Composition, Texture and Diagenesis of Carbonate Sediments: Effects on Benthic Optical Properties

R. Pamela Reid
Marine Geology and Geophysics
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
phone: (305) 361-4606; fax: (305) 361-4632; email: preid@rsmas.miami.edu

Award #: N00014910010

LONG-TERM GOAL

Our long term goal is to understand how physical and chemical characteristics of bottom sediment affect the optical properties of the shallow sea floor. Of particular interest is sorting out how inorganic and organic parameters of the sediment interrelate to determine benthic light fields.

SCIENTIFIC OBJECTIVES

Our research focuses on sedimentologic characteristics of carbonate grains. Specific objectives are (1) to determine feedback mechanisms between mineralogical and textural (e.g. size, shape, surface roughness, density, and packing) sediment parameters, light fields within the sediment, and benthic biological community structure and organic production, and (2) to use these relationships to model spectral reflectance and its contribution to the upwelling component of scalar irradiance.

APPROACH

In May, 1998, we participated in the first CoBOP field program at Lee Stocking Island, Exuma Cays, Bahamas. Sediment cores were collected at seven sampling sites (Fig. 1), representing a variety of sub-environments (Fig. 2). The uppermost centimeter of each core was saved for laboratory analysis of grain composition, size and shape, index properties (water content, porosity, bulk density, and grain density), total carbonate content, and mineralogy. In addition, the cores were subsampled using 6 mm diameter straws; these ‘mini cores’ were fixed in formalin and gluteraldehyde for SEM examination of surface texture and organic-inorganic interactions. Our sampling was conducted in coordination with data collection by other members of the CoBOP team, including analyses of sediment pigments and polymers. Optical measurements of bi-directional reflectance distribution function (BRDF) and spectral reflectance were also made by collaborating investigators at many of the sediment sampling sites, and selected sediments were imaged with the Fluorescent Imaging Laser Line Scan (FILLS) system. In addition to laboratory analyses of field samples, we will conduct measurements of artificial sediment mixtures in order to identify the effects of individual compositional and textural parameters on BRDF, reflectance and in sediment light fields; these measurements will be conducted in collaboration with Dr. Ken Voss, University of Miami, and Dr. Brad Bebout, NASA Ames Research Center.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Composition, Texture and Diagenesis of Carbonate Sediments: Effects on Benthic Optical Properties**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Miami,Rosenstiel School of Marine and Atmospheric Science,4600 Rickenbacker Causeway,Miami,FL,33149**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

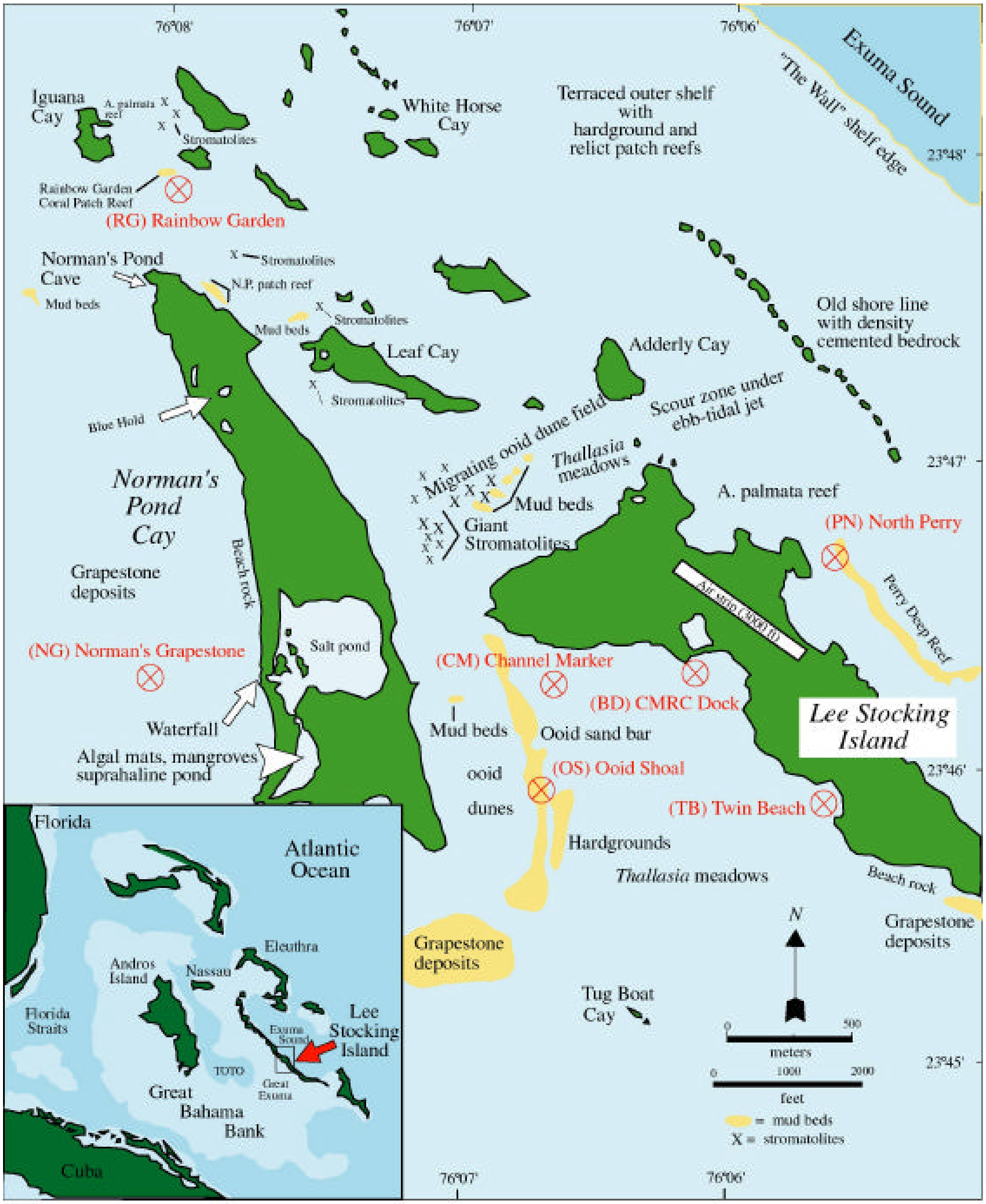

Figure 1. Sampling sites at Lee Stocking Island, Bahamas; after Dill, 1991.

Sampling Site	Sub-environments
Twin Beaches	sand with film (f), shrimp mound with seagrass (m), shrimp mound w/o seagrass (n), sand below seagrass detritus (d)
Rainbow Gardens	bare sand (s), sand with seagrass (g), sand in coral patch reef (c)
North Perry	sand with film (f), bare sand (s), sand along FILLS transect (t)
Channel Marker	sand with thin seagrass (t), sand with dense seagrass (d), bare sand (s)
CMRC Dock	sand with seagrass (g)
Norman Grapestone	sand with yellow mat (y), sand with little mat (w)
Ooid Shoal	sand from the crest of sand wave (c), sand from trough (t)

Figure 2. Sub-environments at sampling sites indicated on Fig. 1.

WORK COMPLETED

Our first field expedition to Lee Stocking Island was successful. Our coring procedures worked well, allowing sub-sampling of the upper centimeter of the sea floor. Sediment analyses are currently in progress. Measurements of index properties and grain size distributions are complete; methods are outlined in Louchard et al., 1998.

RESULTS

The Lee Stocking sediments exhibited characteristic differences in bulk density, porosity, and water content (Fig. 3). Samples of grapestone with a yellowish surface film had the highest water content (192%) and porosity (82%) and the lowest wet (1.3 g/cm^3) and dry (0.48 g/cm^3) bulk densities. Index properties of samples from the "Ooid Shoal" site were distinctly different from those of grapestone sediment. Ooid sand from the crests and troughs of the shoal had the lowest water content (31-34%) and porosity (45-48%) and the highest wet (1.92-1.96 g/cm^3) and dry (1.43-1.50 g/cm^3) bulk densities of all samples analyzed.

Sediments from various seagrass areas showed consistent index properties. Measurements from the "CMRC Dock" site of sediment in seagrass for example, were similar to those from the "Twin Beaches" site as well as the "Rainbow Gardens" site. Index properties of sediment from "North Perry" with surface films also had index properties similar to those of sediments in seagrass areas.

Grain size analyses (Fig. 3) indicate that most of sediments sampled are "coarse sands" (500-2000 μm). Treatment of the sediment with sodium hypochlorite reduced the mean grain size of most sediments to "medium sand" (250-500 μm). The exceptions were bleached samples from "Norman's Grapestone" (yellow and white), "Twin Beaches" (mounds with seagrass and without), and "North Perry" (film and sand), which remained coarse even after treatment. Bleaching removes organic material and may reduce the mean grain size by breaking down the clumps of grains held together by organics.
Spectrometer measurements made by Dr. C. Mazel (Fig. 4) indicate that ooids have the highest reflectance of sediments analyzed, with reflectance ratios greater than 0.5 above 600nm. Grapestone was the least reflective sediment, with reflectance ratios less than 0.3 over almost all of the spectrum,

and a reflectance ratio less than 0.2 for the samples with yellow film coatings. The yellow-coated grapestone also showed a drop in reflectivity between 650nm and 700nm. Film coatings and overlying seagrass detritus affected the reflectivity of the sediment from the “Twin Beaches” site, reducing the reflectivity ratio at wavelengths between 650nm and 700nm. The distinct drop in reflectivity at around 670nm in sediment with films or overlying leaf detritus is likely due to absorption by chlorophyll a.

Sampling site	water content (% dry weight)	wet bulk density (g/cm^3)	porosity (%)	dry bulk density (g/cm^3)	mean grain size (μm)
T. Beaches film (f)	77%	1.58	67%	0.90	532
T. Beaches mound w/leaves (m)	65%	1.64	63%	0.99	257
T. Beaches mound no leaves (n)	38%	1.88	50%	1.37	564
T. Beaches detritus (d)	85%	1.59	66%	0.91	355
Rainbow Garden sand (s)	42%	1.84	52%	1.31	614
Rainbow Garden grass (g)	51%	1.75	57%	1.17	600
North Perry film (f)	59%	1.68	61%	1.06	649
North Perry sand (s)	41%	1.84	52%	1.30	624
North Perry transect (t)	50%	1.75	57%	1.17	588
Channel Marker thin grass (t)	56%	1.73	59%	1.13	275
Channel Marker dense grass (d)	54%	1.72	59%	1.12	262
Channel Marker sand (s)	36%	1.90	49%	1.40	406
CMRC Dock grass (g)	73%	1.61	65%	0.94	551
Norman Grapestone yellow (y)	192%	1.31	82%	0.48	1110
Norman Grapestone white (w)	63%	1.66	62%	1.02	875
Ooid Shoal crests (c)	31%	1.96	45%	1.50	598
Ooid Shoal troughs (t)	34%	1.92	48%	1.43	647

Figure 3. Summary of index property values and mean grain size.

FILLS measurements over the transect at “North Perry” showed differences in fluorescence between bare sand and sand with a surface film. Bare sand exhibited a yellow-green fluorescence. The same sand with a film layer fluoresced red. A sample of quartz sand placed along the transect showed no fluorescence. Disturbed areas, such as those where divers’ fins had moved the sediment surface, showed reflectance values similar to those of bare sand, suggesting that the layer of sediment that produces the red fluorescence is confined to the uppermost sediment layer.

IMPACT/APPLICATION

Our results to date indicate that carbonate sediments with distinct sedimentological parameters have unique optical properties. End members sampled in May 1998 are (1) grapestone, which is the coarsest sediment with the highest porosity and water content, the lowest wet and dry bulk densities, and the lowest reflectance; and (2) ooids, which have the lowest porosity and water content, the highest wet and dry bulk densities, and the highest reflectance. Further knowledge of how optical signals of carbonate sediments are affected by composition, texture and diagenesis will have important applications for remote sensing mapping of bottom types.

TRANSITIONS

The results from our study are being made available to other members of the CoBOP team on an internet database. Our analyses will also provide ground truth measurements for the ONR HyCODE program, which will develop methods for using hyperspectral remote sensing data to define bottom types and water depths.

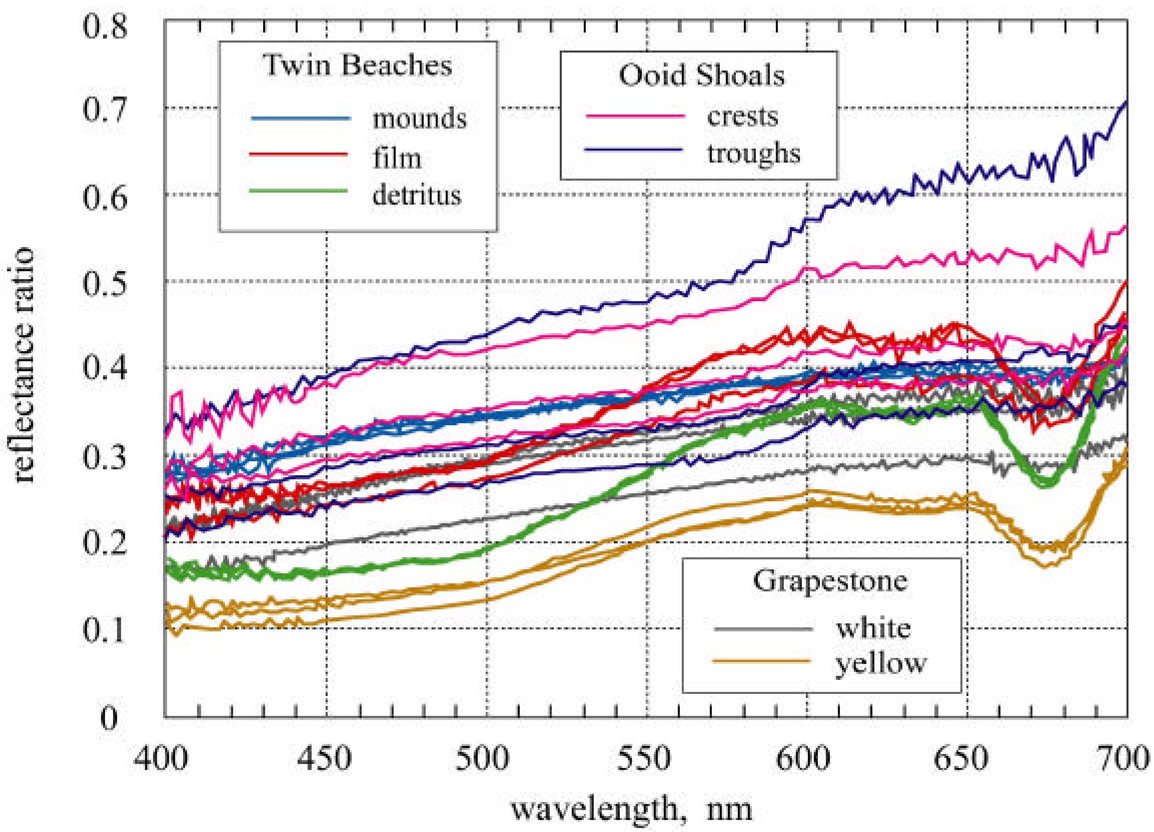

Figure 4. Reflectance of a variety of sediments in the vicinity of Lee Stocking Island

RELATED PROJECTS

1. I am currently investigating the microstructure of modern marine stromatolites in a project sponsored by NSF. Of key interest is the development of lithified micritic layers within cyanobacterial mats in the Exuma Cays, Bahamas.

2. I obtained funding from the Major Research Instrumentation Program at NSF for purchase of a field emission environmental scanning electron microscope for the University of Miami. This microscope,

which will allow high resolution imaging of hydrated samples, will be valuable for examining organic-inorganic associations within the sediment in my CoBOP work.

REFERENCES

Dill, R., 1991, Subtidal stromatolites, ooids and crusted-lime muds at the Great Bahama Bank Margin. Society for Sedimentary Geology, SEPM Special Publication No. 46, p. 147-171.

Louchard, E.M., Reid, R.P., Voss, K, J., Mazel, C.H., Strand M.P., 1998, Optical properties of shallow water sediments: all sediments are not created equal. Extended Abst. for Ocean Optics XIV, Kona, Hawaii.