Shallow marine multiple-event deposits: Core examples from the Upper Cycle V (Late Miocene) of Baram Field, Baram Delta, offshore Sarawak

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The Baram field is a small oil field situated in the north-eastern side of the Baram Delta Province, offshore Sarawak. The cored intervals of the Upper Cycle V (Late Miocene) of Baram field display reservoir successions dominated by thick swaley cross stratified (SCS) sandstones and other associated wave- and storm-dominated, shallow marine facies. The vertical facies organisation of a genetic unit of upward-coarsening, upward-shallowing SCS-dominated successions suggest deposition during shoreface progradation associated with fall of relative sea level.

The dominant SCS sandstones display complex internal stratification and heterogeneity, which is the product of several different sedimentological and depositional events. The thick SCS units essentially consist of fine to very fine grained swaley cross stratified sandstone; however, this apparent 'homogeneity' is punctuated by several hierarchical orders of boundary surfaces and thin intervals of minor sub-facies termed here as "heterogeneity elements".

The different heterogeneity elements recognised within the thick SCS units are the *first-order scoured bases, second order truncation surfaces, third-order laminar surfaces, mudstone intraclasts conglometaric horizons, bioturbated sandstone and siltstone, sideritised sandstone horizons, medium-grained massive sandstone* and *collapse structures*.

A first-order scoured base is the basal, erosive contact surface of a single SCS bed with the underlying strata. Second-order truncation surface is the boundary that define the swaley lamina set. Small-sized mudclasts may sometimes occur along this surface. Third order laminar surfaces define the individual laminae within an SCS bed.

Mudstone intraclasts conglomeratic horizons commonly occur immediately above first order scoured bases, indicating the reworking of older clay beds and laminae. Intense bioturbation in sandstone and siltstone is the result of the long time available for biogenic activity per unit accumulation of sediment. This suggests long periods of quiescence in areas below storm wave base. Stable isotope studies have shown that the diagenetic siderite cement in the sideritised horizons formed at very shallow level below the sediment water interface; however, the rate of the siderite precipitation cannot be determined. The medium-grained massive sandstone horizon are all bounded by a basal first order scoured base, indicating a different storm event for its deposition. Collapse structures are closely related to vertical *Ophiomorpha nodosa* escape races, suggesting periods of deposition within an environment with relatively high velocity currents.

The presence of the heterogeneity elements within the thick SCS units indicates multiple-event deposition, separated in time, by discontinuities, in the order of hours, days, weeks or years. The stratigraphic stacking pattern of these shoreface sand units suggests that the depositional environment remained at a stable sea level (highstand) or/and at regressional lowstand for a long period of time. In summary, the offshore mudstone and silty layers represent continuous single- or multiple-event deposition at very low rate of sedimentation. On the contrary, the thick, amalgamated shoreface sandstones are produced by multiple-event deposition at high rates of sedimentation; however, discrete sand packages were deposited in discontinuous fashion by temporally different wave and storm-events.