

# CERAMAH TEKNIK TECHNICAL TALK

## Tectono-stratigraphy and development of the Miocene delta systems on an active margin of northwest Borneo, Malaysia

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**Abstract:** The Paleogene regional tectonic setting of Sabah is very complex with southeasterly subduction of the proto-South China Sea in NW Borneo (Hall 1996), followed by a period of continued deposition of deep marine Rajang Group turbidites. The Late Eocene tectonic deformation is characterized by folding, thrusting and regional uplift related to the collision of the Luconia Continental Block against NW Borneo (Sarawak Orogeny; Hutchison, 1996).

Barckhausen & Roeser, (2004) reinterpreted paleomagnetic data and concluded that the sea floor spreading in the South China Sea, which began at 32 Ma, had already ceased by 20 Ma. This indicates that subduction ceased in the Early Miocene as opposed to the previously interpreted Middle Miocene (Brias *et al.* 1993) when the Dangerous Grounds micro-continental fragments collided with NW Borneo (Clennell, 1996; Hutchison *et al.*, 2000. This predates the timing of the Sabah Orogeny including the earlier 20 Ma timing proposed by Balaguru & Hall (2008), and it coincides with the Base Miocene Unconformity (BMU) in Sabah. The Early Miocene (22-20 Ma) deformation is a major tectonic event involving the formation of the Sabah mélanges significant uplift and erosion; patches of Burdigalian limestone formed during this uplift. This period was followed by a change in depositional environment from deep-water clastics to a shallow-water deltaic setting.

The Miocene to recent regressive fluvio-deltaic systems have been progressively deformed and overlie the Oligocene Crocker accretionary complexes generally regarded as the economic basement (Stage II or TB1.5sb). The Oligocene comprises slightly metamorphosed, highly deformed deep-water turbidite sediments known as the Crocker and Temburong Formations of onshore equivalents.

The overlying Neogene section has an unconformable relationship with the underlying section and can be divided into three deltaic complexes that generally young from east to west. The Meligan Delta (Stage III or TB 2.1-2.3) is the oldest and it accumulated in the mid-Early Miocene, forming the sand-dominant Meligan and shale-dominant Setap formations. The Meligan Formation is dominated by thick sandy deltaics with subordinate sandy shallow marine facies; the Setap Formation contains thin interbeds of sandstone within an overall shaley succession representing the distal equivalent facies of the Meligan Delta. All of offshore Sabah was under slope- to deep-marine conditions during Early Miocene to early Middle Miocene time.

A significant Middle Miocene unconformity (also known as Deep Regional unconformity) (MMU/DRU) separates the Meligan Delta from the overlying middle to late Miocene Champion Delta (Stage IV-ABC). This stage generally is characterized by coastal aggradation and progradation sequences comprising the onshore outcrop equivalents of the Belait, Miri and Sibuti Formations of NW Sabah. The Stage IVA (TB2.4-2.5) is a widespread regressive lower coastal plain to marginal marine (deltaic to shoreface) succession, whereas the Stage IVB (TB 2.6) is a major transgressive sequence of offshore marine deposits. The Stage IVC (TB3.1) is a major regressive sequence with widespread coastal to shallow marine and deep-water deposits followed by a period of prolonged sea-level lowstand. The Belait and Miri Formations are dominated by fluvio-deltaic sandstones with laterally equivalent coastal plain to marine sandstone successions that comprise the topsets of the Champion Delta depositional system. The Lambir and Seria formations are lithologically similar, but contain more fine-grained sandstone interbedded with mudstone representing the foresets of the delta. The shale-dominated marine deposit of the Sibuti Formation represents the distal equivalent or bottomsets of this relatively large delta system. Outcrop studies indicate that the Champion Delta is a complex NW prograding delta system with stacked sequences (from bottom to top) of fluvial sands, marginal marine (estuarine & deltaic) and shoreface deposits.

The Baram Delta succession is the youngest of the three deltaic systems. The late Miocene Shallow Regional Unconformity (SRU) separates the Champion Delta sequence from the younger Baram Delta (Stage IV-DEFG) succession; this most prominent unconformity in Sabah coincides with significant regional uplift and erosion. Stage IV (DEFG) of the Late Miocene to Pliocene is composed of stacked fluvio-deltaic sequence of the Baram Delta System with equivalent offshore shales and deep-water turbidite deposits. The late Miocene to Pliocene was a period of active regression with moderate aggradation punctuated by short periods of minor transgression. The deposits

include the onshore equivalent of the Liang Formation of NW Sabah and Brunei that unconformably overlies the Belait and Seria formations. The Liang formation also consists of fluvial sandstones and conglomerates, marginal marine sediments and shoreface sandstones and shales.

Integrated evaluation indicates that the NW Borneo Delta province evolved during the Early Miocene to present day from a foreland basin to a shelf margin. Multiple phases of compressional folding and faulting events have affected the region, causing uplift of the hinterland, large deltaic progradational events, and inversion of gravity-related faults. New geological mapping, detailed field studies and reinterpretation of existing data suggest that the region consists of west-vergent fold-thrust belts formed in the Early Miocene with syn- and postdeposition of the large Meligan, Champion and Baram Delta Systems on an active margin in NW Borneo. Most folds are detached, buried and thrust cored anticlines and they are younging towards west. The Labuan and Jerudong/Morris anticlines and Belait syncline formed during the Late Miocene as fault-bend and fault propagation folds. The prodelta shale was progressively buried by the prograding delta front and likely became overpressured and mobilized above reactivated basement structures during Pliocene, further complicating the deformation style. Pliocene- Pleistocene inversion on NNE- and N-trending structures with continued growth on NE-trending structures is most likely controlled by the regional NW-trending sinistral shear zones. Flower structures and thrust cored anticlines were developed above the reactivated structures. This study provides new insight into the tectonic evolution of rapidly prograding Tertiary delta systems and reveals how the compressional tectonics have migrated basinward as the delta system prograded.