Subaqueous Soils or Not?

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Introduction

In recent years, pedological research has targeted soils that are permanently under water, subaqueous soils (Bradley and Stolt, 2003; Demas and Rabenhorst, 1999; Ellis, 2006; Osher and Flanagen, 2007). These are aquatic soils and are outside the extent of terrestrial soil surveys. The water-ward extent of terrestrial soil surveys traditionally ends at the edge of water bodies or where terrestrial vegetation ends (Figure 1). This presents two questions that we address in this research:

- In our efforts to realize aquatic soil survey, are we ignoring frequently exposed aquatic areas by focusing on subaqueous soils? (Figure 2)
- Do these soil areas represent subaqueous soils or terrestrial soils?
- If the extent of terrestrial soils is the existence of the edge of a water body or the end of terrestrial vegetation, how do we statically delineate such a dynamic feature?

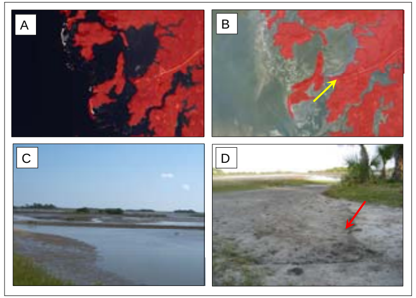

Figure 1. The terrestrial/subaqueous transition zone. Terrestrial soil survey (Slabaugh, 1996) covers land at Mean High Water and above (red areas in A and B). A is a photograph at high tide while B is a photograph at low tide. Much of the adjacent land is exposed each day (C) thus it is not subaqueous. The influence of water on the terrestrial soils can be seen (red arrow in D).

Objective

Document the continuum of soil morphology across the terrestrial/aquatic interface in an effort to demonstrate pedogenesis throughout the interface.

Methods

We present a series of morphological descriptions of soils along catenas crossing the terrestrial/aquatic border to document the continuum of soil morphology. We do this for two types of locations: barrier island / lagoon and drowned flatwoods.

Results

Big Bend FL: Drowned Flatwoods

Near Cedar Key, FL, the marine environment is an extensive system shallow flats. The flats inside salt marsh areas are unvegetated while those outside the marsh are vegetated with seagrasses. No barrier islands are present to protect these flats. They are instead protected by there expanse. Such a large area of the Gulf Coast of Florida (the Big Bend) is expansive and shallow, that the water energy is very low.

These expansive flats are actually drowned flatwoods (Figure 2a). The Spodosols that are typical of flatwoods (Figure 2b) are also typical of the beaches, intertidal flats, and subaqueous soils near Cedar Key. Figure 2 shows a typical beach in the Big Bend area. The beach is actually a truncated E horizon of a Spodosol.

Rising sea level has caused coastal forest retreat, as evidenced by the downed tree in Figure 2a. Figure 2c shows organic carbon leaching out from the Spodic horizon on to the beach during a low tide. Figure 2d shows the upper part of a typical pedon occurring in these intertidal zones. Note the redish-brown colors indicated by the yellow arrow. This is the in-tact, drowned Spodic horizon. Subaqueous soils can have dark colors also, but the reddish hues combined with the ability of the clay and organic carbon to stain the water (Figure 2e) are indicators that this material is Spodic.

Subaqueous soils are also influenced by the terrestrial soils. Figure 3 shows originating from Spodosols but currently supporting seagrasses.

Figure 2. Typical drowned flatwoods beach occurring in the Big Bend area of Florida (A). Note that Spodosols are typical of flatwoods (B) and these spodic materials (C, D, and E) are present today after being drowned by rising sea level.

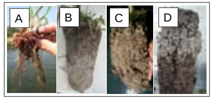

Figure 3. Vegetated subaqueous soils. *Thalassia testudinum* is a tropical seagrass that has an extensive root system (A). It is show rooted in two soils (B and C). *Halodule wrightii* is show rooting in a soil (D) with a Spodic horizon.

Location	Terrestrial	Intertidal	Subaqueous
Shell Mound	A1 0-3 cm; very dark brown (10YR 2/2) loamy sand; weak medium subangular blocky structure; very friable; common fine roots; <1% shell fragments; abrupt smooth boundary. A2 3-15 cm; very dark gray (2.5Y 3/1) loamy sand; weak medium subangular blocky structure; very friable; many fine and medium roots; common vertical and horizontal rhizomes; <2% shell fragments; moderately alkaline; clear smooth boundary. A3 15-40 cm; very dark brown (10YR 2/2) loamy sand loamy sand; weak medium subangular blocky structure; very friable; common fine roots; <2% shell fragments; moderately alkaline.	A1 0-4 cm; black (N 2.5/0) loamy sand; very fluid (*n* value >1); abrupt wavy boundary. A2 4-9 cm; very dark gray (2.5Y 3/1) loamy sand; weak medium subangular blocky structure; very friable; common fine roots; <2% shell fragments; moderately alkaline; clear smooth boundary. A3 9-27 cm; very dark gray (7.5YR 3/1) and 5% gray (2.5YR 5/1) loamy sand; weak medium subangular blocky structure; very friable; common fine roots; 5% shell fragments; moderately alkaline; clear smooth boundary. A4 27-40 cm; very dark gray (7.5YR 3/1) loamy sand; weak medium subangular blocky structure; very friable; few fine roots; <2% shell fragments; moderately alkaline.	A 0 to 6 inch; black (N 2/) silty clay loam; massive; sticky; very fluid, flows easily between fingers when squeezed, and leaves little or no residue in hand; few fragments of partly decomposed wood; common crab holes; strongly saline; moderately alkaline; abrupt wavy boundary. Cg1 6 to 20 inches; very dark gray (10YR 3/1) clay loam; massive; sticky; very fluid, flows easily between fingers when squeezed; common crab holes in upper part; strongly saline; moderately alkaline; clear smooth boundary. Cg2 20 to 80 inches; dark grayish green (5GY 4/1) clay loam; massive; sticky; very fluid, flows easily between fingers when squeezed; strongly saline; moderately alkaline.
Panama City Beach	C 0-8 cm; white (N 10/0) sand; few black sand grains; loose; few very fine roots; slightly alkaline; abrupt wavy boundary. A 8-19 cm; light gray (2.5Y 7/1) sand; 20% dark grayish brown (2.5Y 4/2); few black sand grains; loose; very friable; many fine roots; slightly alkaline; clear smooth boundary. CBh 19-26 cm; 50% light brownish gray (2.5Y 6/2) and 50% brown (10YR 4/3) sand; few black sand grains; very weak medium subangular blocky structure; very friable; many fine roots; slightly alkaline; abrupt smooth boundary. Eg 26-34 cm; light gray (10YR 7/2 and 2.5Y7/1) sand; very weak subangular blocky structure; very friable; few fine roots; moderately alkaline.	C1 0-14 cm; stratified olive gray (5Y 4/2, light gray (5Y 7/1), and dark gray (5Y 3/1) sand; 10 % black (2.5Y 2.5/1; loose; few medium shells; common 3-7 mm fecal pellets on surface; moderately alkaline; clear smooth boundary. BhC 14-35 cm; faintly stratified dark grayish brown (2.54/2) and light brownish gray (2.5Y 6/1) sand; 2% black sand grains; loose; very friable; few fine shell fragments; moderately alkaline; clear smooth boundary.	C 0-3 cm; dark gray (10YR4/1) and light olive gray (5Y 6/2) sand; loose; few fine shells; moderately alkaline; abrupt wavy boundary. A1 3-8 cm; olive gray (5Y 5/2) and dark grayish brown (2.5Y 4/2) sand; weak medium subangular blocky structure; very friable; many fine and medium roots; few fine shell fragments; moderately alkaline; clear smooth boundary. A2 8-23 cm; dark grayish brown (2.5Y 4/2) and light gray (2.5Y 7/1) sand; weak medium subangular blocky structure; very friable; common fine and medium fine roots; few fine shell fragments; moderately alkaline; clear smooth boundary. A3 23-35 cm; dark grayish brown (2.5Y 4/2) sand; 10% gray (5Y 6/1); weak medium subangular blocky structure; very friable; few fine and medium roots; few shell fragments; moderately alkaline.

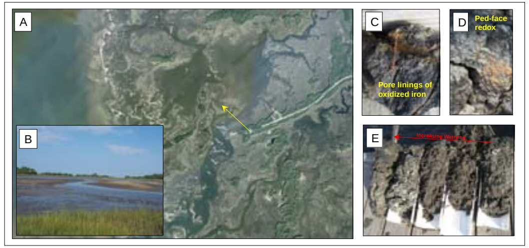

Figure 4. Shell Mound state park in Levy County, FL. Aerial photographs (A) show both the aquatic and terrestrial nature of the area. Extensive flats that are inundated from 25% to 75% dominate the area. The yellow arrow in A corresponds to the photograph B. Iron in pore linings and ped-face concentrations are evident. This features were present in the first soil in E (1st from left).

Panhandle FL: Barrier Island / Lagoon Soils

In the panhandle region of Florida, the subaqueous soils occur in the lagoonal areas behind the protection of barrier islands. These barrier islands, also form flatwoods. The Spodosols that occur in these flatwoods influence the subaqueous soils. Near the barrier island, local reworking of the island causes either albic or spodic material to migrate across the intertidal zone and into the subaqueous zone. Therefore, subaqueous and intertidal soils form in locally reworked or truncated Spodosols. A typical landscape showing the transition from the terrestrial barrier island through the intertidal zone and into the subaqueous zone is shown in Figure 4a. The influence of the Spodosols can be seen either in the presence of a Spodic horizon (Figure 4c and d) or in the low chroma / high value color of the soils (Figure b and e).

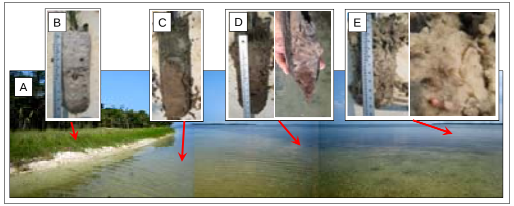

Figure 3. Typical landscape where barrier islands are connected to the subaqueous environment (A). Spodic and Albic horizons provide the parent material in which the intertidal (B and C) and subaqueous soils (D and E) form.

Discussion

Big Bend, FL

The morphologies of the terrestrial, intertidal, and subaqueous soils are each influence by podzolization. This terrestrial pedology is surprisingly persistent under subaqueous conditions.

Though not reported in this study, we observed an absence of podzolic influence in areas where dunes were the prevalent terrestrial landform. Most dunes in Florida consist of Spodic Quartzipsamments which are high-chroma soils that have not undergone the intense podzolization that the flatwoods soils have. Typical flatwoods soils are Alaquods. Near the dunes, the beaches were higher in chroma as were the intertidal and subaqueous soils.

This further underscores the importance of pedology in an aquatic environment. Understanding terrestrial soil formation and distribution allows for the understanding of the connected intertidal and subaqueous soils.

Contemporary pedogenesis was also apparent in the form of bioturbation and soil structure. Along worm tubes (Figure 4c) iron was concentrated. This iron was observed leaching out of some intertidal and terrestrial soils. Ped-face redox concentrations can be observed in terrestrial soils, but the occurrence of these in an intertidal or subaqueous soil is not known to have been documented (Figure 4d).

Panhandle FL

The terrestrial influence on intertidal and subaqueous soils was evident in the panhandle soils as well. The influence of the terrestrial over the intertidal and subaqueous is consistent with what occurs in the Big Bend area.

Conclusions

There is no clear separation between terrestrial land and aquatic land in many areas of Florida. Gentle slopes combined with tidal fluctuations create expanses of soils that were originally terrestrial and are now influenced by aquatic processes. These areas do not support rooted vegetation due to their exposure at average and low tides. However, the degree of pedogenic influence, both relict and contemporary, is unmistakable. These areas are comprised of soil.

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