Rapid Scour, Sand Rim Construction, and Basin Migration of a Carolina Bay in Southeastern North Carolina

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Abstract

Ongoing geomorphological fieldwork at Herndon Bay in northern Robeson County, North Carolina, has revealed evidence for rapid bay basin scour and landform migration. LiDAR data show a regressive sequence of sand rims that partially backfill the remnant older bay basin, with bay migration of more than 600 meters to the northwest. Similarly, other bays in the region show evidence of significant migration.

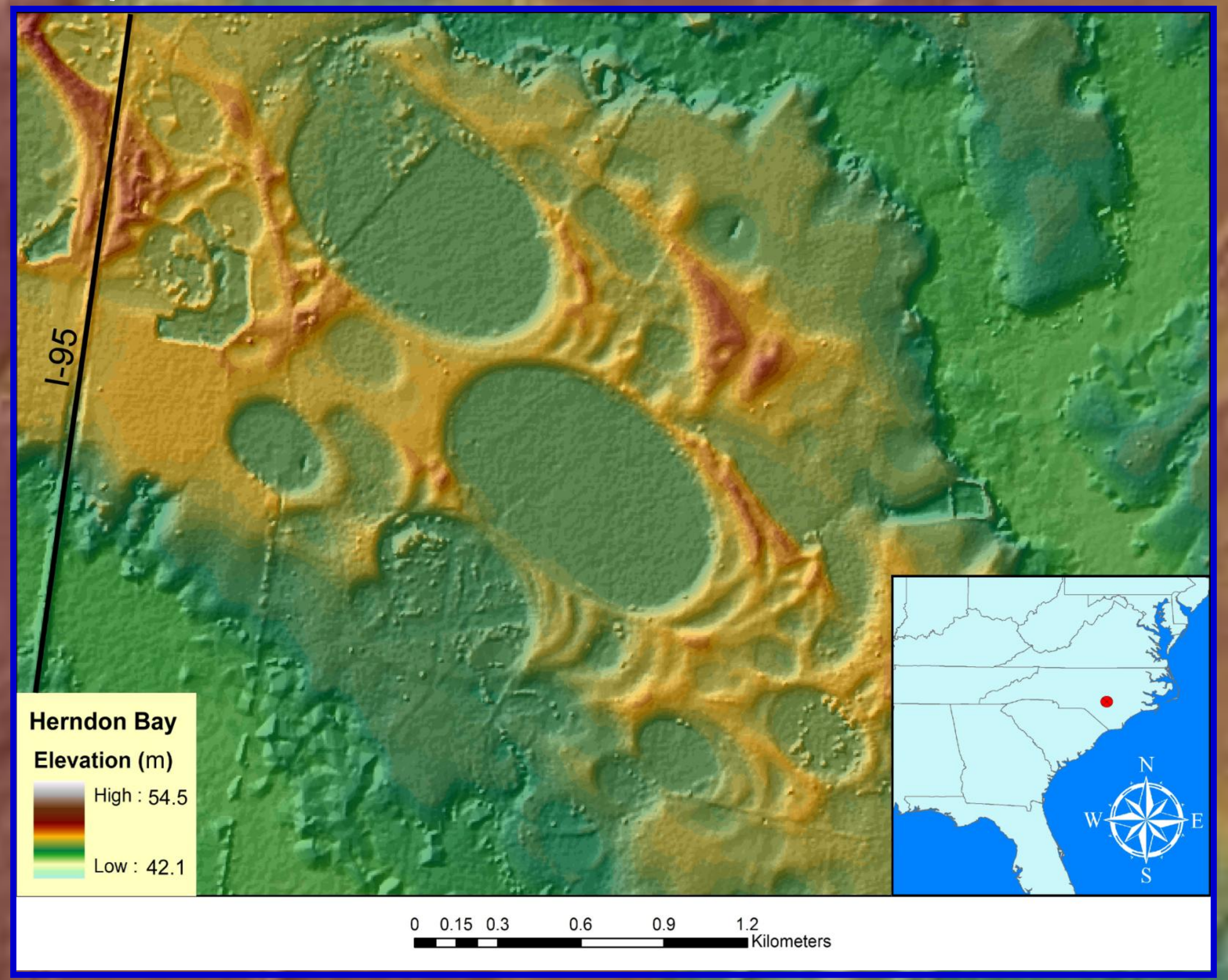
A series of Geoprobe® cores (n=4), basal OSL samples (n=3), and GPR data were collected along transects that cross-cut multiple bay sand rims along the bays southeastern margin. Cores were subsequently analyzed to determine basic lithologies, grain-size statistics of lithologic units (i.e., lithofaces), and magnetic susceptibly. These data, along with GPR data and OSL age estimates are used to reconstruct landform geomorphology and provide a geochronology for bay rim development. Evidence suggests bay migration, including scouring of the underlying mud facies. This migration is punctuated by periods of high-energy shoreline processes leading to the development of a regressive sequence of bay sand rims with basal muddy sands incorporated into the earliest sand rims. Single grain OSL place the initial formation of each sand rim from oldest to most recent as ca. 36.7 +/- 4.1, 29.6 +/- 3.1, and 27.2 +/- 2.8 ka. This chronology indicates that migration and rim construction events began during late MIS 3 and continued during the early part of MIS 2. Elsewhere in the Southeast, source-bordering eolian dunes attest to considerably greater average wind speeds, prevailing winds out of the west and southwest, and sparse tree-cover during this time (e.g., Swezey et al. 2013). Evidence for high-energy subaqueous basin scour and rapid construction of multiple sand rims at Herndon Bay is consistent with strong prevailing winds and ecological reconstructions of the late Pleistocene Southeast. The fact that these landforms can migrate, yet maintain their characteristic oval shape, orientation, and rim sequences demonstrate that Carolina bays are oriented lakes shaped by lacustrine processes. Clear evidence of basin scour into the underlying Tertiary marine sandy clays reveal that Carolina bay are capable of creating, shaping, and migrating through their own basins while backfilling remnant basins with a regressive sequence of paleoshorelines.

Objectives and Methods

Geological fieldwork was conducted at Herndon Bay in North Carolina for purposes of collecting a series of cores useful for geomorphic characterization of the landform. Cores were collected from several bay sand rims with the use of a truck-mounted Geoprobe®. Coring locations corresponded to the locations where previous basal samples were collected for OSL dating at the University of Washington Luminescence Dating Laboratory. Ground-penetrating radar (GPR) data were also collected along transects that cross-cut multiple bay sand rims and Geoprobe core/OSL sample locations. In total, 4 complete cores were collected at Herndon Bay (including one bay rim not sampled for OSL). Geoprobe cores were subsequently analyzed to determine basic lithologies, grain-size statistics of lithologic units (i.e., lithofaces), and magnetic susceptibility.

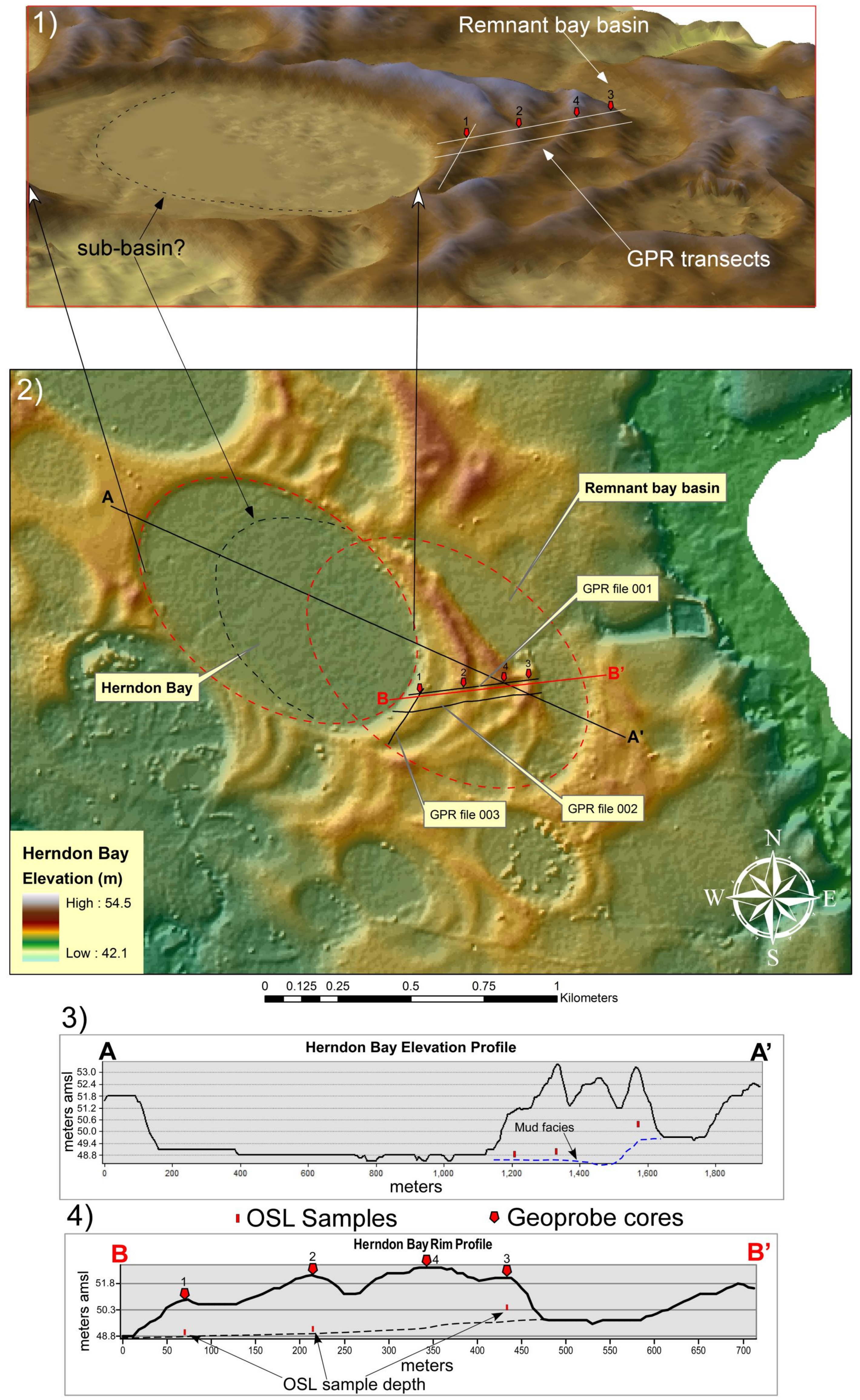
GPR surveys were conducted using a Geophysical Survey Systems (©GSSI) SIR-3000 unit with 200MHz ©GSSI antennae. A recording window of 100-150 ns provided potential data acquisition to a depth of ~5-9 m using a dielectric constant of 6-10. Depth to major lithologic boundaries was verified by auguring and Geoprobe® (direct push) coring. GPR data were collected using a ©GSSI survey wheel set at 10 scans per meter and 1024 samples per scan. Survey lines were georeferenced with a Trimble differential GPS. GPR data were processed using Radan v6.5 software (©GSSI), including bandpass filtering and gain-enhancement. Surface normalization was based on LiDAR elevation data. These data were then combined with processed core data and single–grain luminescence age estimates from basal samples to reconstruct landform geomorphology of the bay and provide a geochronology for bay rim development and bay migration.

Study Area



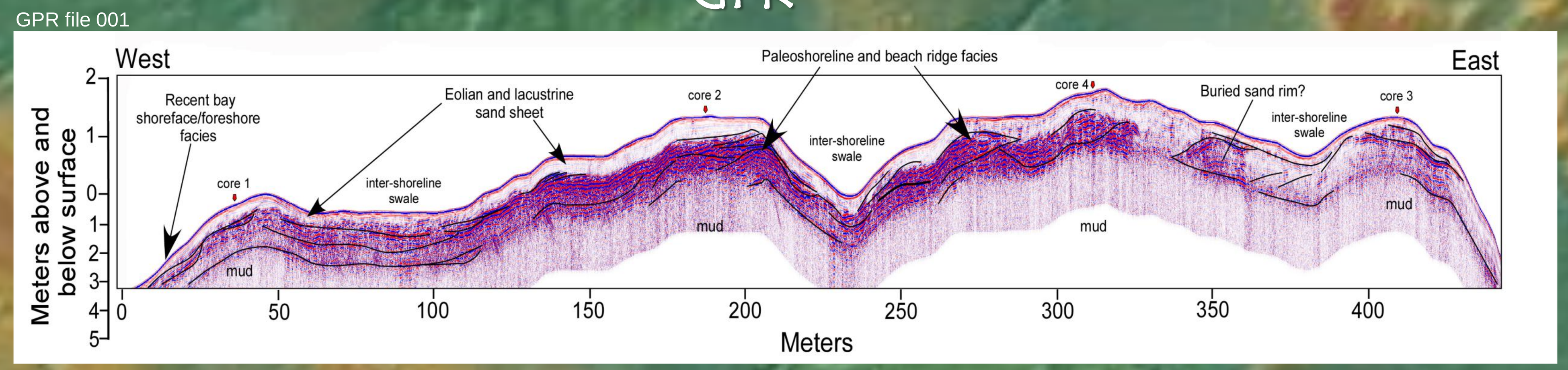
Map of the study area showing the location of Herndon Bay in Northeastern Robeson County, North Carolina.

LiDAR Imagery



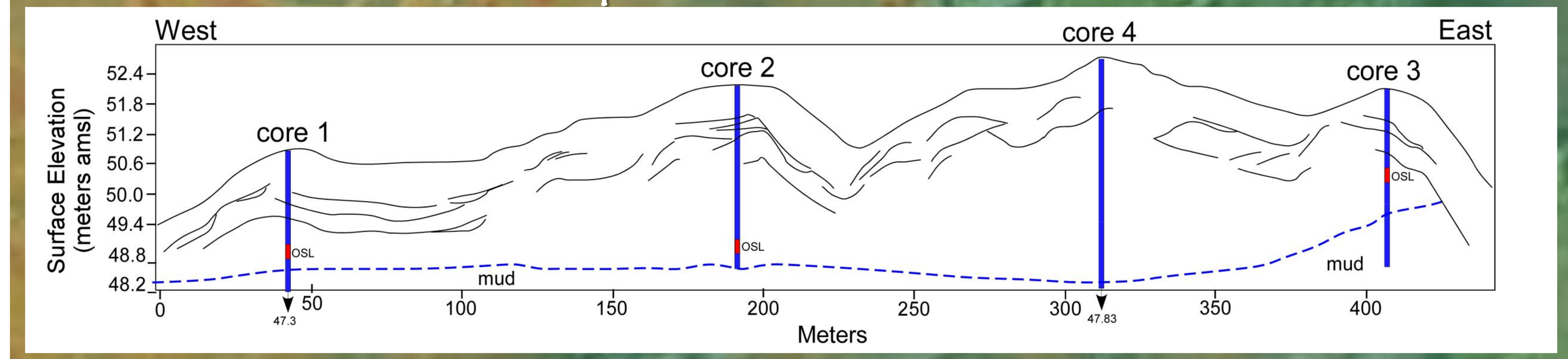
LiDAR imagery and elevation profiles for Herndon Bay in Robeson County, NC. 1) 3D LiDAR view, 2) LiDAR planview showing elevation, GPR transects, and Geoprobe core locations, 3 and 4) elevation profiles showing Geoprobe® core and OSL sample locations.

GPR



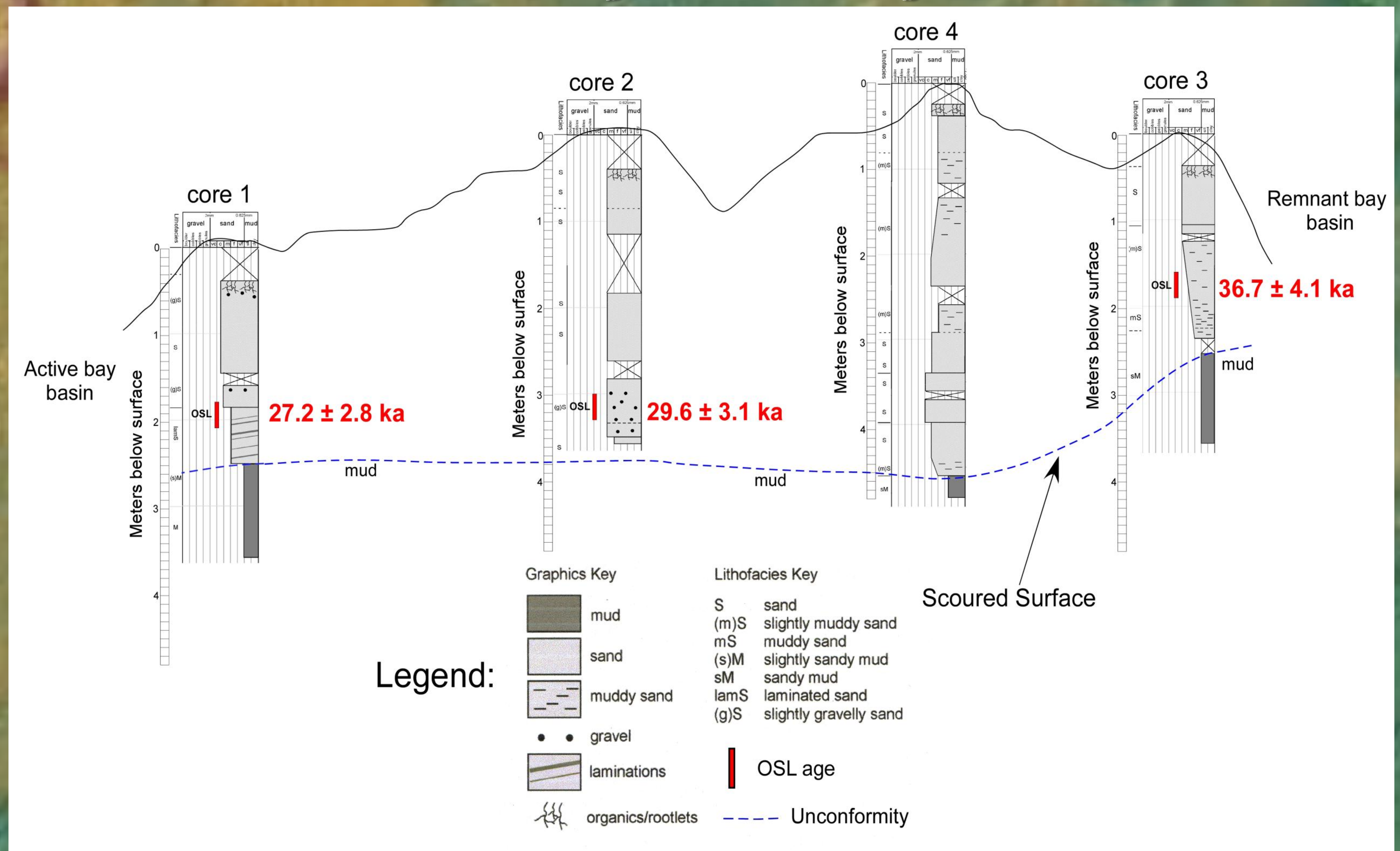
Surface-normalized GPR transect at Herndon Bay showing rim topography, interpreted radar facies, and core locations.
*Vertical scale is exaggerated.

Geoprobe Core Transect

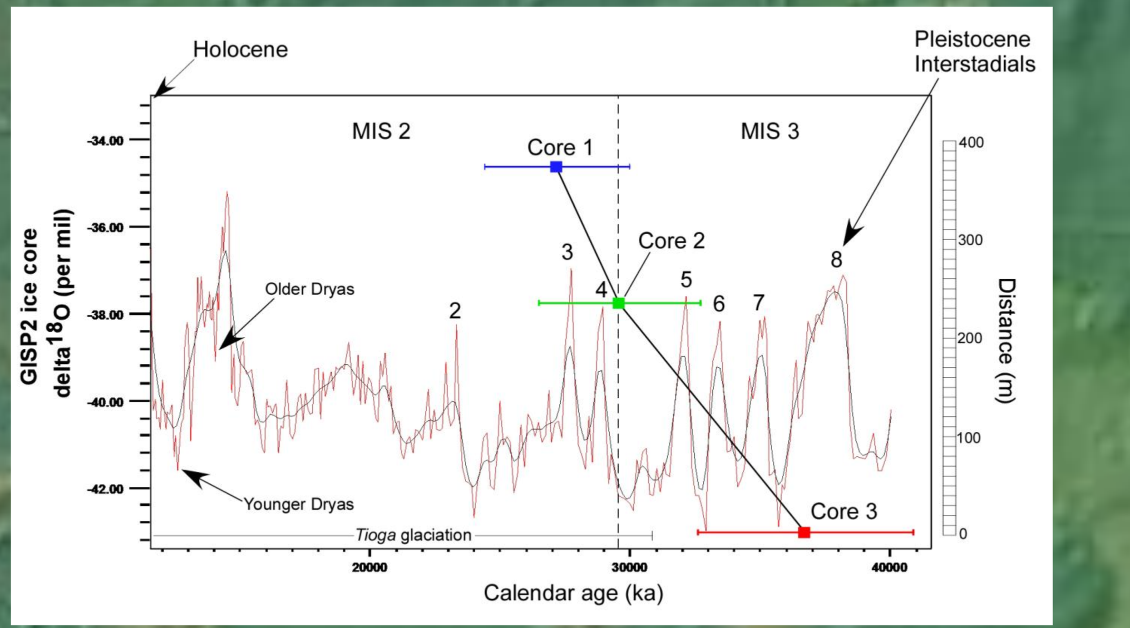


LiDAR-derived topographic cross-section of the GPR transect (001) at Herndon Bay showing the interpreted radar reflections, location of cores, OSL samples, and the contact with underlying mud facies.

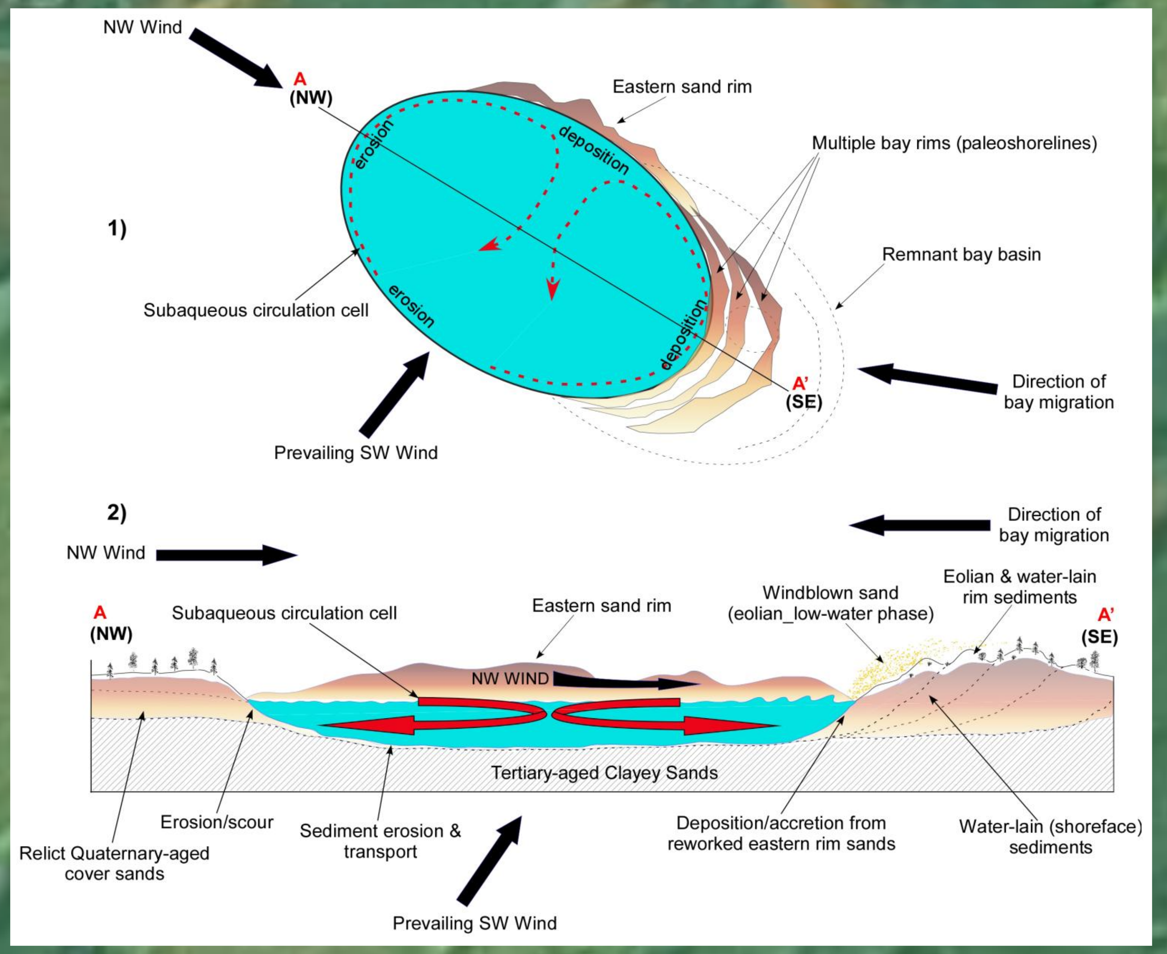
Core Logs & OSL dating



Geoprobe ® core data, corrected for elevation and rim topography, showing major lithofacies and single-grain luminescence geochronology.



Sand rim OSL age/distance relationship plotted over the GISP2 Oxygen Isotope data from Greenland.



Carolina bay formation and migration model based on earlier models by Kaczorowski (1977) and comparison with LiDAR data from North and South Carolina. 1) Overhead view; 2) bay cross-section.

Discussion

Evidence from Herndon Bay suggests periods of bay migration, including scouring of the underlying mud facies. Periods of stability are punctuated by periods of high-energy shoreline processes leading to bay basin migration and the development of a regressive sequence of sand rims.

GPR data reveal structural features of sand rims, including dipping clinoforms and evidence for a buried sand rim between cores 3 and 4. Single-grain OSL dating of 3 sand rims indicates a period of fairly rapid bay migration between 40.8 and 24.4 ka, with the development of distinct sand rims in a regressive sequence occurring over a period of time between ca. 8,000 and 16,500 years and over a distance of 370 meters. Assuming gradual formation, this equates to a migration rate of between ~22 and 44 meters per millennium towards the northwest; however the distinct nature of the individual rims is consistent with punctuated and very rapid migration over short distances followed by periods of stability and rim formation.

Geoprobe core data reveal down-cutting with muddy sands incorporated throughout the oldest sand rims during the initial period of high-energy lacustrine processes and basin scour into underlying Tertiary muds. The basal portions of more recent sand rims contain gravelly sands and laminated sands but lack the muddy sands common in the oldest sand rims.

Following Kaczorowski (1977), a Carolina bay migration model was developed to explain processes that shape, orient, and lead to bay basin migration and the development of a regressive sequence of sand rims along the southeastern margin of Carolina bays. Kaczorowski's wind table modeling suggests obvious mechanisms for these processes, with circulation cells in shallow ponded water eroding along southwest and northwest margins and depositing (lacustrine sand rims) on the downdrift sides (eastern and southeastern margins). Bay migration is perpendicular to the most common or prevailing wind (from the southwest in the Carolinas) although this research suggests a significant role for winds out of the northwest. In this scenario, strong prevailing winds from the southwest are principally responsible for bay shape, orientation, and the development of sand rims along the eastern or northeastern margins of bays, while more seasonal and stronger northwest winds appear to drive limited bay migration and development of multiple southeastern sand rims in a regressive sequence towards the northeast. Principally in the lower Coastal Plain of North and South Carolina, expansive, flat terrain, along with easily eroded cover sands, facilitate the lateral expression of bays through migration. In the Upper Coastal Plain, bay migration is often restricted due to dissected terrain and antecedent topographic highs. Punctuated periods of bay migration and rim formation at Herndon Bay likely occurred during transitions between cooler/drier and warmer/wetter conditions during Pleistocene interstadials 3 to 8 during late MIS 3 and early MIS 2.

References and Acknowledgements:

Kaczorowski, R. T. *The Carolina Bays: A Comparison with Modern Oriented Lakes*. Technical Report No. 13-CRD, Coastal research Division, Department of Geology, University of South Carolina, Columbia, South Carolina. 124 pp. ; **Swezey, Christopher S. et al.** 2013 Quaternary eolian dunes in the Savannah River valley, Jasper County, South Carolina, USA. *Quaternary Research* 80:250-264; GISP2 Ice core data was provided by the National Snow and Ice Data Center, University of Colorado, Boulder and the WDC-A for Paleoclimatology, National Geophysical Data Center, Boulder, Colorado.

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