A stratigraphic and sedimentologic preview of the Miocene Stage III and Stage IVA of Labuan Island and Klias Peninsula, Borneo

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Abstract: Labuan Island and Klias Peninsula have great outcrops for the study of the Miocene Stage III and Stage IVA strata. The Stage III and IV have an estimated combined thickness ranging between 4 and 7 kms and comprise interstratified sandstones and shales deposited in environments ranging from non-marine fluvial, marginal marine deltaics, shoreface and deep-water turbidites. Exposed on the Klias Peninsula and Labuan Island, the Stage IV sits on the Middle Miocene Unconformity (MMU) which marks the onset of the next major phase of sediment accumulation after the Stage III in NW Sabah.

The Stage III was studied at two main outcrops, Batu Linting on the Klias Peninsula and Kampung Bebuloh on Labuan Island. Batu Linting is composed of thinly (5-30 cm) interbedded sandstones and shales with an estimated net sand of 80-90%. Kampung Bebuloh is also composed of thinly-bedded (5-10 cm) interbedded sandstones and shales with an estimated net sand of 40-50%. Sand beds at Batu Linting contain a sharp base with flute- and gutter-casts, and contain massive-, planar- and current ripple-bedding representing incomplete Bouma successions; within-bedding bioturbation is rare. The sand beds at Kampung Bebuloh are similar containing flute-casts on the bed bases and physical sedimentary structures including planar- and current ripple-bedding. Within-bedding bioturbation was rarely observed. Both outcrops contained abundant bedding-plane trace fossils of the Nereites ichnofacies including Paleodictyon, Spirorhaphe, Helminthoida, Taphrehelminthopsis, Cosmorhaphe, and Scolecia. The Stage III at these 2 locations is interpreted as inner to middle turbidite fan at Batu Linting, and middle to outer turbidite fan at Kampung Bebuloh.

The Stage IVA was studied at the Batu Luang and Bethune Head outcrops. The lower portions of the outcrops are dominated by 30 metres of fluvial conglomerate with thin sandstone lenses (Batu Luang) or 120 metres of stacked trough cross-bedded sandstones (Bethune Head). This interval, interpreted as lowstand, is capped by a highly bioturbated sandstone with sand-filled burrows extending up to ½ metre into the underlying shale interpreted as a Glossifungites surface; this marks the onset of transgression. A tidal flat with small tidal creek deposits are observed capping the fluvial succession at Bethune Head.

The middle portions of the studied outcrops are dominated by wave-dominated delta (Batu Luang) to shoreface sandstones (Bethune Head) and shales. The sandstones are dominated by swaley cross-stratification punctuated by intervals of trough cross-bedding; ichnofauna from the Skolithos, Cruziana, and Zoophycus ichnofacies dominate the rocks. Thicker, offshore (Bethune Head) to prodelta (Batu Luang) shale sections are interpreted as the maximum flooding surfaces (MFS), which signal the end of transgression and the beginning of the relative sea-level highstand.

The upper portion of the two outcrops are composed of coarsening-up sandstone packages deposited in a wave-dominated delta system containing tidal flats, distributary channels, delta front sands and prodelta sediments. As observed in the middle portion of the outcrops, the sands are dominated by swaley cross-stratification and are punctuated by intervals of trough cross-bedding, which become more abundant moving up the section. The ichnofauna observed tend to belong to the Skolithos and Cruziana ichnofacies. These sand packages are contained within the clinoforms of the delta as it prograded into the basin during the highstand.

A petrographic analysis of the Stage IVA sandstones determined that most of the samples can be classified as quartz-dominated, sub-lithic arenites with pore-systems dominated by primary pores and subordinate secondary pores formed by the dissolution of unstable grains (feldspars and lithics). Overall reservoir quality varies with facies type; the fluvial and deltaic sandstones can have similar porosity measurements, but the higher degree of sorting in the deltaic sands is an indicator of better permeability in this facies. Although the lowstand sands have relatively good reservoir quality, the transgressive and highstand shelf sediments have a wider distribution making them more targetable.

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