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# Geology of Rum Cay, Bahamas: A Field Trip Guide

John E. Mylroie
*Mississippi State University*

James L. Carew
*College of Charleston*

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

Jonathan B. Martin
*University of Florida*

Thomas A. Rothfus
*Gerace Research Center*

*See next page for additional authors*

Authors
John E. Mylroie, James L. Carew, H. Allen Curran, Jonathan B. Martin, Thomas A. Rothfus, Neil E. Sealey, and Fredrick D. Siewers

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**14th Symposium on the Geology of the Bahamas and Other Carbonate Regions**

**Gerace Research Center**
**San Salvador, Bahamas**
**2008**

**COVER PHOTOGRAPH:** Looking east at Jim Carew on a pinnacle, Signal Point, Rum Cay. The eolianites shown here are Holocene, North Point Member of the Rice Bay Formation. The dune ridge rises to 25 m elevation (see Stop 6 description, Figures 18 and 19). All photos in this field guide that are unattributed, as is this photograph, were taken by John Mylroie.

and Other Carbonate Regions

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John E. Mylroie
Dept. of Geosciences
Mississippi State Univ.
Mississippi State, MS 39762

H. Allen Curran
Dept. of Geology
Smith College
Northampton, MA 01063

Thomas A. Rothfus
. Gerace Research Center
San Salvador, Bahamas

James L. Carew
Dept. of Geology
College of Charleston
Charleston, SC 29424

Jonathan B. Martin
Dept. of Geological Sci.
Univ. of Florida
Gainesville, FL 32611

Neil E. Sealey
Media Enterprises Ltd.
P.O. Box N-9240
Nassau, Bahamas

Fredrick  D. Siewers
Dept of Geography & Geology
Western Kentucky Univ.
Bowling Green, KY 42101




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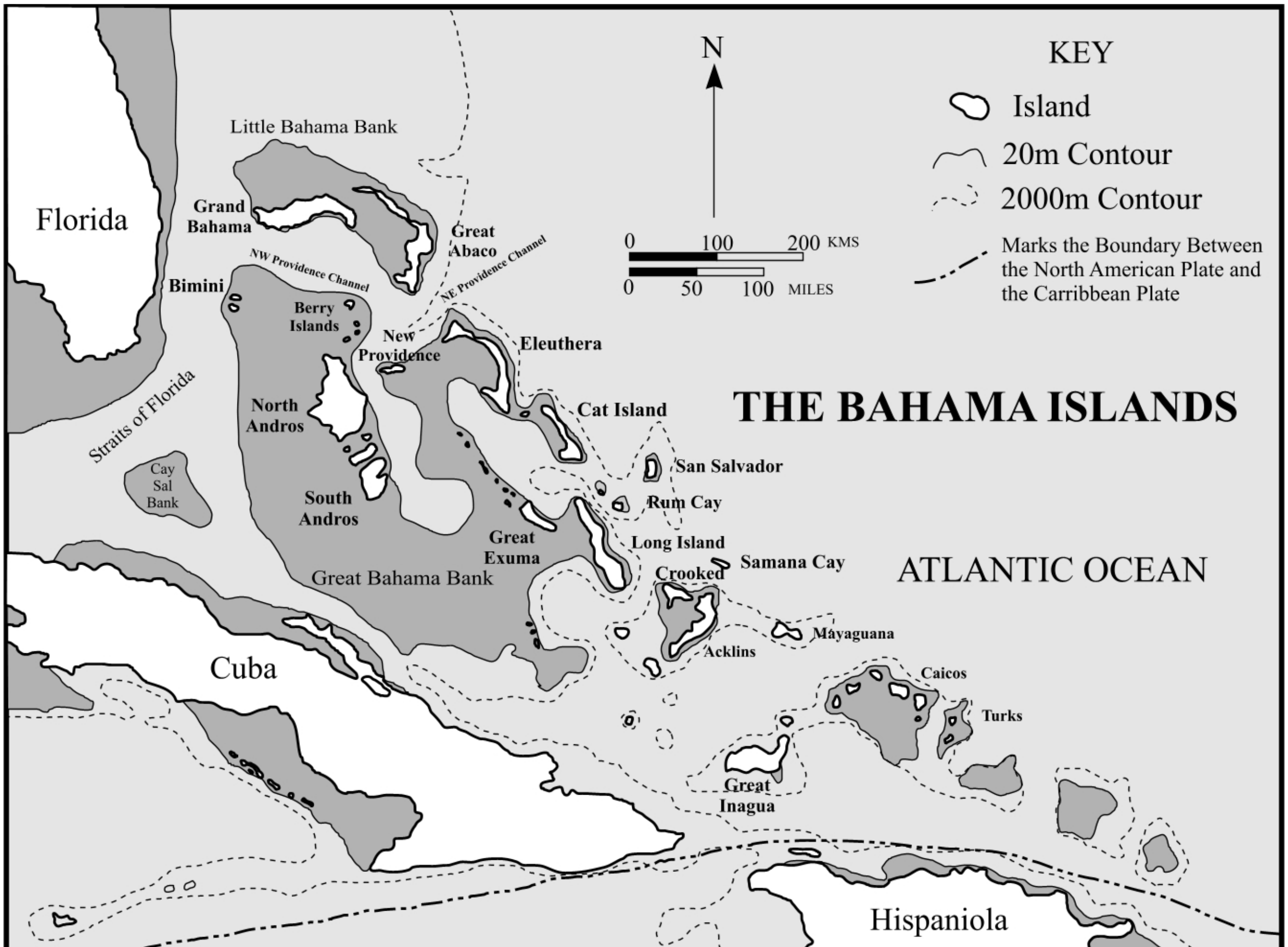


Figure 1. Map of the Bahamian Archipelago, showing the location of San Salvador Island and Rum Cay . Conception Island is the tiny island northwest of Rum Cay. From Walker, 2006.

# INTRODUCTION

Rum Cay, Latitude N23 42’ 30” Longitude W74 50’ 00”, is the second island visited by Christopher Columbus in 1492; he named it Santa Maria de la Concepcion (Albury, 1975). Conception Island is now the name of a small island 22 km to the northwest of Rum Cay (Figure 1). The Lucayans called Rum Cay “Mamana”; the name Rum Cay allegedly came from some early Spanish explorers who landed on the island and found a keg(s) of rum washed up on the beach ((Popov and Popov, 1988). In 1670, King Charles II gave a group called the Lord Proprietors a grant of land on Rum Cay that included salt royalties. Salt became a major export, and Rum Cay was second only to Great Inagua Island in salt production, producing 300,000 bushels of salt in 1802 (Wilson, 1992). The salt industry was wiped out by a major hurricane in 1853, and while it recovered some of its capacity in later years, it was never again able to compete with Great Inagua (Albury, 1975). Cotton had been an early crop, but the soil could not support long term production, and that industry failed (Albury, 1975). Pineapple was also a money crop for Rum Cay, but was out competed by the Hawaiian Islands and fell by the wayside (Wilson, 1992). A major hurricane in 1926 ended major pineapple production on the island (Popov and Popov, 1988). Sisal was also an export crop, and survived until the 1930s when synthetic fibers began to replace it (Popov and Popov, 1988).

In the mid-19$^{th}$ century, the island population was once as much as 800 people, but by 1886, it had dropped to 350 (Albury, 1975). Today, the population hovers just under 100 people (Popov and Popov, 1988). Tourism revived the economy of Rum Cay to some extent in 1981 with the establishment of the Rum Cay Diving Club (Popov and Popov, 1988), but that enterprise eventually failed. A marina and hotel exist at Sumner Point, and a number of vacation homes and tourist villas dot the area between Port Nelson, the main community, and the marina at Sumner Point (Figure 2). New development, the Rum Cay Resort Marina, is currently taking place at Cotton Field Point (Figure 2), and if successful, will bring all the rewards and troubles of development to this peaceful island. The runway was recently enlarged to 1375 m to accommodate the expected increase in tourist traffic.

One claim to fame for Rum Cay is the wreck of the HMS Conqueror, the first propeller-driven warship in the British Navy. The vessel, built in 1855, struck the reef and sank in 10 m of water off Rum Cay in 1861 (http://www.rumcay.net/). Remains of the ship can still be seen by scuba divers, but it is a protected landmark of the Bahamian government.

Rum Cay is shaped a bit like a lamb chop, trending east-west, with the thick end to the east (Figure 2). It is 15 km east-west, and 8 km north-south, with an area of 78 km$^2$. The Rum Cay platform is 175 km$^2$ in area (Mitchell, 1987). The highest elevations are at the northeastern end of the island, with the high point being slightly in excess of 37 m, about 1 km southwest of Junkanoo Rock at the northeast tip of the island. Hills are found across the island, but elevations decrease progressively westward, and the highest hills in the west are only 12 m at Black Rock. There are extensive lowland plains, and numerous inland water bodies of many sizes. The largest are Carmichael Pond in the west (2.5 km long and 0.5 km wide); and Lake George in the east, an almost circular water body approximately 2 km in diameter. Smaller ponds and blue holes are scattered and abundant. A large tidal lagoon, Port Nelson Salt Lake, has a narrow connection to the open ocean on the east coast, and was the main site for salt production in the heyday of Rum Cay salt exports. Old dikes, water control structures, and dams can be seen in that area. Beautiful white sand beaches are

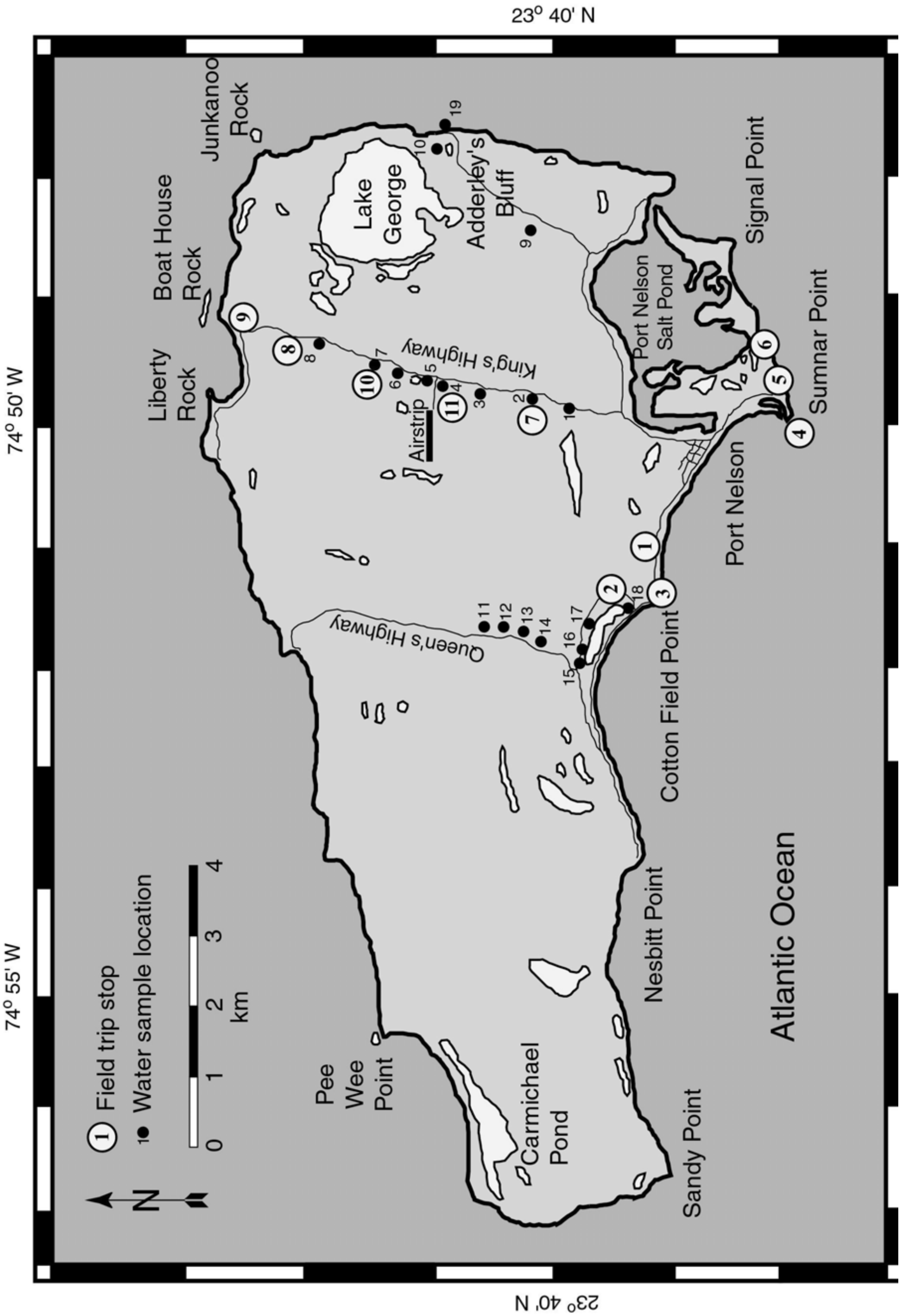


**Figure 2. Map of Rum Cay showing the major landmarks, primary roads and tracks, inland water sampling locations (small dark circles), and field trip stop locations (large open circles). Cartography by Jon Martin.**

interspersed with rocky headlands on all Rum Cay coasts. Roads are paved only in the area of Port Nelson and north to the airport. Dirt roads make up the rest of the transport network, some of which are barely more than tracks in the bush. These tracks are amazingly accessible with rugged golf carts, used in lieu of rental cars by island visitors. The new tourist development project is expanding the road network, but parts of the island, especially to the northwest, are not accessible by vehicles.

Unusual in our experience in the field across numerous Bahamian islands, Rum Cay has abundant feral cattle, and we came across them in groups of two to four a number of times. Fresh cow flops are commonly found on the road and trails. Goat scat is very common in the caves, but no live goats were seen in the wild, except a sick baby goat in a cave entrance.

## PROCEDURES AND GUIDELINES

Many of the sites we will visit are on private or restricted lands and special permission is necessary for entry to some of these areas. For these reasons, it may not be possible for someone who is using a copy of this field guide at a later date to follow precisely in our footsteps. Last-minute changes owing to weather conditions or time constraints may result in our field trip taking alternate routes and visiting a slightly different selection of sites than presented in the text. We are guests on Rum Cay, and all field trip participants are urged to treat the areas we visit with the utmost respect. It is illegal to undertake scientific research in the Bahamas without a government research permit.

**PLEASE DO NOT MAKE ANY SAMPLE COLLECTIONS AT ANY FIELD STOP WITHOUT ASKING THE FIELD TRIP LEADERS IN ADVANCE. WE REQUEST THE SAME LEVEL OF RESPECT FOR PRESERVATION OF THESE GEOLOGIC SITES FROM ALL SUBSEQUENT USERS OF THIS GUIDEBOOK.**

A section on the geology of the Bahamas, and a section on island karst processes, have been included in this field guide for those field trip participants who are unfamiliar with the Bahamas. Those sections follow immediately. For all of you "old hands", you can skip these sections and proceed directly to the **Geology of Rum Cay** section, to see what we turned up during our reconnaissance trip in February of this year. The official name for the country we are in is "The Bahamas", but "Bahamas" will be used in this field guide, as experience has taught us that readers get confused when "The" is used; as they assume a new sentence has begun. Despite recent changes in the stratigraphic code, the term "Quaternary" will be used in this field guide. The depositional events of the Bahamas are tied to Quaternary sea-level position. As a result, the Marine Isotope Stage or MIS (formally the Oxygen Isotope Stage or OIS) designation for Quaternary sea-level events is utilized in this field guide. The term "carbonates" is used in the text to include the common mineralogies of calcite, aragonite, and dolomite. The Late Quaternary carbonate units of the Bahamas have significant aragonite, as their young age has preserved the original depositional mineralogy of the allochems, and inversion to calcite has not proceeded to a conclusion as in older rocks in continental settings. Dolomite is rare in the subaerially-exposed carbonate rocks.

The Gerace Research Centre has undergone a series of name changes since its founding in the early 1970's. What began as the College Center of the Finger Lakes field station, or CCFL, became in the late 1980's the Bahamian Field Station. In 2002, in honor of its founder, Dr. Donald T. Gerace, the field station was renamed the Gerace Research Center as a 30th anniversary recognition. In 2007, as a result of closer oversight by the College of the Bahamas, the word “Center” in the title became “Centre”, the British spelling. Understanding the evolution of the field station name is important for sorting out publications from the field station cited in the literature. The field station website is now www.geraceresearchcentre.com

## REGIONAL SETTING

The Bahama Islands comprise a 1,000 km long portion of a NW-SE trending archipelago that extends from Little Bahama Bank off the coast of Florida to Great Inagua Island, just off the coast of Cuba (Figure 1). The archipelago extends farther southeast as the Turks and Caicos Islands, a separate political entity, and terminates with Silver Bank and Navidad Bank. The northwestern Bahama islands are isolated landmasses that project above sea level from two large carbonate platforms, Little Bahama Bank and Great Bahama Bank. To the southeast, beginning in the area of San Salvador Island, the Bahamas comprise small isolated platforms capped by islands that cover a significant portion of the available platform area. The Bahamian platforms have been sites of carbonate deposition since at least Cretaceous time, resulting in a minimum sedimentary rock thickness of 5.4 km (Meyerhoff and Hatten, 1974) and perhaps as much as 10 km (Uchupi et al., 1971). The large platforms to the northwest are dissected by deep channels and troughs (Figure 1), whereas the isolated platforms of the southeastern Bahamas are generally surrounded by deep water. Water depths on the platforms are generally less than 10 meters.

The origin of the Bahama platforms has been the subject of much debate, from which two main theories have evolved. Mullins and Lynts (1977) proposed a "graben" hypothesis, which explains the current configuration of the Bahama Archipelago as the result of plate tectonic motion that opened the Atlantic Ocean in the Jurassic. The pattern of banks, troughs and basins is explained as resulting from an initial horst and graben pattern consistent with continental rifting. The competing theory is the "megabank" hypothesis (Meyerhoff and Hatten, 1974; Sheridan et al., 1981; Ladd and Sheridan, 1987), which holds that the modern Bahamas are a segmented remnant of a much larger and continuous Mesozoic carbonate platform. Recent work by Eberli and Ginsberg (1987), Mullins and Hine (1989; 1990), Melim and Masaferro (1997), and Manfrino and Ginsberg (2001) has demonstrated that the Bahama banks are undergoing both depositional progradation and erosional segmentation.

The geologic literature on the Bahamas is extensive, but until recently the bulk of that literature dealt with the carbonate banks and related deep-water environments. With the exception of San Salvador, comparatively little work had been done before 1980 on the subaerial geology of other Bahamian islands. The first modern geologic map of a Bahamian island was not published until Titus' work on San Salvador in 1980 (Titus, 1980). Hutto and Carew (1984) on San Salvador, Garrett and Gould (1984) on New Providence, Carew and Mylroie (1985) on San Salvador, Wilbur (1987; 1991) on Little San Salvador and West Plana Cay, Carew and Mylroie (1989a) on South Andros, and Kindler (1995) on Lee Stocking Island, represent some of the initial attempts to provide geologic descriptions of whole islands. A thorough overview of Bahamian island geology can be found in Curran and White (1995), and in the three papers found in Chapter 3 of Vacher and Quinn (1997).

## SUBAERIAL GEOLOGY OF THE BAHAMAS

The exposed rocks of The Bahamas are all mid to late Quaternary carbonates, dominated by eolianites and subtidal facies at low elevations, and solely by eolianites at elevations above 8 m. Paleosols can occur at all elevations. The glacio-eustatic sea-level changes during Quaternary time alternately have flooded and exposed the Bahamian platforms, subjecting them to cycles of carbonate deposition and dissolution, respectively. Significant carbonate deposition has occurred only when the platforms are flooded.

The carbonate sequences of the Bahama islands and banks comprise sedimentary packages deposited during each sea level highstand that flooded the banktops, separated by erosional unconformities (usually marked by paleosols) produced during each sea-level lowstand (Carew and Mylroie, 1995a; 1997). Each depositional package consists of three parts: a transgressive phase, a stillstand phase, and a regressive phase. These phases each contain a subtidal, intertidal, and eolianite component. Holocene sea level is sufficiently high that the only marine deposits exposed on land today are those associated with the high stillstand phase of marine isotope substage 5e (MIS 5e), about 131,000 to 119,000 years ago (Chen et al., 1991). At its maximum, sea level then was about 6 m higher than at present. The transgressive and regressive marine deposits of substage 5e are below modern sea level, and the stillstand subtidal deposits of sea-level highstands prior to those of substage 5e also are not visible. Given isostatic subsidence rates of 1-2 m per 100,000 years (Mullins and Lynts, 1977; Carew and Mylroie, 1995b), earlier highstands were either not high enough, as for stage 7, or if high enough, occurred too long ago, as for stage 9 and earlier, to have those subtidal deposits expressed above modern sea level. In contrast, eolianites form topographic highs that extend well above past and modern sea levels, so eolianites from numerous highstands, from the mid Pleistocene to the Holocene, are widely exposed on Bahamian islands.

During transgression, carbonate sediments are deposited when bank tops flood, and beach sediments are continually remobilized by the bulldozing action of the advancing sea. Large dunes are formed, which may be subsequently attacked by wave action as sea level continues to rise. Only the largest or most favorably positioned transgressive eolianites survive the rise of sea level to a maximum. During the stillstand of an interglacial sea-level high, subtidal and intertidal facies are deposited, but as the system reaches equilibrium, eolianite production is apparently less than during transgression. This decrease in eolianite production may be a response to reefs growing to wave base, and lagoons becoming more quiescent, such that sand supply to the beaches is reduced. During regression, stillstand subtidal lagoon deposits are reworked as wave base and beach processes pass through them, and substantial eolianite packages can be formed. These regressive eolianites are eventually abandoned as sea level falls below the bank tops and sediment production effectively ceases. As sea level moves off the platform, erosional forces take over and soils are produced that will eventually be preserved as paleosols. It is important to recognize that during the Quaternary, the Bahamas have been in a sea-level lowstand condition as a result of glacio-eustasy for about 85 to 90% of the time. The Quaternary carbonate units seen exposed in the Bahamas today represent deposition during that small fraction of the time when sea levels were high enough to flood the banks and turn on the carbonate sediment factory.

In the Bahamas, the most complete sequence of deposits representing a transgression, stillstand, and regression cycle is the depositional package formed during the MIS 5e event. Older packages are incomplete, for the reasons given earlier, and the Holocene package does not, as yet, contain a true regressive phase (although it does contain progradational regressive deposits). A general model for the development of the stratigraphy of Bahamian islands was first proposed by Carew and Mylroie in 1985. This model was developed using San Salvador Island as the specific example, but has been successfully transported

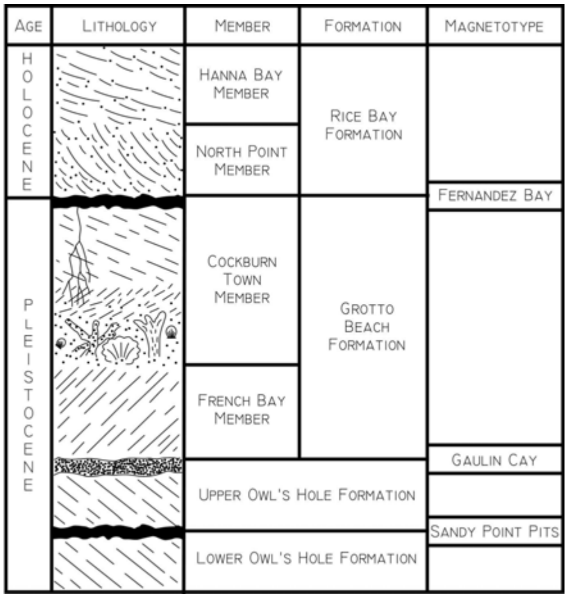


**Figure 3. Stratigraphy of the Bahamas. Note that the magnetotype designations cannot be recognized in the field.**

to other islands by Carew and Mylroie (1989b) and by other workers (Wilbur, 1987, 1991; Kindler, 1995). The model has been modified with the accumulation of new data (Carew and Mylroie, 1989b; 1991; 1995a; 1997). A stratigraphy developed from this model is presented in Figure 3, and it is the basis for the stratigraphic assignments and descriptions given in this field guide. This stratigraphy is based on field relationships, and does not require the use of geochronological tools, although it subsequently has been substantiated by a number of geochronologic methods (Carew and Mylroie, 1987). A spirited debate developed in the 1990s about Bahamian stratigraphy (see Carew and Mylroie, 1997, and references therein) centered on the reliability of amino acid racemization (AAR) analyses for making stratigraphic subdivisions in the absence of evidence provided by field relationships.

The eolianite packages older than MIS 5e were initially lumped together as the Owl's Hole Formation, although it was recognized at the time that this unit probably contained eolianites from a number of pre-substage 5e sea-level events (Carew and Mylroie, 1985). AAR data were subsequently used to subdivide the Owl's Hole into multiple units on San Salvador Island (Hearty and Kindler, 1993). While AAR data were considered controversial, it was later established on Eleuthera Island that subdivisions of the Owl's Hole could be demonstrated in the field (Kindler and Hearty, 1995; Panuska et al., 2002). Paleomagnetic analysis of the secular variation in paleosols also indicated that the Owl's Hole could be subdivided (Figure 3) into at least an upper and lower unit on San Salvador Island (Panuska et al., 1999). The eolianites of the Owl's Hole Formation are predominantly bioclastic, and ooids are extremely rare. The Owl's Hole Formation is usually recognized in the field by its relationship to overlying deposits. Efforts to subdivide units in the Bahamas by petrologic methods have been attempted (e.g. Kindler and Hearty, 1996; 1997), but demonstrated petrologic variability among single Pleistocene units, as well as in Holocene units, indicates that this technique is not reliable (e.g. Sparkman et al., 2001).

Overlying the Owl's Hole Formation, and separated from it by a paleosol or other erosion surface, is the Grotto Beach Formation. This formation was deposited during MIS 5e time, and it consists of two members. The older French Bay Member is a transgressive eolianite (Carew and Mylroie, 1985; 1997). In some places, transgressive eolianites are marked by an erosional platform on which later stillstand fossil corals are found (Halley et al., 1991; Carew and Mylroie, 1995a). The Cockburn Town Member is a complex array of stillstand subtidal and intertidal facies overlain by regressive eolianites. In earlier versions of the stratigraphic model (Carew and Mylroie, 1985; 1989b), the Grotto Beach Formation also contained the Dixon Hill Member, an eolianite thought to have been deposited during MIS substage 5a about 85,000 years ago. This member was later eliminated (Carew and Mylroie, 1995a; 1997) because it was based solely on amino acid racemization data that later proved to be incorrect (Mirecki et al., 1993). During Grotto Beach time, ooids were produced in great numbers, and the vast majority of eolianites in the Grotto Beach Formation are either oolitic or contain appreciable ooids.

Another debate concerning Bahamian geology involves the existence of MIS 5a eolianites (see Carew and Mylroie, 1997; Kindler and Hearty, 1997 and references therein). As noted above, AAR data were used to identify a substage 5a eolian unit in 1985 (Carew and Mylroie, 1985), but that unit was dropped when field work demonstrated that the unit in question was older than substage 5e (Carew and Mylroie, 1997), and laboratory tests indicated that use of the land snail *Cerion* for AAR work was extremely unreliable (Mirecki et al., 1993). Subsequently, it was argued that whole rock AAR data was reliable and it has been used to identify substage 5a eolianites on a number of Bahamian islands (Kindler and Hearty, 1997 and references therein). However, no field evidence has been able to demonstrate, one way or the other, that substage 5a units exist in the Bahamas. AAR data have been used to identify substage 5a eolian units on Bermuda (Vacher and Hearty, 1989).

Overlying the Grotto Beach Formation and separated from it by a paleosol or other erosion surface are the rocks of the Rice Bay Formation, deposited during Holocene time. The Rice Bay Formation also is divided into two members, based on their depositional history relative to Holocene sea level. The North Point Member consists entirely of transgressive-phase eolianites. North Point foreset beds can be followed at least 2 m below modern sea level in some places. Whole rock carbon-14 measurements from the North Point Member indicate ages centered around 5,000 yBP (Carew and Mylroie, 1987). Laterally adjacent, but rarely in an overlying position, is the younger Hanna Bay Member (see Curran, et al., 2004 for an example of the Hanna Bay Member overlying the North Point Member). This unit consists of intertidal facies and eolianites deposited in equilibrium with modern sea level. The eolianites have a radiocarbon age centered around 3,000 yBP, but some beach rock has ages as young as 400 yBP (Carew and Mylroie, 1987). While weakly developed ooids have been reported from the early stages of North Point Member deposition (Carew and Mylroie, 1985; Carney and Boardman, 1991; White, 1995), the Rice Bay Formation rocks are predominantly peloidal and bioclastic, although in some places, such as Cat Island, there are highly oolitic Holocene rocks. North Point Member rocks around the Bahamas are now being attacked by wave erosion. Sea caves, talus, and coral communities on wave-cut eolianite benches of the North Point Member exist, as mentioned earlier for the rock record of the transgressive French Bay Member of the Grotto Beach Formation.

## FRESHWATER LENS HYDROLOGY AND KARST PROCESSES

In any essentially homogeneous body of rock like that of the carbonates forming the Bahamian islands, the freshwater lens floats on underlying, denser seawater that permeates the subsurface. The model for the ideal behavior of such water masses is the Ghyben-Herzberg-Dupuit model. In reality, variations in rock permeability and other factors result in distortion of the ideal lens shape in the Bahamas (e.g. Vacher and Bengtsson, 1989). Nonetheless, the Ghyben-Herzberg-Dupuit model serves as a useful first approximation of the relationship between the freshwater and underlying marine groundwater in an island.

During past higher stands of the sea, the fresh groundwater lens in each island was as high, or higher than it is today. Beneath the surface of those past freshwater lenses, within the limestone rock of the islands, caves were produced by dissolution. Each time sea level fell, the caves became abandoned and dry. Under today's climatic conditions the Earth is warm and sea level is relatively high, but not quite as high as at some times in the past. We can therefore enter dry caves today throughout the Bahamas. In contrast, the blue holes of the Bahamas lead into caves that are flooded by seawater. These blue holes represent the cumulative dissolution and collapse that has occurred during many sea-level fluctuations. The complexity of cave passages found in blue holes is the result of overprinting of repeated marine, freshwater, and subaerial conditions throughout Quaternary time. Conversely, the presently dry caves of the Bahamas formed during the relatively short time periods of the late Pleistocene when sea level was higher than at present. Bahamian caves that formed above modern sea-level elevation prior to MIS 5e time today lie below modern sea level owing to isostatic subsidence of the platforms (Carew and Mylroie, 1995b); however some data can be marshaled that call this interpretation into question (Lascu, 2005). Taking isostatic subsidence into account, sea level was high enough to produce the observed subaerial caves for a maximum of about 12,000 years of the MIS 5e time period. In addition, during that sea-level highstand, only the eolian ridges and a few beach and shoal deposits stood above sea level, and island size in the Bahamas was dramatically reduced compared to that of today's islands. As a consequence, freshwater lens volumes and discharges were comparably reduced. An end result of this scenario is recognition that dry Bahamian caves seen today represent development during a very short time period within small freshwater lenses and with minimal overprinting by later events. Any model that attempts to explain development of these dissolutional caves must operate under these tight constraints of time and space.

The largest of these caves develop by mixing dissolution at the distal margin of the fresh water lens, under the flank of the enclosing landmass, so they are called *flank margin caves* (Mylroie and Carew, 1990). Abundant, but smaller caves develop at the top of the lens, away from the lens margin. In the Bahamas, they commonly develop in the broad, low-elevation regions that make up significant parts of these islands. As a result, their roofs are prone to collapse, and they are common features. Once collapsed, they collect soil and vegetative debris, as well as water and are favored for the growing of specialty crops, such as bananas, which is how their name, *banana hole*, was derived. Figure 4 is an idealized representation of the major karst features found in the Bahamas, excepting blue holes.

The Bahamas were the starting point for the development of what has become the Carbonate Island Karst Model (Jenson et al., 2006) or CIKM. The salient points of this model are shown in Table 1. The key aspects are that cave and karst development in carbonate islands is very different from that found in carbonate rocks of continental interiors, where most such research has been done. Basically, karst development under the CIKM is controlled by the youthful age of the rock involved (almost always Cenozoic, commonly Quaternary), the dissolutional aggressivity provided by mixing of freshwater and seawater, and the change in sea level created by glacio-eustasy and tectonics. Island configuration, especially as regards carbonate and non-carbonate rocks is also crucial. This last item has little meaning in The Bahamas, as these islands are 100% carbonates. The youthfulness of Bahamian carbonate rocks creates different water-flow dynamics than are found in the dense, diagenetically-mature carbonates of continental interiors. The Bahamas exemplify what has been described as *eogenetic karst*, defined by Vacher and Mylroie

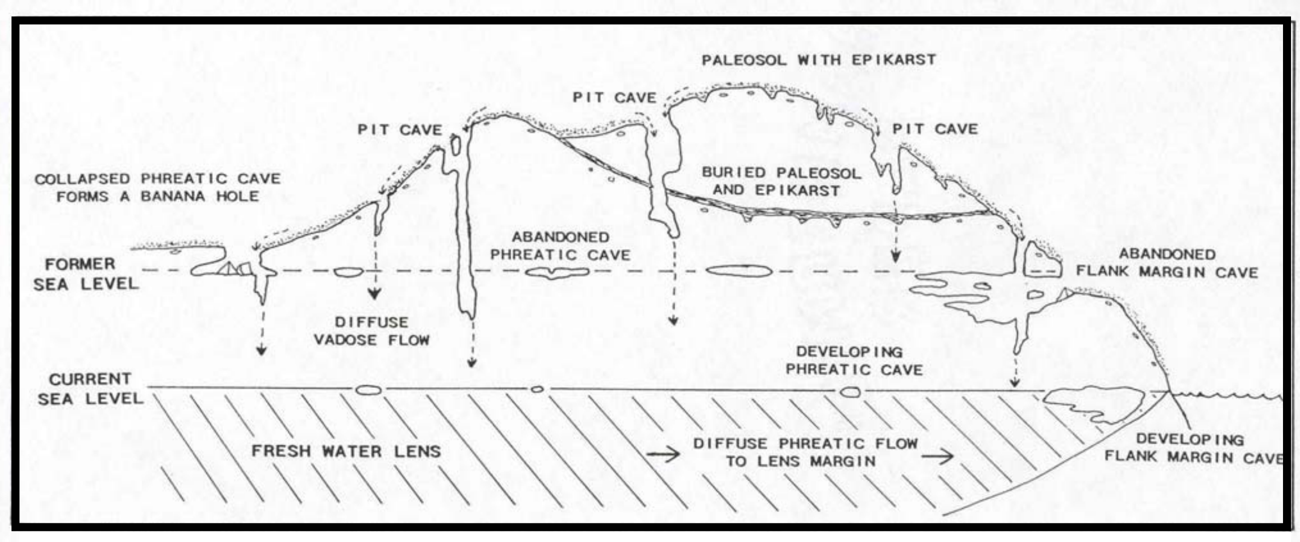


**Figure 4. Cave and karst features commonly found in the Bahamas, excepting blue holes.**

(2002, p. 183) as "the land surface evolving on, and the pore system developing in, rocks undergoing eogenetic, meteoric diagenesis." The term "eogenetic" was taken from Choquette and Pray (1970, p. 215) who defined the three time-porosity stages of carbonate rock evolution: "the time of early burial as *eogenetic*, the time of deeper burial as *mesogenetic*, and the late stage associated with long-buried carbonates as *telogenetic*." Eogenetic carbonate rocks have not been extensively compacted or cemented and retain much of their primary depositional porosity. Most carbonate islands, and almost all carbonate islands found in tropical or subtropical locations, are made up of eogenetic limestones (Late Cenozoic) that were deposited proximal to the setting in which they presently occur. The term eogenetic karren has been applied to the unique etching and dissolution of surface carbonates on carbonate islands and coasts (Taborosi et al., 2004), which encompasses interior forms as well as the traditional coastal "phytokarst" of Folk et al. (1973). Taborosi et al. (2004) also review the various terms and mechanisms proposed over the years to describe and explain such karren, providing updated interpretations. Island karst has been defined as that which forms under the constraints of the CIKM, whereas karst that develops in the interior of islands, removed from CIKM controls, is karst on islands (Vacher and Mylroie, 2002). For example, the caves and karst found in the Bahamas is island karst, but the cockpit karst of Jamaica, or the Mogote karst of Cuba and Puerto Rico, is karst on islands, as it differs little from what would be found in a tropical, continental interior karst.

A famous karst feature of the Bahamas is the blue hole. The term "blue hole" has been used in a variety of ways. A complete review of the history of blue hole studies, and the various uses of the term, can be found in Mylroie et al. (1995). A different approach to defining and describing blue holes can be found in Schwabe and Carew (2006). Blue holes are defined here as: "subsurface voids that are developed in carbonate banks and islands; are open to the earth's surface; contain tidally-influenced waters of fresh, marine, or mixed chemistry; extend below sea level for a majority of their depth; and may provide access to submerged cave passages." (Mylroie et al., 1995, p. 225). Blue holes are found in two settings: "ocean holes open directly into the present marine environment and contain marine water, usually

**Table 1. Carbonate Island Karst Model or CIKM**

| ***Common attributes*** **that distinguish** ***island karst*** **from karst of interior settings** | ***Distinct geomorphic types*** **that distinguish carbonate islands from one another** |
|---|---|
| The karst is *eogenetic*. | *Simple Carbonate Islands:* Non-carbonate rocks remain below the zone of fresh-water influence, and recharge is exclusively autogenic. (Fig. 1a) |
| *Dissolution is enhanced at the surface, bottom, and margin of the freshwater lens* by mixing of waters and trapping of organic materials at these boundaries. | *Carbonate Cover Islands:* Non-carbonate basement rocks deflect percolating water and partition the fresh-water lens. (Fig. 1b) |
| *Glacio-eustatic sea-level fluctuations* impose dissolutional and diagenetic imprints reflecting the vertical migration of the lens. | *Composite Islands:* Non-carbonate basement exposed at the surface, and allogenic recharge is delivered to insurgences on the contacts. (Fig. 1c) |
| *Tectonic uplift and subsidence* overprints the glacio-eustatic imprints with additional dissolutional and diagenetic imprints, as well as structural modifications | *Complex Islands:* Interfingering of carbonate/non-carbonate facies and faulting combine to produce complex aquifer features. (Fig. 1d) |

with tidal flow; inland blue holes are isolated by present topography from marine conditions, and open directly onto the land surface or into an isolated pond or lake, and contain tidally-influenced water of a variety of chemistries from fresh to marine" (Mylroie et al., 1995, p. 225). The most common alternative use of the term "blue hole" is to describe large and deep karst springs in continental interiors (Mylroie et al., 1995).

In the northwestern Bahamas, blue holes with depths in the 100-125 m range are common, and it was thought that their depth was limited by the position of the lowest glacial sea-level lowstand, which was about 125 m below present sea level. However, exploratory wells commonly intersect voids below that depth, e.g. depths of 21 to 4082 m; the deepest of these voids was large enough to accept 2,430 m of broken drill pipe (Meyerhoff and Hatten, 1974). Dean's Blue Hole on Long Island is known to be over 200 m deep, ending in a vast chamber (Wilson, 1994). Blue holes commonly lead into major horizontal cave systems, such as Lucayan Caverns on Grand Bahama Island, and Conch Blue Hole on North Andros Island.

## GEOLOGY OF RUM CAY

Little work has been done on Rum Cay and thus its geology is not well known. One of the rare papers on the geology of Rum Cay is by Mitchell (1987), who presents a broad overview of the islands rocks and landforms. Interestingly, its "References Cited" list includes almost no other geology publications about Rum Cay, excepting a land resources study by Little et al. (1977). In February 2008 we conducted four days of fieldwork to assess the geology of the island and set up the field trip presented here. Although this field guide represents a step forward for the understanding of Rum Cay geology, we have barely scratched the surface. As a result, the potential for significant geological discoveries remains.

### Island Stratigraphy

The stratigraphy seen on Rum Cay follows the general pattern established on San Salvador (Carew and Mylroie, 1995a; 1997) and other Bahamian islands as presented in a series of Grace Research Centre field guides: New Providence Island (Carew et al., 1996), South Andros Island (Carew et al., 1998), Eleuthera Island (Panuska et al., 2002), Long Island (Curran et al., 2004), and Cat Island (Mylroie et

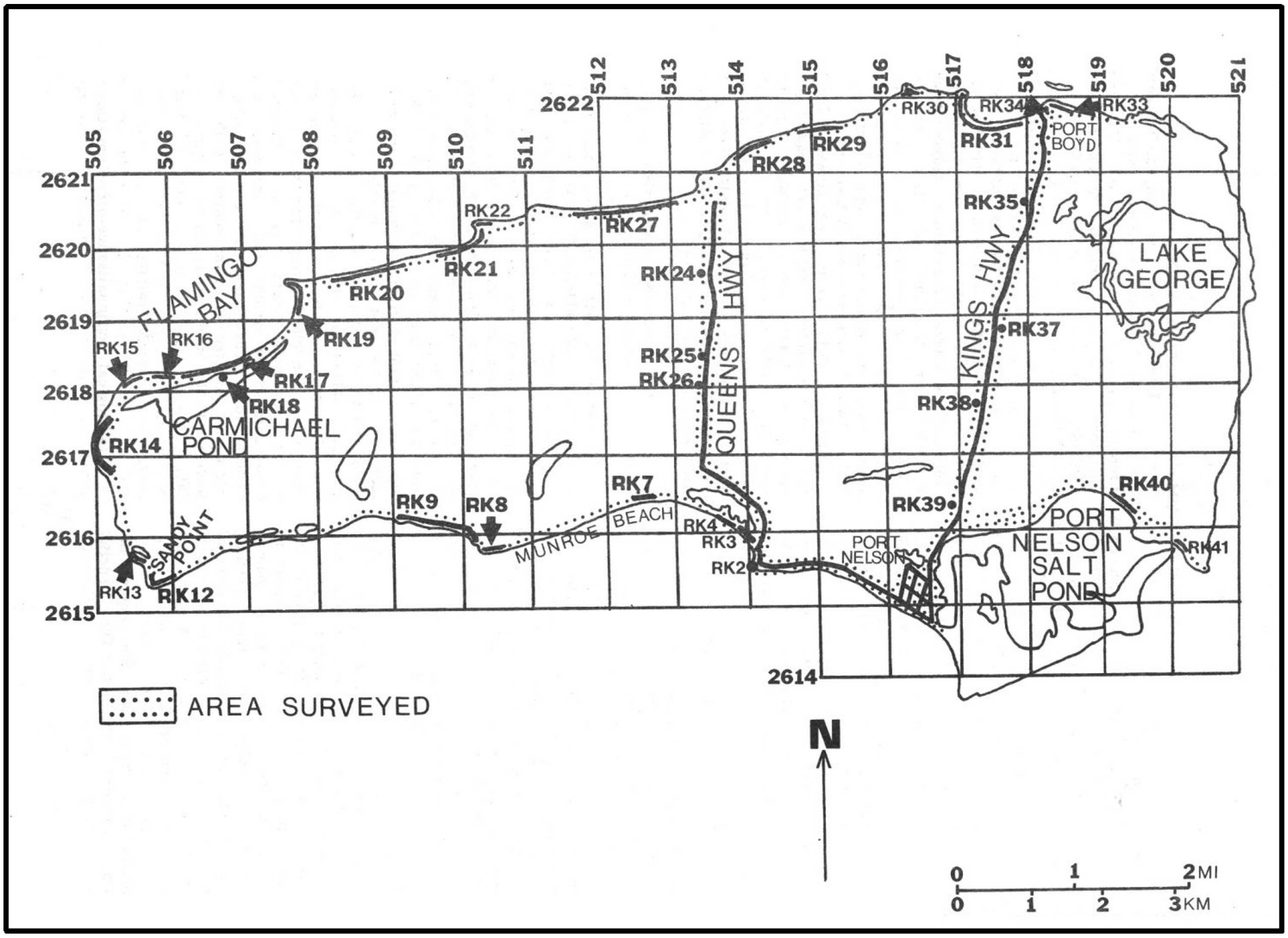


**Figure 5. Mitchell (1987) Figure 1, showing Rum Cay, major landmarks and roads, sampling locations for July 1984, and UTM grid coordinates.**

al., 2006). That stratigraphy is presented in Figure 3. All the major Bahamian surficial geologic units, including the Owl's Hole Formation, the Grotto Beach Formation, and the Rice Bay Formation, appear to be present, although the evidence for the Owl's Hole is not conclusive. Within the Grotto Beach Formation, it is clear that Cockburn Town Member subtidal and stillstand/regressive-phase eolian facies are present, but there was no solid evidence of the French Bay Member transgressive-phase eolianites. The Rice Bay Formation is well represented by voluminous North Point Member transgressive-phase eolianites as well as Hanna Bay Member stillstand-phase eolianites.

Mitchell (1987), based on an island wide reconnaissance (Figure 5), recognized both Holocene and Pleistocene units, dividing them up into five separate lithofacies: one Holocene "Beach-Dune Complex"; and four Pleistocene units, a "Poorly Cemented Eolianite" and an older "Well-Cemented Eolianite", "Tidal Creek Pelsparites and Pelmicrites", and "Coastal Shallow Subtidal Calcarenite". It is tempting to consider the poorly cemented and the well-cemented eolianites to be of different ages, as Mitchell interpreted. However, the 20+ years of fieldwork since Mitchell's publication have indicated that cementation is a very unreliable age indicator in the Bahamas,

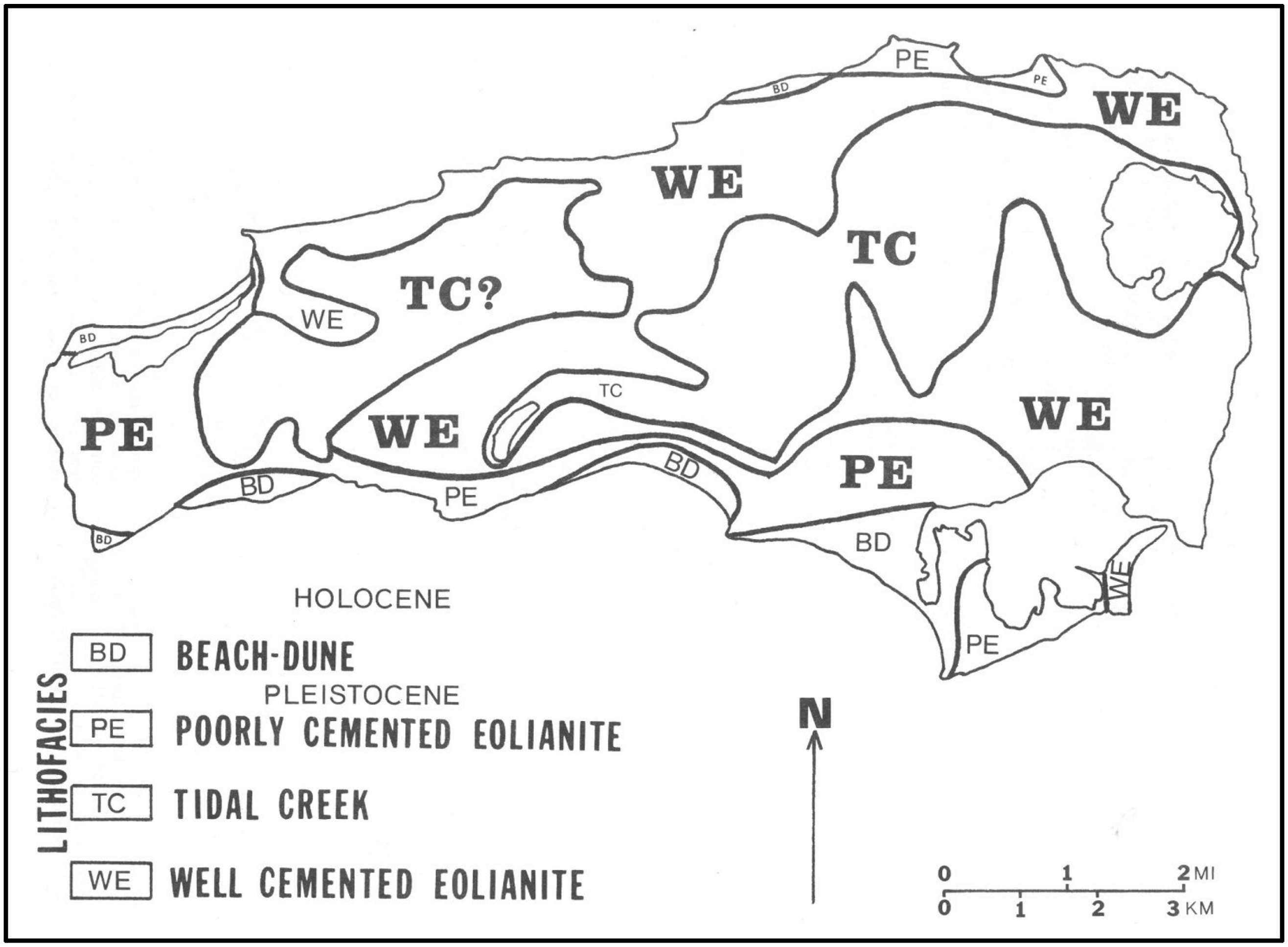


**Figure 6. Mitchell (1987) Figure 5, a preliminary geologic map of Rum Cay showing the distribution of lithofacies, and rock ages as interpreted in 1984.**

as are allochem types and distribution (Mylroie and Carew, 2008, and references therein). For example, in Figure 6 (Mitchell, 1987, Figure 5), a simplified lithofacies map of Rum Cay, eolianites from Sumner Point to Signal Point are described as “Poorly Cemented Eolianite” and Signal Point itself as “Well Cemented Eolianite”. As will be seen at Stops 4 and 6 (Figure 2), we interpret Signal Point as Holocene North Point Member eolianites, and the rocks to the southwest (to Sumner Point) are interpreted as a mix of Holocene Hanna Bay Member to Pleistocene Cockburn Town Member and Owl’s Hole Formation eolianites. These outcrops once again demonstrate how degree of cementation, especially in eolianites, is usually inconclusive as regards rock age.

Mitchell (1987) reported calcarenites comprising oosparites, pelsparites, biopelmicrites, and biosparites from various locations on Rum Cay. He considered the interior of Rum Cay to have been a large tidal creek system, the “Lake George Tidal Creek System”, during MIS 5e, and he speculated that the molluscan species present indicated warmer conditions than today. Mitchell recognized fossil corals at three coastal locations around the island, and reef rubble and subtidal calcarenites at many other locations. We will see one fossil reef locality at Stop 3 (Figure 2). Mitchell was especially interested in the tidal creek facies, and presented a five-fold classification of the facies present. We will see some of these facies at Stops 7 and 11 (Figure 2).

Mitchell (1987) accomplished his fieldwork on foot, hiking around all of Rum Cay, except the eastern coast, including two north-south interior traverses (Figure 5). This was an extraordinary accomplishment, especially considering it was done in July, 1984. Field guide authors James Carew and John Mylroie conducted a similar hike around San Salvador for 6 weeks in May and June of 1984, but did no cross-island transects. They also had the advantage of vehicle drop-offs and pick-ups and residency at the Gerace Research Centre, and still it was hot, tough work. Steve Mitchell's 1984 Rum Cay effort deserves special recognition.

### Island Hydrology: Preliminary Analysis of Water Salinity of Rum Cay.

Potable water is a limited resource across the Bahamian Archipelago and most water resources are derived from ground water (Sealey 2006). During the reconnaissance for this field trip (16-19 February 2008), 18 pools of surface water around Rum Cay were measured for their salinity, conductivity, temperature, and pH to assess the nature and distribution of the fresh water lens on the island. The sampled pools included small karst features, moderate-sized shallow lakes, and a new marina that has recently been dredged to the west of Cotton Field Point (Figure 2). In addition to the inland pools, seawater on the eastern side of the island near Adderley's Bluff was measured for salinity, conductivity and temperature. All measurements were made using an Orion model 130 portable conductivity/salinity meter and an Orion model 250A pH meter. The latitude and longitude of each pool were measured using a handheld GPS. Sample locations are shown in Figure 2, and results of the measurements are reported in Tables 2 and 3.

All of the pools that were measured had salinities that were significantly lower than seawater, although sampling occurred during the dry season. Salinity values ranged from 0 to 27.4 practical salinity units (psu), with an average salinity of all the pools of 6.4 psu. Other than a small pond south of Lake George (location 10, salinity = 27.4 psu) and the northern most pool on the Queen's highway (location 11, salinity = 19.8 psu), no pool had a salinity greater than 5.7 psu (Table 2). These results are surprising in that Mitchell (1987) reports gypsum crusts from Carmichael Pond in the far west of Rum Cay. While February is the dry season, it is not deep into the dry season and the full effects of evaporative loading may not yet have been expressed.

The low salinity of surface water on Rum Cay differs greatly from surface water on neighboring San Salvador Island, which is mostly hypersaline (Davis and Johnson 1989; Martin and Moore 2008). Davis and Johnson (1989) have compiled the most detailed description of water composition on San Salvador Island and report Cl concentrations of surface water that range from about 31 g/L to as much as 139 g/L. For comparative purposes with salinity data from Rum Cay, these concentrations can be converted to salinity assuming they are primarily seawater that has been concentrated through evaporation and originally had a Cl concentration and salinity identical to unaltered seawater of 19.8 g/L and 35 psu, respectively. With these assumptions, the average salinity of surface water on San Salvador is around 77 psu, or about an order of magnitude more salty than the average value on Rum Cay.

Davis and Johnson (1989) proposed a conceptual model for the cause of hypersaline conditions on San Salvador Island. This model

**Table 2. Salinity, Conductivity, Temperature, and pH of water of select surface water pools on Rum Cay, Bahamas**

| Road | Location | Site* | Latitude | Longitude | Date | Time | Salinity (psu) | Conductivity (µS/cm) | T (ºC) | pH |
|---|---|---|---|---|---|---|---|---|---|---|
| **King's Highway** | Tanker Site | 1 | 23º 39.765'N | 74º 49.978'W | 16-Feb-08 | 8:00 | 0.1 | 655 | 25.0 | 8.4 |
| | Ophiomorpha Pit | 2 | 23º 40.218'N | 74º 49.797'W | 16-Feb-08 | 9:00 | 0.0 | 62 | 23.5 | 8.4 |
| | North of well field | 3 | 23º 40.626'N | 74º 49.747'W | 16-Feb-08 | 9:10 | 0.0 | 45 | 23.9 | 8.3 |
| | Salt Pond | 4 | 23º 40.928'N | 74º 49.687'W | 16-Feb-08 | 9:40 | 3.8 | 6260 | 25.2 | 8.3 |
| | Unnamed pool 1 | 5 | 23º 41.094'N | 74º 49.660'W | 16-Feb-08 | 9:50 | 0.0 | 67 | 23.2 | 9.1 |
| | Unnamed pool 2 | 6 | 23º 41.265'N | 74º 49.553'W | 16-Feb-08 | 10:00 | 0.0 | 95 | 22.1 | 8.3 |
| | Twin sisters | 7 | 23º 41.454'N | 74º 49.524'W | 16-Feb-08 | 10:05 | 0.0 | 291 | 23.7 | 8.9 |
| | Mermaid pond | 8 | 23º 41.863'N | 74º 49.355'W | 16-Feb-08 | 10:20 | 0.3 | 988 | 25.1 | 8.2 |
| **East coast road** | Adley's pond | 9 | | | 16-Feb-08 | 15:30 | 4.8 | 7540 | 30.9 | 8.6 |
| | South of L. George | 10 | | | 16-Feb-08 | 16:50 | 27.4 | 38000 | 31.3 | 8.3 |
| **Queen's Highway** | Pool 1 | 11 | 23º 40.513'N | 74º 52.555'W | 19-Feb-08 | 11:10 | 19.8 | 31731 | 28.1 | 8.6 |
| | Pool 2 | 12 | 23º 40.445'N | 74º 52.060'W | 19-Feb-08 | 11:20 | 0.2 | 403 | 24.3 | 8.0 |
| | Pool 3 | 13 | 23º 40.391'N | 74º 52.060'W | 19-Feb-08 | 11:25 | 0.2 | 332 | 30.4 | 8.9 |
| | Pool 4 | 14 | 23º 40.152'N | 74º 52.077'W | 19-Feb-08 | 11:35 | 5.7 | 11116 | 28.9 | 7.9 |
| **New Marina** | Mangrove, west end | 15 | 23º 39.627'N | 74º 51.783'W | 19-Feb-08 | 11:50 | 3.7 | 8298 | 27.8 | 9.0 |
| | W. Channel | 16 | 23º 39.615'N | 74º 51.738'W | 19-Feb-08 | 12:00 | 2.6 | 6701 | 25.0 | 9.3 |
| | Main pool (surface) | 17 | 23º 39.508'N | 74º 51.571'W | 19-Feb-08 | 12:05 | 2.1 | 5903 | 26.1 | 8.9 |
| | Channel to ocean | 18 | 23º 39.288'N | 74º 51.611'W | 19-Feb-08 | 12:20 | 11.5 | 20354 | 27.5 | N/A |
| **Ocean water** | East side of island | 19 | | | 16-Feb-08 | 17:50 | 39.7 | 53100 | 26.3 | |

* Site numbers keyed to location map

| Table 3. Conductivity and Temperature gradient in main pool of new marina | | | |
|---|---|---|---|
| Depth (m) | Salinity (psu) | Conductivity (µS/cm) | Temperature (ºC) |
| 0 | 3.4 | 5903 | 26.1 |
| 0.5 | 3.4 | 5903 | 26.0 |
| 1.0 | 3.4 | 5903 | 26.0 |
| 1.5 | 3.4 | 5903 | 25.9 |

consists of multiple sources of water to the inland lakes, including rainwater, seawater flowing through conduits connecting the lakes to the open ocean at the edge of the island, and water seeping from fresh water lenses below the eolianite dune ridges that are pervasive across the island. A negative water budget exists in this region of the Bahamas, with evapotranspiration of between 1375 and 1500 mm exceeding precipitation of about 750 to 1000 mm (Sealey, 2006). This negative water budget, coupled with the large surface areas of the inland lakes, causes the lakes to become hypersaline, particularly in the dry season. Because San Salvador is located only about 20 miles to the northeast of Rum Cay, climate is unlikely to cause the difference in salinity of their surface water. The difference in salinity is more likely a result of differences in their topography, specifically the limited number of eolianite dune ridges and large lakes on Rum Cay compared to San Salvador Island. Consequently, surface water is limited on Rum Cay and seepage from what is probably a single large fresh water lens represents a more important control on the salinity of surface water than evaporation from the lake surfaces as on San Salvador Island. Additional evidence for a comparatively large fresh water lens on Rum Cay is suggested by the salinity measurements at the new marina that has been dredged on the southern side of the island at Cotton Field Point. Salinity of water at the top of the pool ranges between 2.1 and 3.7 psu and was 11.5 psu in the channel dredged between the marina and the open ocean. There is no salinity gradient in the upper 1.5 m of the pool, which is the limit for the cable length on the conductivity probe (Table 3). There is a slight, 0.2 ºC, gradient in temperature through the upper 1.5 m of the water column, indicating that the pool is stably stratified by temperature and density. The relatively low and constant salinity throughout the marina suggests that although the fresh water lens has been breached during its construction, there has been as yet little intrusion of seawater into the pool. The main channel between the marina and the ocean is not yet completely open, however, and when opened, more saline and dense seawater flowing into the marina may intrude into the fresh-water lens.

## FIELD TRIP STOPS

Arrive at Rum Cay Airport, exit the planes, board the vehicles, and proceed south on the King's Highway to Port Nelson. Take the diagonal road southwest to bypass Port Nelson and proceed due west past the old airport runway to the fence and gate at the edge of the Rum Cay Resort Marina property (aka Montana Holdings Group). Pass through the gate (GPS reading of 23$^{o}$ 39.124', 74 $^{o}$ 51.199') and turn left and park. Exit the vehicles and walk south through a small road cut to the beach.

## STOP 1 – SOUTH SHORE COAST AND COASTAL PROCESSES

This location on the leeward, south coast of Rum Cay provides an excellent view of the broadly arcuate beach and bay that lies between

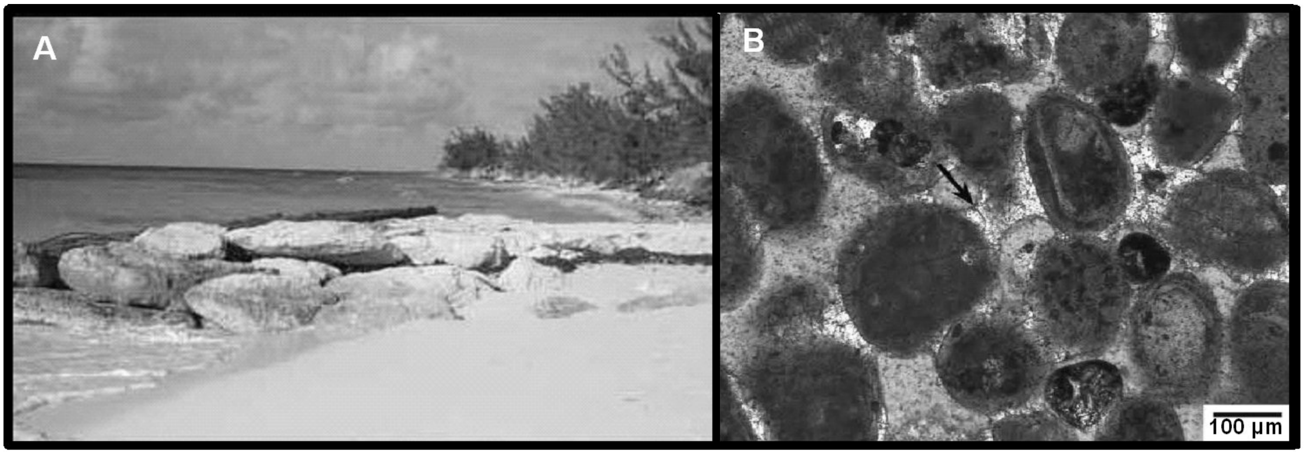


**Figure 7. Stop 1 locality. A) View looking west at Stop 1 toward Cotton Field Point. In the foreground is the Montana Holdings Group's jury-rigged off-loading ramp for heavy equipment. Note the buildup of beach sand on the east side of the ramp. Photo by Al Curran. B) Thin section photomicrograph of dune sediments held together by meniscus cements (arrow). Cement is composed of low magnesium calcite. Dune sediments consist of superficial ooids, micritized bioclasts, and coated grains. Barge landing cut, just east of Rum Cay Resort Marina. Photomicrograph by Fred Siewers.**

Sumner Point to the east and Cotton Field Point to the west. Port Nelson, the only town on Rum Cay, is at the middle point of this bay (Figure 2).

The beach itself is typical of many in the Bahamas. It is narrow, composed of fine to medium peloidal skeletal carbonate sand, and has a consistent, somewhat steep, seaward dip. Here, the backshore is classically lined with Australian pine trees (*Casurina equisetifolia,* L.), an exotic that many scientists consider to be a "nuisance" species (Sealey, 2006). The low rocky cliffs seen both to the east and west at various places along this reach of coast are formed mostly of Holocene beds of the Hanna Bay Member of the Rice Bay Formation.

The focal point of this stop is the makeshift ramp (Figure 7A) constructed by the Montana Holdings Group for the off- and on-loading of ships transporting heavy equipment used in excavating the new Rum Cay Resort Marina boat area and preparing the nearby resort development site (Stop 2). A large barge (6 x 27 m) was "permanently" moored lengthwise to the beach to form the outer edge of the ramp. Boulders of local rock and other fill materials were imported and graded to allow access to the main road. There has been a very visible effect on the beach in response to this poorly designed ramp. The natural long-term westward transport of sand by longshore currents and beach drift has been disrupted, and sand is piling up on the east side of the ramp. A starved sand supply to the coast west of the ramp has allowed erosion by waves to cut back the beach, exposing beachrock and older Hanna Bay Member beds. One might hope that this ramp will be someday removed, but refloating and moving the barge will not be an easy task.

Allochems of the Hanna Bay Member eolianites consist of superficial ooids, micritized bioclasts, and coated grains (Figure 7B). The allochems are held together by low-magnesium calcite meniscus cements. Degree of cementation, especially for beds low in a given section on seaward-facing exposures, can be modified by sea spray.

Return to the vehicles, and proceed west along the coast road approximately 1 km to Cotton Field Point, where the Rum Cay Resort Marina is under construction. Where the vehicles park, and what we will see here depend in part on the status of the work on the day we arrive (June 12, 2008). The next major phase of the work on the resort is scheduled to begin on July 1, 2008, so we hope to be able to see outcrops here without a problem.

## STOP 2 - RUM CAY RESORT MARINA

This stop is an excellent illustration of one of the conundrums of life in the Bahamas. Developments such as the Rum Cay Resort Marina offer Bahamians a chance to increase their standard of living while avoiding migration to the other, more populous Bahamian islands that dominate the employment market in the country. The downside is the destruction of natural habitat (recognizing that earlier lumber and agriculture practices since the year 1500 A. D. have re-arranged that "natural" habitat). At this site, mangrove destruction has been especially dramatic (Figure 8). The excavation work produced by such development is also a bonanza for geologists, who get a peek at outcrops that would not otherwise exist. The carving of the marina has created vertical cuts that reveal much information. A shallow canal at the entry to the area shows a well-developed terra rossa paleosol, indicating the rock is Pleistocene (Figure 9A). The deep marina excavation highwall shows subtidal calcarenites overlying a rubbly zone of rounded clasts and large shells such as *Strombus gigas* (Figure 9 B&D) above modern sea level, indicating that these Pleistocene rocks are part of the Cockburn Town Member of the Grotto Beach Formation. Rubble piles created by the excavation contain a variety of typically lagoonal species (Figure 9C).

The south side of the marina cut has intersected an infilled dissolutional cavity (Figure 10). The cavity could be a surface dissolution sinkhole, in which case its development could have occurred anytime since the rocks were deposited and then became subaerial at the end of MIS 5e. If the void is a collapsed phreatic cave, a small flank margin cave or banana hole, then a fresh-water lens had to be present above modern sea level. The only way to have a fresh-water lens at that position would have been during MIS 5e. The sands above the rubble layer could have been prograding during MIS 5e to produce a strand plain deposit, in which case a fresh-water lens could have occupied that strand plain and the dissolution

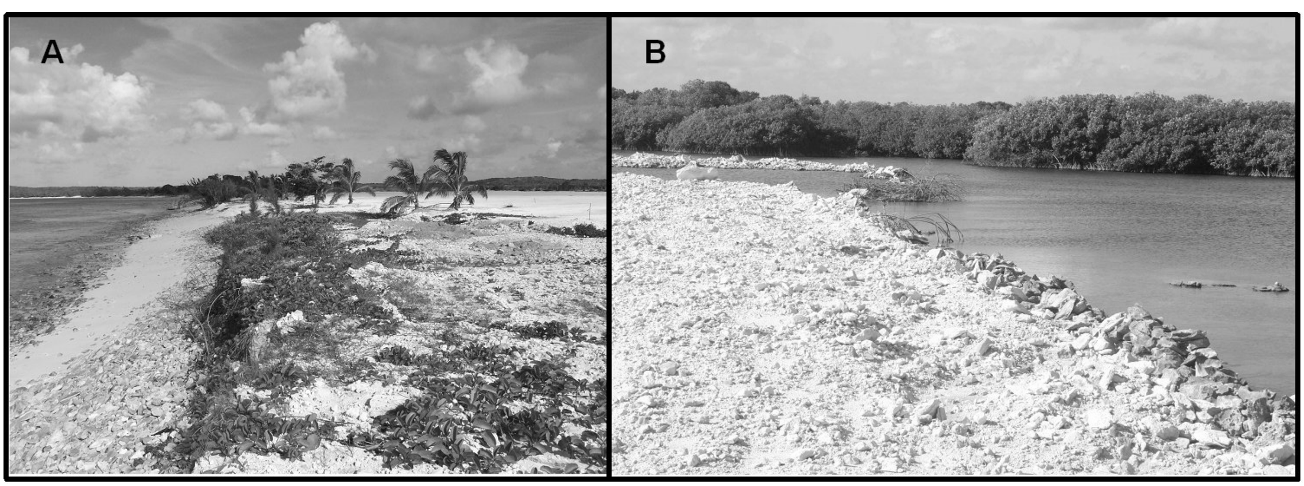


**Figure 8. Stop 2 locality, Rum Cay Resort Marina. A) Coastal dunes cleared for construction; palm trees in the distance are recently planted. B) Mangroves being destroyed by marina development. Photo by Al Curran.**

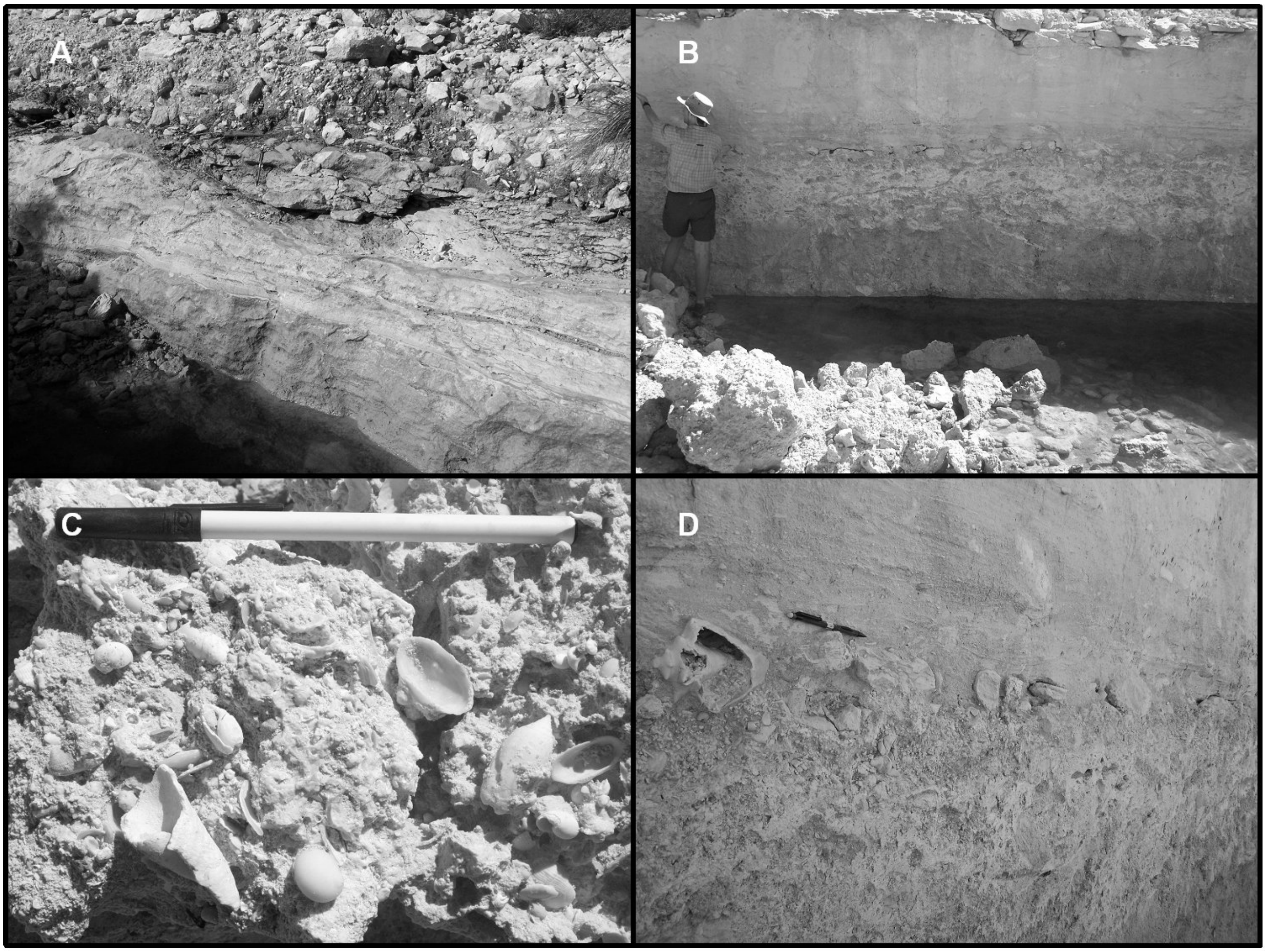


**Figure 9. Stop 2 locality, Rum Cay Resort Marina. A) Shallow canal with terra rossa paleosol. B) Rubble layer in marina basin excavation, overlain by subtidal calcarenites. C) Excavated loose rock from the marina basin, rich in molluscs. Pen = 15 cm. Photo by Al Curran. D) Close up of the sand-rubble contact shown in 9-B. Note the *Strombus gigas* shell on the left, and the rounded nature of the large clasts. Pencil = 15 cm.**

void developed in the shallow subsurface. Similar dissolutional collapse features are seen at French Bay on San Salvador Island (Florea, 2001). Such development of caves in prograding sand bodies has been demonstrated on San Salvador Island (Florea et al., 2004) and on New Providence Island (Mylroie et al., 2008). Such caves are syndepositional (White et al., 2007), that is, their development is synchronous with the deposition of the rock.

As noted in the Island Hydrology section, the salinity of water at the top of the marina basin pool ranged between 2.1 and 3.7 psu in February (Table 2). There was no salinity gradient in the top 1.5 m (Table 3). Salinity was 11.5 psu in the channel dredged between the marina and the open ocean (seen in Figure 9A). This was an unexpected result in a location so close to the coast and almost freely open to the ocean.

**Figure 10. Stop 2 locality, Rum Cay Resort Marina. Infilled dissolution feature.**

Return to the vehicles and drive south, swinging east a few hundred meters to where coastal outcrops of rock can be seen. Park (23˚39.150', 74˚51.554') and walk out onto the coastal outcrops.

**STOP 3 - COTTON FIELD POINT FOSSIL REEF**

From the parking area, take the short access path to the beach. As at Stop 1, there is a good view eastward along the coast toward Port Nelson (Figure 11A), and the beach itself has similar characteristics to those described from the earlier stop. Large Australian pines line the backshore of the beach, and several manifestations of *Casurina*-induced coastal erosion, as described by Sealey (2006), can be observed here.

Walk westward about 60 meters toward Cotton Field Point to the initial outcrops of the fossil coral reef. One will first encounter low, poorly exposed outcrops of Holocene Hanna Bay Member grainstone (peloidal biosparite) beds of the Rice Bay Formation. Go a short bit farther, and low, partially buried outcrops of a reddish iron-stained paleosol surface are visible. These are upper Pleistocene rocks (MIS 5e, based on stratigraphic position), and they mark the beginning of fossil coral reef beds of the Cockburn Town Member of the Grotto Beach Formation. At several places, Hanna Bay Member beds are in direct contact with the upper Pleistocene rocks (Figure 11B).

The main section of the fossil coral reef forms Cotton Field Point. This is a classic exposure of Cockburn Town Member patch reef facies, similar to, but somewhat smaller than, the Sue Point fossil patch reef on San Salvador described by White (1989). The diversity of corals preserved here is low, with the patch reef dominated by colonies of the brain coral, *Diploria strigosa*, with colonies of *Montastraea annularis* secondary in importance (Figure 11 C-E). The colonies of both corals can be quite large here. One large

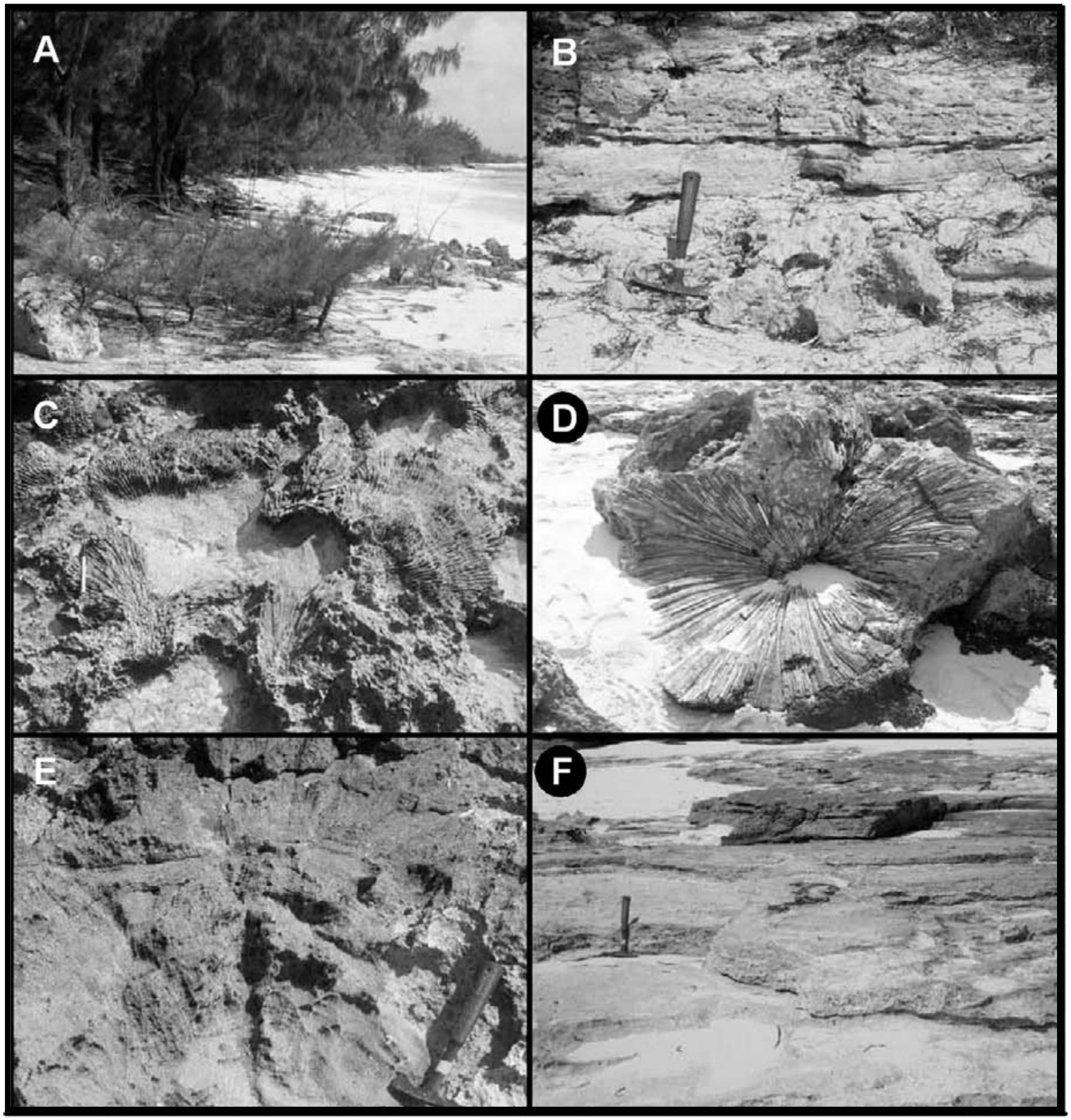


**Figure 11. Stop 3 locality, Rum Cay Resort Marina. A) View of the beach looking east from the eastern access point for Cotton Field Point and its fossil coral patch reef. Note the luxuriant stand of Australian pine trees lining the back of the beach. B) Contact between upper Pleistocene rocks of the Cockburn Town Member of the Grotto Beach Formation and Holocene beds of the Hanna Bay Member of the Rice Bay Formation. Rock hammer length = 26 cm. C) Several colonies of the brain coral *Diploria strigosa*. Pen = 15 cm. D) The fossil "throne" coral, a large *Diploria strigosa* colony; pen for scale. E. A large *Montastraea annularis* coral colony; hammer for scale. F) Seaward-dipping beds of a late Pleistocene beach cap the coral patch reef; hammer for scale. All photos by Al Curran.**

*D. strigosa* colony (Figure 11D, 1.25 m diameter) is split open so that one can sit within it. Dubbed the "throne" coral by the field trip reconnaissance crew, this specimen presents an excellent photo opportunity (GPS: 23˚39.128', 74˚51.609'). There is an even larger *D. strigosa* specimen (1.9 m diameter) adjacent to and seaward of the "throne" coral.

The coral patch reef is buried in shelly grainstone (biosparite) that shallows upward into beach beds, which are well exposed a bit farther westward around the point (Figure 11F). The burial sequence is very much like that described by White (1989) for the Sue Point reef on San Salvador and follows the entombment scenario envisioned by White and Curran (1995) for MIS 5e reefs on Great Inagua and throughout the Bahamas. A terra rossa paleosol caps the sequence and there are well-developed, large vegemorphs in several places, with some having diameters of up 3 cm.

Return to the vehicles and drive east back past Stop 1 into Port Nelson. Park the vehicles at a small picnic area across from the Ocean View Restaurant and Bar. This location will be our lunch stop. The Ocean View can be patronized for more sophisticated beverages. After lunch, re-board the vehicles and continue southeast out of Port Nelson, passing over a canal once used in salt production, and on toward Sumner Point, 1.2 km to the southeast. Keep to the road on the north side of the Sumner Point marina channel, and drive to a small parking area at the end of Sumner Point.

**STOP 4 - SUMNER POINT**

The Holocene sands seen on this peninsula actually overlie a Pleistocene eolianite. Walking south down the slope to a narrow beach, and around the point to the east shows that the Holocene sands overly a lithified eolianite that has a well-developed terra rose paleosol on top (Figure 12A). These underlying rocks are therefore Pleistocene, and based on comparison with other eolianite outcrops on Rum Cay, are speculated to be Cockburn Town Member of the Grotto Beach Formation. Continuing north up the east side of the point, the top of the point and the vehicles can be reached. Looking north, a beach continues to another headland (Figure 12B). This headland has several cave openings in it, about 4 m above modern sea level (Figure 12 B&C). These caves are all small, but have characteristic phreatic dissolutional bedrock morphologies inside them, and so appear to be flank margin caves, and not tafoni or sea caves. This observation indicates that the headland must be either French Bay Member of the Grotto Beach Formation, or the older Owls' Hole Formation. In the far distance, bluffs associated with the Stop 6 discussion can be seen (arrow just above headland in Figure 12A).

Return to the vehicles, and drive 100 m northwest and down slope to a flat area adjacent to the marina channel. Park the vehicles and proceed west to the cliff and quarry opening.

**STOP 5 – THE ARCHES, PROBLEMATIC DEPOSITIONAL AND DISSOLUTIONAL FEATURES**

These features, named "The Arches" create an unusual vista (Figure 13). This small area is awkward to traverse, but exhibits a number of unusual features. A small flank margin cave, somewhat altered by bulldozer work, opens into the hillside to the east (Figure 14A). This ridge is the same one that forms the headland containing the small, breached caves of Figure 12. Differentiating small openings such as this (or the ones seen to the north at Stop 4) from sea caves or tafoni caves can be difficult. In this case, the cave contains phreatic dissolutional morphology which leads to it being interpreted as a flank margin cave. Flank


**Figure 12. Stop 4 locality, Sumner Point. A) Looking north from Sumner Point to the next headland north. Black Bluff (Stop 6) can be seen peeking above the headland (arrow). Note Holocene sands in the foreground. B) Headland north of Sumner Point showing breached flank margin caves (arrows). Person in oval for scale. C. Looking south to Sumner Point, from inside one of the flank margin caves seen in B.**

margin caves, sea caves, and tafoni caves can also be differentiated by area to perimeter ratios, and entrance width to maximum width ratio (Waterstrat, 2007; Owen, 2007). Continuing north, two rock arches open on the marina channel (Figures 13 and 14B). These features look like highly eroded flank margin cave segments (Figure 14B), but they are developed in a fallen block and talus deposits next to the hillside (Figure 14C). A similar feature was discovered in December 2007 on Crooked Island, Bahamas (Figure 14D). The interior cave wall morphology is consistent with a phreatic dissolution origin.

Continue north past the arches to the edge of a flooded quarry (Figure 15A). A dramatic contact appears to exist part way down the quarry wall. As the upper unit has a terra rossa paleosol on top, if this contact also had a terra rossa paleosol, then the lower unit would have to be Owl's Hole Formation. It is also possible that both units are Owl's Hole Formation. Close examination of the contact did not yield agreement among the authors as to its nature. If the contact is not a terra rossa paleosol, then the entire outcrop could be Grotto Beach Formation. The presence of the flank margin caves here, and as seen north of Stop 4, indicates that if the rocks are Grotto Beach

**Figure 13. Stop 5 locality. Looking northeast across the Sumner Point marina waterway at Stop 5, showing two bedrock openings of the Arches. Dark spot in the hillside to the extreme right is a breached flank margin cave. The quarry shown in Figure 15A is just out of the frame to the left.**

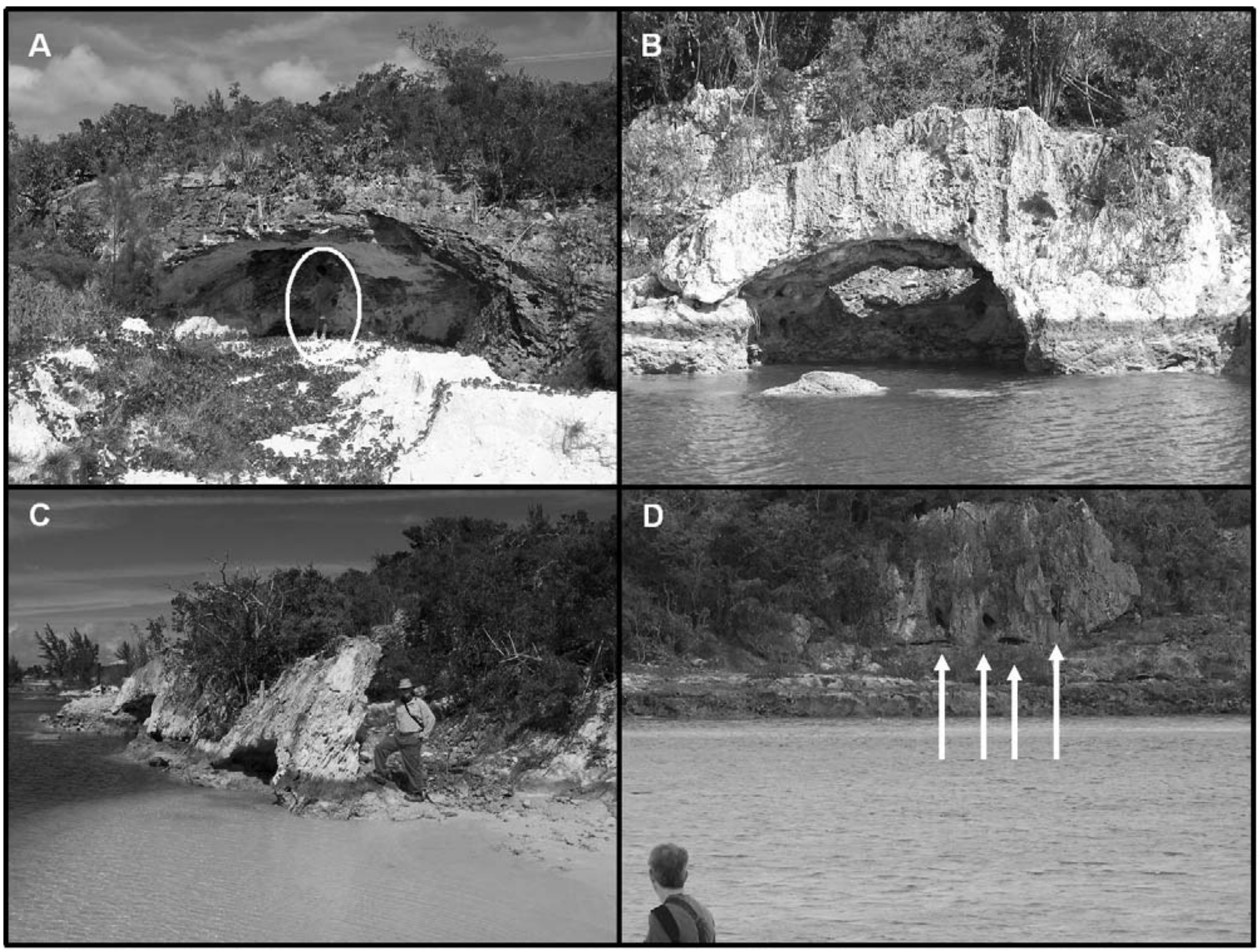


**Figure 14. Stop 5 locality. A) Breached flank margin cave seen in Figure 13. Person in oval for scale. B) The west arch of the Arches, note phreatic interior morphology. Opening is 2+ m wide. C) The Arches are developed in a rock fall and talus deposit. D) A cave in a rockfall deposit, Crooked Island. Cave entrances identified by arrows.**

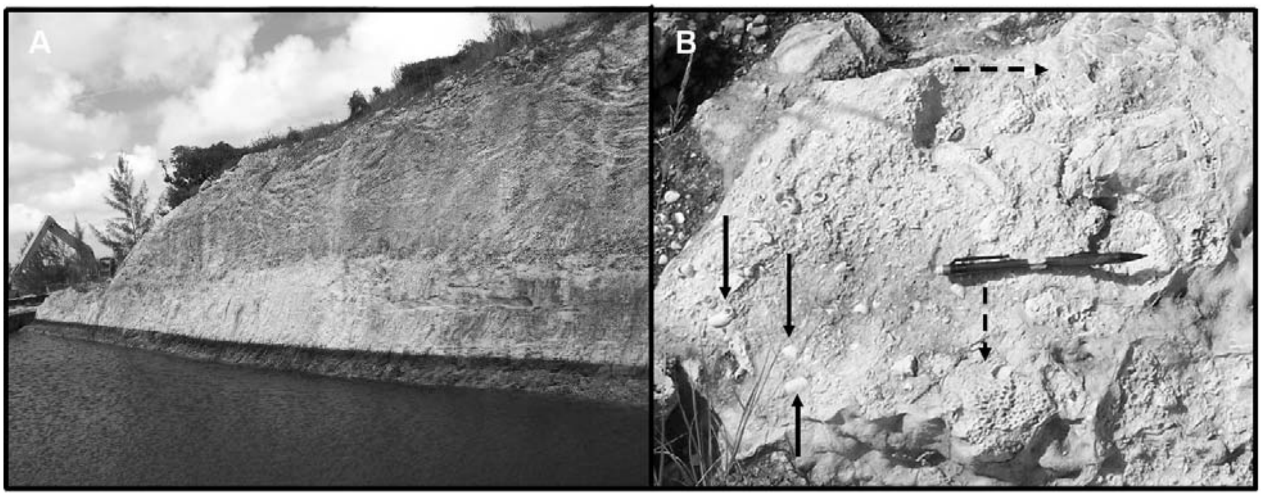


**Figure 15. Stop 5 locality. A) Quarry wall displaying a problematic contact. Large backhoe at extreme left for scale. B) Terra rossa paleosol with mixed fossils between the quarry and the Arches. Solid arrows point to *Cerion* sp., a land snail; dashed arrows point to fossil corals. Pencil = 15 cm.**

Formation, they must be French Bay Member. A terra rossa paleosol is exposed between the bedrock arches and the quarry. It is interesting because it contains both coral and *Cerion* sp. fossils, a mix of marine and terrestrial fauna (Figure 15B).

Walk back to the vehicles and re-board them. Drive up and over the hill and continue northwest along a sandy flat until a large hill is seen ahead and to the right (east). Park at the driveway into a large beach house, walk past the house to the beach and left (northeast) to the base of the bluff. This large hill is Black Bluff.

## STOP 6 - BLACK BLUFF EOLIANITES

Black Bluff is one of two prominent bluffs that occur along a NE trending beach that is catenary between the headlands of Sumner Point (Stop 4) and Signal Point (Figures 2 and 16A). The bluff exhibits well-developed eolianite cross-bedding interrupted by truncation surfaces and calcarenite protosol horizons (Figure 16). Tafoni caves (Owen, 2007) occur near the top of the bluff (Figure 16B). Field investigations reveal at least 3 protosols (Figure 16C) within the main body of the bluff. A terra rossa paleosol occurs near the top of the bluff.

The eolianite at Black Bluff consists of bioclastic sands. All of the recognized calcarenite protosol horizons are developed on those sands; most of the paleosols examined have associated pisolites (soil glaebules). The shells of *Cerion* land snails are common throughout the eolianites and are particularly abundant in the vicinity of the calcarenite protosol horizons (Figure 16D).

The existence of a bluff-top terra rossa paleosol indicates that the eolianite at Black Bluff is Pleistocene in age. The calcarenite protosols, vegemorphs, and abundant *Cerion* are typical of stillstand to regressive-phase eolianite seen elsewhere in the Bahamas. Based on these field observations, the eolianite at Black Bluff is assigned to the Cockburn Town Member of the Grotto Beach Formation (Carew and Mylroie, 1995a; 1997). This bedrock geology remains the same between Black Bluff and White Bluff although it is somewhat obscured by low Holocene dune sands that blanket back-beach areas between the bluffs.

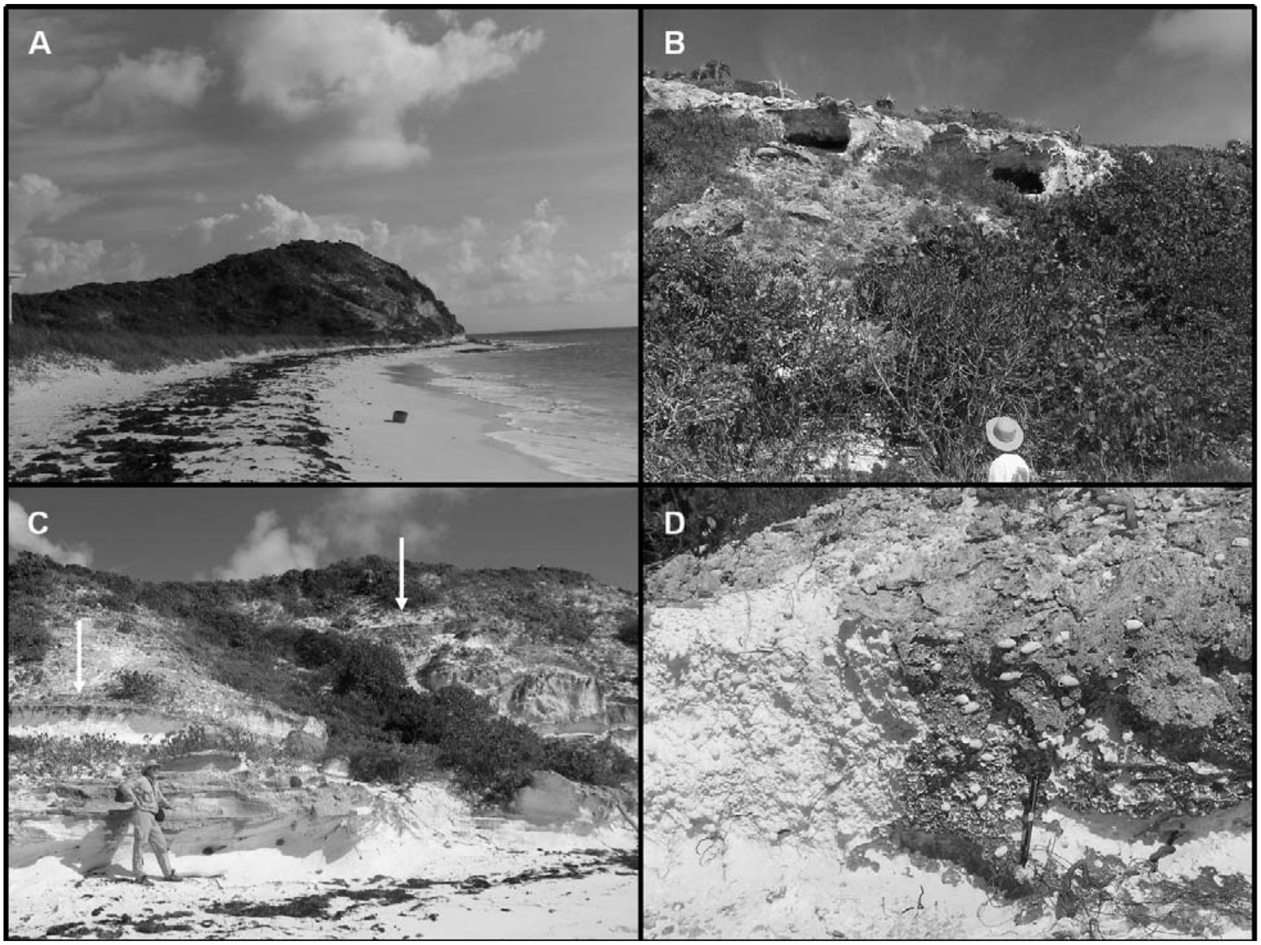


**Figure 16. Stop 6 locality. A) The view along the beach northeast to Black Bluff, Cockburn Town Member. B) Black Bluff tafoni. C) Black Bluff calcarenite protosols. At least two separate protosols are present (arrows). D) Black Bluff *Cerion* sp. and pisolites. Pencil = 15 cm.**

From a distance White Bluff appears to have the same geology as Black Bluff. Cross-bedded eolianites and tafoni caves are clearly evident (Figure 17A). However upon closer inspection noteworthy differences become apparent. Most significantly, neither the terra rossa paleosols nor the calcarenite protosol horizons that characterize the geology of Black Bluff occur at White Bluff. Instead the rocks at White Bluff consist of bioclastic sediments without significant truncations or discontinuities. The depositional dip of the eolianite differs as well; in several areas the depositional dip can be shown to be congruent with modern sea level. Because of these observations, the rocks of White Bluff are decidedly Holocene. The lack of a terra rossa paleosol and the dip of the eolianite indicate that the eolianite at White Bluff belongs to the Hannah Bay Member of the Rice Bay Formation (Carew and Mylroie, 1995a; 1997).

At White Bluff and for several hundred meters northeast, the beach is littered with slabs of limestone (Figure 17B). These slabs are white and rounded and are commonly imbricated. No angular blocks are evident and red paleosol crusts are notably absent. These slabs are interpreted as cemented Holocene beach sands (beach rock). Some of the more angular blocks are likely breakdown from the adjacent Holocene-age bluff.


**Figure 17. Stop 6 locality, beyond where we will visit. A) White Bluff, lacking a terra rossa paleosol, is Hanna Bay Member. B) White Bluff beach slabs grading left into talus. Signal Point in the distance to the northeast (right side of image).**

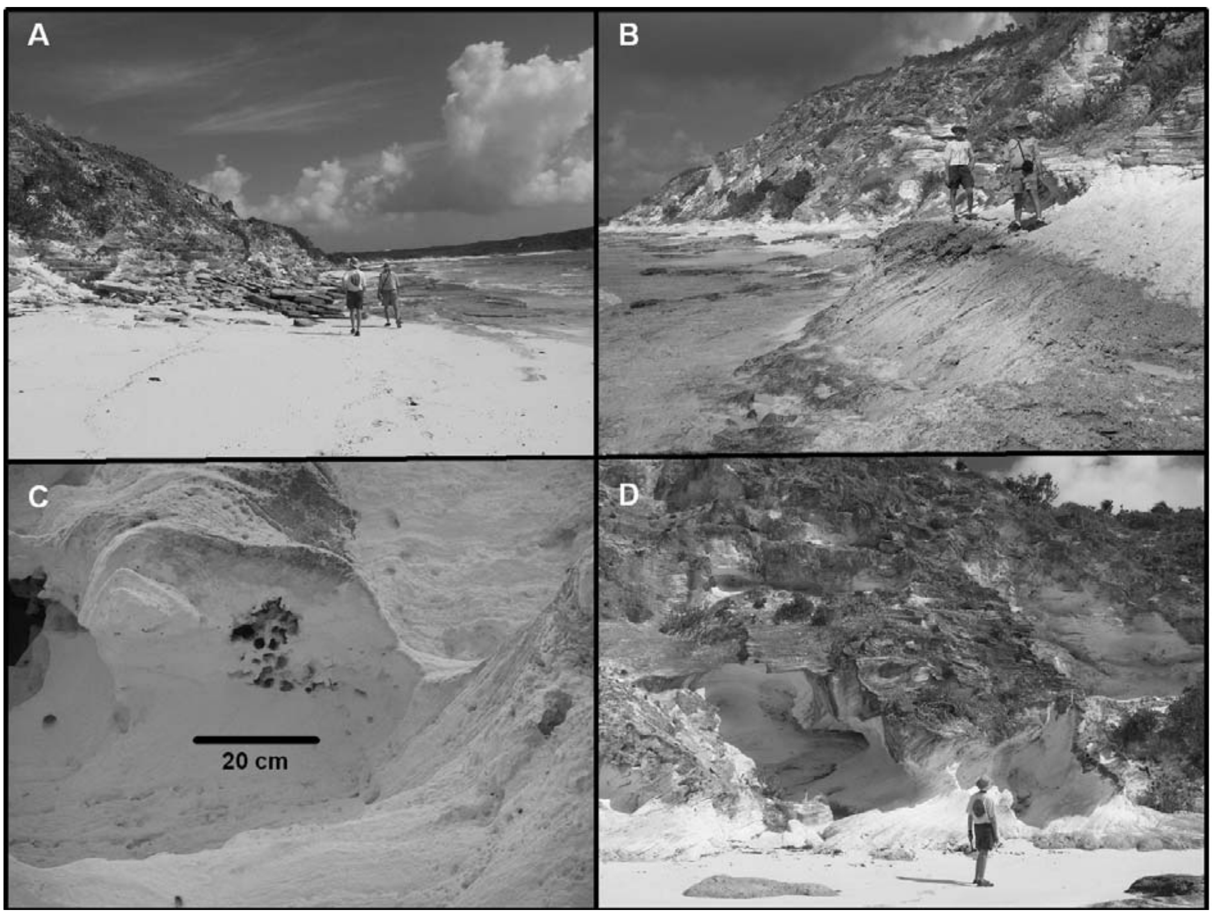


**Figure 18. Stop 6 locality, beyond where we will visit. A. Lithified Holocene dunes, beach and beachrock, Hanna Bay Member. Signal Point ahead and to the right. B) Signal Point, with North Point Member beds dipping below sea level. C) Signal Point eolianite showing cluster burrow in an overhanging ledge, as seen from below. D. Tafoni caves, Signal Point. See also the cover photo for another Signal Point image.**

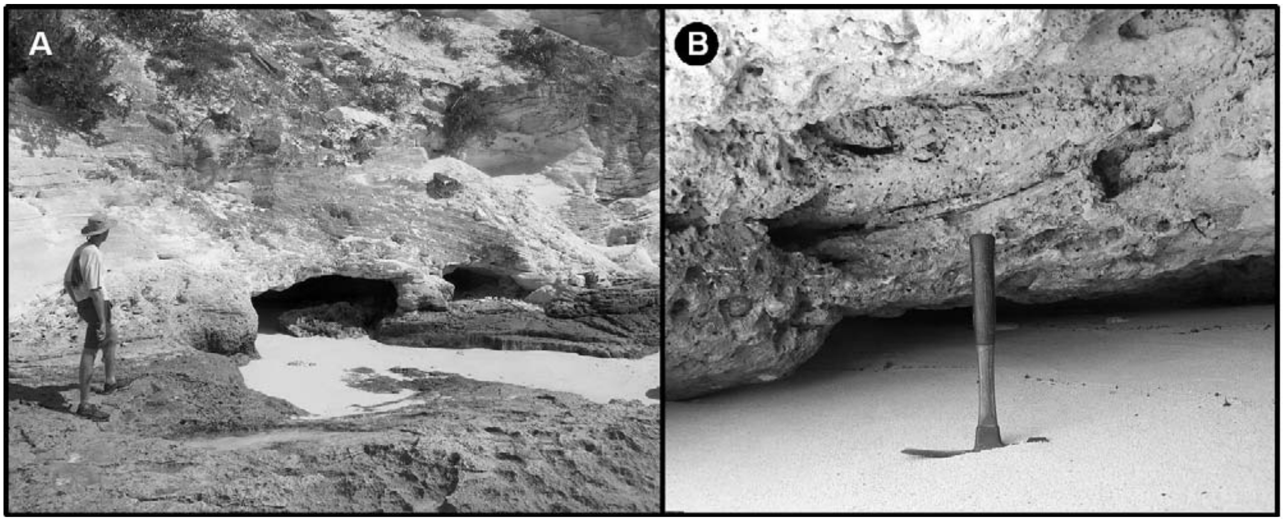


**Figure 19. Stop 6 locality, beyond where we will visit. A) A possible Holocene flank margin cave at Signal Point. The wide, low entrance segmented by bedrock pillars is not a likely sea cave morphology. B) Interior of the cave, showing dissolutional morphology in the ceiling. Rock hammer is 26 cm long for scale.**

From White Bluff to Signal Hill, the geology consists of Holocene sands of the Hanna Bay Member (Figure 18A). Most of the sands are bioclastic and poorly lithified. A low vegetated dune parallels the beach for most of this distance. At Signal Hill and around to Signal Point, the geology once again changes. Most notably the dip of the eolianite bedding clearly extends beneath modern sea level (Figure 18B) which suggests deposition at a time when sea level was lower than at present. Field observations of the Signal Point area reveals no terra rossa paleosols and no calcarenite protosols either along the beach or on the bluff. Based on these observations, the bluff at Signal Point is assigned to the Holocene North Point Member of the Rice Bay Formation (Carew and Mylroie, 1995a; 1997). Also present in these rocks are stellate burrows (*Celliforma*?) and cluster burrows (Figure 18C), both common to Holocene eolianites in the Bahamas (White and Curran, 1988; Curran and White, 2001).

Other interesting features at Signal Point include well-developed tafoni caves (Figure 18D) and a possible Holocene flank margin cave (Figure 19). North Point Member limestones extend for a distance to the north and east of Signal Point before becoming blanketed by Holocene dune sands at the Port Nelson Salt Lake inlet.

Walk back off the beach, past the house, and back to the vehicles. Re-board and drive back to Port Nelson, and north on the King's Highway. About 1 km north of Port Nelson, on the west side of the road, is a shallow quarry. Park (23˚40.218',74˚49.797') and walk into the quarry.

**STOP 7 - PLEISTOCENE TIDAL CREEK OR LAGOONAL FACIES AND TRACE FOSSILS.**

This small road metal quarry (Figure 20A) was Steve Mitchell's field site RK38, and the rocks found here were assigned (Figure 6) to the "Pleistocene Tidal Creek Lithofacies" on his preliminary geologic map of Rum Cay (Mitchell, 1987, his Figure 5). Mitchell suggested that this lithofacies was deposited during the Eemian (MIS 5e) sea-level highstand, when a large tidal creek-lagoon complex that he designated the Lake George Tidal Creek System covered much of the interior of Rum Cay. This will be our best chance today to examine rocks of this important lithofacies, which very likely is extensive on Rum Cay and other, similar Bahamian islands such as San Salvador (Hagey et al., 1995; Noble et al., 1995). However, this facies typically is not well exposed because it was deposited in low interior areas of the islands.

The quarry is somewhat overgrown with vegetation and partly covered by surficial materials. Low areas are wet, but good outcrops can be found on both the north and south sides of the quarry. The rocks cropping out are mostly a shelly packstone (oopelsparite according to Mitchell, 1987), with a thinly laminated grainstone commonly present at the top of the section. A thin caliche surface caps the sequence and can be seen at several points around the quarry.

The packstone beds contain a moderately diverse molluscan fauna of bivalves and gastropods and are heavily bioturbated in most places. Mitchell (1987, p. 237) discussed this molluscan fauna in some detail and provided a listing of the common species. The most common bivalves found on our reconnaissance visit were *Chione cancellata* and *Lucina pennsylvanica*; the most common gastropod was *Bulla striata* (or *B. occidentalis*). A few minutes of observation here will yield a very representative visual sample of Bahamian molluscan fossils of the "Pleistocene Tidal Creek Lithofacies."

After a brief examination of the north wall of the quarry, move along to the back area and southeast corner. The packstone beds exposed here, and along the south wall of the quarry, reveal some excellent burrow shaft and tunnel specimens of the trace fossil *Ophiomorpha* (Figure 20B), as well as exhibiting maximum intensity levels of bioturbation (Figure 20C). *Ophiomorpha* burrows are well lined, with smooth interiors and distinctly pelleted exterior surfaces, and they display complex branching patterns. Linings can be several millimeters thick and are composed of an admixture of fine sand- and clay-sized material originally cemented with mucus secreted by the tracemaker organisms. *Ophiomorpha* shafts and tunnels found at this location are quite robust, with typical outside diameters of 3-4 cm. In addition, robust *Ophiomorpha* mazes are present, some with components having diameters of 5+ cm. Large *Ophiomorpha* turnaround structures also occur here (Figure 20D). These are bulbous dead ends of tunnels, constructed to permit the inhabitants to re-orient within the burrow systems. A similar occurrence of robust *Ophiomorpha* tunnels with turnarounds was reported by Curran (2007) from upper Pleistocene beds on Harry Cay, Little Exuma Island.

*Ophiomorpha* is widespread in the upper Pleistocene grainstone and packstone rocks of the Bahamas that were deposited in shallow subtidal environments (Curran, 2007, and earlier references cited therein). The tracemakers were callianassid shrimp that today are commonly the dominant element of the deep-tier fauna in the shallow-subtidal to intertidal environments of the Bahamas and similar tropical areas elsewhere. Also present, but not common in the exposures of this quarry, are the trace fossils *Conichnus conicus* and *Planolites*, thought to be formed respectively by sea anemones moving upward with sediment deposition and by deposit-feeding worms. This association of trace fossils is common in the shallow-subtidal Pleistocene rocks of the Bahamas, although the relative percentage occurrence of each trace fossil within a given assemblage can vary considerably (Curran, 2007).

Callianassid shrimp can be thought of as "ecosystem engineers" (Curran and Martin, 2003). This is nowhere more evident than in the shallow carbonate environments of the

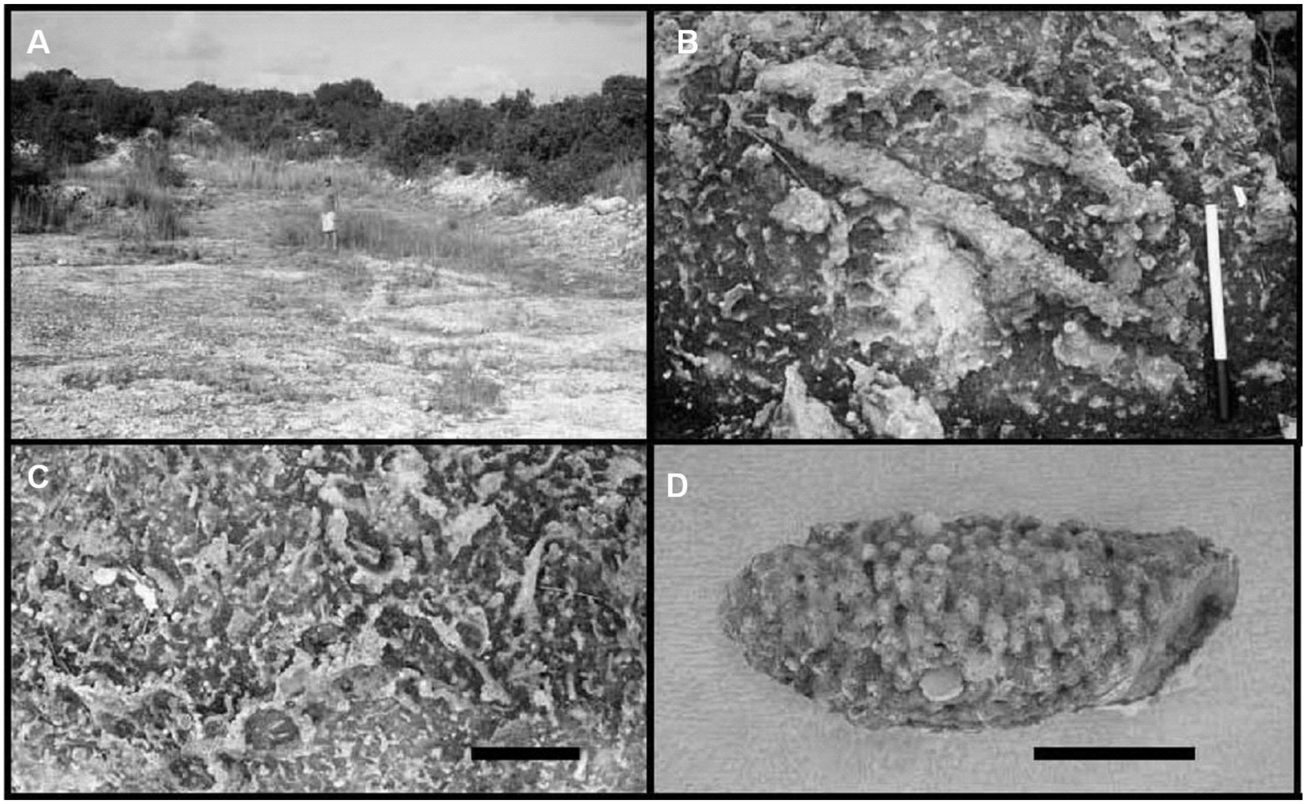


**Figure 20. Stop 7 Locality. A) Overview of the Stop 7 road metal quarry. B) Large, oblique shaft of an *Ophiomorpha* burrow in outcrop toward southwest corner of the quarry; sections and fragments of other *Ophiomorpha* burrows also present. Pen = 15 cm. C) Maximum intensity *Ophiomorpha* ichnofabric in the packstone of the south-side quarry wall. Scale bar = 4 cm. D) Large *Ophiomorpha* turnaround structure, presumably formed at the end of a burrow tunnel; note the very large pellets on this outer surface of the burrow lining. Scale bar = 6 cm.**

tropics where numerous species are present. Their burrowing activities can totally transform original depositional fabrics into distinctive ichnofabrics, like the *Ophiomorpha* ichnofabric shown in Figure 20C. This ichnofabric is widespread in the Pleistocene marine rocks of the Bahamas and the Miami Limestone of southeastern Florida, and has important implications for the development of highly permeable macroporous zones (Cunningham et al., 2008).

Re-board the vehicles and drive north on the King's Highway, past the new airport, and continue another 2.5 km to Zion Hill, a 20 m high east-to-west trending ridge with a road cut 3 m deep at the top. Park and exit the vehicles.

**STOP 8 - ZION HILL ROAD CUT**

This road cut provides an excellent opportunity to observe well-cemented eolianites that characterize much of the higher elevations of Rum Cay. Here, the eolianite is nicely exposed on either side of the Kings Highway. Mitchell (1987) noted that eolianites such as these form the bedrock geology of the steep eastern coast of the island, and can be found in central sections of the island as well. The outcrop also displays a well-developed terra rossa paleosol formed on steeply dipping eolianite, indicating that the dune ridge is Pleistocene in age (Figure 21A). The complex vegemorphs and abundant *Cerion* sp. fossils associated with the paleosol (Figure 21B) indicate that the dune is a


**Figure 21. Stop 8, Zion Hill. A) Zion Hill Roadcut, showing a well-developed terra rossa paleosol with vegemorphs. B) Close-up of the vegemorphs, showing fossil *Cerion* sp. (arrows). Pencil = 15 cm. C) Photomicrograph of biomicritic limestone from the eolianite facies at Zion Hill. Arrow points to an intraclast of biosparite. Photomicrograph by Fred Siewers.**

stillstand or regressive-phase eolianite (Carew and Mylroie, 1995a; 1997). The cross-stratification of the eolianite is primarily planar and dips landward. Lithologically, the eolianite is a grainstone consisting of biosparite and biomicrite. Micritized marine bioclasts, rounded intraclasts and coated grains are common throughout (Figure 21C).

To the west, a short trail leads to the dune crest and an old plantation-era ruin. The view here allows inspection of the north coast, with the increasingly higher dune ridges to the north and east.

Re-board the vehicles, and drive north down the hill ~0.5 km to a parking area near the beach. Exit the vehicles and proceed north and east to the rocky point (23˚42.500’, 74˚49.259’).

**STOP 9 - BOAT HOUSE ROCK EOLIANITES**.

Stop 9 provides an opportunity to examine several geological features and facies relationships that are key to unraveling the stratigraphy and sedimentology of Quaternary limestones in the Bahamas. This stop also demonstrates how complex the geology can be

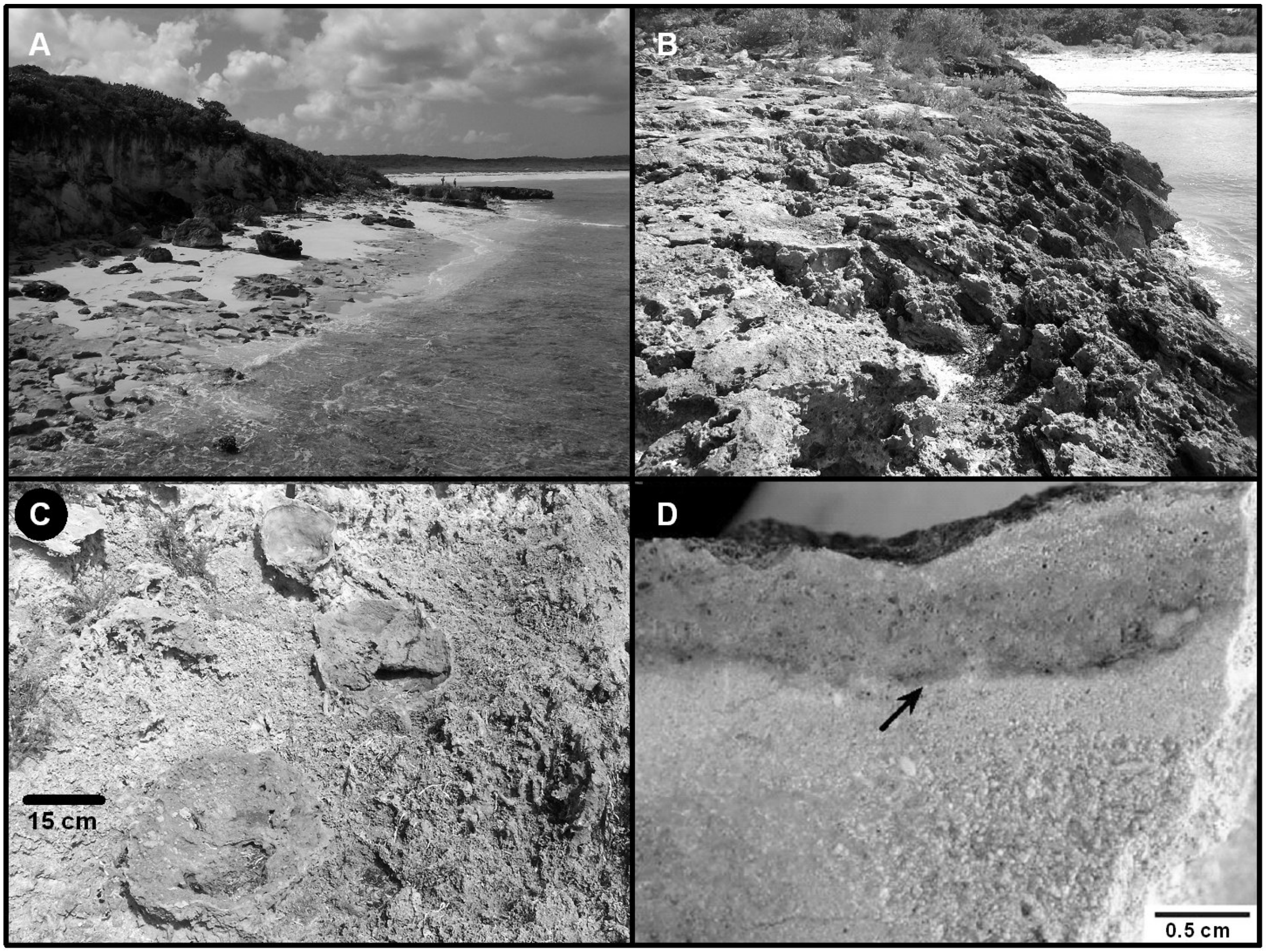


**Figure 22. Stop 9, Boat House Rock. A) Overview looking west of the initial western outcrops at Boat House Rock. Peninsula in the distance is the first locality visited. B) Terra rossa paleosol on the peninsula mentioned in A above. Sloping surface to the right in the image is dipping eolianite beds; the center and left are a truncated surface covered by the paleosol. C) Eroded paleosol as circular patches surviving in what were hollows in the landscape; vegemorphs are common, especially visible in the right side of the image. D) Close up view of paleosol crust (arrow) and underlying bioclastic sediment. Preliminary x-ray diffraction of the crust did not reveal any oxide minerals; only a mixture of low magnesium and high calcites (7 mol. % $MgCO_3$) and probable organic compounds. Photo by Fred Siewers.**

along rocky Bahamian coastlines, even over short distances.

The first area of interest is a flat limestone peninsula that juts northwest out into the ocean at the east end of the beach (Figure 22A). The upper surface of this bench varies from smooth and undulating to karstic with numerous depressions and cavities (Figure 22B). Lining those cavities and mantling most of the bench is a reddish resistant crust with numerous vegemorphs (Figure 22C). This surface is a well-developed terra rossa paleosol similar to that cropping out at Mt. Zion (Stop 8) and many other locations in the Bahamas. Although this surface is dark and appears rich in oxide minerals (Figure 22D), preliminary X-ray diffraction analysis revealed no metal-

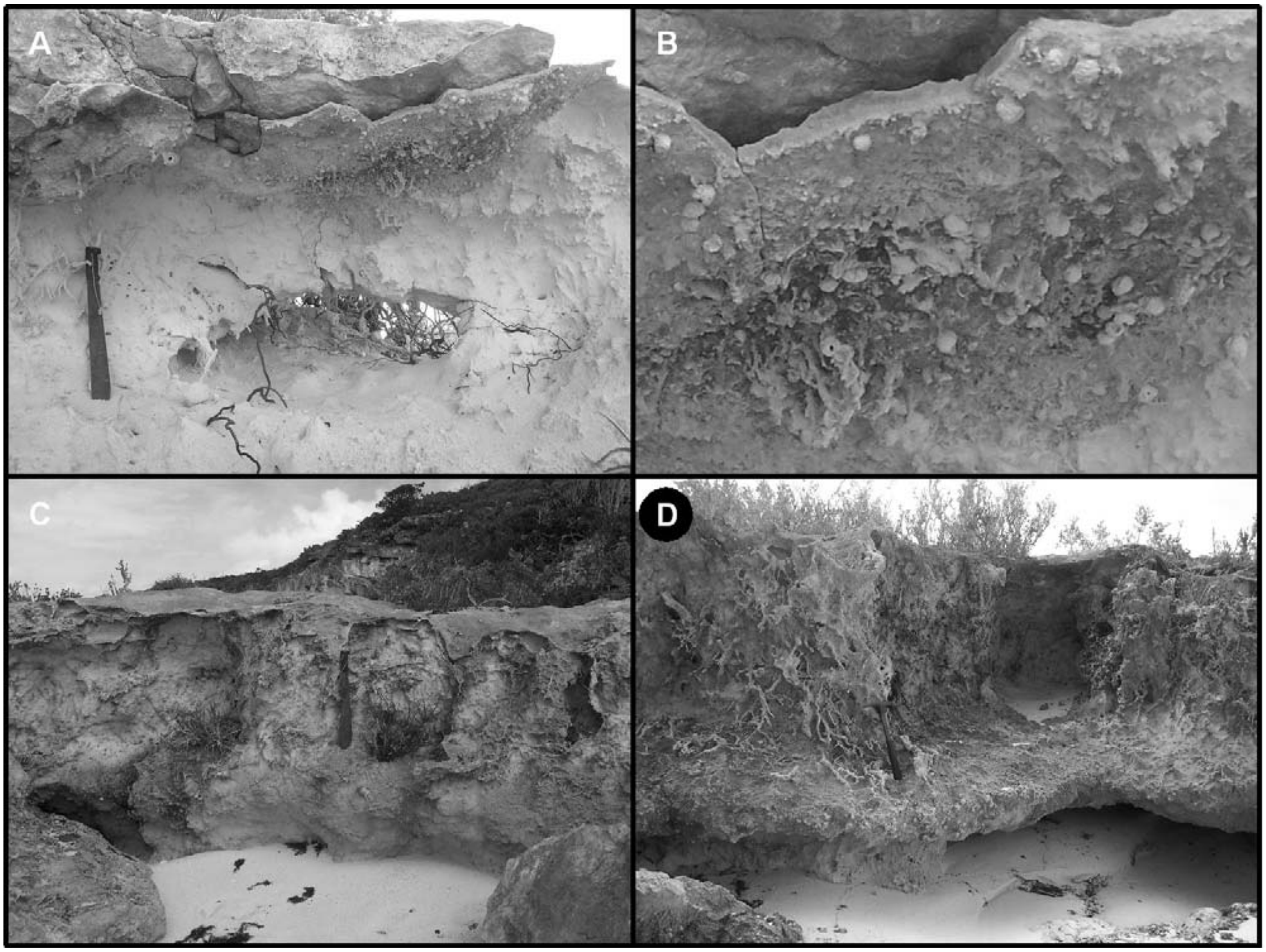


**Figure 23. Stop 9, Boat House Rock, immediately east of the peninsula in Figure 22A. A) Complex terra rossa paleosol with multiple crusts, vegemorphs, and pisolites. Note modern roots. Machete = 70 cm. B) Close up of the pisolites in A. C) Vegemorphs in terra rossa paleosol; note "drape" of paleosol into hollows. D) Terra rossa paleosol with a hard upper crust, thick vegemorph section, and lower pisolitic resistant ledge.**

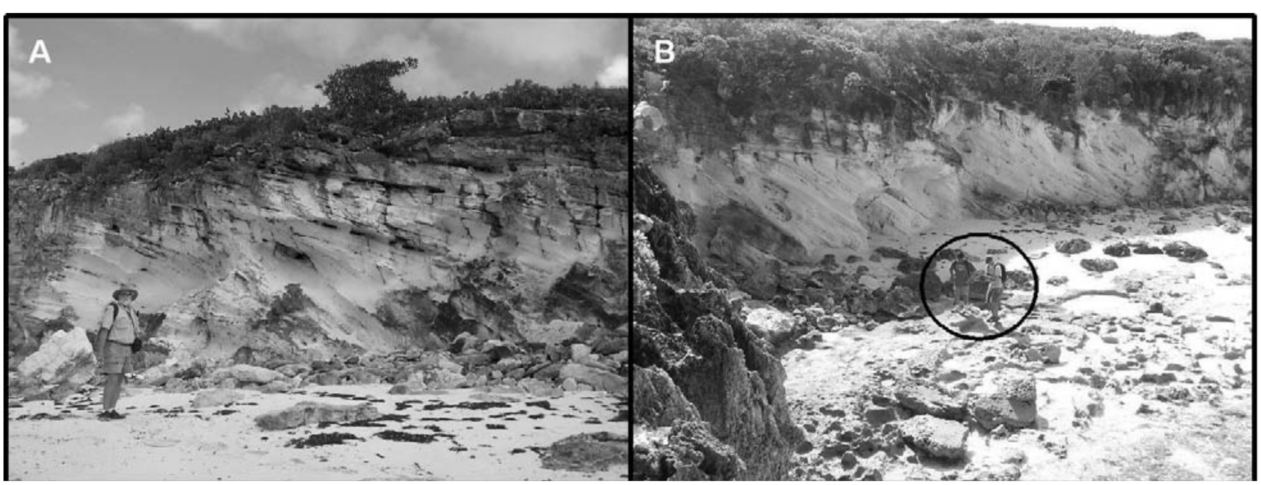


**Figure 24. Stop 9, Boat House Rock, at the embayment shown in the foreground of Figure 22A. A. Steeply dipping beds of the dune unit above that shown in Figure B. B) East of A, a truncation surface on steeply dipping beds, with planar beds above, is visible in upper left (persons in oval for scale).**


**Figure 25. Stop 9, Boat House Rock, small headland from which Figure 24B was taken. A) Vertical pinnacles on eolianite dipping to the lower right; the next embayment to the east visible in the distance. B) Vertical tubes in dipping eolianite, probable palm trunk molds (arrows). Machete = 70 cm.**

bearing oxides. Instead this crust contains a mixture of low-magnesium calcites, high magnesium calcite (with approx. 7 mol.% $MgCO_3$), and what are likely organic compounds.

The peninsula outcrop carries information that may allow its interpretation as Owl's Hole Formation. Figure 22B shows a terra rossa paleosol overlying a flat surface. The eolianite beds dip steeply to the southwest, but are truncated to form the flat bench of the peninsula. The eolianite contains a large number of vegemorphs (Figure 22C). If the vegemorphs are assumed to indicate a regressive-phase eolianite, and the flat bench to represent a marine truncation surface from MIS 5e, then the eolianite had to be in place prior to MIS 5e. It could not be a regressive-phase eolianite of the MIS 5e highstand (Cockburn Town Member of the Grotto Beach Formation) and still be wave truncated by that highstand. The outcrop is not French Bay Member, as transgressive-phase eolianites have very few vegemorphs. So the outcrop would be older than MIS 5e, and it could be tentatively assigned to the Owl's Hole Formation.

Walking east over the bench and to the next rocky point affords an opportunity to observe the sediments and sedimentary structures that underlie the terra rossa paleosol crust. Noteworthy features include pisolites attached to the underside of the paleosol crust (Figure 23A&B) and a meter-thick interval of bioclastic sediment extensively penetrated by vegemorphs (Figure 23C&D). Pisolites are common to caliche soil horizons (Esteban and Klappa, 1983). The bioclastic sediment here is often poorly cemented, and in areas where that sediment has eroded away there are excellent opportunities to observe the vegemorphs in three-dimensions. Beneath the vegemorph interval is a prominent 20 to 30 cm thick calcarenite ledge rich in pisolites and bioclasts (Figure 23D). This ledge lacks a mineralized surface and is similar to some of the calcarenite protosol horizons observed at Black Bluff (Stop 6).


**Figure 26. Stop 9, second embayment, shown in the background of Figure 25A. A) Steeply dipping beds beneath a truncation surface, horizontal beds above. B) Close up of unstructured layer in lower dune of A. Interpreted as a grainfall deposit or a slurry bed. Rock hammer = 28 cm. Photo by H. Allen Curran.**

The next area of interest is found just east of the rocky point. Climb carefully over the rocky point (beware of pits and depressions!) and approach a steep-faced bluff exhibiting high-angle cross-bedding. This eolianite appears similar to eolianites observed earlier at Black Bluff (Stop 6) with steeply dipping eolianite cross-bedding (Figure 24A) and occasional centimeter-diameter tubular structures. These eolianites are capped by a paleosol that is not clearly related to the paleosol first encountered at this stop. Absent in this eolianite are a well-developed vegemorph horizon and pisolite-rich layers that suggest that soil development on this eolianite was different than that at the earlier described site. The east end of the outcrop displays a deflation surface separating steeply-dipping eolianite beds below from gently-dipping beds above (Figure 24B). Proceeding east along the beach, more and more of the uppermost portions of the eolianite are revealed. To fully examine this upper portion, one must climb up a rocky point at the east end of the beach. ONLY THOSE WHO ARE SURE OF FOOT SHOULD PROCEED BEYOND THIS POINT.

The rocky point is capped by deeply weathered eolianite with well-developed 0.5-1.0 m high pinnacles (Figure 25A). Decimeter-scale vertical cylindrical tubes (Figure 25B) are common in this part of the eolianite and are further discussed below. On the far, or east, side of this rocky point, another beach re-entrant occurs and the cross-bedded eolianite is once again exposed. Here there are two noteworthy changes in bedding. In the lower cross-bedded eolianite, a 0.5 meter-thick bed of bioclastic sediment occurs that lacks any fine-scale lamination (Figure 26). Similar beds, although typically thinner and of much lesser extent, have been described from eolianites elsewhere in the Bahamas. White and Curran, (1988), interpreted such beds as the result of grainfall deposition (or liquefied sediment flows, or slurries). The second feature is a pronounced truncation surface separating the lower cross-bedded eolianite with the upper more deeply weathered eolianite (Figure 26A).

Similar to the eolianite capping the rocky point just crossed, this unit contains pinnacles and vertical, cylindrical structures (Figure 27A&B).

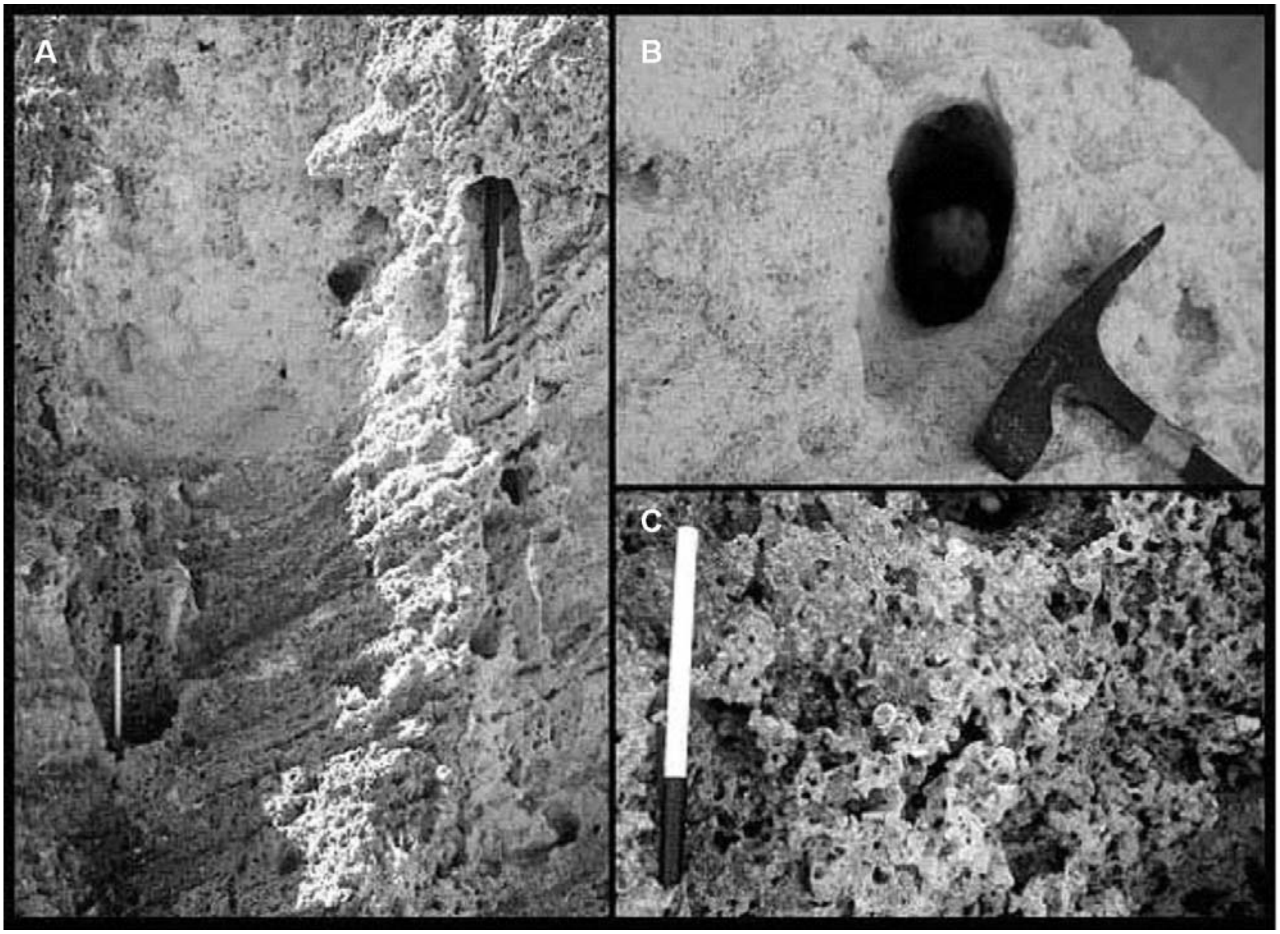


**Figure 27. Stop 9, second embayment. Vertical structures and texture of late Pleistocene eolianites at Boat House Rock. A) Pair of vertical cylindrical structures in eolianite, interpreted as silver thatch palm trunk molds. Pen = 15 cm. B) Vertical structure in cross section and looking downward. Hammer head length = 14 cm. C) Characteristic spongiform texture of eolianite horizons in which vertical cylindrical structures are common. Pen = 15 cm. All photos by Al Curran.**

Similar structures occur in Holocene beds on Long Island (Curran et al., 2004). Recently, Curran et al. (2008) reviewed the occurrence of such structures throughout the Bahamas and suggested that they represent the molds of palm tree trunks, very possibly the silver thatch palm, common along Bahamian coastlines today. As viewed from the beach, it appears that this upper unit exhibits planar bedding. However, observations from elsewhere in the area indicate that this change in cross-stratification is simply a function of cross-bed dip orientation, with the apparent planar beds appearing when the dip of the cross-beds is toward the observer. In areas associated with the presumed palm trunk molds, the rock has a spongiform texture (Figure 27C). While this texture has long been reported from the Holocene Hanna Bay Member (Carew and Mylroie, 1995a; 1997), it has not often been observed in the Pleistocene (Figure 28). Field relationships similar to those observed here can also be seen 1.3 km to the west at Liberty Rock (Figure 29).

Having observed the main features at this field stop, the fundamental question at this point in the trip is this: how does the geology of the Boat House Rock area fit into the geology seen

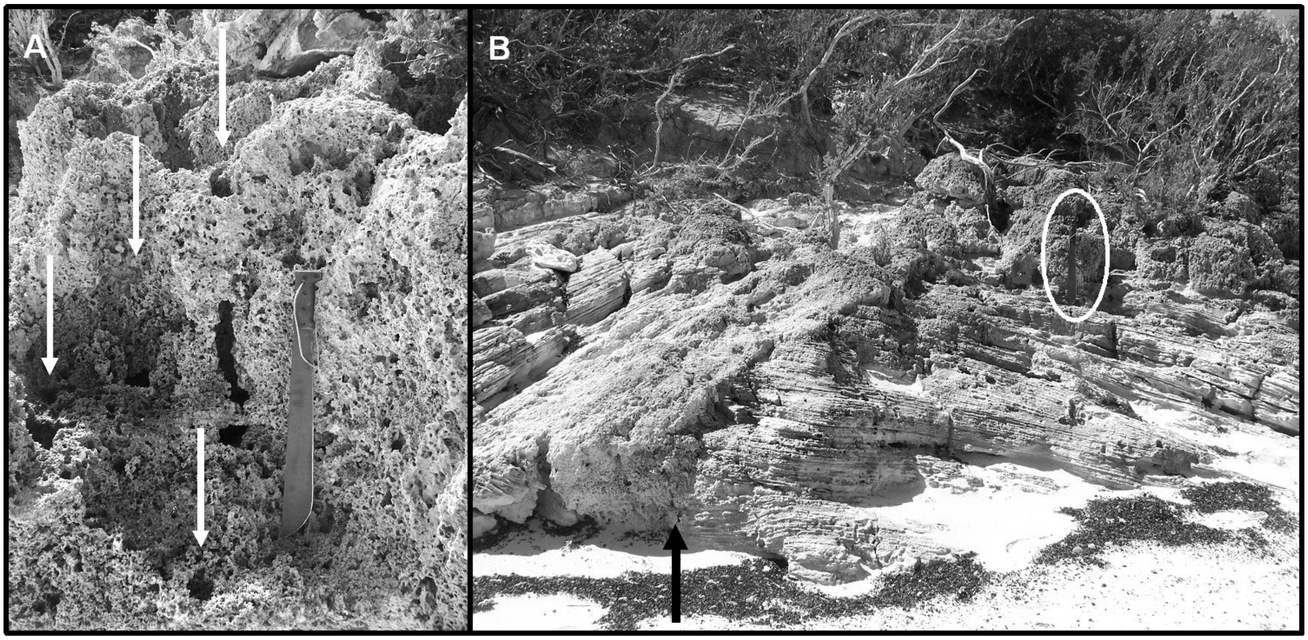


**Figure 28. Stop 9, second embayment. A) The association of spongiform texture with trunk molds (arrows). B) Spongiform texture, upper center to lower left of image, with eolian bedding of different orientations on either side. Arrow shows abrupt contact. Machete = 70 cm (in oval in B).**

elsewhere on Rum Cay and throughout the Bahamas? All of the rocks observed are clearly Pleistocene because terra rossa paleosols cap both the eolianite bluffs and the shoreline flat-topped limestone benches. The bluff-forming eolianites cropping out along the east portion of this outcrop area have the field expression of transgressive-phase eolianites described by Carew and Mylroie (1995a; 1997). Those eolianites are characterized by preservation of fine-scale lamination and limited vegemorphs. While there are features such as palm trunk molds that are not typically associated with transgressive phase eolianites seen elsewhere, they differ markedly from the eolianite underlying the flat-topped benches first observed at this stop. Those eolianites contain vegemorphs, pisolites and an underlying calcarenite protosol. These features are typically associated with stillstand and regressive-phase eolianites of the Carew and Mylroie (1995a; 1997) model. The relationship between the transgressive and regressive-phase deposits is not clear at this site. The most reasonable explanation given the observations at hand is that the transgressive eolianites are younger, perhaps French Bay Member, whereas the regressive-phase deposits may be older, Owls Hole Formation rocks. If this is the case, then the flat-topped surface initially observed at the peninsula represents a truncation surface, perhaps a paleosol-encrusted wave-cut bench, as discussed earlier.

What is needed here are outcrop observations showing the relationship of the paleosols capping the transgressive-phase eolianite and the regressive-phase eolianite. It is expected that these paleosols will merge in those areas where the overtopping transgressive (French Bay Member?) eolianite gives way to the underlying regressive (Owls Hole Formation?) eolianite. Similar relationships have been observed elsewhere in the Bahamas (e.g., Watlings Quarry, San Salvador Island). Future

**Figure 29. Liberty Rock, 1.3 km west of Stop 8 (see Figure 2). Horizontal eolianite beds overlie a truncation surface on steeply dipping lower eolianite beds. Photo by Fred Siewers.**

fieldwork should resolve the stratigraphy at this field stop.

On the way back to the field vehicles, it is worth looking closely at the lithified limestones cropping out in the surf zone and extending in some cases to the base of the eolianite bluff. The age and origin of these limestones is not entirely clear. The limestone is bioclastic and similar in composition and texture to the adjacent beach sands. These observation suggest that these limestones may simply be Holocene beach rock. However, fragments of coral suggestive of a Pleistocene subtidal facies occur in the limestone (Figure 30A). The dipping beds of the eolianite can be observed to butt sharply against the underlying horizontally-bedded limestone (Figure 24B, foreground). The presence of coral fragments cemented into a terra rossa cave deposit on the bench, already suspected to Owl's Hole Formation (Figure 30B), suggests that the marine material found in the embayment of Figure 24B is Pleistocene. Both of these observations suggest that the shoreline limestone may in fact be Pleistocene. More observations are needed before the age and origin of these rocks can be interpreted with confidence.

Walk back to the parking area, and re-board the vehicles. Drive south up and over Zion Hill

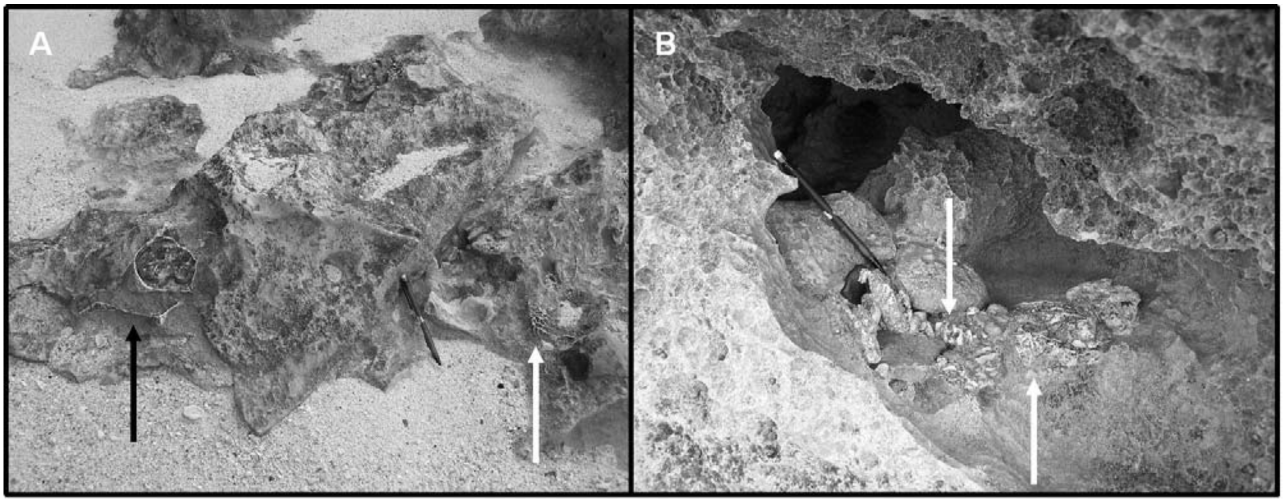


**Figure 30. Stop 9, first embayment, shown in Figure 24B. A) Conch shell (black arrow) and coral (white arrow) cemented to the wave-washed platform. B) Small cave in low headland shown in Figure 23. Coral fragments (arrows) are cemented into a reddish cave-fill material, suggesting a Pleistocene age. Pencil = 15 cm.**

and 1.5 km from the hill top is Two Sisters Hole, one of a series of karst features in this area. Park and exit the vehicles.

**STOP 10 - TWO SISTERS HOLE**

These shallow karst basins appear to be collapsed banana holes, but they could be surficial dissolutional basins (Figure 31). As shown in Table 2, the salinity here in February 2008 was zero. Rum Cay, and most Bahamian islands, have numerous wide, shallow basins such as displayed here. They are most abundant in the flat areas between eolianite ridges, at 1 to 8 m elevation above sea level. Their absence at higher elevations suggests that they are not the result of surface dissolution downwards, but result from phreatic dissolution during the MIS 5e highstand, when the fresh-water lens was elevated above modern sea level. They can be present in densities up to 3,000/km$^2$ (Harris et al., 1995). As they are commonly found in subtidal facies above modern sea level, they are likely syndepositional karst features, as noted at Stop 2.

Re-board the vehicles and drive south 1 km to Salt Water Pond at the junction of the new airport road with the King's Highway. Park and exit the vehicles.

**STOP 11 - SALT WATER POND**

This circular water body is at least 6 m deep on the north side, but the overall bathymetry of this water body is unknown (Figure 32). Water testing here in February 2008 yielded a salinity of 3.8 psu (Table 2). The feature meets the criteria of a blue hole as proposed by Mylroie et al. (1995).

A small excavation at the northeast corner of the pond, presumably made to provide easy access to the water's edge, provides good exposure of the underlying grainstone to packstone bedrock. The presence of a terra rossa paleosol indicates a late Pleistocene age, and a sparse marine molluscan fauna plus scattered trace fossils (*Ophiomorpha, Conichnus conicus,* and *Planolites,* as at Stop 7, but with a much lower level of bioturbation) indicate subtidal deposition above modern sea

**Figure 31. Stop 10, Two Sisters Hole, a partially-flooded banana hole. Note the circular bedrock rim.**

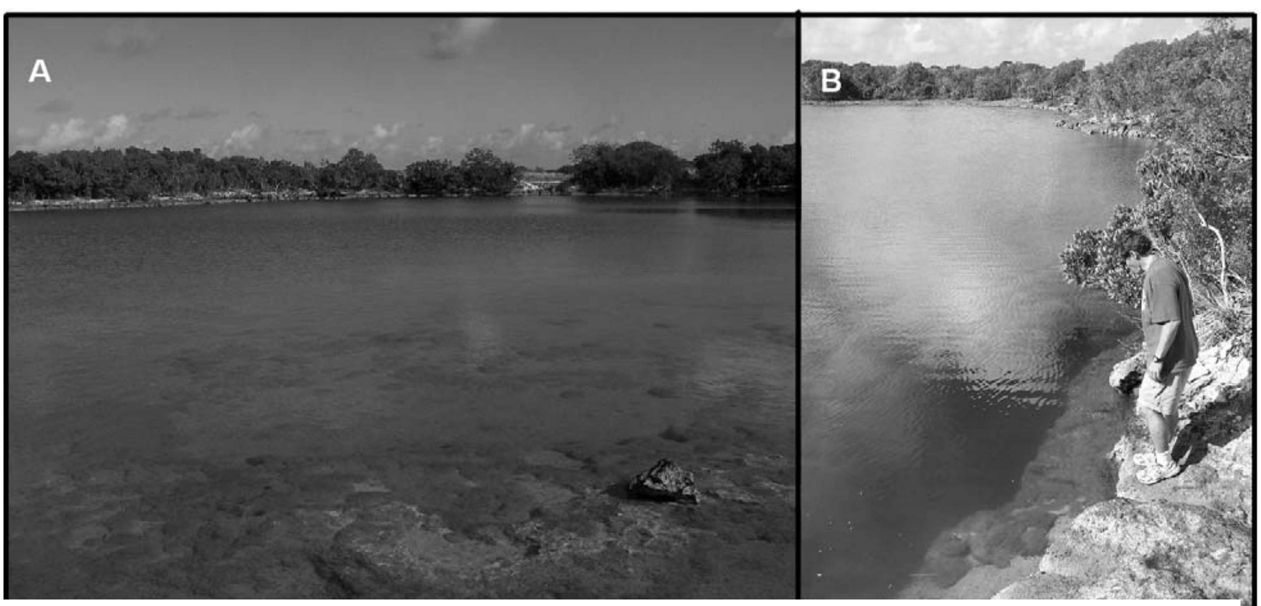


**Figure 32. Stop 11, Salt Water Pond. A) Pond overview, note that the foreground is shallow water. B) Deep spot in the north side of the pond, ~6 m.**

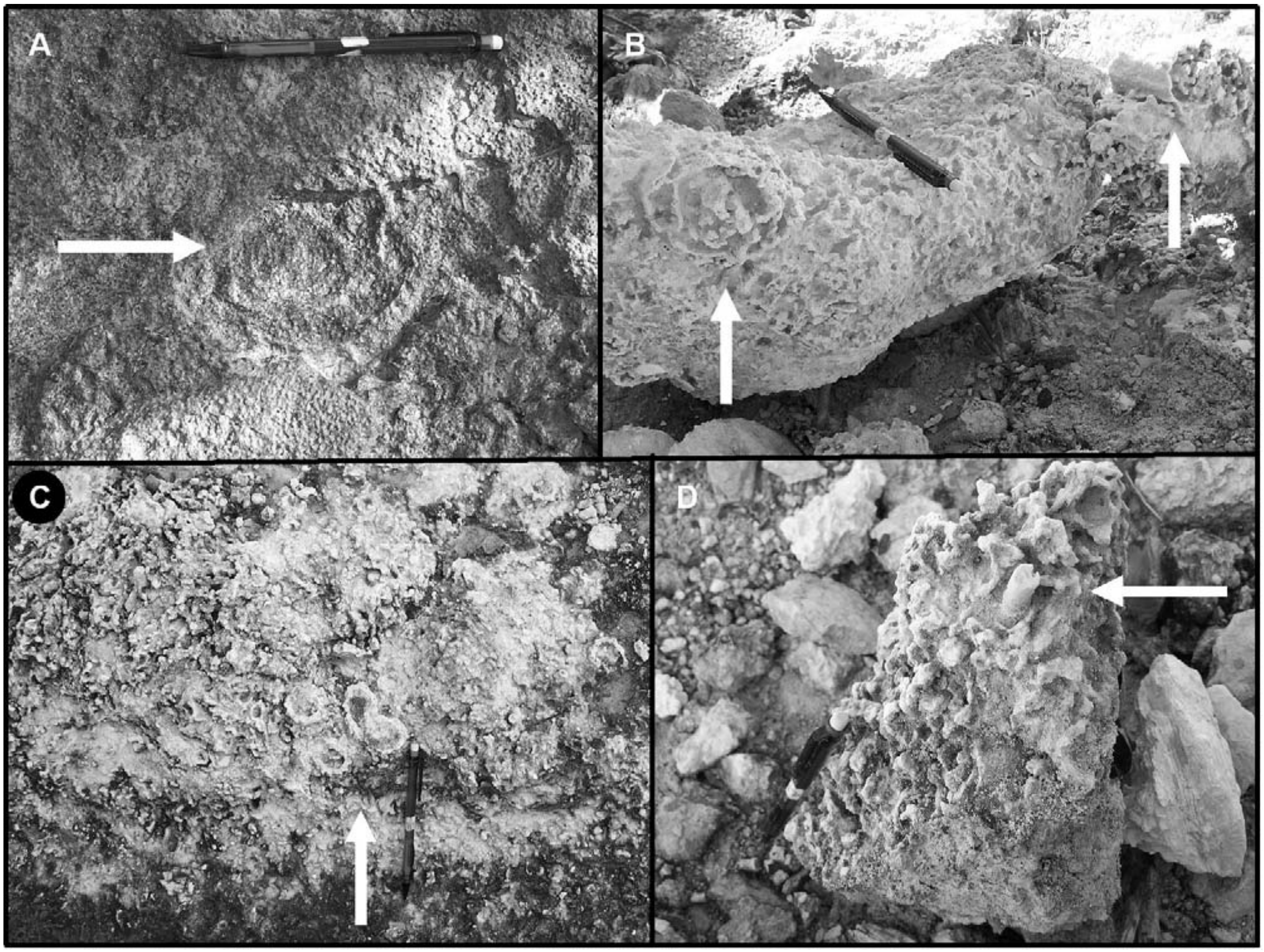


**Figure 33. Stop 11, Salt Water Pond. A. A *Conichnus conicus* fossil, *in situ* on a horizontal surface, south side of pond (arrow). Pencil =15 cm. B) *Conichnus conicus* fossils in a loose block, north side of pond (arrows). C) *Ophiomorpha* fossils, north side of pond, *in situ* (arrow). D. *Ophiomorpha* fossils in a loose block, north side of pond (arrow).**

level (Figure 33). Therefore, these strata must be assigned to the Cockburn Town Member of the Grotto Beach Formation.

Re-board the vehicles and make the short drive west to the airport waiting area. Board the planes and fly to San Salvador Island.

## IMPORTANT OUTCROPS THAT WILL NOT BE VISITED

Because of the small population of Rum Cay, the resulting primitive road network, and the limited time available, it is not possible to visit all the outcrops visited by the field guide authors in February 2008. Here are descriptions of the most significant of these localities.

**West of Stop 2:** Continuing on the coast road (or track) west of Stop 2 (Figure 2), beaches alternate with rock outcrops. The rocks change from Hanna Bay Member (Rice Bay Formation) to Cockburn Town Member (Grotto Beach Formation) and back. In many places, the Hanna Bay Member overlies the Cockburn Town Member. Some sites have the Cockburn Town Member peeking through small erosional "windows" in the overlying Hanna Bay

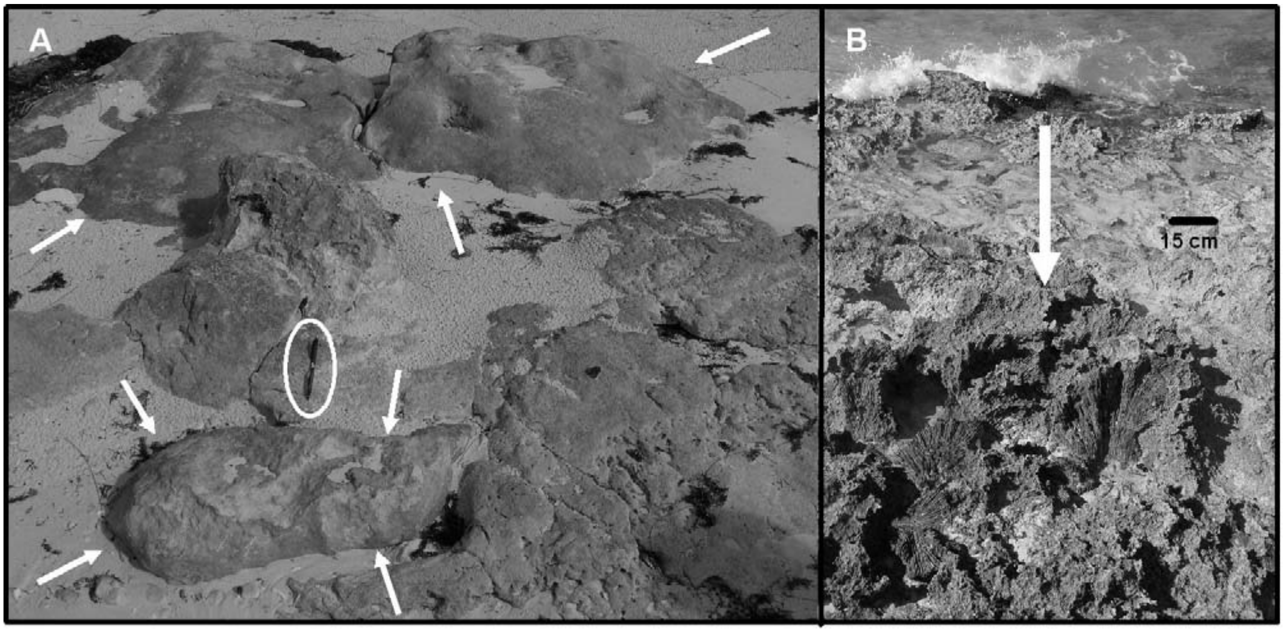


**Figure 34. Munroe Beach, west of Stop 2. A) Pleistocene Cockburn Town Member subtidal sands with a terra rossa paleosol (arrows), peeking through a Holocene Hanna Bay Member cover. Pencil in oval = 15 cm. B) Fossil coral (arrow) near Nesbitt Point, west of A.**

Member, other sites have little eroded "islands" of Hanna Bay Member lying on top of a broad Cockburn Town Member outcrop (Figure 34A). Fossil corals are found in some places, continuing westward to Nesbitt Point, our western limit of investigation (Figure 34B).

**Queens Highway to Hartford Cave:** West of Stop 2, taking the inland road west, leads to a junction with the Queens Highway, which heads 4 km due north to the north shore of the island. Along the way there are numerous rock outcrops, three of which were described by Mitchell (1987). His sites RK24 and RK25 are described as "Pleistocene Well-Cemented Eolianite Lithofacies", interpreted by Mitchell to have been deposited as dunes during MIS 5e. We agree that the eolianites are Pleistocene, as indicated by their inland position and terra rossa paleosol cover. However, a definitive MIS 5e, or Grotto Beach Formation identification, is not possible, as the dunes could be Owl's Hole Formation based on the information available.

South of those low ridges is Mitchell's RK 26 site, described as part of the "Pleistocene Tidal Creek Lithofacies". The presence of subtidal facies above modern sea level indicates these rocks are Cockburn Town Member of the Grotto Beach Formation. Water samples were taken from shallow ponds and wetlands along this road by the field guide authors in February 2008, those results are reported in the Island Hydrology section, which follows later in this guide (see Table 2).

At the north coast, the road ends at a rocky headland of eolianite, which is Pleistocene as indicated by its well-developed terra rossa paleosol. The north or coastal side of this headland is a low cliff revealing an intersected lenticular dissolutional void, infilled with breccia and terra rossa paleosol material (Figure 35). A phreatic dissolutional void or cave at this position requires the rock be either French Bay Member of the Grotto Beach Formation (and the cave is therefore syngenetic), or the rock is Owl's Hole

**Figure 35. Coastal cliff at the north end of the Queens Highway (see Figure 2). Infilled cave with solution collapse breccia.**

Formation. The cave is remarkably similar to cave and fill deposits found in the French Bay Member at its type location on San Salvador Island (Florea et al., 2001), supporting a speculation that the rock is French Bay Member.

Continuing west from this headland down to a beach, isolated low rocky outcrops and open beach eventually coalesce into a continuous rocky coast (Figure 36A). A well-developed terra rossa paleosol, with abundant vegemorphs, dominates the upper regions of the outcrop, above routine wave swash, and the paleosol "drapes" over the eolianites (Figure 36B&C). Seaward, the beds flatten and lose their undulatory nature, appearing to be grading into a back beach facies, making a contact with lower units (Figure 36D). Mitchell (1987) reports marine facies in this area, his RK27 locality. The rocks are definitely Pleistocene; the abundant vegemorphs, and the similarity of the outcrop to many along the east side of San Salvador Island, along with reports (Mitchell, 1987) of marine facies above modern sea level here, suggest these rocks are Cockburn Town Member of the Grotto Beach Formation.

At Hartford Cave Point, 2 km west, the aforementioned rock unit appears to onlap an older rock unit. At this point two flank margin caves are visible. A small one on the east side of the point, and a large one, Hartford Cave, at the point itself. The small cave entrance is at the back beach, and is low, about 1 m high, but about 6 m wide (Figure 37A). It leads south into a low, wide chamber, the east side of which, near the entrance, housed a young goat. Goat scat is abundant. The chamber is about 12 m wide. The floor slopes inward such that the ceiling rises to 1.5 m high, and then at the

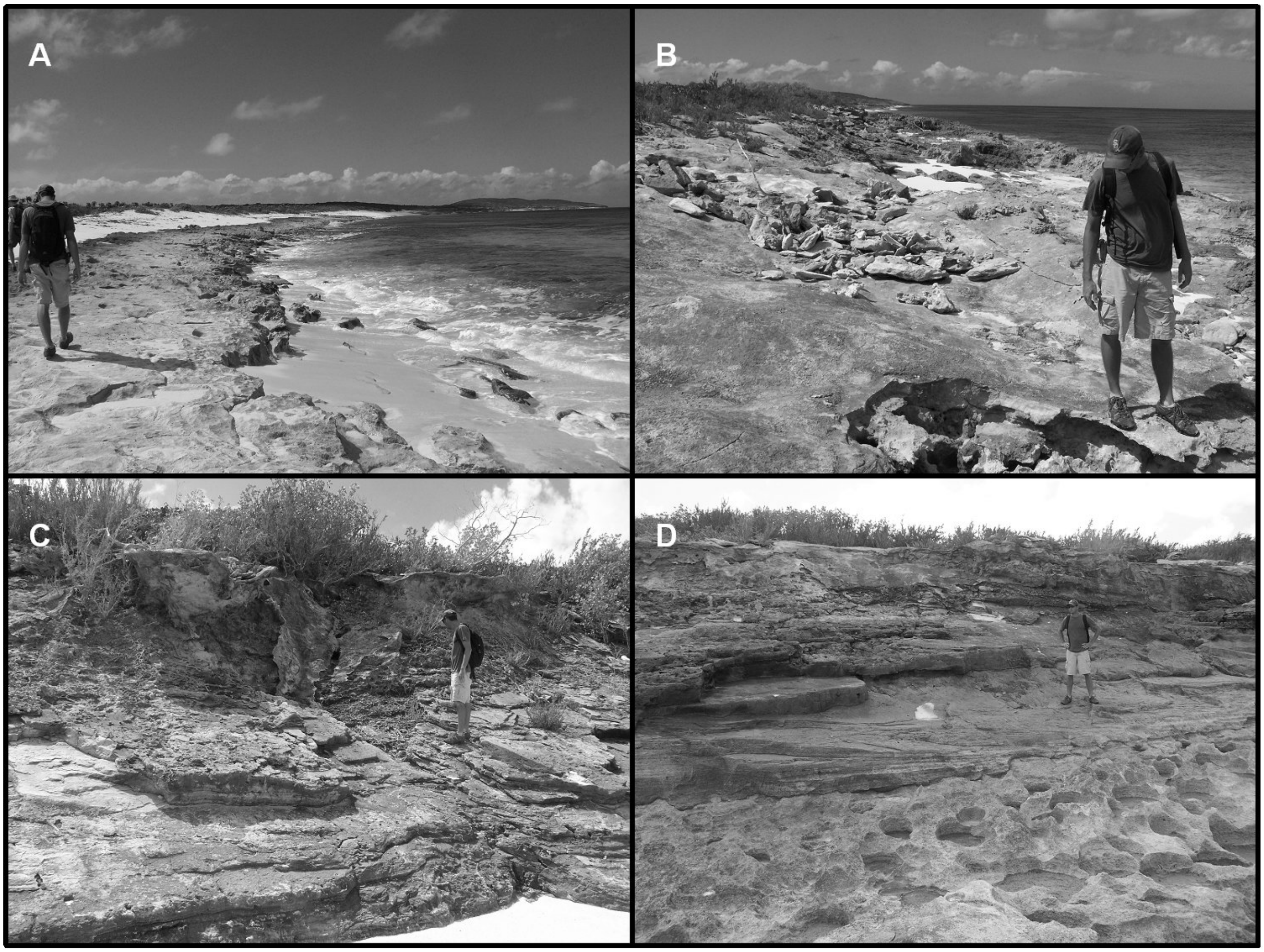


**Figure 36. Coastal cliff at the north end of the Queens Highway, heading west to Hartford Cave. A) Beach and beachrock at start of the Hartford Cave hike. B) Terra rossa paleosol appearing to "drape" over underlying eolianite. C) A dramatic example of paleosol "drape" in upper center of image, with abundant vegemorphs. D) Bedding of low dip overlying a prominent contact.**

rear of the chamber, 10 m from the entrance, the roof rises into a higher section 3 m high, with numerous bell holes (cylindrical shafts) dotting the ceiling. These bell holes lead upward 2 to 3 m and form a complex cluster (Figure 37B). A patchy, dark crust found in the bell holes is likely to be gypsum, and associated minerals, as determined for Lighthouse Cave, San Salvador (Onac et al., 2001).

Slightly west is Hartford Cave itself. The cave has a large entrance about 30 m wide and 5 m high (Figure 38). The entrance faces directly on the beach, and beach sands spill into the cave. The cave is a large, single chamber. Its globular shape and cuspate interior configuration (Figure 39A) are very similar to the Caves Point West Cave's inner chamber, on New Providence Island, Bahamas (Carew et al., 1996). The cave is about 25 m deep and 30 wide. The floor consists of large breakdown blocks interspersed with storm debris brought in by waves (Figure 39B). Goat scat is ubiquitous. The ceiling has numerous bell

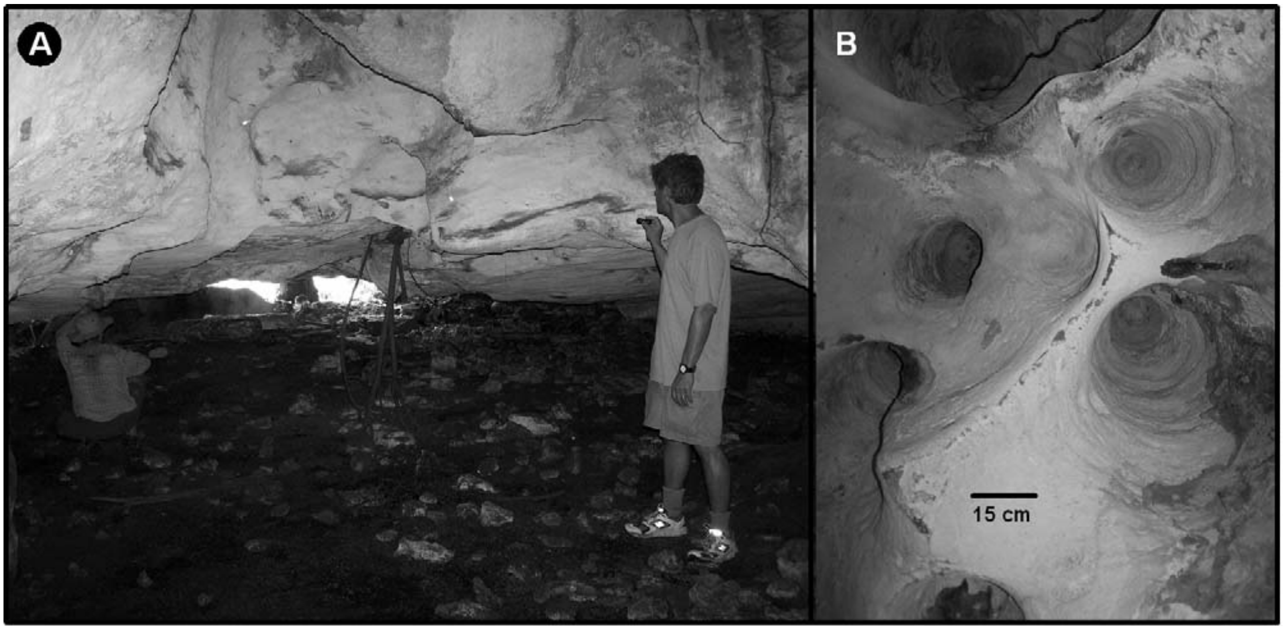


**Figure 37. Hartford Cave area. A) Main chamber of the small cave just east of Hartford Cave, looking out the low, wide entrance. B. Bell holes in the ceiling at the rear end of the small cave. Patchy, dark crust is probably gypsum.**

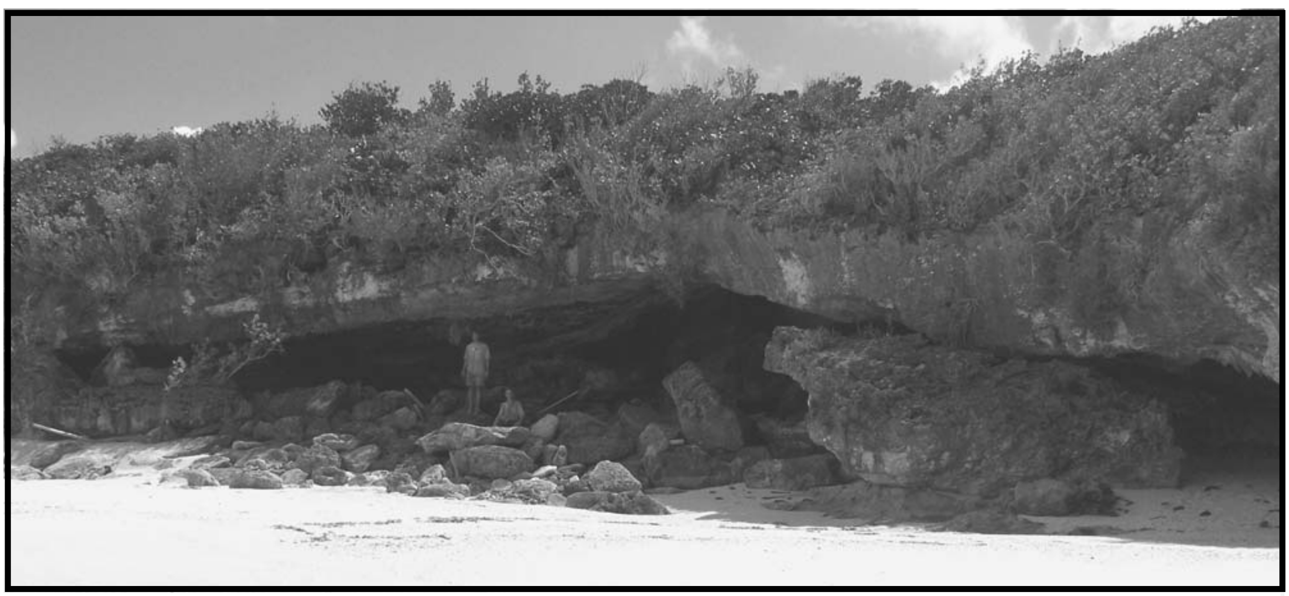

**Figure 38. Hartford Cave Entrance.**

holes, some of which have been breached by surface denudation. Other roof collapses exist, and the interior of the cave is reasonably well-lit on a sunny day (Figure 39 C&D). The most noteworthy features of Hartford Cave are the extraordinary petroglyphs, or rock carvings, covering the walls, especially the western and southern (back) walls (Figure 40). They are more abundant, and more sophisticated, than any the authors have seen elsewhere in the

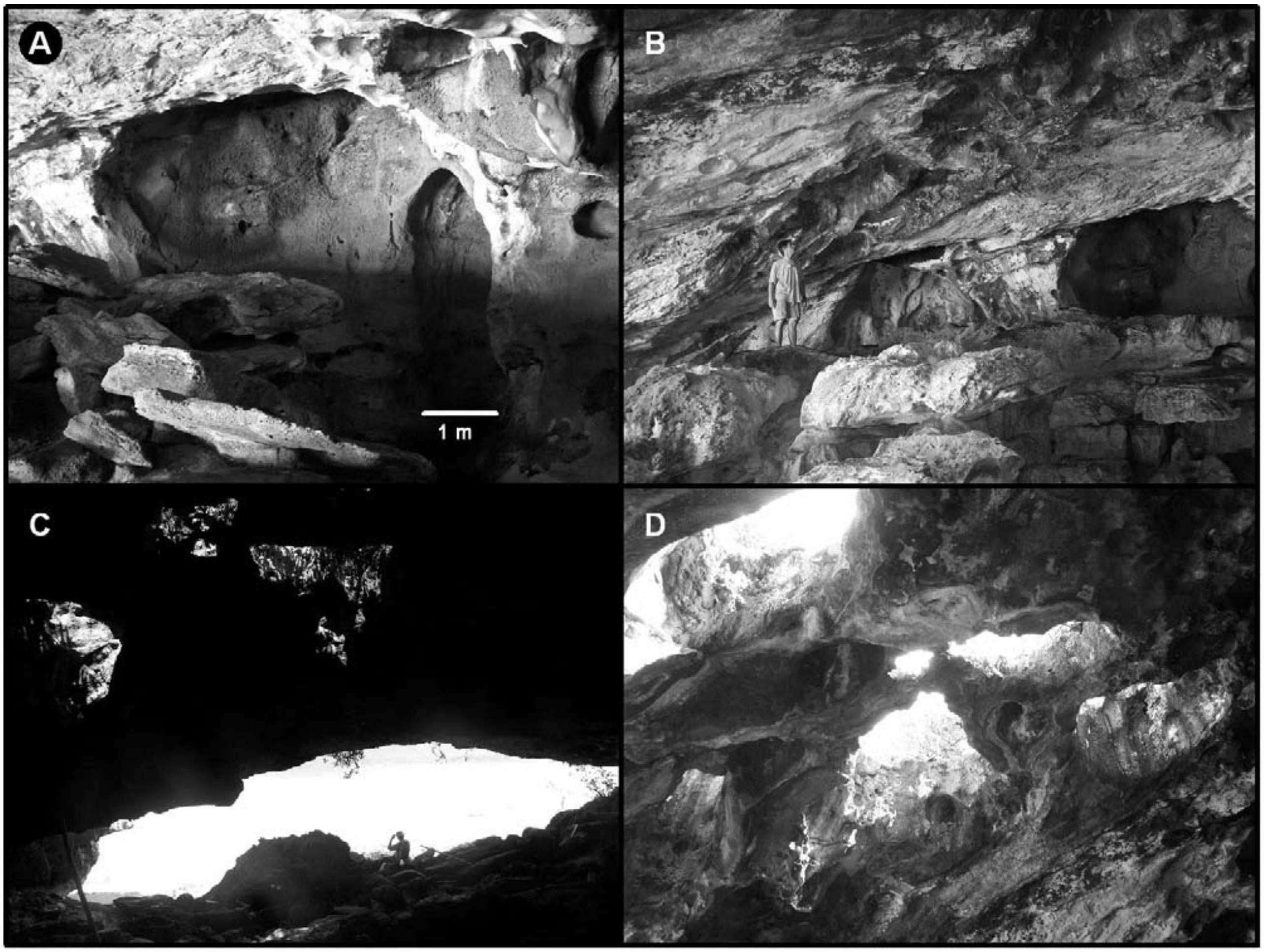


**Figure 39. Hartford Cave. A) Globular and pocketed chamber wall pattern. B) Main chamber of the cave. C) Looking north out the cave entrance, with roof skylights. D) Skylights form a fretted cave ceiling.**

Bahamas. They are remarkably similar to those seen in Cueva del Indio, a cave also developed in Pleistocene eolianites on the north shore of Puerto Rico (Kambesis, 2007). The rock containing the cave is most likely Owl's Hole Formation, given the size of the cave and the onlap of the younger rock on either side, but a French Bay Member designation is still possible. Farther west are outcrops at which Mitchell (1987) reported some fossil reef facies, his RK22 site. Mitchell also reports contacts with marine lithofacies intermittently from his RK27 site east of Hartford Cave, on east to his RK 33 site, just east of Boat House Rock. Interpretations of some of these outcrops are a bit problematic, as was seen at Stop 9 of the field trip.

**West of Boat House Rock:** The Kings Highway road ends at Boat House Rock on the north shore of Rum Cay. Stop 9 is to the east of this road head. To the west, a broad beach with some beachrock curves 1 km to another headland, Liberty Rock (Figure 29) and a rugged track continues west an additional 1 km to the next rocky headland, the end of the rugged track. Eastward back to Boat House Rock the authors saw only Pleistocene eolianites, although Mitchell (1987) suggests marine facies may be present. These eolianites

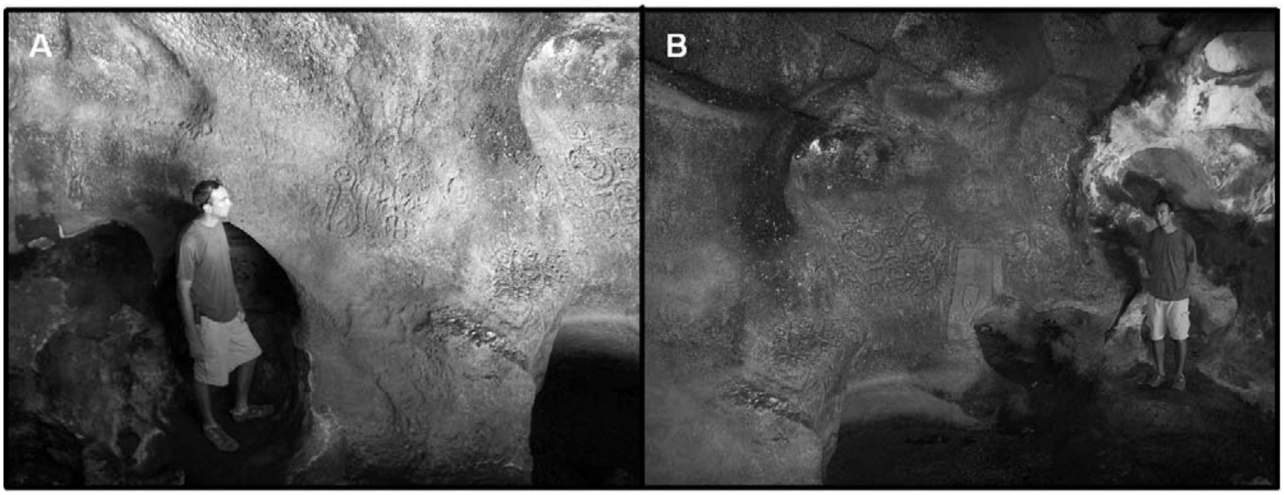


**Figure 40. Hartford Cave A) Petroglyphs, left rear of main cave chamber. B) Petroglyphs, rear of main cave chamber. Note in front of the person that one petroglyph has been sawn out and taken.**

show complex features, which are discussed in the Stop 9 description.

**Northeast of Zion Hill**: On the Kings Highway, north of Zion Hill but before Boat House Rock, a crude track heads 400 m east to Adderleys Pond, an interior water body with a salinity of 4.8 psu (see Island Hydrology section). Feral cattle were seen here in February 2008 (Figure 41). The track become impassible for vehicles at this point, but a trail continues eastward into rising eolianite ridges, looping around Lake George southeast to reach the east coast at a point accessible by a crude road (see next description). The eolianite ridges in this northeastern part of Rum Cay are the highest on the island. Outcrops visited all showed a terra rossa paleosol, indicating a Pleistocene age, but further differentiation is not possible with the data at hand.

**Coastal Outcrops East of Lake George:** Approximately 1 km north of Port Nelson, a dirt road leads east. After 2 km, this road forks. The east, or right-hand fork leads to the north side of Salt Pond (see next description). The northeast, or left-hand fork, becomes difficult to traverse, passing up and over numerous dune ridges. The rocks are all Pleistocene, based on abundant terra rossa paleosol evidence.

**Figure 41. Feral cattle at Adderleys Pond northeast of Zion Hill. Salinity here was 4.8 psu in February, 2008.**

Eventually, after 3 km of traverse, the east end of Lake George becomes visible to the north, and the Atlantic Ocean is visible to the east. Holocene sands cover both the 6 m high coastal ridge, and the swale inland and just west of that ridge. The thickness of the Holocene sands on

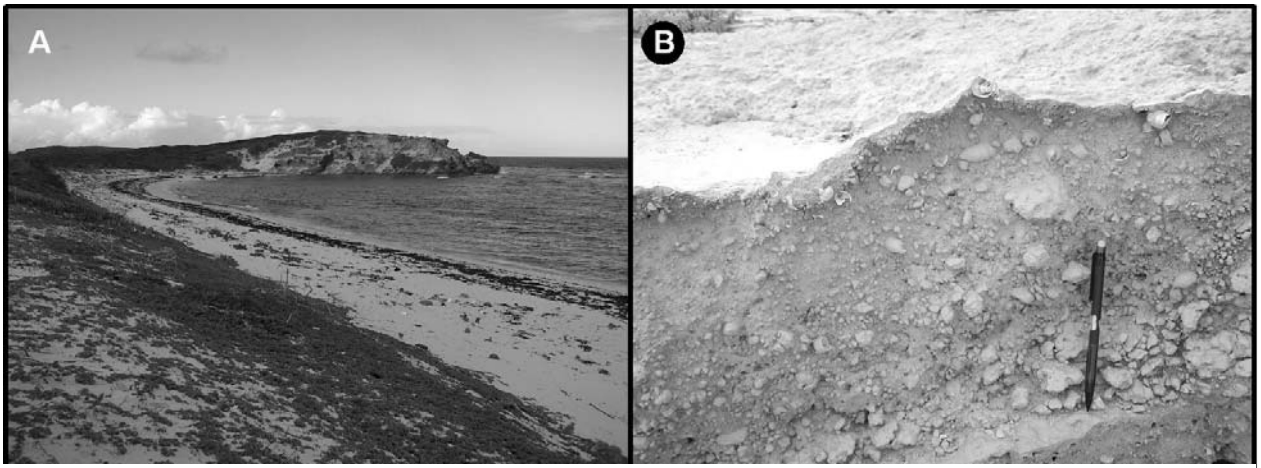


**Figure 42. Sea coast north of Adderleys Bluff. A) View north, with Holocene ridge in foreground, and Cockburn Town Member bluff in the distance. Lake George is off the image to the left of the bluff. B) Complex, fossil and pisolite-rich terra rossa paleosol covering the Cockburn Town Member rocks at the bluff. Pencil = 15 cm.**

the ridge is unknown, and the coastal ridge may have an eolianite rock core (see Stop 4). Walking north along this coastal ridge leads to a higher ridge which is a lithified, but poorly-cemented, eolianite (Figure 42A). This ridge has imposing sea cliffs 12 m or more high. From a distance the ridge looks remarkably similar to Holocene eolianites, but as is seen at Stop 6, close examination reveals a well-developed terra rossa paleosol on the ridge crest (Figure 42B). The ridge, which could be seen to extend north toward Junkanoo Rock, on close inspection looks much like the Cockburn Town Member regressive-phase eolianite bluffs that dot the east coast of San Salvador Island (The Bluff, Almgren Cay, Crab Cay, and also

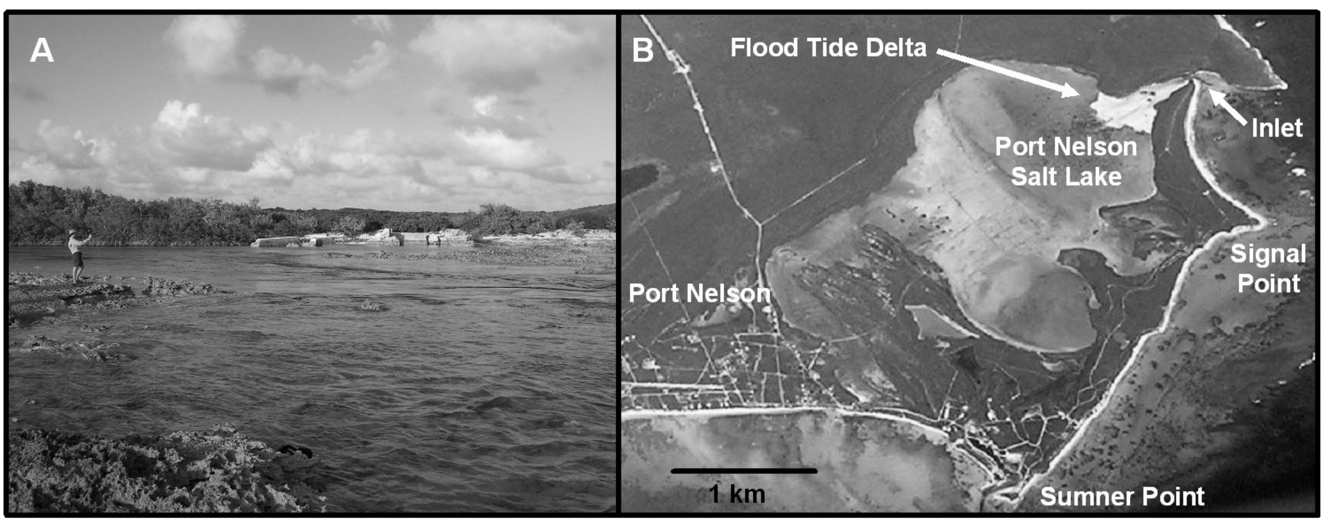


**Figure 43. Port Nelson Salt Lake and inlet. A) Inlet showing strong ebb-tidal flow in February, 2008 (seaward to the right, or east) and ruined water control structures from the salt production era on the far, north shore. B) Aerial photograph of the Port Nelson area, showing localities mentioned in the text. Note the obvious flood-tide delta into Port Nelson Salt Lake, in contrast to the ebb-tidal delta at Pigeon Creek San Salvador. Photo by Neil Sealey.**

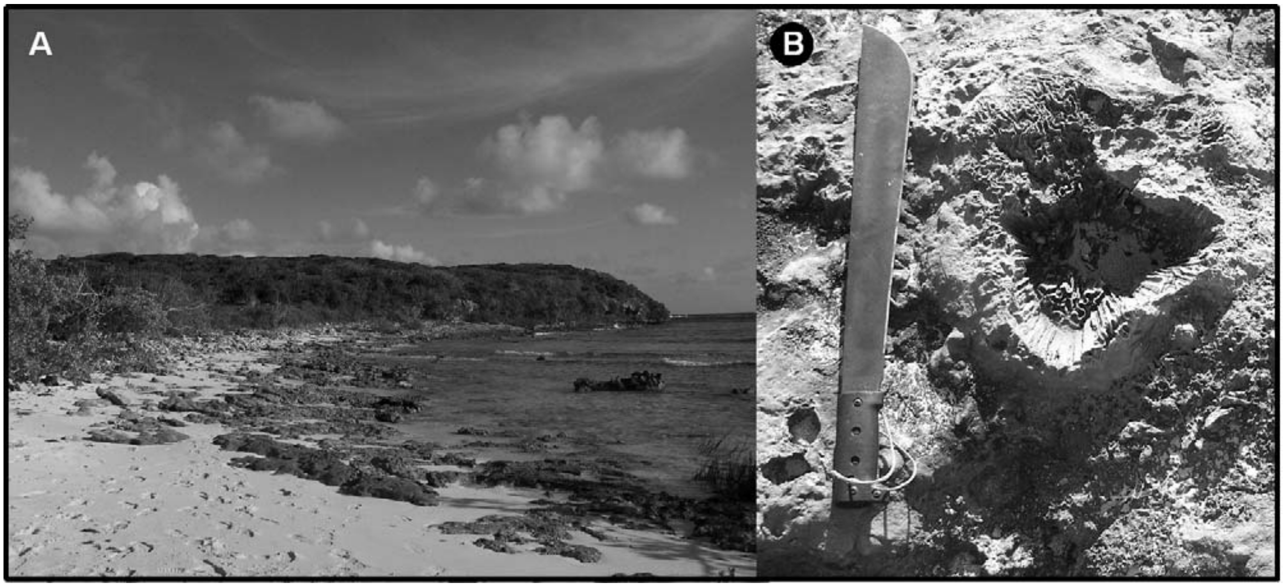

**Figure 44. North shore of the Port Nelson Salt Lake inlet. A) Small beach and rocky bench leading east, and narrowing against the hillside which becomes a sea cliff. The hillside has numerous cave entrances. Tidal control ruins of Figure 43A are immediately behind the photographer. B) Fossil coral partially covered by a terra rossa paleosol on the bench shown in A. Machete = 70 cm.**

Manhead Cay). The previously described trail from Zion Hill around the north side of Lake George reaches the coast at the Holocene beach ridge/Pleistocene eolianite junction. The last portion of the road from Port Nelson to this locality is very difficult going, as it is a newly bulldozed part of the recent development occurring on Rum Cay.

**North Shore of the Port Nelson Salt Lake Inlet:** From the road fork mentioned above, avery difficult road (but an easy hiking trail) trends east and southeast 1 km to the north shore of Port Nelson Salt Lake, then heads 500 m east over a Pleistocene dune ridge to the north side of the lake inlet. This ridge has numerous pit caves and other karst features on it. The trail continues east, but a side trail goes downhill to the ocean side of the inlet. The inlet is narrow, only a few tens of meters across, and when flowing maximally at mid-tide, displays a powerful current (Figure 43A). The water elevation difference at this time between the inland and ocean portion of the channel can be seen to be a half a meter or more, a dramatic hydraulic head. The current has deposited a large flood-tide delta in Salt Pond (Figure 43B). Many ruined concrete and stone structures, left over from the salt production era, are present at the inlet (Figure 43A).

Heading eastward, a low, flat bench runs parallel to the north side of the inlet, with an eolianite ridge rising farther to the north (Figure 44A). This bench narrows and pinches out against the eolianite ridge, and the north side of the tidal inlet bay then becomes a sea cliff. The bench is covered by a partially eroded terra rossa paleosol, and the rock underneath has many fossil corals in it (Figure 44B). The bench is thusly interpreted to be the Cockburn Town Member of the Grotto Beach Formation. The eolianite ridge forming the north boundary of the bench extends inland and parallel to the bench from the sea cliffs on the east to the interior in the west. This inland portion of the ridge is notched, perhaps as a

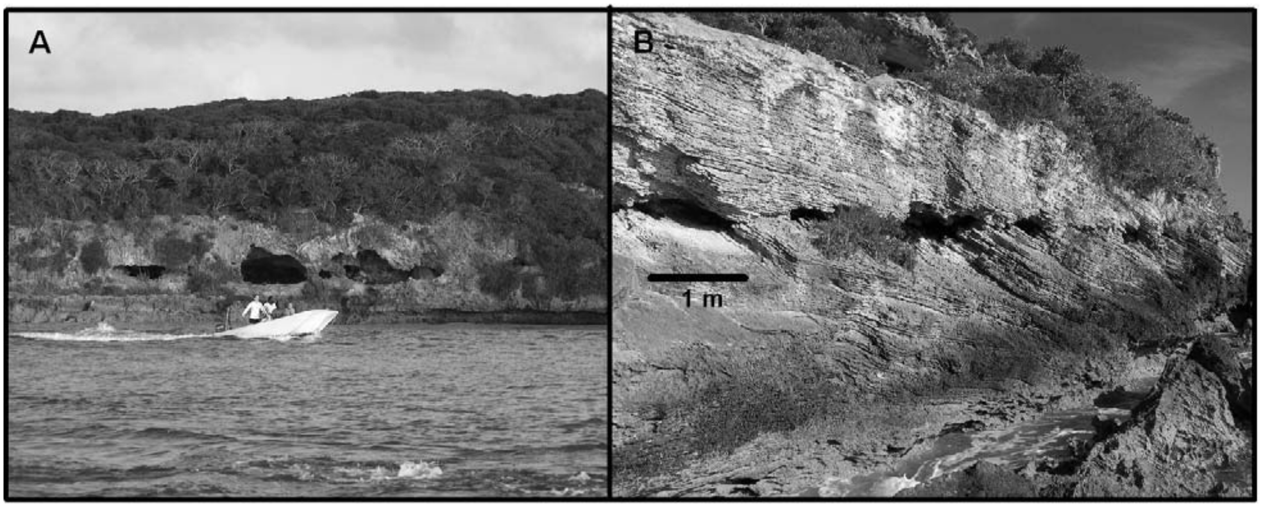


**Figure 45. North shore of the Port Nelson Salt Lake inlet. A) Flank margin cave entrances displaying "beads on a string" morphology. B) Beads on a string morphology at the small scale, above and right of those seen in A.**

paleo-sea cliff, and numerous flank margin cave entrances are present in this notch (Figure 45). These flank margin cave floors are at about 2 m above modern sea level, and their dissolutional ceilings rise up to 6 m or more above modern sea level (Figure 46). While there are many cave entrances, several of these entrances link up with a single cave inside the ridge, while others lead only to an isolated chamber. This pattern of laterally continuous and discontinuous caves and entrances has been called "beads on a string" (Mylroie and Mylroie, 2007), and represents a typical pattern for flank margin cave development in the Bahamas and around the world (Figure 45). The caves penetrate into the ridge a maximum


**Figure 46. North shore of the Port Nelson Salt Lake inlet. A) Flank margin cave entrance, looking out to the southeast. This entrance is the large, central one seen in Figure 45A. Photo by Al Curran. B) Flank margin cave passage in steeply-dipping eolianite. Note how the dissolutional ceiling maintains a horizontal profile.**


**Figure 47. North shore of the Port Nelson Salt Lake inlet. A) Breached cave above and right of those in Figure 45A. Note the truncation surface separating horizontal eolianite beds from steeply dipping ones below. Machete in oval = 70 cm. B) Fossil coral in a terra rossa paleosol at the mouth of a flank margin cave. C) Close up of B to show fossil coral clearly.**

of 15 m, and fall into the medium-sized classification of Roth et al. (2006).

Two additional features can be observed at this locality. In the sea cliffs to the east, where the bench pinches out, are a series of open cave chambers, but at elevations 6 m or higher above modern sea level. It is unclear from thesuperficial investigation made in February 2008 whether these features are breached flank margin caves, or tafoni caves. These caves reveal the interior of the dune ridge, and display a pronounced deflation surface within the eolian structure (Figure 47A). The age of the eolian ridge is undetermined. It could easily be Owl's Hole Formation, notched by the MIS 5e sea-level highstand, with concurrent flank margin cave development in the distal margin of the fresh-water lens just inside of that notch. Alternatively, the eolianite may be French Bay Member of the Grotto Beach Formation, and developed on the MIS 5e transgression. Continued rise of sea level to its highstand could have notched the dune, allowing the corals to grow on the subsequent hardground, and flank margin caves to form within the flank of the dune. Modern sea level is high enough for wave energy to cross the MIS 5e bench and further erode the eolianite, breaching the flank margin caves. Fossil corals can be found right up to the entrances of the flank margin caves (Figure 47B), but not on the entrance floor itself, or inside the cave (as has been seen in Isla de Mona, Mylroie and Mylroie, 2007). Therefore it does not appear the caves were breached during MIS 5e time. The cave development inside the flank of the ridge, and the coral growth adjacent on the wave-cut bench on the eroded side of the dune, could be synchronous.

Across the inlet, and sweeping to the southeast to Signal Point, is a large eolianite ridge. As noted in the Stop 6 discussion, this ridge is Holocene, the North Point Member of the Rice Bay Formation. Inland and due south of the inlet, the rock is Pleistocene as indicated by ubiquitous terra rossa paleosol.

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**Geologists with too much sun and too little water (or too much alcohol) demonstrate how to spell out Flank Margin Cave to the tune of "YMCA".**


Fred In Seat 1
Fred *In Situ*