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Geologic framework of the northern North Carolina, USA inner continental shelf and its influence on coastal evolution ☆

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ABSTRACT

The inner continental shelf off the northern Outer Banks of North Carolina was mapped using sidescan sonar, interferometric swath bathymetry, and high-resolution chirp and boomer subbottom profiling systems. We use this information to describe the shallow stratigraphy, reinterpret formation mechanisms of some shoal features, evaluate local relative sea-levels during the Late Pleistocene, and provide new constraints, via recent bedform evolution, on regional sediment transport patterns. The study area is approximately 290 km long by 11 km wide, extending from False Cape, Virginia to Cape Lookout, North Carolina, in water depths ranging from 6 to 34 m. Late Pleistocene sedimentary units comprise the shallow geologic framework of this region and determine both the morphology of the inner shelf and the distribution of sediment sources and sinks. We identify Pleistocene sedimentary units beneath Diamond Shoals that may have provided a geologic template for the location of modern Cape Hatteras and earlier paleo-capes during the Late Pleistocene. These units indicate shallow marine deposition 15–25 m below present sea-level. The uppermost Pleistocene unit may have been deposited as recently as Marine Isotope Stage 3, although some apparent ages for this timing may be suspect. Paleofluvial valleys incised during the Last Glacial Maximum traverse the inner shelf throughout the study area and dissect the Late Pleistocene units. Sediments deposited in the valleys record the Holocene transgression and provide insight into the evolutionary history of the barrier-estuary system in this region. The relationship between these valleys and adjacent shoal complexes suggests that the paleo-Roanoke River did not form the Albemarle Shelf Valley complex as previously proposed; a major fluvial system is absent and thus makes the formation of this feature enigmatic. Major shoal features in the study area show mobility at decadal to centennial timescales, including nearly a kilometer of shoal migration over the past 134 yr. Sorted bedforms occupy ~1000 km^2 of seafloor in Raleigh Bay, and indicate regional sediment transport patterns between Capes Hatteras and Lookout that help explain long-term sediment accumulation and morphologic development. Portions of the inner continental shelf with relatively high sediment abundance are characterized by shoals and shoreface-attached ridges, and where sediment is less abundant, the seafloor is dominated by sorted bedforms. These relationships are also observed in other passive margin settings, suggesting a continuum of shelf morphology that may have broad application for interpreting inner shelf sedimentation patterns.

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1. Introduction

The inner continental shelf links the subaqueous portion of the continental margin and the subaerial coast. Sedimentation on the inner shelf influences coastal evolution at a variety of timescales, from hours to millennia (Swift, 1976; Wright, 1995). Understanding inner shelf geologic setting, morphology, and processes can improve models of coastal evolution (Cowell et al., 2003; Fagherazzi and Overeem, 2007) as well as provide a basis for evaluating resource availability (Finkl et al., 2007) and marine species habitat (Woodland et al., 2012).

Geophysical surveys of the inner continental shelf provide a basis for understanding the geologic history of the coastal system (Anderson et al., 2004), furnish insight into coastal sediment flux (Schwab et al., 2000; Denny et al., 2013), and can be used to identify sand resources and potential implications for mitigating erosion hazards through beach nourishment (Lazarus et al., 2011). Coastal areas with limited sediment supplies, such as North Carolina, are significantly influenced by the geologic framework of older stratigraphic units that occur beneath and seaward of the shoreline (Riggs et al., 1995). In this area, as with much of the eastern United States, rivers no longer introduce significant quantities of new sand to the coastal system. The sediment available to maintain modern beaches is derived from erosion and

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transport of sediment from either the adjacent coast or the inner continental shelf (e.g., Schwab et al., 2013). Thus, antecedent geology of the marine and subaerial portions of the coastal zone can determine the morphology of the nearshore zone and can strongly influence modern coastal change (McNinch, 2004; Miselis and McNinch, 2006).

Here we present a synthesis of new geophysical and geologic data that describes the regional geologic framework of the North Carolina inner continental shelf from False Cape, Virginia to Cape Lookout, North Carolina (Fig. 1) in high detail. This portion of the U.S. Atlantic margin has a long history of study that yielded several foundational concepts in shelf morphology, stratigraphy, and coastal evolution (e.g., Duane et al., 1972; Swift et al., 1972; Field and Duane, 1976; Swift, 1976; McBride and Moslow, 1991) that have informed the understanding of modern and ancient passive margin sedimentation worldwide (e.g., Franks, 1980; Hassouba, 1995; Cattaneo and Steel, 2003; Dillenburg and Hesp, 2009). This includes issues such as how Late Quaternary sea-level change and sedimentation can create geologic templates for modern coastal features (Riggs et al., 1995), the role of sediment availability in determining inner continental shelf morphology and coastal evolution (Schwab et al., 2000; 2013), and the interpretation of bedform characteristics to understand sediment transport patterns, sources, and sinks (Goff et al., 2005). Using a large-scale, high-resolution dataset, we review and test existing interpretations of seafloor features, and offer different and alternative explanations for their origin and evolution; present new stratigraphic data to evaluate local relative sea-levels during the Late Quaternary; and interpret seafloor bedforms to provide new constraints on inner shelf sediment transport that influences coastal evolution.

2. Regional setting

The northeastern North Carolina coastal system (Fig. 1) is located within the Albemarle Embayment and contains a ~90 m thick, well-preserved Quaternary stratigraphic record (Mallinson et al., 2005; Mallinson et al., 2010, hereafter referred to as M2010). The Albemarle Embayment is a structural basin bounded by the Norfolk Arch to the north and the Miocene Cape Lookout High to the south (Brown et al., 1972). During the latest Quaternary, the embayment has been bounded to the east by a relict inter-stream divide, which is now occupied by the Outer Banks barrier islands (Mallinson et al., 2005). Pliocene and

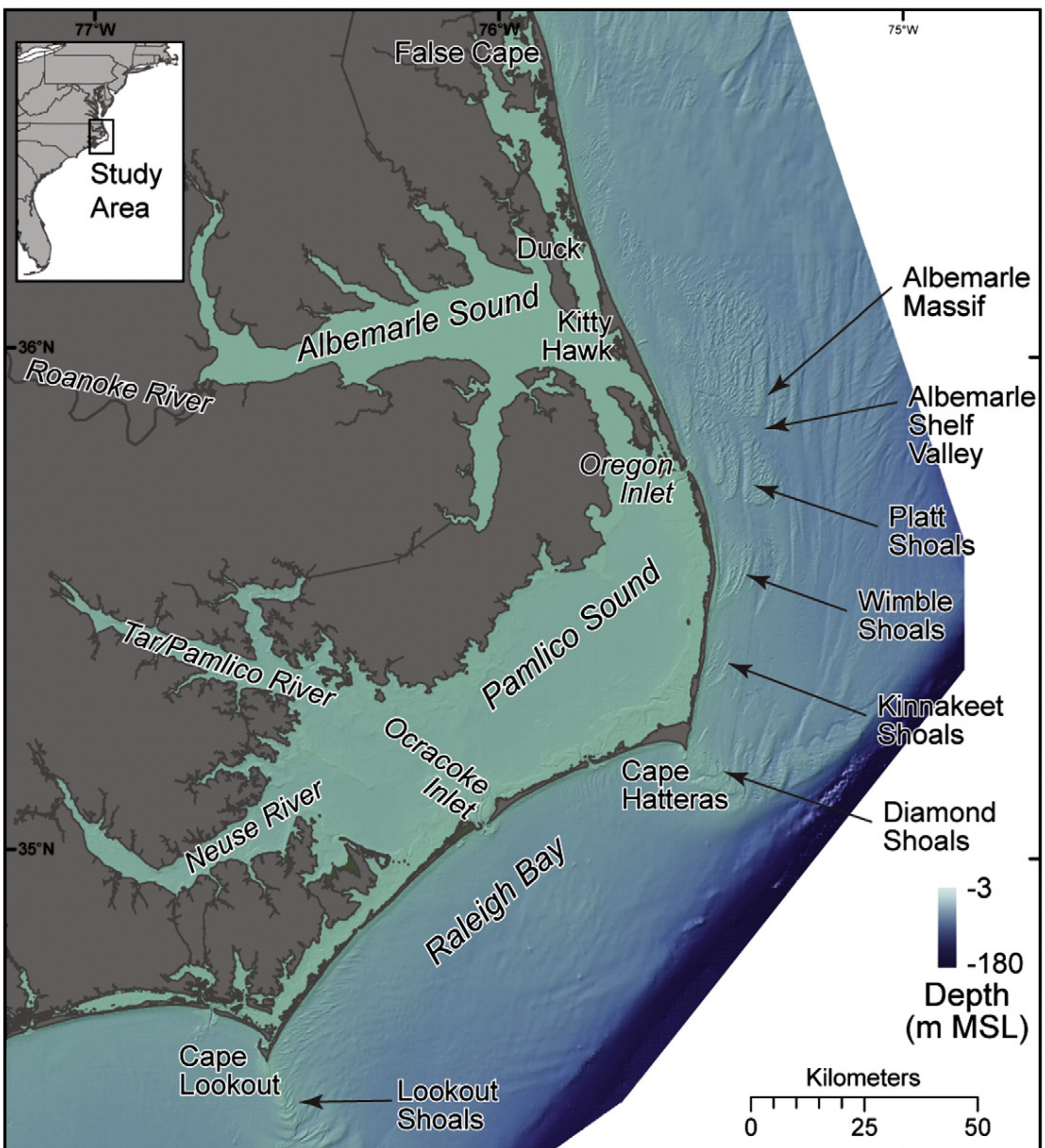

Fig. 1. Map of the study area in northeastern North Carolina. Bathymetry data is from the NOAA NGDC Coastal Relief Model (www.ngdc.noaa.gov/mgg/coastal/startcrm.htm) and this study.

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