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Foraminiferal and sedimentary response to sea level fluctuation in late Quaternary tropical mixed siliciclastic-carbonate environments

Introduction and Background

Continental margins are dynamic systems, continually adjusting to a variety of environmental changes. Sea level fluctuation particularly influences continental margins, greatly affecting sedimentation patterns and faunal assemblages. Studies focusing on response to sea level change typically treat margin environments as purely siliciclastic or purely carbonate systems, depending on whether terrigenous clastic or shallow biogenic carbonate sources dominate sediment supply (*e.g.*, Posamentier and Vail, 1988; James and Kendall, 1992; Schlager *et al.*, 1994). However, considerable input from both siliciclastic and carbonate sources occurs in many tropical margins both today and in the past.

Understanding sedimentary response to sea level in these mixed systems is of great interest to petroleum exploration as porous carbonate formations can contain significant hydrocarbon accumulations.

The reciprocal sedimentation model (Fig. 1), based on classic sequence stratigraphic principals and established for pure siliciclastic and pure carbonate environments, has traditionally been used to interpret sedimentation in tropical mixed siliciclastic-carbonate systems (*e.g.*, Wilson, 1967; Dolan, 1989; Sarg, 1988; Cant, 1992; Schlager *et al.*, 1994). During low sea level, siliciclastic sediments are transported through incised river systems, bypassing the exposed continental shelves, increasing siliciclastic flux to the basin, and producing large basinal lowstand fan deposits. In contrast, carbonate bank production is greatly hindered by lowered sea level, starving the slope and basin of carbonate sediments. Sea level transgression is a time of increased siliciclastic deposition on the shelf, greatly reducing slope and basin sedimentation. Increased accommodation space allows prolific carbonate bank production, elevating carbonate flux to the slope and basin. During sea level highstand, siliciclastic deposition is widespread on the shelf, allowing moderate flux to the slope and basin, while high carbonate bank productivity permits maximum slope and basin carbonate sedimentation. This reciprocal sedimentation model is primarily constructed from ancient sedimentary rock records (*e.g.*, Silver and Todd, 1969; Dolan, 1989; Handford and Loucks, 1993; Whalen *et al.*, 2000), where diagenesis and dating provide significant problems.

Recent mixed siliciclastic-carbonate studies of the Walton Basin, offshore Jamaica (Glaser and Droxler, 1993), and along the northeast Australian margin (Fig. 2) (Peerdeman and Davies, 1993; Dunbar and Dickens, 2003; Page and Dickens, 2003; Beaufort *et al.*, unpublished) indicate deviations from the conventional reciprocal sedimentation model. Dating of alternating carbonate and siliciclastic horizons from piston cores taken on the slopes and basins of these regions indicates siliciclastic fluxes to the slope are greatest during sea level transgressions and lowest during sea level lowstands. This deviation from clastic sequence stratigraphic models greatly effects interpretation of mixed siliciclastic-carbonate sediments in the rock record and has lead to the suggestion of two possible models to explain deposition in these environments. The broad, flat nature of the continental shelves bounded by the outer shelf reefal deposits could prevent terrigenous clastic transport to the slope and basin during lowstands. Terrigenous clastic material could then be released to the slopes and basins during transgressions (Woolfe *et al.*, 1998; Dunbar and Dickens, 2003; Heap *et al.*, 2002). Alternatively, increased precipitation and riverine discharge during transgressions could produce the observed increase in slope and basin siliciclastic deposition (*e.g.*, Rankey, 1997; Galloway, 1998; Goodbred and Kuehl, 2000).

Proposed Work

The proposed work comprises my doctoral study at Rice University and includes sedimentologic and micropaleontologic analyses of piston cores taken in three tropical mixed siliciclastic-carbonate environments: (1) the Yucatan Basin (offshore Belize); (2) the Walton Basin (offshore Jamaica); and (3) the Ashmore and Pandora troughs (offshore Papua New Guinea). Emphasis will be placed on the response to sea level change, relationship to stratigraphic principles, and preservation in the rock record. The combination of sedimentary and foraminiferal proxies is a powerful way to reconstruct paleoenvironments and establish relationships between sedimentary and biogenic response to sea level change. Of key interest will be to establish late Quaternary siliciclastic and carbonate fluxes to the slope and basin during sea level lowstands, transgressions, and highstands, and determine contemporaneous preservation in the biologic record. All core samples will be split; one half will be used to determine bulk and clastic grain size, siliciclastic and carbonate mass percent (weigh bulk sample, digest carbonate component, weigh clastic component), and siliciclastic minerologic composition (**XRD**) and the other half will be used to evaluate foraminiferal (>63μm) isotopic composition, population assemblages, and radiocarbon dates, as well as carbonate (<63μm) minerologic composition (**XRD**).

In July of 2002, a 37.73 m core (MD02-2532) was taken on the Marion Dufresne coring vessel in the Yucatan Basin, 3 km offshore of the central Belize Barrier Reef. This core was taken in 333 m water depth and has an estimated bottom age of 720-450 kyr based on preliminary nannofossil assemblages (Luc Beaufort, pers. com). The upper 24 m of core expresses distinct units of light color reflectance and low magnetic susceptibility alternating with units of darker color reflectance and high magnetic susceptibility, likely reflecting variations in carbonate and siliciclastic influence. MD02-2532 was recently sampled every 10 cm (10 cc volume, ~377 samples total). In May of 2003, I participated as a scientist onboard the Marion Dufresne where two periplatform cores were acquired in the Walton Basin, offshore of the southern Jamaican Shelf, and sampled at 20 cm intervals (10cc volume, ~200 samples total). A 26.57 m core (MD03-2628) was taken in 846 m water depth and a 13.45 m core (MD03-2629) was taken upslope in 13.45 m water depth.

I recently began initial analysis of MD02-2532 at Rice University and plan to start analysis of MD03-2628 and MD03-2629 this fall. Sedimentological data (bulk and clastic grain size, siliciclastic and carbonate mass percent, and siliciclastic and carbonate minerologic composition) will be obtained and paired with core descriptions and physical property data acquired onboard (magnetic susceptibility, P-wave velocity, density, porosity, and color reflectivity) to establish intervals of critical change. Foraminiferal species assemblages (species abundances, cluster analysis, factor analyses) will be evaluated throughout each core, with greater emphasis across intervals of change expressed in the sedimentologic data. A robust chronology will be established

through benthic foraminiferal isotopic curves (δ^{18}**O**) with radiocarbon dating to ground truth the youngest portion of the curve. Comparison of the sedimentologic and faunal data within and between each core will reveal critical relationships between depositional histories, biofacies, and sea level changes, allowing comprehensive evaluation of sequence stratigraphic models applied in these mixed siliciclastic-carbonate environments.

Funded by the National Science Foundation (**NSF**) Source-to-Sink MARGINS Initiative, multiple piston cores will be taken in the Gulf of Papua in March of 2004 on a 45-day seismic and coring cruise on the R/V Thompson. These cores will be sampled and compared to Belize and Jamaican mixed siliciclastic-carbonate margins. Sedimentological analysis of these cores, similar in methodology as described above, will be completed by another Rice University doctoral candidate. My proposed work on the Papua New Guinea margin will emphasize micropaleontological analyses, a component not included in the funded **NSF** Source-to-Sink proposal but critical to understanding these mixed environments.

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Figures

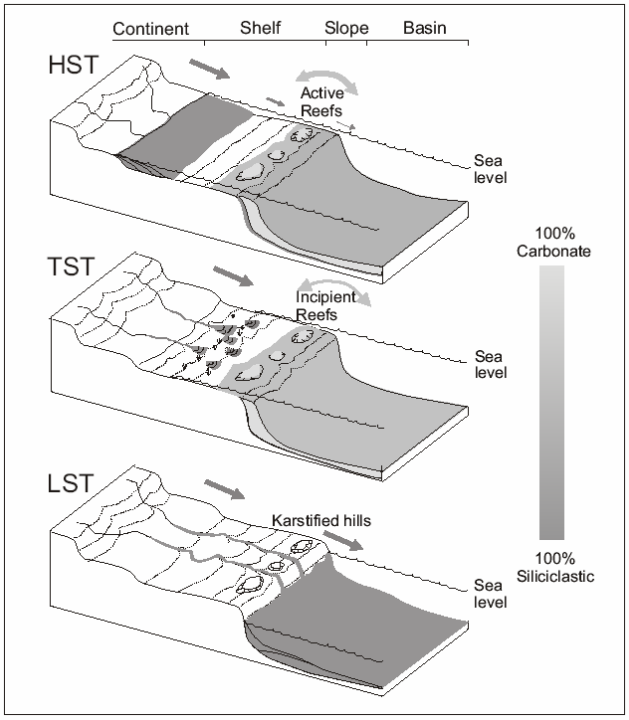

Figure 1: Schematic representation of cyclic and cyclic and reciprocal sedimentation model proposed for mixed siliciclastic/carbonate systems. Figure reprinted from Dunbar and Dickens (2003).

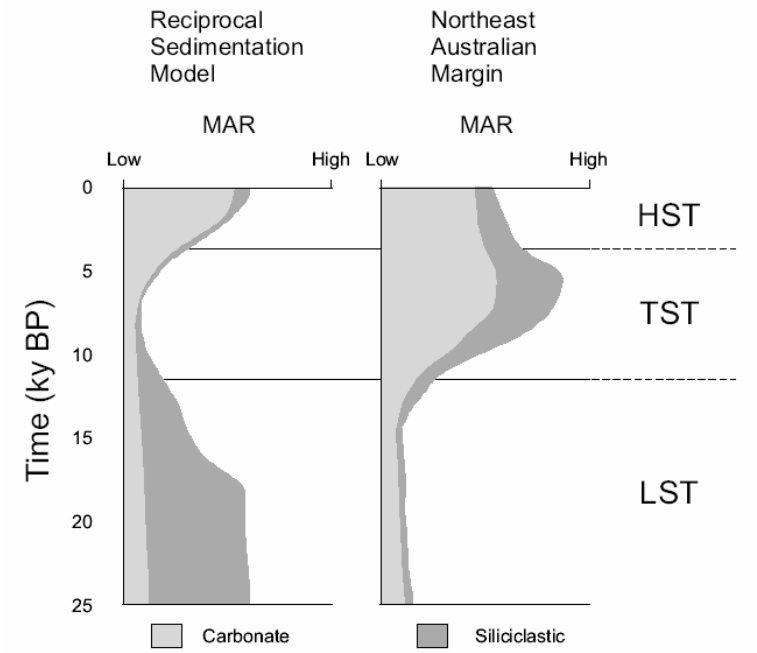

Figure 2: Schematic representation of off-shelf sediment flux on the Northeast Australian Margin. Figure reprinted from Page and Dickens (2003).