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# The Holocene Carbonate Eolianites of North Point and the Modern Marine Environments between North Point and Cut Cay

Brian White
*Smith College*

H. Allen Curran
*Smith College*, acurran@smith.edu



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BRIAN WHITE AND H. ALLEN CURRAN

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# THE HOLOCENE CARBONATE EOLIANITES OF NORTH POINT AND THE MODERN MARINE ENVIRONMENTS BETWEEN NORTH POINT AND CUT CAY

Brian White and H. Allen Curran
Department of Geology
Smith College
Northampton, Massachusetts 01063

## INTRODUCTION

The goals of this part of the field trip are to study the types of strata, sedimentary structures, trace fossils, and dune morphologies of the Holocene eolianites excellently exposed along the coasts of Rice Bay and North Point. We will show how eolian deposition of carbonate grains occurs and how dunes are initiated and evolve. Toward the end of this excursion, a short snorkel dive will be conducted in the shallow, sheltered waters between North Point and Cut Cay to study grass beds, sandy substrates, and hardgrounds and to compare their associated sediments, plants, and animals. The area to be visited and the locations of field stops are shown in Figure 1.

### Previous Work

Adams (1980), in his pioneering study of the geology of San Salvador, briefly described the eolianites of North Point. He distinguished lobate dunes that have large-scale cross-beds on their leeward faces and flanks and smaller, more varied, cross-beds on their windward slopes. In their overview study of the petrography of the eolianites of San Salvador, Hutto and Carew (1984) found that most are dominantly oolitic. However, this was not true for their North Point samples, which have a higher proportion of skeletal grains and pellets. Hutto and Carew (1984) believe that the eolianites of North Point are younger than 10,000 years old and belong to the youngest group of eolianites found on San Salvador. These rocks are assigned to the North Point Member of the Rice Bay Formation as defined by Carew and Mylroie (this volume).

In her more detailed study of the eolianites of the Rice Bay area, Lawlor (1985) found that these rocks are pelsparites with lesser proportions of ooids and skeletal grains. The rocks are dominantly aragonite with incomplete cementation by vadose low Mg calcite. Inverse graded bedding is a common feature of the rocks on a microscopic scale, with somewhat more complete cementation in the finer layers.

## The Eolianites of the Rice Bay to North Point Area

The Holocene dunes of this area are composed of carbonate sand which was blown landward from marine beaches by onshore winds. Initially, small dunes developed landward of the beach, a few around cores formed of the eroded remnants of earlier dunes. In some cases two small adjacent dunes were enveloped by later dune

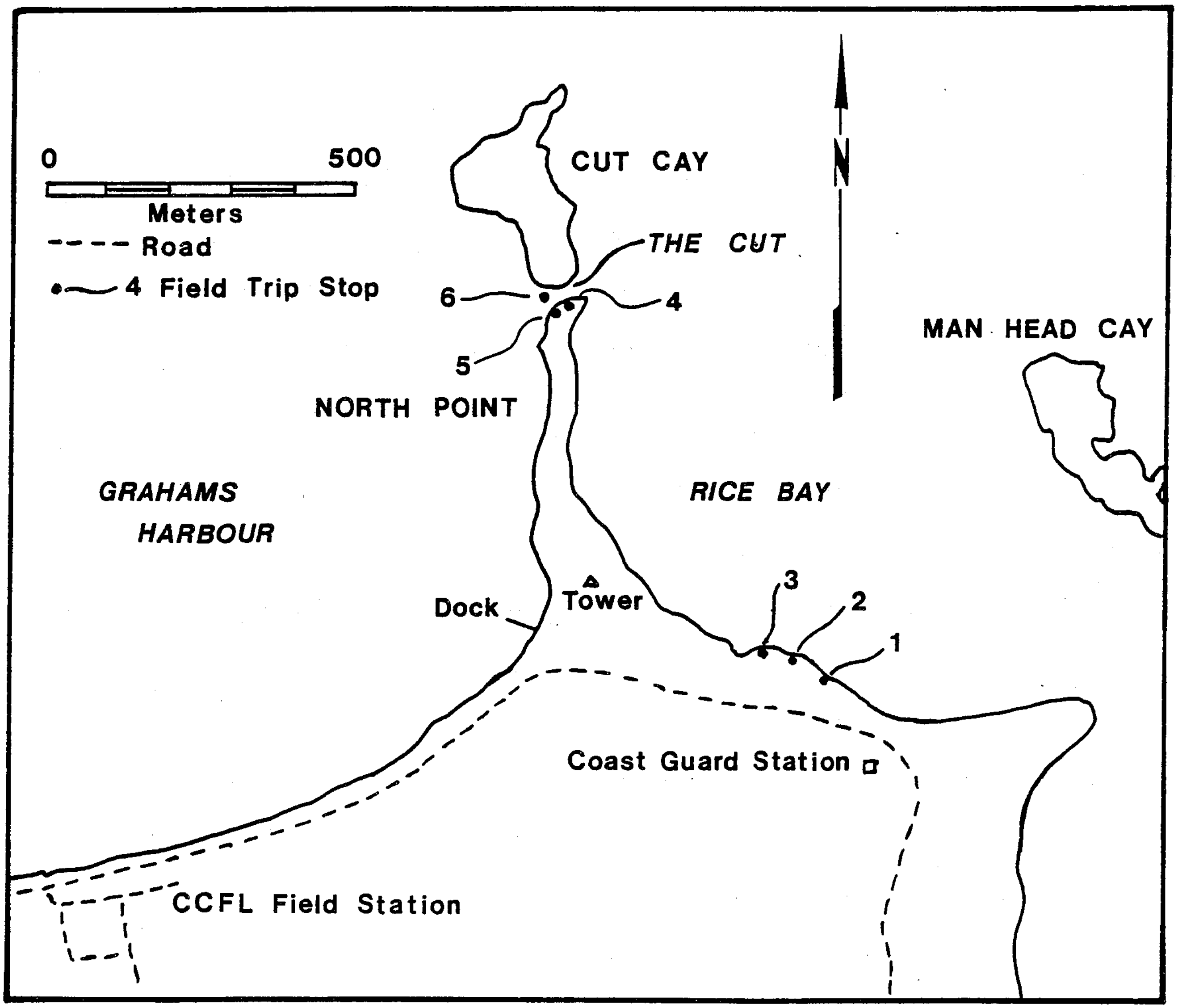



Fig. 1. The North Point area with locations for described stops.

strata to form a compound dune. Elsewhere, dunes grew higher and migrated inland as individual lobes, with slip faces sloping not only downwind, but to the right and left on the flanks of each lobe. Eventually the lower parts of the flanks of adjacent dunes overlapped to cover the interdune areas and thereby form a long, hummocky dune ridge. This dune morphology is clearly reflected in the undulating topography of the west side of North Point as seen from the campus of the CCFL Bahamian Field Station.

Large-scale, steeply-dipping cross-beds occur on many lee slopes and flanks of the lobate dunes. Windward dune slopes reveal a greater variety in scale and type of cross-bedding, including examples of tabular-planar, wedge-planar, and trough sets. The latter are more numerous in the lower parts of dunes. Wind ripples are visible on some bedding surfaces, but they are quite scarce. Although fossil animal burrows are believed to be rare in eolianites (McKee and Ward, 1983), there are several large and well-preserved trace fossils thought to have been formed by invertebrates in the eolianite exposures along Rice Bay. Rhizocretions, trace fossils produced by plant roots, are common in these eolianites. In some of the cross-bedding it is possible to distinguish the different strata produced by climbing wind ripples, grainfall, and sandflow as described from modern coastal dunes by Hunter (1977).

## DESCRIPTIONS OF THE FIELD STOPS

The prominent <u>Casuarina</u> tree located adjacent to the beach in front of the abandoned Coast Guard Station makes a convenient starting point for this trip. From here the view extends northeast over the sandy beach and across the waters of Rice Bay to Man Head Cay. To the northwest (left) some of the North Point eolianite exposures can be seen and the first of these are reached by walking about 90 m along the beach in a northwesterly direction.

Continuous exposures of Holocene dunes in sea cliffs and on narrow, rocky shore platforms along this coast reveal numerous features of the eolianites. The stops described below were selected to demonstrate particularly good, and readily accessible, examples of trace fossils, sedimentary structures, and stratum types found in the eolianites, and of dune morphology. After walking about 1 km along the peninsula, the end of North Point is reached, where final observations of the dunes can be made. The small beach on the west side of the point is a good place to begin a snorkel dive to view the nearby hardgrounds, <u>Thalassia</u> grass beds, and sandy substrates and to examine their associated sediments, floras, and faunas.

<u>STOP 1</u>. To reach this stop, walk northwest along Coast Guard Beach to the first rock exposures and then continue over outcrops and a small sandy bay for 60 m. Here sea cliffs 3 to 4 m high are cut into an 85 m wide fossil dune (Fig. 2a). Along much of this dune's

width, cross-bed dip directions are rather variable, but generally towards the southwest, and dip angles range from almost flat-lying to 15°. On the northwest flank of the dune, dips are northwesterly and steepen to 30°, with some sandflow cross-strata evident. At the southeast end of the dune, steepening cross-strata dip to the south at angles of up to 20°. Most of the strata are in small wedge-planar sets, suggesting variable wind directions, and climbing wind-ripple strata are evident in some places.

A prominent trace fossil consisting of a cluster of vertically oriented burrows is exposed in a small cliff face here, and in a large counterpart block that has fallen away from the cliff. The trace fossil cuts vertically across 1.4 m of small-scale, wedge-planar and trough cross-strata sets, which are obscured in places by bioturbation. Fine, millimeter laminations are evident on much of the cliff face and weathered surfaces reveal some very thin laminations of slightly coarser calcarenite. In the rocks immediatedly overlying this trace fossil, rhizocretions are prominently displayed on some bedding planes, where they weather out in relief (Fig. 2b).

In detail, this trace fossil consists of multiple, straight to gently curved, unlined shafts. Shaft diameters are 1 to 2 centimeters (average 1.2-1.4 cm), and shaft lengths can be as long as at least 1.4 meters (Fig. 2c). This is a minimum length for the shafts of this specimen because a break in the cliff face in which

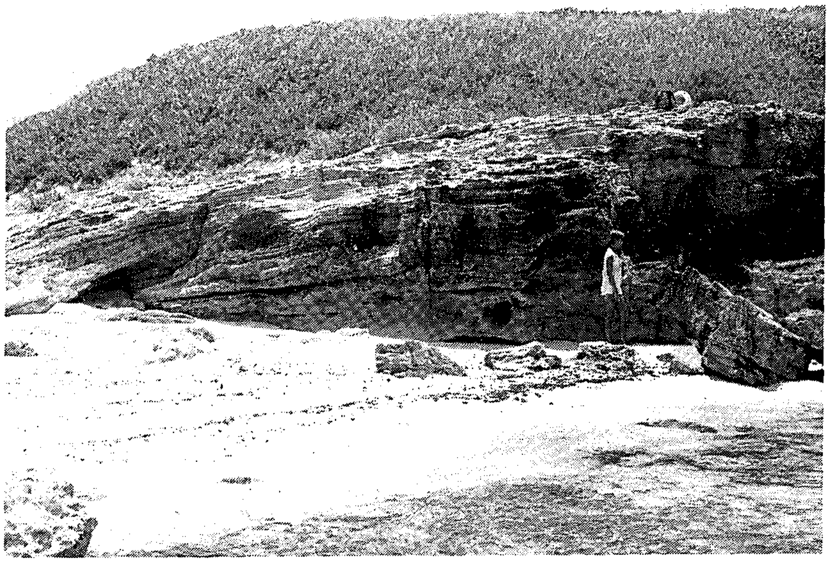


Fig. 2a. Holocene dune profile viewed from Rice Bay. The type locality for the trace fossil described for Stop 1 is in the cliffs above the large blocks seen on the foreshore.

Fig. 2b. Rhizomorphs on an eolianite bedding surface, Stop 1.

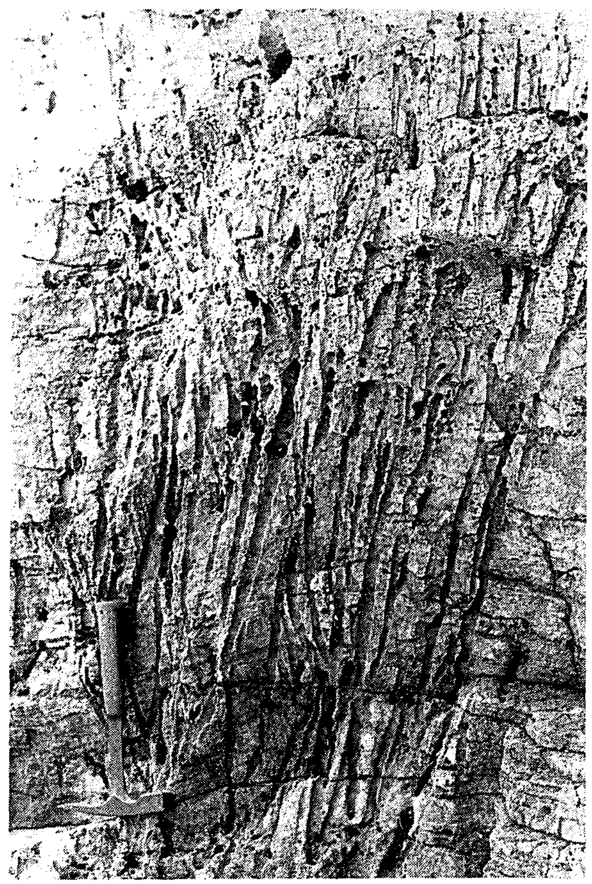


Fig. 2c. Vertical, straight to gently curved, unlined shafts of the cluster burrow trace fossil at Stop 1. Burrow shafts are up to 1.4 m in length; about 45 closely spaced shafts occur in this exposure.

it is exposed terminates the lower part of the specimen. Shafts occasionally branch in the upward direction and some definite cross-overs also occur. Shaft diameters appear to contract somewhat toward their upward ends.

At present, we do not know the affinities of the tracemaker organism. The apparently obligatory clustered nature of the shafts and their large number suggest that the structure records the brooding/hatching activity of an invertebrate organism, with the shafts having been formed by juveniles burrowing up to the surface. Again, the large number of shafts combined with our proto-dune or dune paleoenvironmental interpretation leads us to propose that some type of burrowing insect made this structure.

About 50 m northwest of the trace fossil just described, a similar one is revealed in horizontal cross-section. Here the circular nature of the cluster and the large number of individual burrows (about 800 shafts) that it contains are clearly revealed. Here, too, this trace fossil is within a sequence of small-scale, wedge-planar and trough cross-strata sets, with scattered rhizocretions and climbing-ripple laminations. Of additional interest is a small bedding surface at least 1 m below the cluster trace fossil and within the present day intertidal zone. On this bedding plane there are ripple marks with their crests oriented perpendicular to the strike of the bedding plane, a feature believed to indicate an eolian origin (McKee and Ward, 1983). The ripples have a very low amplitude and ripple indices of 25 to 30, further evidence that they are wind-formed ripples (McKee, 1979; Tanner, 1967). Two interesting conclusions may be drawn from these observations. As wind-deposited strata are located in the present intertidal zone, this clearly means that sea level was lower at the time of formation of these beds than at present. The presence of wind-formed ripples beneath the trace fossil confirms that the burrowing took place in an eolian dune and not in a beach or nearshore environment.

STOP 2. This next locality is reached by dropping down the northwest flank of the dune at Stop 1 to a broad, rocky shore platform, some 80 m long and up to 20 m wide, backed on its landward side by low cliffs and extending seaward into the intertidal zone. Because of the extensive horizontal and vertical exposures, this is an excellent place to study sedimentary structures and the early stage of dune development.

In the landward cliffs several small dune cores are exposed (Fig. 3a). Some of these are better lithified and contain more abundant rhizocretions than overlying strata and appear to be the eroded remnants of earlier dunes. Large-scale trough cross-beds occur immediately adjacent to some of the dune cores (Fig. 3b), and these may have formed by windscouring around the dune remnants. Subsequent deposition of wind-blown sand buried the dune cores and the growing dune extended laterally and vertically to encompass them into a form of compound dune.

Other sedimentary structures well-displayed here are convex-upward cross-strata sets, trough cross-beds, and wedge-planar sets. Some of the latter have cross-strata with acute angular relationships to the underlying set, whereas others show a tangential relationship (Fig. 3c). Several bedding surfaces have ripple marks (Fig. 4a) with ripple indices between 23 and 32, clearly wind ripples (McKee, 1979; Tanner, 1967). Again, some of these are within the present intertidal zone, confirming the conclusions drawn at Stop 1 about lower sea level at the time of eolianite deposition.

Beyond the rocky terrace of Stop 2, follow the coast as it takes a short jog to the west, then cross a 30 m wide bay with a sand and rock floor, to reach another promontory. Scramble down the northerly side of this headland and traverse the narrowing beach for about 40 m, until a small rock arch is reached. Progress along here will be blocked at some point, exactly where depending on wind conditions and the state of the tide. In any case, from the vicinity of the small arch, climb upward obliquely across the cliffs to a small gully, which constitutes the next stop.

<u>STOP</u> <u>3</u>. In this locality are exposed, in close proximity, three types of wind-deposited strata that were produced by mechanisms described by Hunter (1977, 1981) as grainfall, sandflow down lee

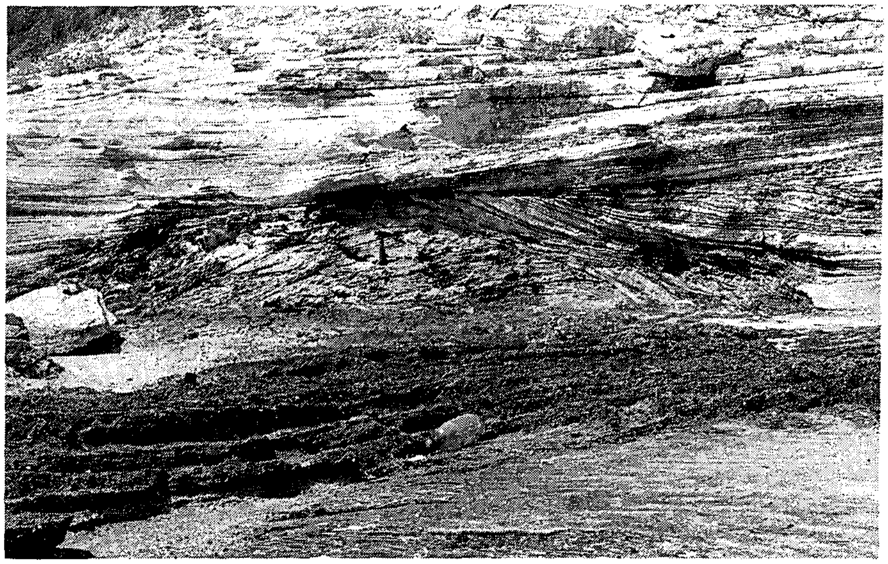


Fig. 3a. Eroded remnant of an older dune overlapped by younger eolian strata, Stop 2.

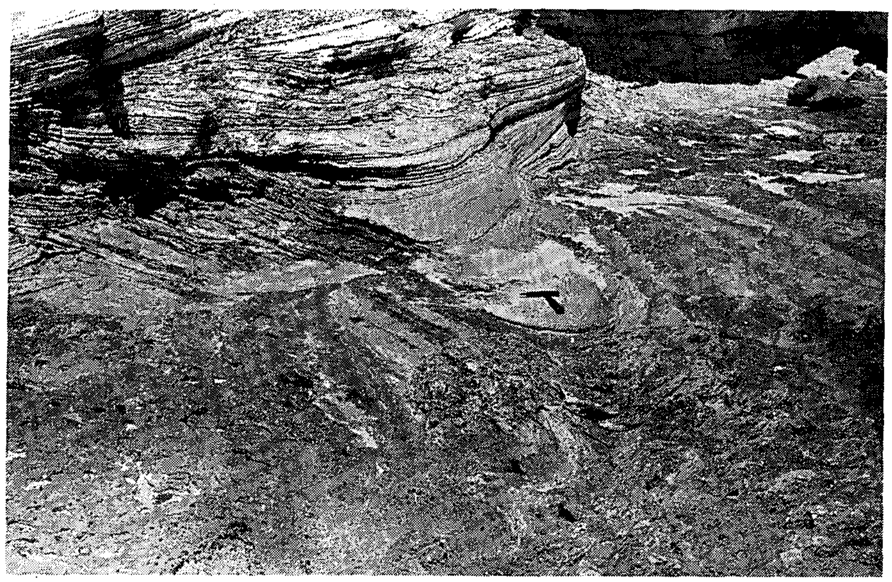


Fig. 3b. Trough cross-beds occur adjacent to an older dune core at Stop 2.

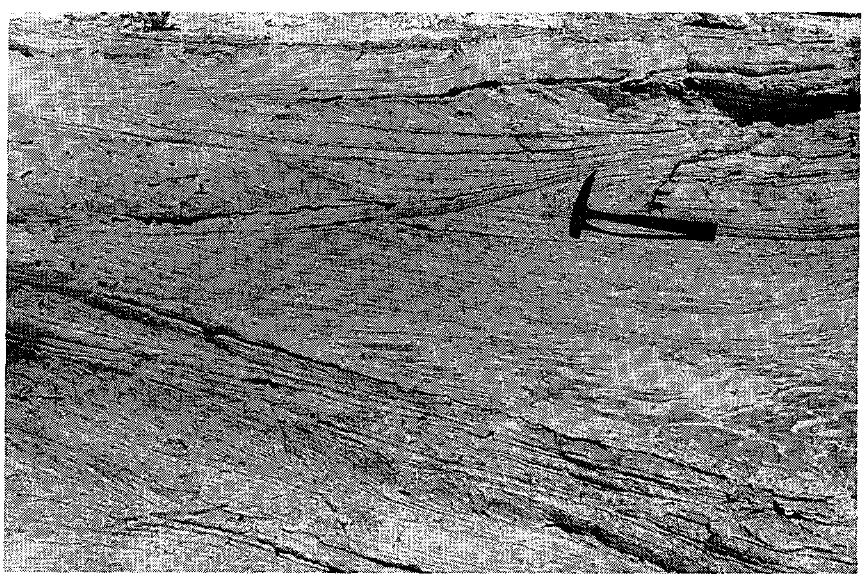


Fig. 3c. Wedge-planar cross-bed sets show a tangential relationship towards underlying strata, Stop 2.

slopes, and climbing wind ripples (Fig. 4b).

The strata produced by climbing wind-ripples are millimeter laminations with even thickness and sharp contacts resulting from inverse size grading, although the latter detail is not always readily visible in the field. If net sedimentation is to occur by the migration of wind-ripples, then each successive ripple must climb relative to the stratum deposited by the previous one. Grain size segregation in wind-ripples concentrates relatively coarse sediment on the crests and relatively fine sediment in the troughs. As the crests and troughs migrate, they deposit a layer of relatively coarse grains overlying a layer of relatively fine ones; hence the upward size grading within each stratum produced during deposition by a migrating wind-ripple. Wind-ripples may climb up, down, or along both lee and stoss sides of dunes. Thus the dip angle and direction of the resulting strata are more a function of the geometry of the surface over which they have migrated than the direction of the driving wind. The passage of many wind-ripples can lead to the accumulation of sets of ripple-formed strata. On lee slopes these strata may be preserved under grainfall sediments or sandflows, providing the latter are not erosive.

Grainfall occurs when moving air currents carry saltating and suspended sediment into a sheltered area, for example the zone of separation to the lee of a dune crest. The sediment settles like falling snow and accumulates on the lee slope of the dune, where it may be joined by grains that crept over the dune crest in response to collisions with saltating grains. Grainfall strata tend to be thin and indistinct, and, because they commonly form on lee slopes, they often have a high initial dip (Hunter, 1981). On small dunes, though, grainfall could occur as far forward as the toe of the dune, and the strata would lie at low angles. In wind tunnel experiments conducted by Fryberger and Schenk (1981), grainfall strata deposited on lee slopes consistently wedged thinner downslope, and this may be anticipated on natural dune lee slopes as well.

Sandflow strata form by resedimentation of sands that accumulate on the upper part of lee slopes, often by grainfall, until the slope oversteepens and becomes unstable. If the sands are dry, they will flow non-cohesively, but, if crusted or partially lithified in some way, they may founder as blocks subject to all kinds of jumbling and deformation. Sandflow strata are typically thicker than other wind-deposited strata, commonly exceeding 1 cm. They have sharp contacts, lie close to the angle of repose, and tend to pinch out towards the base of a foreset (Hunter, 1981). They have a distinctive lenticular shape when seen in strike cross-section or in horizontal exposures (Fig. 4c).

These types of wind-formed strata were recognized by studying modern coastal dunes (Hunter, 1977). Several attempts have been

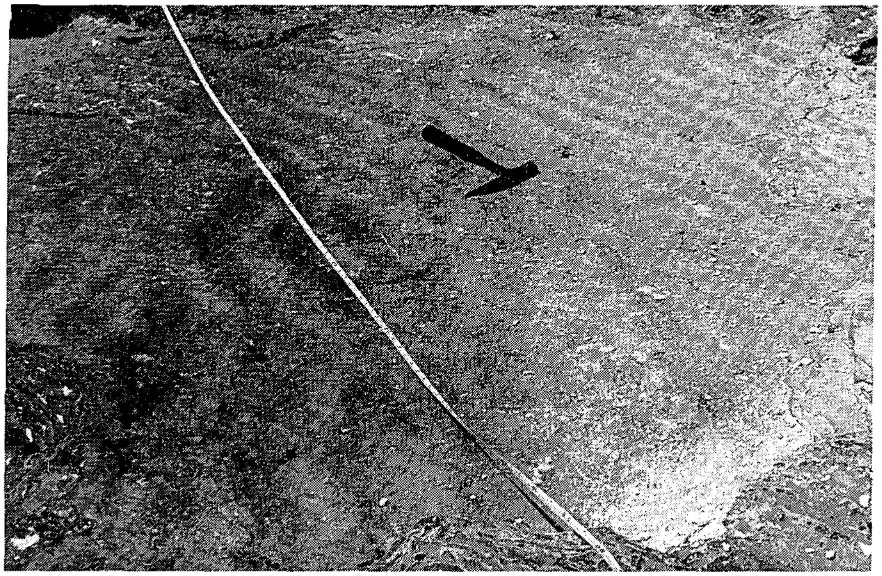
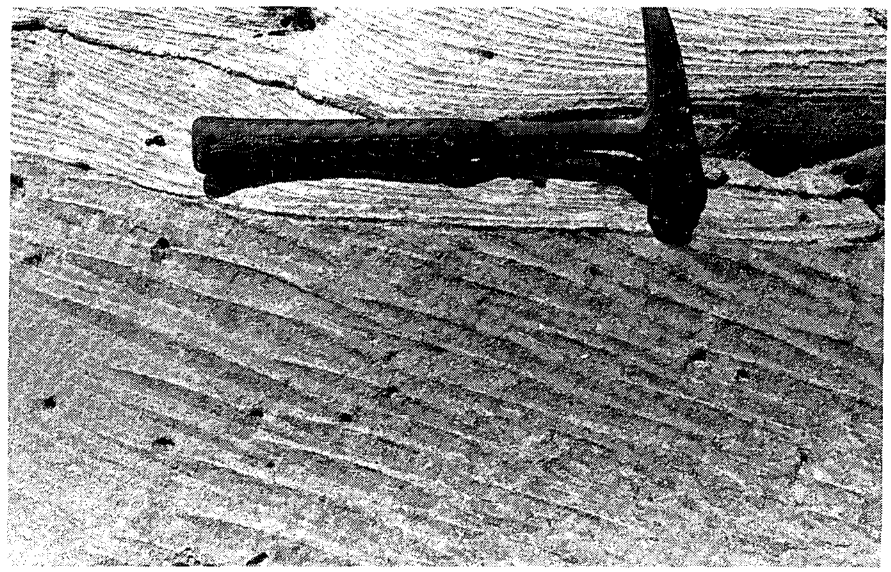


Fig. 4a. Wind-formed ripples on a bedding surface at Stop 2. Ripple indices here are 23 to 32.

Fig. 4b. Sandflow strata occur within grainfall strata at Stop 3, with both overlain by wind-ripple-formed strata.



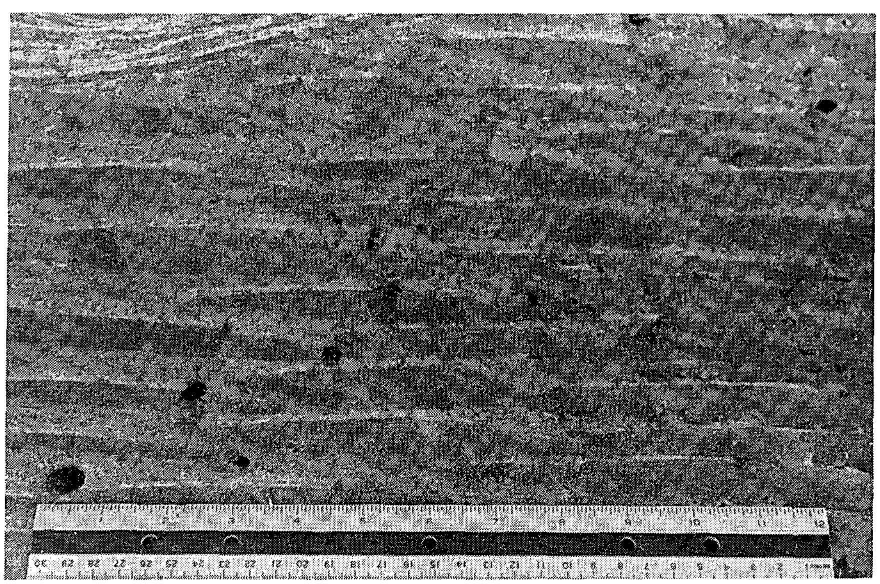


Fig. 4c. Lenticular sandflow strata within grainfall deposits, Stop 3.

made to use these strata to identify and more closely characterize ancient siliciclastic rocks believed to be of eolian origin. A sampling includes: Pleistocene of Oregon (Hunter, 1980); Permian of Arran, Scotland (Clemmensen and Abrahamsen, 1983); and various Paleozoic and Mesozoic formations of the western United States (Fryberger and Schenk, 1981; Hunter, 1981). Prior to this study, similar analyses do not seem to have been reported for carbonate rocks, and these various wind-deposited strata are not mentioned in a recent review of carbonate eolian environments (McKee and Ward, 1983).

To continue this field trip, stay at the top of the sea cliffs and walk around the small bays and headlands for about 200 m. Hereabouts a more prominent trail joins from the south, and the wreck of a misplaced tanker scars the coast to the northeast. Follow the winding trail northward along the spine of the narrowing peninsula. Along the way one will pass many exposures of eolianites, and one can enjoy fine views to the west (left) over Grahams Harbour and to the east over Rice Bay and Man Head Cay. After walking about 400 m beyond the wreck, the edge of a cliff is reached, overlooking a tidal inlet and an island to the north. This is the next field trip locality.

STOP 4. Here, at the north end of North Point, the cliffs are formed by the north flank of a well-developed lobate dune, and the cross-bedding dips north and steeply down into the sea. A 40 m wide inlet, The Cut, separates North Point from the nearby island of Cut Cay. The cliffs of the south end of Cut Cay are part of the south flank of another dune, and the cross-bedding dips down into the sea on that side too, but in a southerly direction. Evidently, the sea has driven through along a low interdune area and separated Cut Cay from the rest of the peninsula. According to legend, The Cut did not exist at the time of Columbus' visit in 1492.

From this location a good view of the seafloor to the west out into Grahams Harbour and to the northwest towards Cut Cay can be obtained. This perch provides an excellent overview of the three different substrates which are easily explored by snorkeling in this calm (usually) water (Fig. 5a). The dark green grassbeds are dominated by Thalassia, the pale green areas are sandy bottoms, and the tan areas are hardgrounds. Calcareous green algae, including Halimeda, Penicillus, Udotea, and Acetabularia, grow in the grassy and sandy areas, their abundance and distribution varying from time to time, perhaps seasonally. A considerable variety of invertebrate animals lives among the various plants of these different environments and await careful and sharp-eyed explorers.

Following this preview, climb down the west side of North Point by taking the only obvious (and safe) route to the small beach. This is the location of the next field trip stop and the starting point for the snorkel dive.

STOP 5. A number of well-developed lobate dunes are clearly exposed in the cliffs on the west side of North Point (Fig. 5b and 5c). Here the dunes have reached a more mature stage of development than some seen along Rice Bay. The opposing flanks of each dune dip steeply and in opposite directions. Along this part of the coast the relationships between adjacent dunes are revealed. In some cases, one dune flank overlaps the flank of the nearest dune, suggesting that the former was mobile and the latter stabilized, at least temporarily. In other situations, adjacent dune flanks interfinger and both dunes appear to have been mobile. This entire coastline is made up of a row of these coalesced lobate dunes that is clearly visible from the vicinity of the CCFL Bahamian Field Station, especially when illuminated by the setting sun. Dune lobes that coalesce to form such a transverse dune ridge have been described from Pleistocene carbonate rocks of other parts of the Bahamas by Ball (1967) and from Bermuda by MacKenzie (1964a,b).

The fact that wind-deposited cross-beds dip down into the sea here at North Point adds further evidence that these eolian dunes formed before sea level rose to its present position. Additionally, such evidence shows that the wind-blown sands were sufficiently lithified by the time sea level rose to resist simple reworking of the sand.

STOP 6. The small beach here is an excellent place to begin a snorkel dive to explore various substrates and associated flora,

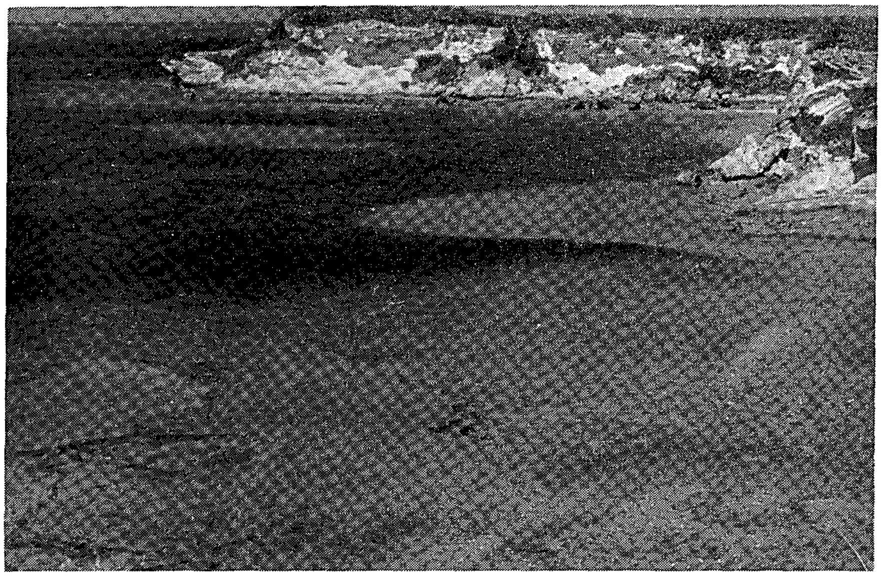
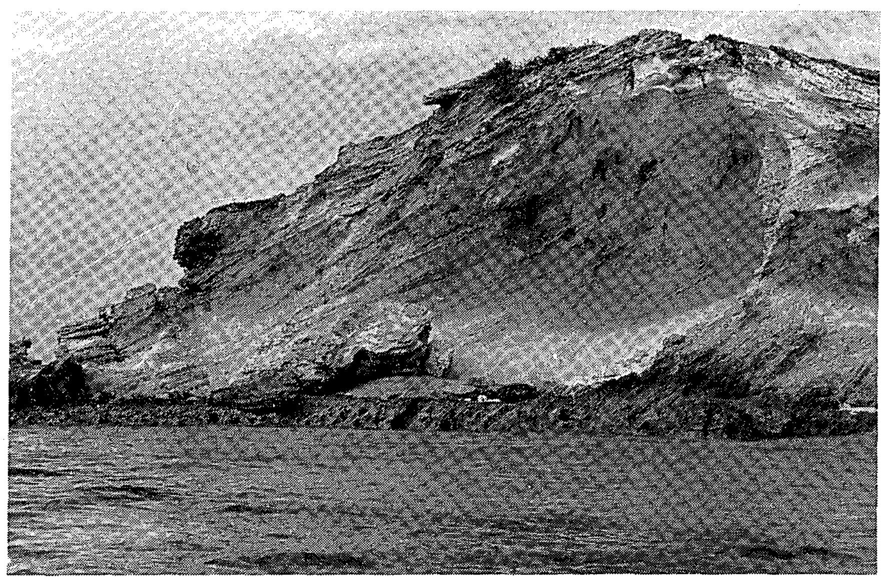


Fig. 5a. Overview from the Stop 4 location on North Point of grass beds, hard-grounds, and sand substrates, looking towards Cut Cay.

Fig. 5b. View from the west of lobate dune forming the north end of North Point, Stop 5.



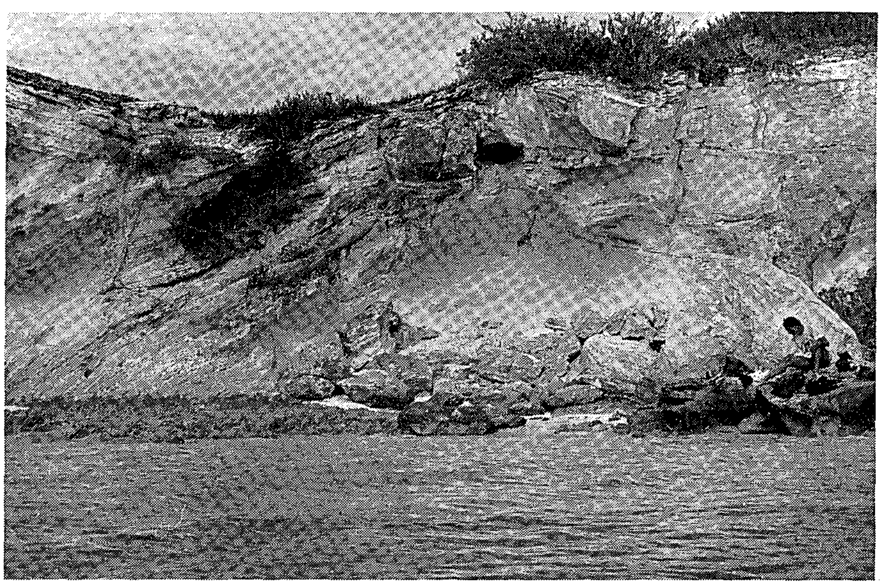


Fig. 5c. View from the west of lobate dune immediately to the right (south) of the dune shown in Fig. 5b, Stop 5.

fauna, and sediments between North Point and Cut Cay. From a short distance offshore an excellent view of several of the coalescing dune lobes may be obtained.

## ACKNOWLEDGMENTS

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