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A Sedimentologic and Petrographic Perspective of the Miocene Stage IVA from the Klias Peninsula to Labuan Island

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The Miocene outcrops in NW Sabah provide an opportunity to study the rocks equivalent to the offshore reservoirs undergoing exploration. The primary target for most exploration is the Stage IV (Figure 1) and it ranges in thickness from 3 to 5 kms and comprises interstratified sandstones and shales deposited within marginal marine to shoreface environments. The Stage IVA which is the focus of this study, sits on the Middle Miocene Unconformity (MMU), also known as the DRU (Deep Regional Unconformity) and marks the onset of the next major phase of sediment accumulation (after Early Miocene Stage III) in NW Sabah.

The Stage IVA is well exposed for study on the Klias Peninsula and Labuan Island (Figure 2). The outcrop sections at Batu Luang on the Klias peninsula, and the outcrops at Bethune Head, Ganggarak Quarry and Layang Layangan Beach provide a look at a nearly complete sequence within the Stage IVA. At Batu Luang the MMU is exposed with 34 metres of braided to gravel-meandering fluvial conglomerates cutting into dark grey to black shales containing sideritized silt- to sandstone stringers. The MMU is not exposed at the Bethune Head location; however, it is visible at both the Ganggarak and Layang Layangan localities. At these locations, the MMU is represented by braided to coarse-grained meandering deposits cutting into underlying Stage III shelf edge delta front/prodelta to slope deposits.

The fluvial deposits range from pebble to cobble-sized conglomerates at Batu Luang to medium-very coarse-grained sandstones and pebbly-sandstones in Labuan. The upper portion of the fluvial succession at Labuan is capped by levee to overbank deposits with local coals as seen at Ganggarak Quarry. The top of the fluvial succession is marked by the presence of a highly bioturbated sandstone with sand-filled burrows in the underlying shales (Glossifungites) at Batu Luang and a thin tidal flat succession at Bethune Head marking the onset of trangression and the top of the lowstand systems tract (LST).

Preserved section above the fluvial deposits is only found at the Batu Luang and Bethune Head locations. This section at Batu Luang is composed of bioturbated, trough cross-bedded to swaley-bedded sandstones interstratified with shale-dominated sections containing thin sandstone interbeds. This upper section is interpreted as deltaic deposits comprising distributary channels, delta front sands, interdistributary/shallow bay deposits and prodelta sediments at Batu Luang and distal deltaic to lower shoreface/offshore deposits at Bethune head. The top of this section is best observed at Bethune Head and is marked by a relatively thick marine shale which within lies the maximum flooding surface (MFS). The MFS was identified by the overall increase in coarsening-upward sand successions above this shale. At Batu Luang the MFS is identified at the top of a prodelta shale-prone section containing bioclasts stringers above which resides a thin section of tidal flat sediments. The MFS, by definition, caps the transgressive systems tract (TST) and the fining-upward sequence.

The section above the TST is made up of inter-stratified sandstones and shales comprising tidal flats, distributary channels and delta front sands at Batu Luang. The more distal outcrop at Bethune Head is composed of coarsening-upward packages dominated by deltaic sediments including distributary mouthbars, delta front, distal delta front and prodelta sediments. These prograding sands packages represent the clinoforms of the delta as it progrades into the basin and is part of the highstand systems tract (HST).

The sandstones in the IVA are typically fall into the quartz-dominated, sub-lithic arenite classification (Figure 3; sensu Potter et al., 1987). The bulk of the detrital mineralogy consists of quartz, lithic rock fragments (granitic, metamorphic, chert and sedimentary), K-feldspar, plagioclase, organics and traces of phosphate, glauconite, muscovite and heavy minerals such as zircon, tourmaline. Matrix illite is observed in some samples and it is likely a mixture of detrital illite and pseudo-

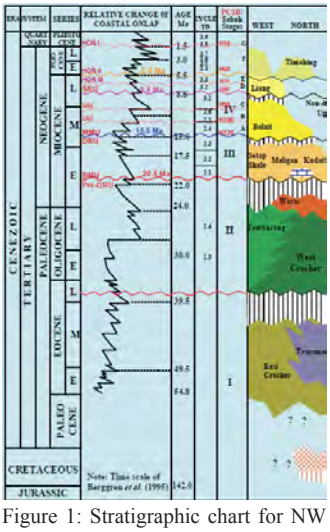

Figure 1: Stratigraphic chart for NW Sabah (Balaguru, 2006).

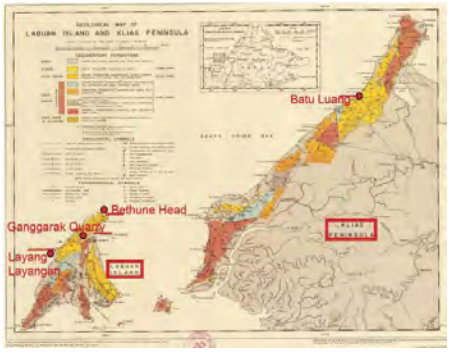

Figure 2: Geological map of Klias Peninsula and Labuan, Sabah. Red dots indicate the outcrop locations (Wilson, 1964).

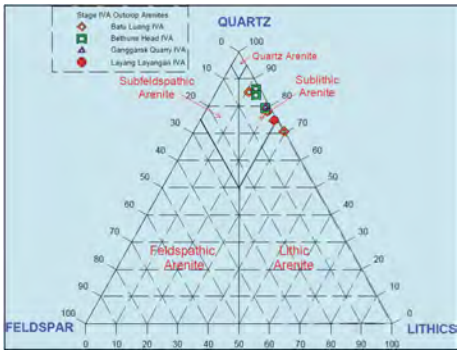

Figure 3: Classification of the Miocene Stage IVA arenites as sampled from outcrop; classification scheme of Pettijohn et al. (1987).

Warta Geologi (Newsletter of the Geological Society of Malaysia), Vol. 38, No. 2, April-June 2012

matrix (squashed mud clasts). Evidence of diagenesis is in the form of thin quartz overgrowths and traces of siderite, pyrite, and pore-lining illite. Dissolution of unstable grains (feldspars and unstable lithics) is also observed which creates a secondary pore-system that enhances the total porosity.

The reservoir quality of the sandstones changes with the facies and environments. The lowstand fluvial sands tend to be coarser grained, but more poorly sorted than the deltaic sands. The deltaic sands are finer grained, but tend to be better sorted than the fluvial sands, likely due to the wave-activity modifying the sands. Although the lowstand sands have relatively good reservoir quality, the shelf sediments are dominated by the transgressive and highstand deposits making them more targetable than the lowstand deposits contained within incised-valleys feeding deepwater systems.

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