Poster 14

A tide- and wave-influenced, barrier island-lagoonal complex within the upper section of the Nyalau Formation (Oligocene-Late Miocene) at Kampong Sungai Plan, north Bintulu, Sarawak

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The Nyalau Formation (Oligocene-Late Miocene) is the onshore extension of Cycles I and II of the Balingian Province of offshore Sarawak, which contain important source and reservoir rocks for oil and gas (Du Bois, 1985). The low-lying, hilly countryside and coastal areas surrounding the Bintulu town in Sarawak form part of the extensive Oligocene to Early Miocene sedimentary succession. Good rock exposures can be found along the Bintulu-Tatau road south of Bintulu town, right up to the north of Bintulu town around the rocky coasts and hill-cuts at Tg. Kidurong, and along the Bintulu-Miri road.

The Nyalau Formation consists of a succession of hard, fine to medium-grained sandstones interbedded with shales. Some coals are present in restricted parts of the formation. Leichti *et al.* (1960) estimated a thickness of 17,000–18,000 feet for this predominantly siliciclastic succession. The Nyalau Formation lies conformably on the Buan Formation but with a sharp transition. Locally, it overlies unconformably the Tatau and Belaga Formations. Since no internal discontinuity has been discovered so far, it is generally thought that the deposition of the Nyalau Formation is continuous during the Oligocene to Miocene time. This clastic unit interfingers with the Setap Shale Formation in the northeast. The top boundary of the formation forms an erosional surface. The formation is moderately folded. The formation is thought to represents a progradational sequence, which comprise a basal shallow marine sandy unit (Biban Sandstone Member), followed by the main Nyalau succession which reflect deposition in the lower coastal plain to marginal marine environments (Leichti *et al.*, 1960; Haile, 1963; Wolfenden, 1960; Kho, 1968; Mohd Idrus & Redzuan, 1999).

A hill-cut at the rear section of Kampong Sungai Plan in north Bintulu near Tanjong Kidurong exposes more than a hundred metres of rock succession belonging to the upper part of the Nyalau Formation. Detailed sedimentological logging of the lower part of the succession reveal facies and stratal organization that can be related to a barrier bar-lagoonal complex strongly affected by tidal and wave processes, with a marked impression of a relative, sea level rise.

Five facies association were recognized in the field. These are informally referred to as SP-1, SP-2, SP-3, SP-4 and SP-5.

Facies association SP-1 is a sandstone unit characterized by rippled, flaser-bedded and cross-bedded structures, with associated carbonaceous/mud laminations and drapes. The trace fossil *Ophiomorpha* can be found scattered throughout the unit. Small, rounded mud chips commonly occur at the lower part of the facies. This medium- to fine-grained sandstone unit is generally flat bedded, with thickness ranging from 200 cm to more than 1500 cm thick for amalgamated, composite units (commonly amalgamated with and overlain by SP-3). Thin units of SP-1 display sharp and flat basal contact with the underlying unit; however, two thick composite unit exhibit distinct, scoured erosive base.

SP-1 is interpreted as a sandy tidal flat deposit, which sometimes overlie and is amalgamated with basal, cross-bedded and erosive-based tidal channel unit. The overall organization of the facies suggests that these cross- and flaser-bedded sandstone layers, and the channelised basal part, were deposited on sandy tidal-flats and sub-tidal channels, located within the back-barrier/lagoon margins of a barrier bar-lagoon complex.

Facies association SP-2 is an interbedded unit of thin, rippled and flasered sandstone layers and lenticular-

bedded mudstone. This unit, when present, overlie SP-1 or SP-3, and together they form an upward fining succession.

Flaser bedding, which is characterized by the presence of remnant mud layers in the ripple troughs, indicates a condition in which the deposition and preservation of sand are more favourable than for the mud (Reineck and Singh, 1986). Lenticular bedding requires conditions of low current or waves action depositing minimum sand, and dominant slack water conditions for mud deposition. Terwindt (1971) suggested that the thin sand layers may represent isolated small-scale ripples that have travelled over a clay bed and which have been covered by clay subsequently. The interpreted environment of deposition for SP-2 is the intertidal, muddy tidal-flat within the back barrier zones.

Facies association SP-3 is characterized by cm to metre thick, flat-bedded and horizontally laminated sandstone. These sandstone beds always overlie the flaser bedded units of SP-1. Except for the very distinctly flat, low angle bedding, these layers display no other structures.

These sub-horizontal stratified sandstones are washover deposits, which are formed when wind-induced storm surges spill over barriers, and form sheet-like deposits of sand into the lagoon behind the barrier bar. Each of the cm to metre thick bed is thought to represent one single overwash event (Reinson, 1992; Schwartz, 1982).

Facies association SP-4 is a well laminated, dull gray, silty mudstone with conspicuous, thin, silt and sand layers. The association of SP-4 with SP-2, SP-3 and SP-5 suggests that SP-4 is probably a proximal, lagoonal deposit. The presence of silt and silt-sand layer in SP-4 may have been due to the dispersal of washover detritus into the back lagoon. In a way, it can be regarded as a wave-influenced lagoonal deposit.

Facies association SP-5 is a fairly homogeneous unit of black, carbonaceous and laminated mudstone. This unit is interpreted to be the subaqueous, lagoonal suspension deposit.

Detailed field logging of the outcrop shows that the different facies associations described above are arranged into three different types of shallowing-upward successions. These are:

I. ***SP-1/SP-2 type***, is a simple shallowing-upward succession, indicating the shallowing-up of the environment from a sub-tidal to an inter-tidal level occurring within the tide-dominated back-barrier areas.

II. ***SP-1/SP-3/SP-2 type***, shallowing-upward succession. Most of the shallowing-upward successions recorded at Kampong Sungai Plan are of this type. The vertical facies organization here indicates the increasing influence of wind-generated wave and storm surges as a depositional mechanism. However, the capping of the succession by SP-2 shows that tidal processes still prevail within the back-barrier/lagoonal environment.

III. ***SP-5/SP-4/SP-1/SP-3 type***, shallowing-upward succession. This succession suggests a marked change in the environment, from a subaqueous lagoon setting to a back-barrier sand flat level. This form of stratal organization is also an indication of the landward migration of the barrier island, which is one of the main processes that occur during a transgression (Reinson, 1992).

The overall stratification of facies at the outcrop in Kampong Sungai Plan, Bintulu, represent a trangressive episode in the depositional history of the Nyalau formation, within a wave-dominated, microtidal barrier island and related lagoon environments.