Geochemical Analysis of Mineralized Layers in Tree Island Peats

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1. Introduction:

We are investigating the origin of cemented layers in sediments of large teardrop-shaped tree islands in Everglades National Park. The layers appear to have formed only on the heads of the islands and two profiles have been fully excavated on Poincianna and Sour Orange hammocks, Eastern Everglades Expansion Area in Shark River Slough. The layers:

- occur at ~25-50 cm depth,
- range in thickness from ~40-75 cm,
- require a concrete saw for penetration,
- are underlain by ~50 cm of additional uncemented sediments containing abundant archaeological artifacts (midden).

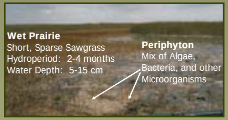
Dated shell tools above and below suggest peat/midden materials in the layer were deposited between ~ 4400-2700 cal yrs BP. The layer was likely misinterpreted as bedrock in previous coring and probing rod surveys and the theory that large teardrop-shaped tree islands are 'fixed', having formed atop bedrock pedestals, needs to be reassessed. The abundant late-Archaic (~5000-3500 yr BP) artifacts beneath the layer indicate that these islands were drier than surrounding wetlands -- and that humans were present in the Everglades -- earlier than previously thought (Schwadron, 2006).

Fig. 1a: Excavation on Sour Orange Hammock showing cemented layer between layers of soft peat/midden materials.
Fig. 1b: Layer with surface midden material removed to illustrate 'bedrock-like' quality of material. Note root penetration into the layer.

2. Two Modes of Layer Formation:

There are two main mechanisms in particular that could create such layers in the South Florida environment, each with different palaeohydrological implications. The layer may be a **palustrine limestone**, a type of algal-precipitated marl formed in shallow water that became hardened upon emergence caused by falling water levels.

In order for marl to precipitate atop the human occupation layer, water would have had to shallowly flood the tree island heads for at least part of each year. Studies show that such conditions need to persist for centuries or more to deposit a 40-75 cm thick marl layer. Merz (1992) reports experimental marl accumulation rates of 10-24 cm per 1000 years.


Wet Prairie
Short, Sparse Sawgrass
Hydroperiod: 2-4 months
Water Depth: 5-15 cm

Periphyton
Mix of Algae, Bacteria, and other Microorganisms

Fig. 2: Wetland near tree islands sampled in ENP.


Wet Periphyton


Dry Periphyton

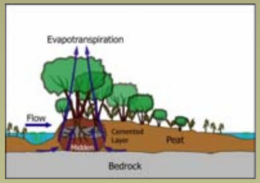
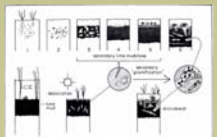


Fig. 3: Schematic diagram of tree island with cemented layer (adapted from Wetzel, et al. 2005).

The layer may be a **pedogenic calcrete**, formed within the soil from dissolved then reprecipitated calcium carbonate. The calcium carbonate source can be soil water percolating from above or groundwater. Potential sources of calcium carbonate include Miami Limestone, shells and dust.

Where there is strongly seasonal precipitation, plants and especially trees often play a major role in pedogenic calcrete formation. High transpiration rates increase water movement through the soil and water uptake at the root-soil interface leads to mineral precipitation in the rooting zone (Figs. 3 & 4). Calcrete formation does not require changing hydrological conditions; but it may be triggered, or be especially effective, during times of drought.

Fig. 4: Wind-thrown tree on Sour Orange Hammock showing cemented material in rooting zone.



From: Wright and Tucker, 1991, Calcretes, Ch. 1.

Fig. 5: Six stages of pedogenic calcrete formation (top) and palustrine sedimentation and emergence (below). Resultant petrological features are very similar.

Palustrine limestones and pedogenic calcrete may have similar properties such as hardness, degree of cementation, mineral composition and structure, cement types, shells, plant remains, and petrological features caused by microbial activity around roots. Fluctuating water tables and vegetation impart strong pedogenic characteristics on exposed marls, rendering them geologically similar to pedogenic calcretes. Palustrine limestones often grade into calcretes (Wright & Tucker, 1991). Therefore, a mixed palustrine/pedogenic origin of the carbonate in the tree islands is also possible.

3. Chemistry:

If the layer is a pedogenic calcrete whose carbonate source is dissolved then reprecipitated Miami Limestone, then older cements in the layer may retain evidence of the marine limestone precursor. Unaltered marine limestone has very high concentrations of magnesium and strontium, while algal-precipitated freshwater marl has much lower concentrations. As emerged marine limestone becomes ***stabilized*** (as it chemically equilibrates to a fresh water environment) strontium and magnesium levels will decrease.

Chemistry of Some South Florida Carbonates

Andrews, 1991	**Sr (ppm)**	**Mg (ppm)**	***Lasemi & Sandberg, 1991***	**Sr (ppm)**	**Mg (ppm)**
Everglades Freshwater Marls	~850	~2480	Stabilized Miami Limestone	~1800-1900	~1400-2000
Florida Bay Marine Muds	~4000-5500	~12,400	Stabilized Tamiami Limestone	~400	~4700
Stabilized Marine Mud	~2100	~4000			

We measured concentrations of these elements in individual layers of carbonate cement by electron microprobe. Individual cement layers represent discrete episodes of cementation and older and younger cements were identified and sub-sampled. Older cements best reflect the carbonate origin. Electron microprobe analysis requires the preparation of geological thin sections. Only the most well-cemented specimens available were suitable for this analysis.

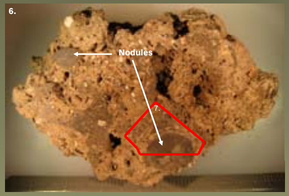
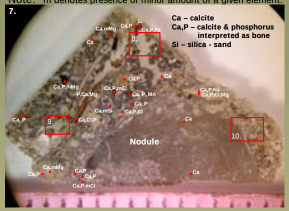


Fig. 6: Cemented midden material from Sour Orange Hammock, sampled 45-54 cm below the surface. The red polygon shows the material selected for thin sectioning and electron microprobe analysis (Fig. 7). A nodule from this layer dated ~5250-4850 cal yr BP, an age that is older than the unconsolidated sediments below the layer. Old, radioactively inert carbon from the underlying Miami Limestone may have been incorporated into these cements and caused the age to appear artificially old.

Fig. 7: Thin section of material shown in red polygon above. Spot samples of elemental compositions of inclusions and cements (red triangles). Additional spot samples on other thin sections are shown in Fig. 11.
Note: m denotes presence of minor amount of a given element.



Ca – calcite
Ca,P – calcite & phosphorus interpreted as bone
Si – silica - sand

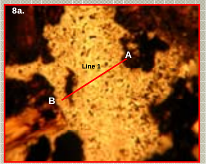


Fig. 8a: Transmitted light microscope photo of calcite cement transect traversed by electron microprobe. A to B = ~600 μm.

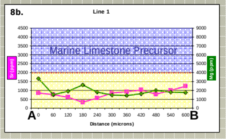


Fig. 8b: Sr and Mg concentrations of calcite cements along transect. The values of Mg and Sr cements are much lower than those of typical marine shells or muds. However, because Mg and Sr are quickly lost during dissolution and reprecipitation of $CaCO_3$, these values do not rule out a marine source such as the Miami Limestone for the carbonate involved in cementing the layers.

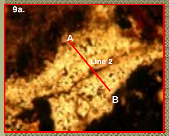
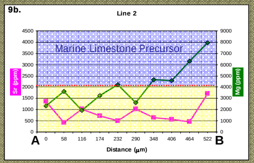


Fig. 9a: Transmitted light microscope photo of transect across calcite cements.
A to B = ~520 μm.

Fig. 9b: Sr and Mg concentrations of calcite cements along transect Line 2. The Mg values of the oldest cements indicate a marine origin.



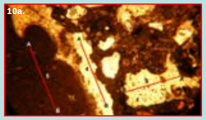
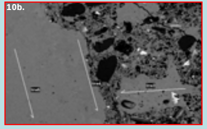
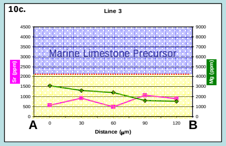


Fig. 10a: Transmitted light microscope photo of transects across calcite cements. Transect 3: A to B = ~120 μm.

Fig. 10b: Back-scattered electron image of above. Note how the different calcite cement generations are no longer discernible as in Fig. 10a.





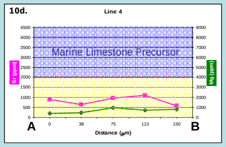
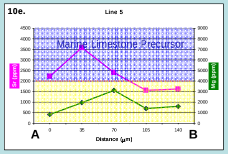


Fig. 10c & d: Sr and Mg concentrations of calcite cements along transect Lines 3 and 4. These values do not indicate a marine origin of the calcite cements.

Fig. 10 e: Sr and Mg concentrations of calcite cements along transect line 5, inside the nodule discussed on Figs 6 and 7. The Sr concentrations indicate a marine origin of the calcite cements. The nodule represents the oldest calcite on this thin-section.



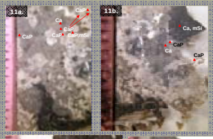


Fig. 11a,b: Thin sections from cemented layer on Sour Orange Hammock. Red triangles show qualitative elemental compositions of various inclusions and cements. Cements are composed of calcite or calcium phosphate.

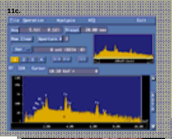
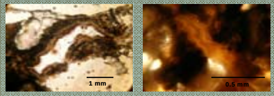


Fig. 11c: Sample energy dispersive spectrum for a qualitative spot analysis of elemental composition, showing a material rich in calcium and phosphorus.

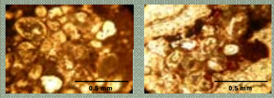
Fig. 11d,e,f: Thin sections the cemented layer on Poincianna Hammock. Red triangles show qualitative elemental compositions of various inclusions and cements. Note the abundant cements composed of calcium phosphate.

4. Petrography:

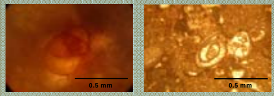
The preparation of thin sections for microprobe analysis also allowed us to carry out a preliminary petrographical investigation of the cemented material. We believe the layer formed *in situ* on the tree island heads and so carbonate cements, as well as inclusions therein, should yield some insight into the environment of formation. Calcrete petrography may strongly resemble that of palustrine limestones, but there are some components and textures diagnostic of palustrine conditions or of older, reworked marine bedrock. For example, the presence of ostracod shells or charophytes would indicate a shallow palustrine environment of deposition; to date, none of these have been found. Below are images and brief descriptions of some interesting and informative features we have encountered.



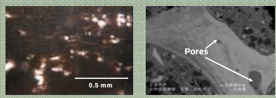
Rhizoliths: These layered cements precipitated around roots in the vadose zone. When mineral-rich groundwater is drawn into the root zone it becomes increasingly saturated during transpiration, causing the dissolved minerals to precipitate around the roots.



Alveolar Septal Structure: These round to ovoid grains may form around roots or fungal filaments. Together with rhizoliths, they indicate a macrophyte influence during precipitation. Many are filled with blocky cements indicating periodic phreatic conditions (i.e. fluctuating water tables).



Gastropod or Foram???: These resemble miliolid forams which are abundant in shallow marine waters but may also be tiny gastropods.



Plant Remains and Bone Fragments: The charcoal fragment (far left) shows plant cellular structure. The back-scattered electron image of the bone fragment (left) shows that calcium carbonate (darker grey) is filling the pores of the bone.

5. Summary and Conclusions:

This first round of geochemical and petrographical studies of the cemented layers on Sour Orange and Poincianna hammocks in Shark River Slough indicate that the underlying Miami Limestone is likely supplying at least some of the calcium carbonate contained in the cements. A robust marine limestone precursor signal was detected in the older cements of the nodule in Figs. 6 and 10 a&b, as well as the older (outer) cavity fills on Fig. 9a. The lower concentrations in some of the younger cements do not exclude the possibility of a marine precursor; however, they fall in the same range as values observed for the freshwater muds. The abundant rhizoliths and alveolar septal structures seen in thin-section (Section 4) and the cement-encrusted roots observed on wind-thrown trees both suggest that trees, via their very high transpiration rates, are drawing mineral-rich groundwater up into the soil zone and promoting the precipitation of minerals in *situ*. This process has been documented and described elsewhere (i.e., Australia – Semeniuk and Meagher, 1981) and is not uncommon in environments experiencing seasonal or longer term moisture deficits. While a palustrine origin of some of the material can not be ruled out at this time, we have found no evidence so far to suggest that palustrine processes played a role in layer formation.

No single technique will conclusively identify the origin of the layer. Geochemical and petrological analyses conducted to date support a marine origin of some carbonate cements but the abundant phosphorus cements identified suggest other material sources, which we are now investigating. We expect that the petrographic identification of successive stages of cementation, the analysis of their Mg and Sr content and the documentation of their relationships to shells, bones and plant fragments will yield enough clues to allow us to piece together the geomorphological and environmental history of the layers, and so of the tree islands that contain them.

6. References:

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