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The Microbial Pedigree of Freshwater Marl: Tracking Textures Through Early Burial and Diagenesis

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Project Objectives

The Florida Everglades has been used as an analogue for paludal, fine-grained carbonate production (marl) (Mertz 1992). However, the nature of the microbial communities and the affect of early diagenetic alteration on the resultant calcitic mud are relatively unknown. The proposed research aims to provide an integrated geochemical and geomicrobial characterization of the freshwater marl deposits actively forming in Everglades National Park. This characterization will integrate depositional fabrics and textural features of the marl sediments with next-generation 16S rRNA microbial surveys and pore water geochemistry. This approach will make it possible to definitively assess the microbial pedigree of the primary deposits and evaluate processes of subsequent diagenetic alteration. This characterization will be used as a calibration to examine ancient (Pleistocene) marl deposits in the shallow subsurface of south Florida. Together, this modern and near-modern characterization of the depositional and diagenetic processes surrounding freshwater marl formation will address the longstanding questions of how microbial deposits are identified in ancient rocks, and the paleoenvironmental interpretation of marl deposits found throughout geologic time. Thus, the objectives are:

1. Characterization of depositional fabrics and textural features of marl sediments in Everglades NP;

2. Characterization of modern microbial communities in freshwater prairies and shallow push cores of marl sediments;

3. Geochemical analysis of pore waters and organics from marl sediments - an assessment of diagenetic changes due to Holocene transgression and pore-water evolution (marine, brackish, and freshwater conditions).

4. Characterization of depositional and diagenetic products preserved in Pleistocene marl deposits in south Florida.

PROJECT RATIONALE

Microbial processes are increasingly recognized for their importance in both carbonate precipitation and dissolution (Dupraz et al., 2005; Reid et al., 2000; Mertz, 1992). However, the specific environmental conditions that influence microbial processes, and visa-versa, are often difficult to discern and at best poorly understood. One of the major challenges in the origin of ancient carbonate rocks is the role or influence of microbes. This difficulty stems from both understanding of the formation of the original carbonate crystals, as well as understanding subsequent diagenetic modification during burial and cementation.

The Florida Everglades has been used as an analogue for paludal, fine-grained carbonate production (marl) (Mertz 1992). However, the nature of the microbial communities and the affect of early diagenetic alteration on the resultant calcitic mud are relatively unknown. Detailed characterization of modern marl formation in the Everglades will provide a means for direct calibration of key identifying microbial features. These microbial features, if preserved, will provide direct evidence of microbial influences within carbonate environments . Furthermore, buried Holocene freshwater carbonate, exposed to changing conditions (freshwater, brackish, marine) during the transgression, can be analyzed to gauge the impacts of changes in pore water chemistry. These early diagenetic environments can be assessed for changes to carbonate texture, organic matter composition, and survival of key microbial indicators. Future studies will include a characterization of ancient (Pleistocene & Pliocene) deposits, delving into the preservation potential of microbial textures, organic matter, and carbonate diagenesis.

PROPOSED SCOPE OF WORK AND SAMPLE ANALYSIS

This project aims to characterize the freshwater marl deposits forming inland and tracking them through the burial process. Microbial textures will be analyzed primarily using ESEM The microbial communities within the carbonate deposits of the Florida Everglades will also be examined in order to better understand the processes and precipitation as well as the microbial affect on carbonate diagenesis across conditions of varying burial during the Holocene transgression. Moving from the inland freshwater prairies to the marine environment of Florida Bay, we will discern the microbial community structure and processes occurring within microbial carbonate deposits.

Three-inch push cores (using aluminum tubes) and vibrocores will be collected from four different burial environments (Figures 1 & 2) at five sites. The inland freshwater environment represents the region of active microbial carbonate formation. The brackish environment currently overlies transgressed microbial deposits and is marked by organic-rich sediments and seasonal changes in salinity. At Florida Bay, Holocene freshwater marls have been cored beneath the coastal levee sediment and in the marine subtidal basins (Wanless 1989) . This freshwater to marine progression will provide a window into the various stages of diagenesis for freshwater microbial carbonates. We propose to collect five 3” cores (see Table 1 for GPS coordinates) in order to best characterize the environment and transition in question. Location of the cores is as followed: 1 in Florida Bay, 1 in Flamingo, 1 at West Lake, 1 in the transition zone at Whitewater Bay, and 1 near Paurotis Pond. The site at West Lake will serve as an alternative to the brackish/transitional Whitewater Bay site in case recovery is poor or the calcitic marl is absent. Samples will be collected by foot, canoe, and small motorboat (for the case of the Florida Bay core). Collection is projected to take less than a day per core, with little-no disturbance of any park visitors, or wildlife. Microbial communities will be documented across the laterally heterogeneous carbonate facies. Genomic DNA will be extracted and the 16S rRNA gene will be amplified using polymerase chain reaction (PCR) with universal bacterial primers. Terminal restriction fragment length polymorphism (T-RFLP) analysis and genetic sequencing of 16S rRNA gene will be used to track changes in the bacterial communities with sediment depth along the cores. This will give insight to the various microbial processes occurring during the different stages.

Table 1. Location and coordinates of proposed core locations.

Core Number on Figure 1	Core Number on Figure 1	GPS Coordinates	Estimated core depth (cm)
1	Freshwater Marl (Paurotis Pond)	25°18'28.16"N, 80°47'51.35"W	20-40 cm
2	Transition Zone (Whitewater Bay)	25°14'50.19"N, 80°47'54.81"W	250-300 cm
3	West Lake	25°12'52.39"N, 80°51'0.49"W	250-300 cm
4	Flamingo	25° 8'12.19"N, 80°56'9.81"W	300 cm
5	Florida Bay	25°4'49.55"N, 80°57'32.85"W	250 cm

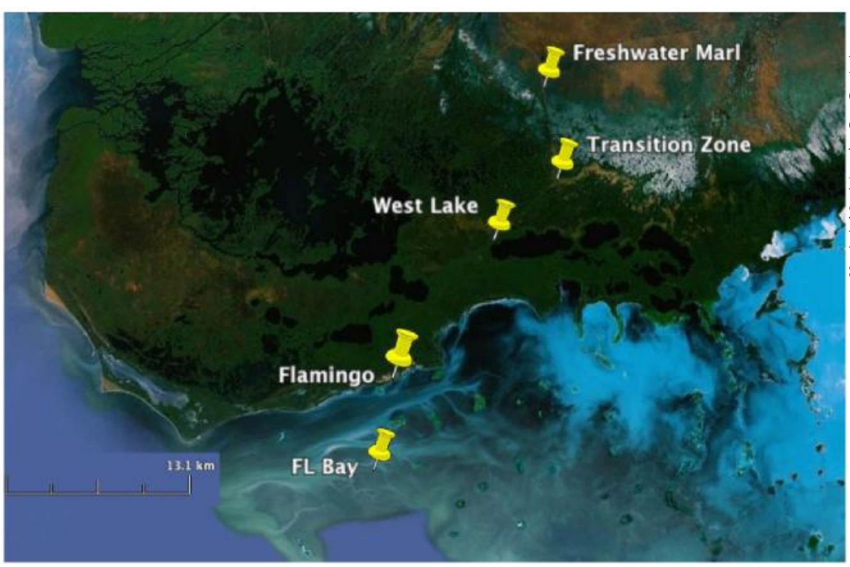

Figure 1. Projected coring sites corresponding to the GPS locations in the designated zones within the Everglades marl system.

Pore water chemistry will be used to provide an indication of the diagenetic evolution of the microbial carbonate marl during early burial and under changing porewater chemical conditions. We will sample the modern setting several times during the wet season and dry season. Porewaters will be analyzed from the brackish setting (Whitewater Bay), the coastal marine setting (Flamingo), and the full marine setting (Florida Bay). Core samples will be squeezed in a mechanical press to separate the sediment and pore fluids. Geochemical analyses of pore waters will include alkalinity and chloride titrations, and trace elements (Ca, Mg, Sr, S) using standard ICP-OES methods. Carbonate mineralogy will be determined using x-ray diffraction and the inorganic $5^{13}C$ and $\delta^{18}O$ composition of the sediment will be measured. These parameters will help characterize the depositional environment and processes occurring during the different stages of diagenesis.

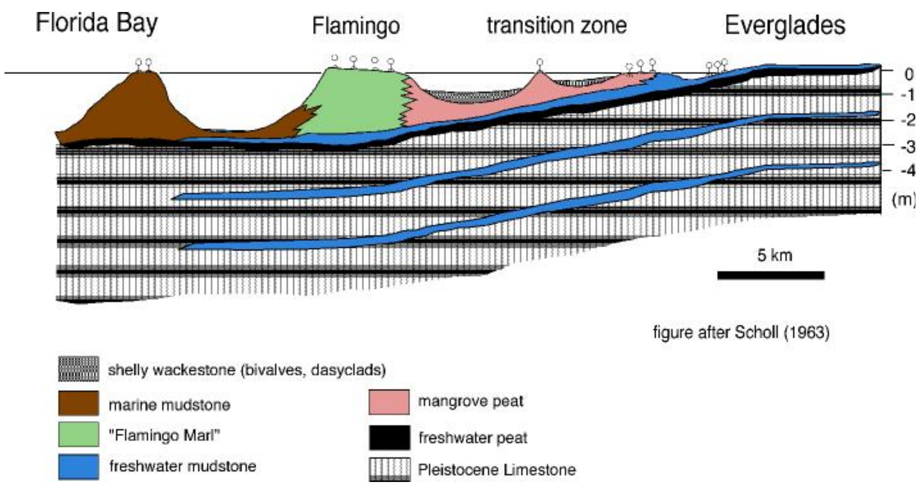

Figure 2. Generalized cross-section of the Pleistocene and Holocene freshwater microbial carbonates (blue).

KEY DELIVERABLES

This study will provide a linked modern -to-ancient calibration and assessment of freshwater microbial carbonates and their associated remnant organic structures. The nature of the site-specific microbial communities and the affect of early diagenesis on the carbonate crystals produced is relatively unknown. Early diagenetic environments can be assessed for changes to carbonate texture, organic matter composition, and survival of key microbial indicators in ancient deposits. Detailed characterization of modern Everglades marl formation will hopefully provide a means for identifying ancient microbial deposits.

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