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Late Quaternary Evolution and Stratigraphic Framework Influence on Coastal Systems along the North-Central Gulf of Mexico, USA

Robert Hollis
University of Southern Mississippi

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Late Quaternary Evolution and Stratigraphic Framework Influence on
Coastal Systems along the North-Central Gulf of Mexico, USA

by

Robert Hollis

A Thesis
Submitted to the Graduate School,
the College of Arts and Sciences
and the School of Ocean Science and Engineering
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Approved by:

Dr. Davin Wallace, Committee Chair
Dr. Michael Miner
Dr. Jessica Pilarczyk

Dr. Davin Wallace
Committee Chair

Dr. Jerry Wiggert
Associate Director

Dr. Karen S. Coats
Dean of the Graduate School

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ABSTRACT

Coastal systems in the Gulf of Mexico are threatened to reduced sediment supply, storm impacts and relative sea level rise (RSLR). The geologic record can provide insights of geomorphic threshold crossings (formation, progradation, transgression, destruction) to these forcing mechanisms to predict future barrier evolution to climate change. The stratigraphic framework and antecedent topography directly influence coastal evolution over geologic timescales. This study synthesizes ~2100km of geophysical data, 700+ sediment cores, and 63 radiocarbon dates to regionally map two sequence boundaries, multiple ravinement surfaces and fourteen depositional facies. One marine isotope stage (MIS) 6 valley's fill provided up to $300 \times 10^6 \text{ m}^3$ of sand to modern systems through transgressive ravinement during the Holocene. Repeated storm breaches or tidal inlets correspond to paleotopographic low's in the MIS 2 surface.

A Holocene geomorphic evolutionary model was created for Petit Bois and Dauphin Island from available data, highlighting RSLR rates and sediment supply. As the MIS 2 surface was flooded, tidal/wave scour supplied sand to migrating marine shoals. These rapidly transgressing shoals converted drowned paleovalleys to estuaries starting about 9ka. Islands formed in their modern positions about 6ka, when sediment supply was high and RSLR rates were 2mm/yr. Between 4ka-1750 CE. Islands prograded due to RSLR rates of 1-0.4mm/yr and sufficient sand supply from alongshore and inner shelf sources. Currently, the islands experience RSLR rates of 3.61 mm/yr and reduced sediment supply resulting in barrier degradation. This study provides geologic evidence of coastal geomorphic thresholds related to RSLR, sediment supply and antecedent topography.

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DEDICATION

This thesis is dedicated to friends, family and loved ones especially Bob, Ellen, Joey and Alli. Their love, appreciation and support allowed me to pursue my scientific passion.

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LIST OF ABBREVIATIONS

<i>MSAL</i>	Mississippi-Alabama
<i>mbsl</i>	meters below sea level
<i>masl</i>	meters above sea level
<i>rslr</i>	relative sea level rise
<i>rsl</i>	relative sea level
<i>mis</i>	marine isotope stage
<i>CE</i>	common era
<i>BP</i>	before present
<i>ka</i>	kilo annum (1,000 years)
<i>DEM</i>	digital elevation model

1-INTRODUCTION

Coastal environments along the Gulf of Mexico are threatened due to sea-level rise, reduced sediment supply, and storm impacts, which will only be exacerbated with climate change. Increased focus has shifted to modeling the future impacts of these climatic forcings. However, observational data used to constrain models are usually limited to the instrumental record, which do not capture longer-term barrier system geomorphic threshold responses (island formation, stabilization, progradation, transgression, destruction). These geomorphic threshold responses result from forcing mechanisms such as changes in sea level increasing accommodation space by flooding antecedent topography (Rodriguez et al. 2004, 2008, Anderson et al. 2014) and changes in sediment supply (Raff et al. 2018, Rodriguez et al. 2018, Odezulu et al. 2018). Many studies show the most complete records of coastal evolution are preserved within paleofluvial incised valleys and partially in antecedent shelf deposits (Anderson et al. 2014, Mallinson et al. 2010, Zaremba et al. 2016, Nordfjord et al. 2005). Comparing the chronologic evolution of these preserved environments to well-constrained Holocene sea level curves sheds valuable insight toward geomorphic threshold parameters (Milliken et al. 2008, Rodriguez et al. 2010). However, research concerning how the regional stratigraphic framework influences modern coastal geomorphology and sediment supply variability is limited to a few study areas (Riggs et al. 1995, Zaremba et al. 2016, Mallinson et al. 2010, Anderson et al. 2016, Belknap and Kraft 1985) and is yet to be constrained for the Mississippi-Alabama (MSAL) barrier island chain.

The MSAL shelf is comprised of a complex network of coastal plain and piedmont incised valley systems (Greene et al. 2007) with compound and simple fill

structures (Dalrymple et al. 1994, Zaitlin et al. 1994). Incised valley geometry and fill architecture controls are related to base-level fall rates and magnitude, shelf gradient, drainage basin geology, subsidence, sediment discharge and climate (Anderson et al. 2004, Mattheus et al. 2007 and references within). This is the major mechanism creating topography in otherwise low gradient coastal settings. Previous studies on the MSAL shelf focus on the five shelf edge deltas (Kindinger 1989, Roberts et al. 2004, Fillon et al. 2004, Bartek et al. 2004) and shelf valleys (Bartek et al. 2004, Flocks 2015, Kindinger 1988, Kindinger et al. 1994). However, there is disagreement concerning the timing and location of large depositional features and associated feeder valleys (Roberts et al. 2004, Bartek et al. 2004, Greene et al. 2007). For example, Gonzalez et al. (2017) reported *in situ* cypress stumps and peats of pre-MIS 2 age offshore of Fort Morgan, Alabama in ~20m water depths. Based on elevation estimates and sea level data the valley fill was estimated to be Holocene (Bartek et al. 2004). Entire sea level cycles may not be preserved, increasing the complexity of the sequence stratigraphy. Furthermore, these studies do not incorporate how these systems influenced Holocene barrier island morphodynamics and generally lack upland fluvial source mapping. The most complete stratigraphic records of coastal evolution are preserved within fluvial incised valleys in highly dynamic settings (Anderson et al. 2014, Mallinson et al. 2010, Zaremba et al. 2016).

Shorelines of the Gulf of Mexico are among the most vulnerable in the United States (Pendleton et al., 2010), and policy and management decisions should incorporate coastal geology (Dolan and Wallace, 2012). They demonstrate highly variable geologic frameworks, sediment flux, subsidence rates and types of evolution, even across

relatively small spatial scales (Anderson et al. 2004, Otvos 2018). The geologic framework and inherited antecedent topography are critical factors impacting island progradational, retrogradational and or aggradational evolution modes (Raff et al. 2018, Timmons et al. 2010), paleovalleys anchoring tidal inlets (Mallinson et al. 2010) and erosional hotspots (Twichell et al. 2013, Hapke et al 2016, Honeycutt and Krantz 2003, Browder and McNich 2006). Stratigraphic framework, antecedent topography and relative sea level rise rates also strongly influences wave ravinement depths, which vary greatly across Texas (8-12m) (Rodriguez et al. 2001, Wallace et al. 2010; Wallace and Anderson, 2013) and Louisiana (10-16m) (List et al. 1994). These same factors along with tidal prism and the number of inlets control the depth of tidal ravinement (Miner et al. 2007, 2009, FitzGerald et al. 2004, Cattaneo and Steel 2013). Together, these transgressive ravinement processes have important implications when estimating barrier sediment supply from reworked offshore relict deposits (Weight et al. 2011) or in times of rapid relative rise, their preservation (Swift et al. 1975). Relict falling stage deltas reworked during the Holocene transgression were the principle sand source for modern coastal systems in Texas (Anderson et al. 2016).

Quantifying the Late Quaternary coastal evolution in the northern Gulf of Mexico (GOM) provides a link between the inner shelf geologic framework and the modern MSAL coastal geomorphology. Another objective of this study is to constrain forcing mechanisms such as changes in relative sea level rise (RSLR) rates and sediment supply over geologic timescales in a regional context that can be applied to similar systems (Rodriguez et al. 2010, Anderson et al. 2016). Both are critical to improve our understanding of coastal geomorphic thresholds moving forward, given that current

relative sea level rise rates have exceeded rates during island formation (Otvos 2018) and the likely future increase in storm frequency and intensity (Emanuel 2005). This study aims to holistically synthesize many previous works in the area (Flocks 2015, Flocks et al. 2014, Twichell et al. 2011, McBride et al. 1991, Kramer 1990, Greene et al. 2007, Hummel and Parker 1995, Hummel and Smith 1996, Otvos 1979, 1981, 1985, 1986, 2018) supplemented with newly acquired geophysical and chronologic data to investigate the coevolution of the barrier islands and other coastal systems, highlighting sand supply through ravinement of the inner shelf.

Figure 1 Study Site

Map of Petit Bois, MS and Dauphin Island, AL. Green areas represent natural preservation areas ie., Gulf Island National Seashore or Grand Bay National Estuarine Research Reserve (NERR). Figure 6, 7, 8 locations shown in white bold lines, dotted black lines represent the sand extent of the active barrier system used for sand volume calculations (table 4).

2-REGIONAL SETTING

2.1 Coastal and Physical Setting

The microtidal, storm dominated, MSAL shelf is a slowly subsiding ($\sim 2\text{mm/yr}$), low gradient, passive margin (Ivins et al. 2007, Flocks 2015). The MSAL barrier chain is located about 5-20km offshore, separating the Gulf of Mexico from the Mississippi Sound (Figure 1). This wind dominated estuary, has a $1.23 \times 10^9 \text{ m}^3$ large tidal prism (Eleuterius, 1980). Tidal currents are 0-0.91 m/s, but vary between inlets (Rucker and Snowden 1990). Meteorological forcings such as frontal passages strongly influence water levels and current velocities.

The significant wave height at 15m water depth on the inner shelf, ranges from 0.4m-0.7m in the summer and winter respectively, which reflects seasonal differences in passing cold fronts and tropical cyclones (NDBC 2016: Buoy 42007, Eisemann et al. 2018). Onlapping marine muds at a depth of 7m mark the toe of the shoreface at the western end of the MSAL barrier chain at Ship Island (Twichell et al. 2013). Shallow cores (Kelso and Flocks 2015) and geophysical data (Forde et al. 2011a, 2011b, 2013) offshore Petit Bois show the toe of the shoreface at 8-10m. Dauphin Island's shoreface toe is marked by exposed Pleistocene deposits at 7m. Dominant southeasterly swells create a net westward longshore current flowing at 0.5-1.5 m/s (Boone 1973). The entire MSAL chain shows sediment transport connection to the Mobile ebb tidal delta to some degree (Byrnes et al. 2013); although significant amounts of sediment are sequestered in tidal deltas and dredge-maintained shipping lanes (Cipriani and Stone 2001).

Mississippi Sound's salinity ranges from nearly fresh to 36 psu from the multiple river systems (Upshaw et al. 1966). The piedmont Mobile-Tensaw River is the sixth

largest river system in the contiguous United States with a drainage basin of 133,500 km² and an average discharge of 1,788 m³/s (Greene et al. 2007). Roughly 15% of its discharge enters Mississippi Sound through Pass Aux Herons (Hummel and Parker 1995). The Pascagoula/Escatawpa River system has a drainage basin of 25,122 km² and discharge of 271 m³/s (Newcome 1967). The Pascagoula is the largest undammed river in the contiguous United States. The coastal plain Fowl River system has a drainage basin of 197 km² and an average discharge 1 m³/s. The coastal plain, meandering La Batre River drainage basin is 75 km² and has an average discharge of 0.4 m³/s (Greene et al. 2007).

2.2 Coastal Response to Sea Level

Sea level cycles are the driving mechanism for coastal evolution over geologic timescales (Anderson et al. 2016). Shackleton (1987) relates marine oxygen isotope records and global ice volume as proxies for eustatic sea level (Figure 2). Large swings in the oxygen isotope data observed from deep sea foraminifera represent global climatic changes between glacial and interglacial periods or marine isotope stages (MIS) (Emiliani 1955). Depositional environments and stratigraphic sequences are directly referenced to sea level cycles in this study similar to other work in Texas (Anderson et al. 2004). During the MIS 6 lowstand, global sea level was about 130 to 140m below modern about 155-136 ka (Figure 2) (Shackleton 1987, 2000). Other studies in Louisiana (Wellner et al. 2004), central Texas (Abdulah et al. 2004), and MSAL (Greene et al. 2007) show larger MIS 6 valley width, greater incisional depth and sediment load compared to the most recent MIS 2 lowstand. This is supported by the large MIS 6 or 8 Lagniappe Delta on the MSAL shelf (Roberts et al. 2004).

During the MIS 5e highstand, sea level was 3-6m above present (Otvos 2005, 2018). A discontinuous barrier ridge complex spans most of Texas through Florida (Otvos 2018). MIS 2-5 represents falling stage to lowstand tracts where global sea level fell to 120 meters below modern about 18,000-26,000 years ago (Shackleton 1987). The MSAL shelf consists of a series of lowstand (MIS 2 and older) incised paleofluvial valleys and fluvial channel deposits (Bartek et al. 2004, Flocks 2015, Greene et al. 2007). Previous studies suggest the MIS 2 surface dips to the southwest (Otvos 1985). These incised valleys were filled with fluvial to marine transgressive sediments during the Holocene and Late Pleistocene (Figure 3), preserving the most complete stratigraphic record on the shelf (Bartek et al. 2004, Flocks et al. 2015).

Detailed composite relative sea level curves span most of the Holocene transgressive (MIS 1) period for the Gulf of Mexico (Figure 2) (Milliken et al. 2008, Törnqvist et al., 2004a, 2004b, 2006). Climate shifts during the Early Holocene caused punctuated rapid sea level rise episodes (Milliken et al. 2008) and sediment supply variations resulting in periods of rapid shoreline and bayline migration along Texas (Simms et al. 2008, Rodriguez et al. 2004, 2010, Milliken et al. 2008), Mississippi (Flocks 2009), and Alabama (Greene et al. 2007). Sea level rise decreased to about 0.6-0.4 mm/yr from about 4,000 years (Milliken et al. 2008) to 1750 CE, when it dramatically increased to 1.3-2 mm/yr based on Florida saltmarsh records (Gerlach et al. 2017). This abrupt sea level rise trend is apparent within the Gulf (Gerlach et al. 2017) and along the US East Coast (Kemp et al. 2011). Between 1966-2017 CE, current RSLR

rates are 3.61 ± 0.59 mm/yr at Dauphin Island (NOAA 2018: Station 8735180).

Figure 2 Eustatic and Texas/Louisiana Sea Level Curves

Composite, non-linear, Holocene sea level curve in the Northern Gulf of Mexico (Anderson et al. 2014, modified from Milliken et al. 2008) based on peat and *Donax* sp. elevations and dates. For full error measurements and methodology see Milliken et al. (2008). Red bars indicate flooding events observed in estuaries along the Gulf of Mexico. Inset figure displays the eustatic sea level curve over the last 200ka based on the Shackleton (2000, 1987) data. Blue numbers indicate Marine Isotope Stage (MIS) number.

2.3 Barrier Formation and Evolution

The MSAL barrier island chain is unique in that the five islands (Cat, Ship, Horn, Petit Bois and Dauphin Island) have different geomorphologies, sizes and erosion rates (Morton 2008). Otvos (1970, 1981) states the MSAL barrier formed from vertical shoal aggradation atop Holocene marine sandy muds. McBride et al. (1991) argues the islands experienced an early transgressive phase. Petit Bois and Dauphin Island make up the eastern part of the MSAL barrier chain. The eastern portion of Dauphin Island is anchored by a Pleistocene Gulfport Formation barrier remnant, while the western Dauphin spit and the rest of the barriers emerged around 5.7-5.0 ka BP (Figure 3) (Otvos 1979, 1981, 1985, Otvos and Carter 2008). During this time, RSLR rates decelerated from ~ 1.6 mm/yr to less than ~ 0.6 mm/yr, aiding island stabilization (Figure 2) (Milliken

et al. 2008). The islands are thought to be anchored by a roughly east-west trending, antecedent wave-cut escarpment of relatively significant relief formed during a sea level still stand (McBride et al. 1991, Otvos 1981, Swift et al. 1984).

Historical charts from 1752 CE show the eastern strandplain of the modern Petit Bois Island attached to Dauphin Island (Otvos 1985, Morton 2008, Buster and Morton 2011). The island was separated by an unnamed Hurricane between 1740 CE and the 1850's CE (Otvos and Carter 2013) and continued to migrate westward to its modern position. The origins of some islands are impossible to conclude due to reworking by transgressive processes and storms (Otvos 1970). Paleo storm records from western Mississippi, document an active hurricane period between 900-600 BP and 2200- 1900 BP (Bregy et al. 2018). The low elevation MSAL barriers are especially vulnerable to storm impacts, evidenced by Katrina in 2005 (Eisemann et al. 2018), which will only be exacerbated with accelerated sea level rise in the future.

Previous studies state that an eroding pre-Holocene headland located in the Florida Panhandle (Stone et al. 1992) and Mobile ebb tidal sands (Otvos 1979) source the MSAL barrier sands through alongshore currents (Otvos 1979). Only minor attention is given to the contribution of reworked shelf deposits (Otvos 1979, Rucker and Snowden 1990).

2.4 Shore Oblique Sand Ridges

The inner shelf surrounding Petit Bois Island is located on the border of St. Bernard prodelta muds and the Mississippi-Alabama-Florida (MAFLA) sand sheet, consisting of numerous post transgressive, shore oblique sand ridges in water depths of 7-20 m (Flocks 2015, McBride et al. 1991). Offshore of Dauphin Island is a relatively

featureless shelf between the Petit Bois Pass and the Mobile ebb tidal delta (Figure 1) (Hummel 1999). Sand ridges generally occur in areas of high sediment availability, sufficient current for sediment transport, and some seafloor perturbation that acts as a depositional nucleus (McBride and Moslow 1991). Flocks (2015) attributes the largest, stable ridges (up to 10 km long, 0.5km wide) seaward of Petit Bois Island to the proximal location of a large fluvial valley sand source (Figure 1). This agrees with Browder and McNich (2006) who showed a significant positive correlation between fluvial channel width and ridge size. It remains unclear whether these detached ridges formed as shoreface attached ridges and became separated through various processes such as shoreline transgression (Hayes and Nairn 2004) and convergence of storm flow (Trowbridge 1995), actively translating ebb tidal delta deposits drowning with sea level rise (McBride and Moslow 1991), or if the shoals formed on the inner shelf (Snedden and Dalrymple 1999).

2.5 Mississippi/Alabama Coastal Geology

Fluctuating sea levels controlled deposition of several marine-fluvial coastal plain sequences comprising the MSAL coast (Figure 3). The 40-60m thick, Late Pliocene age Citronelle Formation represents paralic sand rich alluvial/fluvial to estuarine sequence deposits (Otvos 2001). The Pre-Sangamon terrace represents alluvial deposits luminescence dated at 224-202 ka (MIS 7) (Otvos 2001).

Figure 3 MSAL Coastal Geology and Lidar

The coastal geologic formations of Mississippi and Alabama, ranging from the Early Pliocene to modern deposits, based on the stratigraphic naming convention of Otvos (1985, 2001). The asterisk indicates the Biloxi Formation, which underlies and interfingers with the Prairie and Gulfport Formation. B) Composite 2007 Biloxi, MS and 2009 Mobile, AL DEM topobathy rasters corrected to mean sea level (NOAA 2007, 2009).

The Late Pleistocene units include the alluvial Prairie Formation terrace, the beach ridge Gulfport Formation and the underlying marine to estuarine Biloxi Formation (Otvos 2001). The 3.5-12m thick, pale-yellow to olive-green, clayey sandy Prairie Formation is luminescence dated to 120-90 ka (MIS 5) (Otvos 2005). Lower elevation Prairie terraces in western Mississippi show alluvial deposition continued from 50-30ka (MIS 3) (Otvos 2005). The 3-8m thick, Gulfport Formation represents a nearshore to intertidal to eolian sequence interpreted as barrier ridge and beach deposits (Brown et al. 1944) dating to the MIS 5e highstand (124-115 ka BP) (Otvos 2001). This discontinuous beach ridge deposit is regionally correlated throughout portions of Texas and Louisiana (Ingleside) to the west and Florida to the east. Portions of Dauphin and Fort Morgan Alabama are MIS 5e beach deposits (Otvos 2001). The 4-16m blueish gray muddy sandy

Biloxi Formation represents a fossil rich estuarine- marine unit. Overlying these Late Pleistocene deposits are a series of thin Holocene transgressive coastal plain deposits ranging from marine to fluvial environments.

3-METHODS

3.1 Geophysical Data

This project incorporated ~2050 km and ~950 km of archived chirp and boomer seismic data, respectively. The chirp data sets (Forde et al. 2011a, 2011b, 2015) were collected from 2008-2013 by the United States Geological Survey (USGS) as part of the Mississippi Coastal Improvements Program (MsCIP). Chirp data from Greene et al. (2007) were also incorporated (Figure 4). Boomer and mini sparker seismic data (Bosse et al. 2017a, 2017b, Sanford et al. 2016a, 2016b, 2016c) were collected from 1981-1992 (Figure 4). See references within figure (4) for survey specific method details. Previously collected data set line spacing, resolution and horizontal accuracy varied greatly, which required weighted quality control between datasets and later interpretation. Chirp data collected with an Edgetech SB-512i had the greatest penetration and detail in shallow water depths and areas of thick sand packages. Other instruments (Edgetech SB-216s or SB-424) provided sufficient detail in muddy portions of Mississippi Sound. Recently collected chirp data was weighted higher overall due to greater vertical resolution ($\leq 20\text{cm}$) and spatial accuracy ($\leq 2\text{m}$) compared to seismic data collected with LORAN-C ($\leq 1\text{m}$, $\leq 0.4\text{km}$ respectively). Seismic data were classified based on the amount of ringing or noise present. Due to certain data coverage limitations, seismic was used where chirp was absent and to delineate deep stratigraphic boundaries.

Seismic data collected during this study were acquired using a single-channel Applied Acoustics boomer with a CSP1000 power supply and Hypack data acquisition software. The analog geophysical trace information was converted to a digital signal

using a National Instruments conversation system. Navigation was provided by a WASS enabled Trimble DPGS with a horizontal spatial accuracy of $\sim\pm 3\text{m}$.

Figure 4 Data Coverage

Synthesized data used in this study from various sources (references within figure). Boomer/minisparker seismic and chirp profiles are represented thick black and grey lines, respectively. Sediment cores are represented by black dots. Data collected in this study are shown in red.

Chirp and seismic SEGY data were analyzed and interpreted in SonarWiz 6 (Chesapeake Technologies, 2018) supplemented with sediment cores. Seismic and lithologic facies were constructed based on stratigraphic relationships following facies models and descriptions proposed by Zaitlin et al. (1994), Mitchum et al. (1977), Allen and Possamentier (1993) and Cataneuo and Steel (2003). These reflector picks were exported as xyz data and then gridded using the kriging function in Golden Software Surfer 15. Separate surfaces with nodal points spaced at 75m and 200m resolution were

created and later merged due to the variable chirp and older seismic data densities. A smoothing function and some interpretive surface modifications were made to remove gridding artifacts. Finally, these interpolated surfaces were incorporated into ArcGIS to create paleotopographic maps.

3.2 Sediment Cores

This study integrated over 720 previously collected sediment cores (vibracores and rotary drill cores) from numerous sources to create stratigraphic geometries and ultimately an evolutionary model of the MSAL coastal setting (Figure 4). The compiled legacy cores came from nine studies (Figure 4 and references within). Information available ranged from geotechnical sand prospecting logs with limited photographs to archived cores that were available for sampling. Depending on the data quality of the archive core, some were used to simply ground truth the subaerial exposure surface, indicating the Pre-Holocene contact or lowstand sequence boundary. Other archived cores provided more detailed sedimentary structure descriptions used to interpret lithofacies. Two scuba dive assisted percussion cores and four vibracores collected for this study focused on penetrating and dating inner shelf valley fill deposits and Petit Bois Island stratigraphy. These cores were split using normal logging methods. Lithologic units from these cores were analyzed for grain size, sedimentary structure, shell content, contact relationships, and radiocarbon sample type.

3.3 Radiocarbon Dating Estimates

New macrofossil samples were collected from archived cores at the USGS Center for Marine and Coastal Science (Kelso and Flocks 2015), Geological Survey of Alabama (Hummel and Parker 1995) and cores collected in this study for radiocarbon dating

(Table 1). Twenty-four new radiocarbon dates were obtained using the continuous flow gas bench accelerator mass spectrometer method developed at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) of the Woods Hole Oceanographic Institution. Sampling focused on articulated bivalves when possible. Articulated samples were determined to be *in situ* because following death, the organic ligament joining individual valves decays and becomes very sensitive to currents (Pilarczyk and Barber 2015). Sample preparation followed NOSAMS guidelines. The gas bench ages were calibrated with the Marine13 curve (Reimer et al. 2013) with the standard global 400 year-marine reservoir applied. While there are distinct potential chemical signatures from multiple drainage basins influencing the study area (Milliken et al. 2008, Törnqvist et al. 2015) and potential variations of fractionation locally within a single estuary (Hadden and Cherkinsky 2016, 2017), no additional reservoir correction was made for estuarine samples due to limited data available in the northern-central Gulf of Mexico (Reimer et al. 2001).

Thirty-eight radiocarbon dates from mollusk, peat, wood and other organic sediment samples were synthesized from various literature sources listed in Table 2. Previously published radiocarbon samples were recalibrated using the Marine13 and IntCal13 curves for marine and terrestrial samples, respectively (Reimer et al. 2013). No local reservoir corrections were applied.

All ages (new and recalibrated) are reported in calendar years before present (BP, present being 1950 CE), using median probability with associated two-sigma ranges. All elevations represent meters referenced to mean sea level.

3.4 Sand Volume Calculations

Methods outlined by Weight et al. (2011) were employed to quantify sediment produced by wave and tidal scour (transgressive ravinement) during the Holocene. This involves multiplying the flooded areal extent of the MIS 2 surface (based on sea level curves from Milliken et al. (2008); Figure 2) by the depth of modern transgressive ravinement. The depth of ravinement was assumed to be constant throughout the Holocene, although it was likely variable based on the geologic framework (sand supply and resistance to erosion), rates of sea level rise, and antecedent topography (Swift et al. 1975). In this study, we assume a conservative depth of wave ravinement (wRs) of 7 meters below sea level (mbsl) based on cores and seismic data showing marine muds onlapping shoreface sands or exposed Pre-Holocene deposits. Dense geophysical data have constrained the footprint of several sandy fluvial or deltaic deposits on the inner shelf that have a clear ravinement surface truncation. Sand content (lithology and extent) was estimated from sediment core and geophysical data. Thus, the methodology from Weight et al. (2011) was employed to find the volume of sediment produced from deposits identified as having high sand content only, not the entire inner shelf.

Calculated sand volumes produced through ravinement were compared to that of the active Holocene sections of Petit Bois Island, Petit Bois Pass and the Dauphin Island western spit platforms. Eastern Dauphin is an older Pleistocene barrier deposit (Figure 3) and excluded from volumetric analysis. For this computation, we have defined the active barrier system as the sand content bounded by the toe of the shoreface (based on cores and geophysical), the base of barrier island and inlet fill sands, to the distal flood tidal delta or overwash extent (Figure 1). The volume of sand was calculated between the

basal sand and modern topobathymetric (NOAA 2007, 2009) surfaces clipped to the active barrier system extent. For this calculation, the modern barrier system was assumed to be composed of 100% sand.

3.5 Evolutionary Model

Sea level age and elevation points from the Milliken et al. (2008) curve were used to “flood” the MIS 2 lowstand subaerial surface. These data assumed no Holocene sedimentation and allowed for estimation of marine flooding extents and paleo water depths. Environmental reconstructions throughout the Holocene transgression were made from these maps and were constrained by seismic, lithofacies, and radiocarbon data.

4-RESULTS

4.1 Quaternary Chronostragraphic Framework

Two regional sequence boundaries, several bounding ravinement surfaces and fourteen facies were identified from geophysical and sediment core data. The two sequence boundaries (SB1 and SB2) represent different lowstand, subaerial exposure surfaces with different incisional geometries (Figure 5). Twenty-four new calibrated gas bench radiocarbon ages collected in this study and thirty-eight synthesized radiocarbon dates constrain the evolutionary timing of these facies (Table 1 and 2). The seismic and lithofacies (Table 3) are a culmination of previous work assembled for this study and reinterpreted holistically (Hummel and Parker 1995, Flocks 2015, McBride et al. 1991, Twichell et al. 2011, Kramer 1999, Otvos 1979, 1981 1985, 1986). These seismic-lithologic units reveal the preserved portions of the stratigraphic record and help clarify the Quaternary evolution of the area and geologic framework.

Table 1 New Radiocarbon Ages

Study ID	Core ID	El. (msl)	Material Dated	C ¹⁴ Age	Median $\pm$ Cal. 2 σ Age (yrs BP)	Cal. 2 σ Age Range (yrs BP)	Facies
1	10cct05-02	-11.59	<i>Mulinia lateralis</i>	2,210 $\pm$ 120	1,808 $\pm$ 289	1,526 - 2,104	U Shoreface
2	10cct05-02	-12.61	<i>Mulinia lateralis</i>	2,840 $\pm$ 160	2,570 $\pm$ 393	2,162-2,947	L Shoreface
3	10cct05-02	-13.61	<i>Raeta plicatella</i>	6,500 $\pm$ 120	7,001 $\pm$ 274	6,712-7260	U Shoreface
4	10cct05-03	-14.11	<i>Rangia flexuosa</i>	6,420 $\pm$ 120	6,907 $\pm$ 283	6,629-7,195	Estuarine
5	10cct05-03	-15.80	<i>Crassostrea virginica</i> *	> 38,900	-	-	Estuarine
6	10cct05-3	-15.8	<i>Noetia ponderosa</i> *	> 40,900	-	-	Estuarine
7	10cct05-3	-15.91	<i>Mercenaria campechiensis</i> *	> 41,000	-	-	Marine
8	10cct05-06	-5.14	<i>Cyclinella tenuis</i>	930 $\pm$ 100	537 $\pm$ 229	334-681	Flood Tidal Delta
9	10cct05-06	-5.64	<i>Strombus alatus</i>	2,610 $\pm$ 110	2,295 $\pm$ 313	2,019-2,644	Flood Tidal Delta
10	10cct05-07	-5.79	<i>Abra aquelis</i>	>Modern	-	-	Estuarine
11	10cct05-07	-6.10	<i>Mulinia lateralis</i>	>Modern	-	-	Estuarine
12	10cct05-07	-6.11	<i>Mulinia lateralis</i>	115 $\pm$ 100	-	-	Estuarine
13	10cct05-08	-5.37	<i>Abra aquelis</i>	920 $\pm$ 100	529 $\pm$ 171	329-671	Estuarine
14	PBO17-2	-11.11	<i>Abra aquelis</i>	2,480 $\pm$ 110	2,135 $\pm$ 268	1,855-2,390	Estuarine
15	MS1	-3.55	Shell fragments	2,940 $\pm$ 110	2,702 $\pm$ 280	2,376 - 2,953	Flood Tidal Delta
16	MS1	-4.53	Shell fragments	4,070 $\pm$ 140	4,070 $\pm$ 381	3,725 - 4,486	Flood Tidal Delta
17	MS5	-3.04	<i>Cyclinella tenuis</i>	1,650 $\pm$ 110	1,199 $\pm$ 232	949 - 1,412	Estuarine
18	MS5	-3.69	<i>Trachycardium</i> sp. ^a	2,720 $\pm$ 110	2,450 $\pm$ 274	2,166 - 2,714	Estuarine
19	MS5	-4.07	Shell frag	3,680 $\pm$ 110	3,600 $\pm$ 296	3,319 - 3,911	Estuarine
20	MS9	-3.93	<i>Mulinia lateralis</i>	Modern	-	-	Estuarine
21	MS9	-3.98	<i>Mercenaria Mercenaria</i>	Modern	-	-	Marine/ FTD
22	MS9	-4.88	<i>Abra aquelis</i>	400 $\pm$ 100	-	-	Barrier (overwash)
23a	MS9	-5.85	<i>Cyrtopleura costata</i>	2,150 $\pm$ 110	1,738 $\pm$ 265	1,475 - 2,005	Estuarine
23b	MS9b	-5.85	<i>Cyrtopleura costata</i>	2,120 $\pm$ 110	1,703 $\pm$ 265	1,433 - 1,962	Estuarine

Gas bench radiocarbon dates produced from this study. Marine samples were calibrated using the Marine13 curve (Reimer et al. 2013). No local reservoir corrections were made. All dated samples were in situ, intact, articulated bivalves, except sample 9 (gastropod) and samples with a, indicating one single intact valve or reworked samples. * notes sample beyond the radiocarbon detection limit. Elevation is in meters referenced to sea level. All dates discussed in text are reported as in years before present (BP, present being 1950 CE), median calendar ages with added two sigma ranges.

Table 2 Synthesized Radiocarbon Ages

Study ID	Core ID	El. (msl)	Material Dated	C ¹⁴ Age	Median ± Cal. 2σ Age (yrs BP)	Cal. 2σ Age Range (yrs BP)	Facies	Citation
24	DI-1	-12.30	Peat ^b	23,500 ± 3,825	27,434±8,168	18,875-35,211	Estuarine	Otvos (1979)
25	DI-2	-11.40	Wood ^b	25,840 ± 1,330	29,887±2,606	27,433-32,645	Estuarine	Otvos (1979)
26	DI-2	-11.90	Wood ^b	36,290 ± 2,060	40,434±3,957	36,103-44,018	Estuarine	Otvos (1979)
27	DI-2	-13.20	Wood ^b	30,400 ± 2,185	34,506±4,579	30,254-39,412	Estuarine	Otvos (1979)
28	DI-3	-2.90	Mollusk	6,670 ± 165	7,175±348	6,795-7,490	Inlet Fill/Spit	Otvos (1979)
29	DI-6	-2.57	Oyster Shell ^a	1,215 ± 80	798±145	654-943	Flood Tidal Delta	Otvos (1986)
30	DI-8	-0.20	Humate	7,700 ± 820	8,665±1,874	6,848-10,596	Marsh	Otvos (1979)
31	P-3	-13.63	Wood	7,815 ± 80	8,613±187	8,420-8,793	Estuarine	Otvos (1979)
32	P-4	-18.00	<i>Strombus alatus</i> ^a	38,960 ± 3,125	42,430±6,029	36,162-48,219	Marine Mud	Otvos (1979)
33	R-1	-11.89	Wood	7,315 ± 85	8,127±174	7,975-8,323	Estuarine	Otvos (1979)
34	R-3	-8.40	Dispersed plant	6,765 ± 270	7,635±511	7,155-8,176	Estuarine	Otvos (1979)
35	R-3	-15.40	Wood	7,825 ± 160	8,678±346	8,342-9,034	Estuarine	Otvos (1979)
36	H-1	-11.10	<i>Cardium</i> sp.	4,615 ± 215	4,839±567	4,284 - 5,418	Barrier	Otvos (1979)
37	H-2	-16.20	Peat	8,010 ± 85	8,865±244	8,604-9,092	Marsh (fresh?)	Otvos (1979)
38	H-7	-18.60	Wood	34,935 ± 1820	39,202±3526	35,400-42,451	MIS2 estuarine	Otvos (1979)
39	SS-4	-15.59	<i>Strombus alatus</i>	6,315 ± 80	6,779±156	6,582-6,894	Marine Mud	Otvos (1985)

Table 2 Continued

Study ID	Core ID	El. (msl)	Material Dated	C ¹⁴ Age	Median ± Cal. 2σ Age (yrs BP)	Cal. 2σ Age Range (yrs BP)	Facies	Citation
40	SS-4	-16.50	Oyster Shell ^a	21,640 ± 4,690	24,827±10,440	13,722-34,602	Estuarine	Otvos (1985)
41	SS-8	-15.44	Mollusk	4,160 ± 305	4,223±793	3,438-5,023	Marine Mud	Otvos (1985)
42	SS-8	-18.17	<i>Strombus alatus</i>	4,735 ± 115	5,004±299	4,704-5,302	Marine Mud	Otvos (1985)
43	SS-10	-18.47	<i>Cyrtopleura costata</i>	4,865 ± 175	5,153±407	4,768-5,581	Estuarine?	Otvos (1985)
44	SS-11	-21.20	Wood	8,800 ± 80	9,849±282	9,595-10,158	Estuarine	Otvos (1985)
45	SS-12	-19.68	<i>Mercenaria m. texana</i>	6,560 ± 95	7,070±210	6,847-7,266	Sand Sheet	Otvos (1985)
46	SS-12	-21.20	<i>Mercenaria campechiensis</i> _b	6,400 ± 75	6,879±203	6,686-7,092	Flood Tidal Delta	Otvos (1985)
47	MS-9	-7.12	Peat	6,590 ± 60	7,491±80	7,420-7,580	Marsh	Hummel and Parker (1995)
48	MS-11	-7.57	Organic Sediment	6,040 ± 150	6,905±359	6,544-7,261	Marsh	Hummel and Parker (1995)
49	MS-13	-4.54	Wood (root)	6,860 ± 100	7,710±157	7,565-7,878	Estuarine/Delta	Hummel and Parker (1995)
50	MS-14	-6.06	Peat	6,190 ± 80	7,086±191	6,887-7,269	Marsh	Hummel and Parker (1995)
51	MS-15	-3.85	Oyster Shell	3,700 ± 60	3,618±169	3,460-3,798	Oyster Biostrome	Hummel and Parker (1995)
52	MS-24	-4.15	Oyster Shell	3,570 ± 70	3,465±172	3,301-3,644	Oyster Biostrome	Hummel and Parker (1995)
53	MS-25	-3.82	Oyster Shell	2,690 ± 60	2,401±193	2,262-2,648	Oyster Biostrome	Hummel and Parker (1995)
54	MS-27	-2.48	Wood	4,020 ± 110	4,512±300	4,230-4,830	Estuarine	Hummel and Parker (1995)

Table 2 Continued

Study ID	Core ID	El. (msl)	Material Dated	C ¹⁴ Age	Median $\pm$ Cal. 2 σ Age (yrs BP)	Cal. 2 σ Age Range (yrs BP)	Facies	Citation
55	MS-28	-1.64	Oyster Shell	710 $\pm$ 60	359 $\pm$ 108	257-473	Oyster biostrome	Hummel and Parker (1995)
56	MS-28	-4.27	Wood	19,540 $\pm$ 220	2,3531 $\pm$ 539	22,972-24,049	MIS2 alluvial	Hummel and Parker (1995)
57	MS-29	-5.03	Oyster Shell	3,900 $\pm$ 80	3,877 $\pm$ 225	3,644-4,093	Estuarine	Hummel and Parker (1995)
58	MS-04-1	-7.76	<i>Probythenella lousiana</i>	4,030 $\pm$ 30	4,046 $\pm$ 112	3,935-4,159	Estuarine	Greene et al. (2007)
59	MS-04-1	-8.66	Wood*	>48,000	-	-	MIS2 alluvial/estuarine	Greene et al. (2007)
60	MS-04-1	-10.52	Wood*	>48,000	-	-	MIS2 alluvial/estuarine	Greene et al. (2007)
61	MS-04-4	-5.91	Peat	5,470 $\pm$ 50	6,272 $\pm$ 106	6,184-6,396	Marsh	Greene et al. (2007)
62	MS-04-5	-12.58	Wood*	38,400 $\pm$ 330	42,475 $\pm$ 460	42,017-42,937	MIS2 alluvial/estuarine	Greene et al. (2007)

Recalibrated, previously published radiocarbon dates from the study area. Marine samples were calibrated using the Marine13 curve (Reimer et al. 2013), Terrestrial samples (peat and wood) were calibrated using the Intcal13 curve (Reimer et al. 2013). No local reservoir corrections were made. a notes previously reported reworked samples, b notes previously reported contaminated age samples, and * notes sample beyond radiocarbon detection limit. Elevation is in meters referenced to sea level. All dates discussed in text are reported in years before present (BP, present being 1950 CE) median calendar ages with associated two sigma ranges.

Table 3 Lithofacies Summary Table

Interpreted Facies	Sedimentology	Macrofossils	Seismic Facies Characteristics	Geophysical Example	Facies Association (Overlies: Lateral: Bounding Surfaces)
Sand Ridge (Modern)	Tan to dark gray, massive to planar laminated M-C sand, graded shelly beds/base, few mud filled burrows. Sharp basal lag 1	Echoid spines, sand dollar frag, heavily fragmented bivalves and gastropods 1, 2	Low to med amplitude, low frequency, transparent to dipping reflectors. Mounded external geometry with erosional base 3, 4		Sand Sheet, Inner Shelf Mud, Upper/ Lower Shoreface :: Sand Sheet, Inner Shelf Mud, Ebb Tidal Delta :: sRs
Sand Sheet (Modern)	Tan, massive to crudely planar laminated, F-M shelly quartz sand, some mud filled burrows. Sharp lag at base 1, 5	Sand dollar, <i>Atrina serrata</i> , <i>Parvilucina multilineata</i> , <i>Dosinia discus</i> , <i>Gemma</i> sp., <i>Strombus alatus</i> , <i>Chione</i> sp., <i>Anadara</i> sp. 2	Low to med amplitude, low frequency parallel to sub parallel sheet like reflectors 3, 4		Inner Shelf Mud, Ebb tidal or Estuarine Deposits :: Inner Sand Sheet, Ebb tidal Delta :: wRs
Inner Shelf Muds	Greenish gray, massive bioturbated clean to sandy muds, low organic content 6	<i>Dosinia discus</i> , <i>Gemma Gemma</i> , <i>Chione cancellata</i> , <i>Mercenaria mercenaria</i> , <i>corbula</i> sp., <i>anadara transversa</i> , <i>noelia ponderosa</i> 2	Wavy/horizontal parallel reflectors or transparent. Sheet drape or basin/channel fill like, onlapping ext. geometry 6		Sand Sheet, Ebb Tidal Delta, Estuarine :: Shoreface, Ebb Tidal Delta, Sand Sheet :: wRS
Barrier System (Modern)	Washover- Light gray massive to planar laminated sands, interbedded sands and muds. Dune-well sorted F-VF rooted cross bedded sands 7	<i>Donax</i> sp., <i>Mulinia lateralis</i> , <i>Lucina multilineata</i> , <i>Cyclinella tenuis</i> , <i>Dosinia discus</i> 2	Med amplitude, semi parallel to chaotic reflectors (backbarrier sands). Incisional channels truncate this deposit and sigmoidal dipping reflectors 7		Flood Tidal Delta, Marsh, Estuarine, MIS 2 SB, Barrier Spit :: Flood and Ebb Tidal Deltas, Shoreface, Estuarine, Marsh :: bRs, tRs, and/or TS
Upper / Lower Shoreface	Gray-tan, sometimes interbedded mud and sand, clayey sand, sand and clay pockets, muddy sand dominated upper shoreface and mud dominated lower shoreface, wood, rip up clasts, peat balls, wood and plant material, sand and mud filled burrows. Sharp to gradational base 8	<i>Donax</i> sp., <i>Dosinia discus</i> , <i>Spisula solidissima</i> / <i>Dioncardium robustum</i> , <i>Oliva sayana</i> , <i>Chione cancellata</i> , <i>Anadara transversa</i> , <i>Anadara orvalis</i> , <i>Mulinia lateralis</i> , <i>Gemma</i> sp., <i>Raeta plicatella</i> , <i>Mercenaria mercenaria</i> , <i>Strombus alatus</i> 2	Low to med amplitude, med frequency, semi laminated reflectors. Sheet or wedge ext. geometry 8		Estuarine, Flood(?) and Ebb Tidal Delta, Marsh, MIS 2 SB :: Barrier/ Barrier spit, Ebb Tidal Delta, Inner Shelf muds, Sand Ridge, Sand Sheet :: tRs, wRs, TS
Ebb Tidal Delta (Modern)	Dark gray to gray, well sorted f sands with large shell fragments cross stratification to laminated, some mud ripples, sand and mud pockets, abundant abraded shell fragments, minor sand filled burrows increasing at distal extents. Erosional sharp base 5, 9, 10	<i>Megapitaria maculata</i> , <i>Parvilucina multilineata</i> , <i>Chione cancellata</i> , <i>Cyclinella tenuis</i> , <i>Mulinia lateralis</i> , <i>Lucina amiantus</i> , <i>Lucina crenella</i> , <i>Raeta plicatella</i> 2	Low angle, seaward dipping oblique reflectors. Poor-moderately continuous. Downlap underlying surface. Slight erosive base. Basin fill or lobate ext. geometry 9, 10		Estuarine, Shoreface, MIS 2 SB :: Shoreface, Sand Sheet, Inner Shelf Muds, Sand Ridge :: tRs, TS
Tidal Inlet/ Barrier Spit	Inlet- gray, massive to cross bedded (planar and trough) quartz sands near base, coarse abraded shell lag at base, grainsize and structure fining upwards. Spit- low angle planar cross bedded (wedge sets) with parallel laminations of shell and F-M Sand 7, 10, 13	<i>Parvilucina multilineata</i> , <i>Abra aequalis</i> , <i>Cyclinella tenuis</i> , <i>Mulinia lateralis</i> , <i>Mercenaria mercenaria</i> , <i>Lucina amiantus</i> , <i>Lucina crenella</i> , <i>Raeta plicatella</i> , <i>Anadara transversa</i> 2	Unidirectional, sigmoidal dipping reflectors, erosive base. Cut and fill, laterally accreting geometry 7, 10, 13		Estuarine, Shoreface, Barrier, Barrier Spit, Flood and Ebb Tidal Delta :: Barrier Spit, Ebb and Flood Tidal Delta, Estuarine, and Shoreface :: tRs, TS
Flood Tidal Delta	Brownish gray, laminated to massive silty VF- F sand, some mud ripples, sand and mud couplets, abundant abraded shell fragments, minor sand filled burrows. Erosional sharp base 5, 9	<i>Lucina crenella</i> , <i>Chione cancellata</i> 2	Dip: low angle, landward bidirectional dipping oblique reflectors.Strike: horizontal lobate feature. Poorly continuous. lobate ext. geometry (Simms etal 2010). Proximal to inlet: channel stacking, cut and fill and lateral accretion. Slight erosive base 9, 10		Estuarine, MIS 2 SB :: Shoreface, Sand Sheet, Inner Shelf Muds, Sand Ridge :: tRs, TS
Estuarine Deposits	Gray, laminated or heavily bioturbated organic silty clay. Some silty sand and sandy silt layers, lenticular bedding, sand and mud pockets. Sandier near its perimeter. Articulated mollusk and gastropod shells, shell and wood frag, mod sand and mud burrows 3, 5, 11, 12	<i>Rangia cuneata</i> , <i>Rangia flexuosa</i> , <i>Polymesoda caroliniana</i> , <i>Macoma mitchelli</i> / <i>Crassostrea virginica</i> , <i>Nucula acuta</i> , <i>Nucula conctrirca</i> , <i>Tagelus plebeius</i> , <i>Ensis minor</i> / <i>Abra aequalis</i> , <i>Corbula contracta</i> , <i>Parvilucina multilineata</i> , <i>Cyclinella tenuis</i> , <i>Mulinia lateralis</i> , <i>Chione cancellata</i> 2	Wavy/horizontal parallel reflectors or transparent. Sheet drape or basin/channel fill like, onlapping ext. geometry 3, 5, 11, 12		Fluvial Lateral Accretion Deposits, Fluvial Channel Sands, Marsh, Oyster Biostrome, Flood Tidal Delta :: Flood Tidal Delta, Barrier/ Barrier Spit, Fluvial Lateral Accretion Deposits :: (within valley fill) tRs, wRs, above, TS below. (MS Sound) bRs above, TS below
Oyster Biostrome	Non-cemented, articulated shells beds and inarticulated shells, framework supported with matrix of muddy sand and sand 11	<i>Crassostrea virginica</i> , <i>Brachidontes recurvus</i> / <i>Anomia simplex</i> , <i>Brachidontes exustus</i> , <i>Ostrea equestris</i> 2	Mounded reflectors low continuity, onlapping proximal reflectors 14		Fluvial Lateral Accretion Deposits, Estuarine :: Conformable
Marsh	Brown to dark gray peat or rooted zones, organic silty sand matrix, mottled coloration, mud filled burrows 11	<i>Geukensia demissa</i> , <i>Littorina irrorta</i> (minor) 2	Wavy parallel reflects. Gas masking low continuity Sheet drape ext. geometry 12		Estuarine, Barrier/ Barrier Spit, Fluvial Lateral Accretion Deposits, MIS 2 SB, Fluvial Lateral Accretion Deposits :: Estuarine, Fluvial Lateral Accretion Deposits, Barrier :: TS, bRs
Fluvial/Lateral Accretion Deposits	Tan, white clean M-F sands 1, 6, gray, dark greenish gray clay to organic rich olive gray med to fine massive sand to thinly laminated clayey sand, shell hash, common wood frag, minor bioturbation sand filled burrows. Coarsening upwards sequence 12	Absent of shells to <i>Rangia cuneata</i> , <i>Rangia flexuosa</i> , <i>Tagelus plebeius</i> , <i>Macoma mitchelli</i> 2	Dipping reflectors, prograding into valley 6 Toplapping semi horizontal reflectors in upper section. Slight erosive base. Basin or channel fill ext. geometry 3, 6, 12		MIS 2 SB, Fluvial Channel Sands :: Estuarine, Fluvial Lateral Accretion Deposits :: SB below, TS above
Fluvial Channel Sands	Tan, white mod muddy sands, sands, and gravels with unidirectional, high angle cross strat. heavy mineral grains 1	<i>Rangia cuneata</i> (proximal to estuary), <i>Rangia flexuosa</i> 2	Chaotic to transparent or dipping oblique reflectors. Channel fill geometry 4, 6		MIS 2 SB, Fluvial Channel Sands :: MIS 2 ::SB below, TS above
MIS 2 and older	Stiff, oxidized, yellowish orange, brown and greenish gray clayey sand, sandy clay, clay, burrows, some to absent shells, plant material common, paleosol development 5, 6, 8, 11, 12	Estuarine, deltaic, fluvial alluvial assemblages	Continuous reflector boundary, erosional with variable configurations below. Reflectors onlap this surface 12		Underlies MIS2 SB

Lithofacies and bounding surfaces group results summary. Facies descriptions (bold numbers) were based on the following studies: 1 Parker et al. (1993), 2 Parker (1960), 3 Flocks (2015), 4 Goff et al. (2014), 5 McBride et al. (1991), 6 Thomas and Anderson (1994), 7 Moslow and Tye (1985), 8 Rodriguez et al. (2001), 9 Sirigan and Anderson (1993), 10 Miner et al. (2009), 11 Hummel and Parker (1996), 12 Greene et al. (2007), 13 Simms et al. (2006), 14 Goff et al. (2015). SB=Sequence Boundary, TS= Transgressive Surface, tRs=Tidal Ravinement Surface, wRs Wave Ravinement Surface, bRs= Bay Ravinement Surface, sRS=Sand Ridge Ravinement Surface.

4.1.1 Sequence Boundary 1: Marine Isotope Stage 6

Sequence Boundary 1 (SB1) is characterized by a medium to high amplitude, semi to highly continuous reflector and was mapped 10-45 mbsl (4-25 meters below seafloor (mbsf)). This surface is characterized by incisional channel features that truncate underlying reflectors below with onlapping reflectors above. SB1 likely represents an earlier exposure surface associated with the MIS 6 lowstand (Figure 2 and 5). The larger, wider valleys associated with this lowstand boundary are truncated by another regional sequence boundary (SB2) south of Horn Island Pass. Four dated samples from this stratigraphically deeper valley surface were beyond the radiocarbon detection limit (Table 1 and 2, sample 5, 6, 7 and 62) so an absolute age constraint is lacking. However, the ages pre-date the MIS 2 lowstand. Previous studies working in the area have reported the presence of a similar Pre-MIS 2 surface (Greene et al. 2007, Gonzalez et al. 2017). Roberts et al. (2004) dates the shelf edge Lagniappe Delta to be of MIS 6 or 8 age.

Modern Lidar (NOAA 2007, 2009) shows a large valley updip in the Grand Bay area correlating to the mapped SB1 valley (Figure 1 and 5). According to Otvos (2001) the valley is filled with Prairie Formation alluvial deposits (Figure 3). Otvos (2005) dated the Prairie Formation fill to be ~120ka, which suggests the valley is at least this old. Based on sequence stratigraphy, the most recent lowstand (MIS 6) before MIS 5 produced this valley (Green et al. 2007). Without an absolute age and based on these arguments we assume SB1 represents the MIS 6 lowstand.

Figure 5 MIS 6 and MIS 2 Surfaces

The MIS 6 and MIS 2 lowstand sequence boundary interpolated surfaces overlain with the 2007 and 2009 composite DEM. Interpolated surface elevation represents meters below sea level (MBSL) and DEM elevations represent meters above sea level (MASL).

4.1.2 Sequence Boundary 2: Marine Isotope Stage 2

Sequence boundary 2 (SB2) is characterized by a low to high amplitude, semi to highly continuous reflector, mapped 3-30 mbsl (0-15m mbsf). Flocks (2015) similarly noted this regional horizon (SB2) truncates SB1, supporting our interpretation that SB2 is indeed younger based on cross cutting relationships (Figure 6 and 7). Radiocarbon samples directly overlying SB2 are Holocene age (Table 2, sample 35, 37, 44). This time-transgressive surface represents the most recent lowstand sequence boundary during the Last Glacial Maximum (MIS 2) (Figure 2 and 5), uncomfortably separating Holocene from Pleistocene units below.

4.1.3 Unit 1: Pleistocene

Unit 1 is characterized in sediment cores by indurated, oxidized, mottled yellowish orange, brown gray and greenish grey clays and sandy clays (Figure 8, 9, 10). Paleosol development characterized by oxidized or weathering coloration is common, and represents subaerial exposure processes. Root horizons are fairly common directly overlying this unit indicating this was a vegetated area (Figure 10). This mottled oxidized section is usually found within the upper meter below this contact and not found in all areas, indicating it was either eroded during transgression or located in a subaqueous environment such as a fluvial setting. Cores penetrating unit 1 are characterized by clayey sand to sandy clay to clay deposits with sand and mud filled burrows common near the upper contact. Shell and plant material range from common to absent throughout the entire unit. This unit represents various Pre-Holocene coastal plain deposits from marine through fluvial alluvial facies (Figure 6, 7, 8) (Hummel and Parker 1995, Kramer 1990, Otvos 1981, 1985) that have been correlated to updip formations mapped by Otvos

(2001) in certain locations (Otvos 1985, 1986). Complete delineation of these formations on the inner shelf is beyond the scope of this study.

Unit 1 has variable reflector configurations and is bound by the incisional Surface 1 and 2 in the lower sequence, and the incisional Surface 2 and the Holocene transgressive ravinement surface in the upper sequence (Figure 6, 7, 8).

4.1.4 Unit 2: Fluvial Channel Sands Deposits

Unit 2 consists of tan to white, moderately to poorly sorted fine to gravelly, unidirectional, high angle cross-stratified sands (Parker et al. 1993). Sand sized heavy minerals were also reported. Shells were absent or minimal. Interstate-10 bridge borings (Burns Cooley Dennis Inc., 2016) in the updip section of the Pascagoula River (Figure 1) display correlative 7-16m thick sand deposits matching depths of channel sand packages found in seismic.

Unit 2 is characterized by medium to high amplitude low frequency, chaotic to transparent reflectors with channel fill geometry, which is similar to other work in Florida and Texas (Goff et al. 2014, Thomas and Anderson 1994). This unit was difficult to geophysically image due to its depth in record and mostly homogenous nature. This unit is interpreted as fluvial channel fill sands. Surface 2 and the Holocene transgressive ravinement surface bound the channel fill sands.

4.1.5 Unit 3: Fluvial Lateral Accretion Deposits

Unit 3 is sparsely sampled and only represents the very upper section of the deposit. Cores consist of interbedded grayish brown, medium to fine sands and olive-gray muds to tan well sorted, medium to fine sands (Figure 6, 8). Where described, shell content was minimal throughout the deposit (Kelso and Flocks 2015). Sand and mud

filled burrows, as well as wood fragments are common. The few core samples make interpreting between fluvial bar and bayhead delta deposits difficult.

Unit 3 is characterized by low to medium amplitude, medium frequency, steeply dipping oblique or prograding reflectors into the incised valley. In some cases, there is a central mounded feature with opposite dipping reflectors or top lapping horizontal low amplitude reflectors in the upper sections similar to descriptions by other authors (Flocks 2015, Greene et al. 2007, Bartek et al. 2004, Thomas and Anderson 1994). This unit has either basin or channel fill external geometry and is interpreted generally as fluvial lateral accretion deposits. This implies higher sand content type deposits such as fluvial bars or portions of bayhead deltas.

4.1.6 Unit 4: Marsh Deposits

Unit 4 consists of humate brown to dark gray peat or rooted zones in a poorly sorted silty sand matrix. Shells are mostly absent, and the sediment is mottled with mud filled burrows (Hummel and Parker 1995). Heavy organic beds are common. This unit was sampled on the flanks within incisional valley features on the inner shelf, and within eastern Mississippi Sound.

Where submerged, unit 4 was 0.2-0.6m thick and usually is associated with gas pockets, making it difficult to image in geophysical data (Zaremba et al. 2016). This unit is interpreted as saltmarsh deposits and usually directly overlies Pleistocene deposits, except in backbarrier and bay margin environments (Figure 10). Otvos (1986) reports brackish muddy sediments from the same horizon. This unit was constrained from ~7,500-6,300 BP (Table 2, sample 47, 50, 61).

4.1.7 Unit 5: Oyster Biostrome

Unit 5 consists of articulated and unarticulated shell beds in a framework supported matrix of muddy sand and sand. These deposits are not oyster reefs according to Hummel and Parker (1995). This 0.2-0.8m thick unit consisted mostly of *Crassostrea virginica* (10-30 psu) with sparse *Ostrea equestris* (>30 psu) (Parker 1960). The deposit sampled by Hummel and Parker (1995) within eastern Mississippi Sound was dominated by *Crassostrea virginica*, which prefer water depths of about 2.5 m (Parker 1960).

Unit 5 is characterized by high amplitude, mounded to transparent reflectors, with parabolic to chaotic signal masking below similar to Goff et al. (2015) in Corpus Christi Bay, TX. Due to its relatively small spatial extent it was difficult to image but was only found in Pass Aux Heron in eastern Mississippi Sound. This unit was interpreted as an oyster biostrome and formed 3,900 BP (Table 2, sample 57).

4.1.8 Unit 6: Estuarine Deposits

Unit 6 consists of light to dark gray-brown, laminated to heavily bioturbated organic silty clay and muddy sands. Some silty sand and sandy silt layers, lenticular bedding, sand/mud pockets and burrows are also found (Greene et al. 2007, Hummel and Parker 1995, Flocks 2015, McBride et al. 1991) (Figure 9, 10). Articulated mollusk and gastropod shells, as well as shell and wood fragments, are common (Figure 7). This layer can be highly mottled. This 0.5-7m thick unit was found largely in Mississippi Sound within incisional features identified in geophysical data.

Unit 6 is characterized by low to high amplitude, high frequency, wavy to parallel reflectors but can also be transparent. This unit has sheet drape, basin or channel fill, onlapping external geometry, similar to other studies in the area (Flocks 2015, Greene et

al. 2007). This unit was interpreted as estuarine deposits of ranging salinities, encompassing the enclosed bay, upper bay, open bay and open bay margin facies of Parker (1960) based on mollusk assemblages. Estuarine deposition started 9,800 BP (Table 2, sample 44), reflecting differences in early valley flooding versus recent deposition within Mississippi Sound (Figure 11).

4.1.9 Unit 7: Tidal Inlet Fill or Barrier Spit

Unit 7 consists of grayish brown muddy sand grading to massive fine shelly sand with rare flaser beds. The unit fines upwards to lenticular-bedded clay and muddy fine sand with rare shell fragments and bedded organics, similar to authors in LA, NC/SC, TX (Miner et al. 2009, Moslow and Tye 1985, Simms et al. 2006). This 1.5-3m thick, unit was mostly found landward of Petit Bois Island.

Unit 7 is characterized by low to medium amplitude, laminated to transparent reflectors in the upper section with fill or laterally prograding accreting geometry and a chaotic base (Miner et al. 2009). This unit was interpreted to be tidal inlet fill and first dated to ~7,200 BP (Table 2, sample 28). Inlet fill and spit accretion is also evident from modern deposits from historical charts (Morton 2008, Buster and Morton. 2011).

4.1.10 Unit 8: Flood Tidal Delta Deposits

Unit 8 consists of brownish gray, laminated to massive silty to very fine-fine sand with some faint multi directional cross stratification and dipping beds (McBride et al. 1991, Siringan and Anderson 1993). There were abundant shell fragment layers and moderate sand filled borrows. This 1-4m thick unit was mostly found in the modern tidal inlets (Main Pass (Mobile Bay), Petit Bois Pass, Horn Island Pass) landward of Petit Bois and Horn Islands (Figure 1). Unit 8 is occasionally preserved offshore within valleys.

Unit 8 is characterized by low to medium amplitude, medium frequency, low to medium angled, landward dipping, oblique reflectors. In a strike view the reflectors are horizontally laminated in a lobate geometry. These reflectors downlap underlying surfaces and show a slight erosive base. This unit has basin fill or lobate external geometry (Miner et al. 2009, Siringan and Anderson 1993), interpreted as flood tidal delta deposits. It was constrained to ~1850 CE to modern from historical charts (Buster and Morton 2011) and radiocarbon dates from landward of Petit Bois at 2,300 BP (Table 1, sample 9) and Dauphin at 4,000 BP (Table 1, sample 16) (Figure 9, 10).

4.1.11 Unit 9: Ebb Tidal Delta Deposits (Modern)

Unit 9 is similar to unit 8 except it is coarser grained and displays more sand dominated dark gray, well sorted fine to medium, cross stratified to massive sands with abundant, large shell fragments (McBride et al. 1991, Miner et al. 2009, Siringan and Anderson 1993). Sand filled burrows are more prevalent at distal ends of the ebb tidal delta.

Unit 9 is characterized by seaward dipping reflectors organized in a lobate geometry (Miner et al. 2009, Siringan and Anderson 1993). This unit is interpreted as ebb tidal delta deposits and was only found seaward of modern passes and was not recognized in paleoenvironments. Time-series historical charts show evidence of wave modification, tidal inlet lateral migration, and tidal inlet throat avulsions (Morton 2008, Buster and Morton 2011, Byrnes et al. 2013).

4.1.12 Unit 10: Shoreface Deposits

Unit 10 consists of light to dark gray and tan poorly sorted, sometimes interbedded sands and muds, and muddy sands with sand and clay lenticular beds. The

upper section has higher sand content with few mud beds and *Donax* sp. shells. It becomes more mud dominated with few, thin sand beds down section (Figure 8, 9, 10) similar to the description of Rodriguez (2001) along the Texas coast. There is an increase in mottling, likely due to bioturbation in the seaward distal sections. This unit also contains wood and shell fragments; clay rip up clasts, peat balls, and sand and mud filled burrows (Rodriguez et al. 2001). This 0.5-3m thick deposit was found flanking the modern islands.

Unit 10 is characterized by low to medium amplitude, medium frequency semi-laminated or transparent reflectors (Rodriguez et al. 2001). It has sheet drape or wedge external geometry. Due to its relatively thin nature it is sometimes difficult to distinguish from the seafloor in geophysical data. This unit is interpreted as the upper and lower shoreface and has been constrained geologically to 7,000 to 1,800 BP (Table 1, sample 1, 2, 3). Shoreface deposits are also present in modern environments.

4.1.13 Unit 11: Barrier and Backbarrier Deposits

Two sub-units characterize unit 11. Sub-unit 1 consists of light gray to white massive to planar laminated and cross-laminated bedding of fine to medium quartz sand. This sub-unit also has shell hash layers, detrital organics, peat rip-up clasts, wood fragments, roots traces and sand and mud filled burrows (Otvos 1981, Moslow and Tye 1985). These 3-14m thick sands comprise the islands. Sub-unit 1 is interpreted as barrier lithosome sands consisting of dune and shore facies.

Sub-unit 2 consists of light gray, massive to horizontal and slightly dipping planar laminated muddy sands, with some interbedded sands and muds. This 0.5-2m thick, sub-unit has many fining upward sequences and is found on the backside of the barrier

islands. Medium amplitude and frequency, semi-parallel, massive and chaotic reflectors with a lobate or sheet external geometry characterize the subaqueous portion of sub-unit

2. Sub-unit 2 is interpreted as backbarrier overwash deposits.

4.1.14 Unit 12: Marine Surficial (MAFLA) Sand Sheet

Unit 12 is composed of tan, massive to crudely planar laminated, fine muddy, shelly quartz sand with some sand and mud filled burrows. It has a sharp basal lag (McBride et al. 1991, Parker et al. 1993).

This 0.5-1.5m thick unit is characterized by low to medium amplitude, low frequency, parallel to sub parallel reflectors with a sheet like external geometry (Figure 7, 8) similar to that described in Flocks (2015). Due to the thickness and homogeneity, it is difficult to image in geophysical data. This unit is found throughout the inner shelf from mid Petit Bois eastward and is interpreted as the Mississippi Alabama Florida (MAFLA) sand sheet, which reflects modern shelf current reworking.

4.1.15 Unit 13: Sand Ridge Deposit

Unit 13 consists of tan to dark gray, massive to planar laminated, medium to coarse sand, with echinoid spines and a graded shell uppermost section and base (Flocks 2015, McBride et al. 1991, Parker et al. 1993, Goff et al. 2014). This 1-6m thick unit, is found offshore of Petit Bois, Petit Bois Pass, and seaward of Main Pass (Figure 1, 6).

Unit 13 is characterized by low to medium amplitude, low frequency, parallel to sub parallel reflectors, with a slightly erosional basal reflector (Flocks 2015, Goff et al. 2014). This unit has a shore oblique ridge external geometry (Figure 6). Due to homogeneity, it is difficult to image internal structure. Unit 13 is interpreted as modern

shore oblique attached and detached sand ridges of varying sizes, reworked by modern shelf currents.

4.1.16 Unit 14: Inner Shelf Mud Deposit

Unit 14 is composed of greenish- gray bioturbated clean to sandy muds with lower organic content (Thomas and Anderson 1994, Otvos 1981). Marine fossil assemblages and stratigraphic relationships are needed to identify this deposit (Otvos 1981). In seismic it is characterized by wavy or horizontal parallel reflectors or is acoustically transparent, which makes it is indistinguishable from estuarine deposits based on seismic alone (Figure 6) (Thomas and Anderson 1994). This 0.1-2m thick unit is interpreted as inner shelf marine muds.

4.1.17 Unconformity 1: Transgressive Surface (TS)

This erosional boundary represents the unconformable separation of lowstand deposits such as fluvial channel fill or alluvium from estuarine or marine deposits above (Figure 6, 7, 8). It is a regionally continuous surface that usually becomes amalgamated with ravinement surfaces in interfluvial areas. It is interpreted as the transgressive surface (TS) (Cattaneo and Steel 2003).

4.1.18 Unconformity 2: Wave Ravinement Surface (wRs)

This erosional boundary represents the separation of estuarine to alluvial sediments and marine sediments (Figure 6, 7, 8). It is usually a high amplitude continuous reflector and consists of a coarse shell lag layer in most cases except in paleovalleys. It may be amalgamated with the transgressive or tidal ravinement surface. This surface is interpreted as the wave ravinement surface (wRs) (Cattaneo and Steel 2003), similar to the shoreface ravinement surface in other studies (Rodriguez et al.

2001). Its depth varies within the study site. Bathymetric estimates for the toe of the shoreface are estimated from a break in slope at about 9-10mbsl. This is confirmed through seismic and core data showing a wave ravinement surface between 7-10mbsl represented by thick shell hash, marine muds or shelly inner shelf sand sheet deposits onlapping muddy shoreface sands or exposed Pre-Holocene deposits. It defines the seaward extent of the active barrier system for this study.

4.1.19 Unconformity 3: Tidal Ravinement Surface (tRs)

This erosional boundary represents the separation of alluvial and estuarine deposits below and tidal deposits above (Figure 6, 7, 8). It was found in paleovalleys, the inner shelf and underlying Dauphin and Petit Bois Island. It occurred below the wave ravinement surface in some cases and may be amalgamated with the transgressive surface, such as in the backbarrier. It is usually represented by a coarser grained shell lag layer with an erosional base and is associated with tidal deposits. This is interpreted as the tidal ravinement surface (tRs) (Cattaneo and Steel 2003).

4.1.20 Unconformity 4: Bay Ravinement Surface (bRs)

This erosional boundary represents the separation of alluvial and tidal deposits from estuarine deposits. It is constrained to within Mississippi Sound, eroding Pleistocene unit interfluvial locations and occasionally within fluvial valleys. This boundary is interpreted as the bay ravinement surface (bRs) (Cattaneo and Steel 2003) and represents lower energy wave base erosion relative to open Gulf conditions. This surface can be very difficult to identify in MS Sound if the surface is truncating other estuarine deposits (Greene et al. 2007).

Figure 6 Truncation of MIS 6 Valley Fill

Uninterpreted and interpreted SB-512i chirp profiles (A and B). The MIS 6 and MIS 2 sequence boundaries are shown in red. Ravinement surfaces shown in white unless amalgamated with sequence boundaries. Areal extents of truncated MIS 6 deposits (C) overlain with MIS 6 surface and modern DEM (NOAA 2007, 2009). Clinoform strike and dip estimates are represented by geologic indicators (grey) inferred from 2D seismic at varying orientations. Figure location found in figure 1 and 6C.

4.1.21 Unconformity 5: Sand Ridge Ravinement Surface (sRs)

This erosional boundary represents the separation of sand ridge deposits from highly variable underlying deposits. This surface was interpreted as the sand ridge ravinement surface (sRs) and represents the basal scour erosion from large-scale bedform migration (Goff et al. 2014).

4.2 Antecedent Topography and Paleofluvial systems

4.2.1 Sequence Boundary 1: MIS 6 Surface

4.2.1.1 Fowl and La Batre Systems

The Fowl River valley is a 0.5-1km wide and 20-25 mbsl, seaward bifurcating system with a series of smaller tributary drainages (Figure 5). These features are mapped below the shoreface of western Dauphin Island and likely connect with the Pascagoula/Escatawpa valley to the southwest although data density offshore of Dauphin Island is relatively low. A small, narrow, 20-25 mbsl, bifurcation of the Western Mobile Valley system incises Pass Aux Herons (Greene et al. 2007, Hummel and Parker 1995). Mapping of these valley systems further offshore Dauphin Island is difficult due to spacing resolution of available archive data. Paleohighs separating fluvial incisions were also mapped similar to Greene et al. (2007). There is a thin, likely alluvial, depositional package (~2-5m) separating sequence boundary 1 and 2 on the interfluves (MIS 6 and MIS 2).

Valley fill reported by Greene et al. (2007) consists of sequential fluvial/ alluvial deposits with overlying bayhead delta deposits in the Fowl system and only bayhead delta fill in the La Batre system. The La Batre bayhead delta valley fill is older than MIS 2 interpreted based on two radiocarbon-dead (>48,000 BP) wood samples within this

deposit (Greene et al. 2007). Rindsberg (1992) reports detailed fossil assemblages that could point towards an ancient delta lobe in the area but it occurs below the MIS 2 unconformity (Hummel and Parker 1995) that is believed to be the same MIS 6 feature.

4.2.1.2 Escatawpa/Pascagoula

The Pascagoula/Escatawpa River valley is a 5-10km wide and 25-38 mbsl seaward widening terraced system (Figure 5a). Similar to the Fowl and La Batre systems, surrounding smaller drainages flow into the main valley trunk, and valley shoulders rise to within a few meters of sequence boundary 2 on the interfluvies. It flows under eastern Petit Bois, which is the “MIS 2” valley mapped by Flocks (2015) and the shallower terrace is the valley mapped by Twichell et al. (2011) offshore of Petit Bois Pass. When comparing the geomorphology of the sequence boundary 1 gridded surface with Lidar, valley width and orientation agree (Figure 5). The Lidar shows a bifurcation of valleys to the modern Pascagoula location and to the east towards Grand Bay (Figure 5). This location coincides with the Citronelle fault scarp orientation (Figure 3) (Otvos 1985). The valley fill is capped with Pleistocene Prairie Formation (MIS 5 deposits) alluvium, with Pliocene Citronelle deposits bounding this valley to the northeast (Figure 3).

The valley fill of the Pascagoula/Escatawpa system shows transparent to chaotic reflectors confined to the base of the valley (Figure 6) not directly sampled offshore. However, updip I-10 bridge (Figure 1) borings spanning this valley show a correlative 9m thick sand deposit at similar elevations (Burns Cooley Dennis Inc., 2016). In roughly 15-16m water depth, several, variable size sandy deposits were mapped within the valley. These consisted of oppositely dipping reflectors, which radiate in all directions from a central mounded feature. These steeply dipping reflectors become more gradual from the

center. Only a few cores penetrate the upper section of this deposit and show sands and interbedded sands and muds near the mounds, with more mud dominated deposits in distal sections (Figure 6). Based on these characteristics and the fact they are only found within this large valley, these features are interpreted as fluvial lateral accretion deposits. Seaward of Petit Bois, these fluvial/deltaic features are truncated by an erosional boundary interpreted as the Holocene transgressive ravinement surface (TS) (Figure 6). Within Mississippi Sound, thinly laminated- semi wavy parallel reflectors overly fluvial channel sands and are interpreted as estuarine or alluvial deposits. Greene et al. (2007) did not report a large MIS 6 Pascagoula/Escatawpa system. This could be a result of the limited western extent of their survey and the shallow geophysical data penetration of the 216s chirp compared to the boomer seismic data used in this study (Figure 4).

4.2.2 Sequence Boundary 2: MIS 2 Surface

4.2.2.1 MIS 2 Surface Gradient

Five mainland to backbarrier transects within MS Sound and five inner shelf transects measure the average slope of the MIS 2 surface within the study site. Transect locations focused on slope of interfluvial areas. The average slope of the MIS 2 surface within MS Sound is -0.069 m/km, ranging from -0.256 m/km (western study site) to 0.009 m/km (eastern study site). This reflects the southwest dip of the surface. The average slope of the inner shelf is -0.734 m/km, ranging from -0.867 m/km (western study site) to -0.663 m/km within the study site (eastern study site). The order of magnitude difference in MIS 2 interfluvial slope between Mississippi Sound and the Gulf of Mexico reflect a significant antecedent feature underlying the modern location of the MSAL barrier chain.

Figure 7 MIS 2 Pascagoula Valley Fill

Uninterpreted and interpreted seismic (A) and SB512i chirp lines (B). Seismic line 90KI2-9A(d) shows a much more complete strike orientation of the Pascagoula valley seaward of Horn Island Pass. Detailed interpretation of ravinement surfaces (white) are shown in Chirp line 13i052, which is slightly down dip from the seismic line. Line locations found in figure 1.

4.2.2.2 Fowl, La Batre, Escatawpa Systems

The Fowl incisional system is less than 1 km wide and incises to a depth of 10-14 mbsl (Figure 5b). The La Batre system is even smaller. Greene et al. (2007) reports a series of narrow tributaries incising to 16-17 mbsl but were not mapped since they were beyond the resolution of the survey. These incisional features are filled solely with clay and clayey sand, transparent to wavy parallel reflectors that are interpreted as estuarine deposits. Cores from Hummel and Parker (1995) describe thin peat horizons directly overlying the subaerially exposed MIS 2 sequence boundary (surface 2). A series of

anastomosing dendritic tributary/distributary channel networks was mapped in this study using additional geophysical data. The tributaries continue under the western portion of Dauphin Island (Fig. 5). Estuarine deposition filled these deeper tributary systems. A gently sloping peat facies within eastern Mississippi sound was constrained to roughly 7,500-6,200 BP (Table 2, sample 47, 48, 50, 61), which is consistent with sea level elevations during this period (Milliken et al. 2008).

The Escatawpa drainage system shows small tributary channels about 0.2-0.8 km wide that incise to a depth of 4-10 mbsl within Mississippi Sound. Mullenex (2013) shows a series of roughly 150m wide, roughly 2-6m deep “v” shaped MIS 2 channel incisions that extend into this study’s data coverage. The Escatawpa lacks a major confining MIS 2 valley (Kramer 1990, Mullenex 2013). The incisional geometries and geomorphologies match updip comparisons in Lidar (Figure 5). Kramer (1990) cores show relatively thin 1-2m thick, Holocene fluvial/deltaic sands interpreted as distributary mouth bars overlain by deltaic/ marsh facies proximally located to Grand Bay.

4.2.2.3 Pascagoula System

The Pascagoula system is 1-5km wide and incises to 15-25 mbsl, flowing south through Horn Island and Horn Island Pass. Several complex interfluvial drainage tributaries flow into the main valley trunk, but are difficult to map due to the geophysical data spacing resolution in Mississippi Sound. An interfluvial seaward of Petit Bois Island

Figure 8 Petit Bois and Dauphin Shoreface

Uninterpreted and interpreted shoreface chirp profiles from Petit Bois (09i021, top) and Dauphin Island (10i018, bottom) with sediment cores displaying a thin sandy shoreface and underlying Pleistocene deposits (Kelso and Flocks 2015, USACE 2014). Pleistocene fluvial lateral accretion deposits also shown in figure 6A and 10. Shoreface toe shown at ~7mbsl by exposed Pleistocene deposits (B). Location found in figure 1.

displays a series of ~200m wide, 25 mbsl southwestward draining tributaries coalescing at the main Pascagoula valley (Figure 5). Again, this is consistent with drainage networks

in terrestrial updip sections, especially in the Citronelle and Prairie Formations. A larger tributary drainage underlies the western portion of Petit Bois. Cores from the interfluvial areas and overlying portions of the MIS 6 valley show a shallow subaerially exposed surface (relative to the seafloor). Flocks (2015) shows the eastern valley (interpreted as the older, MIS 6 sequence in this study) reflector is truncated to the west by the MIS 2 Pascagoula valley (Figure 5).

Chirp data show fluvial channel sands at the base (6m), estuarine, and tidal deposits grading into 8m thick marine deposits, separated by a series of ravinement surfaces (Figure 7). Incorporating seismic data shows the rough base of the fluvial deposits, although no cores penetrate this layer offshore (Figure 7). Estuarine and marine muds are differentiated by the description of plant fragments and *Rangia* sp. shells at the base and an overlying layer with dated marine mollusks. Estuarine fill seaward of Horn Island Pass has been constrained to 9,800-5,100 BP (Otvos 1986) (Table 2, sample 43, 44).

In Mississippi Sound, the Pascagoula valley base is difficult to image. R/V Erda 92-4 cruise seismic data seaward of the modern Pascagoula rarely penetrates beyond 20-25 mbsl. Two I-10 bridge borings (Burns Cooley Dennis Inc., 2016) show 7-16m thick, medium to coarse sands at 8-12m below the surface overlying stiff or dense clays, which is interpreted as fluvial channel sands at the base of the Pascagoula valley (MIS 2). Up to 5m of thinly laminated, wavy parallel reflectors drape Mississippi Sound. This sandy mud and mud deposit is exposed at the seafloor and is interpreted as estuarine deposition. No tidal or fluvial deltaic valley fill was identified within the Mississippi Sound.

4.3 Sand Volume Calculations

Seven relatively large sandy fluvial or deltaic deposits were identified based on core and geophysical data within the study area, and all but one are located on the inner shelf (Figure 6). Based on a ravinement surface identified in geophysical data that truncates sandy deposits preserved on the shelf, sand scoured during the Holocene transgression could have supplied up to $306.7 \times 10^6 \text{ m}^3$ (Table 4). This is a conservative estimate based on the lower range of wave ravinement (7-10 mbsl) calculated in this study. This volume is limited to the sandy valley fill deposits and not the entire shelf. This represents about 60% of the sand volume of the active Petit Bois and Dauphin barrier platform and modern sand ridges and sand sheet (Table 4).

Table 4 Sand Source and Sink Volumes

Modern Sink Unit	Volume ($\times 10^6 \text{ m}^3$)	Ancient Source Unit	Reworked volume ($\times 10^6 \text{ m}^3$) (7m rav)
Sand Ridges	8.7*	Fluvial Deposit (2)	82.5
Inter Ridge area	9.4*	Fluvial Deposit (3)	33.0
Active Barrier System	455.0	Reworked FTD (4)	65.4
		Fluvial Deposit (5)	96.5
		Fluvial Deposit (6)	3.5
		Fluvial Deposit (7)	25.8
Total Sand Volume	473.1	Total Possible Reworked Sand Volume	306.7

Volumes for Holocene sink and reworked MIS 6 source units. * Notes volumes adopted from Flocks (2015), sand content estimated from cores. Reworked volumes calculated by multiplying preserved area and the depth of ravinement similar to Weight et al. 2011. Offshore source units correspond to figure 6c.

Figure 9 Petit Bois Shore Parallel Stratigraphic Cross Sections

Backbarrier, barrier, and shoreface cross sections, synthesizing marine vibracores (Kelso and Flocks 2015), Otvos (1979) rotary drill cores and dive assisted percussion core (this study). Core locations overlie MIS 2 sequence boundary surface. Core 10cct05-3 is shown in corresponding shoreface chirp line in figure (8). Facies interpretations aided by previous microfossil salinity data (Otvos 1979, 1985). See table 1 and 2 for radiocarbon details. b notes previously reported contaminated sample, * notes radiocarbon dead sample. Shoreface toe shown in core 10cct05-02 at ~10mbsl, onlapping marine muds to shoreface sand.

Figure 10 Dauphin Shore Parallel Stratigraphic Cross Sections

Backbarrier, barrier, and shoreface cross sections, synthesizing Otvos (1979) and Greene et al. (2007) rotary drill cores and vibracores (Hummel and Parker 1995, Hummel 1999, and references within). The core locations overlie the MIS2 sequence boundary surface. Facies interpretations were aided from previous microfossil salinity information (Otvos 1979). See table 1 and 2 for radiocarbon details. ^b Notes previously reported contaminated sample, * notes radiocarbon dead sample.

5-DISCUSSION

5.1 Pre-Holocene Antecedent Geology and Topography Influences

The different valley geometry, fill architecture and therefore sediment supply during transgression between the MIS 2 and MIS 6 valleys reflect different duration and magnitudes of sea level forcing mechanisms. The MIS 6 lowstand had more extreme base level fall for longer periods relative to MIS 2 (Shackelton 1987, 2000). In Texas and Louisiana, the MIS 6 valleys are much larger and have higher sediment loads compared to MIS 2 (Anderson et al. 2004). During the MIS 6 lowstand the large Pascagoula/Escatawpa river valley flowed through the Grand Bay area, depositing many sandy valley fill units that later would supply sand to the modern barrier island chain through transgressive ravinement (Figure 5 and 6). The terraced valley geometry increases preservation potential during the MIS 5 transgression (Rodriguez et al. 2008). Collectively, an estimated $183.4 \times 10^6 \text{m}^3$ of sand is contained within MIS 6 valley fill (bayhead delta and transgressive fill described in Flocks (2015)). The MIS 6 valley likely had a high sediment discharge based on the thick, acoustically transparent, channel sand package at the base of the valley just seaward of Grand Bay.

Sometime during or prior to the MIS 2 lowstand, the main Pascagoula River valley trunk avulsed to its western, modern outlet location (Figures 3 and 5). Smaller MIS 2 tributaries show fluvial reoccupation of MIS 6 valleys (Green et al. 2007). The MIS 2 surface dips to the southwest similar to previous studies (Kramer 1990, Greene et al. 2007, Ludwick 1964, Otvos 1985) likely due to sediment loading from the Mississippi River deltas. The modern day undammed Pascagoula shows large point bars updip, directly eroding the sandy Pliocene Citronelle Formation. It likely had a similar

meandering channel belt and point bar configuration down dip within the study site during the MIS 2 lowstand. Seaward of the islands, the thin preserved channel sands imply it was likely reworked during transgression (Figure 7). The shallow, wide valley geometry has little preservation potential during transgression (Rodriguez et al. 2008). Based on fill and valley geometries, the shallow eastern portion of Mississippi Sound is characterized by smaller, mud filled-anastomosing tributary drainages (Ndjorford et al. 2005, Greene et al. 2007) with little to no fluvial channel sands at the base. These tributary drainages likely supplied very little sand during the transgression.

Modern barrier chain geomorphology shows correlation to the MIS 2 or antecedent topographic surface, similar to other studies (Zaremba et al. 2016, Mallinson et al. 2010, Rodriguez et al. 2001, Browder and McNich 2006, Riggs et al. 1995). The MIS 2 surface shows a significant break in slope between the modern Mississippi Sound and the inner shelf. This gradient change aligns with the MIS 5e barrier trend between Dauphin and Fort Morgan, AL, and the modern day MSAL barrier chain. A break in slope was originally suggested to anchor the modern barriers but was never regionally mapped (McBride et al. 1991 and Otvos 1981) until now. The combination of decelerating sea level rise rates (Figure 2) intersecting the MIS 5e barrier section of Dauphin Island (Figure 3) and the MIS 2 gradient change (Figure 5) is responsible for the modern position of the MSAL chain.

MIS 2 valley location correlates with modern day points of weakness in the MSAL barrier chain (Figure 5), such as tidal inlets or areas of frequent storm breaching and overwash. Petit Bois Pass and Horn Island Pass overlie the large main MIS 2 Escatawpa tributary and Pascagoula valley, respectively (Figure 5). Katrina Cut in the

western spit of Dauphin Island overlies a smaller tributary channel. The storm breach separating East and West Ship Island, MS is also located at a paleodrainage location (Twichell et al. 2013). This is due to the wave and tidal erosion resistance variability between dense clay rich MIS 2 interfluvies and the less dense younger valley fill (Figure 8). Valleys can be sites of local subsidence as muddy fill compresses (Figure 10). Preexisting semi consolidated, sandy deposits likely offer little erosion variability compared to Holocene deposits.

5.2 Sediment Sourced through Transgressive Ravinement

Truncation of MIS 6 sand rich deposits was likely a major sediment source for the modern barrier island chain through transgressive ravinement (Table 4; Figure 6). Studies from glacial New England coastlines (Schwab et al. 2013) and other coastal plain settings in the Gulf of Mexico (Weight et al. 2011, Rodriguez et al. 2001, Wallace et al. 2010, Anderson et al. 2016 and references within) demonstrate the significance of stratigraphic framework and onshore transport of sands to modern barriers. Conservatively estimating the sand sourced from reworking of lowstand deposits could have supplied about 60% of the modern sinks (barrier platform, sand ridges and sand sheet). Once the sand was reworked, some of this volume was likely transported down drift to other islands in the chain. However, this reworked sand volume estimate is from only one valley. The change in MIS 2 gradient at the modern barrier chain is likely a result of wave ravinement variability. Bay ravinement is much less efficient due to reduced wave climate compared to the open Gulf (Cattaneo and Steel 2003). Paleochannels preserved in Mississippi Sound are completely truncated in the shoreface due to wave and tidal scour offshore of Horn Island Gal et al. (in prep). Entire sea level cycles are not preserved only 30km east

of the study site (Gonzalez et al. 2017). Offshore Fort Morgan, a preserved, radiocarbon dead (<40ka), late Pleistocene cypress forest underlies a thin post transgressive marine sediment package, representing a major unconformity (Gonzalez et al. 2017). The examples of transgressive ravinement presented in this study and others (Gal et al. in prep, Gonzalez et al. 2017) illustrates the importance of onshore sand transport to the modern MSAL barrier systems.

5.3 Holocene Transgressive Evolutionary Model

5.3.1 10ka-9ka Transgressing Shoals

According to the Milliken et al. (2008), sea level was about 16m below modern around 9ka (Figure 11) with RSLR rates around 9mm/yr (Anderson et al. 2016). Bayhead delta deposition started around 9.7ka in northern Mobile Bay (Greene et al. 2007). Mobile Bay transitioned from upland or marsh to an estuary between 9.2ka and 9ka (Greene et al. 2007, Metcalfe and Rodriguez 2003). Around this time, the Pascagoula valley transitioned from fluvial to estuarine dominated processes within the southern study site. This is demonstrated by a 9.8ka piece of wood from the base of a brackish sandy mud in core SS-11 offshore of Horn Island Pass (Otvos 1986) (Table 2, sample 44). Due to its wide, shallow natured geometry and low preservation of transgressive fill succession, it likely became a wave-dominated estuary. Fluvial sand transport to the coast ceased, and transgressive ravinement processes took over (Anderson et al., 2014), likely acting as a critical sediment source to the MSAL chain later on. Some form of physical barrier such as an ephemeral island or marine shoal seaward of this position (Figure 11) created the estuarine, brackish salinities reported by Otvos (1986).

Water depths inside the southern portion of the Pascagoula Valley were up to 8m, tidal and wave processes likely eroded basal fluvial sands. Water depths overlying the older MIS 6 sandy deposits ranged from 2-8m suggesting they were actively being reworked during this time. This is also inferred from the prominent ravinement surface (Figure 6) constrained to older than 7ka (Figure 8; Table 1, sample 4). Milliken et al. (2008) reports a sea level stillstand during 9.5 ka, which would enhance the efficiency of shoreface ravinement. Bathymetric highs such as interfluvial and valley shoulder areas likely focused wave energy, reworking deposits and transporting them landward. Alongshore transport of sand was likely inefficient due to the immature, irregular shaped coastline.

5.3.2 8-7ka Transgressing Shoals

RSLR rates were rapid between 8-7ka with many flooding events (average of 4-5mm/yr, and as high as 6-7mm/yr during flooding events; Anderson et al. 2016, Milliken et al. 2008). Paleo sea levels were about 13m below present rising to 7m below present by 7ka (Figure 11). Estuarine deposition dominates the Pascagoula valley within Mississippi Sound constrained by peat and wood samples from brackish sediments described by Otvos (1979) (Table 2, sample 33, 35, 37). Estuarine conditions now exist north of Petit Bois in a flooded tributary (Table 2, sample 31). Ephemeral islands or shoals likely mirrored antecedent topographic geometries. Transgressive shoals were near the modern position of Horn Island based on 8ka washover/tidal deposits (Gal et al. in prep). The majority of sand was still being sourced from reworking of the inner shelf.

By 7ka RSLR has slowed to about 4mm/yr. The Gulfport Formation section of east Dauphin of the MIS 2 surface acted as a nucleation point for shoal belt deposition as

marine flooding reached this area around 7ka. An ephemeral island or migrating marine shoal similar to the description of Otvos (1981), was located about 2 km seaward of modern Petit Bois Island. This is inferred from similar age and elevation estuarine and sandy nearshore deposits (Figure 11; Table 1, sample 3, 4). This transgressive sand body was unable to stabilize during rapid sea level rise (Figure 6, Table 1, sample 3).

Microfossil salinity data within Mississippi Sound shows upward and landward freshening of mud or muddy sand units resulting from a combination of river discharge and the migrating shoal belt (Otvos 1985, 1986, 1981).

A coastal marsh formed atop antecedent highs in the eastern section of Mississippi Sound (Figure 11, Table 2, sample 47, 48, 49, 50). Although neither Hummel and Parker (1995) or Greene et al. (2007) discussed whether this was salt or freshwater peat, its elevation and age correspond to within 1m of sea level at this time, well within tidal range. Microfossil salinity data from this area suggest brackish environments (Otvos 1985). Otvos (1985) shows the presence of calcareous nearshore marine and intertidal foraminifera found in the deposits proximal to the peats. Therefore, we interpret these as salt marsh deposits. The peats directly overlie the subaerial MIS 2 surface and Hummel (1999) report them underlying sections of the Dauphin Island shoreface (Figure 10). This indicates the early transgressive phase of these landward migrating marine shoals. Deeper drainages in this area likely became tidally influenced estuarine tributaries (Table 2, sample 28). No peats were found in the central or western portion of Mississippi Sound indicating the flooded antecedent topography was deep enough for estuarine deposition or larger waves and more efficient bay ravinement eroded the deposit completely.

Figure 11 Holocene Evolutionary Model

Paleogeographic maps showing the flooding of MIS2 surface based on seismic and core interpretations at various Holocene time intervals. Paleo sea level was inferred from the Milliken et al. (2008) non-linear, sea level curve (Figure 2). Black lines represent modern shorelines; white areas are land. Numbers represent radiocarbon samples cross referenced to tables 1 and 2 to aid in interpretation of depositional environments. Dotted lines represent pre-MIS2 sandy fluvial/deltaic deposits being reworked assuming 7m of wave ravinement; this sand source is eventually shut off as sea levels rise.

5.3.3 6-5ka: Island Formation and Stabilization

Sea level reached the modern mainland shoreline at 6ka, increasing the tidal prism of Mississippi Sound. Between 5.7-5.0 ka RSLR rates were about 2mm/yr (Milliken et al. 2008), allowing the migrating marine shoals to reach a stabilization threshold (Otvos and Carter 2004). The Gulfport section of eastern Dauphin Island, abundant sediment supply and the minor sea level rise rates allowed the islands to establish and aggrade vertically near their modern positions (Otvos 1979, 1981, 2018) (Figure 11). Otvos (1970, 1979, 1981) described a marine sandy mud unit underlying the Horn Island platform (Otvos 1981). This is interpreted as distal flood tidal deposits as the shoals or ephemeral islands continually breached and migrated landward. The newly flooded antecedent topography of Mississippi Sound due to the MIS 2 gradient change from -0.734 m/km to -0.069 m/km (Figure 5b) significantly increased accommodation space. The slower sea level rise likely increased wave ravinement efficiency. The uniform paleo water depths suggest the island chain was becoming more linear and mature.

Fort Morgan Peninsula began to prograde and aggrade at 5.3ka (Rodriguez et al. 2006) constraining the Mobile inlet throat and establishing the Mobile ebb tidal delta. The connection between updrift sand sources suggests sediment supply to the MSAL was both onshore and alongshore transport.

5.3.4 4-2.5ka: Island Progradation

RSLR rates slowed from about 1.4mm/yr to 0.4mm/yr (Milliken et al. 2008) and sea levels were about 3 meters below modern. Tidal and wave scour begin bypassing deeper inner shelf MIS 6 sandy deposits (Figure 6 and 11). The abundant sediment supply from reworked deposits ($306.7 \times 10^6 \text{ m}^3$) (Table 4) and alongshore sources

(Mobile ebb tidal delta and eroding Pleistocene headland in Florida) likely caused rapid westward lateral progradation of the MSAL chain around 4ka (Figure 11) (Otvos 1979). The MSAL barrier chain extended as far as New Orleans at one time (Otvos 1981, 2018). The emergence of oyster biostromes about 3.8ka, landward of Dauphin Island, indicates a fairly continuous barrier island chain with sufficient tidal circulation to Mississippi Sound. The barrier trend was held at its modern position due to the large accommodation space of the flooded antecedent topography of Mississippi Sound and the alongshore currents anchored by the MIS 5e section of Dauphin Island. It is possible due to inlet migration and abundant sand that the shoreface oblique sand rides began to form according to the McBride and Moslow (1991) translating ebb tidal delta model.

As the islands laterally accrete, tidal inlets can become anchored in incised valleys (Simms et al. 2006, Siringan and Anderson 1993) such as the deep tributary underlying western Petit Bois (Figure 5, 9, 11). Amalgamated, laterally offset, flood tidal delta and attendant tidal channel deposits are present landward of western Petit Bois (Figure 1, 5b, 9, 11). These are characterized by vertically aggraded cut and fill patterns in seismic profiles constrained to 2.3ka (Table 1, sample 9). The bathymetric extent of these large flood tidal deltas can be seen in modern bathymetry (Figure 1; NOAA 2007, 2009). Similar relict tidal deltas exist between East and West Ship, which is spatially correlated to paleo tributaries (Twichell et al. 2013).

As pre-existing sand sources on the shelf were exhausted, barrier stabilization and progradation was maintained through lateral inlet migration (Simms et al. 2006, Otvos 1970) to keep pace with RSLR. The islands overlie a thick (3-16m) medium-fine sandy platform (Otvos and Giardino 2004), which could have provided ample sands through

tidal ravinement as islands prograded westward. The sea level still stand allowed Petit Bois to prograde seaward about 2km around 1.8-2.5ka (Table 1, sample 1, 2, 14) (Figure 9, 11). Gal et al. (in prep) and Misellis et al. (2014) show a progradational trend slightly earlier further west in the MSAL chain (2.2-3.8ka Horn Island, 2.5-4ka Cat Island). This implies earlier evidence of Petit Bois progradation was likely reworked or reflects variability in antecedent topography/sediment supply. Studies from coastal Mississippi indicate that 2,200-1,900 BP was a relatively intense stormy period (Bregy et al. 2018). It is possible this increased storm wave action reworked earlier prograded shoreface deposits at Petit Bois. Theoretically inlets were opened through storm breaching, some were maintained like the one landward of western Petit Bois but generally the islands remained stable through this time. It is likely that modern geomorphology such as storm breaches and inlets correspond to MIS 2 valleys (Mallinson et al. 2010, Zaremba et al. 2016, Siringan and Anderson 1993, Twichell et al. 2013).

5.3.5 1750 CE- Modern: Island Degradation

The sea level stillstand (Milliken et al. 2008) ended fairly abruptly, when RSLR rates increased to ~2 mm/yr (Gerlach et al. 2017). This is about the same rate in which the islands stabilized 5.7-5.0 ka (Otvos and Giardino 2004). The majority of sand is transported westward from updrift sources. The combination of increased RSLR and reduced sediment supply led to island thinning and breaching. The 1752 CE D'anville chart shows Petit Bois and Dauphin joined as one island which was later separated by a storm in the late 1700's (Otvos and Giordano 2004). Lateral inlet migration throughout historic times (150 years) (Buster and Morton. 2011) has completely reworked most of Dauphin and Petit Bois through tidal ravinement. Both the modern Petit Bois Pass and

the Katrina Cut on Dauphin Island correlate to MIS 2 tributary channels (Figure 5 and 10). Lower elevation antecedent topography correlates with erosional hotspots or points of weakness during storms (Browder and McNich 2006, Twichell et al. 2013). Islands are severely declining in areal extent, thinning from the Gulf and Sound sides (Morton 2008). Modern sediment budgets indicate mixed results as some clearly show defined littoral cells with little exchange between islands (Cipriani and Stone 2001, Morton 2008) and others show sediment transport generally decreases downdrift (Byrnes et al. 2013). Petit Bois and Dauphin show relatively sand starved features. The lack of ridge and swale topography on the low elevation western spit results from a combination of anthropogenic influences that have altered sediment dynamics and frequent overwash. Dauphin Island's shoreface is sand starved (Figure 8 and 10).

Modern RSLR rates at Dauphin Island are $3.61 \text{ mm/yr} \pm 0.59 \text{ mm/yr}$ (NOAA 2018: Station 8735180), and with very little sand supplied by proximal wave ravinement, the western of Dauphin spit cannot keep up with modern SLR (Figure 6). The shoreface shows very little sand above the stiff, Pleistocene muddy alluvial deposits (Prairie Formation) (Otvos and Carter 2004) (Figure 8 and 10). Other sediment starved beaches show increased overwash during the current, relatively low storminess period illustrating the systems' sensitivity to accelerated RSLR rates (Rodriguez et al. 2018 (Onslow Beach, NC), Odezulu et al. 2018 (Follets Island, TX)). The relatively deep, unconfined Mississippi Sound has greater accommodation space than sediment supply can fill at the current rate of SLR, pushing these islands past stabilization thresholds. This illustrates the significance of changes in sediment supply compared to sea level rise rates and the antecedent topography underlying the barrier islands.

6-CONCLUSION

This study provides a high spatial and temporal resolution data set constraining the Late Quaternary chronostratigraphic evolution of the eastern MSAL barrier chain and Mississippi Sound in response to sea level fluctuations, changes in sediment supply, geomorphic changes, and antecedent topography. The underlying geologic framework directly controls the Holocene evolution of the MSAL barriers. During early transgression, wave ravinement excavated up to $300 \times 10^6 \text{ m}^3$ that was available for incorporation into the barrier system. However, fluvial transport of sand to the study area shut off in the Early Holocene. Estuarine conditions were present in paleovalleys seaward of the modern MSAL chain 9ka, suggesting the presence of some form of seaward physical salinity barrier. However, up until about 6ka, sea level rise rates ($<2\text{mm/yr}$) were too rapid for barrier islands to establish, resulting in landward migrating transgressive ephemeral islands or marine shoals. Sand was supplied mostly from reworked inner shelf sources at this time. As sea level rise rates decreased ($>2\text{mm/yr}$), the balance of sediment supply and accommodation space favored island stabilization as shoal belts vertically aggraded near their present positions about 5.7-5.0ka. The islands sit atop a break in the MIS 2 slope and are anchored by the MIS 5e Gulfport Formation barrier section at Dauphin Island. The MIS 2 surface gradient change is believed to be a result of wave ravinement. Shortly after 4ka, relict sand deposits on the inner shelf were bypassed by transgressive processes. Alongshore and onshore sand supply allowed for island progradation both laterally and seaward during the sea level still stand from about 4ka-1750 CE ($1-0.4 \text{ mm/yr}$). From 1750 CE to modern day, the islands have experienced segmentation, thinning and frequent overwash due to reduced sediment supply and

accelerating sea level rise. Modern tide gauges report $3.61 \text{ mm/yr} \pm 0.59 \text{ mm/yr}$ of RSLR in the area, which is higher than the rate at which the islands formed. Mississippi Sound has large accommodation space, and the islands experienced reduced sediment supply compared with geologic times. As future storminess is predicted to intensify and become more frequent coupled with accelerated sea level rise, the islands may return to a transgressive shoal belt similar to their history 6-7ka. This study provides geologic evidence of coastal system geomorphic threshold crossings related to sea level rise and sediment supply and antecedent topography, which can be used to help predict barrier response to future sea level rise and storm scenarios.

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