

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

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**THE EFFECTS OF HOLOCENE SEA-LEVEL RISE ON THE DIAGENESIS
OF QUATERNARY CARBONATE EOLIANITES,
SAN SALVADOR ISLAND, BAHAMAS**

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ABSTRACT

Fossil coral reefs and associated facies of Sangamon age on San Salvador Island show clearly the diagenetic imprint of falling sea-level that resulted from the onset of Wisconsinan glaciation. Controversy exists as to whether sea level has reached or exceeded modern levels in the interval between the end of the Sangamon high stand and the beginning of the Holocene rise. A test for such a sea-level high stand would be to check for a diagenetic imprint in rocks of Sangamon age that are at the appropriate elevation to have been affected by a sea-level rise. Extensive studies so far have revealed no such imprint. A possible explanation for this is that sea-level rise leaves no diagenetic signature.

On San Salvador Island, wind-deposited carbonate calcarenites (eolianites) of Holocene age are being exposed to sea water for the first time as a result of Holocene sea-level rise. The eolianites were lithified in a non-marine environment by calcite cement that exhibits vadose fabrics. The rocks are not well lithified and they retain considerable porosity and permeability prior to their exposure to marine waters. This situation affords an opportunity to study the diagenetic effects of a sea-level rise on carbonate rocks that previously had not been exposed to marine water.

Holocene eolianite samples were collected from North Point and Cut Cay along six transects from the supratidal to shallow subtidal zones and studied by light microscopy, SEM, and cathodoluminescence. The Holocene eolianites are pelsparites and aragonite cement is present in more than half of the collected samples and from all the peritidal zones. Aragonite occurs mainly as isopachous, acicular crystals that commonly form a mesh-like fabric in intragranular, intergranular, and solution pores. Minor amounts of

micritic and botryoidal aragonite are present. No high-Mg calcite cements have been found.

As a comparative study, Pleistocene eolianites of post-Sangamon age were collected along a single transect on Man Head Cay. The Pleistocene eolianites are biosparites and compositionally distinct from the Holocene eolianites, perhaps reflecting somewhat different source area conditions. Despite the lithological differences, the Pleistocene eolianites have marine aragonite cements formed during the Holocene transgression that are indistinguishable from those found in the Holocene eolianites. The Pleistocene eolianites show no signs of a pre-Holocene marine diagenetic phase.

The results of this study show that rising sea level can leave a diagenetic imprint on carbonate rocks and suggests that such imprints can be expected in rocks that have been exposed to marine waters during earlier sea-level high stands. The implication of these studies is that there has been no sea-level high stand on San Salvador Island comparable to or higher than modern levels in the interval between the end of the Sangamon and the beginning of the Holocene transgression.

INTRODUCTION

Carbonate sediments are particularly susceptible to diagenesis, that is mineralogic and textural changes that occur subsequent to deposition. Diagenesis may begin in the depositional environment and continue throughout the geologic history of a carbonate rock, until its final destruction by solution or conversion to a metamorphic rock (see Tucker (1990) for a recent review of carbonate diagenesis). Major controls on the mineralogy and texture of diagenetic

products include the mineralogy of the carbonate sediments, the composition of pore fluids, and the degree of fluid saturation of pores. The combination of pore fluid composition and saturation leads to the delineation of different diagenetic environments such as freshwater vadose and marine phreatic. Each diagenetic environment leaves a distinctive imprint on the mineralogy and texture of the diagenetic products in a carbonate rock. The diagenetic environments for nearshore carbonate locations that are most relevant to this study were described by Longman (1980). In coastal and nearshore carbonate environments pore saturation and pore fluid composition relate closely to sea level. Rise and fall of sea level can lead to changes in the diagenetic environment and the diagenetic history of a rock should reflect the sequence of sea-level changes.

Quaternary carbonate environments of San Salvador Island and elsewhere have been subjected to changing sea levels as a consequence of fluctuations in ice volume during the waxing and waning of Pleistocene ice sheets. The diagenetic history of the Cockburn Town fossil reef clearly reflects the Sangamon high sea level and subsequent sea-level fall during the Wisconsin ice advance. Aragonite and high magnesian calcite cements formed in the marine environment pre-date non-marine, meteoric low magnesian calcite cements (White *et al.*, 1984). According to Mylroie and Carew (1988) there have been two subsequent sea-level high stands that would have brought the rocks of the Cockburn Town reef back into the marine diagenetic environment, or at least into the meteoric-phreatic environment. No imprint of a second exposure to marine diagenetic environments has been found in the Cockburn Town reef rocks. Possible explanations for this absence include the sea-level high stands did not occur, or such high stands do not leave a recognizable imprint. In this paper we explore the latter hypothesis.

Holocene carbonate eolianites that were deposited and lithified in the non-marine environment (White and Curran, 1988) are being exposed for the first time to marine waters as a consequence of the Holocene transgression (Boardman *et al.*, 1989). This provides an ideal opportunity to investigate the diagenetic effect of a change from non-marine to marine environments. Important questions include whether such submergence does leave a diagenetic imprint and, if so, what are its distinctive mineralogic

and textural characteristics. Answers to these questions could be useful in better understanding the diagenetic history that is recorded in older carbonate rocks and in then relating that history to past changes in sea level.

FIELD WORK

The field studies were conducted mainly at the North Point area in the northeastern corner of San Salvador. Some work also was done on Cut Cay and Man Head Cay, located slightly offshore of the northeastern corner of the island (Fig. 1).

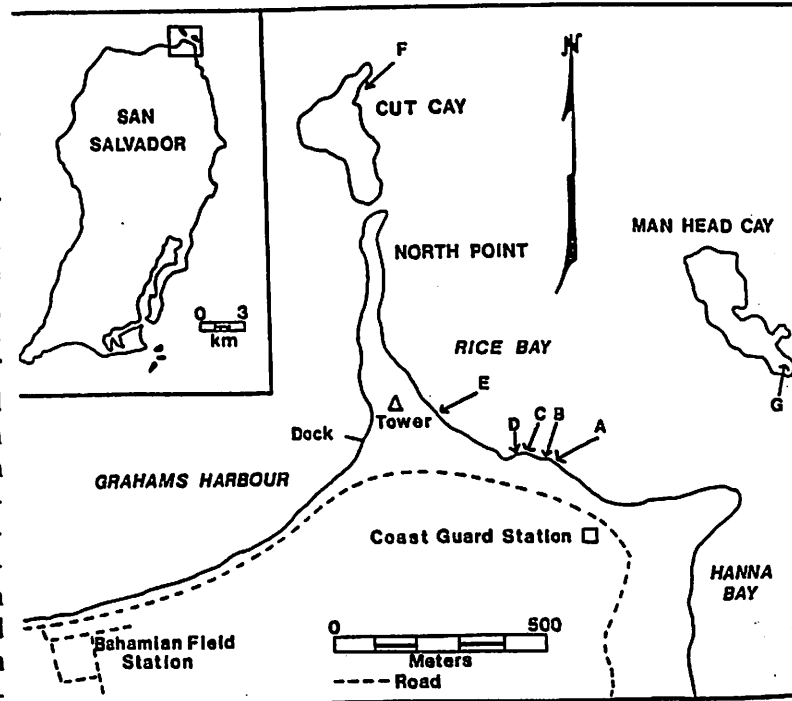
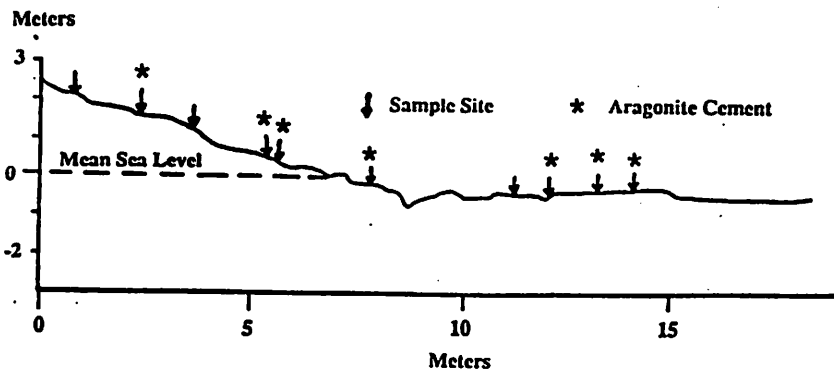


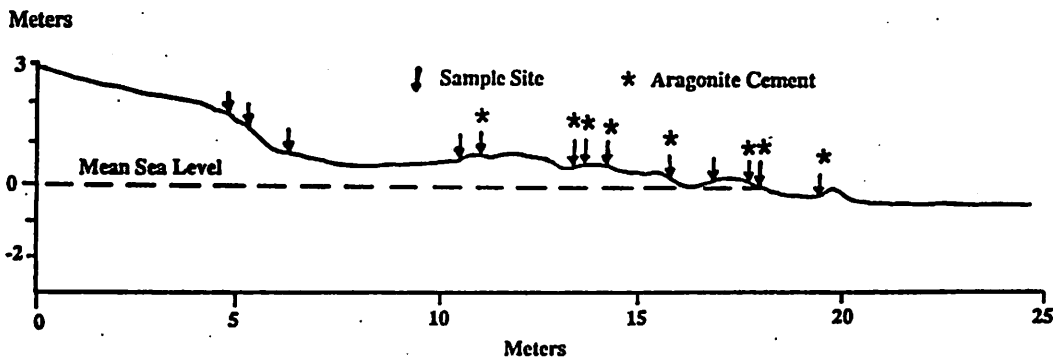
Fig. 1. Northeastern San Salvador Island showing the location of the field area and of the measured profiles.

Seven profiles, six of Holocene age rocks and one of Pleistocene age rocks, were constructed through the eolianites from the vegetation line down through the color zoned intertidal zone into the shallow subtidal. Four of the profiles were located in the main field area at North Point (Fig. 2). A fifth profile is a cliff section farther northwest along the coast, another is on Cut Cay, and the final one is of Pleistocene age and is located on the seaward side of Man Head Cay (Fig. 3). The main field area was selected because it includes differences in topography and morphology of the eolianites. The area

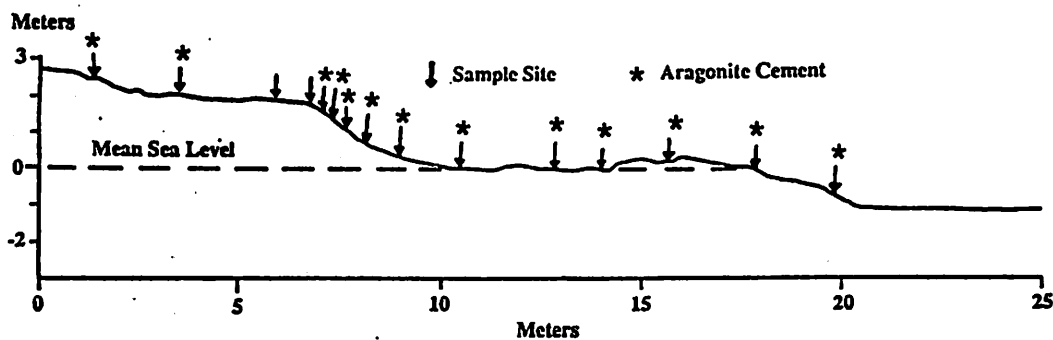
PROFILE A: HOLOCENE, NORTH POINT



PROFILE B: HOLOCENE, NORTH POINT



PROFILE C: HOLOCENE, NORTH POINT



PROFILE D: HOLOCENE, NORTH POINT

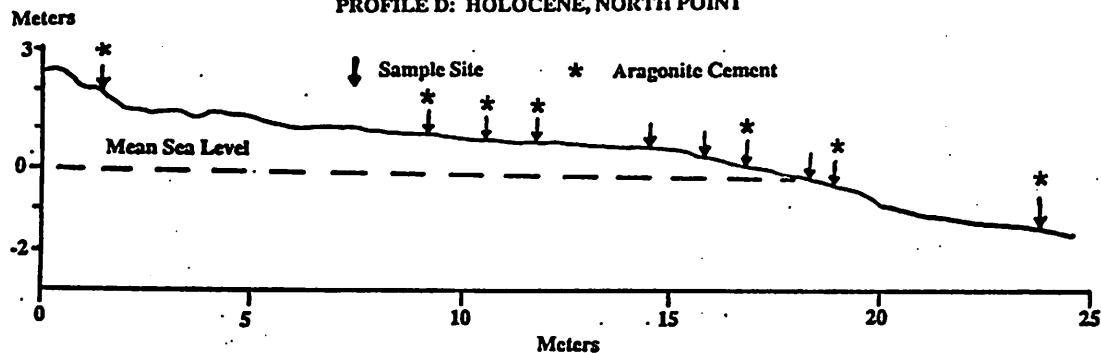
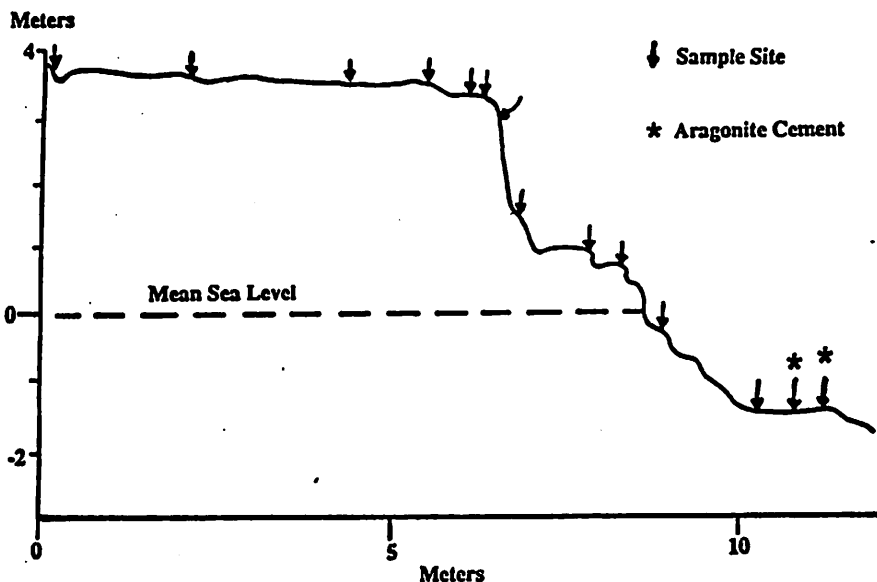
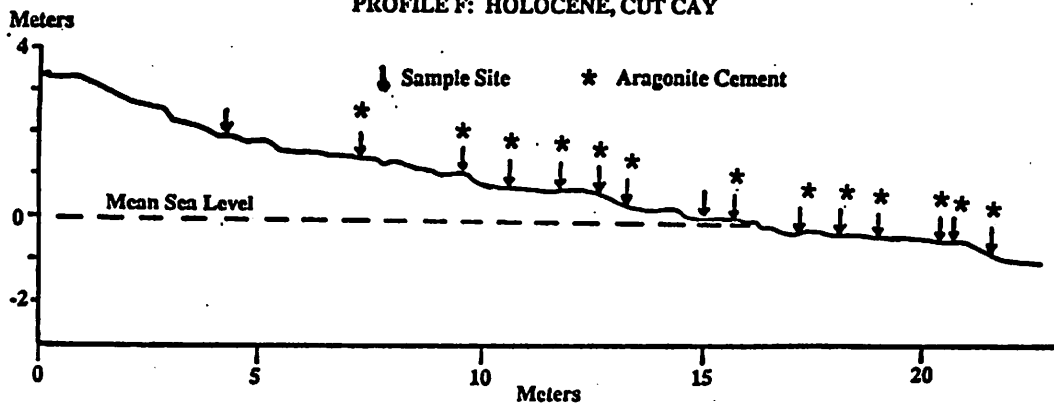


Fig. 2. Topographic profiles A through D in Holocene rocks from North Point showing sample locations and indicating those samples that contain aragonite marine cement.

PROFILE E: HOLOCENE, NORTH POINT



PROFILE F: HOLOCENE, CUT CAY



PROFILE G: PLEISTOCENE, MAN HEAD CAY

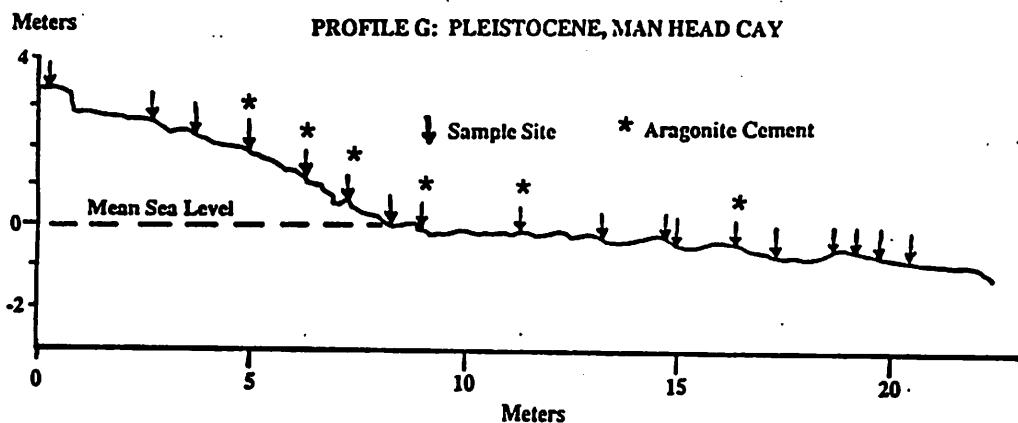


Fig. 3. Topographic profiles E in Holocene rocks from North Point, F in Holocene rocks from Cut Cay, and G in Pleistocene rocks from Man Head Cay showing sample locations and indicating those samples that contain aragonite marine cement.

contains two promontories, a large embayment area, as well as a smaller embayment area. The large embayment area has a rather broad expanse of eolianites while the promontories have more of a vertical section. The differences in morphology and topography allow for differences in the amount of exposure to sea water that the eolianites experience. The promontories undergo much more of a crashing motion of the waves than the embayments, which allows the sea water to reach higher elevations on the eolianites. The embayments accumulate sea water in tidal pools as well as sand in the lower lying areas. The embayments are set back farther towards the interior of the island, and so the sea water really only reaches the higher parts of the eolianites in these areas when there are storm waves affecting the coast.

The other three profiles studied outside the main field area were chosen because one is a cliff section, another is more exposed to the open ocean, and the third is of Pleistocene rather than of Holocene age. The cliff section was selected to study the possibility of waves continually crashing on a vertical surface and the effect on marine cementation. The Cut Cay profile was chosen because it juts off the northeastern corner of San Salvador and is exposed to more open ocean than the other Holocene profiles. The Man Head Cay profile was chosen to serve as a comparison of Pleistocene eolianites to Holocene eolianites.

In this part of San Salvador there is no established survey marker, and so the elevation of the surveying stations was determined by their elevation above the top of the Yellow zone. Through detailed surveying, done of the Cockburn Town fossil reef, based on precisely surveyed bench marks related to accurately measured mean sea level, it has been established that the top of the Yellow zone is 35 cm above mean sea level. Between ten and eighteen samples were taken along each profile. Each sample was taken because of its location along the profile, or because of some textural distinction. The samples were taken from the surface of the rocks, so as to preserve the effects of weathering by the sea water and sea spray, as well as by terrestrial processes.

LABORATORY TECHNIQUES

The rock chips were impregnated with Petropoxy 154 in a small vacuum impregnator fashioned after Allman and Lawrence (1972, Fig.

44, p. 86) for at least twenty four hours. The chips were then cured in a drying oven at approximately 60°C overnight. Any excess resin was removed from the rock chip using a lapping machine with a 220 mesh polishing wheel. The chips were then sonified for at least fifteen minutes and dried in the drying oven at 60°C overnight. They were mounted on glass slides with Norland optical glue and left for approximately forty eight hours to cure under an ultraviolet lamp. A larger amount of glue than usual was needed to mount these rocks because of their high porosity. They were left under the ultraviolet lamp for such an extended period of time to ensure that the bond was strong enough to survive the cutting and polishing stages of production. The thin sections were ground down to a thickness where the carbonate cements could be seen clearly with transmitted light under crossed nicols. This thickness was individual to each thin section. Often if the slides were polished to a uniform thickness, or to a point where the grains could be clearly identified with transmitted light, the cements would be destroyed or plucked from the slide.

The main focus of the petrographic study centered on the thin sections made in the laboratory at Smith College. These 100 or so thin sections were examined extensively, usually under crossed nicols, for marine cement using an Olympus PM-10AD polarizing microscope. The study was supplemented by an equally extensive study of over fifty commercially made thin sections. A thin section from each sample was analyzed for its point count composition data using the standard 300 grain count. Many of the thin sections needed to be polished further in order to identify the grains. This was done manually using 1000 micron carbo-corundum grit. Data from these counts were plotted on a triangular diagram showing the percentages of peloids, ooids, and bioclasts in each sample.

Several thin sections were stained for the presence of high-Mg calcite using the method described in Choquette and Trussel (1978) for titan-yellow stain, except for the use of the permanent stain fixer. Other thin sections were stained for aragonite using Fiegl's solution based on Freidman's methods as described in Schneidermann and Sandberg (1971). This was done in an effort to determine if any of the isopachous, needle-like cements could possibly be high-Mg calcite instead of aragonite.

Samples were then chosen for scanning electron microscope analysis based on their

marine cement content determined from petrographic analysis. The surface of each rock was drilled to produce a small disk that was mounted on a stub using Epotek epoxy. Each stub was then coated with a gold-palladium alloy to avoid the effects of surface charging during the analysis. The samples were observed using the JEOL Scanning Electron Microscope in the Department of Biological Sciences at Smith College. The SEM was operated at an accelerating voltage of 5,000 volts. The samples were examined for the presence of needles and to determine if the needles were bladed, and so aragonite.

One sample with especially well-developed isopachous needle-like cement was analyzed using an Energy Dispersive X-ray Spectrometer, KeveX Microanalyst 8000. The analysis was done to determine the mineralogy of the needle-like cement. The sample was carbon coated and then analyzed.

CHARACTERISTICS OF THE EOLIANITES OF NORTH POINT AND MAN HEAD CAY

Freshwater Cements

All of the Holocene eolianite samples from the North Point and Cut Cay localities contain a significant amount of calcite spar cement that binds the grains together. The calcite spar has a dominant phreatic texture, but in a few places a vadose texture can be seen. The cement crystals are well-developed and generally the same size throughout the sample. It occurs as both an intergranular and intragranular cement. Rarely, a calcite rim cement can be found in the Holocene samples.

The Pleistocene eolianites probably also originally were lithified by a calcite spar cement, but much of this cement has been destroyed. What remains of this original calcite spar is a rim cement found in several of the samples from the seaward end of Profile G. The samples farthest inland contain virtually no cement of any kind. They are barely lithified anymore. This becomes evident when walking on these eolian rocks. There is no extensive equant sparry calcite cement, perhaps due to subsequent weathering. This absence could be because of the lack of an extensive original cement. In arid climates water is scarce and its movement is very slow through the grains. The percolating water often precipitates any excess calcium carbonate it contains by the time it reaches the deeper parts of the fresh-

water phreatic zone, allowing for very little cementation to occur. Thus primary porosity is maintained and any cement that does occur forms as a small rim of isopachous equant calcite (Longman, 1980). Pleistocene eolianites in the Yucatan have been observed to have poor induration and a lack of extensive intragranular dissolution. These observations led to the conclusion that the amount of vadose water moving through the dunes during the Pleistocene was small, and so rainfall must have been infrequent when most of the Pleistocene rocks were lithified originally (Ward *et al.*, 1985). Therefore, it is possible that the rim cements in the Pleistocene eolianites from Man Head Cay indicate that there was an arid climate at the time that these eolianites were lithified.

Marine Cements

The marine cement aragonite is found in at least one sample from each profile that was measured and sampled in the North Point, Cut Cay, and Man Head Cay localities. Of the ninety six samples taken, 57% contain aragonite. The amount of aragonite cement found ranges from a few needles forming intragranularly in a hole in a grain or a chamber in a bioclast to a well-developed isopachous cement that is binding the grains together in a large portion of the sample. The aragonite cement most commonly occurs and is most abundant in the intertidal Yellow and Grey zones, but also occurs uncommonly in the supratidal White zone and in the one sample collected from the subtidal Green zone.

The most common occurrence of aragonite in the samples is in the form of needles growing intergranularly and intragranularly, and forming an isopachous fabric both in holes in grains and on grain edges, especially peloids (Fig. 4). The intergranular acicular aragonite is found as an abundant isopachous cement on every grain in some thin sections. In some cases the cement is so well-developed that acicular aragonite on one grain becomes interwoven with the acicular aragonite on another grain to form a meshwork that holds the grains together (Fig. 5). In other samples the intergranular acicular cement is found scattered throughout a thin section on grain edges, but without an isopachous texture. The isopachous texture and the presence of needles were features that were first used to identify a phreatic marine cement. Later staining with Fiegl's solution for aragonite

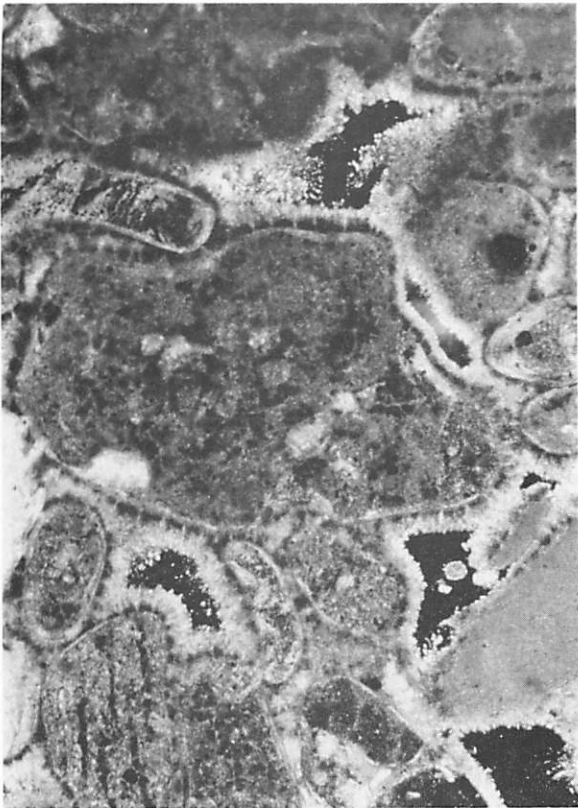


Fig. 4. Photomicrograph showing intergranular isopachous aragonite cement. Crossed polarizers.

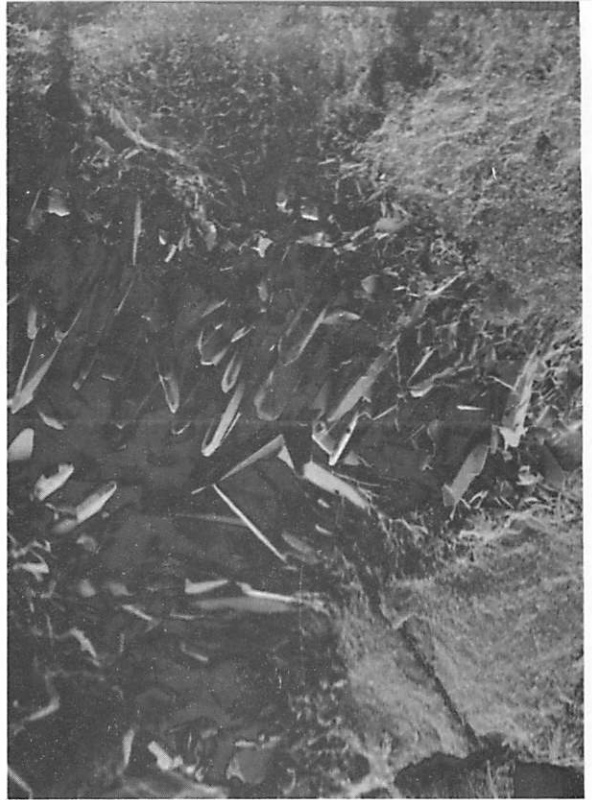


Fig. 6. Scanning electron photomicrograph showing an intergranular meshwork of aragonite cement crystals.

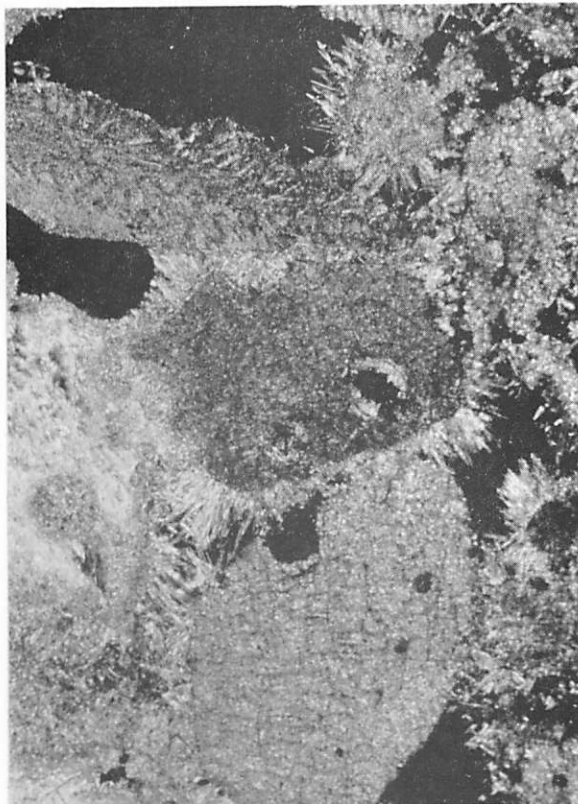


Fig. 5. Photomicrograph showing aragonite cement that forms an interlocking meshwork of acicular crystals that in some places occlude much of the intergranular pore space. Crossed polarizers.

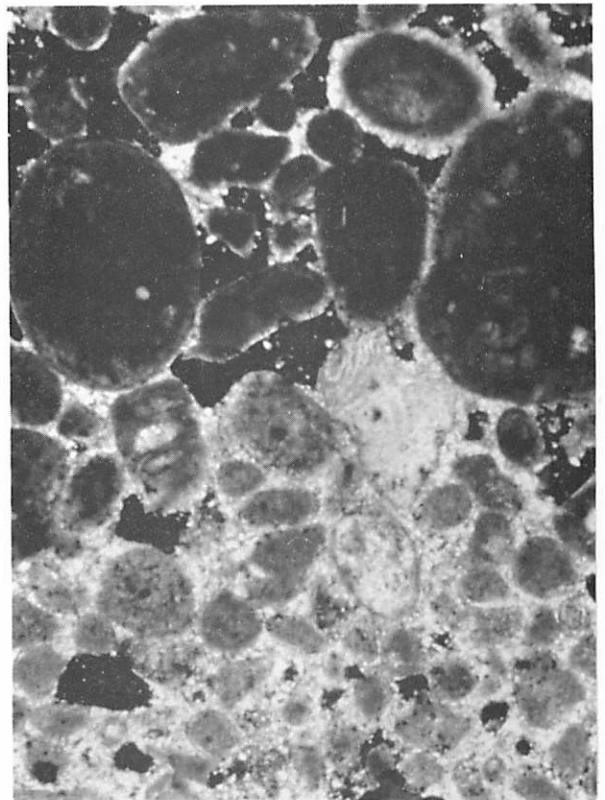


Fig. 7. Photomicrograph showing differential freshwater calcite cementation related to differences in grain size within coarser and finer eolianite laminations. Crossed polarizers.



Fig. 8. Photomicrograph showing well developed interlocking needles of aragonite cement within a fossil gastropod. Crossed polarizers.



Fig. 9. Photomicrograph showing marine aragonite cement post-dating non-marine calcite cement within the chambers of a fossil foraminifer. Crossed polarizers.

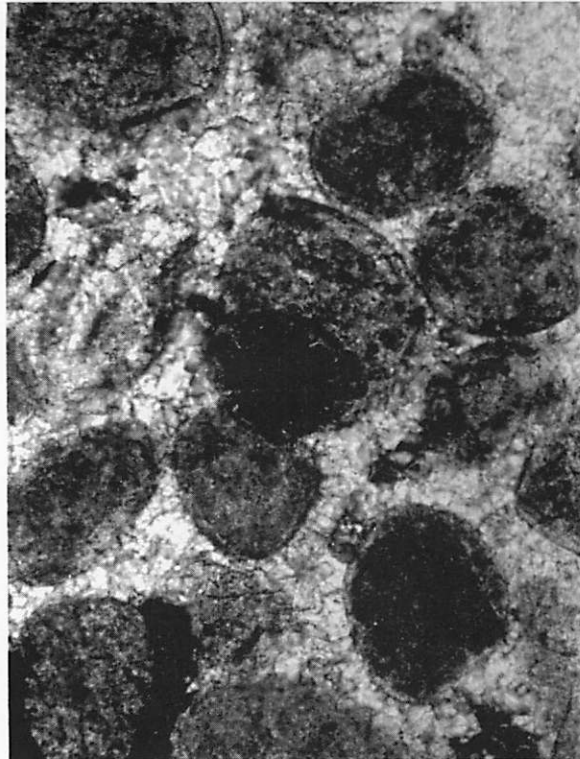


Fig. 10. Photomicrograph showing a dissolution pore that cuts across two adjacent grains and some of the nearby intergranular non-marine calcite cement. The solution pore is lined by needles of marine aragonite cement. Crossed polarizers.



Fig. 11. Photomicrograph illustrating the sequence of cementation with an earlier intergranular non-marine calcite cement upon which grew later marine aragonite cement needles. Crossed polarizers.

(Schneidermann and Sandberg, 1971) and titan--yellow for high-Mg calcite (Choquette and Trussel, 1978) indicated that the needles were aragonite and not high-Mg calcite. This was determined further through Scanning Electron Microscope analysis, which showed that the needles were bladed (Fig. 6), an indication of aragonite (Scoffin, 1987). Some work done on the Kevex Microanalyst 8000 determined that there is a lack of magnesium in the needle-like cements, which also indicates that the needles are aragonite and not high-Mg calcite. The Fiegl's solution staining revealed that there was some aragonite cement that did not form a needle-like crystal, but was instead micritic, or, in rare instances, botryoidal in nature.

The extent of the aragonite cement appears to be somewhat dependent on porosity. The cement is best developed and most abundant in areas in the rocks where the freshwater calcite spar cement is not extensive. This occurs most commonly in coarse-grained layers in the rocks. The coarser grains are farther apart from one another and the porosity is greater, whereas the finer grains are more closely packed and the porosity is much less (Fig. 7). These fine- and coarse-grained layers are the same as those seen in hand sample, which are characteristic of eolianites (White and Curran, 1988). The aragonite cement also develops in chambers of foraminifera and gastropods (Fig. 8), as well as in dissolution holes in ooids and peloids, and can be found forming on both intergranular and intragranular freshwater sparite cement (Fig. 9).

The timing of the late-stage formation of aragonite cement is demonstrated in a sample where an ooid and a peloid are joined and a dissolution hole that cuts through both grains and nearby non-marine cement is lined with acicular aragonite (Fig. 10). The occurrence of acicular aragonite cement on the freshwater sparite cement also indicates that the aragonite cement is younger than the sparite cement and has formed since the grains were lithified (Fig. 11). The growth of aragonite cement on sparite cement is especially important where it occurs inside chambers of foraminifera and gastropods and in holes in peloid or ooid grains (Fig. 8 and 9) because it indicates that the aragonite cement found in these holes has been developed since the grains were lithified and not before they became part of the eolianite rock. Thus this aragonite cement has formed *in situ* as a result of marine diagenetic processes.

Another factor that seems to control the

abundance and development of the aragonite cement is elevation above mean sea level, and so exposure to sea water. This makes sense since aragonite is a marine cement. The dominant zone for the presence of aragonite is between -1m to 2m above mean sea level. There are cases where either limit is exceeded, especially the higher boundary in a promontory section. This is probably because the ocean crashes up onto the promontory during high tide, and so forces the sea water up higher than the actual sea-level. This does not happen in embayment sections, and only strong storm action can force the sea water up the cliff face. The profiles that are exposed to the waves more regularly are those that are on promontories, Profile A and Profile C; exposed to more open ocean conditions, Profile F; and located on the windward ocean side of an offshore island, Profile G. The profiles located in embayments, Profile B and Profile D, or the one that is a cliff section, Profile E, contained much less aragonite cement.

Although the bottom part of Profile E, which is exposed to wave action continuously, does contain very well-developed, intergrown needles of aragonite.

ENVIRONMENTS OF MARINE DIAGENESIS

Although both high-Mg calcite and aragonite can occur as marine cements, only aragonite has been found developing in the eolianite rocks of North Point, Cut Cay, and Man Head Cay. The textures of the aragonite cement are those that are commonly found in the active marine phreatic zone. Although some characteristics of the stagnant marine phreatic zone can be seen in Profile B. Much of the aragonite in this profile occurs intragranularly in chambers of bioclasts or in small holes in peloids or ooids. The particular occurrences of aragonite cement are located in or near small tidal pools that have developed along the profile. Thus the sea water remains in these pools and is not forcefully moved through the grains. Instead, ion diffusion combined with bacteria and micro-boring algae contribute to the development of this aragonite cement (Longman, 1980).

The textures of the aragonite that formed mainly in the intertidal and supratidal zones commonly is isopachous indicating precipitation in fluid-filled pores. This pore saturation may have occurred during high tides, beneath semi--permanent tide pools, or where water was held

within the rocks by local areas of lower permeability.

The fact that the eolianites are only partially submerged by the ocean suggests that there is a possibility of the presence of a mixing zone environment where freshwater and sea water mix to produce a brackish water. Dolomitization can occur in this environment, as well as a calcite cement at the freshwater end of the zone, and a high-Mg calcite cement at the marine end of the zone. There is no indication in the eolianites of this study that there is a mixing zone environment in these localities, perhaps because of the shortage of freshwater.

The fact that only aragonite and not high Mg-calcite occurs as a marine cement can be explained by looking at the characteristics of beachrock. Beachrock forms in the tropics between the high and low tide marks. Cementation of grains on the beach occurs *in situ*. These cements are normally fibrous aragonite, which may be isopachous, or occur at grain contacts with a meniscus texture. The vadose fabrics may develop because of draining water at low tide. The cements are less commonly peloidal, micritic, or fibrous high-Mg calcite (Scoffin, 1987). Thus the type of cement found in beachrock is very similar to the type of cement that has been found in the eolianites of this study. This is especially interesting considering the fact that beachrock is forming today on sandy beaches of Rice Bay just a few hundreds of meters away from the study area.

GRAIN COMPOSITION

The grain composition of each sample was determined using a standard 300 grain point count technique. The percentages of peloids, ooids, and bioclasts for each sample were calculated. The data show that the Holocene rocks all have very similar compositions. Peloids are dominant, occurring usually as 70 to 80% of the grains, but ranging from 50 to 100%. Ooids are the second most abundant grain type. They usually make up 20 to 30% of the grains, but in some case may be 40 to 50% of the grains. Bioclasts are not always present in the Holocene rocks. If they are, they commonly make up 1 to 5% of the grains. The Pleistocene rocks on the other hand are dominated by bioclasts which account for 70 to 90% of the grains, with the remaining grains being peloids except for a few samples that have up to 1% ooids (Fig. 12).

Two things can be determined from this data. One, the source areas for the Holocene and Pleistocene dunes appear to have been rather different. The Holocene source area was dominated by peloids and ooids and almost devoid of bioclasts while the Pleistocene source area was dominated by bioclasts and contained some peloids and few to no ooids. The data from the Pleistocene is not extensive enough to make sweeping conclusions, but it does indicate a possibility of different shelf environments during the formation of the Pleistocene dunes and the Holocene dunes. The second is that the type and amount of marine cement is not dependent on the nature of grains that make up the rocks. The occurrence and characteristics of the aragonite cement are no different in the Pleistocene samples than in the Holocene samples although the compositions of the rocks are very different (Fig. 13). Thus it is very likely that the aragonite is being precipitated directly from the sea water and does not have its source in the grains that make up the rock. This provides more evidence that the formation of the aragonite cement is dependent on the exposure of the rocks to sea water.

CONCLUSIONS

The marine cement aragonite is more abundant and better developed in the promontory localities than in the embayment sections. This can be attributed to the fact that the waves reach farther up the promontory sections because of the active motion of the sea. This energetic environment of crashing waves allows for the sea water to be forced through the carbonate grains and form an aragonite cement. Thus aragonite cement is found farther landward in the promontory sections than in the embayment areas.

The abundance of isopachous aragonite indicates that much of the aragonite formed in fluid-filled pores. However, the samples mostly were taken from the vadose environment. Thus the isopachous texture indicates localized pore saturation located in the vadose zone occurring perhaps in tide pools, during high tide, and in pores surrounded by low permeable material.

The fact that only aragonite is present and not high-Mg calcite suggests that the diagenetic processes occurring in the eolianites of this study are very similar to those that produce Holocene beachrock along tropical beaches.

The fact that the grain compositions of

Fig. 12. Triangular diagram showing the grain composition of the Holocene and Pleistocene eolianites examined in this study.

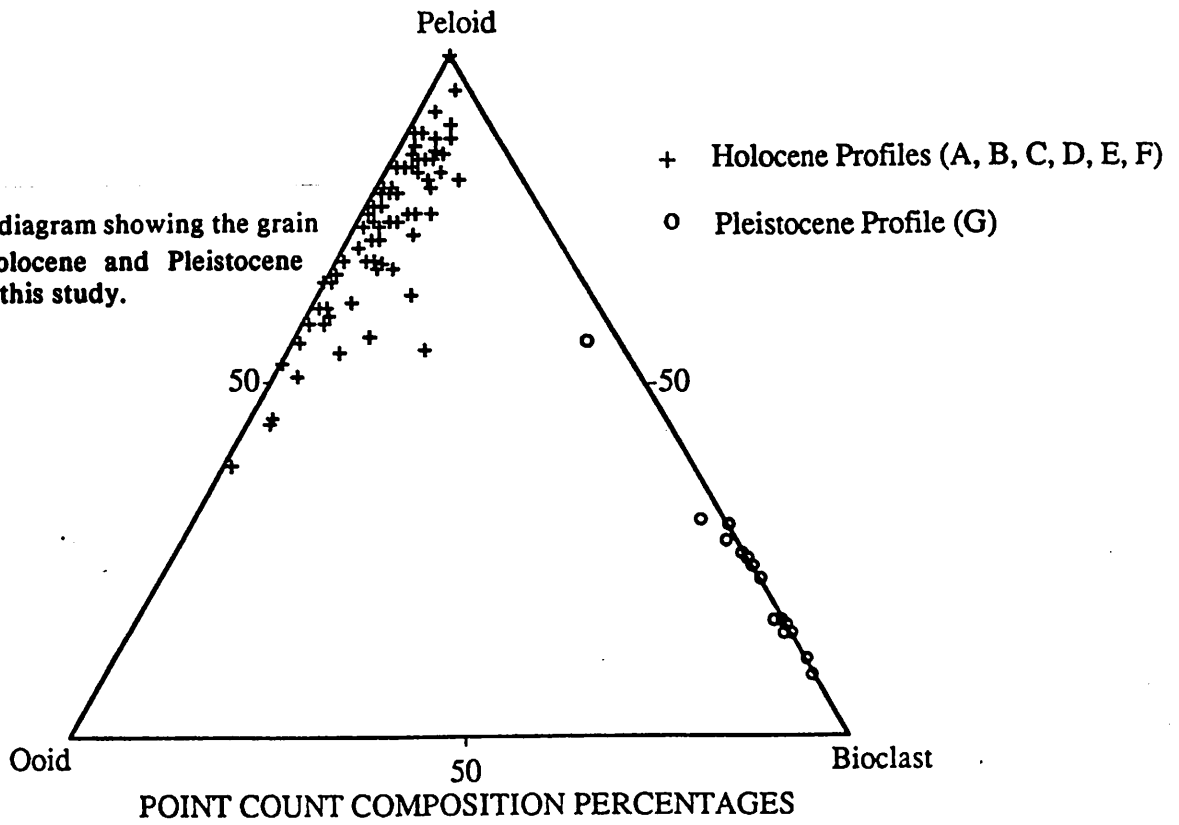
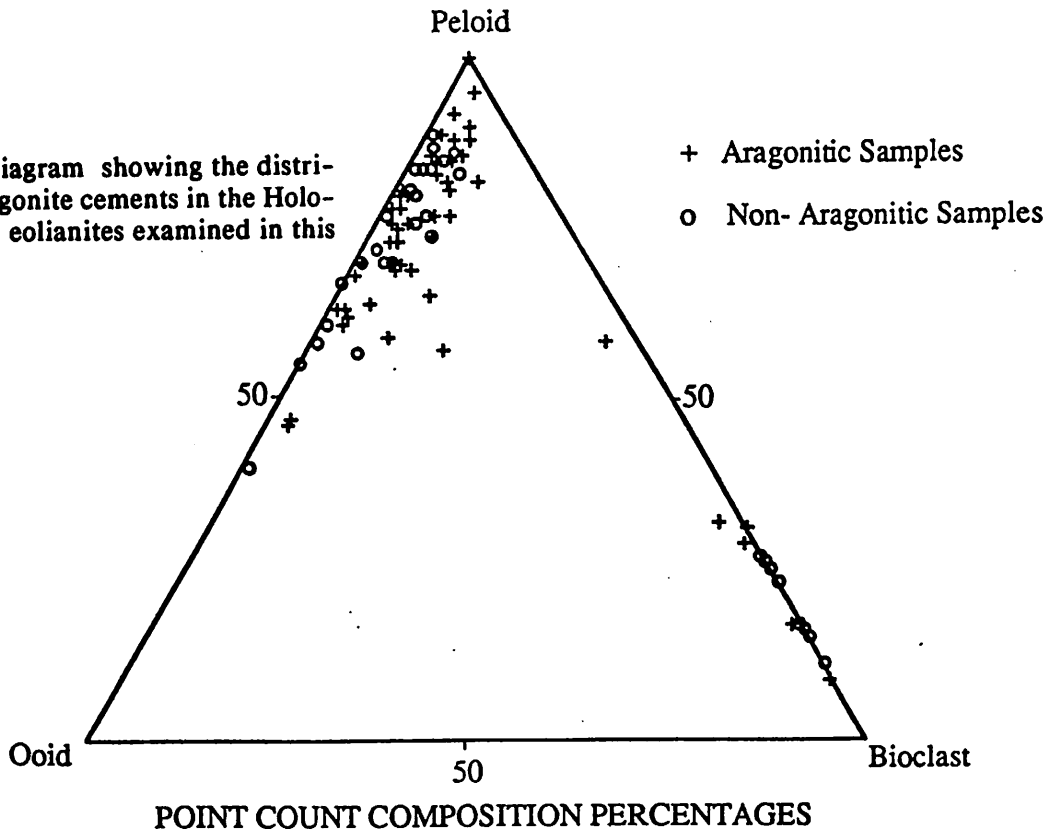


Fig. 13. Triangular diagram showing the distribution of marine aragonite cements in the Holocene and Pleistocene eolianites examined in this study.



the Pleistocene eolianites are very different from the Holocene eolianites and that the marine diagenetic cements are very similar indicates that the development of the marine cement aragonite is not dependent on the composition of the grains making up the eolianites, and so is precipitating directly from the sea water, as it does in beachrock. Thus the presence of aragonite is made further dependent on the exposure of the rocks to sea water.

Since the history of these eolianites is fairly well-known, it can be determined that the Holocene eolianites are undergoing their first marine transgression, and therefore their first period of marine diagenesis. Thus the texture, nature of growth, and composition of the marine cement aragonite have been studied to determine the characteristic diagenetic imprints resulting from a marine transgression. The fact that the Pleistocene eolianites have very similar diagenetic history to the Holocene eolianites suggests that they are also undergoing their first period of marine diagenesis.

These characteristics of marine diagenesis are what would be expected in older rocks on San Salvador, for instance the rocks of the Cockburn Town fossil reef, if they had undergone a period of marine transgression. In the case of the rocks at the Cockburn Town fossil reef, there are no indications of marine cements that postdate the freshwater vadose cements or calichification that have developed during the emergent phase (White *et al.*, 1984). Thus the fact that Holocene marine diagenesis is occurring in rocks that are not completely submerged by the transgressing sea indicates that if there had been a period of late Pleistocene sea level rise to levels equal to, or greater than, present sea level, such as proposed by Mylroie and Carew (1988), there would be marine cements that postdate the freshwater cements that developed in the reef rocks following emergence caused by post-Sangamon sea regression. It is possible to suggest that the marine cements would have changed to more stable forms of carbonate cement since they are metastable in the freshwater environment, and so be unrecognizable as marine cements. However, they should be recognizable because of the acicular isopachous nature of much of the marine cement aragonite. It is also unlikely that the aragonite would have already changed to a more stable state because the original metastable aragonite and high-Mg calcite cements that formed at the time the reef still

was in the marine environment have been preserved (Japy, 1986). Therefore, the evidence of marine diagenesis occurring in the eolianites of the North Point area combined with the detailed work done on the rocks of the Cockburn Town fossil reef indicate that it is unlikely that there was a late Pleistocene sea-level rise to levels similar to present sea level.

To investigate these indications further, more work needs to be done on the Pleistocene eolianites of San Salvador Island to determine if the composition of the Pleistocene eolianites differs as drastically from the composition of the Holocene eolianites as this study suggests. If the compositions differ enough to indicate a difference in source areas it may be possible to establish the exact nature of the San Salvador Bank during the formation of the Pleistocene and Holocene eolianites. This then may give insight on the possibility, extent, and nature of a late Pleistocene sea-level rise.

Further investigation of the older rocks of San Salvador in search of the types of marine cements found in this study to be characteristic of a marine transgression would also provide more information on the possibility of this late Pleistocene sea-level rise. A different sampling method may be necessary to actually find the marine signature. In past studies of the rocks of the Cockburn Town fossil reef, for example, non-weathered samples have been collected in order to determine the older periods of cementation. However, in this study only rocks from the very surface of the eolianites were collected, and thin sections from the top of these samples were used in the petrographic analysis. Therefore it is possible that by sampling the older rocks differently a late Pleistocene sea-level rise may be 'discovered' in these rocks.

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