Quaternary Science Reviews 193 (2018) 212–243

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Coastal barriers, northern Gulf - Last Eustatic Cycle; genetic categories and development contrasts. A review

Ervin G. Otvos

Division of Coastal Sciences, University of Southern Mississippi, Ocean Springs, MS, 39564, USA

ARTICLE INFO

Article history:
Received 12 March 2018
Received in revised form
14 March 2018
Accepted 1 April 2018

Keywords:
Barrier islands and spits
Barrier genesis
Gulf of Mexico
Barrier authorship
Relict shelf landforms
Pleistocene
Holocene
Strand plains
Aridity episodes
Fluvial discharge variations
Delta islands

ABSTRACT

A large body of chronologically well-constrained and detailed Quaternary data accumulated in the last decades from the coastal-shelf region of the northern Gulf of Mexico. Consequently, a preliminary synthesis of major aspects of the late Quaternary barrier and mainland coastal development on the northern Gulf of Mexico is timely. Several major factors account for the striking differences between barrier size and development styles in the three northern Gulf coast regions. Barriers are nearly continuous in the NW where they dominate by the greatest dimensions and continuity. Sand supply from shelf and mainland sources, continued at variable rates throughout six stages of the Last Eustatic Cycle (LEC). Differences in antecedent topography, in fluvial runoff volumes and relative sea level rise, including rapid overstepping-flooding events were critical in the regional distinctions. Leaving fewer and smaller relict fluvial delta behind, drowned shore and nearshore landforms on the shelf, only two large fluvial systems impacted the NE. The NW shelf and nearshore received abundant sediment supply from the Mississippi and lesser streams; indirectly by ravinement erosion of relict landforms and landward-directed cross-shelf sediment transfer. Sands originated mainly in relict deltas, fluvial, tidal channel, and inlet fill, as well as from submerged shore ridge remnants on the continental shelf. Shelf-margin deltas represented major secondary sources. Barrier formation categories and their respective importance in specific areas represent critical aspects of coastal development. The authorship of various formation concepts (e.g., Penck, Gilbert, McGee, Haage, Ganong, and Keilhack) often is still miscredited or remains unrecognized in the literature. Recognition of the stratigraphic and sedimentological diagnostic characteristics of the basic genetic barrier categories plays a key role in testing the validity of barrier evolution models.

Closely-knit process-form relationships prevail between hydrodynamic (sea level change, storm, tidal current, overwash), sedimentary (shoal and island aggradation, rollover, and eolian accumulation) processes, and the resulting landform morphology. The most detailed accounts that deal with the development of the Alabama-Louisiana and Apalachicola barrier chains are particularly instructive. Almost all modern Gulf barriers with identifiable genetic background formed by shoal aggradation between 5.5 and 2.0 ka, during a marked deceleration in sea level rise. Concurrently, a sizable mainland strand plain complex extended the NE coastal plain. Tide- and storm-driven sediment transport to the large Mobile Bay ebb-delta, the focal role of composite east Dauphin Island in establishing the MS-LA island chain and the island-blocking role of Mississippi Delta advance were prime factors in a complex barrier history. Migration, paradoxically, may also occur by *transgressive* rollover concurrently with *regressive* landward progradation of island strand plains. Stream discharge and sand reworked from relict lithosomes on the shelf were insufficient in compensating for wave- and tide-related sediment loss. Gulf levels stayed below the present throughout the mid- and late Holocene.

1. Introduction

Barrier islands are critical ingredients of the coastal landscapes and ecosystems. With the acquisition of increasingly detailed information on late Quaternary sea level, climate, coastal, and

E-mail addresses: otvos@cableone.net, ervin.otvos@usm.edu.

https://doi.org/10.1016/j.quascirev.2018.04.001
0277-3791/

nearshore environmental changes along the northern Gulf, a preliminary overview in this region of increasing population density and environmental vulnerability is now feasible. Conditions that define barrier genesis and destruction are key components of coastal evolution. An improved historical account of the last eustatic cycle may assist with predictions of future coastal and nearshore development, point to significant information gaps, and alert to problematical environmental susceptibilities. In comparison with the other two areas, the coastal and shelf history of the less intensively studied NE region will be treated here in greater detail. Why and how do the three major northern coastal regions differ in terms of the origin, distribution, and volume of primary and secondary sediment sources? NW coast barrier islands and spits reach length of 43–182 km and width of 3-to-5 km. In sharp contrast, only few NE barriers exceed 24 km length and 0.8–1.0 km width. Landform contrasts are also understood in terms of differences between available sediment sources and volumes, associated sea level rise rate, and land subsidence. Major differences also relate to sediment compaction and neotectonic processes, antecedent topography, climate, hydrodynamic and hydroclimate conditions, including sea level-related backstepping-drowning episodes, storm intensities and frequencies, and drought intervals. Negative anthropogenic impact on barrier and shore development increased greatly in the past century (e.g., Wallace et al., 2009).

The following account includes analysis of unpublished new data and offers insight regarding the impact of past and present coastal and shelf processes, including different mechanisms of barrier formation. Claims made for higher than present Holocene Gulf levels is one major issue. The meaning and terminology of *transgressive* or *regressive* barrier development modes are briefly scrutinized and the validity of a highly popular three-stage model of cyclic island genesis evaluated by a wide range of information. Major aspects of this model require more penetrating analysis than received thus far. Comparison and synthesis of historical and current information from the northern Gulf shores and its associated landforms in the three coastal regions is included among the study objectives. LEC spans regressive, lowstand, fluctuating, and transgressive sea level phases since the start of the Last (Sangamonian) Interglacial. Barrier islands and delta ridgeplains in the Mississippi Delta complex are composed of wave-reworked fine to very fine sand deposits, highly susceptible to erosion. Comparative LEC studies of coastal processes and landform histories, conducted in epicontinental basins may lead to broad syntheses on the global scale.

Because their fine sand and muddy sand content, vulnerable to wave erosion, delta barriers possess shorter anticipated life spans than non-deltaic coarser-grained barriers. Subsidence by sediment compaction and tectonic-isostatic processes heavily impaced barrier development in the Mississippi Delta. Of the numerous publications on Holocene sea levels, Tornquist et al. (2004), Anderson et al. (2016); on late Holocene sea level fluctuations, detailed data by Livsey and Simms (2016) are among the most relevant. In terms of geomorphic and area changes, the NE Gulf barriers belong among the most dynamic, fastest changing coastal landforms. Storms, tidal processes, local subsidence, anthropogenic blocking of fluvial discharge and littoral drift reduction played key roles in barrier erosion, while constructive fair-weather wave and eolian impact, unhindered littoral drift transport, shoal aggradation, and dune accumulation contributed to barrier construction.

The recognizability and relative importance of barrier formation categories at given locations are critical in studying coastal evolution. Often, the cited authorship of genetic categories and/or the priority of a given authorship rests on insufficient, even misinterpreted information. While several early workers failed to receive due credit, others are being inaccurately cited for ideas that they did not even propose (*in:* Schwartz, 1971; Ehlers, 1988; Davis and FitzGerald, 2004). The role that barrier studies played on the Gulf of Mexico coast for over a century (e.g., McGee, 1890) lends special importance to the need for clarifying the nomenclature and authorship issues. In addition to a better understanding of hydrodynamic and sedimentological-morphodynamic processes and their geomorphic expressions, details of the Quaternary Gulf history should provide useful comparisons with the development history of epicontinental basins in other coastal regions as well.

2. Barriers islands - formation and development categories

2.1. Definition issues: barriers and littoral drift (longshore transport)

Barrier islands are shore-parallel, wave-constructed nearshore landforms, surrounded by water and often capped by eolian sand. Flanked by subtidal inlets or passes, they face oceanic high wave energy and salinity condition. The islands and barrier spits act as *barriers* in protecting low-energy, brackish, nutrient-rich mud-dominated lagoonal or bay conditions in their rear. Conventional barrier definitions (e.g., Oertel, 1985) exclude mainland shore ridges, delineated landward by intertidal mudflats and wetlands, criss-crossed by tidal creeks. Exception, such as the exposure of extensive tidal flats behind high-mesotidal islands at low tide (e.g., Frisian Coast, North Sea; Ehlers, 1988 and Copper Delta, Alaska; Hayes and Ruby, 1994) should *not* disqualify them as barriers. However, several authors describe the multitude of small islands in sheltered lagoons and bays by this term. While these landforms may be elongated features, occasionally even lying parallel with the mainland shore, and formed by prograding beach ridges - their designation as "fetch -limited *barrier islands*" is clearly a misnomer (Otvos, 2012; Otvos and Carter, 2013). The term, *mainland barrier* refers to shore ridges (e.g., Gulfport ridge complex) that prograded seaward from unbarred mainland shores and were not backed by lagoons.

Attached to the mainland shore or to large barrier islands by one end, *barrier spits* are also elongated progradational landforms, similarly flanked by open marine; landward by lagoonal shores. The subrecent, 4 km long W. Belle Fontaine sand spit, attached to the mainland shore of a major lagoon in SE Mississippi, does not function as a barrier. Its narrow set of dune-capped beach ridges are flanked by microtidal, low-energy brackish lagoonal waters on both sides (Otvos, 1997, p.115). Littoral drift (longshore transport), an indispensable process in barrier evolution, sometimes is used only for alongshore-transported sediments and their volumes (e.g., Davis and FitzGerald, 2004, p.113; Neuendorf et al., 2005, p. 377). However, according to most coastal scientists, including King (1972, p.504), Shepard (1973, p.143), and Hayes and Ruby (1994, p.404) the term applies both to the longshore sediment transport *process* and its *direction* as well.

2.2. Barrier island genetic and development categories (Table 1)

(1) Shoal aggradation. After a pioneering publication by de Beaumont (1845), Penck (1894), Ordemann (1912), Johnson (1919), Barckhausen (1969), and others suggested aggradation-driven emergence of coastal (barrier) islands from subtidal-intertidal sandflats, submarine sand shoals or bars. Gilbert (1885), was among the first who thought that breaker zone sand bars may build up above water level. Gilbert's studies involved four large lakes. One, Lake Bonneville, existed during the late Pleistocene in Utah. By modern definition barrier islands are absent from lakes. Using terms, such as "emergent bar," "barrier," "beach," or "embankment," Gilbert apparently did not refer to islands. Penck