PS Ooids and Grapestone – A Significant Source of Carbonate Mud from Caicos Platform*

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Abstract

Samples of aragonitic oolitic and grapestone sand from agitated shoal, platform and beach environments of Caicos Platform were assessed for grain durability in tumblers. After one week of tumbling with equal weights of 1mm spherical glass spheres, two to seven percent of the oolitic sand had abraded to mud size, aggregate grains releasing most of the mud. Additional durability assessments were made by tumbling only the carbonate sands to determine if they are capable of significantly abrading themselves in the absence of siliciclastic material. In samples that are mostly grapestone aggregates, 2-3 percent of the sand sample was reduced to mud in one week. Samples containing over 85 percent well-rounded, glossy oolitic grains produced 0.3-0.4 percent of mud from their sand fractions in a week.

Scanning Electron Microscope analysis showed that grapestone breaks down by abrasion of the aragonitic marine cement between the constituent grains and by abrasion around pre-existing micro-bore structures. In ooids, observed breakdown is by extension of pre-existing micro-bore structures and grain surface irregularities. The mud produced consisted of broken aragonite needles, most less than three microns in length. The size of the mud component produced is extremely fine and may reflect the common milkiness associated with the waters of agitated shoals.

This study suggests that the in situ growth of ooids and grapestone grainstone sediment bodies is associated with the production of at least an equivalent amount of carbonate mud (Figure 4). This significant source of carbonate mud has been overlooked in both modern and ancient marine settings.

References

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Background

What is the origin of carbonate mud?

Carbonate mud
Photo courtesy Kelly Gibson

In the geological record, there is a greater quantity of carbonate mud than carbonate sand yet there has been a paradoxical focus on sand-sized particles in the literature (Matthews 1966). Currently, there are four proposed models for the origin of carbonate mud. They are summarized by Matthews (1966) as: (1) the production of aragonite needles by physical precipitation from waters of abnormally high salinity and carbonate saturation; (2) post mortem disintegration of calcified green algae; (3) the production of mud-sized skeletal debris by predominately physical processes of particle-size reduction in agitated environments; and (4) by predominately biological reduction (bio-corrosion) in quiet-water environments.

The purpose of this study was to demonstrate that ooids and grapestones from Turks and Caicos Islands are capable of abrading themselves under natural conditions, suggesting that the formation of grapestone and ooid grainstone bodies are associated with a significant amount of mud production. Fabricius (1977) noted close chemical and isotopic similarities between ooids and grapestones and aragonitic mud. He interpreted this to mean that both mud and ooids are primarily inorganic precipitates (Fabricius 1977). However, based on the findings of this study, the similarity may be because the lime mud was generated from the physical breakdown of ooids and grapestones. Mud from the Bahamian archipelago is known to consist of aragonite needles, a few microns in length, however it is debated if the origin of the mud is inorganic or algal (Tucker & Wright 1990).

Aerial photograph of Ambergris Shoal
Photo courtesy Harold R Wanless

Aerial photo of Turks and Caicos Platform:
green x's mark sample locations
Photo courtesy Harold R Wanless

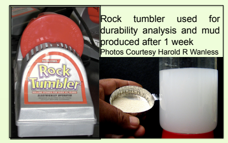
The composition and appearance of lime mud in the Bahamian archipelago is consistent with that of the mud produced in this experiment. This suggests that ooids and grapestones need to be added to skeletal debris as grains that produce mud predominantly by physical processes of particle-size reduction in agitated environments. Indeed, ooid shoals, like other carbonate environments that are subjected to wave and/or current agitation, should be expected to produce lime mud that in most cases will be transported to quiet water for deposition (Matthews 1966).

Methods

Ooids moving along the bottom of Ambergris shoal
Photo courtesy Harold R Wanless

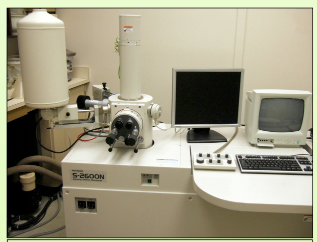
Durability Analysis

1. Sand samples were collected from agitated, bare bottom, shallow-marine environments around the Caicos Platform.
2. Samples were rinsed, sieved into standard size fractions >125 microns, dried and weighed.
3. Samples were subjected to abrasion in small, rubber-lined tumbling barrels for one week according to the method of Wanless and Maier (2007). One trial included an equal weight 1000 micron spherical abrasive and one did not.
4. After abrasion, samples were sieved, dried and weighed.
5. Raw data of the before and after weights of each size fraction were used to calculate the percent weight change according to the formula:



Rock tumbler used for durability analysis and mud produced after 1 week
Photos Courtesy Harold R Wanless

$$\frac{\text{(weight of size fraction before tumbling) - (weight of size fraction after tumbling)}}{\text{(total weight of sample after tumbling)}} \times 100\%$$

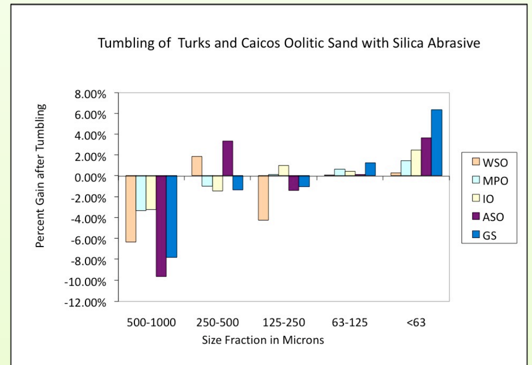


ESEM: Environmental Scanning Electron Microscope
http://www.emlab.ubc.ca/imgequip/EM_hitachi_2600N_VPSEMI.jpg

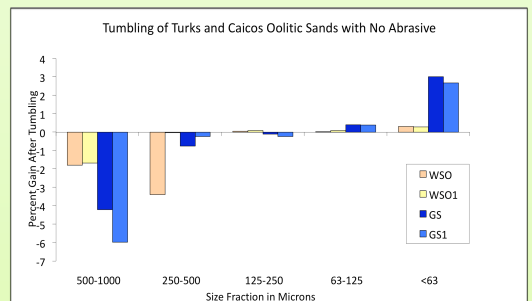
Environmental Scanning Electron Microscopy (ESEM)

1. Pre- and post-abrasion samples were mounted on carbon-backed stubs and palladium coated.
2. Samples were analyzed under high vacuum mode using a Philips XL30 ESEM-FEG at the University of Miami's Center for Advanced Microscopy.
3. Analysis focused on surface grain textures to locate any inherent weaknesses in pre-abrasion samples and evidence of breakdown in post-abrasion samples.

Durability Results



Percent weight change of size fractions after tumbling; positive numbers mean that weight was gained in that size fraction, negative numbers indicate weight loss. All mud-size (<125 microns) fractions were produced entirely by abrasion. The grapestone sample (GS) produced the most mud after one week of tumbling with abrasive. WS = oolitic sample from West Spit, MPO = oolitic sample from Mid Platform Shoal, IO = oolitic and grapestone sample from the platform interior, ASO = oolitic sample from Ambergris Shoal, GS = grapestone sample from interior.



Even without a silica abrasive, carbonate sand grains produced mud-size particles. This self-abrasion process produced <0.5% of mud from sand fractions in the oolitic sample (WSO) but 3-3.5% in the grapestone (GS). GS1 and WSO1 are identical in composition to GS and WSO, respectively.

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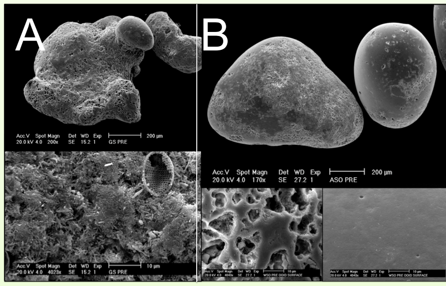
ESEM Results



Before Abrasion

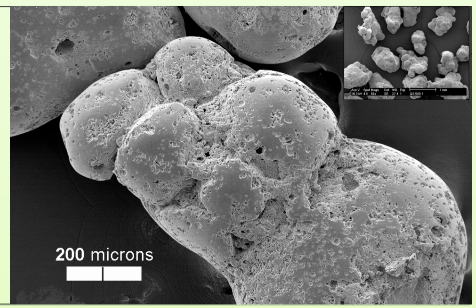
A. Surface textures of grapestones, as seen under ESEM, show aggregate grains held together by a loose mesh of aragonite needles. This cement can incorporate other material, such as the diatom test seen in the lower right hand corner.

B. Oolitic samples have both smooth surface textures and highly porous surfaces with microborings and intricate micro-topography. These features cause weaknesses in what would otherwise be a durable, spherical grain.

After Abrasion

Breakdown trends in the samples are apparent under ESEM. Exposed cement between the grains in the aggregates is preferentially abraded so that, after abrasion, samples in the 500-1000 micron range appear to be much knobbier; with constituent grains protruding excessively out of a reduced cement matrix (see inset).

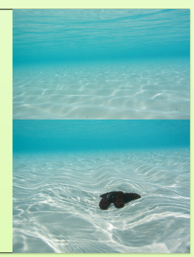
Where the ooids themselves are abraded, the breakdown appears to be an extension or expansion of pre-existing holes or weaknesses from boring or dissolution. Boring algae, fungi and bacteria are known to produce pits and grooves on the surface of ooids (Margolis and Rex 1971; Newel et al. 1960; Harris et al. 1979). These pits are often infilled, but grain irregularities and weaknesses result (Gaffey 1983).



Mud

The mud produced by this process is extremely fine and consists of broken aragonite needles, most less than three microns in length (micrograph shown on left).

Because the mud is so fine, it will remain in suspension for a long time. This mud may reflect the milkiness commonly associated with agitated shoals (photos of milky or hazy conditions shown on right, courtesy Harold R Wanless).



Conclusions

1. **Abrasion of oolitic and grapestone sand produces a significant amount of mud in carbonate systems.**
2. **ESEM work suggests that mud is formed primarily by the preferential erosion of aggregate cement.**
3. **This source of carbonate mud has been overlooked in both modern and ancient marine settings.**

References

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