Chemstrographic and Paleoenviromental Analysis of Rudist Facies in Cretaceous Strata

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STATUS: Long-term project in early stages
TIMING: Significant results to be reported – early results currently available to membership
FUNDING: None

Purpose
This study seeks to understand the conditions that led to the dominance of rudists over corals as the major reef builder in the tropics. The Aptian-Albian and Santonian are particular targets as it has been suggested that warming on the Caribbean Tethys (Super Tethys) displaced corals to higher latitudes allowing for dominance by rudists. The late Early and Late Cretaceous are of great interest as numerous northern South American source rocks and reservoirs probably owe their high OMC to the prevailing oceanographic and paleoclimatic conditions.

Project Description
The Cretaceous was characterized by CO₂ concentration believed to exceed 1000 ppm, ~600 ppm higher than current levels (Skelton, 2003). Geologic evidence from the Cretaceous greenhouse world suggests that ocean circulation, a major temperature buffer in today’s tropical oceans, failed during the Cretaceous. Overheating in the tropics led to decimation of reef-building corals and the evolution of rudist bivalve reef builders. Modern reef building corals can tolerate temperatures 16 – 30 °C and salinities that range from 30 - 40 ppt. The environmental limits for corals has led to the suggestion that variations in Caribbean reef builders during the Cretaceous were controlled by the episodic development overheated and hypersaline oceanic zones in the eustatically elevated Cretaceous ocean in the central paleotropics (i.e., Supertethys) (Kauffman and Johnson, 1996).

Johnson et al. (1996) explored the heat export hypotheses against latitudinal fluctuations of Cretaceous tropical reef boundaries in the Caribbean region. Their results consistently show a dynamic history of episodic contractions and expansions of reef boundary lines. In this scheme, the paleotropical environments were highly dynamics in shallow marine ecosystems (Kauffman and Johnson, 1988). Using stage-by-stage plots of latitudinal Caribbean reef line, Johnson et al. (1996), reconstructed two major geographic expansions of Caribbean rudist reefs that were associated with the development of the Supertethyan mid-tropical zone. The first expansion occurred in the Albian and the second occurred in the Santonian, and major rudist diversity peaks followed these expansions. Global Circulation Models (GCM) support the idea that these expansions occurred in overheated and hypersaline oceanic conditions.

However, Skelton and Donovan (1997) criticized this reconstruction citing the lack of physical and geochemical data to support the Johnson et al. (1996) model. Preliminary δ¹⁸O derived Cretaceous (Santonian) marine temperatures and fluid inclusion salinities indicate ~32 °C (Figure 3) and ~40 ppt (Figure 4) dissolved salt, respectively. Furthermore, our isotope mass balance modeling of Aptian-Albian paleoprecipitation, require that Telethyan surface sea water
be evaporatively enriched by as much of as 2 ‰, and would result in increase salinities (Suarez et al. in press).

This study uses δ13C chemostratigraphy to constrain and correlate the carbonate depositional periods in the Greater Antilles Early Cretaceous strata. Rudist δ18O schlerochronology is used to constrain ocean paleotemperatures and fluid inclusion analysis of early marine cements is used to constrain salinities. Early meteoric diagenetic calcite is used to constrain paleoprecipitation. The resulting chronostratigraphic framework coupled with the schlerochronology and fluid inclusion analysis is used to improve paleogeographic, paleoceanographic and paleoclimatic reconstructions of the Cretaceous in the Caribbean region.

**Deliverables**

- Model of paleoceanographic conditions (sea surface temperature, oceanic circulation, paleosalinities) for the Aptian-Albian and Santonian of the Caribbean.

- An improved high-resolution chemostratigraphic framework for the late Early and Late Cretaceous.

- TOC analysis of northern Caribbean Cretaceous strata. These strata are time equivalent with northern South American oil bearing strata such as la Luna (Venezuela) and Caballos (Colombia) formations.

**References**


Figure 1. Map showing the extent of Tethys (equatorial area bounded by thick dark lines). The red area represents the possible distribution of the warmer and hypersaline marine climatic zone, Supertethys (ST); the blue area represents the normal distribution of the Tropical Tethyan climatic zone (after Kauffman and Johnson, 1996).

Figure 2. Correlation of $\delta^{13}$C record from (a) borehole core T82 in the Pueblo Viejo Gold District (this study), (b) Coppa della Nuvola in Italy (Luciani et al., 2004), (c) Vocontian basin in France (Herrle et al., 2004), and (d) Santa Rosa canyon in Mexico (Bralower et al., 1999). The ages assigned to the borehole core T82 section are derived from the few chronostratigraphic points in the Los Ranchos-Hatillo depositional sequence (U-Pb zircon dates, and ammonite and rudist biozones), and our correlation with the global $\delta^{13}$C record.
Figure 3. Stable isotope schlerochronology of well preserved rudist from the Santonian Cotui Limestone of southwestern Puerto Rico. Data suggest seawater temperature of over 30°C.

Figure 4. Preliminary fluid inclusion analysis from early marine cements of the Santonian Cotui Limestone of southwestern Puerto Rico. Data suggest salinities in the ~ 40 ppt range.