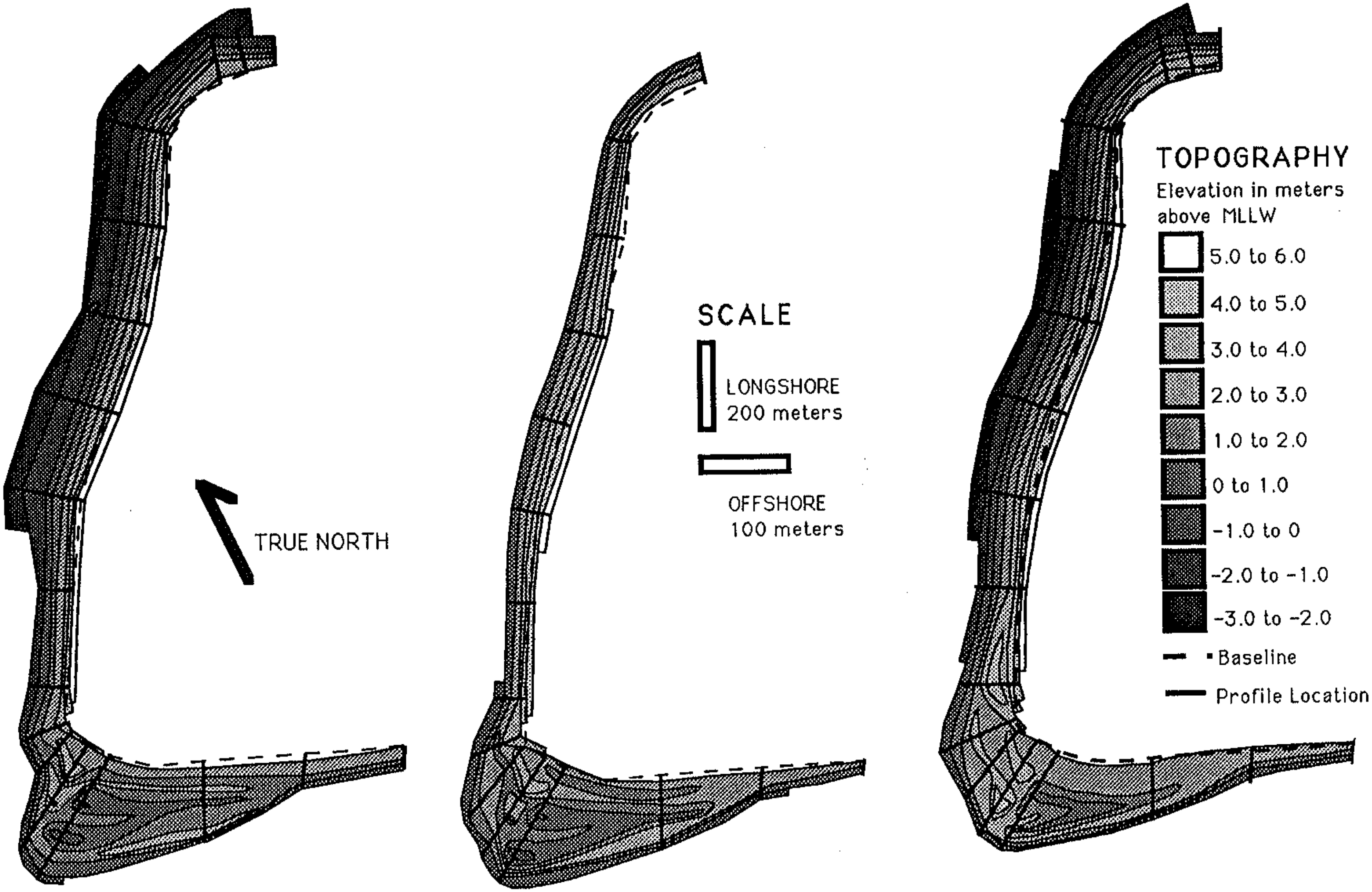

Figures 3a, 3b, and 3c. Topographic maps for Sandy Point Beach for the beginning of June 1992, June 23, 1992, and January 1993. Contour interval 1 meter.

Morphology and Taphonomy of *Neogoniolithon* on San Salvador Island, Bahamas

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Neogoniolithon, a branching, red calcareous alga, is prevalent in the shallow, clear waters surrounding San Salvador and in the fossil record on the island. Calcareous algae are common throughout the Caribbean, past and present. Previous studies have suggested a correlation between the morphology of *Neogoniolithon* and the energy of the environment (Bosence, 1983). Where wave action is high, coralline algal heads tend to be densely packed with short, stubby, and relatively thick branches; in calm environments, the branches are longer, thinner, and more fragile. I concentrated on three locations with environmental energies ranging from the high energy of East Beach through the intermediate energy of Bonefish Bay to the sheltered low wave action of the Pigeon Creek area. I also studied a *Neogoniolithon*-capped fossil patch reef at Grotto Beach. To define the relationship between environmental energy and morphology, I first attempted to find quantifiable features of the branching algae reflecting local environmental factors. I measured three characteristics: the distance between bifurcations along individual branches, the diameter of the branches, and the angle of bifurcation. If these characteristics show a correlation with environmental energy and can be measured in the rock record, these data could be used to estimate the energy intensity of paleoenvironments containing coralline algae. Second, I studied the taphonomy of *Neogoniolithon* and also how it is represented in the sediment. To date, I have tumbled three algae heads to document their breakdown rate and have also studied sediment composition of the three modern sites.

Methods

Live *Neogoniolithon* heads were collected along transects at each of my three study locations on San Salvador Island: East Beach, Bonefish Bay, and Pigeon Creek. All organic matter was removed by submerging the head in a dilute mixture of household bleach. Some fossil *Neogoniolithon* heads at Grotto Beach were also analyzed. I collected sediment samples around the base of the patch reefs studied at East Beach and along the transects at the other two sites.

Measurements

Three different types of measurements were taken using a caliper and a protractor to see if they reflected the environmental conditions of the area. 1) The distances between bifurcations of the branches were measured, 100/head (Figure 1). Branches from the outer third of the algal head were used because the inner portions were much harder to reach and more complex, with one branch merging into another. 2) The angles of bifurcation were measured (100/head), also on the outer third of the head (Figure 2). 3) Diameters were also measured and, due to the distinct difference in appearance between branch diameters of the outer rim and innermost core, I measured them separately (Figure 3). Only 75 measurements were taken of the outer branches; the deviation from the mean is significantly less than that for either the angles or distances. 30 measurements were about the maximum number that could be taken per head for the inner core branches. I calculated the average and standard deviations of the characteristics measured for each head and then overall averages for each location.

Tumbling

To investigate how the heads of *Neogoniolithon* broke down relative to one another and therefore relative to their differing energy regimes, the heads were tumbled. The methods I employed in my tumbling analysis were similar to those of Chave (1964). *Neogoniolithon* heads were tumbled at 30 revolutions per minute in a 4.5 liter, rubber-lined, hexagonal shaped tumbler with distilled water adjusted to the pH of sea water (about 8.0) using "Instant Ocean." The initial mass of each head was determined; after tumbling, the broken-off pieces were dried, sieved, and weighed. The mass of the broken-off pieces was subtracted from the original head mass and the results graphed with respect to total tumbling time (Figure 4). The sieve results at 17 hours for the three sites are shown in Figure 5.

Sediment

The carbonate sediment samples collected at the three study areas were split and made into "rocks" using an epoxy. They were then cut into thin sections for determination of *Neogoniolithon* fragment percentages and other general components.