KINABALU BASIN

OFFSHORE NW SABAH, MALAYSIA

A Comprehensive Geological Dossier

Prepared for Arif Fazil · July 2026

Sources: Balaguru & Hall (2009), Balaguru et al. (2003), Bait (2003),
Madon & Jong (2022), PETRONAS MPM (2025), TGS Choi (2026), EAGE 2026

A geologist's field guide to one of Malaysia's three producing hydrocarbon basins.

1. What Is the Kinabalu Basin?

Definition & Location

The Kinabalu Basin is not simply the area around Mount Kinabalu. In the Malaysian petroleum industry, it is defined as the offshore sedimentary basin along the northwest Sabah margin — from the waters off Labuan Island north toward the Malaysia-Philippines maritime boundary. It is one of only three hydrocarbon-producing basins in Malaysia (alongside the Malay Basin and Sarawak Basin). The remaining five basins (Langkasuka, Penyu, Layang-Layang, Sandakan, Tawau) are frontier status.

The basin spans the NW Sabah continental shelf (<100 m water depth) to the deepwater fold-thrust belt (>1,000 m). Its eastern boundary is the Sabah Trough, a deep bathymetric low that separates the inboard Kinabalu Basin from the outboard Layang-Layang Basin in the Dangerous Grounds region.

Key Numbers

- **Area:** ~25,000 km^2 (explored portion of NW Sabah shelf and slope)
- **Sediment thickness:** >10 km in depocentres
- **Status:** Producing — oil and gas
- **Fields:** Kinabalu (500 MMbbl OOIP), Samarang, Kebabangan, Sumandak, Malikai
- **Recent discoveries:** Zoisit Deep-1, Well A (oil in deeper intervals, 2025-26)

2. Tectonic Evolution

Plate Setting

Sabah sits at the triple junction of the Eurasian, Indo-Australian, Pacific, and Philippine Sea plates. Three marginal basins surround it: the South China Sea (west), Sulu Sea (northeast), and Celebes Sea (east). This unique position has produced a multi-phase tectonic history spanning from Eocene subduction through Miocene arc-continent collision to ongoing Pliocene-Recent transpression.

Phase 1 — Proto-South China Sea Subduction (Eocene–Oligocene, ~55–23 Ma)

The proto-South China Sea plate subducted southeastward beneath NW Borneo. Deep-marine turbidites were deposited in a large NE-SW trending basin (the Crocker Basin). These sediments — now the Rajang-Crocker Group — form the accretionary prism that constitutes the structural backbone of Sabah. The main formations are the East Crocker, West Crocker, Trusmadi, and Sapulut formations, all deep-marine turbidites deformed into tight isoclinal folds and thrusts.

Phase 2 — Sarawak Orogeny (~40 Ma)

Collision-driven uplift and erosion. The West Crocker Formation contains detritus from eroded Rajang Group, indicating uplift along the northern Borneo margin. Deep-marine sedimentation ceased in the Crocker Basin.

Phase 3 — Forearc Deposition & Melange Development (Late Oligocene–Early Miocene, 25–20 Ma)

After uplift, deep-water clastics were deposited in a forearc basin setting: the Labang and Kulapis formations. These formations show abundant syn-depositional extensional faults, indicating active growth faulting during subsidence. Widespread melange development followed (Kuamut, Garinono, and Ayer formations) — tectonic mixtures of rock blocks in a sheared shale matrix.

Phase 4 — Sabah Orogeny: Base Miocene Unconformity (22–20 Ma)

This is the most important boundary in Sabah geology. The collision of the Dangerous Grounds continental block with NW Borneo caused major uplift and erosion, producing the Base Miocene Unconformity (BMU), also called the Pre-Deep Regional Unconformity. Below the BMU: deformed, lithified melange and deep-marine strata. Above the BMU: relatively undeformed shallow-marine to deltaic sediments. Depositional environment changed from deep-water to shallow deltaic.

Phase 5 — Sulu Sea Rifting & Delta Progradation (18–12 Ma)

NW-SE rifting of the Sulu Sea in a back-arc setting rejuvenated the Central Sabah Basin. Regional extension and subsidence allowed vast delta systems to prograde eastward: the Tanjong, Meligan, and Kudat formations. Cumulative sediment thickness reached >6,000 m. Sediment was sourced from the uplifted Rajang-Crocker accretionary prism. All the Neogene 'circular basins' of eastern Sabah were originally part of a single NE-SW trending shallow basin.

Phase 6 — Middle Miocene Unconformity / DRU (15.5 Ma)

Arc-continent collision between the Cagayan Arc and Palawan Continental Block. Extension halted, inversion began. This is the Deep Regional Unconformity (DRU) recognised across offshore Sabah. Marked by cessation of rifting and onset of post-rift sedimentation.

Phase 7 — Post-Collision Deltas (12–5 Ma)

The Champion and Kapilit deltas prograded following the same pattern as the earlier Meligan-Tanjong deltas. Stage IVC through IVG cycles were deposited in offshore NW Sabah — these are the main reservoir units in the Kinabalu Field.

Phase 8 — Mount Kinabalu Granite Emplacement (~10–8 Ma)

The Kinabalu granodiorite pluton intruded the Crocker Range. This massive igneous body (~1,000 km² at depth) contributed to regional uplift, sediment supply, and thermal maturation of source rocks. Today it stands as Southeast Asia's highest peak at 4,095 m.

Phase 9 — Meliau Orogeny: Transpression & Inversion (8.6 Ma–Present)

The Shallow Regional Unconformity (**SRU**, 8.6 Ma) marks major folding and uplift driven by NW-SE strike-slip and transpressional faulting. All the Miocene 'circular basins' of Sabah owe their present-day outcrop pattern to this deformation. Transpressional movement propagated from Sulawesi. This deformation continues today — the 2015 Mw 6.0 Kinabalu earthquake is its most recent expression.

3. Stratigraphy

Simplified Stratigraphic Column (Youngest to Oldest)

Stage IV Reservoir Units (Late Miocene)

The Stage IV series is the primary hydrocarbon-bearing unit in the Kinabalu Basin. It comprises five genetic sequences:

- **Stage IVC:** Coastal progradation. Rapid sediment accumulation on downthrown sides of major growth faults. Mouthbar and channel sands.
- **Stage IVD:** Dominance of stacked coarsening-upward sequences. Outer shelf to shallow marine. Shoal complexes main reservoir.
- **Stage IVE:** Gradual marine transgression. Shore-parallel currents focussing sand deposition on downthrown growth fault blocks.
- **Stage IVF:** Widespread marine transgression. Laterally extensive shoal and sand sheets. Growth faulting reduced.
- **Stage IVG:** Renewed shallowing. Coastal sand bodies.

4. Kinabalu Field

Discovery & Production History

The Kinabalu Field was discovered in 1989 by the **KN-1** well, which encountered **1,043 ft of net oil sand, 113 ft net gas sand, and 310 ft net undifferentiated hydrocarbon sand**. The field lies 55 km west-northwest of Labuan Island in approximately 54 m of water. Total oil-in-place is estimated at **500 million stock tank barrels** (MMstb). Development began in 1997 with first oil in December 1997, reaching a peak of 48,000 barrels per day. By 2003, some 50 million barrels had been produced.

Three Accumulations

The field comprises three separate accumulations: **Kinabalu Main** — the largest. Oil in over 30 sandstone reservoirs (F, J, K, L, M, O). Normally pressured, long hydrocarbon columns. **Kinabalu Deep** — primarily condensate-rich gas with a 250 ft oil rim (S1S2). Mild overpressure (~1,000 psi in W sands). Separated from Main by 1,700 ft of water-bearing sands and shales. **Kinabalu East** — mainly gas-bearing with at least two thin oil rims.

Trap & Structural Geology

The trap is a dip-closure against the major SW-NE trending Kinabalu Growth Fault. The structural dip is approximately 8° toward the WNW. The spill point is to the northeast, controlled by a flexure in the bounding fault. Faulting within the Main block appears limited to small, often sub-seismic faults.

Reservoir Geology (L Sand)

Based on **1,200 ft of core** (530 ft in L reservoirs), three lithofacies were identified: **(1) Poorly stratified sandstone** — fine to medium grained, structureless to faintly stratified. Porosity 23%, permeability 630 mD. **BEST RESERVOIR FACIES**. **(2) Laminated sandstone** — very fine to fine grained, well-developed laminations. Porosity 21%, permeability 126 mD. **(3) Bioturbated sandstone** — highly burrowed, high clay content. Porosity 16%, permeability 11 mD. Poor.

Four genetic sequences are recognised: shoal complexes (stacked coarsening-upward, 10-55 ft thick, por 20-23%, perm 300-630 mD), intershoal sands (fining-upward, storm/tidal, por 22%, perm 480 mD), distal shelf (heterolithics, por 10%, perm 13 mD), and shelf/transgressive muds (seals).

Pressure Maintenance — Water Injection

After one year of production, the L2 reservoir showed a **900 psi pressure drop**. GOR rose from 650 to 1,250 scf/stb. The assumed strong aquifer drive was absent. An innovative solution was implemented: **water sourced from shallow B & C aquifer sands** (213 billion bbl and 69 billion bbl water-in-place respectively) was injected into the L2 reservoir via two horizontal wells. Natural gravity dump-flood achieved ~1,200 bpd. ESPs planned for 20,000 bpd. Recovery factor improved from 21% to 43%, adding an estimated 16 million barrels of reserves.

5. Other Fields & Recent Discoveries

Samarang

Adjacent to Kinabalu. Oil and gas. Shared pipeline infrastructure via the Samarang complex to Labuan Crude Oil Terminal. Stage IV play.

Kebabangan

Gas field 100 km west of Kota Kinabalu. Platform receives tieback from the Malikai deepwater development. Gas exported via pipeline to the Sabah Oil and Gas Terminal.

Sumandak

Discovered September 2001 (Sumandak-1). Seven exploration wells drilled between 2001-2003 in the Samarang-Asam Paya PSC. Stage IVC clastic play.

Malikai

Deepwater oil development tied back to the Kebabangan platform.

Recent Discoveries (2024-2026)

Zoisit Deep-1: Recent discovery confirming continued exploration potential. **Well A:** Proved oil in deeper stratigraphic intervals beneath known gas accumulations — encountering both gas and mixed oil-gas reservoirs. This fundamentally changed the perception of the basin from gas-dominant to oil-prone. **Well B:** Used reprocessed seismic and integrated geological analysis to identify multiple deeper targets across varied play types (EAGE 2026).

6. Petroleum System

Source Rock

No well in the basin has directly penetrated the generative source rock. Based on geochemical data from migrated hydrocarbons and basin modelling, the source is interpreted as Type III and Type II/III organic matter, characteristic of deltaic settings. Maturity range: Ro 0.7-0.8%. Probable depth >3,200 m. Hydrocarbon generation began in the Late Miocene-Early Pliocene and continues to the present day.

Reservoir

Primary reservoirs are **post-MMU Stage IV clastic plays**: coastal to shallow marine sandstones with excellent reservoir quality (por 20-30%, perm up to 630 mD). Secondary potential exists in pre-MMU Oligocene syn-rift clastics and carbonates (proven in the neighbouring Layang-Layang Basin).

Seal

Intra-formational marine shales (10-50 ft thick) within the Stage IV sequences. The transgressive shales of Stage IVF and IVG provide regional seals. Fault sealing is confirmed by seismic amplitude brightening in some locations.

Trap

Structural traps dominate: fault-dependent dip closures against growth faults, and syn-kinematic anticlines associated with the NW Sabah fold-thrust belt. Stratigraphic traps remain underexplored.

Timing — The Critical Risk

Timing of trap formation relative to hydrocarbon migration is the key risk. Hydrocarbon generation began in the Late Miocene-Pliocene. However, the Pliocene inversion event (Meliau Orogeny) can breach earlier traps or cause remigration. The Sandakan Basin demonstrates this risk — despite a working petroleum system, only 5 of 19 wells are discoveries, largely due to trap integrity issues from Late Miocene deformation.

7. Regional Cross-Section: NW–SE Transect

A full NW-SE geological transect across the Sabah margin (~600 km) reveals the following tectonic provinces:

NW: Dangerous Grounds

Extended continental crust of the South China Sea margin. Block-faulted, thin sediment cover. Pre-rift, syn-rift, and post-rift packages. This is the continental fragment that collided with NW Borneo at ~22-20 Ma, triggering the Sabah Orogeny.

Layang-Layang Basin

Oligocene syn-rift basin. Half-graben geometries. Recently revitalised by the Tepat-1 oil discovery (proved working petroleum system). Carbonate buildups developed on structural highs. Frontier status. The 'outboard' basin system.

Sabah Trough

Deep bathymetric low separating the inboard fold-thrust belt from the outboard Dangerous Grounds. The trough marks the subduction suture zone.

Kinabalu Basin (Offshore NW Sabah)

The inboard fold-thrust belt. Post-MMU Stage IV clastic plays. Kinabalu Growth Fault is the dominant structural feature, active between 8.5-6.7 Ma. Toe-thrust structures at the basinward edge. Oil and gas accumulations in fault-dependent closures. Hydrocarbon-producing (mature basin).

Coastal Plain → Crocker Range

The Crocker Range is the uplifted Eocene-Oligocene accretionary prism. Tightly folded turbidites. Multiple thrust fronts. Overridden by the Kinabalu Granodiorite pluton at ~10-8 Ma. The pluton's metamorphic aureole surrounds the intrusion.

Central Sabah — Circular Basins

The Neogene 'circular basins' — erosional remnants of the originally continuous Tanjong/Kapilit delta system. Now preserved as fault-bounded, elliptical outliers. Underlain by the Kuamut/Garinono melange. Products of Pliocene inversion and transpressional tectonics.

Kinabatangan Trough → Sandakan Basin

Eastward transition into the post-rift Sandakan Basin. The Sebahat Formation (Middle-Late Miocene) shows strongly progradational clinoforms — the Sandakan delta system prograded eastward into the Sulu Sea. Five sub-commercial gas discoveries (Nymphe, Benrinnes, Mutiara Hitam, Kuda Terbang).

SE: Sulu Sea

Deep marginal basin (>4,500 m). Post-rift thermal subsidence. Passive margin of the Sulu Sea spreading centre. Sediment supply from the Borneo hinterland via the Sandakan delta system.

8. References & Data Sources

Balaguru, A. & Hall, R. (2009). Tectonic Evolution and Sedimentation of Sabah, North Borneo, Malaysia. Search and Discovery Article #30084. Adapted from AAPG International Conference, Cape Town, 2008.

Balaguru, A., Nichols, G. & Hall, R. (2003). The origin of the 'circular basins' of Sabah, Malaysia. Bulletin of the Geological Society of Malaysia, 46, 335-351.

Balaguru, A., Nichols, G. & Hall, R. (2003). Tertiary stratigraphy and basin evolution of southern Sabah: implications for the tectono-stratigraphic evolution of Sabah, Malaysia. Bulletin of the Geological Society of Malaysia, 47, 27-49.

Bait, B. (2003). Geology of Kinabalu field and its water injection scheme. Bulletin of the Geological Society of Malaysia, 47, 165-179.

Madon, M. & Jong, J. (2022). The structural-stratigraphic framework and petroleum systems of the Sandakan Basin, offshore East Sabah, Malaysia. Bulletin of the Geological Society of Malaysia, 74, 135-160.

PETRONAS Malaysia Petroleum Management (2025). Exploration: Overview of Malaysia's basins. https://www.petronas.com/mpm/malaysia-e-p/exploration

Choi, T. (2026). Unlocking the Oligocene Play in Offshore Sabah: New Insights from Layang-Layang Basin Following Recent Discoveries. TGS Technical Library. Presented at EAGE Workshop on New Discoveries in Mature Basins.

Ab Ghani, A.F. et al. (2026). Unravelling Deeper Play Opportunities in Kinabalu Basin of Sabah, Case Study from Recent Well B Results. 2nd EAGE Workshop on New Discoveries in Mature Basins, April 2026.

Madon, M. et al. (1999). Sabah Basin. In: Leong, K.M. (Ed.), The Petroleum Geology and Resources of Malaysia, PETRONAS, 501-542.

Tongkul, F. (1991). Tectonic evolution of Sabah, Malaysia. Journal of Southeast Asian Earth Sciences, 6(3/4), 395-405.

Hutchison, C.S. (1996). The 'Rajang Accretionary Prism' and 'Lupar Line' Problem of Borneo. Geological Society of London Special Publication.

Hall, R. (1996). Reconstructing Cenozoic SE Asia. Geological Society of London Special Publication, 106, 153-184.