PROCEEDINGS OF THE 13th SYMPOSIUM ON THE GEOLOGY OF THE BAHAMAS AND OTHER CARBONATE REGIONS

Edited By
Lisa E. Park and Deborah Freile

Production Editor
Lisa E. Park

Gerace Research Centre
San Salvador, Bahamas
2008

Front Cover: Rice Bay Formation, looking southwest along Grotto Beach. Photograph by Sandy Voegeli.

Back Cover: Dr. John Milliman, The College of William and Mary. Keynote Speaker for the 13th Symposium. Photograph by Sandy Voegeli.

Produced at
The Department of Geology and Environmental Sciences, The University of Akron

ISBN 0-935909-82-6

A PRELIMINARY GEOLOGICAL RECONNAISSANCE OF ABACO ISLAND, BAHAMAS

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ABSTRACT

Abaco Island is located on Little Bahama Bank at the northeastern extent of the Bahamian Archipelago. Examples from each of the three major field stratigraphic units—Owl's Hole, Grotto Beach, and Rice Bay formations can be identified on Abaco based on observable field relationships. The Owl's Hole Formation is recognized as a vegemorph-rich eolianite, with foresets truncated by wave energy from a subsequent highstand, covered by a *terra rossa* paleosol. Outcrops of the Grotto Beach Formation show fossil coral rubble (Cockburn Town Member) resting directly on an underlying eolianite with no separation by a *terra rossa* paleosol (French Bay Member). Widespread outcrops containing herringbone cross-bedding also belong to the subtidal Cockburn Town Member. Eolianites lacking a *terra rossa* paleosol are Rice Bay Formation rocks, assigned to the North Point Member as shown by foresets dipping below modern sea level. The Pleistocene/Holocene contact can be seen in outcrop as a *terra rossa* paleosol separating Rice Bay Formation eolianites assigned to the Hanna Bay Member from underlying Pleistocene eolianites.

Karst features on Abaco include large and abundant flank margin caves, pit caves, blue holes, karren, and banana holes--all of which are common features of Bahamian islands. The large positive water budget of Abaco has produced landforms resembling tropical cone karst on Pleistocene eolianites. The first documented tafoni caves in the Bahamas, pseudokarst features formed by wind and salt erosion, demonstrate the need for caution when using caves as sea level indicators.

INTRODUCTION

The Bahamas have long been the focus of much geologic work on modern carbonates (Carew and Mylroie, 1997 and references therein; Tucker and Wright, 1990; Multer, 1977; and Illing, 1954). The Bahama Platform (Figure 1) has particular interest to geologists as it provides a modern analog to the dynamics of ancient carbonate depositional platforms, many of which are major petroleum reservoirs.

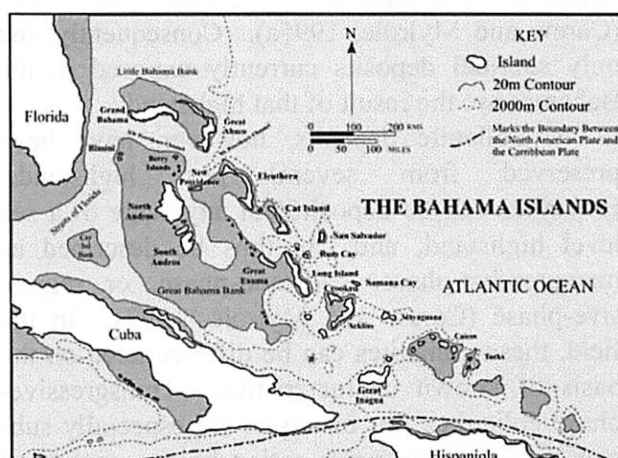

Figure 1. Map of the Bahamian Archipelago (Modified from Carew and Mylroie, 1995a).

The Bahama Platform is composed of a series of thick, shallow-water, carbonate banks along the subsiding margin of North America (Mullins and Lynts, 1977). The current landscape of the Bahamas is largely constructional and is greatly influenced by glacioeustatic sea level fluctuations (Carew and Mylroie, 1997). During sea level lowstands, sea level dropped below the bank margins. Carbonate sedimentation ceased and karst processes dominated on the exposed bank tops. Lowstands are recorded in the sedimentary record by the development of *terra rossa* paleosols. These fossil soil horizons are the result of the concentration of insoluble materials such as atmospheric dust due to pedogenic processes.

During sea level highstands, the banktops are flooded, allowing for the creation and mobilization of carbonate sediments. The glacioeustatic sea level oscillations that have occurred throughout the Quaternary have allowed for the emplacement of several carbonate depositional sequences capped by *terra rossa* paleosols (Carew and Mylroie, 1997). Due to the known subsidence of the Bahamian archipelago of 1-2 m per 100,000 years, sediments that were originally deposited above current sea level may now be inundated (Carew and Mylroie, 1995a). The only sea level highstand above present to occur recently enough to still be exposed today was the +6 m Oxygen Isotope Substage (OIS) 5e highstand, that occurred approximately 125,000 years ago (Carew and Mylroie, 1995a). Consequently, the only subtidal deposits currently exposed in the Bahamas are the result of that highstand.

Eolianite deposits, however, have been preserved from several past highstands. Eolianites can be deposited at any stage of a sea level highstand, and can thus be described as transgressive-phase, stillstand-phase, or regressive-phase (Carew and Mylroie, 1997). In the field, these eolianites can be differentiated on the basis of known characteristics. Transgressive-phase eolianites, for example, are especially subject to cliffing by wave action because sea level continues to rise during their deposition. They are also characterized by a relative lack of vegemorphs, as the coastal vegetative community has not yet had time to develop at the onset of a sea level rise (Carew and Mylroie, 1997). Regressive dunes, on the other hand, contain abundant vegemorphs, as the coastal vegetative community has fully developed by the time of their deposition (Carew and Mylroie, 1997).

A general stratigraphy of the Bahamas was developed by Carew and Mylroie based on their work on San Salvador Island, Bahamas (Carew and Mylroie, 1995b; 1995c; and 1997). It consists of three major depositional packages separated by *terra rossa* paleosols (Figure 2). The Mid-Pleistocene Owl's Hole Formation, which consists of eolianites from several sea level highstands, comprises the oldest rocks in the Bahamas (Figure 2). The Upper Pleistocene Grotto Beach Formation consists of eolianites, beach deposits, and subtidal carbonates deposited during the OIS 5e highstand (Figure 2). The Holocene Rice Bay Formation contains all deposits, primarily eolianites, associated with the current sea level highstand (Figure 1).

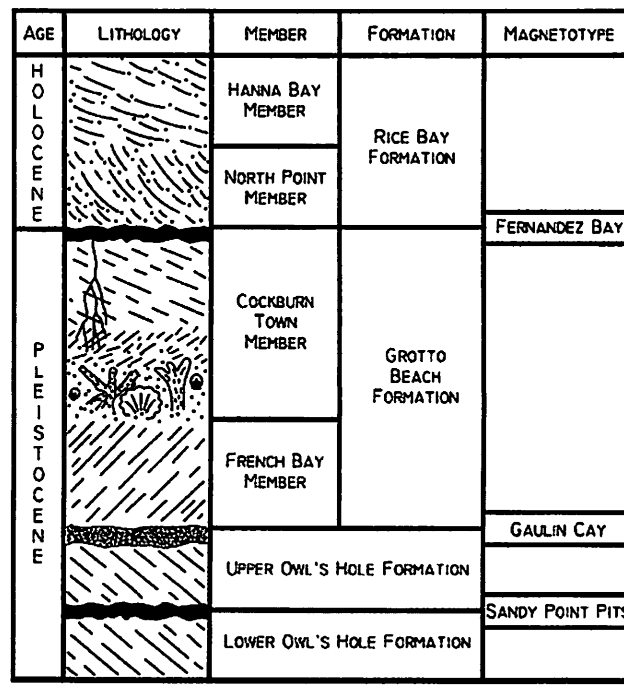

Figure 2. General Stratigraphy of the Bahamas (Modified from Carew and Mylroie, 1997).

Abaco Island is located on Little Bahama Bank and is the most northeastern island in the Bahamian archipelago (Figures 1 and 3). It is bordered on the east by the deep waters of the Atlantic Ocean, on the south by the deep waters of N.W. Providence and N.E. Providence Channels, and on the west by the shallow waters of the Little Bahama Bank (Figure 1). The landmass of Abaco consists of two main islands, Great Abaco Island

and Little Abaco Island, as well as numerous outlying cays (Figure 3).

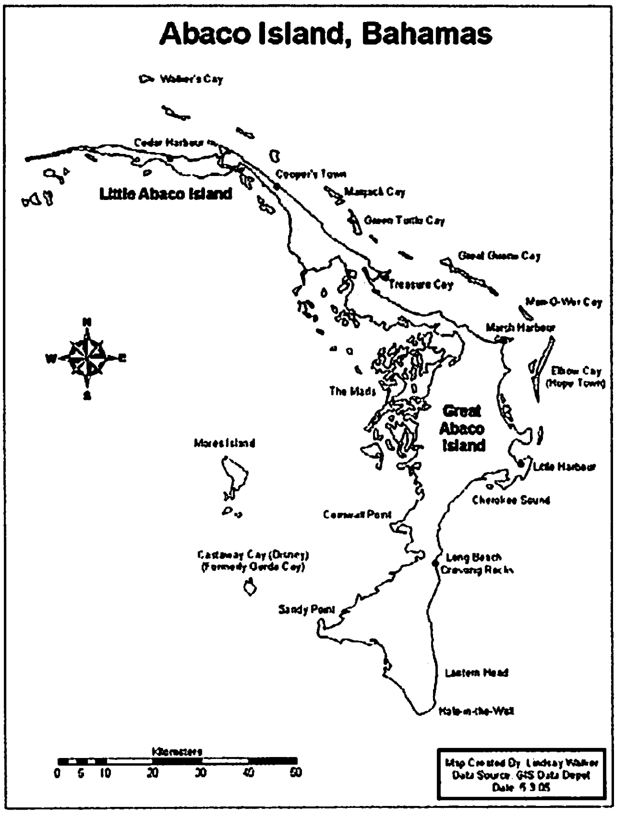

Figure 3. Map of Abaco Island, Bahamas.

Previous geologic work on Abaco has focused largely on offshore sedimentary processes (Mullins et al., 1984; Mullins, 1983; Mullins and Neumann, 1979; and Neumann and Land, 1975) and coastal geomorphology (Raphael, 1975). Very little work has been conducted on the eolian, beach, and subtidal deposits currently exposed on Abaco. The purpose of this study was to conduct a preliminary reconnaissance of the subaerial geology of Abaco Island in order to determine if the Bahamian field stratigraphy of Carew and Mylroie (1997) is also applicable to Abaco.

METHODS

Preliminary fieldwork, focused mainly on locating important geologic outcrops, was conducted March 11-20, 2005. Initial investigation of the karst and pseudokarst features of Abaco, including flank margin caves, cone karst, karren, blue holes, pit caves, banana holes, and tafoni was also conducted. The remainder of the fieldwork was completed from May 15-June 15, 2005 and consisted of mapping all known flank margin caves, documenting the other karst and pseudokarst features, and classifying the geologic outcrops based on the stratigraphy of Carew and Mylroie (1995b; 1995c; and 1997).

The stratigraphy of Abaco was discerned using parameters that could be identified using field observations. The presence of a *terra rossa* paleosol overlying an eolianite, for example, would demonstrate that deposition of the eolianite was followed by at least one sea level lowstand. Consequently, any eolianite overlain by a *terra rossa* paleosol must be Pleistocene in age. The absence of a *terra rossa* paleosol, however, would indicate a Holocene age. Because the only subtidal deposits currently exposed above modern sea level in the Bahamas must have been deposited during the OIS 5e highstand, any exposed subtidal units must belong to the Grotto Beach Formation.

Internal characteristics of eolianites, such as vegemorph development, are also useful because regressive eolianites have an abundance of vegemorphs while transgressive eolianites do not. The abundance of vegemorphs in regressive eolianites also tends to disrupt fine scale eolianite bedding that is often preserved in transgressive eolianites. Other field observations, such as the presence of wave-cut benches and the relationship of deposits to modern sea level can also be used to help discern the stratigraphic position of an outcrop.

Complex interactions of eolianite deposits, such as onlap of a younger deposit onto an older, can take place and possibly obscure the depositional history (Schwabe et al., 1993; Sparkman-Johnson et al., 2001). In many cases, the exact age and history of a deposit could not be determined with the limited geologic data collected during this study. No interpretation presented here should be considered absolute, as further geologic work on Abaco may result in a better understanding of many of the deposits examined in this study. However, as the interpretations presented here are based on direct field observations and not subsequent laboratory analyses, they have practical utility for the casual observer. This work should provide a general picture of the geologic history of the island that will aid later, more detailed investigations.

RESULTS

The Owl's Hole Formation

In several locations on Great Abaco Island, including Cherokee, Little Bay, and Little Harbour (Figure 3), an eolianite containing abundant vegemorphs makes up a large portion of the coastline. This eolianite displays truncated foreset beds with a *terra rossa* paleosol draped over the truncations (Figure 4). A similar situation can be observed on several outlying cays including Guana Cay, Elbow Cay, and Man-O-War Cay (Figure 4).

The abundance of vegemorphs preserved in this eolianite show that it was deposited during a sea level regression. The truncated foreset beds show that wave action from a subsequent sea level highstand planed the top surface of the eolianite. The presence of the *terra rossa* paleosol draped over the truncations not only demonstrates that the eolianite is Pleistocene in age, but also that another sea level lowstand followed truncation of the foreset beds.

The sum of these observations allows the stratigraphic position of the eolianite to be determined. The eolianite must be Pleistocene in age, as evidenced by the *terra rossa* paleosol; however, at least two sea level lowstands must have occurred since its deposition. The first lowstand occurred immediately following deposition of the eolianite. Sea level then rose again, causing truncation of the foreset beds by wave energy. During the following lowstand, a *terra rossa* paleosol was developed over the truncations. The eolianite cannot belong to the Grotto Beach Formation, as there has been only one sea level lowstand since its deposition. Thus, the eolianite must belong to the Upper Pleistocene Owl's Hole Formation.

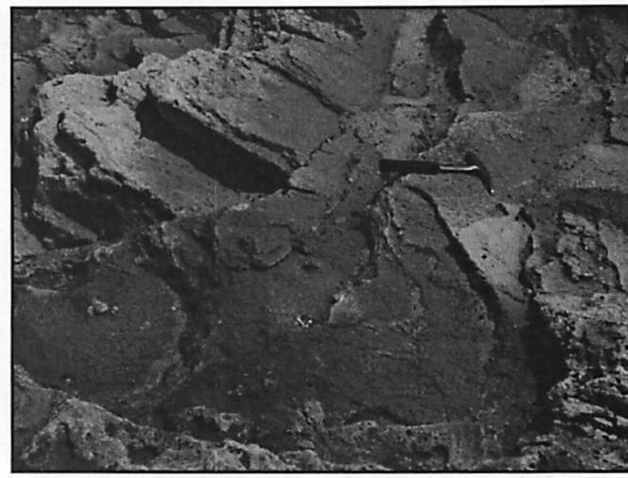

Figure 4. A terra rossa *paleosol (dark grey) deposited over truncated foreset beds on Abaco. Rock hammer for scale.*

The Grotto Beach Formation

At the most southeastern extent of Great Abaco Island there is a long-narrow headland containing a sea arch known as Hole-in-the-Wall. The Hole-in-the-Wall headland is composed of a consolidated eolianite that is covered by a patchy *terra rossa* paleosol. The only vegemorphs present in the eolianite are locally associated with this paleosol. The western side of the headland has a wave-cut bench located a few meters above modern sea level. A boulder coral-rubble outcrop, capped by a *terra rossa* paleosol, is located on this bench (Figure 5). The paleosol on both the eolianite and the coral outcrop indicate both to be Pleistocene in age. However, no paleosol separates the boulder coral outcrop from the underlying eolianite, which implies that they were formed on the same sea level highstand event.

The coral reef rubble outcrop present on the wave-cut bench in these eolianites must belong to the Cockburn Town Member of the Grotto Beach Formation as no other exposed Pleistocene subtidal units are known from the Bahamas. The Cockburn Town corals directly overlie the eolianites making up the headland with no separation by a *terra rossa* paleosol. This is very strong evidence that the eolianites comprising the headland belong to the French Bay Member of the

Grotto Beach Formation. The French Bay Member eolianites were deposited on the initial transgression onto Little Bahama Bank, and were cliffed and notched as sea level continued to rise to the OIS 5e highstand. The coral deposit was then emplaced on this notch during the OIS 5e highstand.

Figure 5. The boulder coral-rubble outcrop. Flashlight for scale.

Exposed subtidal units belonging to the Cockburn Town Member of the Grotto Beach Formation can also be observed along the coast, west of the town of Cedar Harbour (Figure 3). Here, deposits containing oscillation ripples and herringbone crossbedding demonstrate that they were deposited in a subtidal environment. Herringbone crossbedding is also observed in coastal outcrops north and west of Marsh Harbour (Figure 3).

The Rice Bay Formation

One of the most interesting outcrops observed during this study is located on the eastern coast of Great Abaco Island approximately one kilometer north of Lantern Head (Figure 3). It shows a well-consolidated eolianite capped by a thin *terra rossa* paleosol that is overlain by a poorly consolidated eolianite that grades into a modern unconsolidated eolian dune (Figure 6). The upper eolianite is not overlain by a *terra rossa* paleosol.

The lower eolianite is Pleistocene in age as shown by the presence of the *terra rossa* paleosol. However, it is not possible to accurately determine which formation it belongs to (Grotto Beach or Owl's Hole) based on the information available at the outcrop. The upper eoliante must be Holocene in age since it is not capped by a *terra rossa* paleosol. The upper eolianite most likely belongs to the Hanna Bay Member of the Rice Bay Formation because it grades into modern unconsolidated dunes. It also contains vertical structures, possibly related to past vegetation such as palmetto stumps that have been previously described from other outcrops of the Hanna Bay Member (Curran and White, 2001). However, as the outcrop is located several meters above sea level, the definitive evidence for Hanna Bay Member, that of eolian beds grading downward to beach facies at current sea level, cannot be seen. This outcrop is an excellent example of the Pleistocene/Holocene contact on Abaco (Figure 6).

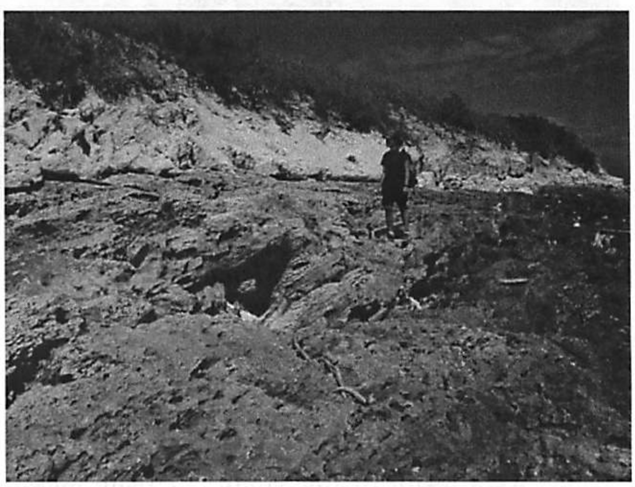

Figure 6. The Pleistocene/Holocene contact on Great Abaco Island. The person is standing on the darker Pleistocene unit. The lighter unit is Holocene in age. A paleosol separates the two units.

Many other examples of the Rice Bay Formation can also be found on Abaco. On Guana Cay, for example, an eolianite is often observed near sea level that is not overlain by a *terra rossa* paleosol. Foreset beds of this eolianite also dip below modern sea level, demonstrating that it was deposited before sea level had reached its current height (Figure 7). This Holocene eolianite belongs to the North Point Member of the Rice Bay Formation and represents rocks deposited on the transgression of the current sea level high-stand. Other examples of the Hanna Bay Member, representing the youngest rocks in the Bahamas, include modern beach and eolian dune sands, as well as beach rock. This modern beach rock has bedding planes that are congruent with the present slopes of the beaches on which it is found, showing it was formed under current sea level conditions.

Figure 7. The North Point Member of the Rice Bay Formation, Guana Cay.

Karst and Psuedokarst Features

As a result of this study, 17 flank margin caves were documented and mapped on Abaco Island. Other karst features found on Abaco that are common on other Bahamian islands include pit caves, banana holes, karren and blue holes. The high positive water budget of Abaco has also allowed for intense dissection of Pleistocene eolianite ridges due to karst, fire, and vegetative processes. This dissection has produced landforms bearing a resemblance to tropical cone karst (Figure 8). To date, these eogenetic cone karst landforms have not been described from other Bahamian islands or any other locality worldwide.

Figure 8. Eogenetic cone karst landform on Great Abaco Island.

This study also allowed for the first documentation of tafoni caves in the Bahamas. Tafoni are psuedokarst voids that are typically formed by wind and salt erosion (Huinink et al., 2004). Tafoni form in a variety of rock types and are common on rocky coasts that are exposed to spray, waves, and wind (Sunamura, 1996). The tafoni caves on Abaco (Figure 9) are found in Pleistocene eolianite cliffs between 10 and 23 meters above modern sea level. They form when wave action on eolianite ridges removes the hard, calcrete crust and exposes the soft interior of the ridge to attack by coastal processes. Similar voids have been observed on other Bahamian islands such as San Salvador (Figure 10).

The presence of psuedokarst voids such as tafoni demonstrates the need for caution when using caves as sea level indicators. Flank margin caves currently exposed in the Bahamas are known to form by mixing dissolution in association with sea level highstands (Mylroie and Carew, 1995a). As a result, flank margin caves are found in continuous horizons and show evidence of phreatic dissolution such as large dissolutional cusps and bellholes. The tafoni caves on Abaco are not found in a continuous horizon (Figure 9) and show surfaces shaped by mechanical rather than chemical processes. It is important not to mistake tafoni and other psuedokarst voids as flank margin caves, especially when using flank margin caves as sea level indicators. While tafoni may form in association with wave action, they do not mark previous sea level positions. Only flank margin caves have implications for past sea levels.

Figure 9. Tafoni voids on Great Abaco Island.

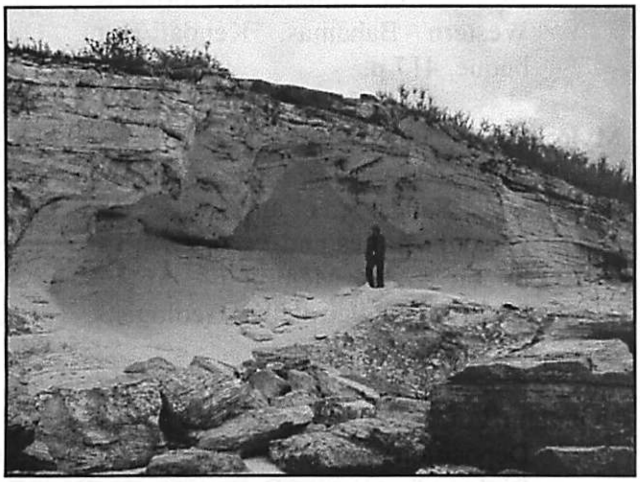

Figure 10. Tafoni void on San Salvador Island.

CONCLUSIONS

The field stratigraphy of Carew and Mylroie (1995b; 1995c; and 1997) is applicable to Abaco Island and each of the three major depositional packages can be observed. Further work on Abaco will lead to a better understanding of the geologic history of the island. Typical karst features that are found on other Bahamian islands, including flank margin caves, blue holes, pit caves, karren, and banana holes, are also common on Abaco.

The wet climate of Abaco as compared to other islands in the Bahamas has allowed for a higher degree of dissection of Pleistocene eolianite ridges than is seen elsewhere. This dissection takes place by a combination of karst, fire, and vegetative processes. The resulting landforms resemble tropical cone karst. Such eogenetic cone karst landforms have not been previously described. Tafoni caves on Abaco are psuedokarst voids that form by mechanical erosion of exposed eolianite ridge interiors. The presence of such features demonstrates the need for caution when using caves as sea level indicators. Tafoni and other psuedokarst voids may be mistaken as flank margin caves by the untrained observer. Only flank margin caves have implications for past sea levels.

ACKNOWLEDGMENTS

The authors would like to thank the Karst Waters Institute, Total SA, and Mississippi State University for providing the funding that made this study possible; the Bahamian government for providing the research permit; Friends of the Environment, Marsh Harbour, Abaco for providing logistical support; all of the residents of Abaco Island that made this study possible, particularly Nancy and Michael Albury, Anita Knowles, Allison Ball, Diane Claridge, and David Knowles; and Brenda Kirkland and Grady Dixon of Mississippi State University for all of their insights and comments during the initial development of this manuscript.

REFERENCES

Carew, J.L., and Mylroie, J.E., 1997, Geology of the Bahamas, *in* Vacher, H.L., and Quinn, T.M., eds., Geology and Hydrogeology of Carbonate Islands: Developments in Sedimentology 54, Elsevier, p. 91-139.

Carew, J.L., and Mylroie, J.E., 1995a, Quaternary Tectonic Stability of the Bahamian Archipelago: Evidence from Fossil Coral Reefs and Flank Margin Caves: Quaternary Science Reviews, v. 14, p. 145-153.

Carew, J.L., and Mylroie, J.E., 1995b, Depositional Model and Stratigraphy for the Quaternary Geology of the Bahama Islands, *in* Curran, H.A., and White, W.B., eds., Terrestrial and Shallow Marine Geology of the Bahamas and Bermuda: Geological Society of America Special Paper 300, p. 5-32.

Carew, J.L., and Mylroie, J.E., 1995c, Geology and Karst Geomorphology of San Salvador Island, Bahamas: Carbonates and Evaporites, v. 10, no. 2, p. 193-206.

Curran, H.A., and White, B., 2001, Ichnology of Holocene carbonate eolianites of the Bahamas, *in* Abegg, F.E., Harris, P. M., and Loope, D.B., eds., Modern and Ancient Carbonate Eolianites: Sequence Stratigraphy and Diagenesis: Tulsa, SEPM (Society for Sedimentary Geology) Special Publication No. 71, p. 47-56.

Huinink, H.P., Pel, L., and Kopinga, K., 2004, Simulating the Growth of Tafoni: Earth Surface Processes and Landforms, v. 29, p. 1225-1233.

Illing, L.V., 1954, Bahamian Calcareous Sands: Bulletin of the American Association of Petroleum Geologists, v. 38, p. 1-95.

Mullins, H.T., 1983, Modern Carbonate Slope and Basins in of the Bahamas, *in* Cook, H.E., Hine, A.C., and Mullins, H.T., eds., Platform Margin and Deepwater Carbonates: Society of Economic Paleontologists and Mineralogists, Short Course no. 12, p. 4.1-4.138.

Mullins, H.T., Heath, K.C., Van Buren, H.M., and Newton, C.R., 1984, Anatomy of Modern Open-Ocean Carbonate Slope: Northern Little Bahama Bank: Sedimentology, v. 31, p. 141-168.

Mullins, H.T., and Lynts, G.W., 1977, Origin of the Northwestern Bahama Platform: Review and Interpretation, Geological Society of America Bulletin, v. 88, p. 1447-1461.

Mullins, H.T., and Neumann, A.C., 1979, Deep Carbonate Bank Margin Structure and Sedimentation in the Northern Bahamas, *in* Doyle, L.J., and Pilkey, O.H., eds., Geology of Continental Slopes: Special Publication of the Society of Economic Paleontologists and Mineralogists no. 27, p. 165-192.

Multer, H.G., 1977, Field Guide to Some Carbonate Rock Environments, Florida Keys and Western Bahamas, Kendall/Hunt, Dubuque, 417 p.

Mylroie, J.E., and Carew, J.L., 1995, Karst Development on Carbonate Islands, *in* Budd, D.A., Saller, A.H., and Harris, P.M., eds., Unconformities and Porosity in Carbonate Strata: AAPG Memoir 63, American Association of Petroleum Geologists, Tulsa, Oklahoma, p. 55-76.

Neumann, A.C., and Land, L.S., 1975, Lime Mud Deposition and Calcareous Algae in the Bight of Abaco, Bahamas: A Budget: Journal of Sedimentary Petrography, v. 45, p. 763-786.

Raphael, C.N., 1975, Coastal Morphology; Southwest Great Abaco Island, Bahamas: Geoforum, v. 6, p. 237-246.

Sparkman-Johnson, S.D., Carew, J.L., and Mylroie, J.E., 2001, The Surficial Geology of the Hard Bargain Area, San Salvador Island, Bahamas, *in* Carney, C.K., and Greenstein, B.J., eds., Proceedings of the Tenth Symposium on the Geology of the Bahamas and other Carbonate Regions: Gerace Research Center, San Salvador Island, Bahamas, p. 67-77.

Schwabe, S.J., Carew, J.L., and Mylroie, J.E., 1993, The Petrology of Bahamian Pleistocene Eolianites and Flank Margin Caves: Implications for Late Quaternary Island Development, *in* White, B., ed., Proceedings of the Sixth Symposium on the Geology of the Bahamas: Port Charlotte, Florida, Bahamian Field Station, p. 149-164.

Sunamura, T., 1996, A Physical Model for the Rate of Coastal Tafoni Development: Journal of Geology, v. 104, p. 741-748.

Tucker, M.E., and Wright, P.W., 1990, Carbonate Sedimentology: Blackwell Scientific Publications, Oxford/London, 482 p.