# *Assessing the Lateral and Stratigraphic Heterogeneity of a Windward Platform Margin, Exumas, Bahamas*

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## Project Purpose

Windward margin stratigraphy and heterogeneity is assessed through mapping the modern facies and coring the Pleistocene parasequence-scale stratigraphy along the ~200 km windward margin in the Exumas, Bahamas (Fig. 1). The results from this three-year study will deliver a baseline for improved carbonate heterogeneity estimation and reservoir characterization in windward margin settings.

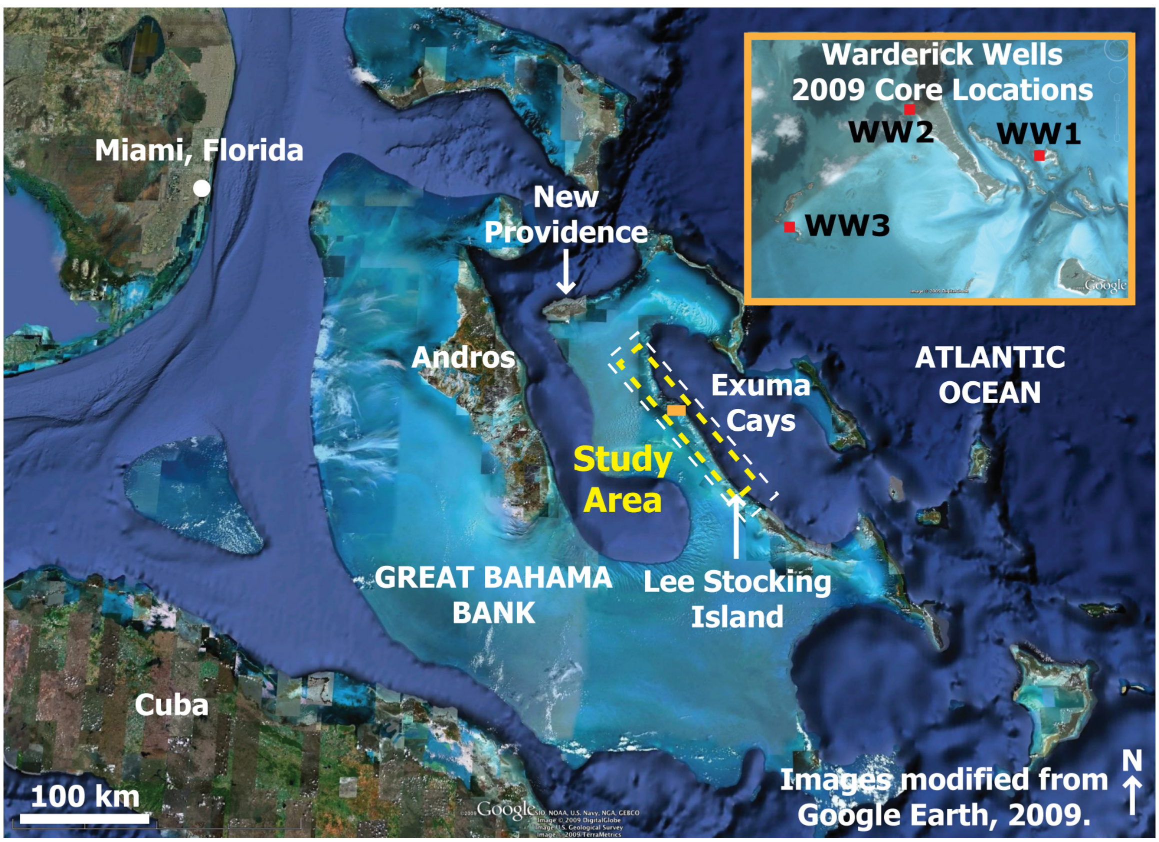


*Figure 1. The Exuma Cays are located along the windward margin of Great Bahama Bank forming the western margin of Exuma Sound.*

## Project Background and Motivation

Sea level has changed throughout Earth's history with variable frequency and amplitude. In the Pleistocene, these changes occur quickly with high amplitudes due to the waxing and waning of ice sheets. During times of high sea level, carbonate platforms like the modern Great Bahama Bank are flooded and a new layer of sediment is deposited. Sea level, however, did not rise to the same level and was not always stable during the highstands. For example, during the last sea level highstand 125 kyrs ago during marine isotope stage (MIS) 5e, sea level peaked approximately 6 m higher than present and before that fluctuated for several meters (Thompson and Goldstein, 2005). Likewise, older sea level highstands were also higher (MIS 9 and 11) or lower (MIS 7) than the current sea level. The Quaternary stratigraphy of the Bahamas records the depositional events occurring during highstands in a complicated array of stacked and laterally accreting marine and eolian deposits for example on Eleuthera Island (Kindler and Hearty, 1996) and New Providence Island (Garret and Gould, 1984; Hearty and Kindler, 1997). Along the Exumas platform margin, the highstand variability and impacts of sea level changes are recorded in stacked successions of shallow-water carbonates (McNeill and Hearty, 2009; Petrie, 2010).

By dissecting the sedimentary architecture, we expect to address the fundamental question of how the frequency and amplitude of sea level influences the stratigraphic facies heterogeneity. Platform interior cycles created by high-frequency sea level changes often maintain uniform thicknesses over several kilometers and their vertical trends in thickness delineate larger scale reservoir units. In marginal settings, cycles vary greatly in shape and because the elevation of each sea level rise varies, a complicated architecture of onlapping and overstepping wedges is produced. Onlapping wedge-shaped deposits characterize those highstands that did not overtop the margin topography; those that flood the platform produce a thicker wedge but both primarily stack laterally and prograde seaward. In the Lee Stocking Island area, the Exumas margin prograded eastward from the older middle Pleistocene (potentially MIS 11 or 13) to the late Pleistocene (MIS 5) (McNeill and Hearty, 2009).

**Project Hypothesis**

The central hypothesis of this study is that the windward margin stratigraphic architecture records the high-frequency sea level fluctuations within Pleistocene sea level highstands.

**Project Tasks**

The hypothesis will be tested by mapping the modern facies and Pleistocene outcrops in addition to coring and dating the Pleistocene parasequences in the Exuma Cays, Bahamas (Fig. 1). Holocene facies mosaics will be evaluated with respect to the underlying Pleistocene topography. Dating of individual parasequences will relate vertical successions to the different Pleistocene sea level changes.

*Task 1: Produce detailed geologic maps of the Exumas windward margin by combining satellite imagery and surface mapping of the Pleistocene/Holocene strata.* Initial reconnaissance field mapping was conducted in 2009 and will continue with surface mapping of outcropping Pleistocene units. This mapping will be integrated with previous studies by McNeill and Hearty (2009) and Petrie (2010) to produce a detailed surface geologic map of the Exumas windward margin. Detailed surface mapping is scheduled for the areas between Warderick Wells and Lee Stocking Island.

*Task 2: Collect core transects to establish the vertical succession and stacking patterns at key locations.* Cores, up to 10 m deep, will be collected using a rotary drill with a tripod and wire-line core barrel system (Fig. 2A). Short 1 m cores will be collected using handheld system (Fig. 2B). Rocks in cores collected at Warderick Wells (Fig. 1A inset) feature a grainstone texture but the sedimentary structures indicate deposition in tidal, beach, and eolian environments. Up to three successions, separated by exposure horizons, document deposition during three Pleistocene sea level highstands. The successions are tentatively correlated to the sea level highstands occurring during MIS 5, 9, and 11 (120, 320, and 400 kybp, respectively). Future dating is planned to confirm these estimates (see Task 3). Transects of cores will test the idea that the Exumas prograded eastward from the older middle Pleistocene (MIS 11 or 13) to the late Pleistocene (MIS 5) as hypothesized by McNeill and Hearty (2009). A ten day drilling campaign is planned for September 2010 onboard the R/V Coral Reef II to recover additional long cores at various locations along the Exumas windward margin. Small cores will be collected during this drilling cruise as well as during other field campaigns in the spring and summer of 2010.

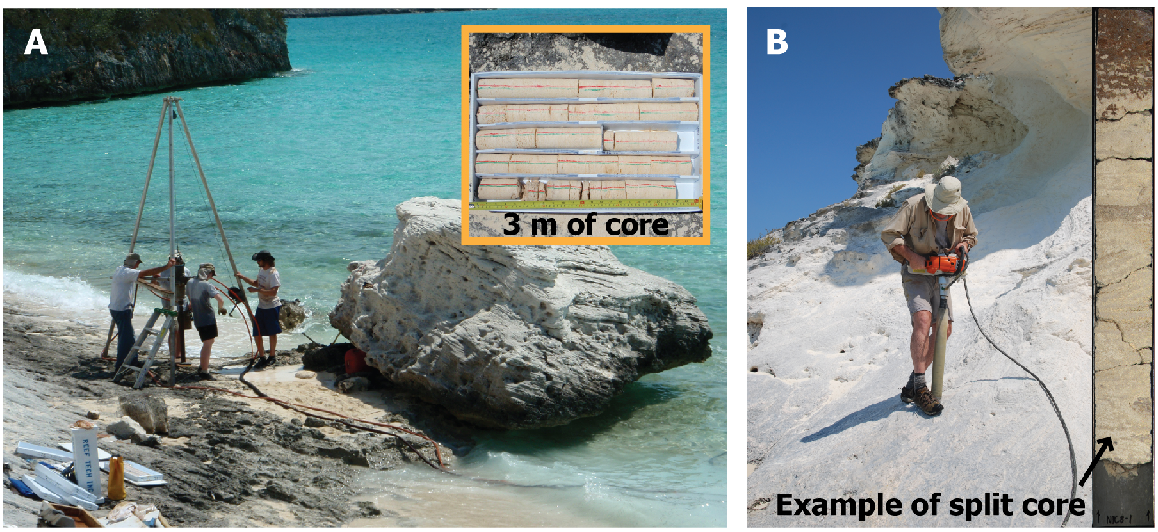


*Figure 2. Drilling methods. (A) A rotary drill with a tripod and wire-line core barrel system was used to collect 5 long cores in April 2009. This setup will be used during the summer 2010 coring campaign. (B) Numerous short cores will be collected during the summer of 2010 using a hand-held coring device to create high-density Pleistocene core transects throughout many islands in the Exuma Cays.*

*Task 3: Age dating of Pleistocene and Holocene strata to correlate and decipher the amplitudes of Pleistocene sea level changes.* To date the Pleistocene facies, we will use a combination of U-Th dating and amino acid racemization.

*Task 4: Conduct petrophysical analyses to understand the pore scale rock-fluid interactions of a carbonate windward margin.* Petrophysical analyses conducted on the NER Autolab 1000 will measure porosity, permeability, Vp, under variable confining pressure, and the pore fluid pressure of carbonate facies. These results will provide the rock type characterization of carbonate platform margin reservoir analogs.

## Expected Results

This study will document the lateral and vertical heterogeneity of the grain-dominated windward margin produced by the sedimentary response to high-frequency sea level changes. The expected outcome is to decipher the ages of orbitally induced sea level changes, the small-scale, high frequency variations during the highstands, and document stratigraphic heterogeneity in relation to the Pleistocene sea level fluctuations. Core data will decipher the coastal response to sea level fluctuations on a windward carbonate platform margin to determine the impact on coastal systems and resulting facies heterogeneity. This interaction directly influences biodiversity including the distributions of stromatolite and coral reef communities (Fairbanks, 1989; Feldmann and McKenzie, 1998). Assessing the stratigraphic heterogeneity of a carbonate platform margin will directly impact hydrocarbon reservoir characterization from the rock pore to the platform margin scale in coastal carbonate systems.

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