PROCEEDINGS

OF THE FOURTH SYMPOSIUM

ON THE GEOLOGY OF THE BAHAMAS

Editor

John E. Mylroie

Production Editor

Donald T. Gerace

Sponsored by the Bahamian Field Station

June 17 - 22, 1988

ISBN 0-935909-31-1

Printed by Don Heuer in the U.S.A.

PRELIMINARY REPORT ON EVOLUTION OF THE COAST ALONG BLACKWOOD BAY, SAN SALVADOR ISLAND, BAHAMAS

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ABSTRACT

The coast of Blackwood Bay on the south side of San Salvador Island is a low-energy carbonate shoreline, the history of which can be reconstructed from five laterally adjacent sedimentologic and geomorphic shore zones. These zones are recognized in a seaward succession: coastal ponds; gravel ridge; sand bench; upper intertidal mangrove trees and gravel; and Pleistocene bedrock. The bay is a platform margin, lagoon-tidal flat complex which is underlain by Pleistocene bedrock. The bay is restricted to the south by a partially destroyed fringing reef with a reef rubble rampart and to the southeast by cliffs and terraces of the Pleistocene Grotto Beach Formation. Abundant cobble-and boulder-sized gravel, composed of coral and rock fragments located in the upper intertidal-shore zone and backshore may represent the cumulative effects of storms striking the coast during the Holocene. The sand bench and mangrove fringing the coast may be the product of quiet interstorm periods resulting in the progradation of the shoreline and filling of the bay.

INTRODUCTION

Blackwood Bay is located on the southern side of San Salvador Island and is part of a small embayment on the eastern side of a larger bay known as French Bay (Index Map 1). Physiographically, the coast of Blackwood Bay is situated between seacliffs to the southeast and a beach-dune complex to the northwest (Fig. 1). The bay is enclosed to the south by a fringing reef and a reef rubble rampart (Pace, 1987a; 1987b; Pace and others, 1988). Pleistocene bedrock, capped by a paleosol, crops out as a rocky shoal and dampens wave energy approaching from the Atlantic Ocean to the south-southwest. The southern section of the coast is a rocky

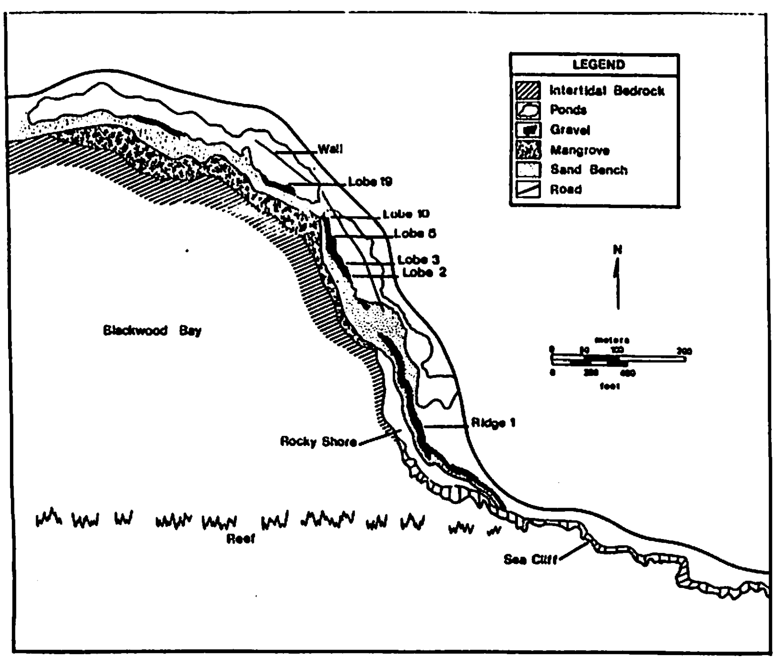

Fig. 1. Map of Blackwood Bay coastline showing shore zones, morphologic features, and sample locations discussed in Fig. 6.

shoreline without mangrove vegetation while the northern section is a partial sandy beach overgrown by red mangrove (*Rhizophora mangle*), and black mangrove trees (*Avicennia germinans*) as well as a variety of terrestrial plants.

The idea for this study evolved from descriptions of lobe-shaped carbonate gravel deposits in Pace (1987a; 1987b) and Pace and others (1988). Since the completion of field reconnaissance and mapping, the present study has grown to include laterally adjacent shore zones and sedimentary deposits. The purpose of this report is to describe the physical and biogenic sedimentary features, show the areal distribution, and interpret the sedimentary and geomorphic history of the shore zones and deposits as they relate to the overall geologic evolution of San Salvador Island.

SEDIMENTARY GEOMORPHOLOGY

Coastal Features

Field work was conducted in January, June and early July, 1988, and included mapping of coastal features and deposits along the coast of Blackwood Bay. Mapping has shown that in the present intertidal to supratidal environments there are five distinct coastal zones characterized by the following features: 1. a shoal of Pleistocene bedrock exposed in the intertidal zone; 2. a thin deposit of gravel associated with a belt of mangrove trees in the upper intertidal zone; 3. a sand body representing a beach ridge and forming a treeless sand corridor and an elevated backshore bench; 4. a discontinuous backshore gravel ridge; and 5. a series of ponds or low-lying areas in the far backshore with associated mangrove vegetation (Fig. 1).

Pleistocene Bedrock

The outcrop pattern of the Pleistocene bedrock merits discussion because it may have affected the sedimentologic and geomorphic development of Blackwood Bay. The extreme eastern edge of Blackwood Bay is characterized by low bedrock cliffs and terraces of the Pleistocene Grotto Beach Formation (Carew and Mylroie, 1985). These cliffs and terraces have been modified by erosion into small embayments and partially collapsed seacaves, the floors of which are lined with pebble-to cobble-size clasts of coral, bedrock, and shells of the mollusc, *Strombus gigas*. The erosional pattern grades into the high seacliffs which comprise the Gulf area on the southern side of the island.

Bedrock underlies the floor of the bay itself and emerges as a mantle of elevated rock shoals extending 2 to 65 meters out from the shoreline. An irregular bedrock surface is exposed in the intertidal zone and has been modified by bioerosion, wave erosion, and phytokarst processes (Fig. 2). A series of joints has disrupted the upper surface of bedrock in a pattern that is parallel and perpendicular to bedding. Mangrove roots and pneumatophores have further wedged apart square- and rectangular-shaped slabs of bedrock along joints. Consequently, rock slabs of similar shape inherited from the joint patterns have been transported higher onto the upper intertidal surface of barren bedrock and mangrove trees. Other gravel reworked with the slabs include smaller clasts of coral, bedrock fragments, and *Strombus gigas* shells.

Intertidal Mangroves and Gravel

Shoreward and adjacent to the zone of exposed bedrock is a tract of mangrove trees characterized by the black mangrove (*Avicennia germinans*) mixed with the red mangrove (*Rhizophora mangle*). They locally occupy upper intertidal and supratidal levels and may extend slightly into the sand bench zone. The mangrove swamp subcommunity on San Salvador Island consists of red mangrove, black mangrove, white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*) (Smith, 1985). Red and black mangrove trees are dominant along the coastal portions of Blackwood Bay, while buttonwood and poisonwood characterize the landward portions of the sand bench.

Square-and rectangular-shaped slabs of bedrock reworked from the exposures of jointed bedrock in the lower intertidal zone have been emplaced among the mangroves (Fig. 3). The slabs and other pieces of coral, shell, and bedrock debris form a layer of locally imbricated cobble- and boulder-size clasts resting on a surface of pneumatophores, sand, and bedrock. The shoot-like pneumatophores of black mangrove trees have grown out from under and in between gravel clasts in some places, partially prop-up local gravel slabs, or appear deformed and crushed underneath gravel slabs in other places. Networks of red mangrove prop roots encage local gravel slabs or bluntly terminate against them in the

Fig. 2. Intertidal bedrock shoal bordering the coast. Note joints, bedrock slabs, and black mangrove pneumatophores.

Fig. 3. Intertidal mangrove trees and gravel. Black mangrove trees are growing in front of and upon sand bench.

Fig. 4. Sand bench showing seaward most swash ridge. Swash debris is composed primarily of Thalassia *blades.*

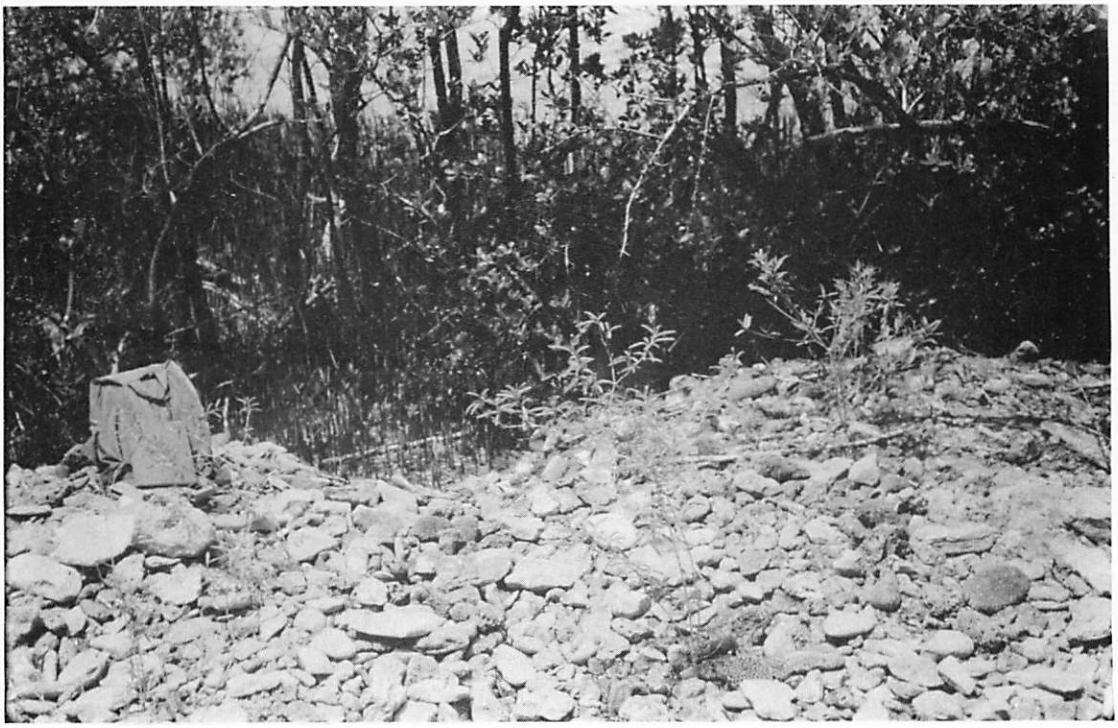

Fig. 5. Gravel ridge with pronounced lobate edge. Dry coastal pond in background.

attempt to emplant themselves in the substrate.

Two large clusters of red mangrove up to 30 meters in width are present along the northern section of the coast. Dense branches and prop roots act as a baffle which has entrapped a layer of dark brown, organic-rich mud up to 30 centimeters thick as well as flotsam brought in by wave and storm currents. A whole assortment of drift and litter has been washed into the mangrove tract. Ship roping and netting is found entangled among mangrove pneumatophores, prop roots, and branches. Plastic, paper, styrofoam, wood and glass articles have been likewise trapped within the mangrove forest. Local plastic wrapping and bottle labels show dates which are within five years old.

Sand Bench

Landward of the mangrove trees, a tract of sand has been built up to form a backshore berm or bench 2 to 35 meters wide. It is overgrown with grass and locally with non-halophytic terrestrial trees. The surface of the bench is characterized by ridge and swale topography where the ridges are composed of linear heaps of *Thalassia*, sargassum, other vegetation and swash debris, which extend parallel along the shoreline (Fig. 4). The youngest, highest swash ridge is 0.5 meters in amplitude and has been built up at the seaward edge of the sand bench; at least 3 to 4 lower amplitude, parallel ridges had been built up behind the youngest one. The crest of the youngest, seaward-most berm is overgrown predominantly by black mangrove trees.

The width of the sand bench may be related to the intertidal bedrock exposures. The bench is wider where the Pleistocene bedrock shoal projects farthest into the bay and narrower where bedrock reentrants occur. Sediment-probing of the most recent, seaward-facing beach ridge indicates that the sediment is 130 to 55 centimenters thick. Thickness of the remainder of the sand bench ranges from 115 to 20 centimeters. In addition to the swash debris, the beach ridges are composed of fine-to medium- grained bioclastic sand which is similar to the sand in the swales. The bench forms a treeless corridor between mangroves in the intertidal zone and mangroves and other trees bordering the ponds and can be seen from the air.

Gravel Ridge

The sand bench terminates landward against gravel deposits that form a topographically elevated ridge which is discontinuous but traceable along the entire shoreline (Fig. 5). The ridge runs parallel to the coast approximately 5 to 20 meters inland of the high tide mark. The gravel is compositionally similar to the gravel located in the upper intertidal zone along the shore. The ridge runs parallel to the coast in a northern direction as a semi-continuous feature for 825 meters. Areas where the ridge is absent are covered by sand bench deposits. The ridge continues to the south for an additional 300 meters as a feature that extends to the seacliffs. The southern section of the gravel ridge is 20 meters wide and 3 to 4 meters high. The southern ridge has steep seaward and landward faces and a subhorizontal top. Along the northern section of the coast, the gravel deposit is characterized by a ridge slightly lower in elevation (1 to 2 meters) compared to the southern ridge; and by a pronounced lobate landward edge. The landward edge forms steep-sided noses or leeside surfaces facing northeast. The lobate edges of the ridge coalesce to form a mega-lobe (Pace, 1987b). The seaward edge of the ridge terminates against the sand bench along a relatively straight margin that follows the shape of the bay. The individual lobes are 4 to 15 meters in length (parallel to shore) and 4 to 9 meters wide (perpendicular to shore). In plan view the lobes are tongue-shaped and elongated landward. The gravel deposit is composed of coral clasts, rock fragments, *Strombus gigas* shells, and local bivalve shells (Fig. 6). The predominant shape of the rock fragments is subangular blocks and slabs. Size of rock fragments of the ridge varies between 5 and 27 centimeters along the longest dimension. The length of the short axis varies between 0.5 and 8 centimeters and reflects the inherited slab or blocky shape of the fragment. Isolated blocks greater that 1 meter in size are present, but are limited to the surface of the ridge. Surface rock fragments are slightly to moderately weathered and are dark grey to black. Gravel underneath the surface layer is yellowish white. The coral clasts on the surface of the ridge have retained their original biologic shape as palmate, branched, rounded-, and finger-shaped clasts. Surface coral clasts range in size from 5 to 23 centimeters. These coral clasts are slightly weathered and identifiable at the species level.

Based on the analysis of 253 surface and subsurface gravel clasts from various ridge locations, the coral and rock fraction out of the total gravel may be divided compositionally into the following (Fig. 6). Extremely abraded, unidentified

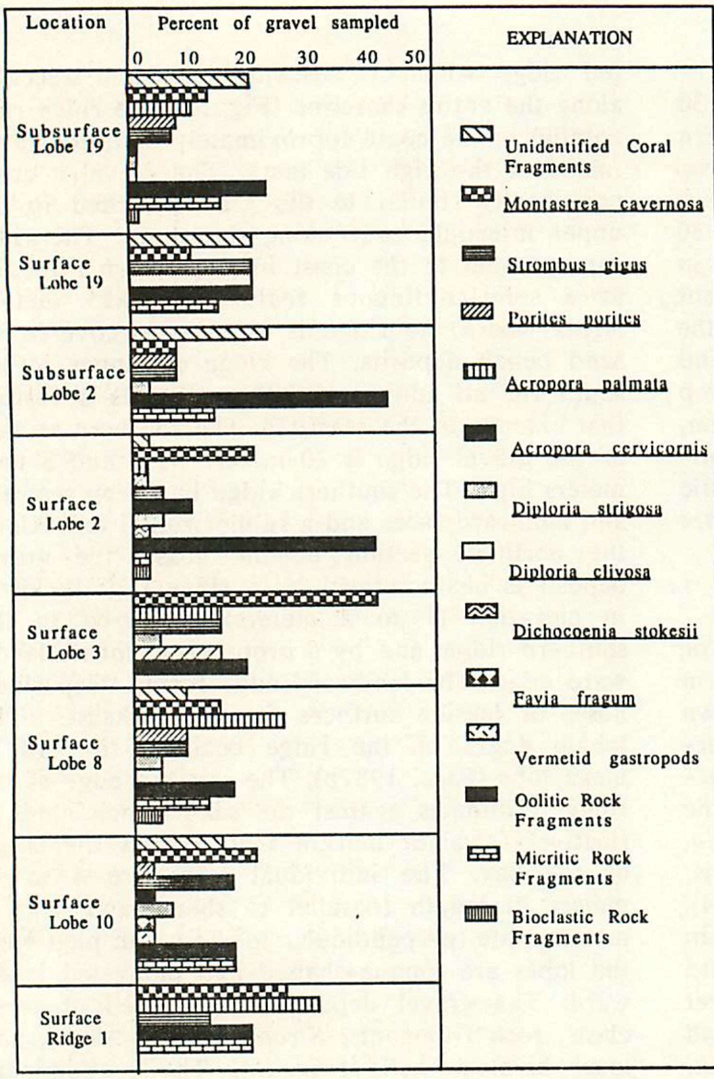

Fig. 6. Composition of gravel ridge deposits based on analysis of 253 surface and subsurface gravel clasts. Sample locations shown in Fig. 1.

coral fragments are present and generally constitute 20% of the gravel material sampled. The percentage of coral clasts ranges between 23 and 68%. The abundant coral species sampled from the ridge surface include: *Montastrea cavernosa*, and *Acropora palmata; Acropora cervicornis, Porites porites*, were fairly common while *Diploria strigosa, Diploria clivosa, Favium fragum*, and *Dichocoenia stokesii* were rare. *Strombus gigas* shells ranged between 30% to none. The occurrence of rock fragments varies between 18 and 55%.

The gravel deposits are characterized by three to four sets of pebble- and small cobble-size material (3-15 cm, long axis), alternating with beds of cobble size material (20 to 30 cm, long axis). Contacts between upper and lower beds are abrupt. The lower pebbly and small cobble beds are 10 to 20 centimeters thick while the upper cobbly beds are 20 to 30 centimeters thick. Lower beds are compositionally similar to the upper beds, although abraded coral fragments are more abundant in the lower beds. Variation in gravel size is most extreme between the uppermost pebble-to small cobble-size bed and the surface material. The gravel on the surface of the ridge is the largest material observed. Total thickness of the gravel deposit is between 90 and 120 centimeters. The gravel is clast supported with sand as a matrix in all but the upper 50 centimeters of material.

Three *Strombus gigas* shells were found 40 to 60 centimeters below the surface of a lobate portion of the gravel ridge. The shells have abraded spires and small circular openings made near the apex of the shell. These features resemble those found on *Strombus gigas* shells that were opened by early inhabitants of the island (Hoffman, personal communication). They result from the use of one shell as a tool to open another to gain access to the flesh. The practice is still occasionally used on San Salvador Island, but is more commonly associated with the early pre-Columbian inhabitants.

A small rectangular structure 4x2x1 meters in size was discovered on top of the southern gravel ridge. The upper layer of cobble- to boulder-size gravel of the ridge was removed and used to build the walls of the structure which rest on an underlying finer gravel bed. The structure is similar to buildings and walls built during an interval of San Salvador Island history known as the Loyalist Period (Sandra Riley, personal communication). The Loyalist Period represents a time of European settlement by American Colonists who were loyal to the British Crown and who were granted lands on San Salvador Island during and after the American Revolution (Gerace, 1982). Most of the land was granted in the eighteenth century and an estimated 2,000 persons occupied the island by the end of the 1780's (Gerace, 1982). A very thick base of a glass bottle was also discovered on the surface of the ridge. The bottle base was from a type of bottle termed a "kick-up" possibly used between the late 1700's and early 1800's (Hoffman, personal communication).

Coastal Ponds

Three shore-parallel ponds are locally contiguous with the landward edge of the gravel ridge. These ponds are formed in the swale developed between the gravel ridge and rising Pleistocene bedrock of the island. The ponds are seasonally flooded with rain water and possibly by marine waters during storms. Salinity of the deepest pond, located at the south-central part of the coast, was 17 parts per thousand as measured during an abnormally wet month of June, 1988. The maximum depth of the pond is 0.8 to 1.0 meters and is filled with water year round. A core collected from the pond 1.5 meters east of the ridge is characterized by a basal peat layer 45 centimeters thick containing abundant gastropods and a cobble size grainstone fragment near the base of the unit (Pace, 1987b). The remainder of the core (153 cm) is characterized by alternating thick beds of ostracode-rich mud (12 to 57 cm), and thinner beds (4 to 9 cm) of fine-to coarse-grained bioclastic sand containing coral, gastropod, and bivalve fragments. A sandy fan-shaped feature, visible from the air, is also present in the southeast corner of this pond. In shape and lateral extent, the sand body resembles a washover fan. Sediment-probing of the south-central pond and another large pond to the north, indicates that sediment in both ponds is 220 centimeters thick near the seaward edge adjacent to the gravel ridge and thins-out to less than 5 centimeters at the mainland edge of the pond. Features associated with the northern pond resemble partially filled tidal channels which provide communication between the pond and the lagoon. These areas are slightly lower in elevation and lined with red mangrove trees that stretch from the pond to the lagoon.

Other low-lying coastal areas are seasonally flooded to form shallow ephemeral ponds. Bottom sediment in these areas forms a thin veneer of fine sand and mud up to 20 centimeters thick. Red and black mangrove trees border the edges of the ponds and adjacent low-lying areas. The landward margin of the ponds and low areas of the coast grades into normal inland portions of the island characterized by lithified Pleistocene aeolian dune ridges and interdune swales.

A stone wall approximately 1 meter in height bisects the ponds; the wall may represent a boundary marker built during the Loyalist Period. The material comprising the wall is different in appearance from the gravel of the ridge and was possibly brought from another source.

DISCUSSION OF THE COASTAL EVOLUTION OF BLACKWOOD BAY

The geomorphic and depositional history of the coastal features along Blackwood Bay may be related to infrequent, severe storm events causing erosional retreat of the bedrock seacliffs, terraces, and shoals that border the coastline, destruction of the fringing reef at the southern edge of Blackwood Bay, and landwand transport of material produced during the storm. Interstorm periods are characterized by low energy tidal conditions and the deposition of sand and mud as a prograding shoreline and general filling of the bay.

Pleistocene Bedrock

Geomorphically, tropical limestone shores differ from siliceous shores because of the soluble nature of the limestone, and the destructive and constructive nature of biogenic processes. The shape, extent, and general nature of the exposed bedrock surface bordering the coast of Blackwood

Bay is controlled by biological erosion followed by reworking by storm currents. Mutler (1969) outlined the various stages of bedrock erosion and cliff line retreat along tropical limestone shores and demonstrated that exposed bedrock is undermined by bioerosion followed by storm waves breaking the remaining weakened rock apart. The erosional modification of the cliffs and terraces at the extreme eastern edge of Blackwood Bay, has created embayments, and collapsed sea caves that follow the pattern expressed by Mutler (1969). The presence of gravel flooring the bottom of the cliffs and sea caves documents the continuous cycle of erosion and breakdown along the exposed coast.

Jointing, and the enhancement of joint patterns by biogenic processes such as mangrove root wedging, and boring by marine organisms have provided the source material for much of the gravel located along the shore. The jointed nature of the bedrock shoal has resulted in production of slab-shaped bedrock fragments that are a common constituent of gravel found higher up on the intertidal portions of the coast. Landwand transport of these slabs, as well as associated smaller clasts of coral, bedrock fragments, and *Strombus gigas* shells are believed to be the result of storm currents either from one storm or a series of storms.

Intertidal Mangroves and Gravel

Mangrove swamps are typical of tropical and subtropical shorelines throughout the world between 25° north and south latitude. The major control of regional mangrove distribution is temperature and more specifically the occurrence of frost. West (1956) suggested that well developed mangrove is found only where average temperatures for the coldest month exceed 20°C. Mangroves are generally found only on low energy accreting shorelines and are largely absent from eroding shorelines, although they may help to stabilize marginal shoreline dynamics (Burns, 1977). The mangrove characterizes sheltered marshes and intertidal mud flats.

Substrate and wave energy impart controls on the local distribution of mangrove. Davies (1977) suggested that mangroves will grow on a variety of sediment substrates including coraline sand, but more commonly on fine grained, soft, organic-rich mud deposited in estuarine and deltaic settings. The mangrove along Blackwood Bay is growing in sandy areas, gravelly areas, and in organic-rich muds. The only relationship that can be made between the trees and substrate is that organic-rich muds are only accumulating in the densest portions of the mangrove forest.

Davies (1977) believed that mangroves are vulnerable to wave action at all stages of their life history, and therefore are absent from exposed stretches of shore and can occur on the open coast in only very low energy environments. The distribution of the mangrove trees along Blackwood Bay's coast may be related to antecedent bedrock topography. The intertidal bedrock shoal acts as a secondary breakwater of wave energy and therefore may create the low energy conditions required by the mangrove. The imbricated gravel and smaller gravels in the upper intertidal zone may also slow incoming water reaching the mangrove. The limiting factor in mangrove colonization of Blackwood Bay is probably energy.

The role that the mangrove trees play in shoreline stabilization or accretion along Blackwood Bay is uncertain. The mangrove trees appear to be taking advantage of areas were sedimentation is occurring. On the other hand, adolescent red mangrove trees have taken root in the lower intertidal areas of the coast and are covered by as much as half a meter of water at high tide. In these cases the limiting factor is time of exposure, which controls the time required for plant respiration. These pioneer plants appear to show that the mangrove fringe is indeed prograding into the bay. The network of prop-roots and entangled debris of the mangrove fringe acts as a sediment trap by causing the deceleration of flowing water and settling out of entrained grains. The land-building role of mangroves has recently been questioned. However, the present consensus would be that mangroves are significant factors of shoreline evolution, but that their significance has sometimes been overstressed (Davies, 1977).

Due to inter-relations between the mangrove fringe and sand bench, time of colonization of Blackwood Bay's shoreline by mangrove vegetation is as yet uncertain. The oldest mangrove tree along the shore may be on the order of tens of years, but the existence of an ancestral coastal mangrove fringe may represent hundreds or thousands of years. Modern coastal mangrove swamps studied by Scholl (1963) suggest that mangrove swamp forests of southwestern Florida began to develop approximately 4,000 years ago as a result of Holocene transgression (post-Wisconsin sea-level rise) across the southwestern margin of the Everglades. Initiation of marine and swamp sedimentation of the Great Bahama Bank is estimated at 3000 to 5000 years ago (Newell and others, 1959). Mangrove colonization along Blackwood Bay could have conceivably begun 3000 to 5000 years ago when the platform was flooded (Pace, 1987b, Andersen and Boardman, 1987).

Sand Bench

Sand beaches to the west of Blackwood Bay, along French Bay, are composed of coarse- to medium-grained bioclastic sediment derived from the reef and other organisms in the shelf environment. The sand bench present inland of the mangroves along Blackwood Bay merges with the beach deposits of French Bay in the absence of mangrove trees. The bench and the most recent beach ridge appears to be inactive at the present time. The dense mass of mangrove fronting the coast is believed to restrict normal wave energy and prohibits net transport of grains along the coast.

If the beach is presently inactive, the beach ridges and swales of the sand bench may represent a series of wave-built storm deposits. Newell and others (1959) described similar alternating ridges and swales along the lagoonal shores of Bimini. They believed that the ridges represented successive storm beaches which were rapidly stabilized by mangrove plants, in particular the red (*Rhizophora mangle*) and black (*Avicennia nitida*). The black mangrove preferentially occupies the most recent shoreward beach ridge along Blackwood Bay as in cases noted by Newell and others (1959). The scenario presented by Newell and others (1959) was characterized by the red mangrove plants forming a protective seaward fringe that effectively anchors the outer ridge, and by trapping sediment they gradually extend the shore until the community advance is temporarily checked by the construction of a new storm beach beyond the mangrove. Due to geomorphic and botanical similarities, the sand bench at Blackwood Bay with its ridge and swale topography may have a similar history.

Gravel Ridge

Fair weather conditions along the coast of Blackwood Bay are not sufficient to account for the large gravel accumulations found in the upper intertidal and backshore areas of the coastline. Hurricanes are known to produce and transport large amounts of gravel debris by momentary high-velocity currents breaking over reef areas. Various authors have described the effects of hurricanes on reefs and coastal areas of south Florida and the Bahamas (Ball and others, 1967, Hurricane Donna; Perkins and Enos, 1968, Hurricane Betsy; Woodley and others, 1981, Hurricane Allen; and Sealey, 1985, Hurricane David). The sedimentary deposits and geomorphic changes in areas such as Blackwood Bay may be related to high-energy currents generated by tropical cyclones. The gravel ridge deposits and the gravel armor in the intertidal-shore zone have characteristics similar to carbonate gravel deposits in south Florida and the Bahamas produced by severe storm events as described by Newell and others (1959); Folk (1966); Ball and others (1967); Perkins and Enos (1968); Adams (1980); Hinman (1983); Scholle, and others (1983); and Scoffin (1987). Hinman (1983) described gravel deposits produced by winter northwesterly storm currents on Singer Beach, along the western part of San Salvador Island, Bahamas. Beaches along other localized parts of San Salvador Island are characterized by similar intertidal and backshore gravel ridge deposits especially on the north and west side of the island, and on cays known as Hinchinbroke Rocks and Middle Cay on the southeast.

Storm currents produce coral rubble that far exceeds the amount produced by normal daily breakdown. An extreme case of reef destruction by hurricane forces was presented by Woodley and others (1981) for the coral reefs of north Jamaica; the planar living areas of the branching *Acropora* were reduced by up to 99 percent along one stretch of reef. In this case, the breaker zone and reef flat were transformed from constructional reefs into a gently sloping rubble rampart. Ball and others (1967) also noted the development of a reef rubble rampart after Hurricane Donna hit the Florida reef tract. The presence of a coral rubble rampart located between the fringing reef and shoreline of Blackwood Bay is evidence for at least one severe storm striking the coast in the Holocene.

The abundance of coral material making up the inland gravel ridge suggests that storm processes are removing material from subtidal portions of the bay and emplacing them along the coast. The 3810 +/- 90 years bp age of a coral clast collected from the surface of one of the gravel lobes suggests that the lobe can be no older than approximately 3900 years (Pace, 1987b, and Pace and others, 1988). However, a younger age for emplacement may be suggested if the coral died prior to deposition. Ball and others (1967) in their study of the effects of Hurricane Donna and Folk (1966) in his morphologic study of the sand cays of Alacran Reef, Yucatan, Mexico suggested that the distance that larger pieces of coral debris move shoreward from the reefs during each storm is measured in feet. The material of the gravel ridge feature may have slowly accreted to the shore. Alternatively, the relatively unbored and unabraded nature of coral on the surface of the ridge would support a rapid emplacement of gravel. Rapid emplacement would limit subaqueous exposure and weathering by boring marine organisms.

The packages of coarsening upward gravel material comprising the inland ridge may represent a series of storm surges during a single storm event, or single storm events over a long period of time. An emergent coral rubble island (Little Molasses, Molasses Reef, Florida Reef Tract) studied by Banks (1959), and later by Ball and others (1967) displayed a similar 0.3 to 0.7m sequence of coarse coral rubble grading downward into fine coral gravel, followed by a thin sand layer and more loose gravel. The coarsening upward nature of the gravel deposit may suggest affinity to fluidized sediment flow or grain flow conditions resulting in inverse grading of beds. Clast-to-clast dispersive pressure created by these conditions act to size-sort grains, pushing larger grains to the top of the flow, the area of least shear-strain rate, and moving smaller grains to the bottom producing reverse grading (Middleton and Hampton, 1973). Little Molasses Island was shown to represent the cumulative product of storm activity which has piled up rubble on the leeward side of Molasses outer reef. The gravel ridge of Blackwood Bay may represent accretion of material from the bay that has accumulated since the bay was initially flooded.

The source of the boulders, cobbles, and fragments of rock that form a large part of the gravel ridge is believed to be the bedrock cliffs, terraces, and shoals that border the coast. The block- or slab-shape of many of the rock fragments of the ridge implies a shape inherited from the jointed bedrock pattern found in the present intertidal zone.

The presence of man-made artifacts such as the box-like structure, pond walls, and glass bottle bottom, possibly related to Loyalist Settlement, on the surface of the ridge suggest that the event which produced the gravel ridge did not occur within the last 200 years. The occurrence of *Strombus gigas* shells (conch) found 40 to 60 centimeters below the surface of the gravel ridge with man-made features suggests that the gravel was not deposited prior to aboriginal settlement.

Coastal Ponds

The ponds occupy a swale area between lithified Pleistocene dunes and the coast and may represent flooded areas resulting from the pre-existing bedrock topography. Another possibility is that the emplacement of the gravel ridge and progradation of the shoreline restricted a landward portion of Blackwood Bay to form brackish ponds. Gradual filling and segmentation of the low areas may have followed. The presence of an active tidal channel along the northern-most pond and a feature resembling a washover fan in the large southern pond may support damming and segmentation. The sediment comprising the washover is composed of medium- to coarse-grained bioclastic sand similar to sediment presently occurring in the bay. Within a core taken by Pace (1987b) four thin sand stringers containing marine fauna within a series of mud sequences may represent normal sedimentation in the pond interrupted by sandy washover deposits formed during storms.

CONCLUSIONS

A proposed history for the evolution of the coast is presented based on the areal extent, lateral relations and distribution of the five shore zones and their characteristic deposits, and analogies between published descriptions of similar carbonate deposits and coastlines. Initial conditions of Blackwood Bay prior to Holocene post-glacial transgression and platform flooding approximately 3800 to 3600 years ago (Pace, 1987b; Andersen and Boardman, 1987), are represented by the existence of an exposed Pleistocene bedrock surface covered with a thin soil (Pace, 1987b).

An interpretation of coastal changes occurring along the coast of Blackwood Bay following platform flooding may be as follows: 1. Between approximately 3900 and 200 years before present, constrained by the radiocarbon age of coral material and human artifacts located on the surface of the ridge, a severe storm or series of storms of hurricane magnitude struck the coast resulting in the breakdown of bedrock cliffs, terraces, and shoals, as well as destruction of the offshore reef. Transport and emplacement as ridge deposits may have been synchronous with the storms; or the gravel may have been deposited in a manner whereby each storm that affected the coast created new material and slowly moved the mass shoreward as a sand and gravel slurry and heaped the debris as a discontinuous, poorly sorted, poorly stratified ridge. 2. The sand bench appears to have formed under higher energy conditions than are presently occurring along the coast. This feature may represent sand size material deposited under higher energy conditions either due to the destruction of the protective reef offshore (related to the storms that produced the gravel material) or due to lesser storms producing swash ridges stabilized by mangrove as a series of accretionary ridges. 3. The mangrove vegetation appears to be a relatively new shoreline feature. This is suggested due to lateral relations between the coastal deposits. The gravel ridge and sand bench landward of the mangrove would appear to be older than the mangrove presently occupying upper intertidal regions of the coast. The mangrove and sand bench could also be coeval, representing a series of storm ridges stabilized by the mangrove vegetation. Alternatively the mangrove forest may have been present along the coast since initial bank-top flooding, dependent upon energy conditions within the bay. 4. During later mangrove colonization and stabilization of the shoreline, another storm event occurred. Currents ripped-up molluscan and reef debris from within the bay and joint-separated slabs of bedrock from the intertidal shoals, and deposited the debris as a patchy, locally imbricated gravel layer atop sand, barren bedrock, and a mat of mangrove pneumatophores in the upper intertidal zone. This gravel layer is the youngest, seaward-building unit along the shore of Blackwood Bay and records the latest storm events.

Further analysis of surface sediment and rock samples collected from each of the shore zones, gravel samples from the backshore ridge and intertidal zone, as well as cores collected from the sand bench, ponds and beneath the ridge may provide answers and new theories on the evolution of the coast of Blackwood Bay.

ACKNOWLEDGEMENTS

We are indebted to Don Gerace, director of the College Center of the Finger Lakes, Bahamian Field Station for full logistical and financial support for this project.

The senior author is especially grateful to Matt Wilkerson (Appalachian State University), and Mac and Lee McKee, Bill Balcerzak, and Rice Mellon (Mississippi State University) for their assistance in collecting samples and cores; to John Hebert, Woody Pace, and Dr. John Mylroie for an introduction to Blackwood Bay; to Karen Andersen for her drafting, typing and immeasurable patience; to Dr. James Teeter and Dr. Charles Hoffman for their guidance and inspiration during field work.

REFERENCES CITED

Adams, R.W., 1980, General guide to the geologic features of San Salvador Island, in Gerace, D.T., ed, Field Guide to the Geology of San Salvador (First Edition): Fort Lauderdale, Florida, College Center of the Finger Lakes, Bahamian Field Station, p. 1-66.

Andersen, C.B., and Boardman, M.R., 1987, Sedimentary gradients in a high-energy carbonate lagoon, Snow Bay, San Salvador, Bahamas, in Boardman, M. R.,ed., A field guide to the modern carbonate enironments of San Salvador and Andros Islands: University of Miami, Ohio.

Ball, M.M., Shin, E.A., and Stockman, K.W., 1967, The geologic effects of Hurricane Donna in south Florida: Journal of Geology, v. 75, no. 5, p. 583-597.

Banks, J.E., 1959, Limestone conglomerates (Recent and Cretaceous) in southern Florida: American Association of Petroleum Geologists Bulletin, v. 43, p. 2237-2243.

Burns, L.A., 1977, Mangrove Swamps, in Clark, J.R., ed., Coastal Ecosystem Management, Wiley Interscience Publication, p. 660-665.

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 Geologic Society of America, Orlando annual meeting field trip: Fort Lauderdale, Florida, College Center of the Finger Lakes, Bahamian Field Station, p. 11-61.

Davies, J.L., 1977, Geographic variation in coastal development, in Clayton, K.M., ed., Geomorphology Texts, Longman Group Limited, p. 199.

Folk, R.L., 1966, Sand Cays of Alacran Reef, Yucatan, Mexico: Morphology, Journal of Geology, vol. 75, p. 412-437.

Gerace, K., 1982, Three loyalist plantations on San Salvador Island, Bahamas, in Carr, R.S., ed., The Florida Anthropologist: Florida Anthropological Society, vol. 35, no. 4.

Hinman, E., 1983, Recent sedimentary lithotypes and ancient facies analogs, in Gerace, D.T., ed., Field Guide to the Geology of San Salvador (Third Edition): Fort Lauderdale, Florida, College Center of the Finger Lakes, Bahamian Field Station, p. 117-144.

Middleton, G.V., and Hampton, M.A., 1973, Sediment gravity flows: mechanics of flow and deposition, in Middleton, G.V. and Bouma, A.H., co-chairman, Turbidites and deep water sedimentation, Pacific Section S.E.P.M. Short Course, Los Angeles, California, May 1973.

Mutler, H.G., 1969, Field Guide to Some Carbonate Rock Environments: Florida Keys and western Bahamas, Miami Geological Society, Miami, Florida, 159p.

Newell, N.D., Imbrie, J., Purdy, E.G., and Thurber, D.L., 1959, Organism communities and bottom facies, Great Bahama Bank: American Museum of Natural History Bulletin, v. 117, article 4, New York, p. 181-226.

Pace, W., 1987a, Preliminary investigation of a platform margin lagoon-tidal flat complex, Blackwood Bay, San Salvador Island, Bahamas, in Curran, H.A., ed., Proceedings of the 3rd Symposium on the Geology of the Bahamas: Fort Lauderdale, Florida, CCFL Bahamian Field Station, p. 109-115.

Pace, W., 1987b, Sedimentology of a Holocene platform margin carbonate lagoon, San Salvador Island, Bahamas, [M.S. thesis]: Mississippi State, Mississippi, Mississippi State University, 116 p.

Pace, W., Mylroie, J., and Carew, J., 1988, Sedimentology of Holocene, platform margin carbonate lagoon, Blackwood Bay, San Salvador Island, Bahamas [abs.]: Abstracts and Programs of the Fourth Symposium on the Geology of the Bahamas, San Salvador Island, Bahamas, College Center of the Finger Lakes, Bahamian Field Station, p. 28.

Perkins and Enos, P., 1968, Hurricane Betsy in the Florida-Bahama area: Geologic effects and comparison with Hurricane Donna: Journal of Geology, v. 76, p. 710-717.

Scholl, D.W., 1963, Sedimentation in modern coastal swamps, southeastern Florida, American Association of Petroleum Geologists Bulletin, v. 47, no. 8, p. 1581-1604.

Scholle, P.A., Bebout, D.G., and Moore, C.H., eds., 1983, Carbonate Depositional Environments, published by the American Association of Petroleum Geologists, Tulsa, Oklahoma, 708 p.

Scoffin, T.P., 1987, An introduction to carbonate sediments and rocks: Blackie & Son Ltd., London, 267 p.

Sealey, N.E., 1985, Bahamian landscapes: an introduction to the geography of the Bahamas: Collin Caribbean, London, p. 69-70.

Smith, R.R., 1985, Major plant communities on San Salvador Island, the Bahamas, in Smith, R.R., ed., Proceedings of the First Symposium on the Botany of the Bahamas, College Center of the Finger Lakes, Bahamian Field Station, San Salvador, Bahamas, p. 35-51.

West, R.C., 1956, Mangrove swamps of the pacific coast of Columbia, Annals of the Association of American Geographers, volume XLVI, no. 1, p. 98-122.

Woodley, J.D., Chomesky, E.A., Clifford, P.A., Jackson, J.B.C., Kaufman, L.S., Knowlton, N., Lang, J.C., Pearson, M.P., Porter, J.W., Rooney, M.C., Rylaarsdam, K.W., Tunnicliffe, V.J., Wahle, C.M., Wulff, J.L., Curtis, A.S.G., Dallmeyer, M.D., Jupp, B.P., Koehl, M.A.R., Neigel, J., and Sides, E.M., 1981, Hurricane Allen's Impact on Jamaican Coral Reefs, Science, Vol. 214, no. 4522, p. 749-755.