PROCEEDINGS OF THE 15TH SYMPOSIUM ON THE GEOLOGY OF THE BAHAMAS AND OTHER CARBONATE REGIONS

Edited by
Douglas W. Gamble and Pascal Kindler

Gerace Research Center
San Salvador, Bahamas
2012

Front Cover: *Porites* colony encrusted by red algae in waters of San Salvador, Bahamas; see paper by Fowler and Griffing., p. 41. Photograph by Pascal Kindler, 2011.

Back Cover:. Dr. Jörn Geister, Naturhistorisches Museum Bern, Keynote Speaker for the 15th Symposium and author of "Keynote Address – Time-Traveling in a Caribbean Coral Reef (San Andres Island, Western Caribbean, Colombia)", this volume , p. vii. Photograph by Joan Mylroie.

Press: A & A Printing

ISBN 978-0-935909-93-7

SEDIMENT PRODUCTIVITY BY THE DEEP-WATER CALCAREOUS GREEN ALGA HALIMEDA COPIOSA, ROATAN ISLAND, HONDURAS

Melanie L. DeVore[1], Deborah Freile[2], and Rob Maitner[2]

[1] Department of Biological Sciences
Georgia College and State University, Milledgeville, GA 31061

[2]Department of Geoscience and Geography
New Jersey City University, Jersey City, NJ 07305

ABSTRACT

Calcium carbonate production rates have been calculated for shallow-water species of *Halimeda*. However, some studies (Jensen at al., 1985; Littler et al., 1986) suggest that one of the deep-water species, *H. copiosa,* is a significant carbonate producer in deep-water environments. Littler and colleagues (1986) documented in October 1985 that the sprawler *Halimeda copiosa* was the dominant species in the *Halimeda* zone (90-130 m) on a seamount located due north of Graham's Harbour, San Salvador, Bahamas. Don Gerace (personal communication, 2004), who joined the field party during submersible studies, noted a rain of *Halimeda* segments from this zone. Algal assemblages present on the wall of San Salvador lack significant populations of *H. copiosa* because of the steepness of the wall and relatively few major undercuts necessary to support *H. copiosa*'s growth habit. On the southern shore of Roatan Island, Honduras, the geometry of the wall, located in some areas less than 100 m from shore, provides prime habitats for *H. copiosa.* A prominent undercut notch occurs at a depth of approximately 20 m and dense coverage of *H. copiosa* is often present. During storm events in 2009, we noted that longshore currents would transport segments of *Halimeda* along the wall. Storm surges, perpendicular to the wall, would transport them down the slopes and up through the spur and grooves of the fringing reef and into the lagoon. In this study, we present a model for sediment production by this alga that we hope to test with detailed sedimentological analyses and *in situ* studies of *Halimeda copiosa.*

INTRODUCTION

Roatan (Figure 1), the largest of the Bay Islands, is located off the north coast of Honduras at the terminal end of the Mesoamerican reef tract. Long valued as a diving destination, Roatan is currently attracting retirees and a wave of new development. Not surprisingly, the only obtainable, published study of sedimentation on Roatan focused on the impact of development on the island and how the

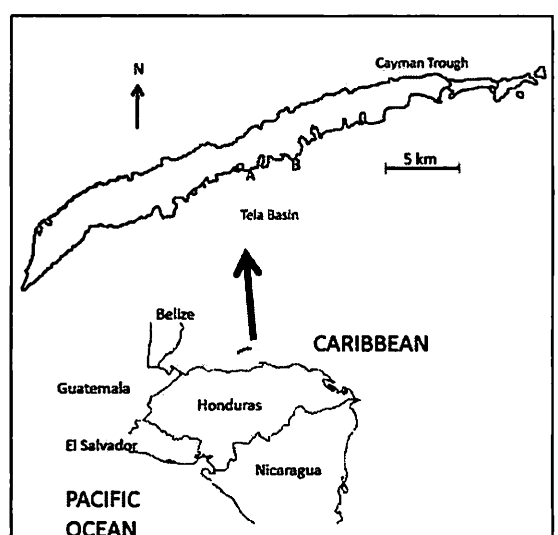

Figure 1. Map of Roatan Island, Bay Islands, Honduras. "A" indicates the location of Coco View Resort at French Harbour and "B" indicates Half Moon Bay.

potential influxes of clastic sediments associated with the increasing number of construction sites on Roatan would impact the surrounding reefs (Mehrtens et al., 2001). Mehrten's and colleagues (2001) study was an initial analysis of sediment composition and an estimation of sedimentation rates for two sites on the western side of the island. Interestingly, although the island bedrock is non-carbonate, the sands analyzed along the transects in the study consisted of *Halimeda*, mollusk, echinoderm, red-algal and coral fragments. Clearly the amount of carbonate sediments generated is substantial and *Halimeda* is an important contributor of the carbonate factory.

The benthic marine macro algae (Bryopsidales) belonging to the genus *Halimeda* and the other genera (*Penicillus*, *Udotea*, and *Rhipocephalus*; Division Chlorophyta) are all calcifying and produce copious amounts of aragonite sediment both in the >63μm (sand) and <63 μm (clay and silt) sizes as they disintegrate. *Halimeda* has long been recognized as a very important producer of calcium carbonate sediment on coral reefs and adjacent lagoons (Judd, 1904; Chapman and Mawson, 1906) and in the last thirty years many researchers have further conducted studies attesting to its continued importance; (Hillis, 1980; Wefer, 1980; Drew, 1983; Hudson, 1985; Orme, 1985; Hillis, 1986a,b,c; Littler et al., 1986; Boss and Liddell, 1987; Drew and Able, 1988; Flügel, 1988; Liddell et al., 1988; Multer, 1988; Payri, 1988, 1995; Fornos et al., 1992; Freile et al., 1995; Freile and Hillis, 1997; Freile, 2004). In addition, *Halimeda* plates are the dominant skeletal component on reef-top sediments (e.g. Milliman, 1974; Bathurst, 1975). On the southern coast of Roatan, where there are few substantial lagoonal habitats to support a sizeable crop of *Halimeda*, appreciable amounts of carbonate sediment, including fragments of *Halimeda*, are present in the sediments.

Calcium carbonate production appears to be substantial in Roatan since the white beaches and nearshore environments clearly mask the contribution of clastic sediments derived from the island bedrock. There have been no studies examining the contribution of *Halimeda* to carbonate sediment production in Roatan. Observations suggest that *Halimeda* plays a significant role in two carbonate factories present on Roatan: one similar to that present in seagrass habitats where *Halimeda incrassata* and *H. monile* produce significant quantities of calcium carbonate and a second located on the wall where draping forms of *Halimeda* (Figure 2) are prevalent. This study is very preliminary and based on initial observations and analyses of

Figure 2. Halimeda copiosa *over the prevalent notch at a depth of approximately 20 m along the wall (photo by Beate Czogalla).*

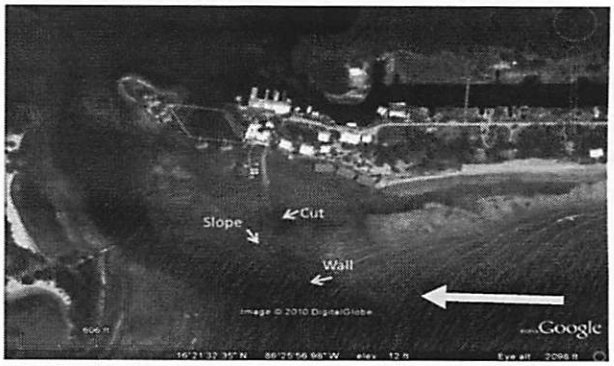

Figure 3. Overview of Coco View Resort. Sediment grab-samples were obtained along the wall, cut, and slope. Slopes of carbonate sands and the westward drift longshore currents (arrow) partially responsible for sediment transport can be seen on the right of the photo (modified from Google Maps, 2011).

Figure 4. Halfmoon Bay. The wall is positioned parallel to the shore and a plume (arrow) of carbonate sediment being transported up and into the bay is clearly visible. These sediments cover clastic sediments derived from the uplifted bedrock along the cut (modified from Google Maps, 2011).

sediments collected at Coco View Resort (Figure 3) and Half Moon Bay (Figure 4).

Unfortunately, the availability of Half Moon Bay as a comparative site was lost to development. It is our intention to provide a brief documentation of an unusual component of the carbonate factory, involving the typically deep-water species *Halimeda copiosa* (Figure 2). In particular, in the absence of substantial crops of upright species of *Halimeda* along significant portions of the southern coast, upward transport of segments from draping forms could be a important contributor of carbonate sands to nearshore environments.

GEOLOGIC SETTING

The Bay and Swan Islands are part of the Bonacca Ridge, a horst dissected by northeast-striking subsidiary faults, positioned just south and parallel to the Motagua/Swan Islands fault zone. To the south of the Bay Islands (Utila, Roatan, Barbareta, Guanaja and smaller islands), a normal fault separates the Bonacca Ridge from the Tela Basin (Pinet, 1975; Rogers, 2003; Cox et al., 2008).

Bedrock on Roatan Island is pre-Cenozoic in age and is composed of rock assemblages interpreted as a low-grade greenschist and overlying high-grade amphibolite facies. The lithological similarity between Roatan and the Motagua Valley (Guatemalan mainland) led workers to suggest that Roatan is a sliver of continental crust from the Chortis block (McBirney and Bass, 1969; Holcombe et al., 1990; Ave Lallemant and Cordon, 1999; Cox et al., 2008). The Flowers Bay Fault cuts across the western portion of Roatan and associated northeast faults intersect the island (Cox et al., 2008).

The elevation and position of fossil reefs and associated carbonate units have been used to document late Quaternary faulting events and four fabrics (informally recognized in the work and not described as designated lithologic units) have been recognized. These consist of: dismicrite (disrupted carbonate mud commonly found in tidal flats); coral boundstone (reef rock); fossiliferous grainstone (limestone with fossil grains); and fossiliferous wackestone (carbonate mud with many fossil grains; Cox et al., 2008).

STUDY SITES AND METHODS

Coco View Resort is located at Carretera Pavimentada, also referred to as French Harbour, on the south shore of Roatan (Figure 1). The north side of Coco View is adjacent to a tidal inlet and associated mangroves and the south side of the resort has direct access to the reef (Figure 3). Both *Halimeda incrassata* and *H. monile* are common members of the seagrass communities of both the tidal inlet and mangroves. On the southern shore of Roatan Island, there are generally no lagoons between the reef crest and shoreline, except where there is a tidal inlet, as is the case at Coco View Resort. Usually, a terrace of fossil reefs and beachrock is present and the extant reef crest terminates directly into a wall. The wall, located in some areas less than 100 m from shore, is vertical and characterized by a prominent, undercut notch at a depth of approximately 20 m. A dense coverage of *Halimeda copiosa* and associated *H. goreaui* is often present along this notch. Another noticeable characteristic of the wall are sandy slopes. The slope and reef crests are dissected by channels and infilled with sediments to form sandy-slopes and chutes (Figure 3).

Two grab samples of sediments were collected within the channel (used as the entrance for shore divers) close to shore, at the slope of the same channel near the adjacent wall, and along the eastern edge of the wall adjacent to the slope and channel entrance (Figure 3). Sediment size and composition were determined by standard sieving procedures (e.g. Folk, 1974). Each sample was treated with bleach to remove organic matter. Sand subsamples were then dry sieved and the fraction retained on each sieve was weighed and the percent each fraction made up of the total sand sub-sample was determined. Selected sediment samples were photographed through a stereomicroscope to determine the constituents.

Half Moon Bay (Figures 1B and 4), not to be confused with a more prominent named feature of the same name located on the north shore of Roatan, is located east of Coco View Resort at Carib Point, and is not associated with mangrove swamps. The beach and nearshore sands were entirely composed of carbonate during visits in 2005 and 2006. In 2009, however, construction of homes along the shore prevented us from collecting samples for this study. As is the case with the wall at Coco View, the reef crest is dissected by a sandy chute that appears to nourish the beach. The actual transport of sediment can be seen in Figure 4.

RESULTS

The sieving and analysis of samples yielded the following characterizations of sediments at Coco View:

<u>Closest to Shore</u> (within the cut; Figure 5) - The sediment is poorly sorted with a median and mean size of -1Φ (2 mm) and a mode of 0 Φ to -1Φ (1-2 mm). The sediment consists of different species of *Halimeda* fragments and echinoid spines along with molluscan fragments.

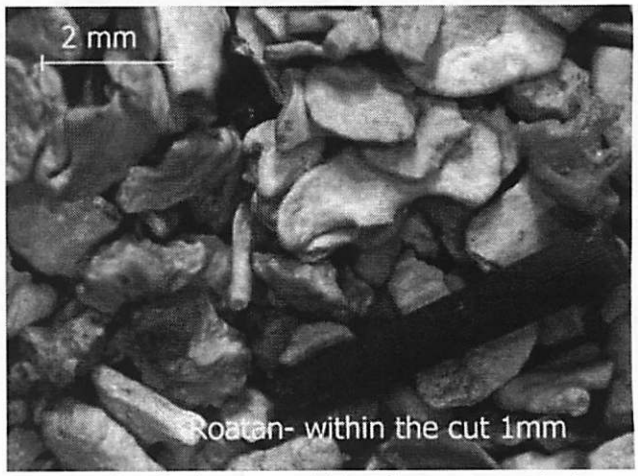

Figure 5. Sediment within the cut consisting of different species of <u>Halimeda</u> *including* <u>H. opuntia</u>, <u>H. goreaui</u>, <u>H. incrassata</u>, *segments of* <u>H. copiosa</u> *as well as echinoid spines and plates, coral and mollusk fragments.*

<u>Slope</u> (Figures 6 and 7) - The sediment is poorly sorted with a mean and median size of 2 Φ (250 µm) and a mode of 3 Φ (125 µm). The sediment consists of foraminifera, echinoid spines and carbonate fragments in that size fraction.

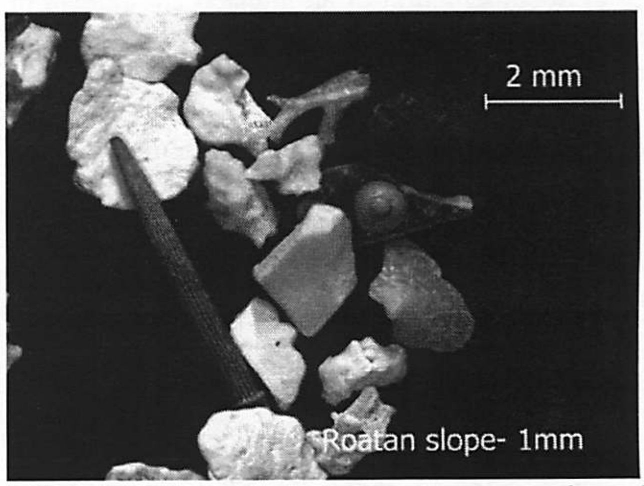

Figure 6. Slope sediment showing echinoid spines and plates, <u>Halimeda</u> *fragments and segments some showing re-calcification and intraclasts.*

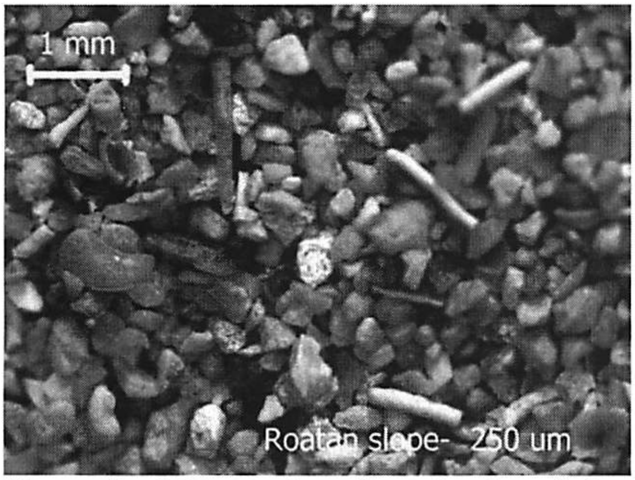

Figure 7. Mean and mode grain size of slope showing primary sediment type; spicules, forams, and intraclasts.

Wall (Figure 8) - The sediment is poorly sorted with a mean and median size of -1.6 Φ and a mode of -1.5 Φ (2.8 mm). The sediment mainly consists of *Halimeda copiosa* segments in the >4 mm sieve size fraction which was >30% of the sediment.

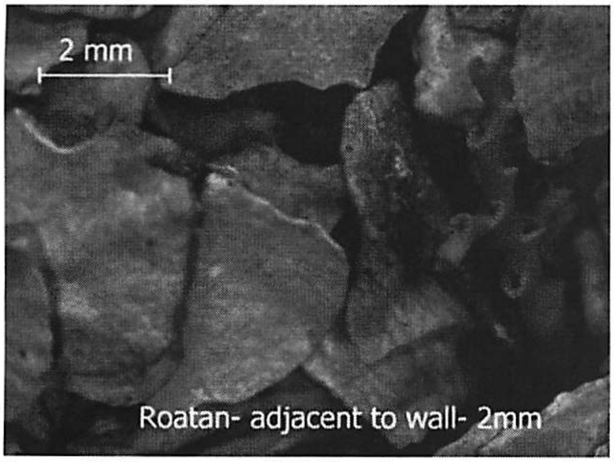

Figure 8. Segments of Halimeda copiosa *and soft corals collected within the notch of the wall at Coco View Resort.*

DISCUSSION

Draping forms of *Halimeda* appear to contribute to the production of sediment. The sample of sediment collected within the cut at Coco View contains some fragments of *Halimeda copiosa*, (the draping species prevalent on the wall) along with numerous segments of *H. incrassata* (the upright species abundant in shallow, near-shore environments). *Halimeda incrassata* thus contributes to the sediments present in the sandy slopes adjacent to the wall, while fragments of *H. copiosa* are transported into the lagoons associated with tidal inlets by a combination of longshore current transport and currents traveling shoreward through the cuts during storm events. Transport of sediment in and out of the cuts was observed on multiple occasions.

Comparing the Coco View and Half Moon Bay Sites, the white sands infilling the bay are transported by longshore currents and wave action through the channels of the reef into the bay (note sediment plume, Figure 4). Half Moon Bay is an erosional feature of low-grade greenschist bedrock. Surveys of Half Moon Bay failed to locate any upright species of *Halimeda* in August of 2005 and 2006 or in July of 2009. Therefore, the only source of carbonate would be grains transported from the sandy slopes associated with Carib Point into the bay. Construction of residences in 2009 prevented access to the site for further studies, however, equivalent sites on the southern shore could provide an opportunity to estimate growth rates of *Halimeda copiosa* and their contribution to nearshore sediments. *Halimeda copiosa* has already been documented as a significant calcium carbonate producer in deep-water environments (Jensen et al, 1985) including the seamount just north of Graham's Harbour, San Salvador Island. However, the low-light environments present along the notched wall of Roatan's south shore present an unusual low-light condition permitting draping forms of *Halimeda* to thrive in near-shore environments.

Halimeda incrassata and *H. monile* both are present in seagrass communities. However, the extent of these communities is limited on the south shore of Roatan. The reef system on the north side of the island, and the lagoon associated with the reef at the easternmost portion of Roatan, are both areas where upright *Halimeda* species may be the greatest carbonate producers.

It is not surprising that sedimentation rates and the occurrence of suspended solids associated with weathering of bedrock has been the focus of studies examining the relationship between reef morphology and sediment attributes of Roatan (Mehrtens et al., 2001). Assessing the impact of suspended terrigenous sediments is a key for managing the islands reefs. To date, the characterization of the carbonate factory for the island is poorly understood and the complexity of the island geomorphology as it relates to genesis of carbonate sediments is largely unknown.

The present study is a small simple observational study suggesting that the draping species of *Halimeda* are part of the carbonate factory. Future studies including dye experiments to calculate the rate of calcium carbonate production of upright *Halimeda* species and marked studies of draping forms would provide insights regarding the comparative rates of carbonate production of both groups of *Halimeda* species. Clearly, selection of additional study sites and establishment of routine measurements of *Halimeda* growth rates are needed. These additional data, as well as a better understanding of the interplay between the island geomorphology, seasonal current regime, and sedimentation would paint a clearer picture of Roatan's complex carbonate factory.

ACKNOWLEDGMENTS

This research was the result of yet another intersection of work and pleasure while participating in a dive trip to Coco View Resort. MLD would like to thank Scott Stefano, dive instructor, for arranging group travel to Roatan. The dive staff of Coco View Resort provided assistance in arranging dives to the study site. Beate Czogalla, Theater Department, GCSU, helped collect sediment samples and photographic assistance. Matthew Boyle, GCSU Biology major, helped to sort and dry material. D. Freile would like to thank NJCU's Office of Grants and Sponsored Programs, the CCRAA grant at NJCU for supporting student assistants (Rob Maitner and Mandy Edgecombe).

REFERENCES

Ave Lallemant, H.G., Gordon, M.B., 1999, Deformational history of Roatan Island: implications for the origin of the Tela Basin (Honduras), *in* Mann, P, ed., Caribbean Basins - Sedimentary Basins of the World 4: Elsevier, Netherlands, p. 197-218.

Bathurst, R.G.C., 1975, Carbonate Sediments and their Diagenesis: Amsterdam, Elsevier, Developments in Sedimentary Petrology, v. 12, 659 p.

Boss, S.K., and Liddell, W.D., 1987, Patterns of sediment composition of Jamaica fringing reef facies: Sedimentology, v. 34, p. 77-87.

Chapman, F., and Mawson, D., 1906, On the importance of *Halimeda* as a reef forming organism: with a description of *Halimeda*-limestones of the New Hebrides: Quarterly Journal of the Geological Society of London, v. 62, p. 702-711.

Cox, R.T., Lumsden, D.N., Gough, K.C., Lloyd, R., and Talnagi, J. 2008, Investigation of late Quaternary fault block uplift along the Motagua/Swan Islands fault system: Implications for seismic/tsunami hazard for the Bay of Honduras: Tectonophysics, v. 457, p. 30-41.

Drew, E.A., 1983, *Halimeda* biomass, growth rates and sediment generation on reefs in the central Great Barrier Reef Province: Coral Reefs, v. 2, p. 101-110.

Drew, E.A., and Able, K.M., 1988, Studies on *Halimeda*: The distribution and species composition of *Halimeda* meadows throughout the Great Barrier Reef Province. Coral Reefs: v. 6, p. 195-205.

Flügel, E. 1988, *Halimeda*: Paleontological record and palaeoenvironmental significance: Coral Reefs, v. 6, p. 123-130.

Folk, R.L., 1974, Manual of Sedimentary Petrology: Hemphill Publishing Co., Austin, TX., 190 p.

Fornos, J.J., Forteza, V, Jaume, C, and Martinez-Taberner, A., 1992, Present-day *Halimeda* carbonate sediments in temperate Mediterranean embayments: Fornells, Balearic Islands: Sedimentary Geology, v. 75, p. 283-293.

Freile, D., 2004, Carbonate productivity rates of *Halimeda* in two different locations, San Salvador, Bahamas, *in* Lewis, R.D., and Panuska, B.C., eds, Proceedings of the 11th Symposium on the Geology of the Bahamas and Other Carbonate Regions: Gerace Research Center, San Salvador, Bahamas, p. 95-106.

Freile, D., Milliman, J.D., and Hillis, L., 1995, Leeward bank margin *Halimeda* meadows and draperies and their sedimentary importance on the western Great Bahama Bank slope: Coral Reefs, v. 14, p. 27-33.

Freile, D., and Hillis, L., 1997, Carbonate productivity by *Halimeda incrassata* in a land proximal lagoon, Pico Feo, San Blas, Panama, *in* Lessios, H.A, and Macintyre, I.G., eds, Proceedings of the 8th International Coral Reef Symposium, v. 1: Smithsonian Tropical Research Institute in Balboa, Panama, p. 767-772.

Hillis (as Hillis-Colinvaux), L., 1980, Ecology and taxonomy of *Halimeda*: primary producer of coral reefs: Advances in Marine Biology, v. 17, p. 1-327.

Hillis (as Hillis-Colinvaux), L., 1986a, Historical perspective on algae and reefs: have reefs been misnamed ?: Oceanus, v. 28, p. 43-48.

Hillis (as Hillis-Colinvaux), L., 1986b, *Halimeda* growth and diversity on the deep fore-reef of Enewetak Atoll: Coral Reef, v. 5, p. 19-21.

Hillis (as Hillis-Colinvaux), L., 1986c, Deep water populations of *Halimeda* in the economy of an atoll: Bulletin of Marine Science, v. 38, p. 155-169.

Hillis, L., 1991, Recent calcified Halimedaceae, *in* Riding, R, ed., Calcareous Algae and Stromatolites, Berlin, Springer-Verlag, p. 167-188.

Holcombe, T.L., Ladd, J.W., Westbrook, G., Edgar, N.T., and Bowland, C.L., 1990, Caribbean marine geology; ridges and basins of the plate interior, *in* Dengo, G., and Case, J.E., eds., The Caribbean Region: Geological Society of America, The Geology of North America, p. 231-260.

Hudson, J.H., 1985, Growth rates and carbonate production in *Halimeda opuntia*: Marquesas Keys, Florida, *in* Toomey, D.F, and Nitecki, M.H., eds., Paleoalgology: Contemporary Research and Applications: Springer-Verlag, Berlin, p. 257-263.

Jensen, P.R., Gibson, R.A., Littler, M.M., and Littler, D.S., 1985, Photosynthesis and calcification in four deep-water *Halimeda* species (chlorophyceae, caulerpales). Deep Sea Research Part A: Oceanographic Research Papers, v. 32, p. 451-464.

Judd, J.W., 1904, Report on the materials from the borings at the Funafuti Atoll: Report on Coral Reef Communities, Royal Society of London, p. 167-185.

Liddell, W.D., Ohlhorst, S.L,, and Boss, S.K, 1988, The significance of *Halimeda* as a space-occupier and sediment producer, 1-75M, north Jamaica, in Choat, J.H., et al., eds, Proceedings of the 6th International Coral Reef Symposium, v. 3: Townsville, Australia p. 127-132.

Littler, M.M., Littler, D.S., Blair, S.M., and Norris, J.N., 1986, Deep water plant communities from an unchartered seamount off San Salvador Island, Bahamas: Distribution, abundance and primary productivity: Deep Sea Research, v. 33, p. 881-892.

McBirney, A.R., and Bass, M.N., 1969, Geology of the Bay Islands, Gulf of Honduras, *in* McBirney, A.R., ed., Tectonic Relation of Northern Central America and the Western Caribbean – The Bonacca Expedition: American Association of Petroleum Geologists Memoir, v. 11, p. 229-243.

Mehrtens, C.J., Rosenheim, R., Modley, M., Young, R.S., 2001, Reef Morphology and Sediment Attributes, Roatan, Bay Islands, Honduras: Carbonates and Evaporites, v. 16, p. 131-140.

Milliman, J.D., 1974, Recent Sedimentary Carbonates: Part 1 Marine Carbonates: Springer Verlag, Berlin. 375 p.

Multer, H.G., 1988, Growth rate ultrastructure, and sediment contribution of *Halimeda incrassata* and *Halimeda monile*, Nonsuch and Falmouth Bays, Antigua, W.I.: Coral Reefs, v. 6, p.179-186.

Orme, G.R., 1985, The sedimentological importance of *Halimeda* in the development of back reef lithofacies, northern Great Barrier Reef (Australia), *in* Harmelin Vivien, M., and Salvat, B., eds, Proceedings of the 5th International Coral Reef Symposium, v. 5: Tahiti, p. 31-37.

Payri, C.E., 1988, *Halimeda* contribution to organic and inorganic production in a Tahitian reef system: Coral Reef, v. 6, p.251-262.

Pinet, P.R., 1975. Structural evolution of the Honduras continental margin and the sea floor South of the western Cayman trough: Geological Society of America Bulletin, v. 86, p. 830-836.

Rogers, R.D., 2003, Jurassic–Recent tectonic and stratigraphic history of the Chortis block of Honduras and Nicaragua (northern Central America). Unpublished Ph. D. dissertation: The University of Texas at Austin, 289 p.

Wefer, G., 1980, Carbonate production by algae *Halimeda*, *Penicillus*, and *Padina*: Nature, v. 285, p. 323-324.