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Transition of a regressive to a transgressive barrier island due to back-barrier erosion, increased storminess, and low sediment supply: Bogue Banks, North Carolina, USA

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ABSTRACT

Although back-barrier erosion is a prevalent process of island narrowing, it is often overlooked in conceptual models of barrier island evolution. In many wave-dominated barrier island settings, the absence of overwash precludes landward movement of the back-barrier shoreline and hence the island as a whole from sustaining its width. Typically, regressive barriers are wide and exhibit high elevations with the most seaward dune ridge possessing the highest elevation. This morphology may prevent overwash and inlets from breaching the barrier, and therefore the associated sediment from reaching the back-barrier shoreline for millennia. Back-barrier shoreline erosion from sea-level rise and storms can be permanent in the absence of sediment supply from rivers, overwash, and inlet processes. With continued narrowing and lowering of the island, regressive barriers may reach a critical state, making overwash and inlet formation imminent and transitioning the island to a transgressive barrier. The modern day morphologic variability along the 40-km long island of Bogue Banks, North Carolina includes both regressive and transgressive segments, making this setting ideal for examining whether the transition between these barrier island types is gradual or threshold-driven.

Bogue Banks consists of two discrete segments characterized by high-elevation beach ridges, large island widths, and stratigraphy consistent with regressive barrier islands. These regressive-island segments are separated by a broad, narrow section of the island devoid of any washover fans, flood-tide deltas or other transgressive elements. Analyses of seismic data from the inner continental shelf reveal paleochannels intersecting the wide sections of the island, while the narrow central part of the island occupies an inter fluvial area. Reworking of fluvial sediment from paleochannels was an important sediment source for the barrier during regression. Optically Stimulated Luminescence (OSL) dates from the most landward beach ridges constrained initiation of island regression at ~3000 cal yr BP, close to when there was a significant decrease in the rate of relative sea-level rise from ~5 mm/yr to ~0.8 mm/yr. Transects of cores, seismic data, ground-penetrating radar data, and radiocarbon and OSL dates show that prior to ~1500 cal yr BP the central narrow section of the island was wide and progradational, similar to adjacent areas. Back-barrier erosion of the central part of the barrier primarily caused island narrowing as a result of increased storminess, which occurred around the Medieval Climate Anomaly (~1100 cal yr BP). This part of the island was more vulnerable to erosion than adjacent areas due to increased bay-ravinement (Bogue Sound is widest there) and its lower elevation (farther away from paleochannel-sediment source). Relict inlet channels exist along the central portion of the island, formed within the last 250 yr, and likely closed shortly after formation. The presence of historical inlets along the narrow central section of the island indicates Bogue Banks may be nearing a critical width threshold and will subsequently transition to a transgressive barrier. Because the change in barrier morphology associated with back-barrier erosion occurred over a period of time when the rate of sea-level rise was relatively low, low sediment supply and increased storm frequency are shown to be the main forcing mechanisms of island narrowing. These impacts, in addition to a predicted increase in sea-level rise rates and human modifications (e.g. maintenance of a high-elevation foredune, closing of inlets, prevention of island overwash and associated sediment delivery to the back-barrier shoreline) will likely promote rapid transition of regressive barrier islands to those dominated by transgressive processes.

1. Introduction

The evolution of a barrier island, like most coastal depositional environments, is largely a balance between sediment accumulation and sediment accommodation, which is closely related to relative sea-

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level. Galloway and Hobday (1983) recognize aggradational, transgressive, and regressive styles of barrier evolution. Aggradational barriers form when the rate of sediment accumulation equals the rate of creation of sediment accommodation and the estuarine and ocean shorelines remain stationary through time forming a thick lithosome like Mustang Island, TX (Simms et al., 2006; Fig. 1A). Transgressive barriers form when the rate of sediment accumulation is less than the rate of creation of sediment accommodation. The estuarine and ocean shorelines of these islands migrate landward through time by wave erosion and overwash, forming a thin and low-elevation coastal lithosome like Core Banks, NC (Moslow and Heron, 1978; Riggs and Ames, 2003) and Matagorda Peninsula, TX (Wilkinson and Byrne, 1977; Fig. 1B). Regressive barriers form when the rate of sediment accumulation exceeds the rate of creation of sediment accommodation and the ocean shoreline progrades seaward while the estuarine shoreline remains relatively stable forming a wide and high-elevation

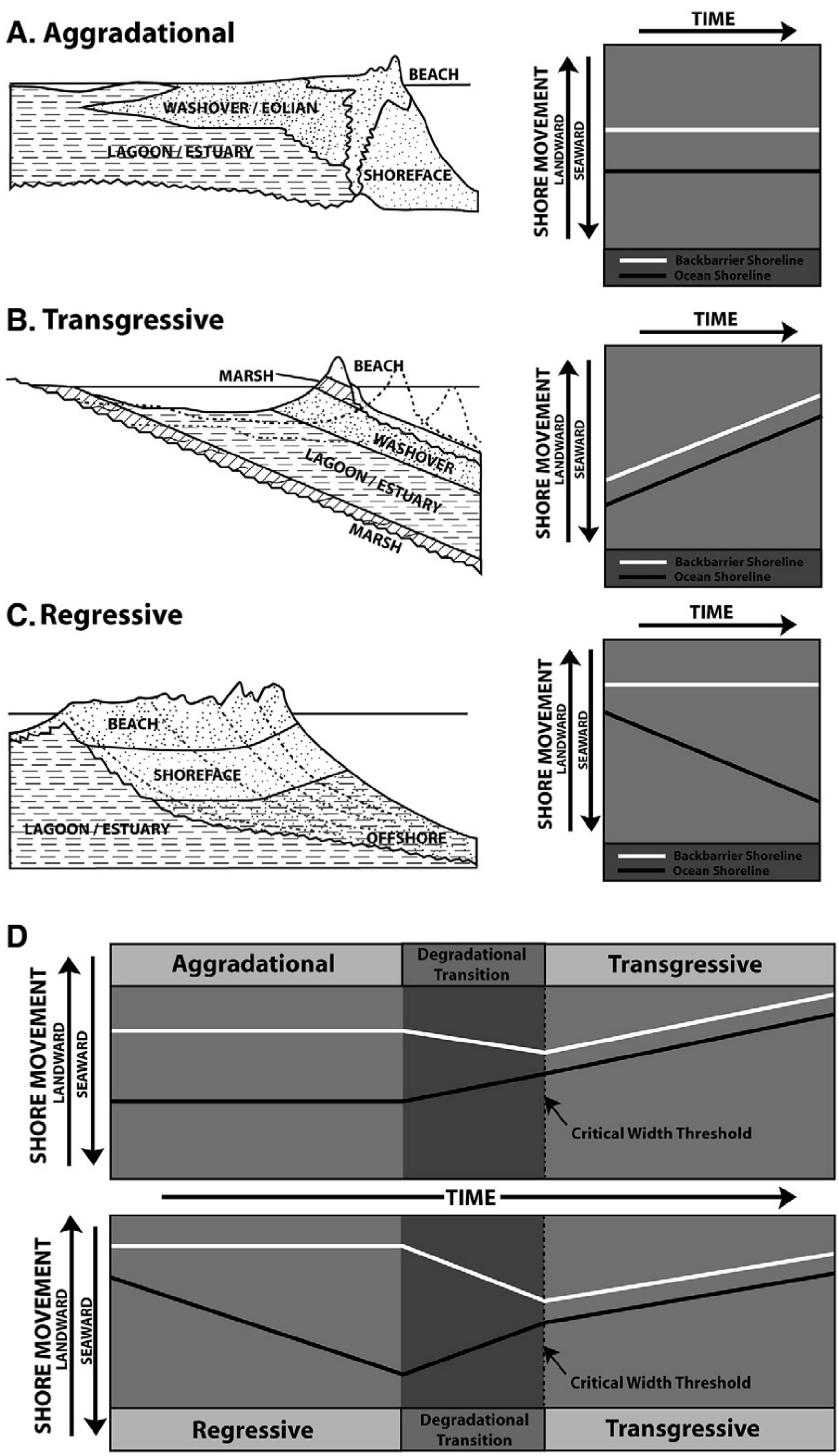

Fig. 1. Models of aggradational (A), transgressive (B), and regressive (C) barrier evolution (after Galloway and Hobday, 1983). Aggradational and regressive barriers narrow through erosion of the back-barrier and ocean shorelines during the degradational transition towards transgressive evolution (D).