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An analysis and comparison of observed Pleistocene South Carolina (USA) shoreline elevations with predicted elevations derived from Marine Oxygen Isotope Stages

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ABSTRACT

Geological maps of South Carolina, covering >6800 km^2, confirm the existence of eight preserved Pleistocene shorelines above current sea level: Marietta (+42.6 m), Wicomico (+27.4 m), Penholoway (+21.3 m), Ladson (+17.4 m), Ten Mile Hill (+10.7 m), Pamlico (+6.7 m), Princess Anne (+5.2 m), and Silver Bluff (+3 m). Current geochronologic data suggest that these eight shorelines correlate with Marine Oxygen Isotope Stages (MIS) as follows: Marietta—older than MIS 77; Wicomico—MIS 55–45; Penholoway—MIS 19 or 17; Ladson—MIS 11; Ten Mile Hill—MIS 7; Pamlico—MIS 5; Princess Anne—MIS 5; and Silver Bluff—MIS 5 or 3. Except for the MIS 5e Pamlico, and possibly the MIS 11 Ladson, the South Carolina elevations are higher than predicted by isotope proxy-based reconstructions. The <4 m of total relief from the Pamlico to the Silver Bluff shoreline in South Carolina, for which other reconstructions suggest an expected relief of ~80 m, illustrates the lack of match. Our results suggest that processes affecting either post-depositional changes in shoreline elevations or the creation of proxy sea-level estimates must be considered before using paleo sea-level position on continental margins.
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Introduction

South Carolina's (SC) Pleistocene marine coastal-plain deposits are well developed and problematic. Lithostratigraphic-based mapping of South Carolina shows relative sea level (RSL) highstand elevations for the last 2 Ma ranging from 42.6 to 3 m above present sea level. However, analysis of the complex processes acting on these shorelines shows they do not entirely fit predicted sea-level histories derived from studies far afield. For example, only eight Pleistocene highstand-related formations are preserved at the surface in SC. This is much smaller than the number of Marine Oxygen Isotope Stage (MIS) highstands (odd-numbered stages) for the Pleistocene. This misfit between the observed and predicted global sea-level highstands indicates the complexity of determining past sea-level elevations. Correlating our work to other locations along the southeast United States (SE US) coast provides a regional-scale perspective of the land-based records as one record of the world-wide Pleistocene sea-level history.

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Background

Evolving concepts of shoreline studies in South Carolina

Our study area lies in the SE US, south of where G. B. Shattuck (1906) published the first stratigraphic maps of Maryland's eastern shore. He introduced the concept of escarpments (scarps) and terraces as markers for former sea-level positions (Supplementary Table 1) following G. K. Gilbert's (1890) description of similar features of former Lake Bonneville, Utah. These scarps represent the inland limit of their associated marginal marine sedimentary terraces, and their packages of associated sediments were called formations (Shattuck, 1906, 1907).

Later C. W. Cooke (1930, 1936) correlated coastal terraces and produced paleoshoreline maps for the Coastal Plain of South Carolina (SC). Colquhoun (1965, 1969a,b, 1974) added boreholes to depict the subsurface lithostratigraphy. R. E. Weems with many other workers (Supplementary Table 1) continued Cooke's and Colquhoun's morphostratigraphic scheme while mapping the central portion of SC's Lower Coastal Plain. W. R. Doar and R. H. Willoughby (Fig. 1; Supplementary Tables 1, 2, 3, and 4) have expanded the spatial coverage of earlier workers. A comprehensive list of authors and publications contributing to the presently known stratigraphy is presented in Supplementary Table 2.

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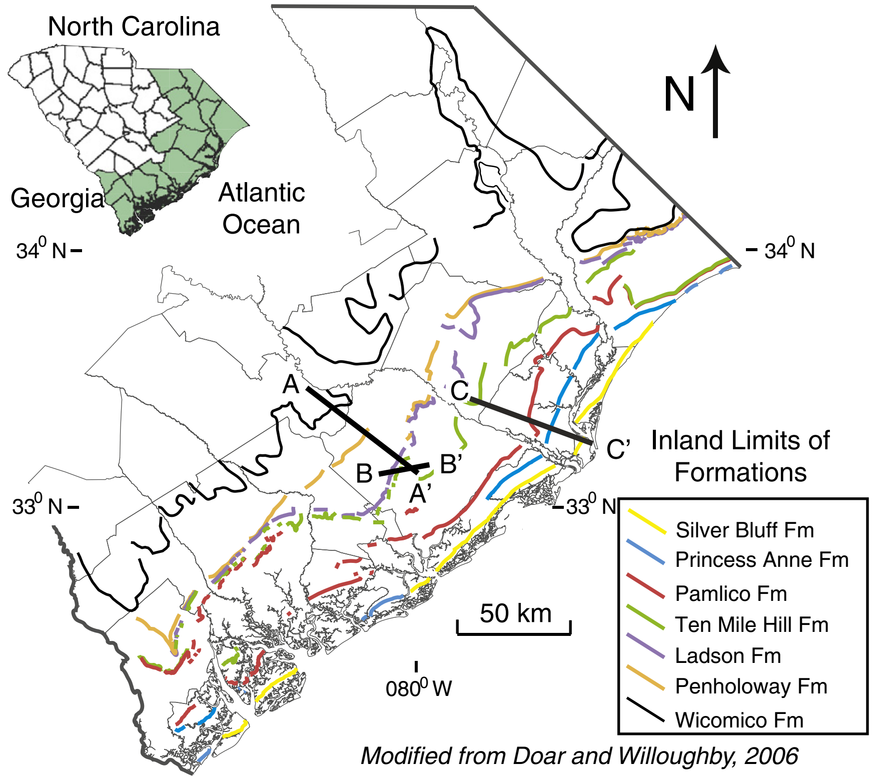

Figure 1. Generalized map of the Pleistocene scarps in South Carolina. The scarps separate the Pleistocene formations at the surface and are used to determine shoreline elevations. More information on individual formations is found in Table 1 and generalized map of the Pleistocene marine deposits (based on 1:24,000-scale geological mapping and physiography) and cross-sections A, B, and C are included in the Supplementary 4.

Our maps show established geologic and geomorphic features, including formations, paleoshorelines, escarpments, and terraces (for terms and definitions see Supplementary Table 4). In SC, various authors mapping scarps and terraces assigned names based on geographic names. Other authors assigned names to the distinct mappable packages of genetically related sediments (Formations). The modern conventions for naming formations (e.g. the North American Code of Stratigraphic Nomenclature, 2005) result in formations and their associated overlying terraces (produced from the same transgression) not always having the same name. To avoid confusion here, we refer to the Formation names throughout this paper for each related transgression.

Relationships of sediments to morphology

The coast of SC is typically a sediment-starved system (Gayes et al., 2002, 2003; Ojeda et al., 2004). In such systems, transgressions create accommodation through shoreline erosion (sensu stricto Jervey, 1988). Transgression is followed by deposition of the eroded sediment into the newly created space, as opposed to infilling with surplus imported sediments. This results in a 1 to 2° seaward incline on the plain (Cronin et al., 1981) creating a physiographical flat terrace (Fig. 2). Each subsequent transgression that does not overtop existing deposits, repeats the process at slightly lower elevations. This produces distinct mappable packages of genetically related sediments, separated by erosional scarps at the surface, overlying each new unconformity (Figs. 2 and 3). Erosional scarps therefore define the inland contact of younger sediments against older sediments and are the surficial expressions of unconformities.

Geologic setting

Following the opening of the Atlantic Ocean, about 180 Ma (Manspeizer et al., 1978), the Atlantic coast of North America, including SC, became a trailing-edge margin. Heller et al. (1982) stated that by the Pliocene and Pleistocene, thermal subsidence related to the Atlantic spreading center had slowed and presently the coastal plain of SC is composed of a southeastward-dipping wedge of calcareous and siliciclastic sediment (Poag, 1985). The Marietta unit (informal), located in the Middle Coastal Plain (DuBar et al., 1974), and its associated Parler scarp (Colquhoun, 1974), mark the inland limit of Pleistocene highstand deposits.

Methods

There are very few exposures of the strata beneath the Coastal Plain surface. The authors have relied heavily on geomorphological assessments and subsurface borings to determine the stratigraphy. About 1500 boreholes were used to produce 52 7.5 min, 1:24,000-scale geological quadrangle maps covering >6800 km^2 (Supplementary Table 4; all maps and logs on file at the South Carolina Geological Survey). Surface elevations were determined from 1:24,000-scale USGS topographic maps [usually ~1.5 m (5 ft) contour interval] with an elevation error of one contour interval. Boreholes were drilled using a modified well-drilling truck fitted with 11.43 cm diameter, 1.52 m long solid-stem continuous-flight auger rods. The hole depths are as shallow as 3 m and as deep as 43 m with an average of 15 m. The borings have an average grid spacing of 3 km. This spacing was modified where needed to verify the presence of scarps and their toes or the discovery of complex subsurface geology. The auger rods were drilled vertically into the ground for 3 m. To minimize disturbance of the sediments, augers were rotated ~1 rotation per auger flight. The auger rods were hoisted to the surface with the sediment trapped between the auger flights. The sediments were examined in the field with a 10× loupe magnifier and their position and physical characteristics were logged (e.g. surface elevation, depth, grain size, composition, sorting, rounding, color, induration).

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