Dominican Republic Drilling Project - Year 2: Integrated Analysis of Cores from Reefal Clinothems

James S. Klaus, Yula Hernawati, Albertus Ditya, Donald F. McNeill, Peter Swart, Gregor P. Eberli, and Ralf J. Weger

Project Ojectives

The principal objective is to determine the facies geometry, diagenesis, and petrophysics of carbonate rocks subjected to repeated cycles of freshwater and marine diagenesis from regional uplift and high-amplitude changes in sea level. The Pleistocene reefs that developed over the past 2.5 million years provide one of the best opportunities to study the complex three-dimensional architecture and controlling factors of fringing reef development during high frequency sea level cycles. A series of laterally stacked reef-skeletal clinothems document successive deposition during uplift and changes in available accommodation space with relative sea-level changes.

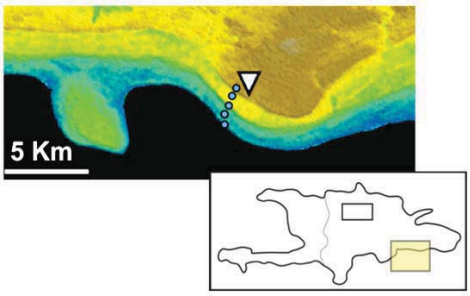

Figure 1: Location of s tudy area an d position of the five core transect acro ss the uplifted terraces in the southern Dominican Republic.

Project Overview

In Summer 2010, a five-core transect, sponsored by the Comparative Sedimentology Laboratory, was bored into Pleistocene fringing reef deposits on the southern coast of the Dominican Republic (DR) (Figure 1). These cores are combined with outcrop and quarry mapping performed during several field seasons. This project aims to characterize the composition, morphology, and physical properties of the reefal clinothems and how early diagenesis has impacted these rocks. The work focuses on three main tasks: 1- lithostratigraphy, chronostratigraphy, and facies; 2- geochemical and diagenetic characterization of the clinothem packages; and 3- petrophysical characterization related to depositional facies and diagenesis. Two masters projects are currently underway and during summer 2011 a doctoral student will begin work on a synthesis of outcrop, seismic, and core data.

Key Deliverables

This project will provide an integrated depositional-diagenetic-petrophysical case study of skeletal deposits within a larger siliciclastic-dominated regional framework. The results of this research are expected to provide an understanding of key depositional and diagenetic parameters controlling acoustic properties in reef limestone and the processes that create petrophysical variations. These data will help the geologist improve the interpretation of stratigraphic, seismic, and log data in reefal successions.

Scope of Work

1-Depositional Facies, Chronostratigraphy, and Transect Correlation of Reef Clinothems

(Jim Klaus & Don McNeill, coordinators)

Since reporting on the initial results of the coring at the 2010 Industrial Associates meeting (October), our efforts have been focused on core description and determining the ages of the deposits for core-to-core correlation. We have collected and analyzed a series of strontium isotope samples, mainly molluscs shells, that stable isotope values have shown to be diagenetically unaltered. The initial set of results, returned in December 2010, tentatively date seven depositional packages (Figure 2). These ages are poorly constrained at this point because relatively few samples have been analyzed so far. We will continue to collect appropriate samples for a second phase of Sr-isotopic dating. We will also collect mini-plugs for paleomagnetic analysis to help refine age correlations.

Textural description, depositional facies, and faunal facies of the five cores are underway and will be integrated with outcrop exposures. Seismic data that resolve the upper Pliocene-Pleistocene facies will be evaluated for development of a regional stratigraphic framework. The stratigraphic framework will provide the basis for the diagenetic and petrophysical characterization of the reefal deposits.

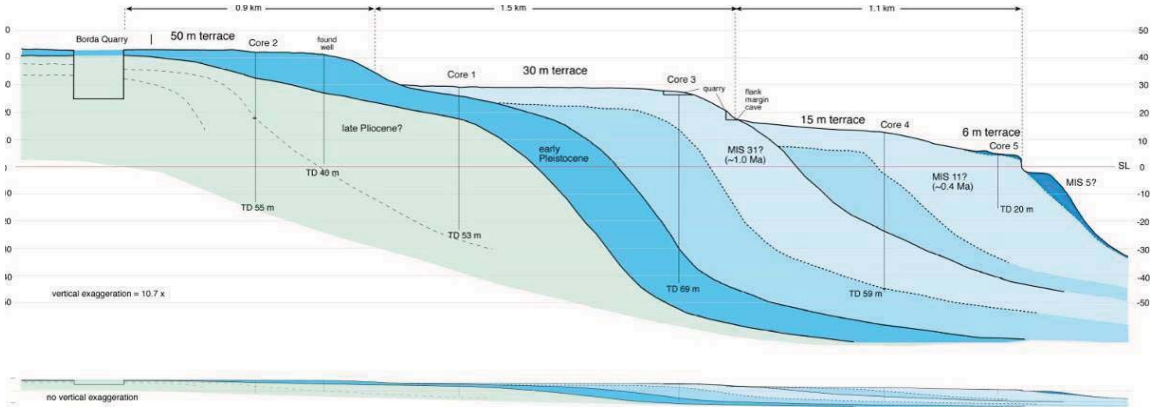

Figure 2. Preliminary stratigraphic correlation of the main depositional units based on initial strontium-isotope age data and the identification of key stratigraphic surfaces within the core borings. Uncertainties still exist in the correlation and additional strontium ages will be determined to refine the stratigraphy.

2 - Diagenesis of Reef Clinothems

(Yula Hernawati & Peter Swart)

The well-developed reef terraces along the southern coast of the DR have undergone several episodes of meteoric diagenesis over the past 1.8 million years as the reefs formed and were subjected to uplift. The uplift produced repeated diagenetic overprints on the older terraces, while the youngest terrace experienced only one episode of exposure. The purpose of this project will be to compare the diagenetic signatures in reefs that have experienced only one episode of exposure with those which have had multiple episodes. In addition, X-ray diffraction has indicated the presence of dolomite in several of the cores. The distribution, volume, and geochemistry of the dolomite will be assessed.

Five long cores (20-69 meters) and several short cores (± 60 cm) were collected from different reef terraces in the southern DR. Samples were collected every 1-2 cm in the short cores and every 10-50 cm intervals in the long cores. Stable C and O isotopes, mineralogy, and trace elements analyses will be performed on all the samples. Diagenetic zones (vadose, freshwater phreatic, and marine) will be identified using sedimentological, petrographical, and geochemical indices. Zones of similar ages will be compared to cores from different terraces.

The classic C and O isotopic signatures accompanying freshwater diagenesis have been described in cores from the Bahamas and Barbados (Allan 1986; Allan and Matthews 1977). The interpretation of such changes have not changed significantly over the past 30 years (Allan and Matthews 1982). In the original work that defined the classic diagenetic zones, no recognition was made of the influence of repeated exposure. This work should help to ascertain whether these signatures change during repeated exposure. The zone of meteoric diagenesis is one of the most promising zone for the development high porosity and permeability, and therefore, the results of this study will be useful for developing a predictive model for the distribution of meteoric and mixing zone induced porosity in carbonate reservoir rocks.

3: Petrophysical Characterization of Reef Clinothems

(Albertus Ditya, Gregor Eberli, and Ralf Weger, coordinators)

This component of the project will characterize the petrophysical properties and the factors that create variations in reefal limestones. We will assess the relationship of pore structure and the petrophysical properties in particular sonic velocity and resistivity. The petrophysical parameters will be integrated with the diagenetic and stratigraphic information to produce a geological and geophysical model of the reef architecture.

Weger et al. (2009) and Verwer et al. (2011) document the strong correlation between quantified pore parameters, such as the perimeter over area (POA) and the dominant pore size (DOMsize) with petrophysical properties such as: velocity, porosity, and permeability and electrical resistivity. Data from outcrop samples corroborate their findings in the reefal limestones investigated from outcrops in the DR (Figure 3).

The recently cored strata have undergone several stages of marine and meteoric diagenesis causing repeated cementation and dissolution that has altered the original pore structures (Anselmetti and Eberli, 1993, 2001). Consistently high acoustic velocities in

the hitherto measured samples is attributed to the occurrence of simple pore system created by early meteoric cementation and dissolution, which emphasizes that diagenesis plays a key role in shaping the pore space.

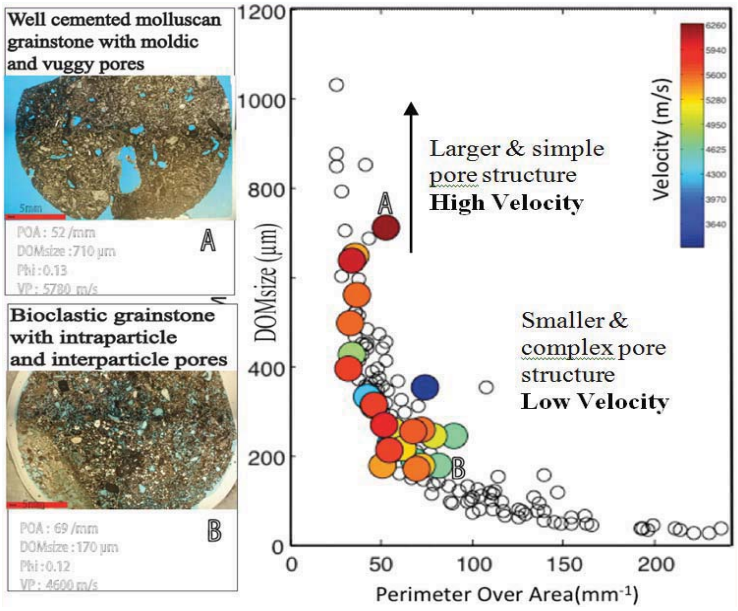

Figure 3. Cross plot POA, DOMsize and Vp in colors superimposed with Weger 2009 et al dataset. Outcrop samples showing simple pore size despite of environments or ages, pore types, or textures. The ir high velocity is influenced by pore structure, which is simple. More data needed to prove larger pores are faster.

One hundred and fifty plugs from the different stratigraphic horizons and more than fifty outcrop sample are being measured for permeability, porosity, ultrasonic velocity, and electrical resistivity. The 150 plugs span different lithologies and diagenetic features. Digital image analysis (DIA) will be used to capture pore structure from thin sections of all samples. Porosity, velocity, and permeability will be correlated with DIA parameters. The petrophysical data will be also be placed into the depositional architecture and facies framework. XRD mineralogic and petrographic analysis, as well as geochemical information, will be integrated to assess the diagenetic pathways versus petrophysical properties. The integration of these data is expected to provide a comprehensive petrophysical characterization that can be explained by the sedimentologic and diagenetic processes in the reefal sections, which potentially can be used as an analog for ancient prograding successions.

References Cited

Allan, J. 1986. Carbon and oxygen isotopes as diagenetic and stratigraphic tools: surface and subsurface data, Barbados, West Indies. Geology, v. 5 ,16-20.

Allan, J.R., and R. K. Matthews. 1982. Isotope signatures associated with early meteoric diagenesis. Sedimentology, v. 29, 797-817.

Anselmetti, F. S., and G. P. Eberli, 1993. Controls on sonic velocity in carbonates: Pure and Applied Geophysics, 141, 287–323.

Anselmetti, F.S., and G.P. Eberli, 2001. Sonic velocity in carbonates—A combined product of depositional lithology and diagenetic alterations, in R. N. Ginsburg, ed., Subsurface geology of a prograding carbonate platform margin, Great Bahama Bank, Results of the Bahamas drilling project: Society for Sedimentary Geology, 70, 193–216.

Weger, R.J., Eberli, G.P., Baechle, G.T., Massaferro, J.L., and Sun, Y.-F., 2009. Quantification of pore structure and its effect on sonic velocity and permeability in carbonates: AAPG Bulletin, no. 10, v. 93, 1297-1317.