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# Palynology of an Extinct Barrier Island Wetland, Isle of Hope, GA

Matthew Toro

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by

MATTHEW TORO

Under the Direction of Lawrence Kiage, PhD and Brian Meyer, PhD

ABSTRACT

Wormsloe Historic Site is located on the Isle of Hope about 16.1 km south of Savannah, GA. Understanding palynological history is critical to assessing geological and biological changes that have occurred in the region. A randomly selected sediment core was taken from the center a smaller shallow depression believed to be a former flowing freshwater wetland. The core was analyzed to identify changes in paleohydrogeology and paleobiology of the area to determine if a freshwater wetland existed at the site that might have supplied potable water to Native Americans and Colonial Settlers. Pollen assemblages documented in the Wormsloe sediment core contained *Pinus, Carya, Quercus, Poaceae*, *and* Cupressaceae, and many trace counts of freshwater taxa, which may suggest the presence of a former freshwater wetland existing near the site. Palynological results are consistent with other studies indicating that southeastern floral elements are stable throughout the Holocene in coastal Georgia.

INDEX WORDS: Palynology, Paleohydrogeology, Wormsloe Historic Site, Depositional environment, Paleoclimate

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# DEDICATION

I dedicate this work to my friends, family, and professors. Without your unconditional love and support this project would not have become a reality.

# ACKNOWLEDGEMENTS

I would like to acknowledge my committee co-chairs Dr. Brian Meyer and Dr. Lawrence Kiage for their tireless efforts and advice throughout my time spent at Georgia State University and during this project. Additionally, I want to thank Dr. Luke Pangle for his attention to detail and encouragement throughout this project. Finally, thank you to the Geosciences Department and all the faculty and staff that have supported me in my academic career.

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# 1 INTRODUCTION

The Wormsloe State Historic Site is located on the Isle of Hope (IoH), approximately 10 miles south of Savannah, Georgia (Figure 1). The property is bordered by Jones Marsh and Jones Creek to the east and the Moon River and associated marsh system to the west. This area represents one of the most significant historical, cultural, and natural sites in the Southeastern United States (Pasqua et al., 2017), noted for its natural surroundings of waterways, forests, and marsh lands (Swanson, 2011). The Wormsloe Historic Site was first occupied by European settlers in 1736 following the colonization of North America by the British. The study site is situated on the southern portion of the IoH covering approximately 3.85 mi by 0.31 to 1.06 mi (Vance, et al., 2016).


*Figure 1. Satellite overview of the Isle of Hope detailing the geographic location of the sediment cores on the island. The inset map presents a satellite image of the Eastern United States.*

### 1.1 Physical and Hydrological Setting of the Study Area

The island core is a relatively high topographic feature with little relief, and the framework sediments of the island are associated with the late Pleistocene Princess Anne paleoshoreline (Hoyt and Hails, 1967; Hoyt and Hails, 1969). Based on previous studies by Rich et al. (2011), Booth et al. (1999), Vance et al. (2016), and Reichard et al. (2014), the island core is mostly composed of Late Pleistocene barrier island deposits that are typically light brown, fine to medium grained sands that have been extensively bioturbated by modern vegetation. Beginning in the 19th century, artesian wells located on the island had hydraulic heads well above land surface (Stringfield et al., 1941; Krause and Clarke, 2001), however, the current Upper Floridan Aquifer potentiometric surface is located approximately 40 feet below land surface.

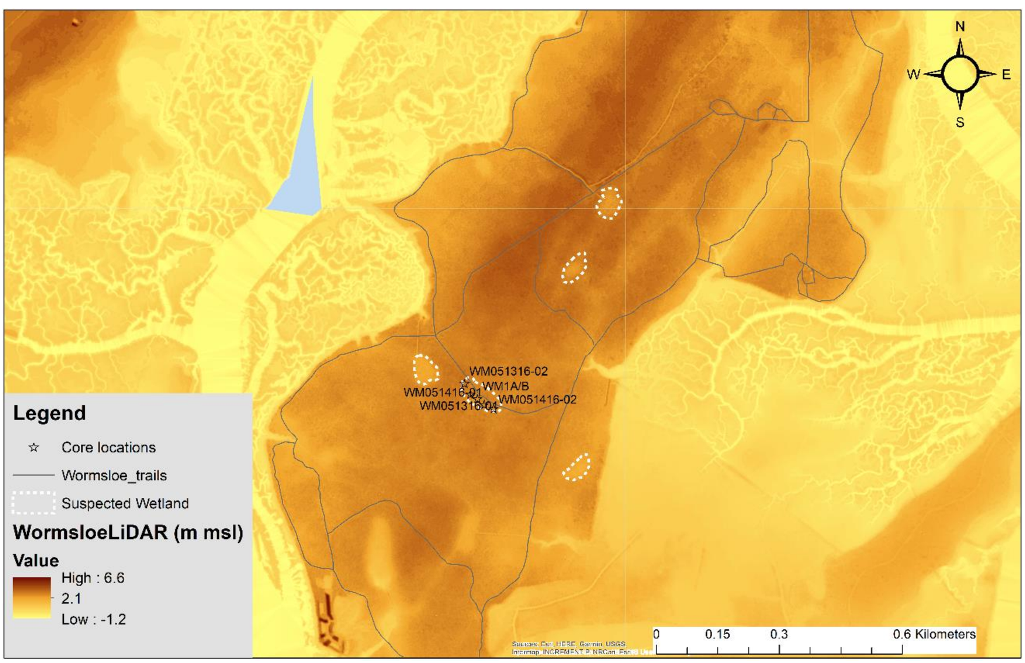


*Figure 2. A map of the general topography of the study area. Elevations are given in mean meters above sea level (m msl). Suspected former wetlands are shown by dashed white boundary lines. Coring locations are represented by a hollow star.*

Present day marsh communities occupy the intertidal portions of the eastern, western, and southern margins of the island. The low marsh zone exists between neap high tide and mean high tide at approximately 0.6 meters to 1.1 meters above the mean low tide line. The high marsh lies between the mean tide and the spring high tide elevations and typically occur from 1.1 meters to 2.0 meters above the mean low tide interval. The modern environment is a grass dominated vegetation associated with the marshes and include *Spartina alterniflora* (smooth or saltmarsh cordgrass), and salt tolerant plants or halophytes such as *Salicornia* (glasswort), *Distichlis* (salt grass), *Juncus* (needlerush), and *Spartina patens* (short marsh grass) (Figure 3). The maritime forest environment contains arboreous species of plants that include *Pinus* (pine), *Quercus* (oak), and members of the *Cupressaceae* (cypress) family.

*Figure 3. Photographs of the modern environment on the Wormsloe Historic Site. Top Left: Depression where cores were collected; Top Right: Depression where cores were collected; Bottom Left: Trail leading to the shallow depression; Bottom Right: Drainage ditch leading to shallow depression. Photos taken by Dr. Meyer in Spring, 2016.*

Previous work (e.g., Booth et al., 1999; Booth and Rich, 1999; Booth et al., 2003; and Rich 1995a) suggest that modern vegetation of the Isle of Hope has seen dynamic changes over the last 10,000 years, especially recently during the colonial period where it operated as a multifunctional farm, producing silk and likely indigo (Swanson, 2011). Studies of Georgia's barrier islands date back to more than 40 years and have histories that are well known (Rich et al., 2014). The geology, physiology, and palynology of local barrier islands of St Catherines, Ossabaw, and Skidaway have been the subject of research, fieldwork, and publication for many years (Rich, 1995a, Rich, 1995b, Booth et al., 1999, Booth and Rich, 1999, Linsley et al., 2008, and Rich et al., 2018). However, palynological studies on the Isle of Hope are completely lacking. Palynology increases the potential of providing detailed records of paleoenvironments. Studying the palynology of cores taken from the Wormsloe Historic Site yields geological and biological snapshots of Holocene Georgia coastlines. Through these snapshots, it is possible to reconstruct the paleohydrologic and paleobiologic history along the Georgia coast.

## 1.2 Research Objectives

Although a rich environmental history of the Wormsloe State Historic Site on the Isle of Hope, Georgia has been previously documented and described, the typical shallow depressions noted in Figure 2 require additional investigation to provide greater detail in the paleohydrological history of the area by using the palynology. This study attempts to evaluate landscape change and alterations in hydrologic conditions using palynology. Specifically, the study aims to answer the following questions:

1) Are the circular to elliptical shallow depressions located in Wormsloe the locations of former freshwater wetlands that would have provided potable water to Native Americans and European colonists?

2) What vegetation can be observed through the analysis of pollen contained in the sediments within the suspected former freshwater wetlands?

# 2 LITERATURE REVIEW

## 2.1 Depositional History

### *2.1.1 Barrier Island Formation*

Georgia's coast is comprised of a string of twelve barrier islands that run parallel to the mainland. These islands are part of the Georgia Bight, and trend from southwest to northeast. Current features of the Georgia coast include barrier islands, marsh islands (called hammocks), tidal marshes, estuaries, river channels, tidal creeks, as well as tidally influenced areas of the mainland and formation of these features began in the Late Pleistocene during an interglacial period (Turck and Alexander, 2013). Sea-level rise and fall has left various new geomorphologies in the coastal geologic record; these features include: coastal notches, marine terraces, and beach rocks (Ricchi et al., 2018). Ricchi further noted that among these features, marine terraces are best known as excellent tracers of paleo sea-level which have been used to study transgression/regression in coastlines (Ricchi et al. 2018).

Barrier islands off the coast of Georgia are topographically and geologically complex formations. There are three proposed explanations on the formation of barrier islands: (1) accumulation of sediments on offshore bars, (2) cutting of inlets through spits, and (3) submergence of ridge-like coastal features (Schwartz, 1971). Some of the earliest descriptions of barrier islands come from Price (1951) and Shepard (1952) who note that barrier islands are formed from offshore bars (Figure 3). However, this terminology (bars) is amended in a paper by Hoyt (1967), where bars are said to be water-covered at high tide, unlike islands which remain above sea level (Figure 3). Hoyt continued to note that barrier islands are constructional features formed of detrital sediments composed mainly of sand and gravel. The barrier islands of Georgia are no exception to this description. Georgia's barrier islands are composed of fine to medium-grained quartz sand with dunes approximately 10 meters high that formed adjacent to the beach (Hoyt, 1967). The sediments found on similar Georgia barrier islands of St Catherines and Skidaway are overlain by tidal-flat-deposited sediments, which are overlain by a thin peat layer derived from an interdunal swale community dominated by *Myrica* (Bayberry) (Booth, 1999). The geomorphology and hydrology of the barrier islands have resulted in a dynamic of salt, brackish, and freshwater marshes, and sandy, well-drained upland soils dominated by southern pine and oak forests (Rich et al., 2011).

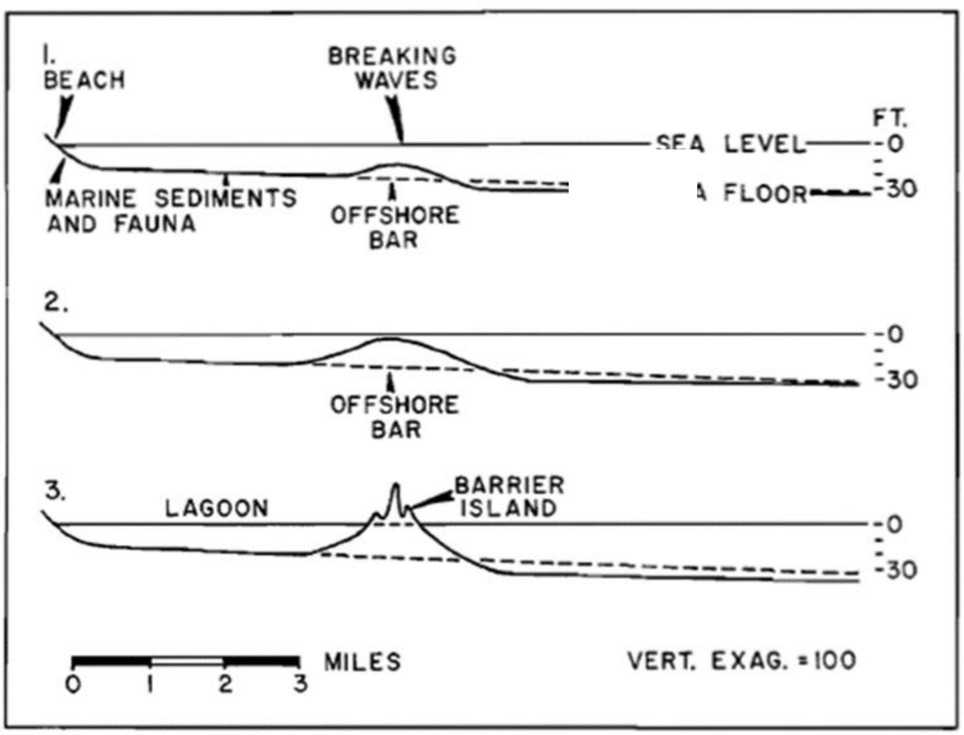


*Figure 4. An idealized cross section of barrier island formation compared to an offshore bar. [1] Wave energy deposits sediments to form a bar. [2] Sediments accumulate to near sea level. [3] The bar is converted to a barrier island with a lagoon (Hoyt, 1967).*

### *2.1.2 Sedimentology of Barrier Islands*

It is well documented and understood that barrier islands off the coast of Georgia formed during the Late Pleistocene approximately 0.129 million years ago (MYA) (Rich, 1995a, Booth et al., 1999, Booth and Rich, 1999, Booth et al., 2003, Linsley et al., 2008, LaMoreaux et al., 2009, Rich et al., 2018, Hargett, 2011). Since their initial formation, these barrier islands have been continually modified by erosional and depositional processes (Rich et al., 2011). Each island is comprised of a Pleistocene core blanketed by a thin layer of Holocene sediments. Due to the juxtaposition of these sediments, it has created a very complex depositional stratigraphic sequence (Linsley et al., 2008).

Deposition of the Quaternary sediments along the Georgia coast lie in topographically distinct bands known as accretionary terrains, or marine terraces, that run parallel to the modern shoreline (Booth and Rich, 1999). The accumulation of these sediments occurred during the Late Pleistocene as global temperatures rose and barrier island systems migrated due to eustatic sea level fluctuations (Russel et al., 2009). Changes in global climate, topography, and sedimentation are reflected in the pollen assemblages of the study area (Booth et al. 1999).

Recent studies have indicated that vibracoring provides deeper, more well-preserved extractions of sediments than other coring methods. Stratigraphic layering, sedimentary structures, fossils, and lithology are well represented in their natural context (Bishop et al., 2011). Vibracoring techniques have been used on various barrier islands along the Georgia coast; however, back-barrier islands such as the Isle of Hope have not been explored in these analyses. The vibracoring method is best suited for the suspected extinct wetlands of the Isle of Hope. Analysis of cores taken via vibracoring from the Wormsloe Historic Site yield higher-resolution sedimentological data. These data have provided greater stratigraphic context in studying the transitionary period of the Isle of Hope.

## 2.2 Palynology

The Late Pleistocene through the early Holocene vegetational changes have been studied on the coastal plain in both Florida and South Carolina, however few locations in the coastal plain of Georgia have been investigated (Booth et al., 1999). Rich et al., (2018) noted that no single focused effort had been made in palynological studies along the Georgia coast. Many studies have shown that palynological analyses provide detailed snapshots of paleoecology and depositional environments within barrier island systems (Booth et al., 2003). Many of Georgia's barrier islands are believed to have similar biological and geological histories (i.e., St. Catherines Island, Skidaway Island, and Sapelo Island) (Rich et al., 2018). Most importantly, the Georgia coast provides excellent reference points for cross-comparison with other coastal areas. This approach has been used to study many of the surrounding barrier islands along the Georgia coast. It is possible to reconstruct paleoenvironments and barrier-beach dynamics through pollen-analytical techniques by isolating organic and fine-grained strata that occur between thick layers of sand in sediment cores (Clark et al., 1986).

Freshwater wetlands have unique palynostratigraphy due to the formational processes of the wetland. Rich (1995a) published core analyses of a wetland from a Georgia barrier island and found abrupt changes in the sediment lithology and palynology that were directly reflected in the pollen assemblages. Further research was conducted by Rich and Booth (1999) where peat petrography was used to conduct palynological analyses of cores taken from a freshwater wetland. This method holds palynological significance as peat contains relatively high abundances of well-preserved pollen grains (Booth et al., 2003). After comparing the pollen assemblages, it was found that pollen grains with low percentages held greater importance than the large relative abundance of pine, oak, and hickory pollen.

Palynology of the Holocene epoch is vastly different from palynology of older sediments (Traverse, 1988). Traverse (1988) further noted that Holocene palynology can ignore the extinct palynomorphs and exotic species based on known present plant associations rather than precise palaeoclimatological deductions. Paleoecological studies in palynology typically rely on stratigraphic sequences of pollen and microfossil assemblages. In most regions, fossil pollen shows large localized changes indicating that major changes in plant communities occurred (Davis, 1969). These changes may be compared with evaluations of sedimentology and biogenic structures (Booth et al., 1999). Palynological analyses can provide insight into local geological, hydrological, and vegetational changes of a given region.

Employing techniques in palynology allows for accurate characterization of paleoclimatic and ecological changes as well as changes in paleohydrology. In Holocene palynology, detailed studies of pollen rain from the potential source plant communities and their ecological requirements make it possible to analyze specific periods within a given study area (Traverse, 1988). Rich (1995a) noted pollen assemblages are useful indicators of a distinct kind of depositional environment, and that these [pollen] assemblages are useful indicators of a distinct depositional setting (Rich, 1995b). This research is of great importance as palynological analyses of the Wormsloe Historic Site have not been performed to the magnitude of other Georgia barrier islands (i.e. Skidaway and St. Catherines Island).

## 2.3 Paleohydrogeology

Paleohydrological events can be directly correlated to changes in local plant communities. In studies by Rich (1995a) and later, Booth et al. (2003), changes in sea-level along with changes in the local plant communities were found during palynological analyses of Georgia barrier islands. It has been proven that paleoecological studies in correlation with palynological analyses have provided insight into the relative importance and rates of autogenic (succession) and allogenic (climate, hydrology, disturbance) processes controlling wetland development in the southeastern United States (Booth et al., 1999). A focus in palynological efforts as they relate to wetlands succession have come from studying relationships between plant distributions (Rich 1995a,b, Booth et al., 1999, Booth and Rich, 1999, Booth et al., 2003, Linsley et al., 2008, and Rich, 2015). Changes in the physical environment appear to play important roles in determining successional trajectories of coastal wetland environments (Booth et al., 1999). Booth et al., (1999) published findings where the modern freshwater pond plant community became established as the salinity of the environment decreased; this was indicated by the increased abundance in freshwater plant taxa found in core samples.

Barrier island evolutionary events occurred due to changing climatic conditions. Sea-level change has left various new morphologies in the geologic record; these features include: coastal notches, marine terraces, and beach rocks (Ricchi et al., 2018). Among these features, marine terraces are best known as excellent tracers of paleo sea-level which have been used to study transgression/regression in coastlines.

During the Pleistocene, the eastern seaboard experienced cooler temperatures and lower eustatic sea fluctuations due to the various glacial and interglacial periods (Traverse, 1988). The Holocene, however, was much warmer. Global temperatures rose, melting glacial icecaps, and increasing the mean sea-level. These changes have been documented in hydrological and palynological analyses along the east coast throughout various investigations (Rich, 1995a, Rich, 1995b, Booth et al., 1999, Booth and Rich, 1999, Linsley et al., 2008, and Rich et al., 2018).

## 2.4 Colonization

Understanding the geomorphology of a landscape allows for a better interpretation of the archaeological record of an area (Turck, 2013). Turck (2013) further notes that ideally geomorphology should remain separate from the archaeology of an area. Barrier island palynology will vary greatly due to colonization of different native peoples, and settlers. Plant communities are known to shift due to cultivation of commercial grains and the pollen assemblages for the durations of cultivation are noted in the palynology of the sediments.

Native Americans first occupied the Isle of Hope some 4200 years ago (Turck, 2013). Turck continued to explain that coastal landforms were rapidly utilized by humans soon after the formation of the landforms. It was first documented that colonization at the Wormsloe Historic Site was in 1736 after European settlers laid claim to the land. Artesian conditions existed on the island as noted in Stringfield et al. (1941) where the piezometric surface broke the land surface creating free-flowing artesian springs on the island. The European settlers began using this freshwater for consumption and irrigational needs to support livestock and agriculture activities on the Isle of Hope. Pasqua et al. (2017) provided contextual phytolith evidence of historical rice cultivation on the Isle of Hope. Pasqua et al. (2017) noted tenants held claim to plots of land, where the shaped and changed the vegetational dynamic of the island. Moreover, palynological analyses of the Isle of Hope provided concrete evidence for rice cultivation on the island (Pasqua et al., 2017).

# 3 MATERIALS & METHODS

## 3.1 Fieldwork and Core Sampling

Five 2.5 cm diameter cores were sampled from a wetland on the southeastern portion of the Isle of Hope, approximately two miles southwest of the Wormsloe Historic Site. Core sampling was done by Dr. Brian Meyer of Georgia State University during the spring of 2016. The cores were collected using direct push technology (DPT). The cores were taken at equal intervals from a shallow depression similar to those presented in Figure 2. Cores 1 and 5 were taken on the outer boundary of the wetland based on LiDAR topography while cores 2-4 were taken within the center of the wetland. Total depth of cores ranged from 0.6-1.2 m. A Field portable GPS device was used to obtain and record the precise latitude and longitude data for each core. Core WM1A was chosen at random for palynological analysis based on observational characteristics noted in the core such as color of the sediment, inclusion of organic materials (i.e. pieces of wood or root fragments), and noted mottling and bioturbation in the lower portion of the core. Later, one larger 7.5 cm diameter core, WM1B, was collected at the site location of WM1A, for detailed analysis of the lithology. The core barrel was cut in half using a circular saw to expose the sediments and the sample was cut in half using a coping saw to minimize disturbance to the sample. Sediment color via Munsell wet color chart, type, grain size and sorting by means of the Wentworth Scale (Wentworth, 1922), layering, sedimentary structures, and fossils (if present) were described in each core. Core logs were produced for each described core.

### 3.2 Loss-on-Ignition

Water, organic matter, and carbonate minerals content were estimated by sequentially measuring weight loss in sediment from core subsamples after heating at selected temperatures (Dean, 1974). The subsamples were placed in weighed crucibles and weighed. Weight loss is measured after heating the samples overnight at 100ºC to remove water, at 550ºC for one hour to remove organic matter, and at 1000ºC for one hour to remove carbonates. After each heating step, the firebrick holding crucibles is allowed to cool completely in the oven or furnace before weighing or placed in a desiccator if crucibles cannot be weighed immediately.

### 3.3 Chemical Preparation

A 10% potassium hydroxide (KOH) solution was prepared by stirring together 200g potassium hydroxide pellets in 1.8L of deionized water until all pellets were dissolved. A 10% HCl solution was prepared by adding 100mL of 38% concentrated HCl to 900mL of deionized water. The acetolysis solution was prepared by carefully pouring 90mL of acetic anhydride into a dry 100mL graduated cylinder. Ten milliliters of concentrated sulfuric acid was added to the graduated cylinder until the meniscus touched the 100mL line. A vigorous reaction occurred due to the exothermic nature from the two reagents. The color of the completed solution was pale yellow.

### 3.4 Pollen Processing and Analysis

A total of 12 sediment samples were taken; 9 of which were sampled at 10 cm intervals, while 3 were sampled at random points (~3 cm, ~21 cm, and ~69 cm) of interest throughout the core. These samples were prepared for pollen analysis following the standard laboratory procedure described by Faegri and Iverson (1989). The procedure involves subjecting the samples to a hydrochloric acid treatment to remove the carbonates, a hydrofluoric acid treatment to remove silicates, potassium hydroxide to remove humic acids, and acetolysis then staining to aid in microscopic identification. Before processing, the samples were spiked with one tablet of *Lycopodium calavatum* spores from batch number 1031 to aid in counting and show pollen concentration (e.g., Kiage and Liu, 2009). Each *Lycopodium calavatum* tablet contained 20,848 spores. Microscope slides were prepared out of the processed samples and pollen counts were performed to assess relative abundances of taxa following Faegri and Iverson (1989). Pollen was counted under an Olympus BX43 light microscope at 400X-600X magnification, and identified to the genus level. Each sample was counted until 300 pollen grains or 1000 Lycopodium spores (whichever came first) had been identified. Pollen counts were plotted using Tilia.it software for palynological analysis.

# 4 RESULTS/ DISCUSSION

## 4.1 Sedimentology, Stratigraphy, and LOI

Core WM1B is 112 cm long and is composed of strata of sand, silt, and peat with interstratified plant materials towards the top of the core. To facilitate discussion, the core is divided into five zones (Zone 1-5) that were partitioned by lithological observations of by sedimentary contacts between layers. Figure 5 shows the detailed stratigraphy of the WM1B core. Additionally, the LOI data is presented in the pollen diagrams (Figures 6-8).

Zone 1 (112-85- cm) is composed of muddy sand, light to dark brown Munsell sediment color 10YR 3/2, fine to very fine sand, with extensive bioturbation near the bottom of the core, mottled from 112-102-cm. This zone observed an initial high water content around 10% at the 90 cm depth and sequentially lowered towards the upper boundary of the core at 70 cm. Organic and carbonate content observed low values under 3%. Core refusal occurred at 112 cm below land surface.

Zone 2 (85-56 cm) is composed of muddy sand, light to dark brown Munsell sediment color 10YR 3/3, fine to very fine sand, with extensive bioturbation, sand filled burrows measuring 1-3 cm diameter, mottled, and observed a progressive gradational contact with Zone 1. Zone 2 contains abundant plant material within the muddy sand. The progressive gradational contact suggests a low-energy environment at the time of sediment deposition. Zone 2 had an initial low water content that progressively increased towards the upper boundary of the zone. Organic and carbonate content recorded similar values to that of Zone 1 at under 3%.

Zone 3 (56-46 cm) is composed of a muddy organic sand, dark brown-gray Munsell sediment color 2.5Y 4/2, fine to very fine sand, abundant plant material. Zone 3 observed a progressive gradational contact with Zone 2.

Zone 4 (46-37 cm) is composed of sand, light brown-gray Munsell sediment color 2.5Y 6/2, fine to very fine sand. There is a muddy rip-up clast, Figure 6, found just above the lower contact with Zone 3. Zone 4 is believed to be a storm overwash deposit evidenced by the rip-up clast, and the abrupt lower contact between Zones 3 and 4. The LOI data reflects the deposition of the anomalous sediment and is evidenced by the sharp reduction in water content shown in Figure 9. Rip-up clasts are common features associated with high-energy environments at the time of deposition and have been described in other local marsh environments by Shchepetkina and Pemberton (2016).

The overwash deposit described in Figure 6 is believed to have been caused by a high energy storm event some time between the mid-1800s to the mid-1900s that deposited several centimeters of sediment over the study area. The rip-up clast supporting this assumption was found at 42 cm below land surface (BLS). In papers by Alexander and Brandes (2017) and Meyer et. al (2016), it was noted that marsh sedimentation rates are equivalent to marine sedimentation rates at ~3 mm/year. Considering that the observational depth of the rip-up clast was 42 cm BLS and annual deposition occurred at ~3 mm/year, a relative age of the washover layer is calculated to 153.3 years before the collection date in 2016. NOAA Historical Hurricane Tracks (HURDAT2) data was used to identify major storm events that made landfall near the study area. Unnamed hurricanes 1854, 1881, 1893, 1896 (Figure 5) were selected on storm intensity (hurricane category >2), total precipitation, and proximity to the Isle of Hope. Tropical Storms from 1853 and 1860 were also selected as they made direct contact over the study area and produced heavy rains.

Zone 5 (37-0 cm), the uppermost portion of the core, is composed of organic rich sand, dark brown-gray Munsell sediment color 2.5Y 4/2, fine to very fine sand, with abundant plant and root fragments. This zone also contains a portion of the topsoil. Zone 5 is the most recent depositional event and represents the modern marsh environment. LOI data shown in Figures 7 and 8 detail an increase in organic and water content to 15.75% and 12.2 respectively. Those values correspond to the changing sedimentology of light gray sand to dark-brown organic rich sand between Zone 4 and Zone 5. The contact between Zones 4 and 5 is unconformable and evidenced by substantial deposition of light gray sand interrupting the deposition of the dark brown-gray organic rich sand.

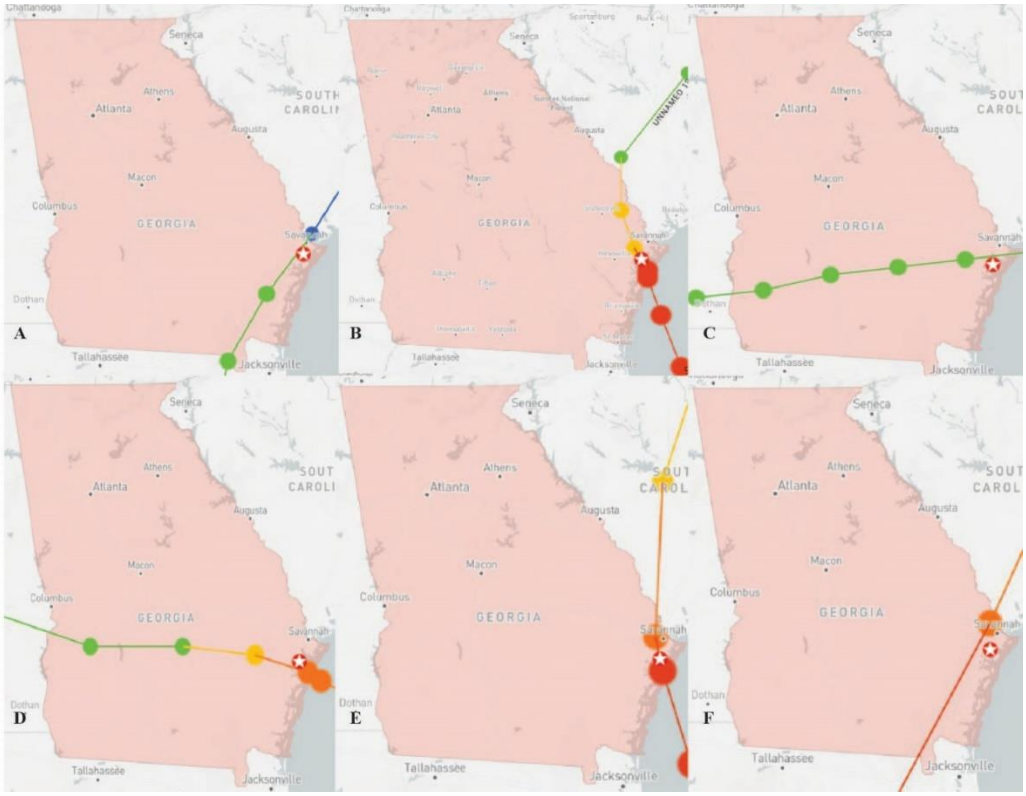


*Figure 5. Hurricane tracks adapted from NOAA HURDAT2. The colors used in* ***A*** *suggest that Tropical Storm 1853 was approaching tropical depression strength as it passed over the core site. Colors used in* ***B*** *suggest Unnamed Hurricane 1854 transitioned from Category 3 to Category as it passed over the core site. The green color used in* ***C*** *represents Unnamed Tropical Storm 1860 that passed over the study area. The colors presented in* ***D*** *suggest a Category 2 hurricane that passed over the study area in 1881. The colors used in* ***E*** *suggest that Unnamed Hurricane 1893 transitioned from category 3 to category 2 strength as is passed over the core site. The colors used in* ***F*** *represent Unnamed Hurricane 1896 that remained a category 3 hurricane as it passed over the core site.*

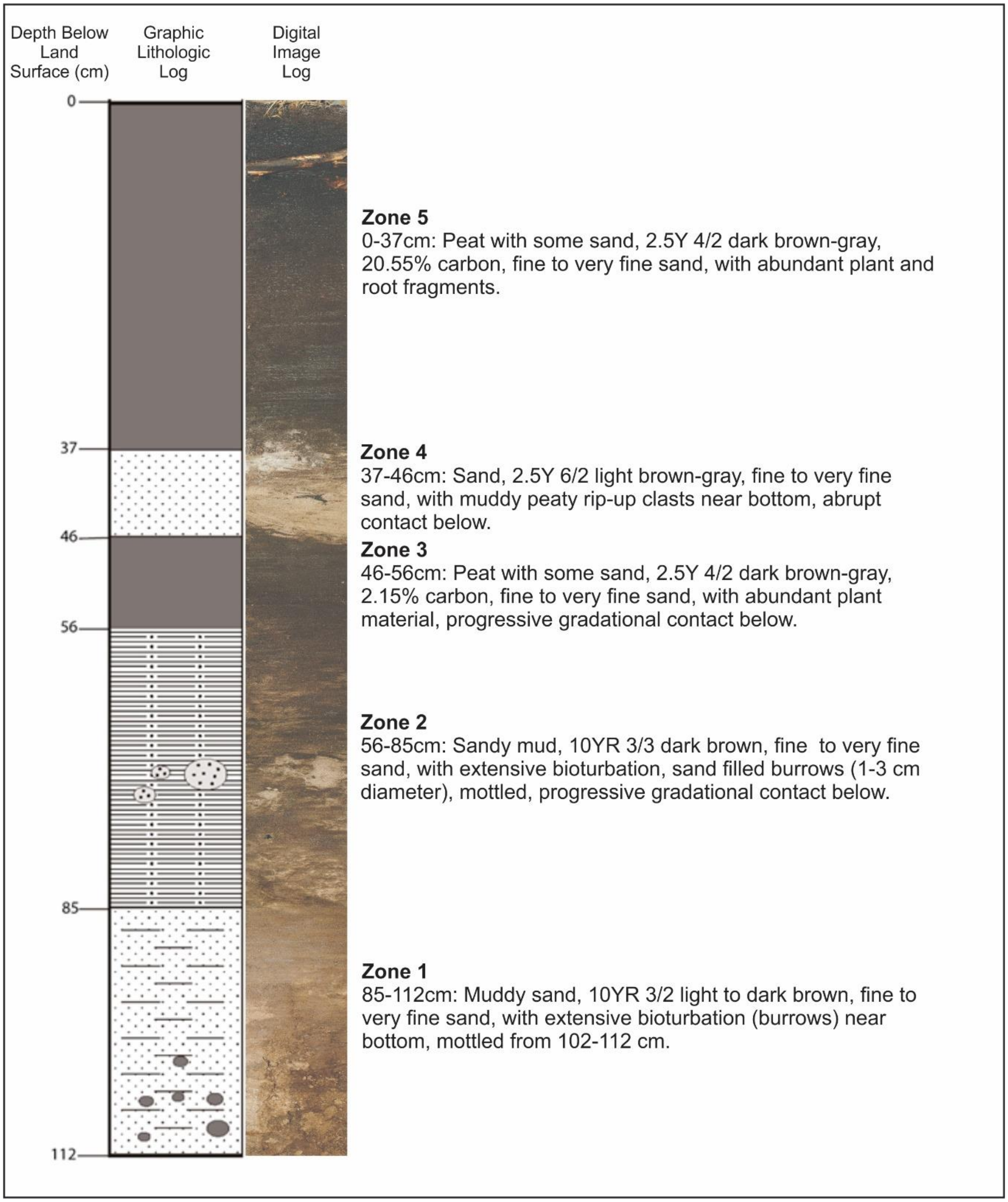


*Figure 6. Stratigraphy of WM1B core*

## 4.2 Palynological Analysis

Figures 7-9 present the results of pollen analysis of core WM1A, CONISS cluster analysis of the pollen data (Grimm, 1987) divided the core into four zones (1-4). The WM1A core contained enough pollen (>300 grains per level) for analysis. Each sample had many taxa found in trace amounts; however, they reflect the study area's overall diversity. A total of 15 taxa were identified in the WM1A. The pollen types were identified to the genus level, with a few exceptions where identification was at the family level. All depths that were sampled for pollen had good preservation, except for two consecutive levels in Zone 2, which had pollen counts below 300 grains. The lithology constraining the two levels in Zone 2 was gray-brown muddy sand.

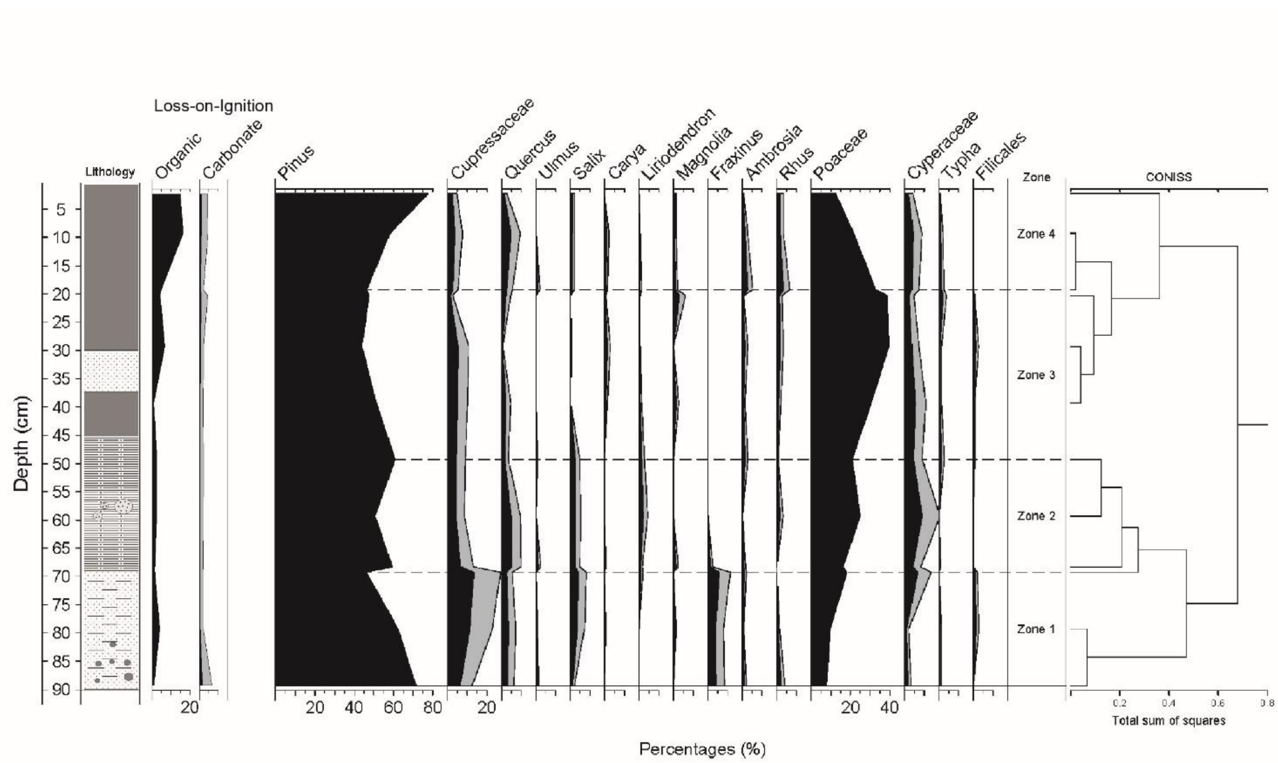


*Figure 7. Relative abundance of major taxa in WM1A. A factor 2 exaggeration was performed on some taxa to enhance curvature of the graphs.*

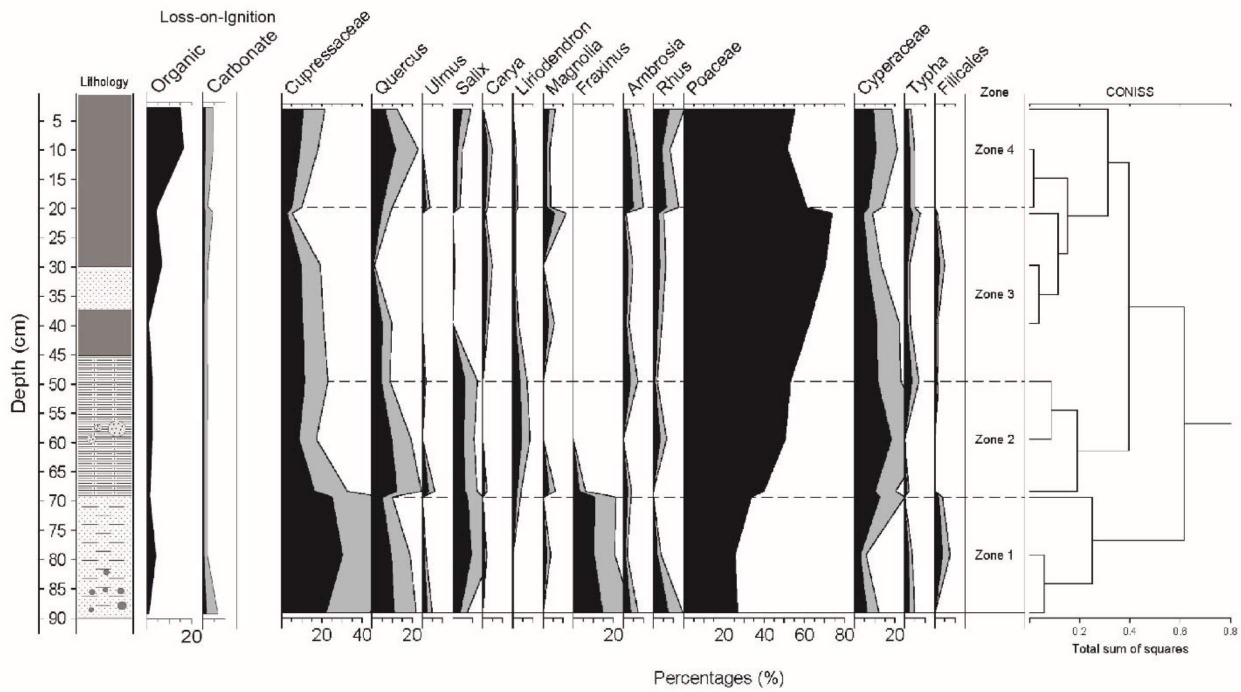


*Figure 8. Relative abundance of taxa in the WM1A core, Pinus removed. A factor 2 exaggeration was performed on some taxa to enhance curvature of the graphs.*

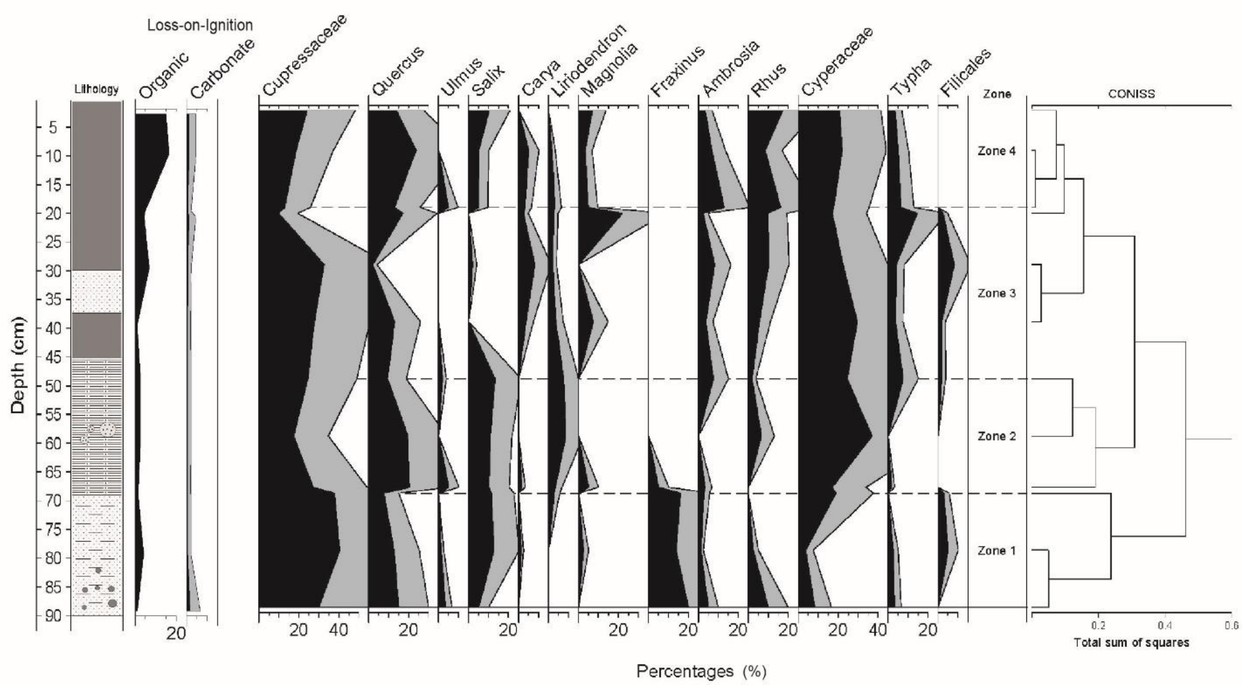


*Figure 9. Relative abundance of taxa in the WM1A core, Pinus and Poaceae removed. A factor 2 exaggeration was performed on some taxa to enhance curvature of the graphs.*

**WM1A**

### *4.2.1 Zone 1: 90-70 cm*

This zone contains the basal sediments of the WM1A core and covers the sediments between 90 and 70 centimeters below land surface. Pollen within Zone 1 were relatively low, which necessitated more counting. *Pinus*, *Poaceae*, and Cupressaceae are the dominant species within this zone at 55%, 11%, and 10% respectively. *Fraxinus*, *Salix, and Carya* were observed in the core which reflected similar findings by Rich, 1995a, Booth et al., 1999, and Rich and Booth, 2011, where the presence of these grains were found in less than 2% on St Catherines Island, Georgia. Additionally, trace amounts of the freshwater species *Typha* were identified in this zone. The lower to middle portion (80-70 cm) of this zone remained relatively stable from a palynological standpoint, where diversity was low and there were no sharp changes to the population size of each species. Towards the top of this zone near the boundary with Zone 2, Cupressaceae, *Cyperaceae, Poaceae*, and *Quercus* began to increase in count, while *Fraxinus* decreased.

### *4.2.2 Zone 2: 70-50 cm*

*Quercus*, *Cyperaceae*, and *Poaceae* rose in count. *Liriodendron* increased in count in the middle section of the zone. Arboreal species such as *Pinus* and Cupressaceae decreased in the middle portion of this zone (Figure 7). Further palynological analysis of two levels in this zone (at 60 and ~69 cm) contained presences of *Ulmus*, *Salix*, *Carya*, and *Fraxinus*. Additionally, Zone 2 is believed to have accumulated near a freshwater wetland evidenced by the presence *Typha*, *Potamogeton*, and *Cyperaceae*. This is further noted in the stratigraphy, where the lower boundary of this zone is extensively bioturbated and burrows are present, similar to previous work by Bishop and Brannen (1993).

#### *4.2.3 Zone 3: 50-20 cm*

This zone remained palynologically similar to Zones 1 and 2 where *Pinus*, *Poaceae*, and Cupressaceae were the dominant taxa observed, however, arboreal types decreased as a whole. Herbaceous species *Poaceae, Rhus* and *Ambrosia* increased. Towards the middle of this zone, a washover deposit (Figure 6) was observed in the stratigraphy and is represented within the palynology of this zone having an overall lowered trend in observed grain count. It is possible that potential transport of unidentifiable and non-native species to the study area occurred due to heavy rains during the storm or post-storm flooding. Figure 8 details the reduction of pollen grains in the middle portion of this zone. It should be noted that preservation of pollen and spores in this zone was poor and most of the grains observed were corroded, making them difficult to identify. *Cyperaceae* increased in count within this zone, and *Typha* remained constant which suggested the possible presence of standing or low flowing freshwater nearby at the time of deposition.

#### *4.2.4 Zone 4: 20-0 cm*

The sediments in this zone yielded high numbers of identifiable pollen and spores, and are representative of the modern environment on the Isle of Hope. This zone observed a strong terrestrial footprint evidenced by high percentages of *Pinus*, Cupressaceae, and *Quercus* grains. *Poaceae* decreased slightly in the transition from Zone 3 to Zone 4, while *Ambrosia*, *Cyperaceae*, *Typha*, *Rhus*, and *Magnolia* rose in count.


*Figure 10. Plate 1: Representative photomicrographs of some taxa encountered in the WM1A sediment core. Magnification x1000. Taken in transmitted light.*

Plate 1:

1. *Ambrosia*
2. *Carya*
3. *Liriodendron*
4. *Liquidambar*
5. *Typha*
6. *Poaceae*
7. *Lycopodium calavatum*
8. *Magnolia*
9. *Pinus*
10. *Potamogeton*
11. *Rhus*
12. *Cupressaceae*
13. *Quercus*

### 4.3 Paleohydrogeology

It has been well documented that environmental, and specifically, biological changes along the Georgia coast has been a byproduct of freshwater pumping from the Upper Floridan Aquifer System (UFA). Withdrawals of freshwater from the UFA has increased the size and magnitude of the cone of depression, directly impacting the rate of saltwater intrusion into the UAF. Figure 10 illustrates the growth of the cone of depression within the study area from 1943 to 1984. The impact of saltwater intrusion into the shallow groundwater system at the IoH are discussed in a previous study by Williams (2019), where monitoring wells were installed across the Wormsloe Historic Site in an effort to document the effects of tidal inundation. Results of the hydrology from this study are discussed below using the palynology and lithology as a proxy for changes in groundwater chemistry.

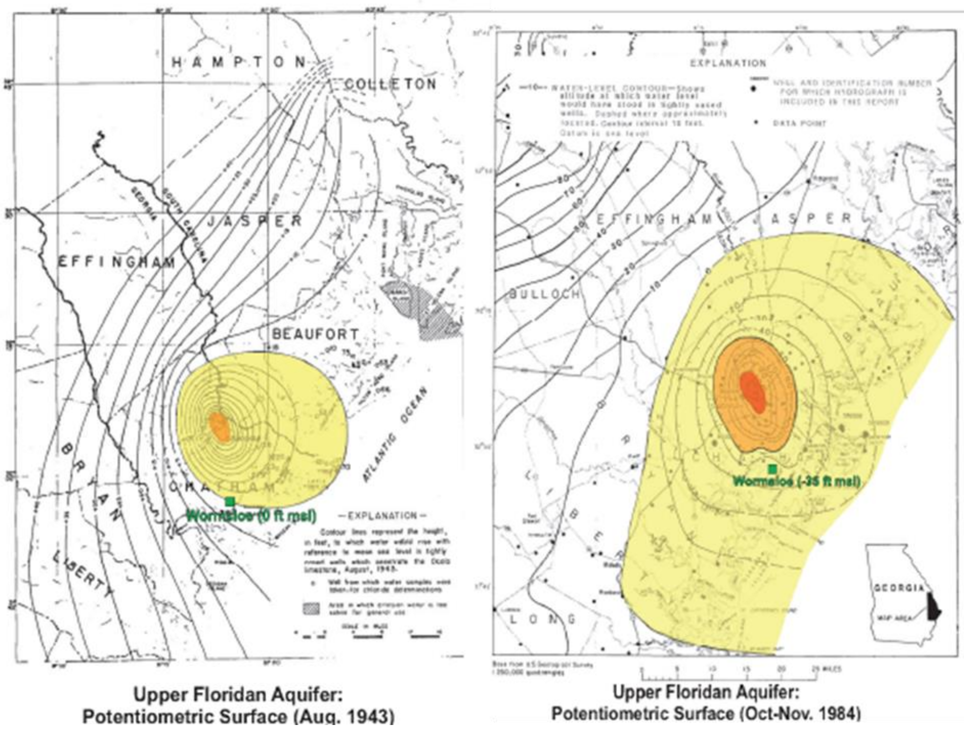


*Figure 11. Upper Floridan Aquifer Cone of Depression Growth 1943-1984; adapted from Krause and Randolph (1989)*

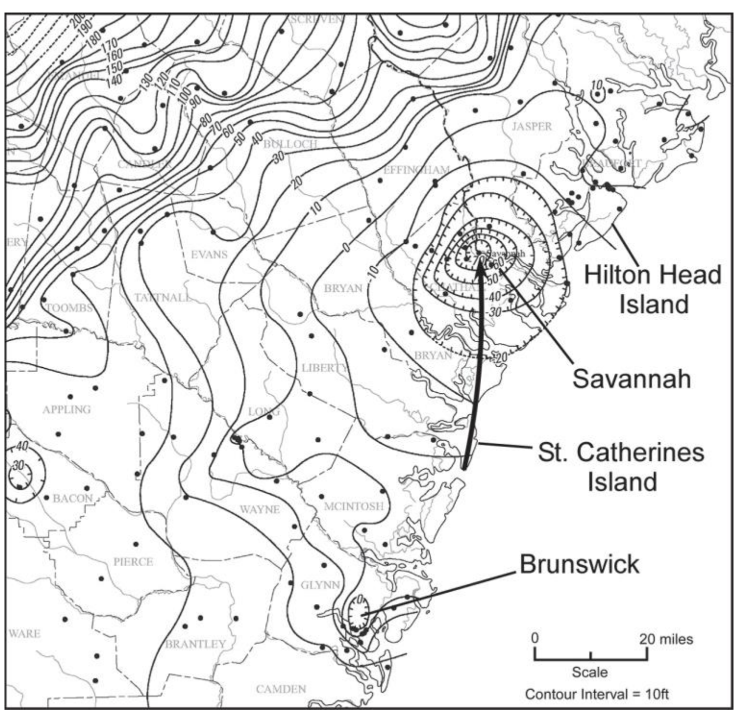


*Figure 12. Map of the potentiometric surface of the Upper Floridan Aquifer in 2010 along the Georgia coast; adapted from Reichard (2014)*

Zone 1 (90-70 cm):

Zone 1 sediments are composed of fine to very fine quartz sand with heavy mineral sands present. The heavy mineral sands were identified through color differentiations from the quartz sands, where heavy mineral sands were more mafic. These sediments are typical of a barrier island foreshore and are considered to be part of the island's core. This portion of the core is extensively bioturbated, with burrows ranging in diameter from 1-3 cm. Burrows were observed in greater detail in the WM1B core (Figure 5). The suppressed pollen count observed in the upper portion of Zone 1 (80-70 cm), as well as prevalent burrows suggest the local environment at the time of deposition was more exposed to sunlight than low lower portion of Zone 1. The palynology of the upper portion of this zone recorded a local community of *Cyperaceae, Typha*, *Pinus*, *Quercus*, and Cupressaceae.

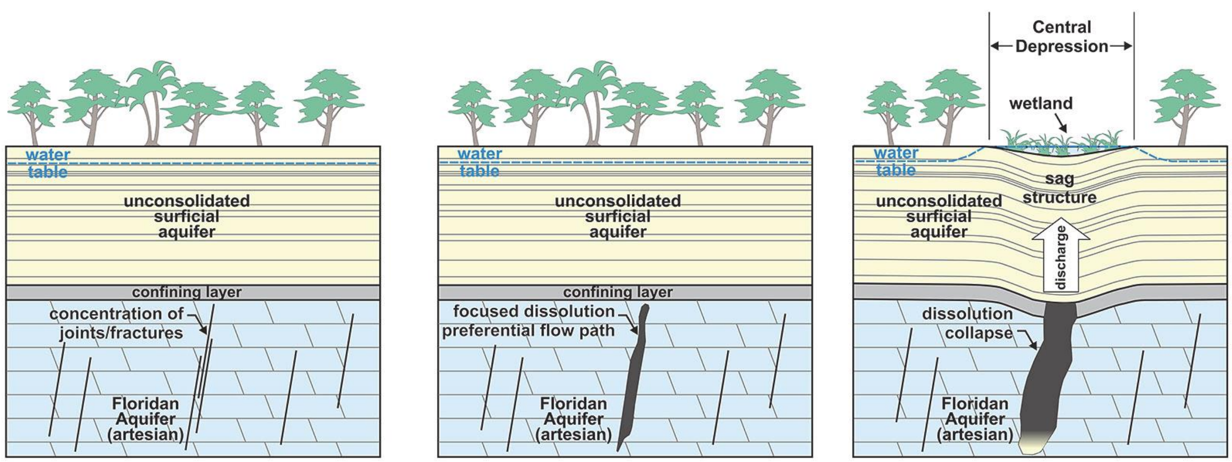


*Figure 13. Illustration showing prior to pumping withdrawals, joint-controlled artesian discharge flowed upward, leading to dissolution features that later collapsed creating sag structures in the surficial aquifer. Adapted from Reichard (2014).*

The lower portion of Zone 1 (90 cm) exhibited similar sedimentological characteristics, however bioturbation and mottling are less severe. Lithological observations of this zone further suggest deposition occurred in a shallow marine ecosystem evidenced by the palynology and the degree of bioturbation and mottling of the basal sediments (Figure 5; Figure 6).

Zone 2 (70-50 cm):

Sediments within Zone 2 consist of muddy sand, fine to very fine, with 2.3% organic content. Results of Zone 2 indicate a hydrology that at the time of deposition observed sources of pollen that accumulated in an environment with a strong terrestrial influence. This is indicated in the palynology, presented in Figure 8, of this zone with the occurrence of taxa such as *Typha*, *Cyperaceae*, *Pinus*, Cupressaceae, and *Quercus*. Representative counts of *Typha* and *Cyperaceae* increased slightly from the middle of Zone 2 to the boundary with Zone 3 (Figure 8), and might suggest the presence of a freshwater ecosystem near the study site at the time of deposition.

Zone 3 (50-20 cm):

This zone contained evidence for a storm washover deposit that was interpreted to be caused by a large storm event that passed over the study site. Further lithological analysis revealed reworking of sediments from Zone 2 that were represented in the palynology (Figure 6). The lower boundary of this zone (approximately 40 cm) observed a slight rise in *Pinus*, *Poaceae*, *Cyperaceae*, *Magnolia*, and Cupressaceae grains and suggests in increased influence of terrestrial components.

Zone 4 (20-0 cm):

The palynology and lithology reflected the overall hydrology of Zone 4, covering sediments from 20 cm to the surface, 0 cm, of the core. The taxa encountered in this zone are representative of the modern maritime forest ecosystem on the IoH, and alone the Georgia Coast. The modern environment is grass dominated with vegetation associated with the Georgia Coast, including *Pinus*, *Quercus*, and members of the Cupressaceae family such as Juniper and Cypress.

Data collected from each sample are consistent with those reported by Rich et al. (2018), and Ferguson et al. (2010) where *Pinus* (pine), *Poaceae* (grass), and *Quercus* (oak) pollen dominate every sample.

*Pinus*, *Quercus*, and Cupressaceae are the dominant arboreal species found in the upper portion of this zone (10-0 cm). The middle to lower portion of this zone observed reduced counts of arboreal taxa, while herbaceous and aquatic species rose slightly in count.

### 4.4 Limitations of Data

The data for this study were collected to evaluate the use of palynology to determine if a smaller shallow depression, Figure 2, found on the Isle of Hope was a former freshwater wetland that might have supplied fresh water to the island's settlers, and to evaluate the land coverage changes. Freshwater taxa were encountered in trace percentages throughout the core. Funding for this project was limited, and did not allow for radiocarbon dating of charcoal to be performed.

## 5 CONCLUSION

The WM1A sediment core from the Wormsloe Historic Site presents an ecosystem that has remained relatively stable throughout the Holocene of Coastal Georgia. While similar studies have been conducted on surrounding Georgia barrier islands, no such study has been conducted on the Isle of Hope. The presence of characteristically southeastern plant taxa, such as *Pinus, Quercus, Cupressaceae,* and *Liquidambar* throughout the sediment core suggest that the climate condition has remained relatively stable throughout the period covered by the core. A majority of taxa that were observed in trace percentages are currently found in the southeast, and these taxa attest to the diverse plant community found at the time of initial sediment accumulation.

This study evaluated the application of palynology to understanding the paleohydrology of the Wormsloe Historic Site. Although limited by the single core used for palynological analysis and low percentages of freshwater flora, the pollen suggest that freshwater conditions were in the vicinity of the study area. The topography of the study area consisted of shallow depressions presented in Figure 2 which are hypothesized to be former wetlands. These observations are further evidenced as the depressions have been mapped as surface water on the 1890 Blandford topographic map, the extensive depth of the peat, and multiple similarities with the St. Catherines wetlands where lithological, palynological, and geochemical data were hydraulically connected to the underlying Upper Floridan Aquifer system via fractures or faults comprising the confining layer. Withdrawals from the Upper Floridan Aquifer have since diminished artesian conditions, and increased the cone of depression by several hundred kilometers, this in turn has also increased the effects of saltwater intrusion and are evident in the palynology.

The hypothesis of occurrence of freshwater may be supported, albeit weakly, by the presence of pollen and spores of plants such as *Typha*, *Potamogeton*, *Nymphaea*, and *Filicales*, albeit in trace amounts. The modern environment is now dominated by Pine, Oak, and salt tolerant grasses.

## 6 Future Work

Palynological analyses of the area should be continued to further assess changes over time from the Late Pleistocene through the Holocene. This work focused on a smaller, more accessible former wetland. Future work should examine a larger wetland on the Isle of Hope to see changes in diversity and plant communities. The collection of 7.5 cm diameter cores in a transect across a larger suspected wetland would be beneficial and also facilitate the logging of sedimentary structures as compared to the 2.5 cm diameter cores in the current study. Extinct and extant wetlands on the Isle of Hope should be studied to create a broader picture of how the

Pleistocene climate affected the Georgia coast. This can then be correlated with studies done at St. Catherines, Skidaway, and Ossabaw Islands to produce a more detailed geologic and anthropogenic record of the Georgia coast. To continue to assess the palynological history of the site, geochronological analyses should be conducted to produce a geologic timeline to better document the transitional periods within the Isle of Hope.

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