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Discovery of an Intact Quaternary Paleosol, Georgia Bight, USA

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Abstract: A previously buried paleosol was found on the continental shelf during a study of sea floor scour, nucleated by large artificial reef structures such as vessel hulks, barges, train cars, military vehicles, etc., called "scour nuclei". It is a relic paleo-land surface of sapling-sized tree stumps, root systems, and fossil animal bone exhumed by scour processes active adjacent to the artificial reef structure. Over the span of five research cruises to the site in 2022–2024, soil samples were taken using hand excavation, PONAR grab samplers, split spoon, hollow tube auger, and a modified Shelby-style push box. High-definition (HD) video was taken using a Remotely Operated Vehicle (ROV) and diver-held cameras. Radiocarbon dating of wood samples returned ages of 42,015–43,417 calibrated years before present (cal yrBP). Pollen studies, together with the recovered macrobotanical remains, support our interpretation of the site as a freshwater forested wetland whose keystone tree species was *Taxodium distichum*—bald cypress. The paleosol was identified as an Aquult, a sub-order of Ultisols where water tables are at or near the surface year-round. A deep (0.25 m+) argillic horizon comprised the bulk of the preserved soil. Comparable Ultisols found in Georgia wetlands include Typic Paleaquult (Grady and Bayboro series) soils.

Keywords: Quaternary paleosol; Atlantic; continental shelf

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1. Introduction

Relatively intact paleosols have been found in diverse marine settings. Recent discoveries include Quaternary paleosols in Haifa Bay [1] and the U.S. Pacific coast [2]. Paleosols are an important resource for terrestrial environmental and climatic reconstructions.

Paleosols have not been previously identified off the U.S. Atlantic coast. This study describes our initial discovery of a paleosol in the Georgia Bight (Figure 1). Recent paleosol research has introduced semiquantitative and quantitative measures for environmental and chronometric reconstructions that provide insight into major regional to global changes in temperature, precipitation, and atmospheric *p*CO2 [3]. Paleosols are essential tools in sequence stratigraphic analyses. Geologically, paleosols are common in ancient shallow marine carbonate sequences, a function of the ofttimes frequent oscillations at sea level which affect shallow or basin-edge seas. Such paleosols have been used as indicators of subaerial exposure, but as our knowledge of past ecologies and paleoclimate has increased, they provide insight into the Earth's system variation from deep time to the Holocene.

Drowned forests located on marine paleosols have been reported on the Canadian continental shelf of British Columbia [4,5]; off Prince Edward Island [6]; the Baltic Sea [7]; in Murrell's Inlet, South Carolina, on the Atlantic continental shelf [8]; and off the Gulf Coast of Alabama [9].

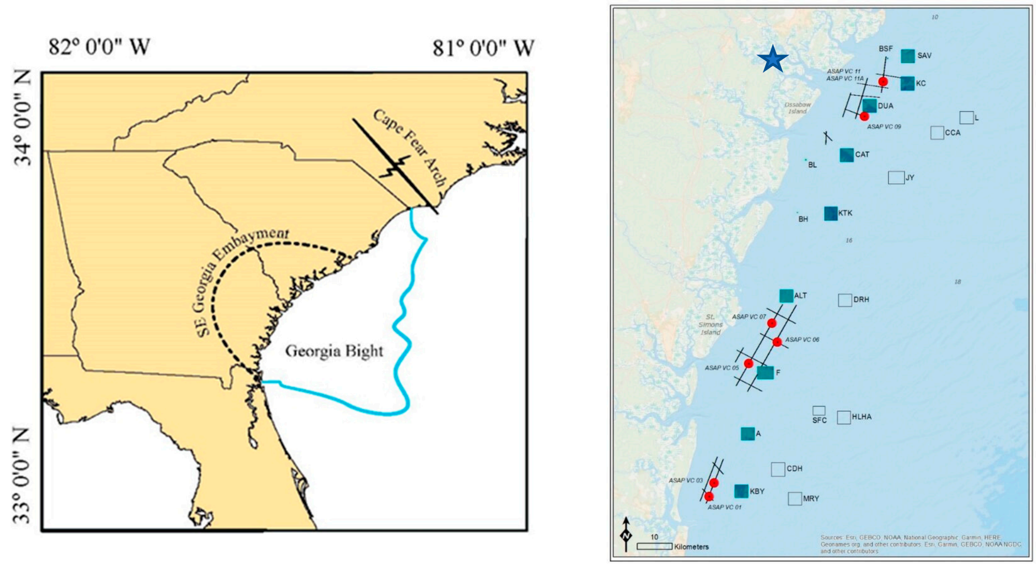

Figure 1. (**Left**) Area of Georgia Bight, U.S.A. (**Right**) Artificial reef locations and inner continental shelf. Reef SAV is the northernmost site shown. Barge 13 is located therein. Tybee Island is marked with a blue star.

A recent four-year research study of Georgia's Atlantic continental shelf investigated large artificial reef structures such as barges, vessel hulks, etc., also known as "scour nuclei", for evidence of paleo-land surfaces and associated paleosols. Turbulence produced by tidal and wind-generated currents in the Georgia Bight has produced scour pits termed by others as "moats" and "comets" [10]. This methodological approach differs from the use of sediment coring to collect and study marine deposits conducted in the early 1980s and again in the early 2000s in the Gulf of Mexico/America [10]. Larger samples of exposed sea floor can be directly collected and studied as demonstrated herein.

The modern palimpsest sand sheet, at these locations, was observed to erode to depths of over a meter, forming "moats" immediately adjacent to an artificial reef structure. Relatively strong tidal currents operate twice daily in the Georgia Bight, with ebb tide currents typically stronger than those associated with the flood tide. Long et al. [11] and Alexander [12] provide the most recent, comprehensive studies of sediment composition and stratigraphy for the nearshore continental shelf off Georgia. Our current study differs from these earlier studies in that we have sought and located extant paleosols on Quaternary landforms exposed by scour processes [10,13]. At Reef SAV (Figure 1), a Marine Isotope Stage 3 paleosol, dated to 42,015 to 43,417 calibrated years before present (cal yrBP), was exposed. We describe this soil and relate its paleoecology to our current understanding of past sea levels and paleoclimates.

2. Objectives and Methods

The questions we asked of this paleosol included the following:

a. What kind of soil?
b. How old is the soil?
c. What type of environment is indicated by the soil?

To address these questions, we used particle size analysis (PSA), X-ray diffraction (XRD), and macrobotanical/microbotanical data.

We collected sediments, using corers, grabs, and hand excavation, from eight large artificial reef structures. Again, as previously reported elsewhere [9,13], our methodology produced evidence of potential Quaternary landforms. That research demonstrated that scour around sea floor structures effectively removes palimpsest sediments, allowing access to older, and potentially intact, land surfaces. The scour at the Barge 13 site removed both Holocene and late Pleistocene sediment strata to depths of over 2 m (Figure 2). Deposits in a moat feature [14] contained both vertebrate and invertebrate fossil elements eroded from strata.

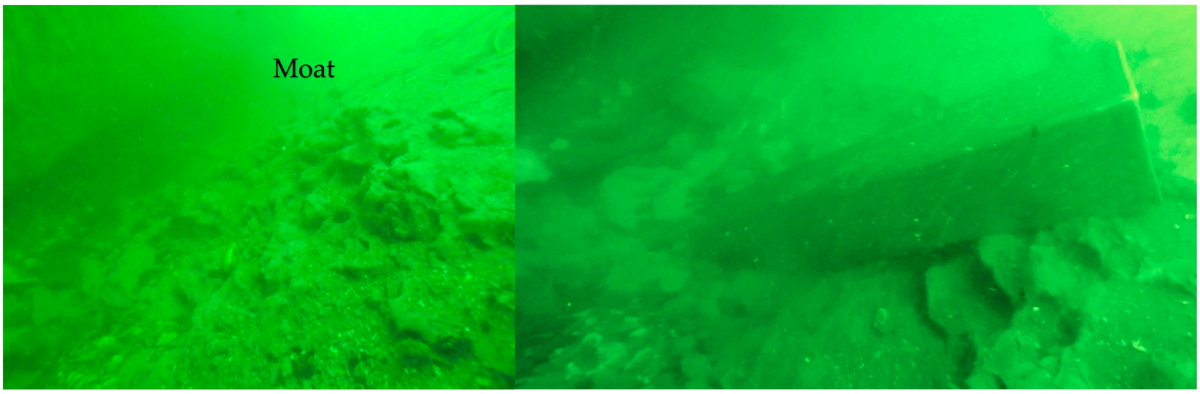

Figure 2. (**Left**) Scour moat at Barge 13, with profile depth ~1.5 m; (**Right**) soil profile push box on moat profile prior to sample collection. The box is 45 cm in length and 7 cm in width.

2.1. Geology of the Research Area

The Georgia Bight is characterized as an erosional–accommodation-dominated shelf whose sea floor can be described as in disequilibrium with erosional surfaces, irregular grain size patterns, shoreface bypassing, and wave/wind and tidal current reworking. Additionally, recent studies (Weems and Edwards, 2001 [14]; Weems and Lewis, 2002 [15]; Harris et al., 2005 [16] and Baldwin et al., 2006 [17]) have shown that this shelf is characterized by stratigraphic heterogeneity. In many areas, the Miocene and Pliocene units are scattered as erosional remnants of arenitic sandstones (Harding and Henry, 1994 [18]; Hunt, 1974 [19]; and Garrison et al., 2008, 2012 [20,21]). Riggs et al. (1996) [22] attribute this shelf morphology, in part, to subaerial weathering, stream erosion, and karst formation.

Outcrops, hard bottoms, and paleo-valleys are of Pliocene age strata until outer shelf/shelf break depths were reached (Harris et al., 2005 [16]). Former coastal drainages of the South Carolina and Georgia shelf are southeast draining rivers incised into upper Cenozoic units creating paleo-valleys subsequently backfilled during cyclic changes in sea level, with sediment types ranging from estuarine muds to clean shelly sands (Antoine and Henry, 1965 [23]; Baldwin et al., 2006 [17]; Foyle et al., 2001 [24]; Garrison et al., 2008 [20]; Riggs et al., 1996 [22]; Swift, 1972, 1976 [25,26]; Harris et al., 2005 [16]; Woolsey and Henry, 1974 [27]). In this study, we postulated that the use of scour nuclei [28] would prove to be a good method to expose and examine these paleo-landforms and soils found thereon.

2.2. Methods

The principal method to study the submerged stratigraphy of the sea floor is sediment coring. In less-clastic deposits, boxes, gravity, and piston corers have proven to be effective. In more arenic or sand-rich sediments, only piston and vibracorers can retrieve deeper sediments. As an example, 38 paleosols were recovered in Haifa Bay using continuous coring to water depths of 98.5 and 120 m terminating at lithic contacts [1]. On the same coast, geoarchaeological studies of submerged prehistoric settlements used hand- and water jet-assisted coring of both archeologically sterile and anthropogenic paleosols [29]. These paleosols included examples of clayey, sandy, and wetland paleosols. Gusick et al. [2] retrieved evidence of multiple paleosols in cores taken from the northern Channel Islands, California, to depths of 1.5 m using vibracoring.

2.3. Sampling

In this study, box coring, Ponar grabs, and hand augers were utilized. The box corers and grabs are only effective in sediments less than a meter thick. One-inch (20 mm) diameter hand augers and a modified soil profile push box (Figure 2) were used to retrieve continuous soil samples up to and in excess of 1 m.

The artificial reef site, Barge 13, was the northernmost site studied at Reef SAV, which was located 10 km east of Tybee Island (Figure 1). The reef site contains numerous structures, including three steel barges averaging over 30 m in length. Two of these barges were extensively surveyed—Barges 6 and 13. We collected 2 cores at Barge 6, deployed from the RV SAVANNAH. Barge 13 was sampled using grabs, soil augers, and excavation samples retrieved by divers. The divers recovered sediment samples from moat areas previously inaccessible to grabs or box coring by using a hand auger and a soil Shelby-style push box (Figure 2). Because no evidence of a paleosol was observed, Barge 6 will not be discussed.

All soil samples were first characterized for Munsell color—wet and dry—and photographed. Splits were taken of the samples and dried for particle size analysis (PSA). Archival splits were refrigerated. Samples were examined with X-ray diffraction (XRD) analysis of clay fractions as well as salient elemental or mineral forms of Ca ($CaCO_3$), Fe (FeS), and Mn (MnS).

2.4. X-Ray Diffraction (XRD)

The University of Georgia's (UGA) XRD system is a Bruker D8-Advance model diffractometer. Computers in the XRD lab are equipped with a wide range of crystallographic software for pattern simulations (NEWMOD and CrystalDiffract), cell refinements (Rietveld refinement), crystal structure presentation (CrystalMaker), and the ICDD PDF-4+ database. The Bruker Eva® program presents raw data and graphs known as diffractograms with patterns and peak positions identified

Sediments were examined using X-ray powder diffraction (XRD) with the University of Georgia Bruker D8-Advance diffractometer. Samples were initially ground using a corundum mortar and pestle and then further ground in ethanol using a McCrone micronizing mill for 10 min to reduce particle size to <10 µm. Powders were backfilled against a glass plate and pressed up to 400 psi to create a flat, self-supporting mount with minimal sample transparency. The D8 optics included a 250 cm goniometer radius, 0.6 mm divergence slit, and Bragg–Bentono geometry. A knife-edge blade was set 2 mm above the sample surface, and data was collected using a cobalt radiation source ($K_{\alpha 1}$ = 1.7890 Å and $K_{\alpha 2}$ = 1.7928 Å) that was operated at 35 kV and 40 mA with a position-sensitive Lynx-Eye® detector. To verify alignment and calibration within 0.01° 2-theta tolerance of the certificate value for the brightest reflection peak position, an external NIST Reference standard SRM1976b corundum (α-Al_2O_3) [30] was used. Using a locked–coupled continuous scan mode with a step size of 0.01° 2θ and a count rate of 0.2 s per step, the scan range was enhanced from 2 to 70° 2θ. The Bruker Eva® program presents raw data and graphs known as diffractograms with patterns and peak positions identified. The raw data was $K_{\alpha 2}$-stripped. Peak locations were compared to information from the powder diffraction file (PDF-4+) database of the International Centre for Diffraction Data (ICDD). Eva software V6 was used with the database to identify the best-fit phases for mineral identification.

Energy-Dispersive Spectroscopy (EDS) is a common analytical approach to evaluate mineralogy in combination with XRD. Identification of individual elements alone is not enough to determine mineralogy. This can be carried out for the elements that appear in major abundances by recalculating the structural formula using an assumed stoichiometric model. We opted to forego EDS analysis of the argillic fraction as our XRD results were confirmatory of a clay-dominated sediment. XRD's more direct mineralogical identification capability precludes additional reliance on stoichiometry.

2.5. Microbotanical

Micro- and macrobotanical inclusions, such as pollen and roots, were collected by sieving the sediments. Wood in the form of free-standing stumps (Figure 3), in situ root systems, and fragments lying on the soil surface were collected by divers. Hand augers were used to retrieve the sediments used in both dating and pollen studies. These macrobotanical remains were freeze-dried in a Labconco Freeze Dryer 4.5 and submitted for identification at Mississippi State University's College of Forest Resources. Radiocarbon dates on wood samples were provided by the Center for Applied Isotope Studies at the University of Georgia.

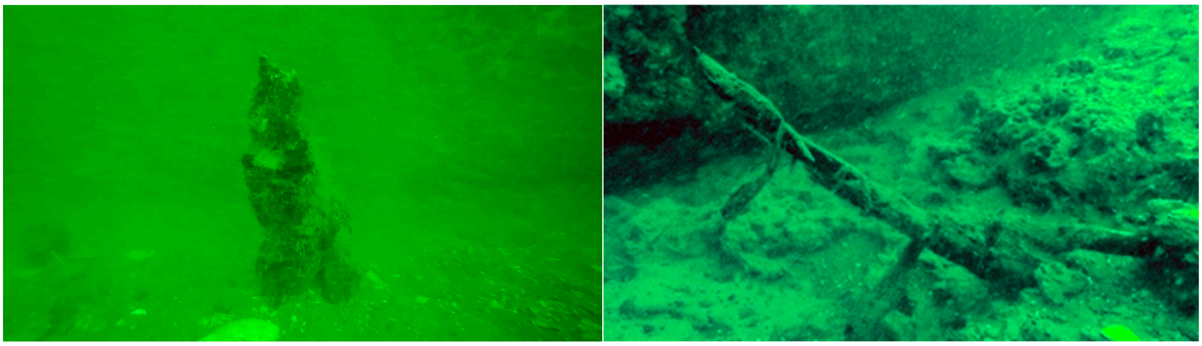

Figure 3. In situ stump and root systems of *Taxodium distichum* (bald cypress), Barge 13, Reef SAV. Barge 13 can be seen in the background of the right panel. The roots are deeply embedded in the paleosol argillic horizon. Additional wood retrieved from the soil was pine (species undetermined).

Palynomorphs were isolated from samples using standard methods: sediment drying at 40 °C; sample weight taken and one *Lycopodium* tablet added for the calculation of the palynomorph concentration [31]; demineralization with HCl and HF; removal of cellulosic and humic matter using acetolysis and 10% KOH; removal of coarse and fine fractions by sieving with 150 µm and 10 µm meshes, respectively; staining with Bismarck Brown; and mounting palynomorphs on microscope slides in glycerin jelly [31,32]. Palynomorph slides and residues are housed in the working collections of the Pollen Laboratory at the USGS Florence Bascom Geoscience Center in Reston, Virginia. At least 300 palynomorphs per sample were identified and counted, and results were deposited in the Neotoma Paleoecology Database [33].

2.6. Sedimentological

Organic content was measured by loss-on-ignition (LOI) tests, with 10 g of processed soil (dried < 2 mm) placed into crucibles. The sample was dried in an oven set at 105 °C to remove hygroscopic water. The weight of this sample was recorded. The sample crucible was placed in a muffle furnace set at 360 °C for two hours, removed, and weighed again. This weight was recorded and represents the combusted organic content of the sample.

We used particle size analysis (PSA) methods that included [1] mechanical sieving for sand–silt fractions, [2] measuring the clay fraction by a pipette using Stokes' Law for settling in solution, and [3] use of a PARIO Particle Size Analyzer to calculate the particle size distribution by Stokes' law, with the range of particle sizes spanning from 63 µm to 1 µm. The results of the three methods were used to cross-check particle size analysis results.

2.7. Chronological

For AMS-14C analysis, four samples were chosen, and analysis was completed at the University of Georgia's Center for Applied Isotope Studies in Athens, Georgia. Samples consist of intact wood recovered as hand-cut samples (cf. Figure 3) or from sediment grabs at Barges 6 and 13. The wood provenance is in situ. The raw AMS-14C data were calibrated using CALIB REV8.2 (CALIB rev. 8; [34]), and the age ranges are reported in calibrated years before present (cal kyr BP) with 2σ uncertainty.

3. Results

An intact landform was exposed in both the moat and comet scour at Barge 13. Divers found in situ trees (Figure 3), and median calibrated dates from in situ *Taxodium distichum* (bald cypress) range from 42,115 to 43,834 cal yrBP (Table 1).

Table 1. Accelerator mass spectrometer (AMS)–radiocarbon ages for wood, Reef SAV. Radiocarbon dates were calibrated using the IntCal20 Northern Hemisphere radiocarbon age calibration curve and Calib Rev 8.2 [34].

UGAMS#	Sample ID	Material	δ^{13}C, ‰	^{14}C Age Years, BP	±	pMC	±
64367	Barge 6	wood	−26.16	49,670	420	0.21	0.01
64368	Barge 13	wood	−25.48	40,800	180	0.62	0.01
67126	Barge 13	wood	−24.59	37,560	220	0.93	0.02
70559	Barge 13	wood	−26.72	39,710	200	0.71	0.02

A natural (macro-archeologically sterile) submerged paleosol was observed in the moat profile at Barge 13. The primary pedological feature observed was that of an argillic Bg horizon typical of an Ultisol (Figure 4). The direct dating, by radiocarbon ages of the trees and wood within auger samples, places the paleosol within Marine Isotope Stage (MIS) 3, ca. 57–29 YBP. Particle size distribution, measured by multiple techniques, was that of a sand-rich, argillic soil (Table 2), which was texturally a muddy sand.

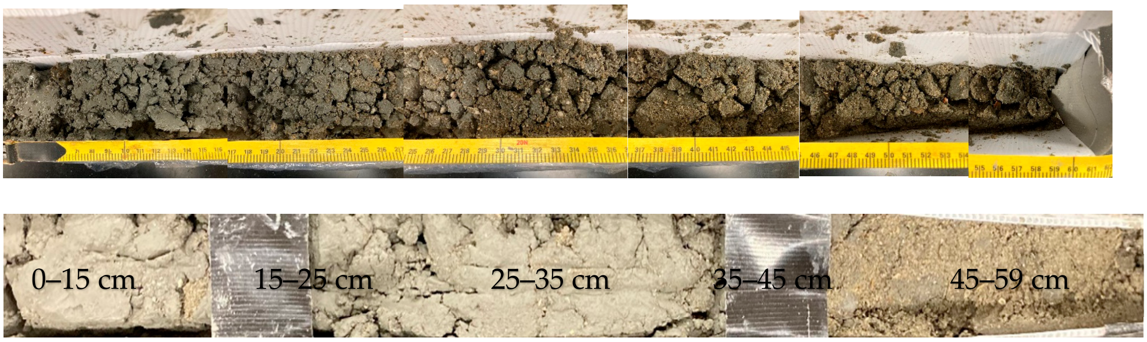

Figure 4. Push core, Barge 13 paleosol. Comparison of upper and lower core sequence, argillic–arenic contact at 28–35 cm. The upper mosaic is of the wet soil; the lower mosaic is soil after drying.

Table 2. Properties of Quaternary paleosol at Barge 13.

Paleosol	Thickness	Munsell Color (Dry)	Loss on Ignition (%)	Sand (%)	Silt (%)	Clay (%)	Clay (XRD)	Fe (%)	Mn (%)	$CaCo_3$ (%)
Barge 13	>1 m	10YR6/1	5	66.9	11.5	21.6	smectite	0–6	0	0–8

The total observed thickness for the paleosol exceeded 1 m in auger samples. Upon recovery, the upper argillic Bg horizon was massive and apedal. Upon partial drying, under refrigeration, a blockier ped structure was observed (Figure 4). The push core was arenic (>66% silty-fine sand) (Table 2), with higher sand concentrations in the lower part of the core. The upper argillic horizon (Bg)—the zone in comparative wetland Ultisols—typically ranges from approximately 10 to 27 cm (26 to 68 inches) as Bg, Btg1, Btg2, and Btg3 horizons (UC Davis Soil Web: https://casoilresource.lawr.ucdavis.edu/gmap/ (accessed on 7 April 2025)) URL accessed 15 May 2025. The depth of the Barge 13 paleosol B horizon was 0.25 m in soil auger samples, taken adjacent to the core (cf. Figure 4), and is similar to depths commonly observed in a sibling Ultisol, the Bayboro series, observed in poorly drained areas on the coastal plain of Georgia (Figure 5) (Soil Survey Geographic Database (SSURGO): https://websoilsurvey.nrcs.usda.gov/ (accessed on 24 Novemebr 2024)).

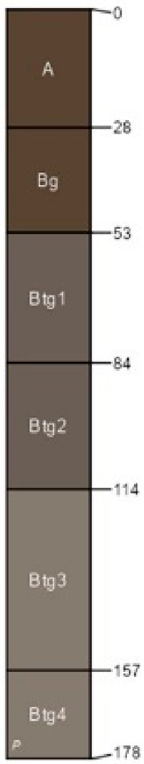

Figure 5. Bayboro series profile. This series is characterized by gleyed B horizons.

XRD analysis identified the clay as principally smectite. The diffractogram for the Barge 13 sample is shown in Figure 6.

Although pollen assemblages are dominated by typical elements of southeastern conifer–hardwood forests (Table 3), the presence of taxa more typical of cool-temperate forests [such as spruce (*Picea*), fir (*Abies*), hemlock (*Tsuga*), and beech (*Fagus*)] is suggestive of a cooler than modern climate. Cypress (*Taxodium*) and tupelo (*Nyssa*) pollen are present in low percentages, as are herbaceous plants commonly found in marshes [including grasses (Poaceae) and sedges (Cyperaceae)].

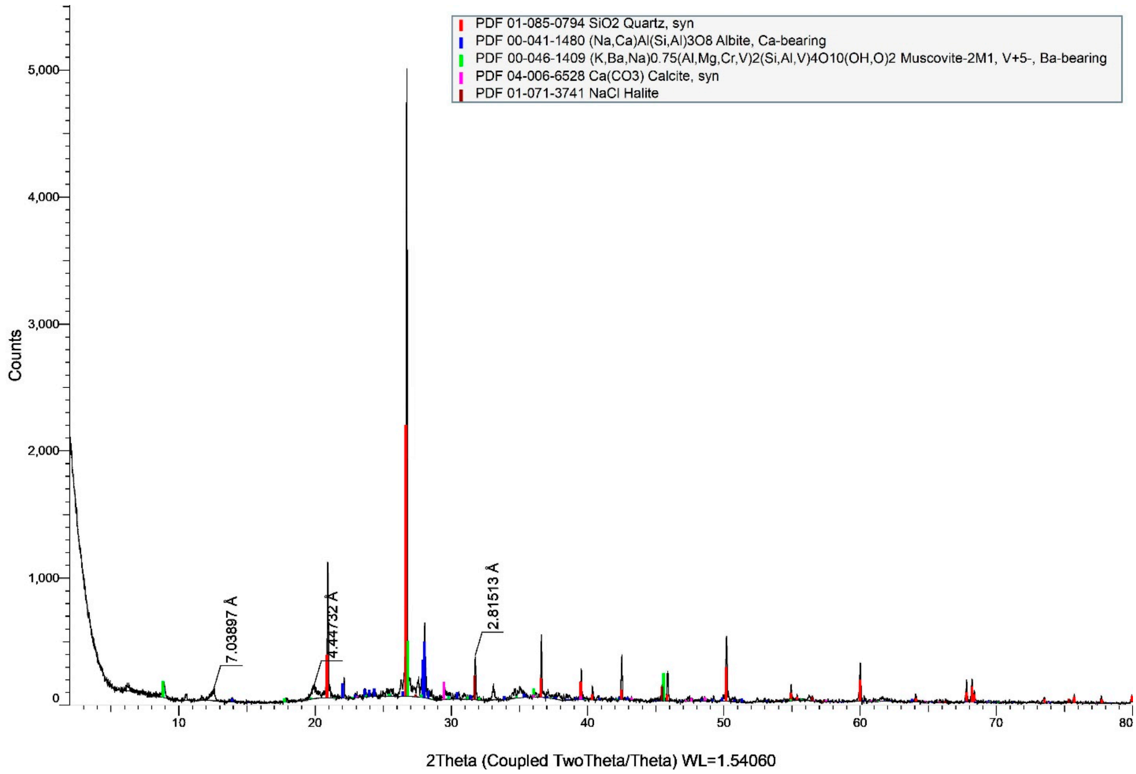

Figure 6. X-ray diffractogram for smectite in the argillic horizon of Barge 13 paleosol. Quartz (red) is the dominant element with albite (blue). The presence of albite in clay is not unusual if feldspar is also found. Intensity is inferred from counts/second versus angular position (2 theta degrees).

Table 3. Percent abundance of major pollen taxa from auger samples, Reef SAV barge.

Modern Vegetation Type	Taxon	Shallow Auger Clay Soil Horizon	Middle Auger Clay Soil Horizon
		Percent Abundance	
Southeastern conifer-hardwood forests	*Pinus* (pine)	63	63
	Quercus (oak)	9	12
	Carya (hickory)	7	7
	Other hardwoods	2	2
Cool-temperate forests	*Picea* (spruce)	3	1
	Abies (fir)	1	0
	Tsuga (hemlock)	1	0
	Fagus (beech)	2	3
Forested wetlands	*Taxodium* (cypress)	1	1
	Nyssa (tupelo, gum)	1	1
Herbaceous plants	Herbaceous angiosperms	3	6
	Lower vascular plants	2	1

4. Discussion

The Barge 13 paleosol is a Paleaquult (Ultisol from wet areas with a high groundwater table). Table 2 lists the quantitative parameters evaluated. Base saturation and pH could not be measured, and Cation Exchange Capacity (CEC) is estimated using soil texture and color. We estimate the CEC of paleosol to be greater than 25 meg/100 g based on its high clay and sand content. The argillic horizon, coupled with preserved trees in situ, removed the ambiguity as to the vegetational paleoecology—forested wetland. Multiple preserved, bald cypress stumps and root systems strongly suggest a wetland with hydric soil formation, in this case, an Ultisol with a deep (~0.25 m) Bg clay-rich horizon (Figure 4). The presence of cypress and tupelo pollen and the dominance of pine pollen is consistent with assemblages from surface samples collected on low ridges and flat environments in forested wetlands along the lower Roanoke River [33]. Although pedogenic clays in many wetland paleosols are formed by in situ authigenic processes, the arenic nature of this paleosol would normally militate against such an origin. However, smectite, whose formation is promoted by seasonal rainfall, is common (≥18%) in authigenic clays, and the smectite content of the Barge 13 paleosol is 21%. Pedogenic smectite typically forms authigenically in poorly drained soils characterized by high pH and CEC [3].

The MIS 3 ages for the Barge 13 are commensurate with those of a 2004 discovery of a drowned cypress forest on the continental shelf off the Alabama coast [35], in which optical stimulated luminescence (OSL) ages for peat and paleosols found there ranged from 72 ka to 56 ± 5 ka. Interestingly, at this Gulf site, a paleosol was found only in the base of cores 16DF8A (~0.1–0.8 m) and 16DF8B (~0.1–0.6 m) [36]. Soil formation at this site was placed at around 44 ka when this site was subaerial and slightly (1–2 m) topographically higher than surrounding landforms [35].

Aside from the Alabama coast site, the only comparable buried peats and cypress stumps have been of the Holocene age, such as those reported from Murrell's Inlet, South Carolina (9.4–10.1 cal yrBP) [36], and the Georgia portion of Atlantic Intracoastal Waterway (AIAA) (7300 ± 40 cal yrBP) [37], which document subaerial exposure during the early Holocene. An even younger exposure was documented from Oregon, where the remnants of a Sitka spruce forest dating to 2000 cal yrBP are preserved on the shoreline [38] (Figure 7). The Reef SAV forest clearly pre-dates the Holocene submergence of the Georgia coastline (Table 1).

Figure 7. Preserved prehistoric Sitka spruce forest (Neskowin Ghost Forest) on the Oregon shoreline [39]. The stumps at Neskowin, Oregon, are 2000 years old, according to carbon dating. Used with permission. Arrow indicates stumps exposed by the surf zone.

The preservation of paleosols normally requires their burial and is a result of the specific taphonomic processes found at respective sites. Hart and Peterson [39] note that in their study of late Holocene submerged forest soils on the Pacific Northwest coast, "The soils deteriorated faster than the stumps. During the first winter season, once stripped of sand, the soil litter (O-horizon) was removed. Removal of the A-horizon followed, but the timing was variable from site to site".

It is likely that the exposure and subsequent submergence of the Barge 13 paleosol and wetland forest followed a similar taphonomic pattern as was observed in Holocene-age records from the Pacific Northwest. All that remains of the Barge 13 soil is the argillic Bg horizon and that of, perhaps, a Bg/C or Bg1 horizon. Wood of both the Pacific Northwest spruce (*Picea*) and southeastern U.S. cypress (*Taxodium*) is capable of surviving submergence. *Taxodium* is a wetland tree that tolerates long hydroperiods (periods of inundation), and its wood is resistant to water rot and insects, as is the wood of Sitka spruce.

At the West Coast, Gulf, and Barge 13 sites, soils were reburied after submergence. In the case of the Gulf site, the soils were located beneath intact peat deposits [40], and a sea-level rise of 10–15 m ca. 40 cal yrBP likely produced widespread floodplain aggradation, burying the swamp and forest sediments [41]. In the Holocene buried spruce forest, thick sand sequences deposited between 7 and 1 cal yrBP buried the forests with at least 3 m of sand, killing the trees and preserving their trunks in situ on the shore platforms [24]. Possible mechanisms for increases in sand supply were identified as [1] latent post-transgressive sand supply from offshore [41] and/or [2] remobilization and longshore transport of beach and dune sand. Once sea-level rise attenuated at 8–7 ka, an asymmetrical wave attack would have delivered the sand to onshore locations.

On the Georgia coast, ebb-tidal deltas are significant sources of sand [42]. Gorsline [43] noted an abrupt change from relatively coarse to fine sediment near the Georgia coast and suggested that it represents the relict-recent sediment boundary. Pilkey and Frankenberg [44] confirmed Gorsline's observations and pointed out that the relict-recent boundary closely corresponds to the 11 m (6 fathom) isobath. Henry and Hoyt [45] estimated the depth of the relict-recent boundary as 15 m, which would be about 15 km from shore. Barge 13 is located 10 km offshore. Ebb-tidal sediments were identified up to 10 km offshore just south of the Barge 13 site [42], and cross-shelf ebb-tidal deposits of Holocene age have been shown to form the palimpsest sediment prism [11,12] that buried the Barge 13 paleosol. Sediment outflow at coastal stream inlets supplies both new sand and recycles palimpsest deposits. The Barge 13 trees and soil were drowned and buried as the sea level overstepped their location during the transition from MIS 2 to the Holocene. The clay-rich nature of these soils likely played a significant role in the preservation of the trees and paleosols, but this resistant facies was ultimately exposed by turbulent flow created around Barge 13.

5. Conclusions

The paleosol formed on a subaerial coastal plain from ~44,000 to 42,000 cal yrBP during the middle of Marine Isotope Stage (MIS) 3 (ca. 57–29 cal yrBP). Based on contemporaneous age data published elsewhere [46], the sea level for the Georgia Bight was already regressing eastward across the continental shelf, where it would reach LGM levels millennia later. The Barge 13 paleosol is a Paleaquult (Ultisol). The argillic horizon, coupled with preserved *Taxodium* trees in situ and the presence of *Taxodium* pollen, indicates that the site was occupied by a forested wetland at this time. The presence of multiple, well-preserved, bald cypress stumps and root systems strongly suggests hydric soil formation in this wetland, in this case, an Ultisol by virtue of a deep (>1 m) clay horizon.

This MIS 3 environment was likely similar to modern wetlands, in which the pedogenic clay forms from in situ authigenic processes, and smectite, whose formation is promoted by seasonal rainfall, is common ($\geq$18%). The clay content of the paleosol is 21.6% smectite. The arenic character of this paleosol, to some extent, works against an interpreted authigenic origin. The argillic content of this paleosol did much to protect it from erosion in an active continental shelf environment.

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