Stratigraphic Heterogeneity of a Windward Platform Margin, Exumas, Bahamas

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Project Purpose

Windward carbonate platform margins are often assumed to stack vertically during sea level highstands but recent studies document a more complicated architecture of onlapping and overstepping wedges that stack laterally and prograde seaward (McNeill and Hearty, 2009). In addition, there is growing evidence that Pleistocene sea-level highstands contain higher frequency, suborbital sea-level fluctuations (Thompson and Goldstein, 2005). Both factors potentially contribute to significant facies and stratigraphic heterogeneity along windward margins. The objectives of this project are:

1. To address the fundamental question of how high frequency sea-level changes influence the stratigraphic facies heterogeneity.
2. To assess windward margin stratigraphy and heterogeneity through mapping the modern facies and coring the Pleistocene parasequence-scale stratigraphy along the ~200 km windward margin in the Exumas, Bahamas (Figure 1).
3. To deliver a baseline for improved carbonate heterogeneity estimation and reservoir characterization in windward margin settings.

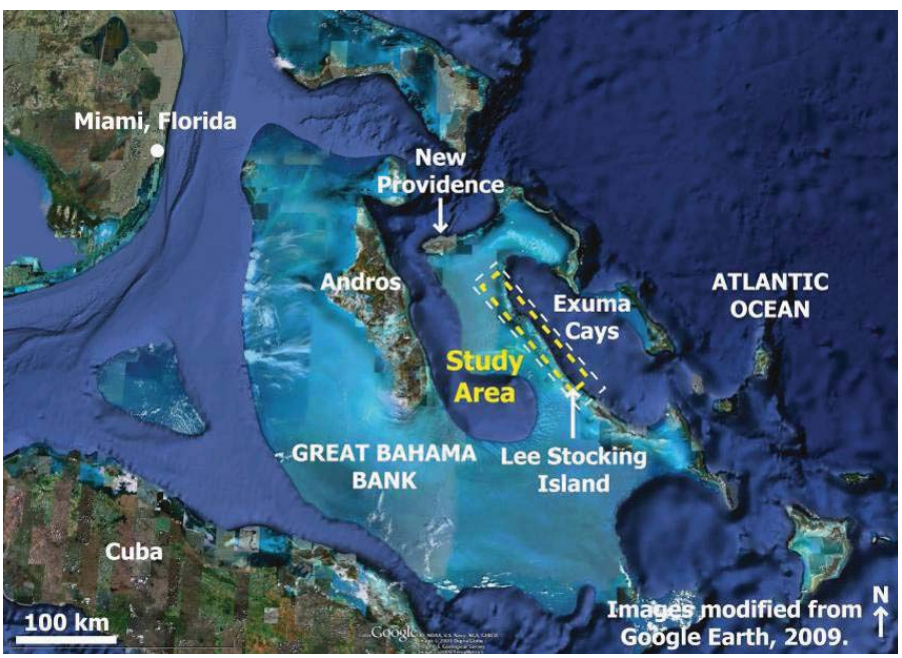

Figure 1: The Exuma Cays are located along the windward margin of Great Bahama Bank forming the western margin of Exuma Sound.

Project Background and Motivation

In the Pleistocene, high amplitude sea-level changes occur quickly 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, 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 as seen on Eleuthera Island (Kindler and Hearty, 1996) and New Providence Island (Garret and Gould, 1984; Hearty and Kindler, 1997; Reid, 2010). 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). Furthermore, there is mounting sedimentary evidence that small-scale sea-level fluctuations within the highstands produce an additional layer of complications both for the lateral facies and the vertical stacking.

The Exumas are an ideal location to address some fundamental questions regarding the sedimentary record of carbonates influenced by high frequency sea-level changes and suborbital, small-scale sea-level variations within highstands.

Project Hypothesis and Approach

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

Mapping the modern facies and Pleistocene rocks, and dating Pleistocene parasequences of the Exuma Cays, Bahamas will test this hypothesis (Figure 1). Holocene facies mosaics will be evaluated in respect to the underlying Pleistocene topography. Dating of individual parasequences will relate vertical successions to the different Pleistocene sea-level changes.

Project Tasks

Task 1: Produce detailed geol ogic maps of the Exumas wi ndward margin by combining satellite imagery and surface mapping of the Pleistocene/Holocene strata.

Surface mapping of outcropping Holocene and Pleistocene units in the Exuma Cays Land and Sea Park, an area extending 35 km along the windward margin, was completed in 2010 (Figure 2). During 2011, we plan to continue mapping the northern, central, and southern Exumas. This mapping will be integrated with previous studies by Petrie (2010) to produce a detailed surface geologic map of the Exumas margin that will document the lateral heterogeneity of outcropping Pleistocene units and the complex Holocene accretion that resulted.

Task 2: Collect core transects to establish the vertical succession and stacking patterns at key locations.

A twelve-day drilling campaign is scheduled for March 2011 onboard the R/V Coral Reef II to recover 5 long cores (up to ~20 m deep) at various locations along the Exumas windward margin (red dots, Figure 2) including a second west – east transect at Darby Island. Cores will be drilled using a rotary drill with a tripod and wire-line core barrel system. These cores will complement the five cores drilled in 2009 and the more than 30 short cores (< 1 m) drilled in 2009 and 2010. In the successfully cored wells (yellow dots, Figure 2) recovered strata document the interplay between Holocene and Pleistocene deposits from MIS 5, 9, 11, and potentially 13. Cores feature carbonate grainstones deposited in subtidal, beach, and eolian environments, as well as calcrete surfaces that mark exposure horizons that separate the Pleistocene deposits.

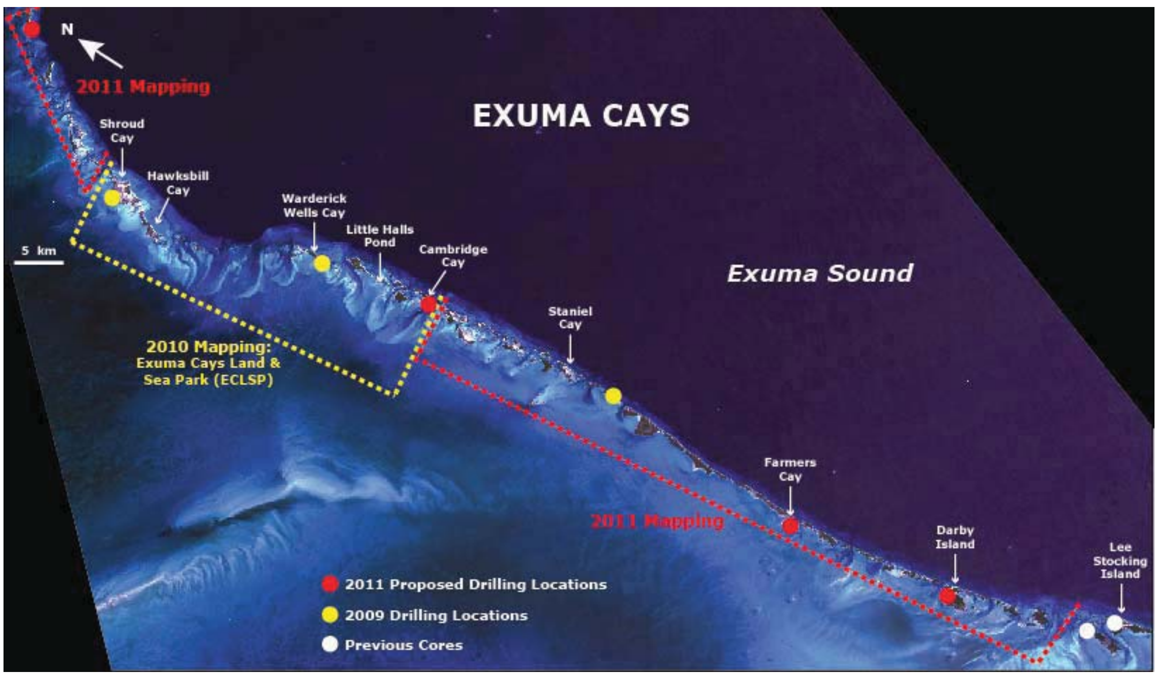

Figure 2: Satellite image of the Exuma Cays indicating region mapped in 2010 (yellow) and proposed 2011 mapping (red). White dots indicate the locations of cores previously drilled that were described and dated by McNeill and Hearty, 2009. Yellow dots indicate locations of the cores (12 – 22 m) drilled in 2009. A transect of three cores was drilled at Warderick Wells. Red dots indicate proposed 2011 drilling locations and will include a transect of two cores at Darby Island.

Task 3: Age dating of Pleistocene and Holocene strata to correlate and decipher the amplitudes of Pleistocene sea-level changes.

The Pleistocene strata will be dated using Amino Acid Racemization (AAR) analyses. In addition to AAR, we also plan to use U-Th dating conducted at RSMAS to try to decipher the ages of Pleistocene units viewed in outcrop and in core.

Task 4: Conduct petrophysical analyses to understand and characterize the reservoir facies of a carbonate windward margin.

Petrophysical analyses will include porosity, permeability, and Vp, under variable confining pressure and pore fluid pressure. The petrophysical analyses will be performed in conjunction with a thorough petrographic analysis to decipher the diagenetic history. Digital image analysis will be used to quantify the pore structures in the various facies and ages.

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 high frequency variations during the sea-level highstands, and document facies and stratigraphic heterogeneity in relation to the orbital and suborbital sea-level fluctuations during the Pleistocene. 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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