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An Enigmatic Carbonate Layer in Everglades Tree Island Peats

Recent archaeological excavations on the heads (i.e., the most elevated and upstream parts) of several large Everglades fixed tree islands may reshape what is understood about the age and formation of these landforms, and about the role of humans in the early Everglades wetland, between 3500 and 1000 B.C. Tree islands are patches of high ground, dry enough to support trees, that rise about 1 meter above the surrounding wetland, and those islands termed as "fixed" are the large teardrop-shaped islands thought to have formed over localized high points in the underlying bedrock (Figures 1a and 1b). A hard, cemented carbonate layer perched in the sediments of two tree islands in the southern Everglades was discovered by U.S. National Park Service archaeologists, and penetration of it with a concrete saw revealed that beneath the layer are unconsolidated sediments containing archaeological artifacts dating back to late-Archaic times (3000–1000 B.C.) [*Schwadron*, 2006].

The artifacts are a surprising discovery because archaeologists typically have believed that late-Archaic human populations in south Florida lived along the coast, with little reason to venture into an interior where surface water and associated resources were scarce [*Griffin*, 2002]. Fixed tree islands also were thought to be relatively young (<3500-year-old) features in the Everglades landscape where peat deposition began only as rising eustatic sea levels approached modern levels between 4500 and 3000 B.C. [*Gleason and Stone*, 1994]. Although archaeologists previously have noted cemented layers on former tree islands in the now-drained eastern Everglades [*Mowers*, 1972], those layers were far less hardened and less dominated by carbonate.

Current Theories of Tree Island Formation

Previous paleoenvironmental reconstructions suggested that sites where tree islands formed were occupied by marshes where water was shallower than in surrounding areas for as much as 1000–2000 years before incipient tree island vegetation consisting of forbs, shrubs, and ferns took hold. Only within the past 1500 years or so was mature tree cover established on the heads [*Willard et al.*, 2006, 2002]. *Willard et al.* [2002, 2006] proposed that tree island initiation and maturation occurred in response to lowered water levels during multidecadal droughts. On the heads of fixed tree islands, peat thickness was often found to be less than on lower portions of the islands, and the deposits had younger basal dates (<1500 B.C.) than sediments elsewhere on the islands or in adjacent wetlands. These thinner peat deposits supported the theory that fixed tree islands formed atop and downstream of high points in the underlying bedrock [*Sklar and van der Valk*, 2002].

A persistent problem with this theory has been the difficulty in explaining the regular distribution of islands forming a patterned landscape in the freshwater Everglades; such a distribution would require a similar pattern in the bedrock basement. We suggest that the carbonate layers formed in situ and often gave scientists false impressions of bedrock. The newly discovered layers and underlying artifact-bearing sediments necessitate a reassessment of theories of tree island formation, development, and human use in the late-Archaic Everglades.

Reexamining Fixed Tree Island History

Tree islands are the only topographic highs in the Everglades where, in surrounding marshes, the elevation range is only a few decimeters. With tree islands raised by a meter or so, they provide invaluable high ground for many plants and animals that could not otherwise flourish in the wetland. Fixed islands are a relatively large type of tree island (Figure 1a) that is common in Shark River Slough, the main channel draining the Everglades. They are oriented along the direction of the water flow, with heads situated upstream of tails that taper off in the downstream direction (Figure 1b). Vegetation zones in the Everglades are controlled by local relative elevation—through its effects on hydrology—and peats that form in different zones exhibit distinct characteristics useful for paleoenvironmental reconstructions.

Archaeological shovel tests and probing rod surveys revealed cemented material at relatively shallow depths on 20 large, fixed, tree island heads in central Shark River Slough, making this potentially a regionally important phenomenon [*Schwadron*, 2006]. Verifying carbonate layers on all islands, or determining whether some of these islands actually are fixed to bedrock, requires more extensive drilling or open-pit excavations down to confirmed bedrock. The layer seems to be restricted to the heads of fixed tree islands where it appears to be continuous and overlies sediments with basal dates approaching 3000 B.C. Radiocarbon dates and artifact types above and below the layer on the two islands excavated to bedrock indicate that organic materials in the carbonate layers were deposited between approximately 2500 and 850 B.C. Yet a single radiocarbon age obtained from carbonate within the layer was 10,000 years before present, suggesting that ^{14}C-depleted groundwater bicarbonate (likely dissolved Miami limestone) was incorporated during diagenesis.

As noted above, the late-Archaic artifacts below the carbonate layer (including shell tools, fiber-tempered ceramics, and worked and unworked bone) are a significant archaeological discovery [*Schwadron*, 2006]. These new findings support emerging evidence that humans were present in the early Everglades wetland and were using tree islands, or nascent tree islands, as resource extraction camps, for habitation, and possibly as burial grounds [*Carr*, 2002] much earlier and more intensively than previously thought.

Mechanisms of Carbonate Layer Formation

But what of the carbonate layer itself? At two archaeological excavations completed to date, the 50- to 70-centimeter-thick layer appeared at depths of 25 and 50 centimeters below surface (Figures 1c and 1d). The carbonate sediment ranges in color from light grey, where the material is harder and less porous, to dark brown, where the material is softer and more porous. Throughout, there are varying amounts of inclusions such as shells, bone fragments, plant remains, and charcoal. Diagenetic and petrologic characteristics include vugs, spar crystals, nodules, and probable root voids (Figure 1e).

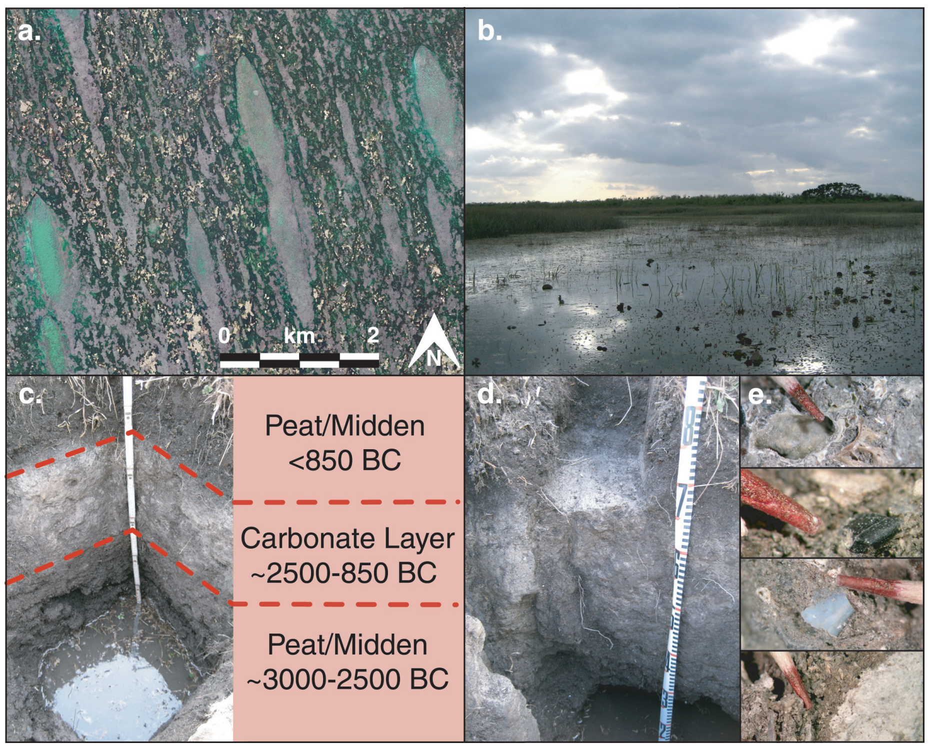

Fig. 1. (a) Aerial view of a fixed tree island landscape in Shark River Slough, Everglades (~25°54'N, 80°41'W). (b) Everglades landscape in Shark River Slough with slough (open water) and sawgrass marsh in foreground and Jaula Hammock tree island head (area with tallest trees) and tail tapering off in downstream direction (to the left) in background. (c) Archaeological test pit exposing mineralized layer and unconsolidated sediments below. (d) Carbonate layer with surface sediments removed. (e) Microscopic enlargement of carbonate layer and inclusions: (top to bottom) vug with crystals; charcoal; shell fragment; contact between darker, more porous material (cemented midden) and lighter, less porous material (possibly a carbonate nodule). For scale, the red pointer is 2 millimeters.

Cemented layers are common and well-documented features in arid landscapes, but they are rarely described from subhumid locations such as south Florida. However, Florida's distinctly wet/dry climate with a pronounced seasonal moisture deficit and very high evaporation rates can be conducive to such formations [*Alonso-Zarza et al.*, 2006]. Deposits discussed in the literature are usually Pleistocene-age or older and are thought to have formed over several thousands to millions of years. Yet relevant late-Holocene deposits do exist and include capillary-rise calcretes that developed beneath forested coastal dunes in southwestern Australia [*Semeniuk and Meagher*, 1981] as well as thick subsurface calcite accumulations that form islands in Botswana's Okavango Delta [*McCarthy et al.*, 1998]. High transpiration rates of trees were considered important to the development of cemented layers in both studies.

Fundamental questions regarding the carbonate layer concern the original environment in which sediments were deposited and processes of cementation. Calcium carbonate can be deposited directly, as algal-precipitated marl, and this is common in shallow marshes in the southern Everglades. The 10,000 years before present date of the carbonate in the cemented layer on one tree island eliminates this possibility for that island because dates from typical Everglades marls show little or no influence from ^{14}C-depleted groundwater [*Gleason et al.*, 1984]. Alternatively, calcium carbonate precipitation can occur within a soil by dissolution of the underlying limestone and upward transport of dissolved $CaCO_3$ species in groundwater. Similar processes are associated with calcretes, which are near-surface accumulations of dissolved and reprecipitated calcium carbonate in soils or bedrock and are usually associated with arid or semi-arid regions. A mixed origin also is possible, with marl sedimentation followed by later cementation and diagenesis of the sediment. Subaerial exposure or repeated wetting and drying are possibly involved in the hardening of the sediments.

Implications of the Carbonate Layer

A marl origin of the carbonate layer requires shallow (minimum of 5–15 centimeters deep) water over tree island heads during deposition and implies a climate shift to wetter conditions. A calcrete origin suggests a prolonged, perhaps ongoing process, possibly initiated by drought and driven by transpiration and seasonal water table fluctuations. Other sedimentary evidence exists for pronounced and prolonged shifts in the flooding regime throughout Everglades marshes. A soft marl layer dated approximately 800–300 B.C. is often found within peats deposited in marshes in the southern Everglades [*Gleason and Stone*, 1994]. A buried layer of lake mud occurs in a similar stratigraphic position (before twentieth-century soil destruction) near the northern boundary with Lake Okeechobee [*Gleason et al.*, 1984]. Perplexingly, the marl suggests drier conditions while the lake mud suggests wetter conditions. Both indicate significant changes in Everglades hydrology during the late Holocene. Paleoenvironmental reconstructions from the Caribbean [*Higuera-Gundy et al.*, 1999] suggest that approximately 2400–600 B.C. (3950–2490 ^{14}C years before present) was very wet with a trend toward drier conditions starting around 1500 B.C.

The carbonate layer may affect the size and stability of tree islands. The layer is resistant to erosion and would also limit elevation loss resulting from south Florida's occasional peat fires. According to evidence to date, the carbonate layer occurs on the heads of large fixed tree islands in Shark River Slough but not on other kinds of tree islands such as peat-hummock islands and strand islands found elsewhere in the Everglades. Fixed islands with the carbonate

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layer may be more resilient to environmental change. A survey of all types of tree islands in Water Conservation Area 3A, just north of Everglades National Park, counted 1251 tree islands on aerial photos from 1940 and only 577 on photos from 1995, a 61% net loss of tree island area [*Sklar and van der Valk*, 2002]. Tree island loss is a major concern in the Everglades, and it is generally attributed to compartmentalization of the wetland by levees, extensive canalization, and water management in the northern portions of the Everglades. Assessing and mitigating tree island loss and preserving the essential habitat that tree islands provide is a major focus of Everglades restoration efforts.

Future Work

There is much work to do before we fully understand the ecological and human history of these islands; the nature, origin, distribution, and paleoenvironmental significance of the carbonate layer; and the effect this layer exerts on tree island morphology, stability, and resilience. Ongoing work on paleoenvironmental reconstructions from complete stratigraphies on two representative tree islands will be correlated with archaeological findings at both sites. We are also undertaking a petrologic study of the carbonate rock itself to determine modes of deposition and secondary diagenesis. Combined, these two avenues of investigation should clarify the hydrologic, and thus climatic, conditions leading to the development of the carbonate layer within the broader story of Everglades tree island formation.

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