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Anatomy of a shoreface sand ridge revisited using foraminifera: False Cape Shoals, Virginia/North Carolina inner shelf

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ABSTRACT

Certain details regarding the origin and evolution of shelf sand ridges remain elusive. Knowledge of their internal stratigraphy and microfossil distribution is necessary to define the origin and to determine the processes that modify sand ridges. Fourteen vibracores from False Cape Shoal A, a well-developed shoreface-attached sand ridge on the Virginia/North Carolina inner continental shelf, were examined to document the internal stratigraphy and benthic foraminiferal assemblages, as well as to reconstruct the depositional environments recorded in down-core sediments. Seven sedimentary and foraminiferal facies correspond to the following stratigraphic units: fossiliferous silt, barren sand, clay to sandy clay, laminated and bioturbated sand, poorly sorted massive sand, fine clean sand, and poorly sorted clay to gravel. The units represent a Pleistocene estuary and shoreface, a Holocene estuary, ebb tidal delta, modern shelf, modern shoreface, and swale fill, respectively. The succession of depositional environments reflects a Pleistocene sea-level highstand and subsequent regression followed by the Holocene transgression in which barrier island/spit systems formed along the Virginia/North Carolina inner shelf ~5.2 ka and migrated landward and an ebb tidal delta that was deposited, reworked, and covered by shelf sand.

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1. Introduction

Shelf sand ridges are common features on the US Atlantic continental shelf, often forming ridge and swale topography with persistent, elongate sand bodies creating the topographic highs with older muds exposed in the swales (Duane et al., 1972; Swift et al., 1972b). While shelf sand ridges may be shore-parallel (Stubblefield et al., 1984; Swift et al., 1984), this paper focuses on those sand ridges oriented at oblique angles to the adjacent shoreline. Shore-oblique sand ridges are typically oriented at angles between 10° and 50° to the adjacent shoreline, with an average orientation of ~30° (McBride and Moslow, 1991), are usually over 1 km in length, 0.5 km wide with a relief up to 10 m and side slopes that average less than 1° (Duane et al., 1972; Field, 1980; Figueiredo et al., 1981). The distribution of shelf sand ridges has been extensively studied, and their origin and evolution widely debated, since the 1930s, in part due to the occurrence of significant petroleum reserves in some ancient shelf sand shoals, yet important basic questions remain regarding the origin and evolution of these features despite several insightful studies on the subject (Swift and Field, 1981; McBride and Moslow, 1991; Snedden and Dalrymple, 1999; Snedden et al, 1999).

Early morphologic studies of the mid-Atlantic shelf, based on depth recordings and later bathymetric mapping, defined the distribution, clustering and migration of sand ridges (e.g., Veatch and Smith, 1939; Uchupi, 1968), and surficial sampling documented surface sediment texture (e.g., Sanders, 1962; Swift et al., 1972a). With this information and measurements of current- and wave-generated flows, hydrodynamic models were developed to explain sand-ridge development, maintenance, and migration. Huthnance (1982) devised a simple hydrodynamic model by which a sand ridge forms around an initial bathymetric irregularity large enough to disturb linear water flow under conditions of adequate available sand and active currents. This model, however, neglects to define the nature of the initial irregularity. Knowledge of the internal stratigraphy of and microfossil distribution within sand ridges is necessary to define the initial irregularity and to determine the processes that may subsequently modify the ridges.

In this study, microfossils from cores collected from False Cape Shoal A, a well-developed shoreface-attached sand ridge on the inner continental shelf near the Virginia/North Carolina border, were examined in order to document the internal stratigraphy and benthic foraminiferal assemblages, as well as to reconstruct the depositional environments recorded in down-core sediments.

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2. False cape shoals

False Cape Shoals is a system of three shoreface-attached and detached sand ridges located immediately offshore the Virginia/North Carolina border (Fig. 1). The shoals display a maximum relief of 6.1 m and slopes of $\leqslant 2^\circ$ (Duane et al., 1972; Swift et al., 1972a). False Cape Shoal A trends northeast at a 16° angle to the shoreline (McBride and Moslow, 1991) and emerges from the shoreface as a single ridge before bifurcating into two subridges to the north.

False Cape Shoals were extensively studied by Swift et al. (1972a) who analyzed the bathymetry, surficial sediments and stratigraphy of this shore-oblique three-ridge system. Bathymetric mapping revealed a change in slope of the shoreface at ~9 m water depth. False Cape Shoals A and B emerge from the upper, steeper shoreface and continue on the lower, less steep shoreface; Shoal C lies directly on the inner shelf floor which intersects with the shoreface at a water depth of ~17 m, and is not attached to the shoreface (Swift et al., 1972a). Surficial sediment samples revealed a relationship between grain size and topography in which ridge crests were covered with fine- to medium-grained sand, the shoreface, ridge flanks and trough margins were covered with fine to very fine sand, and trough axes were floored by pebbly, medium- to coarse-grained sand overlying dense clay (Swift et al., 1972a). The general stratigraphy of False Cape Shoals consists of a basal clayey fine sand unit, an intermediate muddy unit, and an upper sand sheet that forms the ridges (Swift et al., 1972a).

No microfossil examinations of False Cape Shoals exist prior to the research presented here. Detailed foraminiferal assemblage data for the modern North Carolina and Virginia continental shelves, however, are provided in Schnitker (1971) and Cronin et al. (1998), respectively. Rine et al. (1991), Snedden et al. (1994) and Culver and Snedden (1996) studied foraminiferal assemblages in New Jersey shelf sand ridges, documenting distinct assemblages found in inner- and mid-shelf ridges, but these studies lack sufficient microfossil sampling intervals to interpret acute environmental changes recorded in the sand-ridge sediments.

3. Materials and methods

3.1. Laboratory

Fourteen vibracores were collected from False Cape Shoal A in June 2001 (Table 1, Fig. 1). Once collected, each vibracore was cut into 1 m sections that were split longitudinally, trimmed, described in detail, and photographed. Half of each core was archived; the other half was sampled for microfossil analysis at approximately 20–25 cm intervals, with additional samples collected immediately below and above sedimentologic contacts and at other locations of stratigraphic interest. Core FCS-01-14, due to its complete and complex stratigraphy, was sampled at ~12.5 cm intervals.

For microfossil analysis, sediment samples of ~10 cm^3 were processed using standard procedures in which bulk samples are dried in an oven at $\leqslant 50\,^\circ$C, weighed, then disaggregated in a beaker with warm tap water and ~2 ml of dilute sodium hexametaphosphate solution (5 g/1 L water). The samples were agitated on a shaker for 1 h, washed through a 63 μm sieve to remove clay and silt-sized material, and dried in an oven at $\leqslant 50\,^\circ$C. In sandy samples, the foraminifera were concentrated by the soap-floating technique described in Harris and Sweet (1989). A split of 300–350 benthic specimens was sought from the >125 μm size fraction. FCS-01-3 was examined for microfossils at both >125 and >63 μm size fractions to ensure that smaller species were not overlooked by the choice of a larger size fraction for this study. No additional species were found in the expanded size fraction, though individual species percentages in individual samples did rarely differ from the corresponding >125 μm

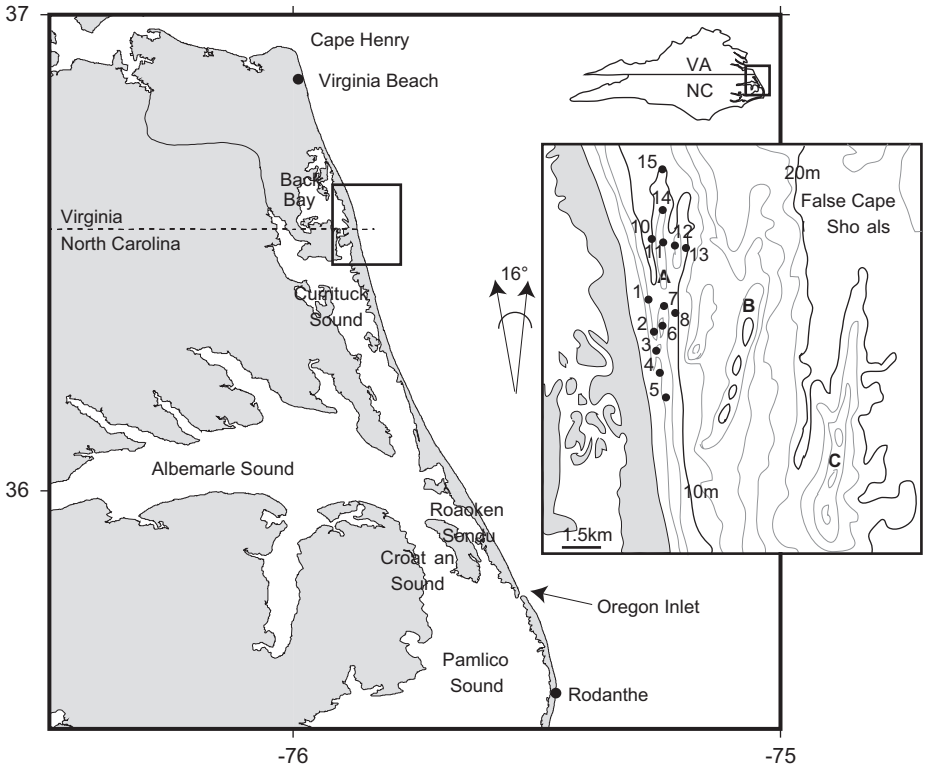

Fig. 1. False Cape Shoals A, B and C and core locations on the inner continental shelf of Virginia and North Carolina.