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Geologic control on the evolution of the inner shelf morphology offshore of the Mississippi barrier islands, northern Gulf of Mexico, USA

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ABSTRACT

Between 2008 and 2013, high-resolution geophysical surveys were conducted around the Mississippi barrier islands and offshore. The sonar surveys included swath and single-beam bathymetry, sidescan, and chirp subbottom data collection. The geophysical data were groundtruthed using vibracore sediment collection. The results provide insight into the evolution of the inner shelf and the relationship between the near surface geologic framework and the morphology of the coastal zone. This study focuses on the buried Pleistocene fluvial deposits and late Holocene shore-oblique sand ridges offshore of Petit Bois Island and Petit Bois Pass. Prior to this study, the physical characteristics, evolution, and interrelationship of the ridges between both the shelf geology and the adjacent barrier island platform had not been evaluated. Numerous studies elsewhere along the coastal margin attribute shoal origin and sand-ridge evolution to hydrodynamic processes in shallow water (<20 m). Here we characterize the correlation between the geologic framework and surface morphology and demonstrate that the underlying stratigraphy must also be considered when developing an evolutionary conceptual model. It is important to understand this near surface, nearshore dynamic in order to understand how the stratigraphy influences the long-term response of the coastal zone to sea-level rise. The study also contributes to a growing body of work characterizing shore-oblique sand ridges which, along with the related geology, are recognized as increasingly important components to a nearshore framework whose origins and evolution must be understood and inventoried to effectively manage the coastal zone.

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1. Introduction

Shore-oblique sand ridges are common along sandy coastlines yet their origin and evolution are the subject of debate. A growing body of work focuses on the formation of these features, and their contribution to shoreface processes, especially on the northeast US Atlantic shelf (Goff et al., 1999; Schwab et al., 2000; Swift and Field, 1981). Hydrodynamic models suggest ridge formation is due to non-linear flow over seafloor perturbations during storm events (Dalrymple and Hoogendoorn, 1997; Trowbridge, 1995). The ridges are thought to form close to shore (Hayes and Nairn, 2004), and migrate laterally until detached from the shoreface through shoreline retreat. Swift and Field (1981) suggest that their oblique orientation relative to the shoreline is a function of water depth, with the shoreface end of the ridge migrating faster, while McBride and Moslow (1991) attribute the orientation to migratory deposition of ebb-tide delta deposits from which the ridges originate. In a transgressive environment, shoal-migration rates decrease as sea-level rise submerges the ridges below wave base. Eventually, the detached ridges stabilize on the inner shelf (Nnafie et al., 2014). The studies point to water depth as the controlling process that drives ridge evolution. However, discrepancies between the Atlantic Bight and the ridges within this study area, such as shoal size, distribution, and inverse correlation to water depth, suggest oceanographic and geologic processes are also important factors driving ridge origin and evolution.

This study investigates the relationship between ridge distribution and the near surface stratigraphy, using a high-resolution geologic characterization of the shallow Pleistocene–Holocene stratigraphy and seafloor morphology offshore of the Mississippi barrier islands (Fig. 1). Recently acquired chirp sonar, sidescan sonar, interferometric swath bathymetry and sediment cores were used to better understand the geologic framework and seafloor morphology and their relation to the adjacent barrier island platform. This area of the inner shelf is an important component of the coastal zone, and the occurrence of the ridges create relief on

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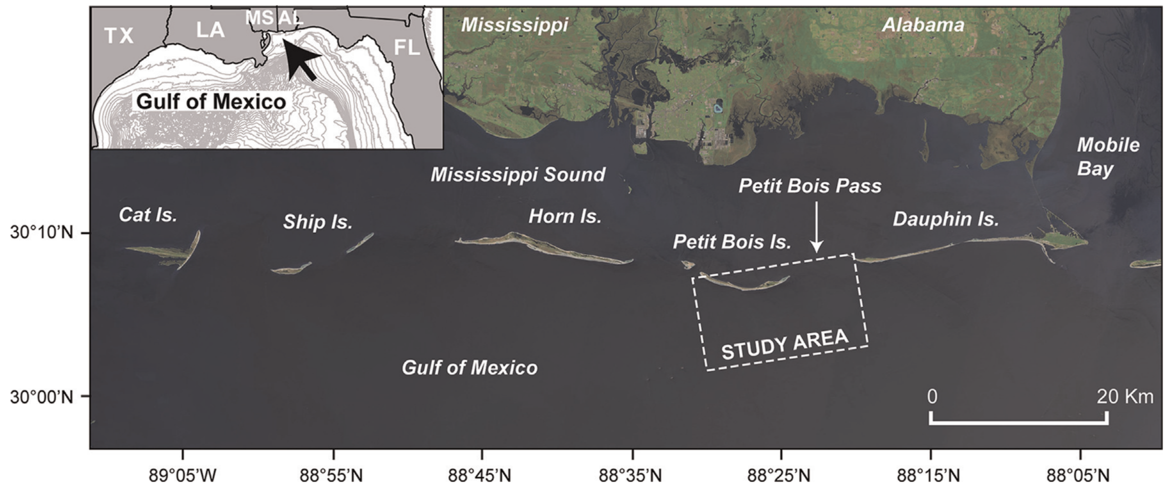

Fig. 1. Satellite imagery (2014 Landsat 8) of the Mississippi barrier islands that comprise the Gulf Islands National Seashore (GUIS), northern Gulf of Mexico (inset). Location of the study area is shown.

an otherwise flat inner shelf, influencing the oceanographic processes impacting the adjacent barrier islands. Over the past century the Mississippi barrier islands have been in a state of decline, with land areas severely reduced by storms, sea-level rise, and human alteration (Morton, 2008; Byrnes et al., 2013; Otvos, 2011; Otvos and Carter, 2013). This geologic investigation provides an opportunity to examine the correlation between the stratigraphy, morphology and physical processes affecting this nearshore environment.

2. Setting

The inner Mississippi-Alabama shelf is a slowly subsiding, passive continental margin bound to the west by the Mississippi River delta, and to the east by the DeSoto Canyon located offshore of the Florida panhandle (Sydow and Roberts, 1994). The shallow stratigraphy of this region is the product of fluvial-marine sedimentation, driven by sea-level oscillations during the late Pleistocene to Recent (Flocks et al., 2011). During glacial periods of low sea-level, the region was a flat, low-lying coastal plain, with low-gradient rivers that meandered across the coastal plain (Kindinger et al., 1994; Bartek et al., 2004). The paleo-channels of these fluvial systems are preserved in the stratigraphy throughout the study area, infilled with fluvial deposits as well as reworked transgressive deposits from early-Holocene sea-level rise.

At the surface, mid- to late-Holocene sand sheets blanket the seafloor. The inner shelf is characterized as microtidal with low-wave energy (except during tropical storms). The muddy sand sheets, known collectively as the Mississippi-Alabama-Florida (MAFLA) sand sheet (Doyle and Sparks, 1980), are in general 1 m thick, and contain abundant shell material. Within the study area the sand sheets are interrupted by a series of shore-oblique sand ridges, not seen elsewhere west of Mobile Bay. The sand ridges range in length from 1–10 km, increasing in size from east to west.

Landward of the sand ridges a substantial barrier island system protects the coastal plain of the mainland. The Mississippi barrier islands (Dauphin, Petit Bois, Horn, East Ship, West Ship, and Cat, Fig. 1) range in length from 2–20 km, are less than 2 km wide, and are highly dynamic. Storm-induced island breaching and

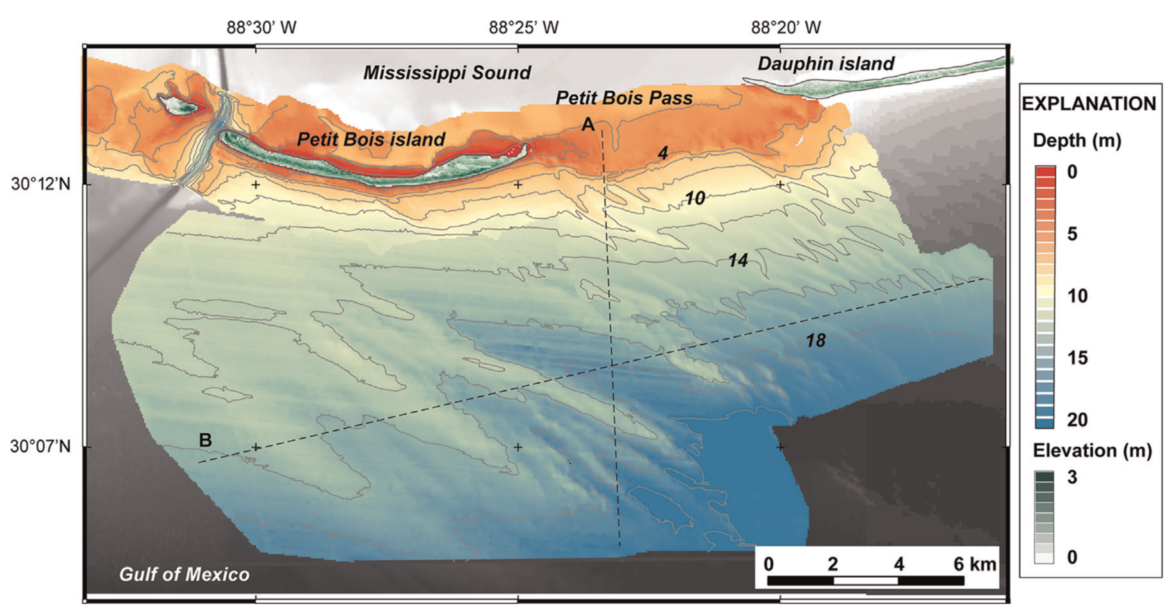

Fig. 2. Water depths within the study area collected from single-beam (nearshore) and interferometric swath (offshore) bathymetric acquisition systems (DeWitt et al., 2012, 2014), with 2 m contours shown. Black dashed lines are locations of bathymetric profiles shown in Fig. 4. Island elevations are derived from 2008 topographic lidar surveys (Bonisteel-Cormier et al., 2010). Grayscale bathymetry background from NOAA NGDC DEM (Taylor et al., 2008).