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Diagenesis and reservoir quality of mixed carbonate-siliciclastic units, Mahakam Delta, Borneo

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Clastic sedimentation on shallow marine shelves is generally thought to inhibit carbonate production. However, delta front reefs are common down to depths of 100 m around the major, active Mahakam Delta in east Borneo, SE Asia. Outcrops and core through carbonates within the Neogene deltaic succession are analogous to the present day and indicate that delta front reef development is not just a recent phenomenon (Wilson & Lokier, 2002; Hook & Wilson, 2003; Wilson, 2005). The diagenesis of mixed carbonate-siliciclastic deposits in tropical regions is very poorly known, but is key to understanding potential reservoir development in both the carbonate and clastic units. This study evaluates diagenetic environments and processes affecting porosity and permeability development through a combined petrographic, geochemical and permeametry study of outcrop and subsurface samples.

The formation of the modern Mahakam Delta has been influenced by moderate tides of about 3 m, a steady, high fluvial input, with an average sediment input of 8 x 103 m^3/yr (Allen *et al*., 1976), and very low wave energies. Studies of these modern and ancient delta front reefs shows that coral patch reefs developed in less than a few tens of metres water depth, whereas *Halimeda* dominates in deeper water reefs. The shallow water coral reefs may be up to 2-4 km across, were sited on delta lobes or mouth bars, and in the sedimentary succession have post-compactional thicknesses generally up to 40 m (Wilson & Lokier, 2002; Wilson, 2005). The deeper water buildups and carbonate platforms have similar dimensions, formed on ravinement surfaces and are inferred to have developed during periods of transgression (Roberts & Syndow, 1996, Saller et al., submitted). In outcrop, the coral reefs consist of lithologies dominated by platey, branching, head, branching and platey corals passing successively up section from base to top of the carbonate unit. These cycles represent apparent shallowing then deepening of the depositional environment that probably relate to terrestrial runoff rather than actual depth changes. Partial and multiple cycles may occur, especially where clastics are interbedded with the carbonates. There is considerable lateral facies variations across the coral or *Halimeda* buildups and stratigraphic thicknesses vary laterally within the buildups. Reefs may coalesce or when covered by clastics often form slight highs on which later carbonate buildups preferentially form.

Diagenetic features observed throughout the muddy, nearshore patch reef deposits include micritization, chemical and mechanical compaction, cementation, neomorphism, dissolution and dolomitisation. The inferred diagenetic history is of minor marine diagenesis, passing to predominantly meteoric and burial process. Diagenetic processes throughout the patch reefs have led to near-complete porosity and permeability occlusion. In comparison, neighbouring

siliciclastic facies show minor chemical compaction features and quartz overgrowth cements that partially occlude porosity. The siliciclastics have higher potential as hydrocarbon reservoirs since primary intergranular porosity is retained (10-15%). It is suggested that the nearshore carbonate reefs may provide seals for hydrocarbon accumulation, or act as baffles to fluid flow. Comparisons can also be made between the nearshore reefs of this study and those developed more distally, where porosity and permeability although variable is generally higher and reservoir quality is present (Saller et al., submitted).

The development of these delta-front reefs was controlled by a complex array of factors, including climate, relative-sea level changes, oceanographic factors, sediment and nutrient input. A comparison is made with other deltaic systems in the region and carbonates developed in clastic localities. This study has implications for the interactions between clastics and carbonates in tropical marine settings and shows that carbonate producers can thrive in areas of high clastic input. Carbonate and clastic deposits developed in deltaic settings show highly variable diagenetic features with widely differing porosity and permeability characteristics. Although further studies are required, initial analysis indicates original depositional conditions, development of freshwater lenses, mineralogy, and relative impact of meteoric versus burial diagenesis were all important in potential reservoir formation.

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