

**PROCEEDINGS  
OF THE  
SEVENTH SYMPOSIUM  
ON THE  
GEOLOGY OF THE BAHAMAS**

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**Cover Photo: Outcrop showing Pleistocene soil profile,  
caliche crust, and rhizcretions,  
San Salvador, Bahamas.  
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**LONG-TERM, STORM-DOMINATED SEDIMENT DYNAMICS ON  
EAST BEACH AND SANDY POINT,  
SAN SALVADOR ISLAND, BAHAMAS**

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**ABSTRACT**

Beginning in June, 1990, the carbonate sand strandlines at East Beach (windward) and Sandy Point (leeward) on San Salvador Island have been monitored biannually for morphologic and sedimentologic change by students and faculty of the Keck Geology Consortium (Brill et al., 1993; Loizeaux et al., 1993). The present study builds on findings from these two earlier reports and focuses on the monitoring period of January, 1992, to January, 1993.

East Beach is located on the windward, northeastern coast of San Salvador. Surveys of 9 transect lines along 1 km of beach were combined with data from 6 offshore profiles to evaluate changes from January, 1992, to January, 1993. Between June, 1992 and January, 1993, net erosion of 4000 m<sup>3</sup> of sediment occurred along the foreshore with deposition in offshore areas and along the duneline. Brill et al. (1993) also documented net erosion of sediment during the July to January period in previous years, principally from the effects of late fall and winter wave energy. At East Beach, sediment is restored to the foreshore during the January to July period, resulting in a progradational beach. This seasonal pattern of cross-shore sediment migration has been the norm for East Beach over the four-year monitoring period.

Located along the southwestern corner of San Salvador, Sandy Point is a highly dynamic, partially leeward strandline. At Sandy Point, 2.4 km of beach were surveyed along 17

transects twice in June, 1992, and again in January, 1993. The two June data sets clearly document the effects of a strong southwesterly storm which resulted in significant deposition and movement of sand lobes at the point of Sandy Point. Offshore sediment characteristics at the northern end of the study area confirm storm-related longshore sediment migration patterns observed along the foreshore of Sandy Point. Sediments transported to the north from around Sandy Point and deposited offshore are very well sorted, fine sands, whereas sheltered Grotto Bay sediments are another distinct sediment population of moderately sorted, coarse sands which are transported south during winter northwesterly storms. Sediment distribution along both Sandy Point and East Beach is controlled by sediment exchange between the nearshore and beach environments as dictated by spatial and temporal patterns of storms.

**INTRODUCTION**

The major purpose of this study was to complete a four-year monitoring program for the East Beach and Sandy Point beaches and to compile a record of sediment distribution patterns in order to achieve better understanding of long-term change on carbonate island beaches. Sediment sampling and offshore profiling were used to extend mapping efforts beyond the foreshore of these beaches and to supplement the sediment distribution data taken along the shore. Although the geology of San Salvador

has been intensively studied, the beaches, which are among the island's most dynamic environments, have received little detailed attention (Clark et al., 1989). Further, Sandy Point is unique since carbonate strandlines with beachrock have had few previous morphodynamic field investigations (Loizeaux et al., 1993).

This research is part of a longer term study of beach processes and sediment movement on windward and leeward beaches on San Salvador. The first comprehensive studies of modern beaches on San Salvador was begun in June, 1990 by Brill (1991) and Loizeaux (1991). Brill focused part of his research on the morphodynamic changes of East Beach. A 1 km baseline was laid out with 9 profile stakes spaced 125 m apart, and sieve analysis of 54 sediment samples was completed for the June, 1990 beach (Brill, 1991). East Beach was then reprofiled at six month intervals through January, 1992 (Brill et al., 1993). A parallel study was begun in June, 1990 by Loizeaux (1991) who studied the morphodynamics of a leeward beach from Sandy Point to Grotto Bay. He surveyed a 1.925 km baseline with 10 evenly spaced profile locations and analyzed 49 sediment samples from the June beach for grain size distribution. Sandy Point was reprofiled in December, 1990 and January, 1992 (Loizeaux et al., 1993). The second phase of field research was conducted from June, 1992 through June, 1994, but this paper concentrates only on the period from June, 1992 through January, 1993.

Patterns of sediment transport and composition on both windward and leeward coasts are the focus of the sediment analyses. These coral-algal sediments consist of sands composed of skeletal fragments from a variety of reef and near-reef organisms, as well as non-skeletal grains which may be allochthonous or produced nearby (James, 1983). Examining sediment distribution patterns near patch reefs around San Salvador, Marrack (1989) concluded that because a high degree of variation occurred both within and among areas proximal to patch reefs, windward and leeward sites cannot be distinguished strictly on the basis of grain size relationships. It appears that modern transport patterns are site specific, and we have not attempted to extend our findings to rock record interpretation.

Transport of carbonate sediments is hydrodynamically different from the siliciclastic sediments upon which most original research has been done, since carbonate grains are more highly controlled by sediment source and breakdown mechanism (Swinchatt, 1965; Fagerstrom, 1987) and are less dense than siliciclastic grains (Tucker, 1981). Even with these hydrodynamic differences, Folk and Robles (1964) performed grain size analysis on carbonate beaches and concluded that the same parameters developed for siliciclastic beaches were applicable to carbonate systems.

## GEOLOGIC SETTING

San Salvador provides a unique natural laboratory for the study of windward versus leeward carbonate sediment transport since the island [19 km long (N-S) and 11 km wide (E-W)] is located on a stable platform isolated from the Great and Little Bahamas Banks. Two field areas were selected for this study on the basis of prior field research, but they also correspond to the windward and leeward margins of the island (Fig. 1). Prevailing easterly Trade Winds which average 10 knots (U. S. Naval Weather Service Command, 1974) combine with a northward flow of water from the Antilles Current to create north-flowing currents on both sides of San Salvador (White et al., 1984). These easterly winds make the eastern margin of San Salvador the island's windward side; therefore, it should follow that the field area on East Beach would be most strongly influenced by wave energy when compared with a more protected leeward shoreline. However, the presence of a 3 km wide, shallow, gently sloping shelf with prolific patch reefs offshore from East Beach actually helps to dissipate the wave energy driven by the easterly winds (Clark et al., 1989).

These offshore patch reefs and grassbeds are sites of sediment production and also act as controls on distribution patterns of sediments which are rippled by current and wave activity along the shelf. Alongshore, East Beach has a characteristic periodicity of 500 m for shoreline protuberances and bays, so a 1 km section of beach was selected for study to encompass two of these cycles (Brill et al., 1993). Other characteristics of East Beach's microtidal coast (tide range = 0.5-1.5 m) are

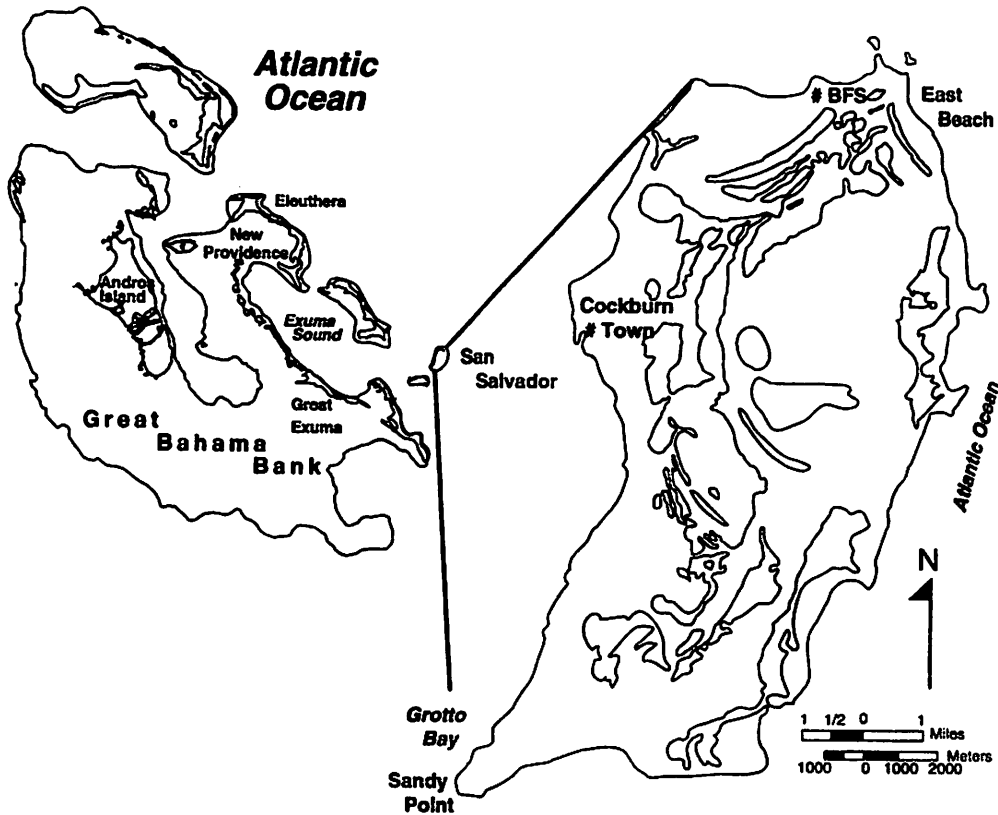


Figure 1. Location of San Salvador Island and the beach study areas of East Beach and Sandy Point. The East Beach study area is 1 km long, and the Sandy Point study area is 2.4 km long.

reworking of sediment into cusps and horns by higher order harmonics and dense wracklines of mixed *Sargassum*, seagrasses, and considerable anthropogenic debris from offshore. There is no evidence of consolidation of this medium to very fine-grained biogenic sediment into beachrock on East Beach (Bain, 1988). Adjacent to the shoreline, protodunes are rapidly being colonized and stabilized by vegetation. The landward side of East Beach is marked by extensive dune ridges of compacted sediments which can easily be distinguished from Pleistocene deposits since the sediment is poorly cemented with only a weak surficial crust. These extensive dune ridges support the hypothesis that East Beach is an accreting windward shoreline, as originally proposed by Titus (1984).

Sandy Point beach on the southwestern corner of the island extends for 2.4 km from the Pleistocene cliffs at Grotto Bay southward around the point of the island to Pleistocene

rock headlands to the East (Fig. 1). Sandy Point differs from East Beach in its smaller non-progradational dune system and the presence of discontinuous Holocene cliffs and beachrock along the shore. This beachrock and the beach sediments are primarily composed of fine to very coarse, highly polished grapestones, but skeletal grains of *Halimeda*, foraminifera, coral, and mollusc fragments are other components of this sediment (Loizeaux et al., 1993).

The beach at Sandy Point is very dynamic, with a large lobe of sand that oscillates around this SW corner of the island and a constantly reworked ridge and runnel system along the southern side of the point. A more prominent cusped topography is developed along the western shoreline. The dynamic sediment patterns can be attributed to swift currents flowing northward around the western margin of San Salvador, storm activity, and wave harmonics. Ocean currents come very close to shore at Sandy Point due to

the steep bank margin beyond the narrow shelf. Farther north, the quiet areas of Grotto Bay are dotted with patch reefs, characteristic of a leeward shore when easterly Trade Winds prevail. Since winter storm activity can reverse this pattern of sedimentation and focus storm energies on the leeward areas, Sandy Point is a storm-dominated system characterized by longshore transport of sediment.

## METHODS

The morphodynamics of two beach-dune systems were monitored by a series of stake and horizon and offshore profiles. Offshore sediment samples were also collected in June, 1992, along each of the two beaches. Stake and horizon profiles, as described by Fox (1990), were run from baseline stakes located on the primary dune to a depth of 1.5 m offshore where possible. Large waves prevented some of the profiles from reaching the 1.5 m depth, but offshore profiles made by snorkeling were used to continue many profiles to a depth of 3 m. During profiling, the time when the water's edge was reached was noted for each profile and tidal height was used to correct all profiles to MLLW (Mean Level of Low Water). Profiles corrected to elevations

above or below MLLW were plotted as elevation in meters above or below MLLW versus horizontal distance in meters using Cricket Graph. June, 1992 and January, 1993 data for Profile 1 along East Beach show the location of the stake, foreshore, MLLW, and offshore measurements (Fig. 2).

Corrected profile data from 9 East Beach locations and 17 Sandy Point locations was used to contour topographic maps for June, 1992 and January, 1993 on baseline maps for both East Beach, modified from Brill (1991), and Sandy Point, modified from Loizeaux (1991). A post-storm event map also was created for June 23, 1992 on Sandy Point to document the short-term changes in beach morphology which occurred in a storm event. All of these shoreline maps use a 2:1 offshore exaggeration to define shoreline features.

Differences in elevation between June, 1992 and January, 1993 were calculated by subtracting the June elevation from the January elevation. Maps illustrating net erosion and net deposition were created with this difference data for East Beach and Sandy Point. Using the topographic maps from June, 1992 and January, 1993, calculation of the volumes of sediment present on each of these beaches for a six-month interval allowed for direct quantification of the amount of

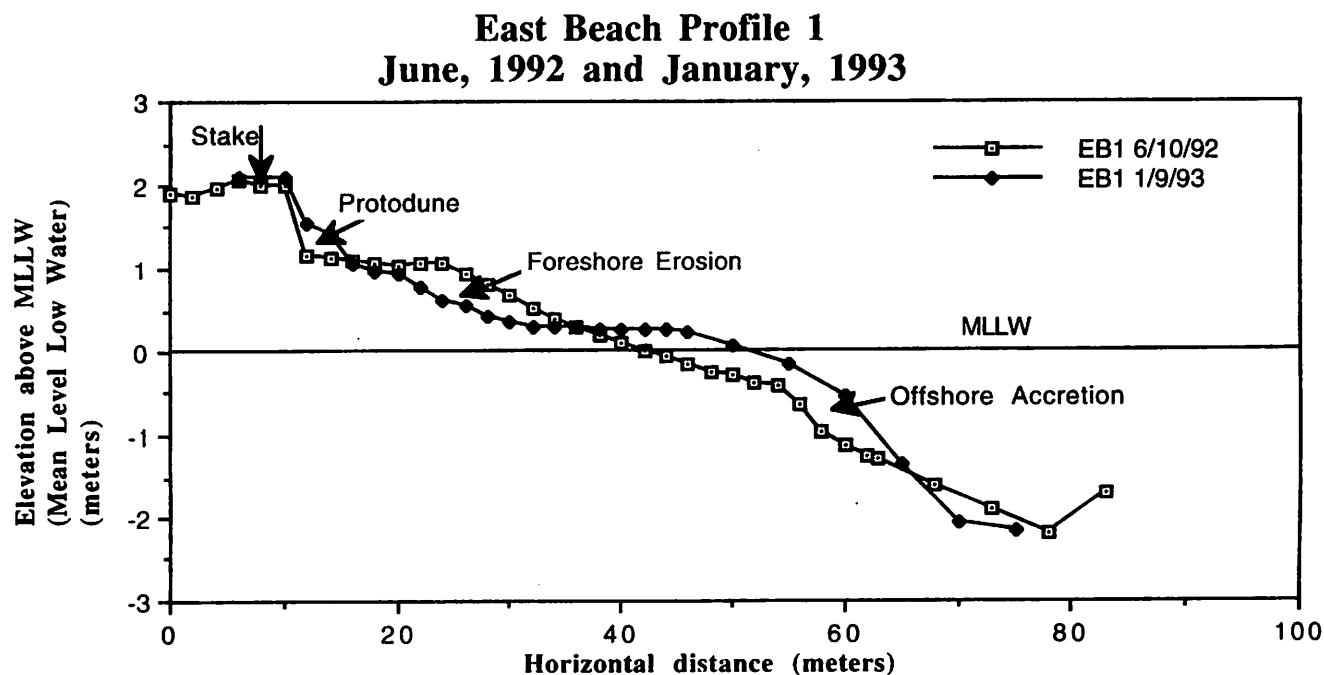


Figure 2. Profile 1 (the northern-most profile) along East Beach in June, 1992 and January, 1993, showing the locations of the stake, protodune, foreshore, MLLW, and the changes that occurred offshore during a 6-month period. The protodune is an area of sediment accretion in front of the dunes.

sediment that moved seasonally through these systems.

Building upon the sediment record compiled by Brill et al. (1993) and Loizeaux et al. (1993), 54 offshore sediment samples for East Beach and Sandy Point were collected in June, 1992 along each of 6 profiles. Sample locations began at the lower foreshore with the start of a snorkel profile and continued at regular intervals from shore ending at 50 m from shore. All sediment samples were rinsed, dried, split, and sieved using a set of U.S. Standard wire mesh sieves and a Ro-Tap shaker. Raw sieve weights for each phi size were entered into the IBM PC Program SIEVE designed by Fox (1991) which calculates weight percent and the Folk and Ward (1957) graphical statistical parameters of mean grain size ( $\phi$ ) and standard deviation ( $\phi$ ) values for each subsample. Using basemaps created by Loizeaux (1991) and Brill (1991), offshore sediment distribution patterns were contoured and maps for mean grain size and standard deviation were created using CANVAS.

#### EAST BEACH

Along the east-facing coastline of East Beach, stake and horizon profiles were oriented at a bearing of 80 degrees true north. Consistency in location enabled each profile to be taken across the same portion of the beach. Following the initial study by Brill in June, 1990, East Beach was reprofiled in December, 1990, July, 1991, and January, 1992 (Brill et al., 1993). Profile data collected during June, 1992 and January, 1993 from 9 stake and horizon profiles and 6 offshore profiles (Profiles 1, 2, 4, 6, 8, and 9) were hand contoured to create topographic maps (Figures 3a and 3b). The June, 1992 and January, 1993 maps indicate the undulating foreshore with bays and protuberances spaced approximately 500 m apart. These topographic maps provide a general idea about the shape of the beach, but changes in the beach over a 6-month interval are best visualized by subtracting June, 1992 profile data from January, 1993 profile data and contouring a map for net erosion and net deposition (Fig. 4). Evaluation of net erosion and net deposition along East Beach during this period indicates a pattern of accretion along the base of the dunes. Accretion along the dunes is strong evidence to support Titus' (1984) theory that

East Beach is a prograding shoreline, building eastward onto the San Salvador shelf.

Major dune plant species were identified from Smith (1982) and were used to recognize colonization patterns of this beach-dune system. Dominant species that colonize and vegetate these protodunes and dunes are *Sesuvium portulacastrum* (Sea Purslane), *Ernodea littoralis*, *Cenchrus incertus* (sandspur), and *Uniola paniculata* (sea oats). *U. paniculata* has consistently become more prevalent in the stabilization of the protodune area. A prograding protodune area has been documented by profile data (Fig. 2) and is visible as a vegetated bulge of sediment along the backshore, which is primarily colonized by *E. littoralis*.

Net erosion is occurring along the foreshore and is evidenced by erosion scarps. Erosion scarps form when the waves erode parts of the foreshore, removing sediment and debris and forming scarps. Along East Beach, characteristic dense, heavy wracklines of mixed *Sargassum* and seagrasses are prominent. These wracklines generally mark the high tide line and can be preserved landward of active erosion scarps.

Offshore patterns of erosion and deposition are influenced by the presence of patch reefs and grass beds, observed northward longshore transport, and cross-shore exchange of sediment between the foreshore and shelf. From June, 1992 through January, 1993, erosion occurred offshore at Profiles 8 and 9 in the south while deposition occurred offshore along Profiles 3 through 6 (Fig. 4). Analysis of sediment collected along the June, 1992 offshore profiles cannot confirm that sediments eroded from the southern sites are deposited along the northern profiles with net northward longshore transport.

In June, 1992, 19 offshore sediment samples were collected from East Beach, sieved, and analyzed according to the graphical statistical parameters of Folk and Ward (1957) for mean grain size and standard deviation (sorting). For June, 1992, mean grain size ranged from 2.13  $\phi$  to 3.12  $\phi$  (fine to very fine sand), and sediments were moderately to very well sorted (0.27  $\phi$  to 0.91  $\phi$ ). Broad bands of fine sand are characteristic of the offshore sediments of East Beach, but offshore sampling indicated poorer sorting with increasing distance offshore. Since sediment

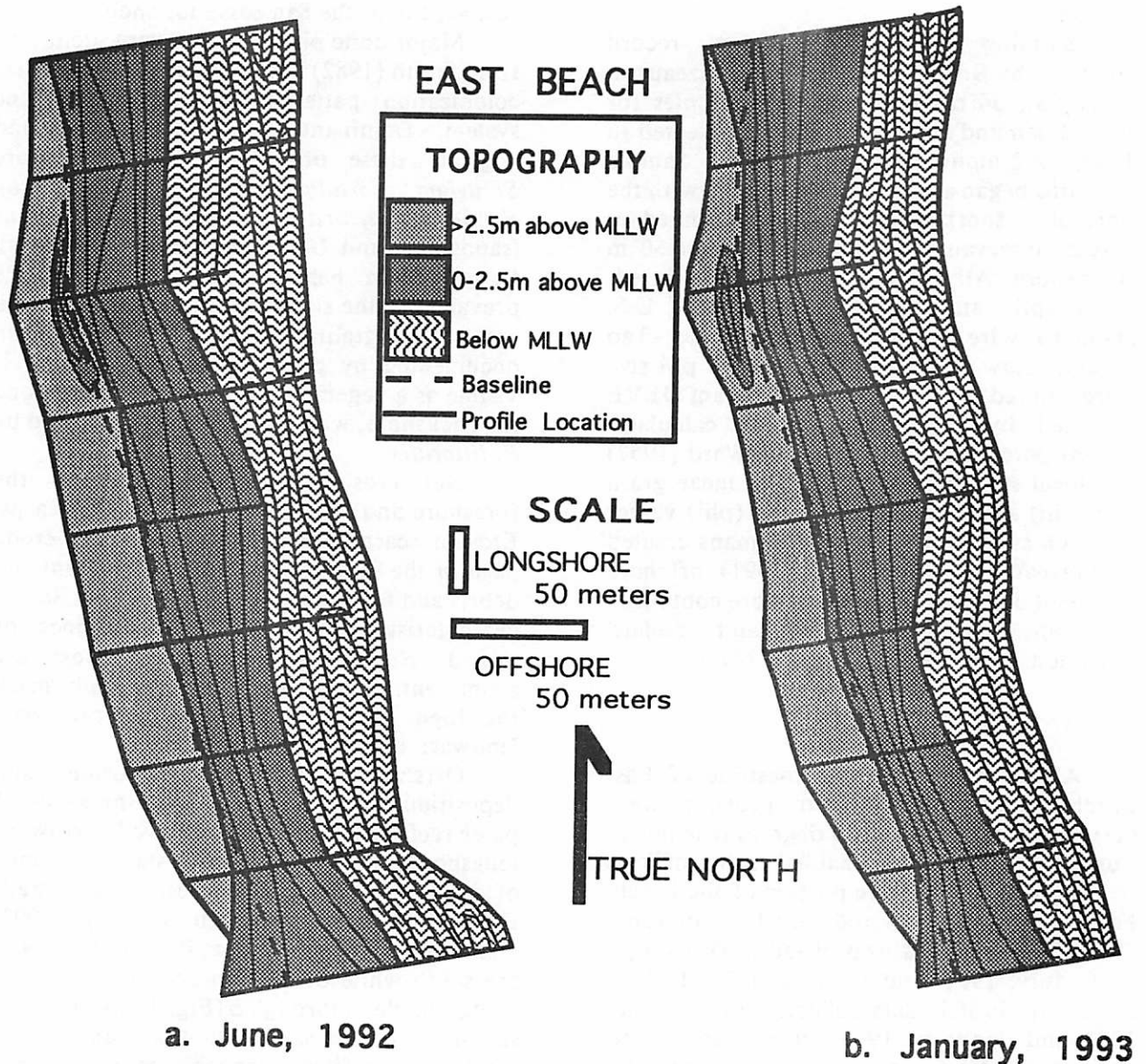


Figure 3. (a) June, 1992 and (b) January, 1993 topographic maps for East Beach. 2:1 offshore exaggeration and hand contoured. Ocean is to the right. Note the cusped shoreline with roughly 500 m periodicity.

source and breakdown mechanism play an important role in grain size distribution patterns, the influence of patch reefs and grass beds as sediment sources offshore of East Beach cannot be ignored when evaluating grain size distribution patterns. The skeletal component from these sites comprises the largest portion of the sediment offshore from East Beach (Marrack, 1989). Minor longshore transport may occur in the East Beach system, but the sediment distribution offshore of East Beach in June, 1992 does not support well

defined longshore transport of distinct sediment populations. Rather, cross-shore movement appears to be the dominant mechanism in sediment distribution patterns along East Beach with finer sands offshore.

Net accretion along East Beach can be documented by comparisons of data from several years, but comparison of data from June, 1992 to January, 1993 indicates net erosion of 4000 m<sup>3</sup> of sediments along East Beach. In total, 4000 m<sup>3</sup> of sediments were deposited chiefly in offshore areas while 8000



# EAST BEACH

June, 1992-January, 1993

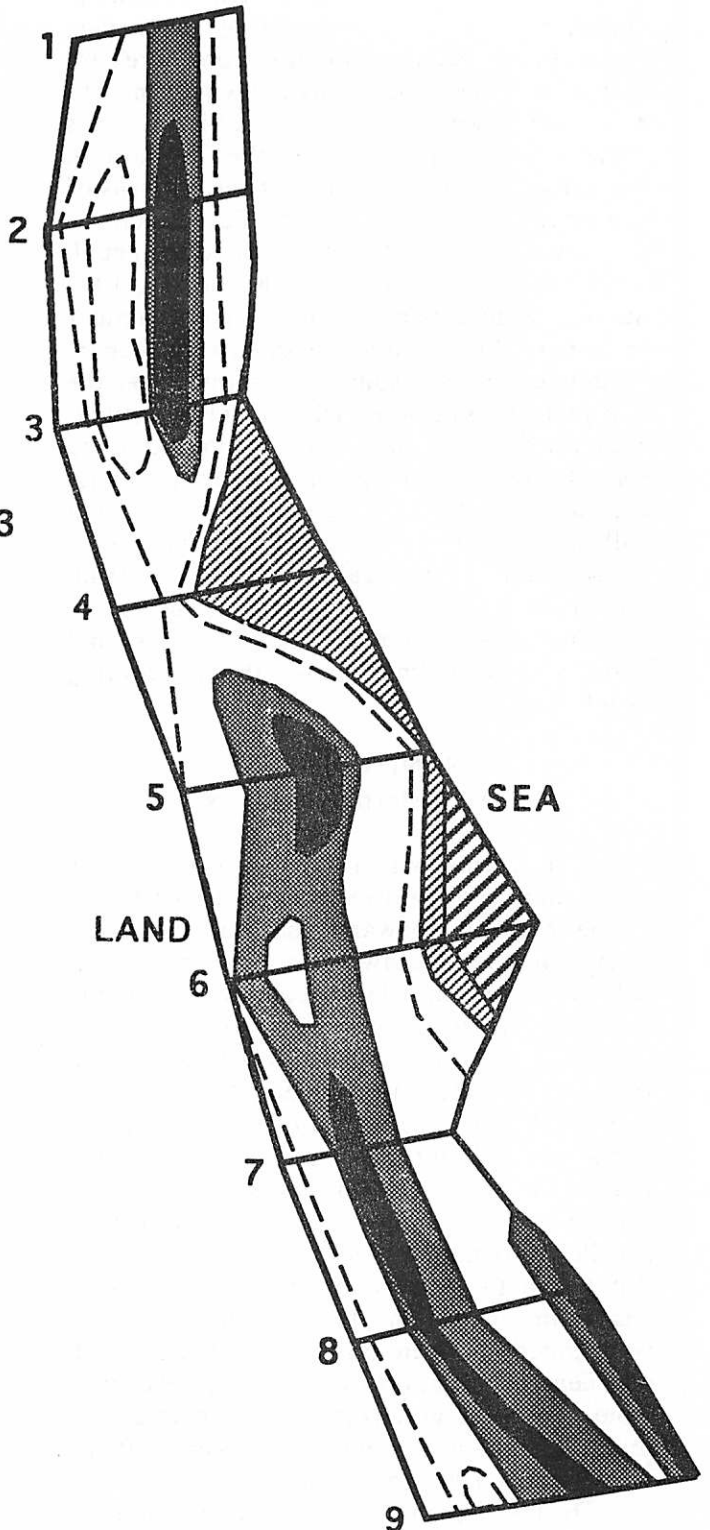
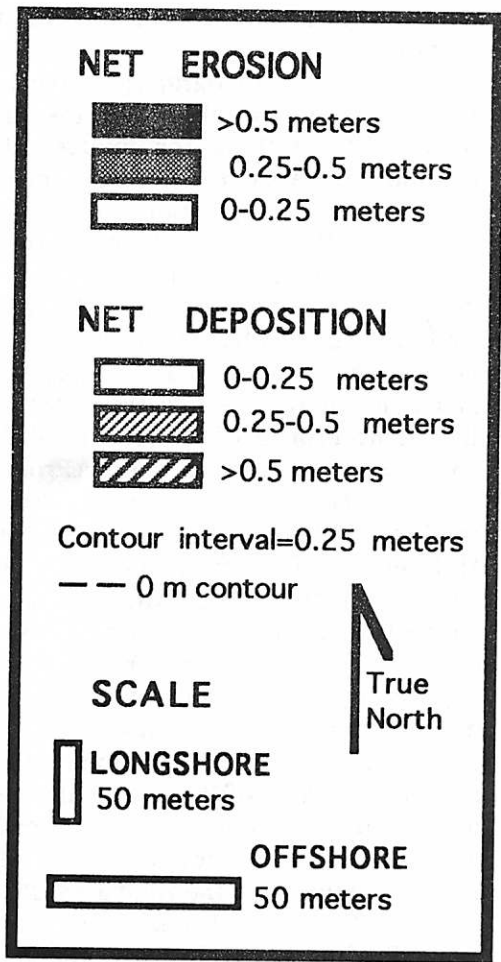


Figure 4. Net erosion and deposition from June, 1992 to January, 1993 for East Beach. 2:1 offshore exaggeration and hand contoured. Ocean is to the right. Erosion occurred mainly along the foreshore with deposition offshore from profiles 3-6. 4000 m<sup>3</sup> of net deposition occurred from June, 1992 to January, 1993.

m<sup>3</sup> of sediments were eroded, mainly from the foreshore. With cross-shore exchange, sediments eroded from the foreshore are transported offshore during the winter months with higher wave and current activity. This same sediment may return to the foreshore in the summer months to support the patterns of dune accretion observed along East Beach.

Past studies by Brill (1991) and Brill et al. (1993) for June, 1990 through January, 1992 also indicated patterns of erosion from summer to winter, but even more deposition occurs from late winter to summer months. Over the two year period of the Brill et al. (1993) study, 14,000 m<sup>3</sup> of sediments were deposited along East Beach. A long-term pattern of net deposition exists along East Beach. Erosion still occurs during summer to winter due to autumn storms, but calmer conditions from winter to summer and further cross-shore exchange of sediment provide for net deposition of sediment along this prograding beach.

#### SANDY POINT Beach Morphodynamics

Contrasting with the seasonal pattern of cross-shore sediment exchange on East Beach is the partially leeward coastline of Sandy Point on the southwestern corner of San Salvador. From Pleistocene cliffs on the eastern side of Grotto Bay, the carbonate beach curves to the south and then east along the southwestern shore of San Salvador. In June, 1990, Loizeaux (1991) designed the initial Sandy Point study and marked a 1.925 km baseline parallel to the shore with 10 profile stakes. In June, 1992, five additional profiles were added to the southern portion of this beach to better quantify the amount of change in this system. Two additional profiles were added in Grotto Bay to permit analysis of sediment distribution due to wave reflection from the cliffs at Grotto Bay. In total, 17 profiles were surveyed along Sandy Point during June, 1992 and January, 1993.

During spring and summer, wave-generated currents and prevailing Easterly Trade Winds cause sedimentation on the point of Sandy Point. Winter storms from the Northwest can reverse this pattern of sedimentation and create conditions which cause net erosion and shifting of the Sandy Point sediment lobe, as demonstrated between

January and June, 1992 (Loizeaux et al., 1993). During June, 1992, an intense southwesterly storm over a two-day period caused the distribution of sediment along Sandy Point to change dramatically. These changes were documented by subsequent beach profiles.

Profile data from all 17 stake and horizon profiles and 6 offshore profiles (Profiles 5 through 10) were contoured to create three topographic maps for Sandy Point. The June 10, 1992, June 23, 1992, and January, 1993 maps indicate the reworking of sediment along Sandy Point, most easily noticed by the shifting lobe of sand around the point (Fig. 5a-c). It was possible to collect offshore profile data only in the northern part of this field area and during lower wave energy periods. Due to these limitations in field work, the greatest depths are only recorded in the northern section.

Changes in topography of the beach are best visualized by subtracting the June, 1992 numbers from those for January, 1993 and contouring the differences on a map for net erosion and net deposition for this six-month period. This map of net erosion and deposition (Fig. 6) emphasizes areas of net deposition, severe erosion, and reworking of ridge and runnel channels along the point. Net deposition occurred at three major locations along the shore: next to the cliffs in Grotto Bay along Profile 10A, offshore of Profile 9, and along the western shore (Profiles 1-7). Along Profile 10A, deposition up to 1m above the June, 1992 level was observed. Next to the Holocene cliffs that underlie modern dune vegetation (Profile 9), sediment maintained a constant level, but some deposition occurred offshore. Along the western coast, over 2m of deposition occurred along Profiles 2 and 3 and deposition continued offshore.

Areas of net erosion along Sandy Point included offshore of Profile 9A at the entrance to Grotto Bay, along the foreshore of the western coast (Profiles 8-6), and along the eastern extension of the field area (Profiles 1A and 1B). Erosion of 1 m of sediment occurred along Profile 9A. This sediment may have been deposited further inshore in Grotto Bay, along Profile 10A next to the cliffs in Grotto Bay. Along the west coast of this study area, minor foreshore erosion of up to 0.6 m occurred (Profiles 8-6). Minor erosion of the foreshore might be attributed to the reworking of the cusp and horn topography (13 m

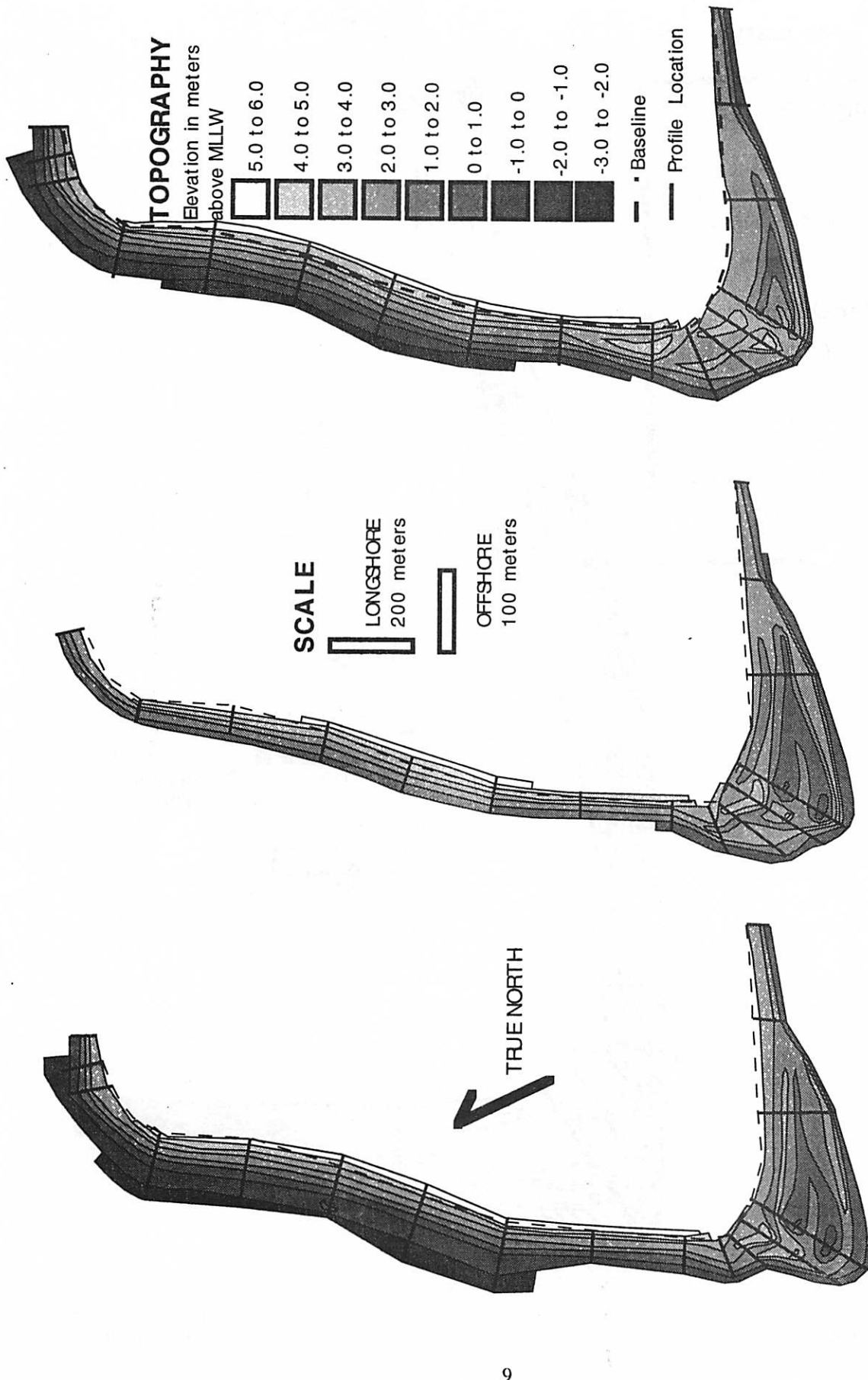


Figure 5. (a) June 10, 1992, (b) June 23, 1992, and (c) January, 1993 topographic maps for Sandy Point, 2:1 offshore exaggeration and hand contoured. Ocean is to the left. Note shifting lobe of sediment along Sandy Point and progressive accretion on the western side.

# SANDY POINT

June, 1992-January, 1993

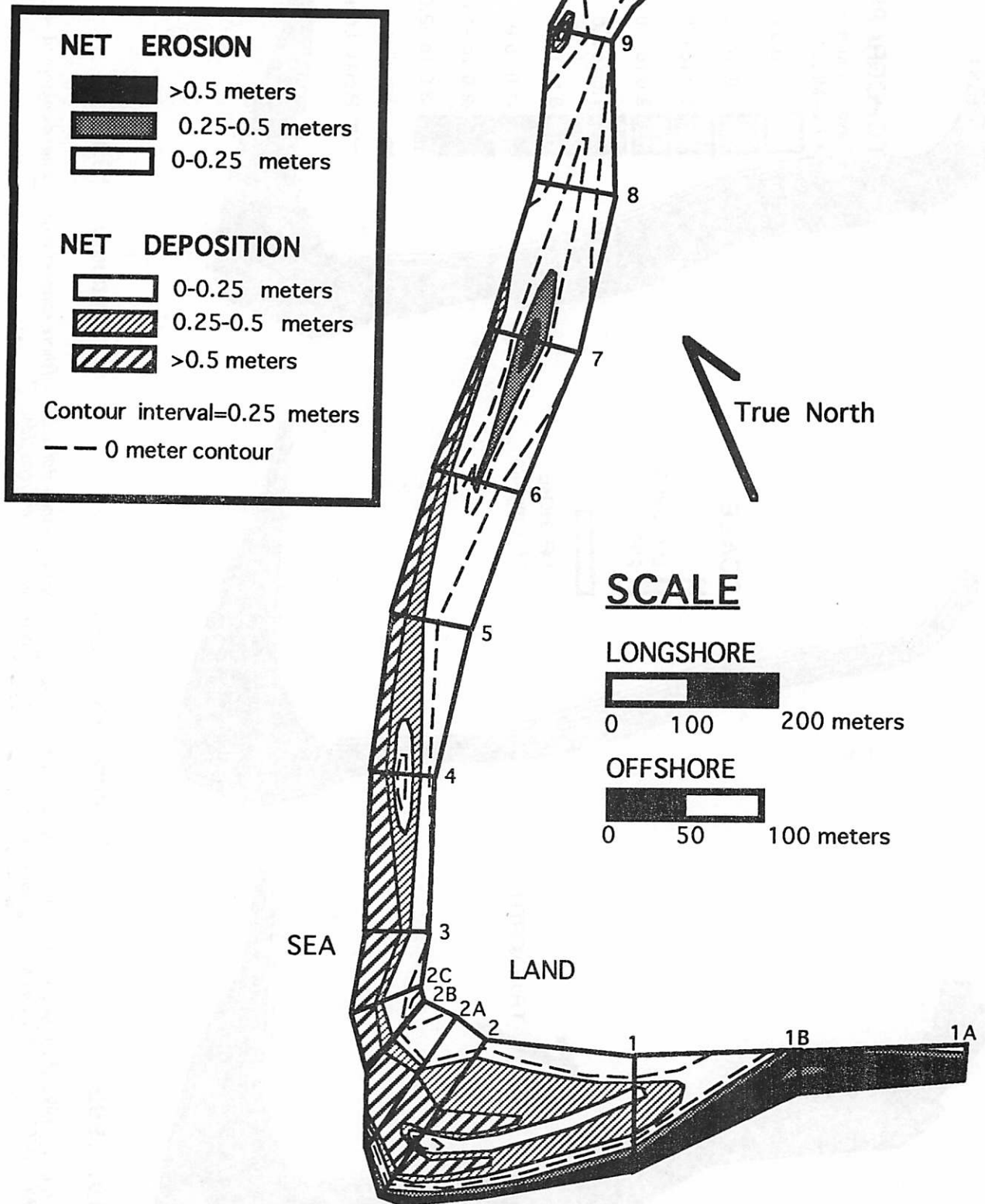


Figure 6. Net erosion and deposition from June, 1992 to January, 1993 for Sandy Point. 2:1 offshore exaggeration and hand contoured. Ocean is to the left. Significant deposition occurred offshore from Profiles 1-7, whereas erosion was focused in the eastern section (Profiles 1A-1). Net deposition of 7000 m<sup>3</sup> of sediment occurred from June, 1992 to January, 1993.

periodicity), but this reworking also could result in accretion along another profile. The eastern extensions of the field area (Profiles 1A and 1B) exhibit large amounts of foreshore erosion, but the amount of erosion occurring in each of these profiles is limited by the presence of cliffs of Pleistocene rock.

Stable areas on the foreshore coincide with outcrops of beachrock. These areas (Profile 4) never accumulate much sediment, nor do they allow large volumes of sediment to be eroded from the foreshore. Studies of beachrock in the future may indicate the ways these blocks influence the hydrodynamics of the nearshore environment.

Reworking of sediment along Sandy Point has resulted in a dramatic shift in the topography. From June, 1992 to January, 1993, an isolated runnel which had been cut off from open water circulation was filled with sediment. Farther east, a new, wider ridge and runnel system formed. As normal tides do not usually exceed the 1.5 m tidal range, these runnels and welded berms do not form from normal tidal activity. Storm waves 3-4 m high have been observed off the southern portion of Sandy Point and accompany the storm front and surge. Such large-scale features as this dynamic ridge and runnel system are formed during one storm system and preserved on the eastern lobe of sand at Sandy Point until another storm event can rework this sediment.

Calculations of the total volumes of sediment eroded or deposited along Sandy Point indicated a net deposition of 7000 m<sup>3</sup> of sediments along Sandy Point between June, 1992 and January, 1993. 32,800 m<sup>3</sup> of sediments were deposited while 25,800 m<sup>3</sup> of sediments were eroded. A previous study by Loizeaux (1991) indicated that 31,000 m<sup>3</sup> of sediments were eroded from Sandy Point between June, 1990 and December, 1990. This is not a direct comparison because a larger area was profiled in June, 1992 and January, 1993 than during previous studies. Nonetheless, data from 2.5 years of monitoring at this beach indicates net erosion is occurring in the Sandy Point system.

#### Offshore Sediment Populations

Sediment analysis was performed for a total of 35 sediment samples collected along 6 offshore profiles (Profiles 5-10) to evaluate sediment characteristics, transport

mechanisms, and sediment sources. Offshore sediment sampling at Sandy Point was restricted to the northern part of the field area. Swift currents around the southwestern tip of Sandy Point make this area dangerous for swimming. The graphical statistical parameters of mean grain size and standard deviation were contoured on basemaps for Sandy Point for the June, 1992 sediment samples (Fig. 7a, b).

Graphic mean grain size for offshore sediment samples collected on the northern part of this field area in June, 1990 was coarse to very fine sand (0.30 to 2.50 phi). A contour map of this data indicates the offshore variation in Grotto Bay to the north and along the western coast (Fig. 7a). A fine sand population (2.0 to 2.5 phi) was detected offshore of Profiles 5 through 7, whereas medium to coarse sediments (1.77 to 0.78 phi) were found in Grotto Bay. In Grotto Bay, bottom sediments are highly rippled and document interference patterns from incoming waves and waves reflected from the Pleistocene cliffs. The dominance of medium sands in the northern section but finer sediments offshore of the western section indicates northward transport of sediment from the lobe of Sandy Point to the area of Profiles 5-7 during the spring months preceding sampling June, 1992. Another pattern of sediment transport is found from Grotto Bay to the south. Sediment samples from Profiles 8 and 9 document a medium sand population (1.34 phi for sample 8E) which resulted from mixing of the coarser Grotto Bay sediment with the finer sediments from Sandy Point.

These two sediment populations are further defined by calculations of standard deviation for the samples. As a statistical parameter used to assess the relative energies of environments on a beach, standard deviation is often referred to as sorting. The best sorted sediments are usually found in the higher energy areas with the larger degree of sediment transport, and the sorting patterns for Sandy Point offshore sediments are distributed in this manner. Standard deviation values for these very well to moderately sorted sediments (0.34 to 1.31 phi) reflect their sediment transport patterns. The best sorted sediments (phi values from 0.34 to 0.39) are located in the southern portion of the study area offshore of Profiles 5 and 6, where the highest current

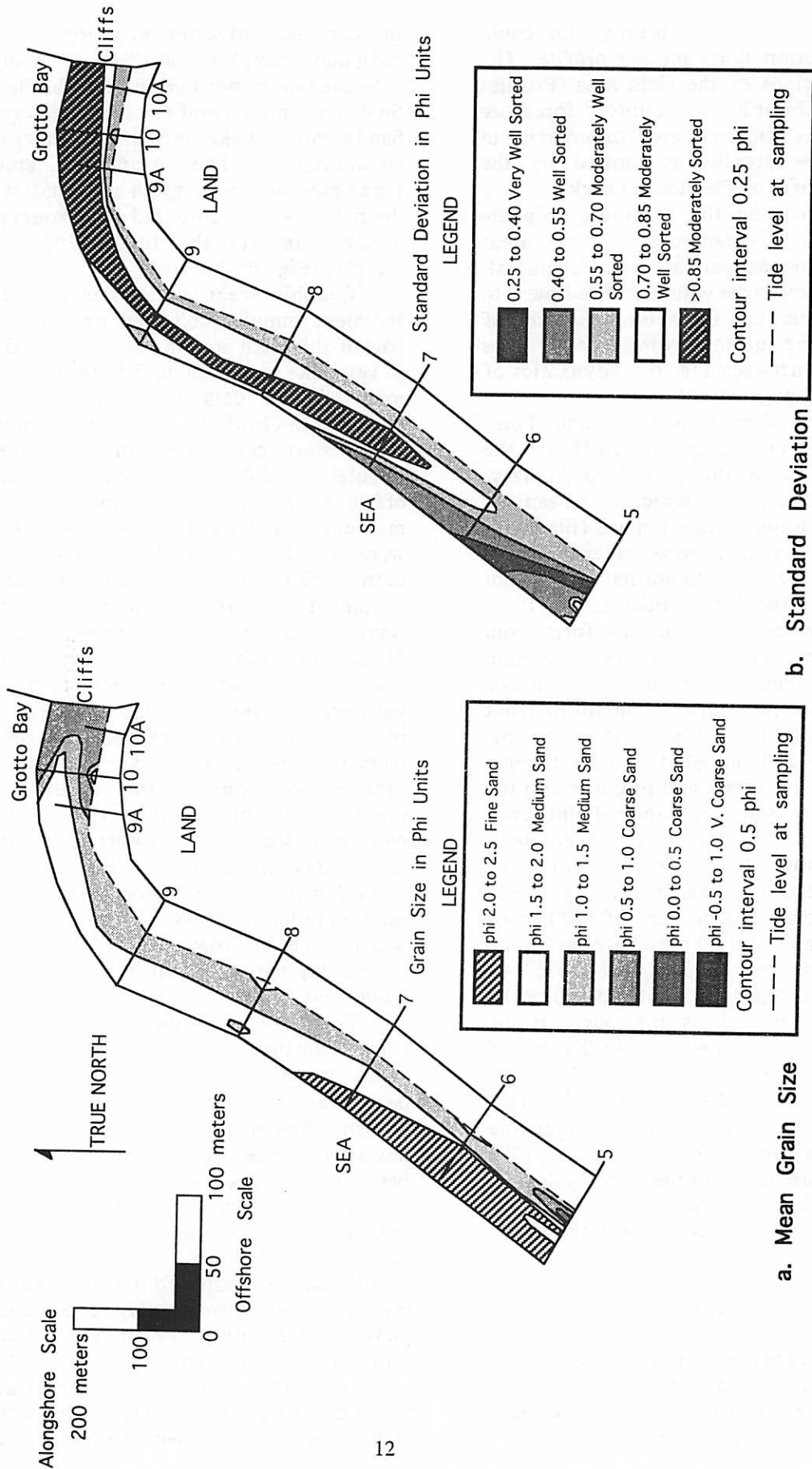


Figure 7. (a) Mean Grain Size and (b) Standard Deviation (sorting) sediment distribution maps for Sandy Point, 2:1 offshore exaggeration and land contoured. Ocean is to the left. Note two sediment populations - one coarse, poorly sorted population from Grotto Bay and another fine, well sorted population transported north from Sandy Point.

activity transports this sediment. Closer to Grotto Bay, moderately sorted sediments ( $\phi$  values from 0.52 to 1.03) are more common. This protected area of the leeward coast does not experience as much of the constant wave and current activity that sorts the sediments on the southern portion of the beach. Also sediment from patch reefs in Grotto Bay and erosion of the Grotto Bay cliffs may be coarser sediment sources.

This study of offshore sediments has demonstrated that Grotto Bay is a possible source area for sediment along Sandy Point. Offshore sediment sampling north of Sandy Point has indicated the presence of two distinct sediment populations. The fine sand population, with a modal size of 2.75-3.25  $\phi$ , is dominant in the south at Profile 7 and is mixed with the coarser sand population with a modal size of 0.75-1.25  $\phi$  at Profile 8. In Grotto Bay, the coarse sand (0.75-1.25  $\phi$ ) becomes the dominant sediment population. Offshore sediments of Grotto Bay are moderately sorted, coarse sands, whereas sediments transported north from around Sandy Point and deposited offshore of Profiles 5-7 are very well sorted, fine sands. Areas offshore of Profiles 8 and 9 indicate mixing of these two populations.

The offshore sediments of Sandy Point are controlled by the swift currents which flow from the east around the southwestern tip of Sandy Point and up the west coast. The narrow western shelf at this part of the platform also does not provide a source of sediment for the beaches nor does it offer much space to store sediment.

One question which remains to be answered for Sandy Point is dominant sediment source for this stretch of beach. Since the southern shelf area does not have the patch reefs and grass beds generally associated with carbonate sediment production, other areas must be investigated to determine the sediment source(s). This study indicates that Grotto Bay may be one site of sediment generation, but further investigation is needed to quantify the amount of sediment this area is capable of generating.

## CONCLUSIONS

With four years of monitoring research on two beaches of San Salvador Island, we are able to make some generalizations about the

sediment dynamics on stretches of windward and leeward carbonate coastline. On the windward strandline at East Beach, cross-shore exchange of sediment is facilitated by dominant easterly Trade Winds, but the leeward side of the island at Sandy Point is highly impacted by seasonal storms. The lower daily energy levels on the leeward coast contrast most sharply with the high energy levels resulting from seasonal northwesterly and southwesterly storms. Sandy Point further illustrates that the width of adjacent shelf areas and source(s) of sediment are also major controls on the beach and offshore sediment dynamics.

Specific conclusions for East Beach are:

1) Although net erosion of 4000 m<sup>3</sup> of sediment occurred along East Beach from June, 1992 to January, 1993, comparison of sediment budgets for East Beach over the longer period from June, 1990 through January, 1993 indicates that net deposition is occurring in this system. Deposition, with growth of protodunes, supports the progradation of East Beach out onto the shallow shelf of the San Salvador platform, as proposed by Titus (1984).

2) Seasonal cross-shore exchange of sediments is common along East Beach and helps to balance the energies of storm events in this system. Typically, erosion occurs from late summer through winter storms, but calmer conditions from winter to summer provide for net deposition of sediment along this prograding beach.

Specific conclusions for Sandy Point are:

3) There are at least three dominant patterns of sediment movement at Sandy Point. Erosion east of Sandy Point and reworking of the sediment along Sandy Point into ridge and runnel systems during storm events is accompanied by continued accretion of sediment on the western side of Sandy Point. Net deposition of 7000 m<sup>3</sup> of sediment during June, 1992 to January, 1993 was less than past studies documented due to corresponding decreased amounts of erosion in this system during this period.

4) Offshore sediment sampling north of Sandy Point indicates the presence of two distinct sediment populations. One population is a coarse sand with a mode at 0.75-1.25  $\phi$ , and the other is a fine sand population with a mode at 2.75-3.25  $\phi$ . The coarser sediments are moving to the south from Grotto Bay, and the

finer sediments are moving northward from Sandy Point. Migration and mixing of these sediments is facilitated by storms, such as the southwesterly storm that occurred on June 21, 1992. Sandy Point is an event-driven storm system with seasonal storm patterns for longshore migration of sediment.

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