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Cover photo: *Diploria strigosa*, the common brain coral, preserved in growth position at the Cockburn Town fossil coral reef site (Sangamon age) on San Salvador Island. Photo by Al Curran.

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GEOLOGY OF LITTLE SAN SALVADOR ISLAND AND WEST PLANA CAY: PRELIMINARY FINDINGS WITH IMPLICATIONS FOR BAHAMIAN ISLAND STRATIGRAPHY

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ABSTRACT

Two small islands (Little San Salvador and West Plana Cay) located along the eastern margin of the Bahamas were examined in order to determine their basic stratigraphic framework and the relationship of depositional units to Late Quaternary sea level fluctuations. Although the geology and physiography of the two islands is significantly different, both exhibit common elements in their response to platform flooding. Both islands consist of a: a core of Pleistocene-age rock (~125 ka), b: peripheral accretion terrains developed early during Holocene flooding (>5 ka), c: sea cliffs and notches developed in both the Pleistocene and early Holocene deposits during platform drowning (>2 ka), d: later Holocene terrains developed during still-stand (<2 ka), e: similiar non-marine deposits in inter-terrain sites (<1 ka) and f: exhumed beach rock and beach rock conglomerates formed in response to a possibly very recent sea level surge (~1 ka). The major difference between the two islands is that the core of LSS is a series of dune ridges which rise to 20+ m while the core of WPC consists of reef facies with a maximum elevation of +4.5 m.

The islands examined in this study may typify all or parts of most Bahamian islands as they exist today. It is suggested that all Bahamian island can be stratigraphically dissected into seperate island "blocks" composed of discrete depositional "terrains" which have distinct physiographic and time/facies relationships. Geologically and physiographically different island types may develop due to the relative importance of either dune or reef deposits and the interplay of erosion vs shoaling phenomenon.

The preliminary results presented in this study in combination with previously published island studies suggests that there are correlative deposits throughout the Bahamas related to common island response to major sea level events. Such deposits chronostratigraphically link geographically seperate islands, while clearly setting them apart in the overall stratigraphic perspective of platform development.

The carbonate islands of the Bahamas may be one of the most depositionally sensitve systems for determining the frequency, amplitude, and rate of major platform-flooding events. Although islands and their response-to-flooding hold important implications for the overall understanding of carbonate margin development, their significance in this regard remains largely unassessed.

INTRODUCTION

Little San Salvador Island (LSS) and West Plana Cay (WPC) are two small (~10 km^2) islands located along the eastern margin of the Bahamas (Fig. 1). Both islands are within 10 km of the Bahama Escarpment (due north at both sites) and are subject to a tidal range of ~1 meters. Both islands lie in the

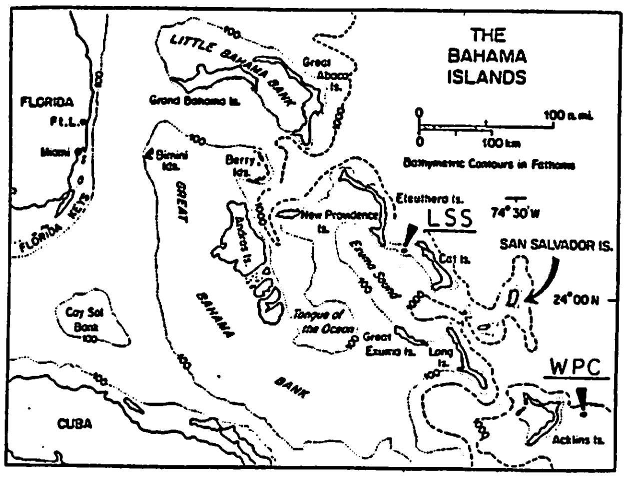


Fig. 1. Index map of the Bahamas. Little San Salvador (LSS) is 150 km northwest of San Salvador. West Plana Cay (WPC) is 170 km southeast of San Salvador.

latitudinal band of the Trade Winds (LSS at 24°00'; WPC at 22°30'N) and are thus strongly affected by the dominant east-to-west energy flux of the established wind and wave patterns as well as the frequent easterly passage of tropical low-pressure systems (Hine and Neumann, 1977; Harris, 1979; Garrett and Gould, 1984).

These two islands were examined in order to determine: a: their basic stratigraphic framework, b: the lithofacies and environments of deposition of the stratigraphic units defined, c: their history of development as related to Late Quaternary sea level fluctuations, and d: their relationship to the geology of other Bahamian islands. Both islands have been investigated through a program of aerial photo mapping, with ground-truth from field work and lab analysis of rock and sediment samples.

The purpose of this report is to a: present the preliminary findings on the geology of these two islands, b: compare these results with previously published work from San Salvador and elsewhere, and c: discuss implications derived from this study which are of general importance to the stratigraphy of Bahamian islands in general.

RESULTS

Little San Salvador

General Description. Little San Salvador is the larger and better studied of the two islands dealt with in this report. LSS is located on the westernmost extent of the Cat Island shelf between Cat Island (18 km to the east) and Eleuthera (17 km to the west) (Fig. 1). The island is ~9 km long, 2 km wide at its mid-point and is distinctly elongate with an E-W orientation (Figs. 2, 3). The northern edge of the Cat Island shelf lies 2-4 km north of LSS and roughly parallels the trend of LSS's north shore. The southern margin of the shelf (adjacent to Exuma Sound) is <500 m offshore from the entire western half of LSS (Fig. 3a). The trend of the shelf edge is SE and thus diverges from the trend of LSS's south shore. The easternmost tip of LSS lies ~5 km north of the shelf edge. In addition to the 1:10,000 stereo pairs used for mapping (Fig. 2a, b), over 100 rock and 200 sediment samples have been obtained from LSS (Fig. 3b). All have been examined in hand sample and with binocular microscope and classified as to lithofacies and sedimentary types. Fifty of the sediment samples have been sieved, weighed, and counted for compositional make-up.

Physiographically and geologically LSS is most properly viewed as three islands of similar age and related depositional history which, although physiographically separated for the most part, are peripherally "fused" at present by deposits of a very recent or modern age. Each of these island "blocks" consists of a core of old rock surrounded and partially buried by a series of progressively younger accretional terrains. The three island blocks of LSS are indicated on Figure 3b and consist of a: the western block (or "wing" of LSS) extending from North Point to West Point, b: the northern block extending from North Point to Northeast Point, and c: the southern block running from the Chute at West Bay to the easternmost extent of the lagoon.

Pleistocene Deposits. The oldest rocks present in each of these blocks comprise a series of arcuate ridges of slightly different orientation but with a strong E-W linearity (Figs. 3a, 4a). These ridges and their points of intersection are some of the highest areas of LSS. The main ridge in this group is the western block ridge which is 15-20 m high along its entire length. The ridge intersection just south of North Point also rises 15 m while the cliffs at Chute Point are 10 m high. All other sections of these ridges are <5 m, and the long easterly ridge extensions of both the northern and southern blocks are low remnant features commonly less than 3 m in height.

These ridges are clearly eolian dune features deposited when sea level was lower than today. Evidence for this includes a: the arcuate geometry of the ridges, b: height of the ridges, c: lobate spill-over features on the back side of prominant ridges (most clearly developed along the south side of the western and northern block ridges, Fig. 2), and d: the presence of high-angle, planar cross-beds dipping steeply down to present sea level. The primary dip direction of the foreset beds in the western and northern blocks is to the south while the primary foreset dip direction for southern block ridges is to the north.

Petrographically these units are all well-sorted, medium-sized, oolitic-pelletal

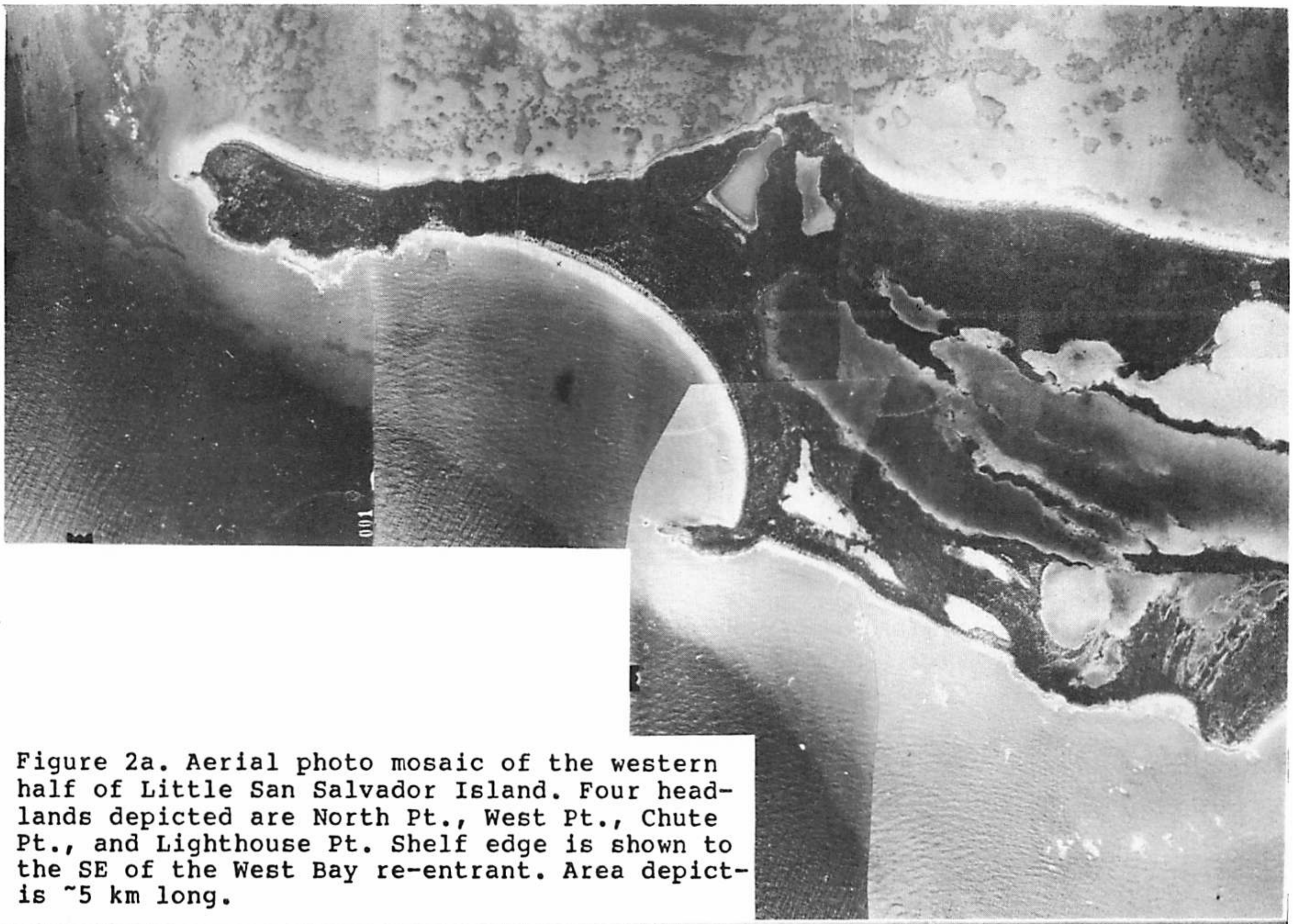


Figure 2a. Aerial photo mosaic of the western half of Little San Salvador Island. Four headlands depicted are North Pt., West Pt., Chute Pt., and Lighthouse Pt. Shelf edge is shown to the SE of the West Bay re-entrant. Area depict- is ~5 km long.

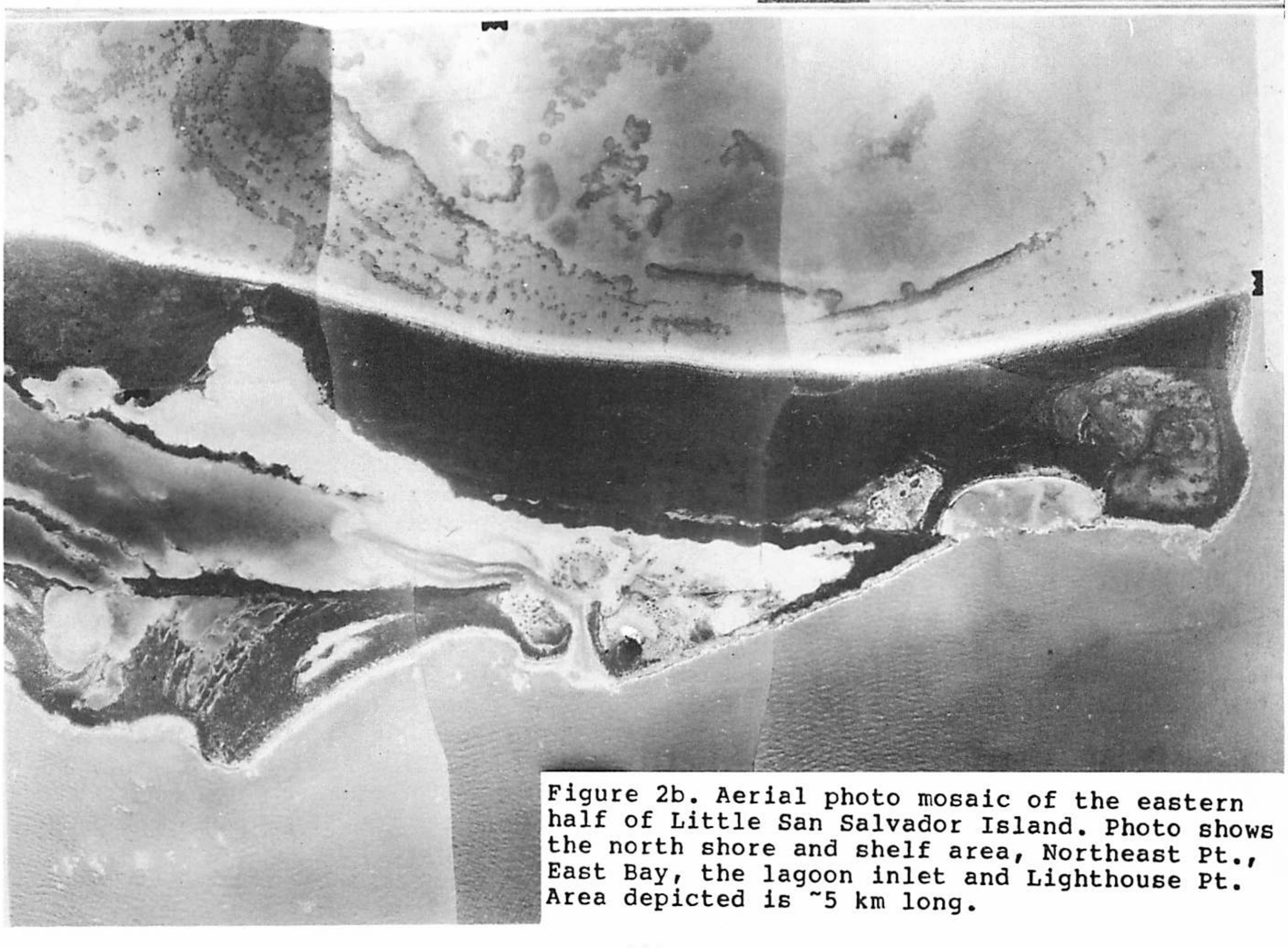


Figure 2b. Aerial photo mosaic of the eastern half of Little San Salvador Island. Photo shows the north shore and shelf area, Northeast Pt., East Bay, the lagoon inlet and Lighthouse Pt. Area depicted is ~5 km long.

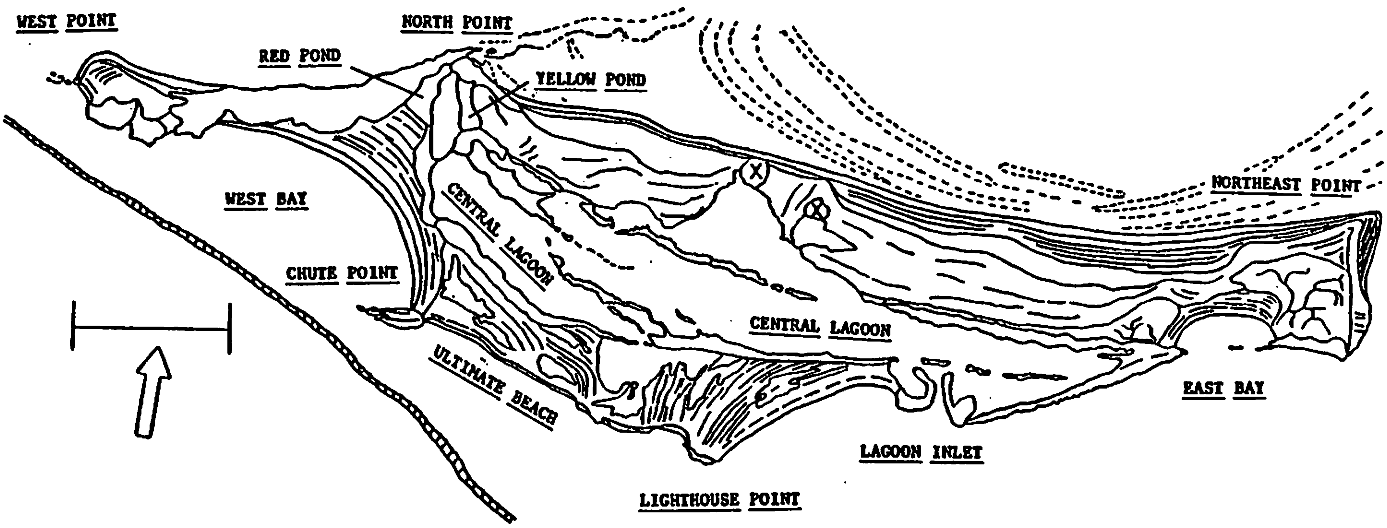


Fig. 3a. Outline sketch for geology/physiography of LSS. Lines delimit "terrains" or show arcuate trends of dune ridges. Place names are those referred to in this report. X's are highs. Bar scale is 1 km.

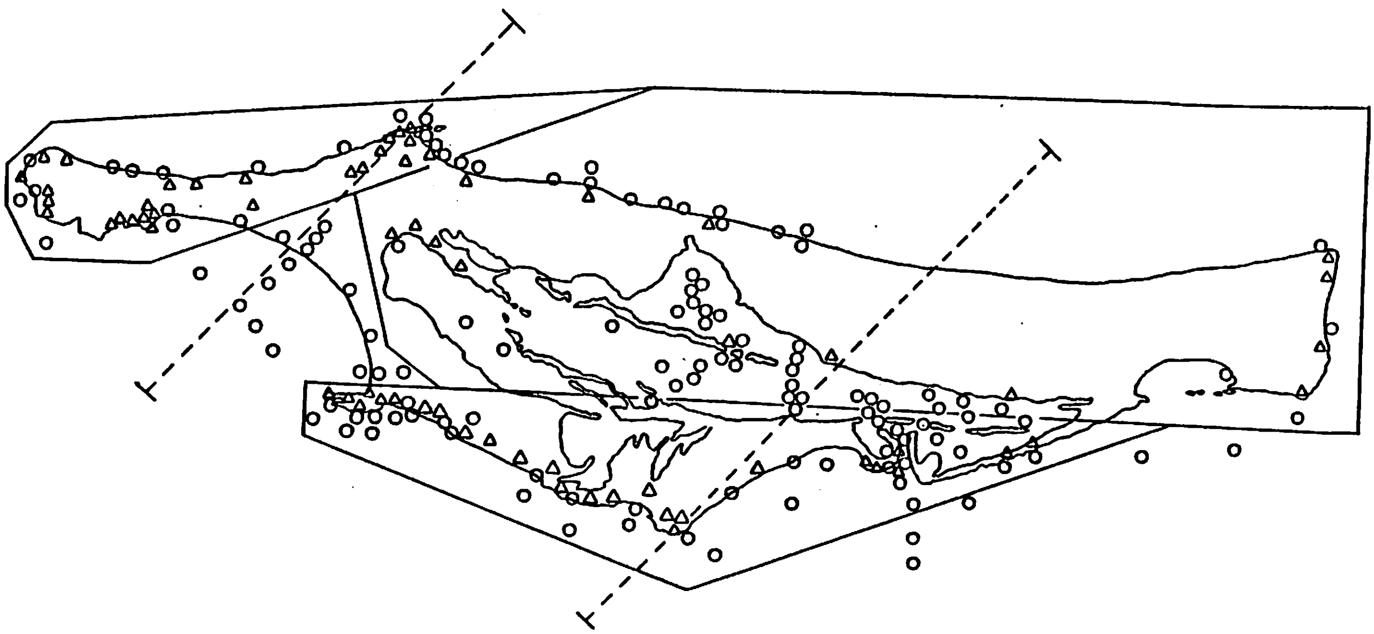


Fig. 3b. Sample sites for LSS. Circles indicate sediment samples; triangles indicate rock samples. Solid lines enclose three island blocks discussed in text. Dashed lines indicate lines of cross-section.

grainstones with relatively few skeletal components. The rocks are extremely well cemented in the upper 50 cm but may be friable and poorly consolidated below.

The upper surface of these ridges shows abundant evidence for extensive subaerial exposure. Commonly present are: a: a single, well-developed, laminated caliche horizon (2-7 cm thick) (Fig. 5d), b: a multiple caliche zone, c) dense zones of rhizoliths commonly weathered out in positive relief, d: red paleosol pockets, also weathered out in positive relief, and e: extensive karst/-dissolution features (Fig. 5b). Combinations of these features are common and, as a whole, this evidence for extended subaerial

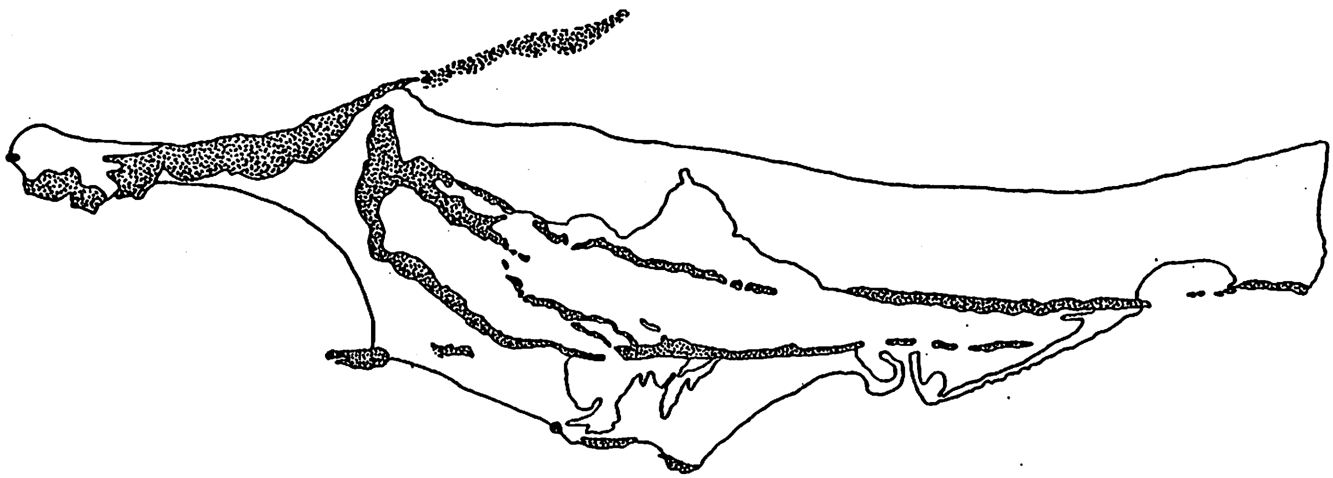


Fig. 4a. Late Pleistocene deposits on LSS. Eolian grainstones.

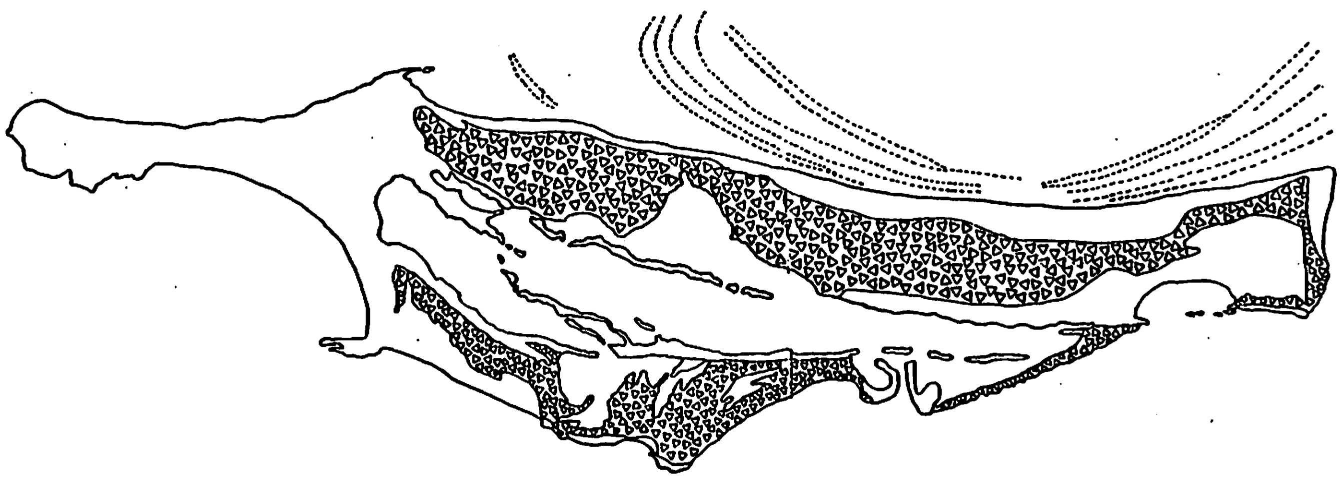


Fig. 4b. Early Holocene deposits on LSS. Eolian grainstones.

exposure is easily identified atop all the ridges mapped in Figure 4a.

The caliche horizon is easily traceable along ridge outcrops and very clearly covers the physiographic expression of these ridges as it existed prior to the calichification event. In some areas (e.g. the south side of the western block ridge), the caliche conforms to the primary deposition slope of the foresets, while in other areas (e.g. the north side of the same ridge), the caliche "drapes" over truncated dune cross-beds. Although it is not clear how much surface reduction of original topography occurred during calichification, it is apparent that there has been little erosion due to subaerial processes since its formation. The only significant erosion of caliche-covered ridges occurs in conjunction with bioeroding organisms in intertidal and supratidal exposures (Fig. 5a,c). The caliche and related features clearly distinguish these units as the oldest on the island and none of the remaining units on LSS are covered by thick crusts or paleosols. Indeed, field relationships such as onlap and partial burial of the caliche are of primary importance in establishing relative ages on LSS (Fig. 5c,d).

The eolian ridges underlain by the caliche comprise nearly 30% of the present island mass of LSS. These ridges may not all be of the same absolute age. The catenary

Fig. 5a. Chute Point cliffs. Note notch-like feature at +3-4m.

Fig. 5b. Contact between Late Pleistocene and Late Holocene units. Karst surface exposed in intertidal zone at Chute Point.

Fig. 5c. Composite headland at Lighthouse Point. Late Pleistocenea dunes in foreground are overlain by Early Holocene units behind. Height of Holocene dunes is 6 m.

Fig. 5d. Pleistocene/Holocene contact at Lighthouse Point. Caliche surface to right dips to north beneath Holocene units.

effect of the northern block ridges on the western block (near North Point) and southern ridges (in lagoon exposures) suggests that the northern block ridges are younger than either of the other two areas (Fig. 4a). Field evidence (including caliche drape, homogeneity of the lithofacies and diagenetic overprint) does not indicate a great time difference in the deposition of these features, and all may have been deposited in association with the same major sea level event. If the time of caliche formation was during the Wisconsin sea level minima (~20 ka; Mylroie and others, 1985; Carew and Mylroie, 1986), then all rocks underlying this crust are at least Late Pleistocene in age. These units were probably deposited as sea level dropped from the high stand of 125 ka and/or during the lesser flooding events indicated for ~100 ka and ~85 ka (Mesolella and others, 1969; Bloom and others, 1974; Aharon, 1983;Dodge and others, 1983; Boardman and others, 1984; Carew and others, 1984; Carew and Mylroie, 1986). Thus the core rocks of all three blocks of LSS are the age and partial facies equivalent of rocks of the Cockburn Town Member (125 ka) and/or Dixon Hill Member (85 ka) of the Grotto Beach Formation of San Salvador (Curran and White, 1985; Carew and Mylroie, 1985). The deposits on both islands are similar in style of deposition, lithofacies, as well as post-depositional alteration and preservation.

There is some evidence to indicate that some or parts of the Pleistocene ridges were deposited during the 125 ka sea level rise or indeed pre-date this event. Poorly defined features which may be elevated sea level notches are found along the south side of the western block ridge and at Chute Point (Fig. 5a). Interpretation and tracing of such potential paleo-sea level notches is obscured by the extensive Holocene erosion and cliff-formation discussed below. However, this evidence is consistent with the geometric relationships of the ridges and, as such, the western and southern ridges may be French Bay Member equivalents (Carew and Mylroie, 1985). The lack of subtidal facies preserved in the Pleistocene rocks on LSS makes this distinction particularly difficult. The absence of a subtidal record in combination with the aforementioned dune characteristics does suggest a: retreat-phase deposition from the 125 ka high, or b: flood/retreat phase deposition in association with the "lower" highs of ~100 ka and ~85 ka for the time of deposition of these ridges.

Early Holocene Deposits. The next oldest units on LSS comprise nearly 50% of the total island mass and >80% of both the northern and southern blocks (Fig. 4b). Deposits of this age are not clearly present in the western block of LSS where it is likely they have been removed through erosion. The deposits are present as distinctive arcuate dune ridges as well as more homogenous dune fields which have clearly accreted through catenary extension between and progradation seaward of anchor points of late Pleistocene rock. The dunes are generally low ridges, less than 10 m in height in the southern block, but elevations of 15 m in the hummocky terrain of the northern block are common. The highest points on LSS (two round hills along the north shore; Fig. 3a) are both capped by deposits of this age and rise up to 30 m.

These rocks are remarkably homogenous in their lithofacies. All are well-sorted, medium, eolian grainstones, the dominant constituents of which are ooids and pellets. Incipient subaerial discontinuity features (of the paraconformity type described by Longman and others, 1985) are present on the upper surface of these rocks, but no well-developed caliche or soil zones are present. These units may be very well cemented in the upper 10-30 cm but are extremely friable below this level. As with all units on LSS, regardless of age, nearshore exposures are always the most well-cemented due to intergranular precipitation of (and surficial glazing by) aragonite cements in the intertidal and spray zones.

Deposits of this age are in clear contact (overlying the caliche) with the late Pleistocene units in numerous exposures in both the northern and southern blocks (e.g. North Point, Lighthouse Point, Fig. 5d). It is likely that these units have buried low-lying Pleistocene ridges, particularly in the northern block where the central high mounds are probably composite build-ups.

As with the Pleistocene-age rocks, the dunes of these terrains were clearly deposited while sea level was lower than present. Where these units are exposed along the shore they dip below even the lowest tide level. As with the older dune ridges around which these have grown, the primary dip direction for the northern block is to the south whereas primary dip direction for the southern block is to the north. In some exposures in the southern block (south shore near East Bay) and along the eastern shore, north dipping units are overlain by south dipping beds capped by a paraconformity. This relationship indicates dominant dune migration from the north and/or a slightly younger age for the northern block dunes. Cliffed exposures of these deposits elsewhere show both single massive dune building (North Point) as well as multiple dune building events separated by paraconformities (Lighthouse Point, Fig. 5c).

In consideration of style of deposition, lithofacies, degree of cementation, and diagenesis, as well as their relationship to demonstrably Pleistocene-age rocks, these units are assigned an early Holocene age. They were apparently deposited rapidly following the flooding of the Cat Island Shelf. Over 95% of the Cat Island Shelf was flooded by ~5 ka while sea level was still 6 meters below present (Dominguez and others, 1986). Sediment production at this time (almost entirely to the east of LSS) apparently fed the accretional terrains of both the northern and southern blocks. The geomorphology of ridges in these terrains suggests east-to-west sediment transport which "wrapped around" and prograded seaward of the pre-existing Pleistocene highs. As sea level continued to rise to its present near-stationary level ~2 ka (Donn, 1986; Donn and Boardman, in prep), these deposits were severely eroded along all seaward exposures. These units are the age (and lithofacies) equivalent of the North Point Member of the Rice Bay Formation on San Salvador Island (White and Curran, 1985; Carew and Mylroie, 1985).

A series of very clearly defined arcuate outcrops present in the shallow subtidal area to the north of LSS (Figs. 2b, 4b) may be the same age or slightly younger than the subparallel ridges of this terrain in the northern block. It is also possible that the offshore ridges are Pleistocene in age. These ridges, which have been progressively flooded as sea level rose, now serve as the substrate for *Neogoniolithon* and scleractinian coral patch reefs which are the major sediment source for the north shore beaches.

Late Holocene Near-Shore Deposits. Accretional around both the late Pleistocene and early Holocene units are a number of later Holocene terrains which have both added material to the separate island blocks and linked these blocks into one contiguous island mass (Fig. 6a). These are all beach/-dune deposits which have developed in equilibrium with the present sea level. They have been deposited during the last 2-3,000 years (Donn, 1986; Donn and Boardman, in prep) and are the age equivalent of the Hanna Bay Member of the Rice Bay Formation on San Salvador (Carew and Mylroie, 1985).

Prior to the deposition of these terrains, nearly 100% of LSS's open shore was a rocky, erosional coast (Fig. 6a). Bioeroded notches at or very near present sea level are found at the contact between all older rocks and the late Holocene terrains. The entire southern side of the late Pleistocene ridge of the western block is a partially buried, bioeroded surface which is traceable along the western shore of Red Pond and out to North Point A similar bioeroded surface (and notch) is present along the eastern shore of Red Pond. This clearly shows that Red Pond (currently a hypersaline pond which receives marine water through periodic storm flooding from the north) was as recently as 1 ka an open marine embayment subsequently closed by sediment moving into West Bay from the west. Prior to this the entire western block or "wing" of LSS was separated from the northern block by a narrow strait at North Pt. Similarly the contact between the early Holocene dune fields of the northern block and the late Holocene beach/dune terrain fronting them (Fig. 6a) is also a bioeroded zone the base of which is at present sea level.

The relatively rapid shift from an actively eroding, cliffed island to the present situation where over 60% of the shore is sandy beach is probably most directly attributable to the change in the rate of rise of sea level, and its near stationary position over the past 2000 years. The one stretch of shoreline along LSS which has been erosional throughout the Holocene sea level rise is the north shore of the western block. Here a well-developed bioeroded terrace of similar size, slope, and position to the one investigated by Donn (1986) on Andros supports the idea that local sea level in the central Bahamas has been stationary over the past 2-3,000 years. Most of the accretional

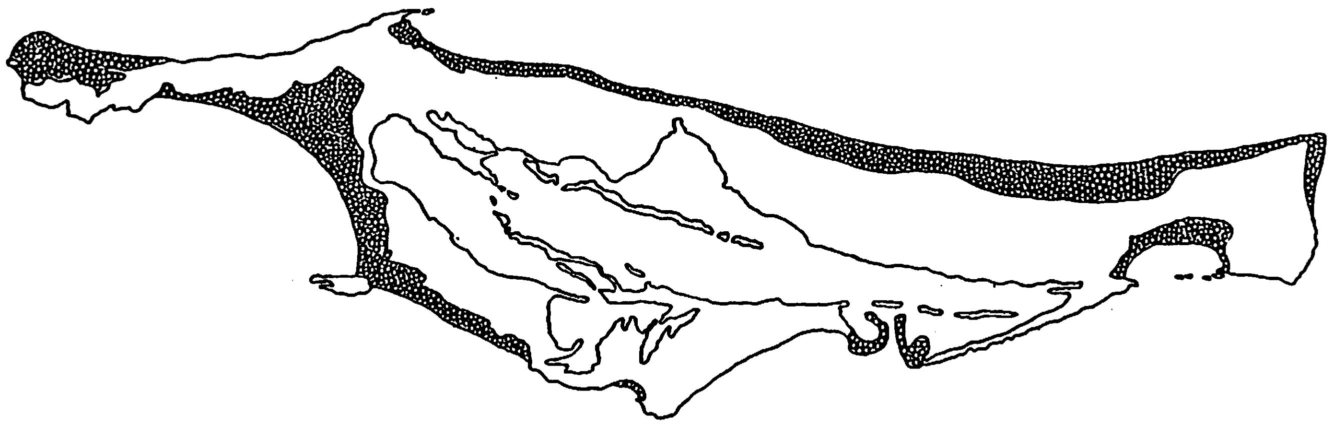


Fig. 6a. Late Holocene deposits on LSS. Eolian grainstones and beachrock.

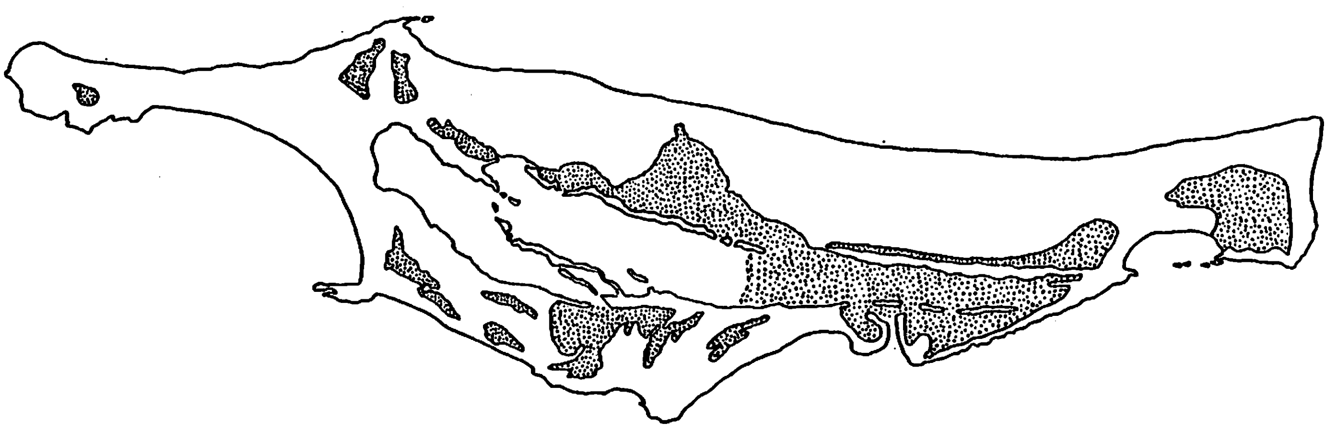


Fig. 6b. Late Holocene deposits on LSS. Hypersaline and fresh-water pond deposits and flood tidal sequences.

activity of this time has taken place along the northern shore and in the West Bay re-entrant, where all three separate island blocks have been joined in the very recent past.

The sediment and rocks involved in this most recent deposition indicate that both nearshore reworking of sediment from eroding headlands (Pleistocene and, more importantly, early Holocene in age) as well as the input of fresh skeletal material from shelf patch reefs have been important in island-building. Sedimentary facies of the near-shore and shelf environments adjacent to LSS have yet to be finally determined, but it is clear based on the samples examined to date that: a: deposits of this age are the first on LSS with a clear skeletal signature, b: the skeletal sands are found along the northern shore beach, all around the western end of the island, and throughout the West Bay re-entrant, and c: the relatively minor deposits along the south shore (i.e. Ultimate Beach, inlet beaches, and East Bay) are <u>not</u> skeletal but rather are dominated by reworked oolitic/pelletal material from pre-existing units. This implies that a: the very rapid outbuilding of the West Bay terrain has been the result of the delivery of skeletal sands from the north shelf which have "hooked" around the west end of the island and b: Chute Point at the eastern side of West Bay is a major sedimentary transport barrier. "Hook-back" sedimentation for the filling of West Bay is certainly indicated by both the geomorphology of the deposits and the nature of the sediment. The actual dynamics of such a process are not well understood but may be related to wave refraction around West Point. The expected east-to-west transport of sediment along the southern coast is apparently delivering oolitic-pelletal sediments across the narrow shelf south of Chute Point to the Exuma Sound slope (Crevello and Schlager, 1980). Because of the proximity of the shelf-edge and the prominence of Chute Point few of these sediments are delivered to West Bay.

The skeletal sand beaches of the north shore and West Bay appear to be actively prograding at present. *Neogoniolithon* patch reefs in the surf zone of the north shore, which are partially buried by beach deposits, provide a modern analog for the Grotto Beach reef of San Salvador (Carew and Mylroie, 1985; Warren and others, 1986). The non-skeletal beaches of the south shore (Ultimate Beach, Inlet beaches) are all characterized by exhumed beach rock and beach rock conglomerate. Over 50% of the south shore beaches are presently "armored" by such deposits. These may be the result of a very recent (<100 years) surge in the rise of sea level. Global tide gauge data indicate such a surge over the past 40 years (Emery and Aubrey, in press; Braatz and Aubrey, in press), and the exhumed beach rocks and beach rock conglomerates of LSS and numerous other Bahamian islands (Bain, 1985; Strasser and Davaud, 1986) may be the first depositional evidence of this rise.

Late Holocene Inter-terrain Deposits. The remaining deposits on LSS are also of a late Holocene age and these consist of low-lying fill-in deposits which are found peripheral to and between the previously described terrains. These deposits are outlined in Figure 6b and include: a: hypersaline pond deposits such as Red Pond and Yellow Pond, b: very recently exposed and sparsely vegetated flood tidal deposits (two areas in the eastern part of northern block), c: currently active flood tidal deposits of the central lagoon, and d: minor fresh-water pond deposits (most frequently present between dune ridges within a specific terrain).

Of these, the flood tidal deposits of the lagoon inlet are the most extensive. These deposits are highly burrowed, pelletal and oolitic muddy sands, the origin of which remains somewhat problematic. The primary burrowers of the extensive tidal flats are crustaceans (*Callianassa*) but the pellets are hard, elongate and of molluscan origin. There does not now appear to be enough molluscs present in the lagoon to account for the pellets, although *Batillaria* is found peripheral to the main delta deposits.

It is possible that at least some of the sediment deposited in the delta has come from the erosion of younger oolitic-pelletal units along the south shore of LSS. Such units are actively eroding in friable cliff exposures both to the west and east of the inlet. Currents up to 3 knots have been measured in this inlet, and there is no ebb tidal delta present at the site. The nature of the sediments as well as the geometry of the deposits suggests that the inlet is a significant local "sink" for sediments involved in long-shore transport along the south shore. The entire tidal flat area (nearly 50% of the eastern lagoon is exposed during spring low tides) is the age and facies equivalent of the Pigeon Creek flood tidal delta on San Salvador Island (Teeter, 1985a; Teeter and Thalman, 1984).

The hypersaline deposits of Red Pond are the age and facies equivalent of Granny Lake on San Salvador (Teeter and Thalman, 1984; Teeter, 1985b).

Proposed Developmental Sequence For Little San Salvador. Two representative cross-sections of LSS are presented in Figure 7. These sections visually summarize the sequence of development outlined in Table 1. This sequence is proposed for the geochronologic development of LSS based on the samples obtained and analysis completed to date.

West Plana Cay

General Description. West Plana Cay is located in the southeastern Bahamas between Acklins Island (20 km to the west) and Mayaguana (36 km to the east, Fig. 1). WPC occupies ~50% of a small, pedestal-like platform along an E-W trend of the Bahama Escarpment. Both WPC and its platform are somewhat elongate in a N-S direction with WPC measuring approximately 6 km x 2 km

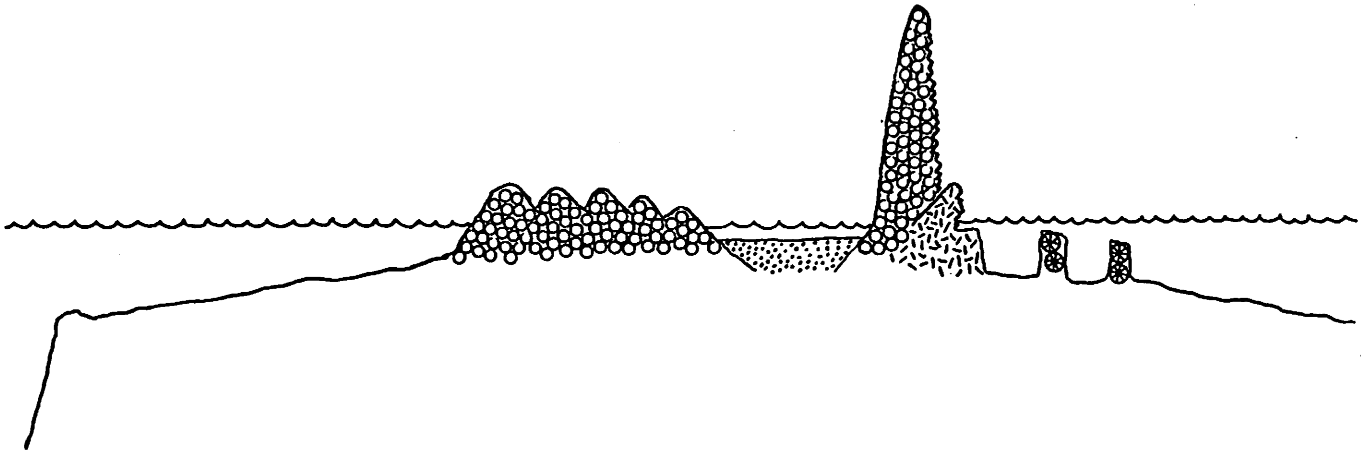


Fig. 7a. Cross section of Little San Salvador Island from West Bay (left) to North Point. Vertical exaggeration = 40X.

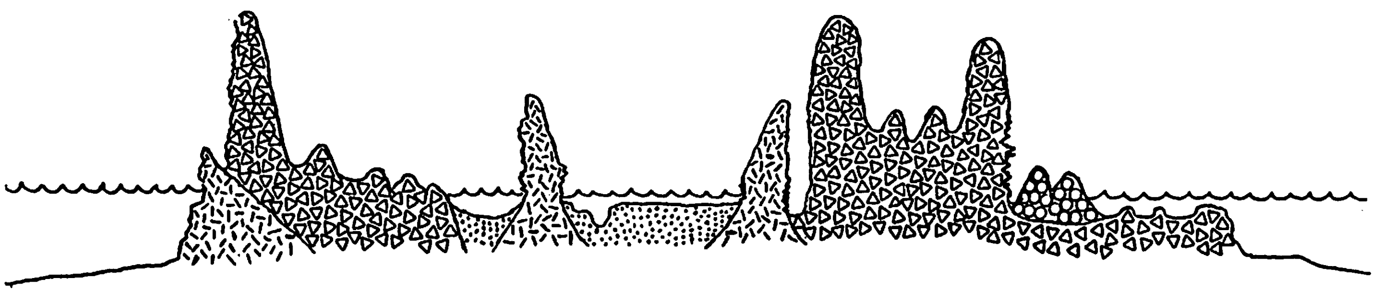


Fig. 7b. Cross section of Little San Salvador from Lighthouse Point (left) to North Beach. Vertical exaggeration = 40X.

(Figs. 8, 9). WPC's neighboring island, East Plana Cay, also covers ~50% of an elongate pedestal. In contrast to WPC, East Plana and its platform are elongate E-W and closely parallel the trend of the escarpment. The islands are separated by 5 km of open water and the two pedestals are separated by a narrow channel which is approximately 500 m wide and 200 m deep. The two pedestals and islands are separate depositional system because of this deep channel.

In addition to the 1:10,000 stereo pair photographs used for mapping (Fig. 8), 40 rock and 35 sediment samples have been obtained from WPC (Fig. 9b). All have been examined in hand sample and with binocular microscope and classified as to lithofacies and sediment type.

Physiographically and geologically WPC is most properly viewed as a single island block consisting of a core of old rock surrounded by a series of progressively younger terrains which have added peripherally to the island mass (Fig. 9a).

Pleistocene Deposits. The oldest rocks on WPC are those exposed throughout the island's flat, elevated interior and peripheral to this terrace. The terrace itself is the most notable physiographic and geologic feature of this island, and the deposits of the terrace make up >50% of the island mass (Fig. 10a). All rocks obtained from this area consist of *in situ* scleractinian coral boundstones and related coral rubble facies (coral rich rudstones, floatstones, and packstones). Common corals include *Diploria*, *Montastrea*, *Acropora*, *Porites*, and *Siderastrea*. These rocks are well exposed along The Bluff and at North Point, the Palisades, and Veranda Terrace (Fig. 9b). The height of the interior terrace as measured at The Bluff is ~4.5 meters above present sea level. The terrace is essentially flat or gently sloping to the east over much of the island interior and is marked by numerous solution holes and an extremely pitted upper surface. All rocks examined from this terrace are very well lithified and highly altered diagenetically. Moldic porosity (most noticeably dissolution of molluscan skeletal fragments) and extensive replacement of corals is common. A caliche horizon and related paleosol indi-

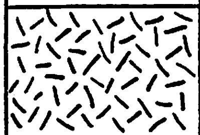
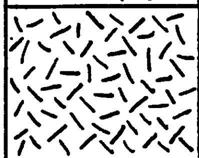
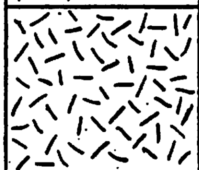
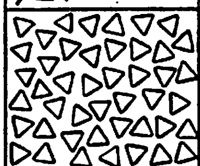
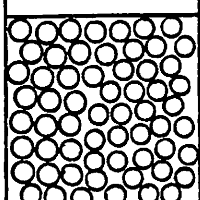
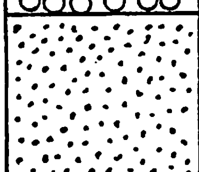
	SEA LEVEL / TIME	PROCESS	DEPOSITS	SAN SALVADOR EQUIVALENT
	RISE or FALL >125 KA	DUNE BUILDING	WEST BLOCK(?) SOUTH BLOCK(?) FIGURE 4A	FRENCH BAY
	FALL <125 KA	DUNE BUILDING	WEST BLOCK(*) SOUTH BLOCK(*) FIGURE 4A	COCKBURN TOWN (DUNE FACIES)
	RISE or FALL ~100 KA ~85 KA	DUNE BUILDING	WEST BLOCK(?) SOUTH BLOCK(?) NORTH BLOCK(*) FIGURE 4A	DIXON HILL
	RISE >5 KA	DUNE BUILDING	NORTH BLOCK SOUTH BLOCK FIGURE 4B	NORTH POINT
	RISE >2 KA	INTERTIDAL BIOEROSION	ALL PRE-EXIST-ING UNITS	NUMEROUS SITES
	STILL STAND <2 KA	BEACH/DUNE ACCRETION	NORTH SHORE WEST POINT WEST BAY EAST BAY FIGURE 6A	HANNA BAY
	STILL STAND <1 KA	FLOOD TIDAL DEPOSITION HYPERSALINE DEPOSITION	LAGOON RED POND YELLOW POND FIGURE 6B	PIGEON CREEK GRANNY LAKE
	RISE(?) <.1 KA	BEACH ROCK EXPOSURE & BRX CONGLOM-ERATE FORM.	ULTIMATE BCH. INLET BEACH NW POINT	NUMEROUS SITES

Table 1. Proposed geochronologic development of Little San Salvador Island. Symbols for different island terrains in left column are those used in Figures 4-7. San Salvador Island stratigraphic equivalents are indicated in the right column.

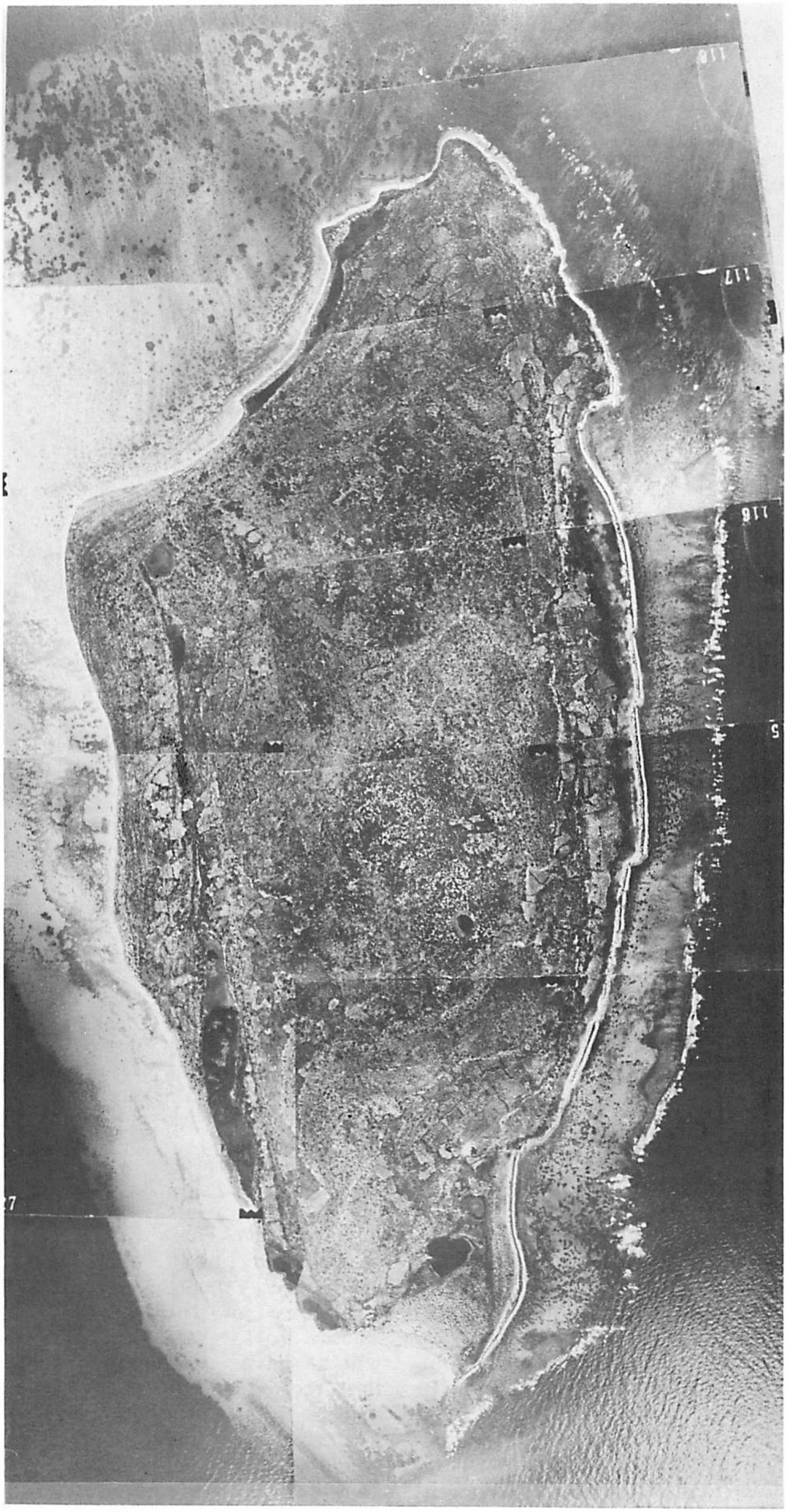


Fig. 8. Aerial photo mosaic of West Plana Cay.

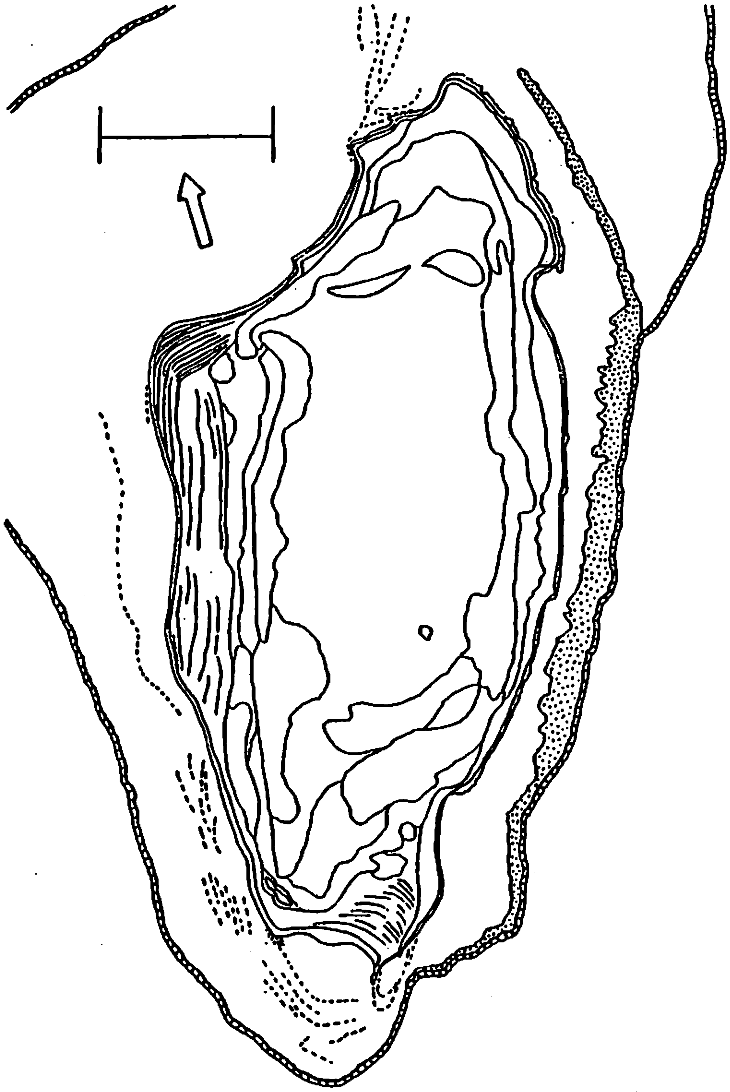


Fig. 9a. Outline sketch for geology/-physiography of WPC. Lines delimit "terrains" or show arcuate trends of dune ridges. Shelf edge is double hachured lines. Present windward reef track is stippled. Bar scale is 1 km.

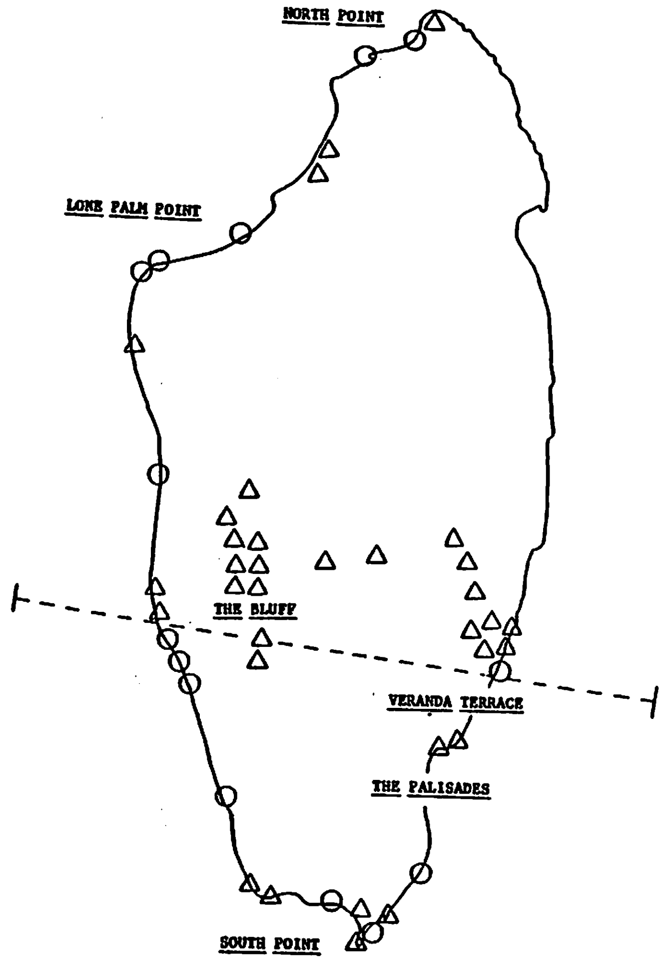


Fig. 9b. Sample sites for WPC. Circles indicate sediment samples; triangles indicate rock samples. Dashed line indicates line of cross-section.

cators are present in places atop this terrace, but these are relatively patchy features.

Near to the seaward edge of this terrace are found rocks of different lithofacies which are related to both the geometry and age of the reef terrace. The highest deposits on WPC occur along the eastern edge of the terrace and form a linear ridge which extends along ~60% of WPC's windward shore (Fig. 10b). Maximum height of this ridge is 10-12 m. A similar, slightly lower ridge is found along the western edge of the reef terrace. The rocks of these ridges (sampled at eastern site) are well-sorted, medium grainstones lacking noticeable sedimentary structures or obvious skeletal components. These rocks are apparently dune ridges which have developed in conjunction with the reef terrace. The contact between the reef flat and the dune ridge is (along the western side of the eastern ridge) an erosional sealevel feature indicating that dune-building pre-dated the sea level high stand which deposited the reef.

Adjacent to the dune ridges and occupy

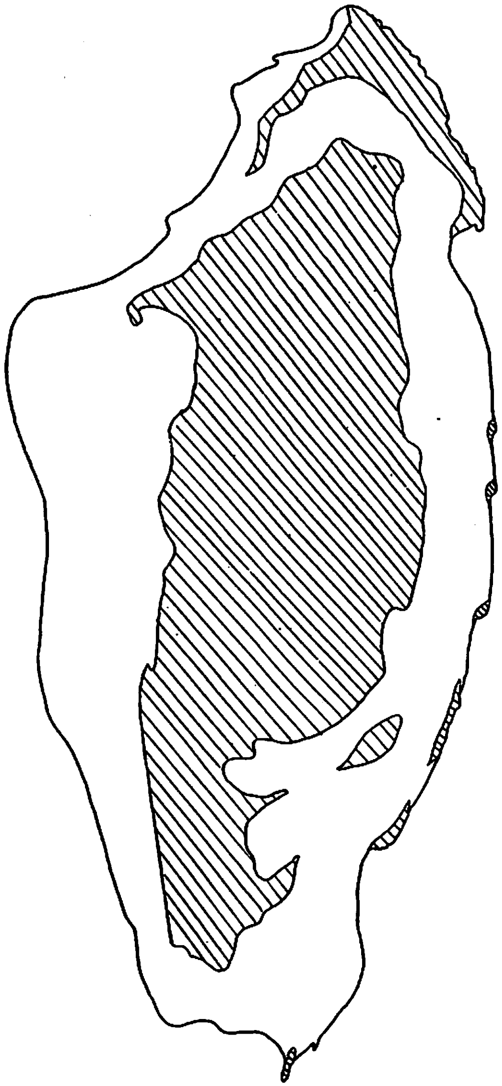


Fig. 10a. Late Pleistocene deposits on WPC. Coral reef terrace and related rubble deposits.

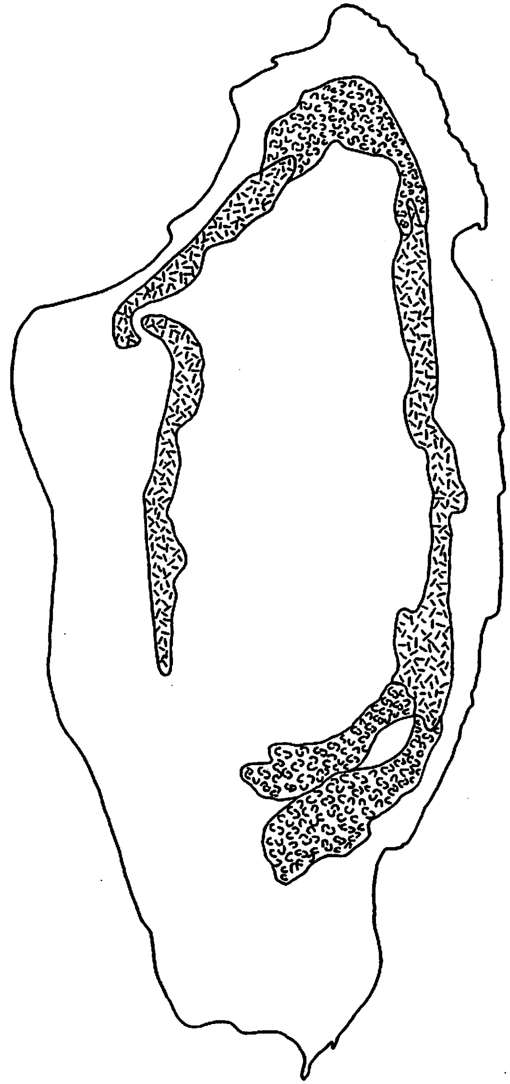


Fig. 10b. Late Pelistocene deposits on WPC. Eolian grainstones and subtidal grainstones.

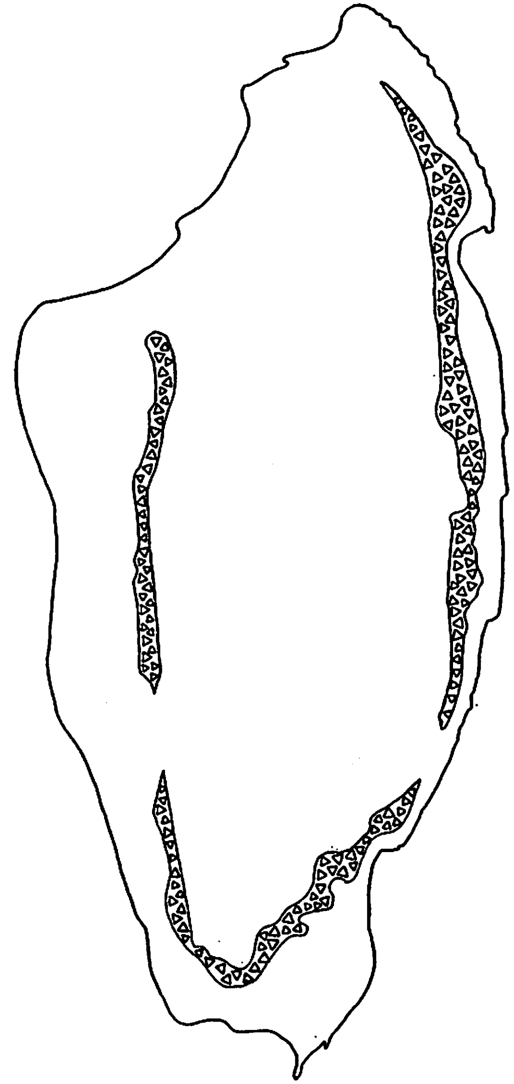


Fig. 10c. Early Holocene (?) deposits on WPC. Eolian and/or storm rubble deposits.

ing relatively lower areas of WPC are lobate deposits of coarse skeletal grainstones (Fig. 10b). These are distinctly subtidal facies which appear to extend from the ends of the dune ridges and overlie the reef deposits (Fig. 10b). Together these three rock units make up nearly 70% of WPC.

Based primarily on the height of the terrace and the nature of the terrace deposits, these units are considered to have been deposited during the sea level rise and still stand of 125 ka. Of all possible flooding events of Pleistocene age the 125 ka transgression is the only one which is consistently indicated to have been high enough to account for the elevated reef deposits of WPC (Mesolella and others, 1969; Shackleton and Opdyke, 1973; Bloom and others, 1974; Neumann and Moore, 1975; Thierstein and others, 1977; Szabo and others, 1978,; Matthews and Poore, 1980; Aharon, 1983; Harmon and others, 1983). These rocks are the age and environmental equivalent of the Cockburn Town Member (reef facies) of the Grotto Beach Formation of San Salvador (Curran and White, 1985; Carew and Mylroie, 1985).

The dune ridge deposits along the east and west sides of the terrace apparently existed prior to final reef deposition. Two possibilities for their development are that: a: the ridges are older features deposited in conjunction with sea level events which pre-date the 125 ka rise or b: the dunes developed during the same sea level rise and still-stand which deposited the reef rock. Of these, the latter situation is more likely. Although the contact between these two facies is an erosional (sea level) scarp, other field evidence does not indicate a long period of exposure between the deposition of dune and reef. The dune ridges were probably deposited as the reef developed and were eroded to present form at the sea level maxima.

The subtidal shoal deposits are also most probably contemporaneous with the reef and eroding dunes. The geometry and physiographic relationships of these three facies suggests that subtidal shoals extended from eroding dune lines and buried lowlying sections of the reef terrace during maximum trangression (Figs. 10a,b).

Although these time-facies relationships certainly require further investigation and possible revision, the basic facies, physiography, and geometric relationships of the Pleistocene-age rocks on WPC are distinct.

Holocene Deposits. The seaward edge of outcrops of Pleistocene-age rocks on WPC are all either presently exposed and being eroded in the intertidal zone or have been in the very recent past. This pattern of Holocene erosion is similiar in extent to that described for LSS, and the erosion of WPC during the Holocene has produced remarkably linear contacts between Pleistocene rocks and all younger units (Figs. 10c, 11). This effect is most noticeable along The Bluff which extends over 3 km in a nearly perfect N-S line along the western edge of the reef terrace (Figs. 10c, 11). The Bluff is clearly a bioeroded feature, the base of which has been measured at or very close to present sea level. A narrow seaward sloping terrace to the west of The Bluff (eroded into reef rock) has a remnant covering of beachrock blocks (Fig. 11c). These blocks are clearly Holocene in age (unaltered skeletal material, fibrous aragonite cement) and this contact has been critical in establishing relative ages on WPC.

The deposits mapped in Figure 10c form a physiographically distinctive terrain seaward of the cliff which marks the Pleistocene outcrop. These deposits have only been examined in two locales and neither age nor facies are well-established. Their position seaward of the erosional contact with Pleistocene rocks indicates that they are Holocene in age but pre-date younger Holocene deposits found seaward of these units. Field examination shows that they are supratidal dune and storm rubble facies which were deposited against the eroding reef terrace as sea level rose. For purposes of this report they are considered the approximate age equivalent of the North Point Member of the Rice Bay Formation on San Salvador (Carew and Mylroie, 1985).

Seaward of these deposits on all sides of the island lie later Holocene units which have been deposited in equilibium with present sea level (Fig. 11a). These are both dune and storm rubble deposits along the eastern (windward) side of the island and multiple beach/dune ridges along the western side of the island and at the southern tip. The aforementioned remnant beachrock found at the base of The Bluff is apparently some of the oldest of this material. Island-building during this latest depositional period (<2 ka;

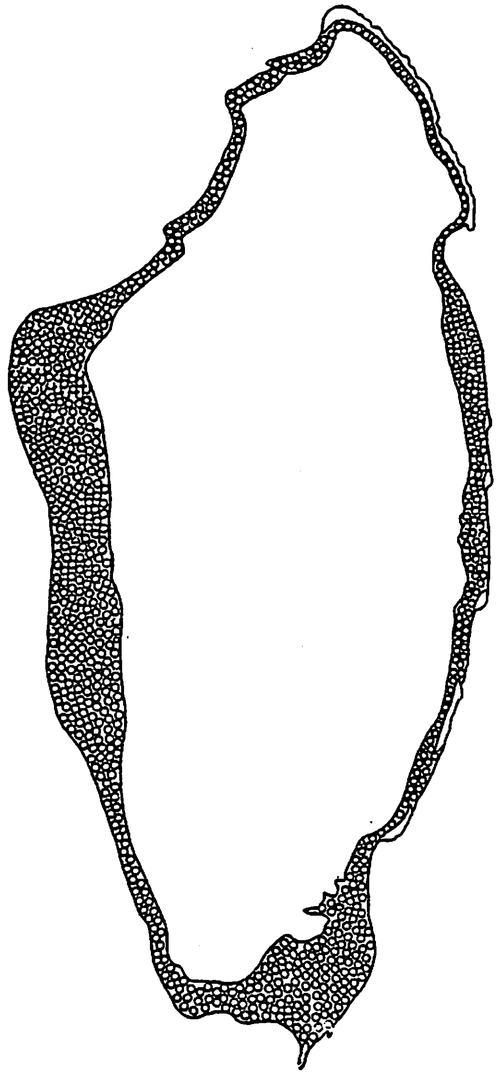


Fig. 11a. Late Holocene deposits on WPC. Eolian grainstones and beach rock.

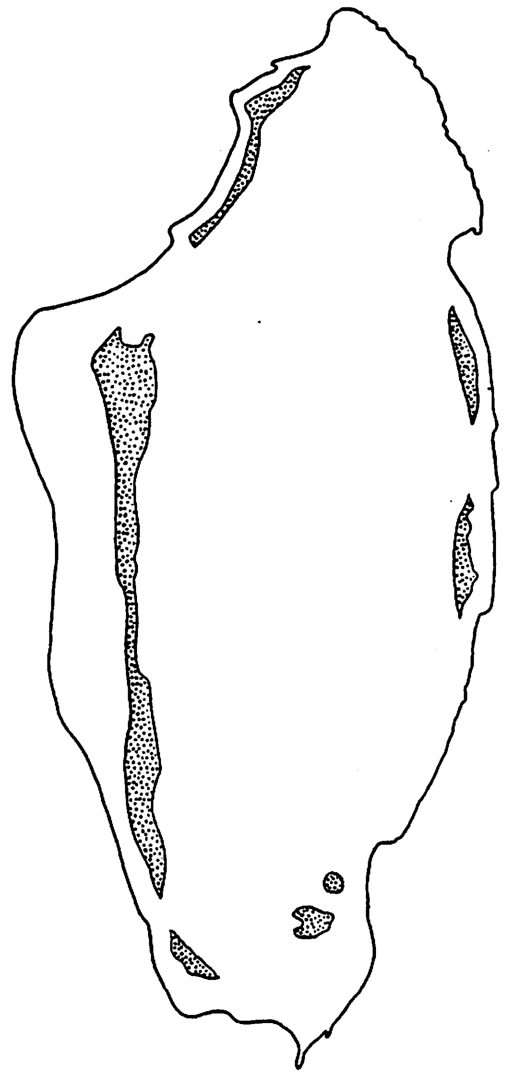


Fig. 11b. Late Holocene deposits on WPC. Hypersaline and fresh-water pond deposits.

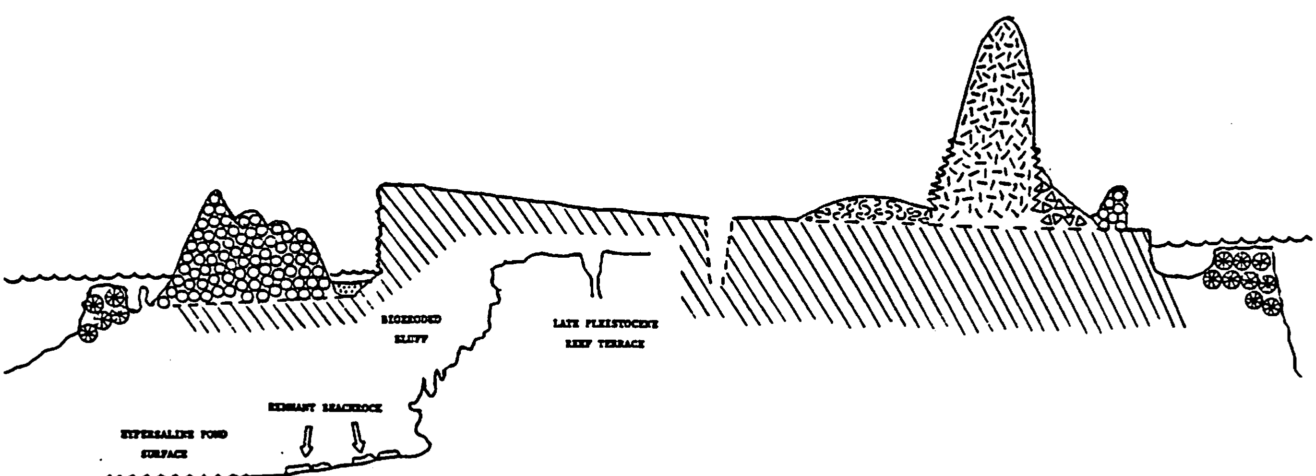


Fig. 11c. Cross section of West Plana Cay from west shelf (left) to windward reef. Insect shows detail of facies relationships at base of Bluff. Vertical exaggeration = 40X.

Hanna Bay equivalent) has been most extensive along the western side of the island where up to 3/4 km of material has been added to the island very rapidly. At present nearly 70% of this "sandy" coastline consists of multiple beachrock exposures and beachrock conglomerates such as those found along the south shore beaches of LSS.

In contrast to LSS, the near shore sediments of WPC comprise a single sedimentary facies and are composed almost entirely of fresh coral-algal-molluscan sands produced on the eastern reef and/or in the patch reef province on the northwest shelf (Fig. 8).

As on LSS, low-lying inter-terrain areas between the late Holocene nearshore deposits and all younger units are occupied by a variety of non-marine deposits. These include both hypersaline and fresh-water pond deposits. Most notable are the series of ponds which occur seaward of The Bluff. These ponds, which run from the SW shore to Lone Palm Point, vary in salinity from <2 °/oo to >80 °/oo.

Proposed Developmental Sequence For West Plana Cay. A cross section of the central portion of WPC is presented in Figure 11c. This section visually summarizes the sequence of development outlined in Table 2. This sequence is proposed for the geochronologic development of WPC based on the samples obtained and the analysis completed to date.

DISCUSSION

In considering the overall stratigraphy and geochronologic development of the Bahama platforms during Quaternary time, a number of factors are of major importance. These include: a: a relatively slow and constant regional subsidence rate of 1-3 m/10^5 yrs., b: glacio-eustatic sea-level fluctuations with a strong 10^5 year periodicity and a less-pronounced 10^4 year signal, c: the rapid sedimentary response of the bank-top environments to flooding by marine waters, and d: the sheet and lenticular geometry of most bank-top deposits.

The first-order conceptual model of Quaternary stratigraphy in the Bahamas is one of multiple, vertically stacked, sheet and lens-shaped deposits of subtidal origin. These units are commonly 1-5 m thick and are chronostratigraphically defined (sequences) with subaerial discontinuities as both lower and upper bounding surfaces. Such sequences vary laterally in lithofacies from coarse skeletal and/or oolitic grainstones along the margins to finergrained wackestones and packstones in the platform interiors. Vertical intrasequence facies succession commonly indicates shoaling conditions near the upper bounding surface. These units are deposited rapidly during flooding events generated by the 10^5 year pulse of sea level and commonly attain depositional equilibrium with the physical conditions existing at sea level maxima. The bounding surfaces for these sequences are developed during subaerial exposure at sea level minima most notably the 10^5 year lows.

Such a model is derived from and supported by high-resolution seismic studies and drill data from a number of areas on the northern Bahamas platforms as well as the sediment distribution patterns as they exist today (Newell and others, 1959; Purdy, 1963; Supko, 1970; Enos, 1974; Neumann and Moore, 1975; Boardman, 1976; Hine and Neumann, 1977; Palmer, 1979; Locker, 1980; Beach and Ginsburg, 1980; Wilber, 1981; Hine and others, 1981; Pierson, 1982; Wilber and others, 1985; Williams, 1985; Wilber and others, 1986; Rasmussen and Neumann, in press). This model remains to be tested by a comprehensive drilling program, but the basic outline of vertically stacked, laterally extensive subtidal deposits is essentially confirmed by the data presented to date.

Of the depositional environments present on the bank tops, the interior lagoons are the most areally extensive, and the deposits of these environments are not only monotonous in lithofacies but conform most closely to the first-order model. During total flooding of a major platform, lagoonal facies may comprise over 90% of the bank top deposits. Thickness to width to length ratios (Z:X:Y) for such deposits may be $1:10^5:10^5$.

Of the other platform depositional environments, only two exhibit truely anomolous characteristics in terms of depositional geometry and rate of deposition. These are a: the subtidal reef framework and b: the eolian dune environments. Both of these environments are able to rapidly deposit lithologically distinct units which may be an order of magnitude or more thicker than the adjacent subtidal sheet deposits. This increase in the Z depositional dimension is effected by these environments

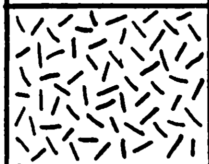
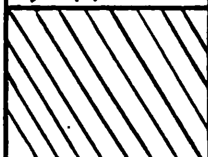
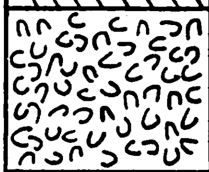
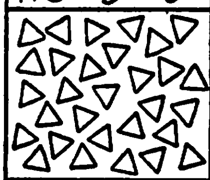
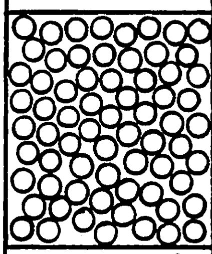
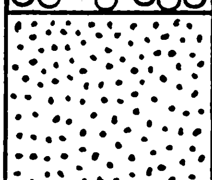
	SEA LEVEL/ TIME	PROCESS	DEPOSITS	SAN SALVADOR EQUIVALENT
	RISE >125 KA	DUNE BUILDING	LINEAR RIDGES EAST, WEST FIGURE 10B	FRENCH BAY
	STILL STAND 125 KA	REEF BUILDING	INTERIOR REEF TERRACE FIGURE 10A	COCKBURN TOWN (REEF FACIES)
	STILL STAND 125 KA	SHOAL DEPOSITION & DUNE EROSION	ARCUATE SHOALS FIGURE 10B	COCKBURN TOWN (SHOAL FACIES)
	RISE 5 KA(?)	DUNE BUILDING STORM DEPOSITION	PERIPHERAL TO PLEISTOCENE FIGURE 10C	NORTH POINT(?)
	RISE >2 KA	INTERTIDAL BIOEROSION	ALL PRE-EXISTING DEPOSITS	NUMEROUS SITES
	STILL STAND <2 KA	BEACH/DUNE ACCRETION STORM DEPOSITION	WEST SHORE SOUTH SHORE EAST SHORE FIGURE 11A	HANNA BAY
	STILL STAND <1 KA	LACUSTRINE DEPOSITION: HYPERSALINE AND FRESH	INTER-TERRAIN LOWS: WEST, NW AND EAST FIGURE 11B	GRANNY LAKE
	RISE <.1 KA	BEACH ROCK EXPOSURE AND BRX CONGLOMERATE	WEST SHORE, NORTH SHORE	NUMEROUS SITES

Table 2. Proposed geochronologic development of West Plana Cay. Symbols for different island terrains in left column are those used in Figs. 10-11. San Salvador Island stratigraphic equivalents are indicated in the right column.

being able to build deposits up to absolute sea level (as in the reef) or very high above it (as in the dunes). It is only these type of deposits which are capable of developing anomolous highs which significantly alter the layer-cake stratigraphy of the Bahamas by producing and maintaining carbonate islands. As such, additional influences are also of major importance in assessing the stratigraphic picture of the islands of the Bahamas. These include: a: the height of present-day sea level relative to earlier high-stands, b: the rate of rise or fall of sea level, c: the destructive action of bioerosion on pre-existing rock highs during a flooding event, and d: the importance of pre-existing rock highs to the development of both the reef (substrate control) and dune (shoaling phenomenon) environments.

The Bahamian islands which have been studied demonstrate common threads in their style and timing of response to sea level events. These characteristics not only link geographically seperate islands to one another and the first-order stratigraphic model but clearly set islands apart in the overall stratigraphic perspective of the platforms. The data presented to date indicates that nearly all Bahamian islands can be dissected as a series of discrete depositional terrains of different ages which have distinct physiographic and geometric relationships not only on a single island but between islands. Further it is not surprising that nearly all Bahamian islands which are at least 3 m in elevation are either a: eolian deposits which pre-date the Sangamon events by 10^5 years or more, b: framework reef deposits and/or exceptionally thick (usually submarine cemented) subtidal shoals, c: eolian dune ridges which are 10^5 years in age, or d: eolian deposits which are $<10^4$ years old (Lind, 1969; Harris, 1979; Wilber, 1981; Pierson, 1982; Gerhardt, 1983; Garrett and Gould, 1984; Titus, 1984; Carew and Mylroie, 1985; Titus, 1986). Further it must be noted that if the 125 ka flooding event had not been so high relative to present sea level (+6 to +8m) or if regional subsidence were 2-3 times more rapid, the only possible deposits for present-day Bahamian islands would be those of (c) and (d).

The islands examined in this study are illustrative in this overall scenario in that at two comparably-sized yet geographically seperate sites there is evidence to suggest that although there is common island response to sea level events, dramatically different island types can develop due to the relative importance of either reef or dune deposits and the interplay of erosion vs shoaling phenomenon. Common to both islands are a: a core of 10^5 year rock, b: peripheral accretionary deposits developed early during Holocene shelf flooding, c: severe bioerosional scarping of both (a) and (b) during continued sea level rise up to a still-stand 2-3 ka, d: rapid peripheral accretion during the still-stand, e: exhumed beach rock and beach rock conglomerates as possible indicators of a very recent sea level surge, and f: similiar non-marine deposits at inter-terrain sites. The big difference between LSS and WPC is that the core rock of LSS is a series of dune ridges which rise to 20+ m while the comparably-aged rocks of WPC are subtidal reef facies with a maximum elevation (+4.5 m) determined by the 125 ka high stand and subsequent regional subsidence.

In some ways the two island described in this study may be considered as geologic/-physiographic "end members" typical of all or parts of most Bahamian islands as they exist today. San Salvador (Titus, 1984; 1986; Carew and Mylroie, 1985), New Providence (Garrett and Gould, 1984), Cat Island (Lind, 1969) and Mayaguana, Acklins, Crooked, and Great Inagua (Pierson, 1982) are all islands which are similiar to LSS, although elements of WPC-like reef facies are found on many of these. An overall look at the geometry and physiography of present-day Bahamian islands suggests that most of the larger ones exhibit responses similiar to dune-dominated islands such as LSS and San Salvador. Reef-dominated islands such as WPC are exceedingly rare throughout the Bahamas but the importance of the reef facies in island development is apparently increased in the southeast Bahamas.

In many ways the study of Bahamian island stratigraphy is an excercise in poorly-defined ephemera. During sea level minima all the Bahama platform tops are islands. During very high maxima (e.g. 125 ka) emergent bank-top features are nearly non-existent. The islands as they presently exist could be completely obliterated by erosive processes in the face of renewed sea level surges. Alternatively, present day island masses may be preserved as distinct topographic highs (even adding elevation and mass) should sea level fall from its present high. Because of this sensitivity to sea level, the study of island stratigraphy is particularly useful in determining the frequency and amplitude of major sea level fluctuations. They may in fact be one of the most depositionally sensitive systems for platform flooding events due to their proximity to the margins and rapid response mechanisms. Bioerosion, dune building, and intertidal lithification are extremely rapid processes all of which are directly responsive to sea level conditions.

Additionally the shallow submerged margins of the Bahamas today are commonly dominated by the flooded arcuate outcrop patterns of former island terrains (e.g. western and northern margins of Little Bahama Bank and western margin of Great Bahama Bank). These occurrences suggest the importance of islands and their response to sea level in the overall evolution of carbonate bank margins. To date this has been a largely overlooked aspect of margin development.

ACKNOWLEDGMENTS

Little San Salvador and West Plana Cay have been investigated by the staff and students of the Sea Education Association for over five years. Investigations are carried out from the R/V WESTWARD, which makes 2-3 day stops at each island once or twice per year. Over 35 student research projects have been directed at studying a wide spectrum of topics related to the biota, chemistry, and geology of the islands and their surrounding waters. The work of Laura Gentile, Adam Baker, Tom Dunkelman, Karen Holtz, Walt Poleman, Matt Smith, Gordon Brooks, Sue Fuertsch, Dave Johnson and particularly Rick Wilson contributed greatly to the LSS results. The work of Bob Bell, Tisa Hughes, John Woodwell, and particularly Ed Conti were important in compiling the WPC information. I would especially like to thank Dr. Arthur Gaines who initiated the Little San Salvador studies, Captains Wallace Stark, Paul DeOrsay, Carl Chase, and Terry Hayward who skillfully piloted WESTWARD to the islands, and the Sea Education Association which has supported this work.

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