# The stratigraphy of northern Labuan, NW Sabah Basin, East Malaysia

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**Abstract:** The stratigraphy of northern Labuan, East Malaysia, has been re-examined to include new field information. It is proposed that the three-fold subdivision of the strata in this part of Labuan into (in younging order) Temburong, Setap Shale, and Belait formations is incorrect. The strongly deformed argillaceous strata which underlie the Belait conglomerate ridge near Layang-Layangan are more typical of the Temburong Formation and may have been incorrectly included within the Belait Formation. This sequence of deep to shallow marine sediments is overlain unconformably by fluvial conglomerates of the Belait Formation, suggesting that the Setap Shale Formation, as re-defined by Brondijk (1962), is absent.

## INTRODUCTION

The stratigraphy of Labuan island is basically an extension of onshore west Sabah, Brunei, and northern Sarawak (Liechti *et al.*, 1960; Wilson, 1964, Potter *et al.*, 1984). Wilson (1964) recognised three lithostratigraphic units in Labuan: Temburong Formation, Setap Shale Formation, and Belait Formation. No significant advances in the geology and stratigraphy of Labuan has been made since Wilson's 1964 memoir. Lee (1977) provided a useful and comprehensive summary of the geology and stratigraphy of the island. The aim of this paper is to report some new field observations in the northern part of Labuan and their implication for current stratigraphical nomenclature.

## **REGIONAL SETTING**

The island of Labuan is situated in the Northwest Sabah Basin, a Neogene basin filled with > 12 km of sediments deposited on the formerly active northwestern continental margin of Sabah (Fig. 1). The basement of the basin is exposed in Sabah as the Paleocene-Eocene Rajang Group foldbelt which consists of highly deformed deepwater deposits, underlain by ?Jurassic to Lower Cretaceous complex of ultramafic intrusive rocks, radiolarian chert, and spilite (e.g. Basir and Sanudin, 1988). The Rajang Group, which includes the Crocker, Trusmadi and Wariu formations, is generally regarded as representing an accretionary wedge that was formed during the subduction of an ocean basin underneath Sabah during late Eocene to middle Miocene times (e.g. Tan and Lamy, 1990).

Regional uplift at the end of subduction in middle Miocene times caused the erosion of the Rajang foldbelt and resulted in a regional unconformity at the landward margin of the basin (western Sabah onshore and adjacent offshore). The unconformity is referred to as the 'late Te5' unconformity in onshore areas (Liechti et al., 1960) or the 'Deep Regional Unconformity' (DRU) in offshore areas (Levell, 1987). It represents a break in sedimentation, which was followed by northwestward progradation of coastal to shallow marine clastic sediments in middle Miocene to early late Miocene. This period of sedimentation is represented in onshore Sabah, Brunei, and Sarawak by the Belait, Seria, Miri, Tukau, and Lambir formations (Potter et al., 1984) and offshore by the Stage IV sequences (Levell, 1987) (Fig. 2).

Since middle Miocene times, the basin was subjected to syn-sedimentary deformation which resulted in numerous narrow NNE-SSW trending anticlines and intervening deep broad synclines. The island of Labuan is at the northeastern end of one of the anticlines, the Labuan Anticline, which extends into onshore Brunei as the Bukit Malan Anticline. Several workers have suggested that the anticlines or 'ridges' were formed by deep-seated strike-slip faulting in the basement (Bol and van Hoorn, 1980; Levell, 1983).

# STRATIGRAPHY

#### **Temburong Formation**

The oldest unit on Labuan, the Temburong Formation, crops out mainly in the southwestern part of the island, where it forms the core of the Labuan anticline (Fig. 3). The formation is considered to be equivalent to the upper part of the West Crocker Formation in Sabah. Like the West Crocker, the Temburong consists of mainly deepwater argillaceous deposits, but is thought to represent a more marginal environment (basin slope or flank) (Brondijk, 1962). The Temburong Formation on Labuan is not well-dated, but its correlative on Klias Peninsula has been dated as Te5 (Wilson, 1964).

#### **Setap Shale Formation**

There is some confusion with the nomenclature for the Setap Shale Formation. In Liechti *et al.*'s (1960) compilation, the Setap shale Formation is defined as the argillaceous succession underlying the Belait, Miri, and Lambir formations and overlying the Belaga, Melinau Limestone, or West Crocker formations. Brondijk (1962), however, recognized the Te5 unconformity within the Setap Shale and suggested that the term 'Setap Shale Formation' be restricted to that part of Liechti *et al.*'s Setap Shale which is above that unconformity. The older part of the shale below the unconformity has been re-defined as the Temburong Formation.

In his reproduction of P. Heybroek's 1954 map of Labuan, Wilson (1964) showed the Temburong Formation to be in contact with Belait Formation near Tg. Layang-Layangan (Fig. 3). The Setap Shale Formation was thus implied to be absent. This contradicts with Wilson's (1964, p. 69) statement that Setap Shale Formation is exposed 'below the Belait Formation outcrops'. The question then is: do the 'grey mudstone' and 'weathered clay with some buff sandstone blocks' along Jln. Layang-Layangan belong to Setap Shale Formation (as claimed by Wilson, 1964, p. 69) or should they be



Figure 1. Schematic geological map of Sabah and location of Labuan (modified after Bol and van Hoorn, 1980).

included in the Temburong Formation?

## **Belait Formation**

The Belait Formation is very well-exposed along the coast from Kubong Bluff to Bethune Head at the northeastern tip of the island, and can be traced along strike westward towards Tg. Layang-Layangan. It forms the northern flank of the Labuan anticline and has dips ranging from as low as 10°N at Kubong Bluff to 70°NW at Tg. Læyang-Layangan (Fig. 5). The Belait consists of conglomerate, sandstone and shale (and some coals at Bukit Kubong), passing upwards (northwards) into thinly bedded shales and sandstones. These deposits have been interpreted by earlier workers (Wilson, 1964, p. 73) as fluvial to shallow marine sediments.

The Belait conglomerates are fluvial deposits that rest directly on shales. Brondijk (1963) reported that shales underlying Belait conglomerates at Kubong Bluff contain a pelagic fauna and grades into very sandy strata with brackish water fauna (*Ammobaculites*). This implies a shallowing-upwards character of the sequence. The occurrence of nonmarine fluvial conglomerates directly above marine shaly strata, however, indicates an unconformable relationship between the two sequences. The presence of conglomerate above the DRU or Te5 unconformity was also reported offshore in Kimanis Bay (Levell, 1987, his Fig. 7).

Wilson (1964, p. 75) reported *Globigerinoides* of Tf1 age (basal middle Miocene) in the Belait Formation at Kubong Bluff. This implies that the unconformity at Kubong Bluff is probably of Te5 age and may be related to the same orogenic event that folded the West Crocker Formation. Following Brondijk's (1962) nomenclature, the shales underlying the Belait conglomerates should be included in the Temburong Formation rather than, as mapped by Heybroek, in the Belait Formation.

# "LAYANG-LAYANG UNITS" AS PART OF TEMBURONG FORMATION

The conglomerates of Belait Formation form a prominent strike-concordant ridge that can be traced from Kubong Bluff to Tg. Layang-Layangan, where they overlie a sequence of "rapid alternations of thin buff sandstone with thin sandy clay beds" (Wilson, 1964, p. 71). This argillaceous sequence (the "Layang-Layangan units" of Lee, 1977) is shown



Figure 2. Stratigraphical summary of NW Sabah offshore (modified after Bol and van Hoorn, 1980), showing the relationship between Belait, Setap and Temburong formations.



**Figure 3.** Sketch of Labuan geology adapted from P. Heybroeks's map using Wilson's (1964) nomenclature. The "Layang-Layangan units" (diagonally shaded, and labelled "LY") were originally mapped as part of the Belait Formation but is now included in the Temburong Formation.

in Heybroek's map as belonging to the Belait Formation (Fig. 3) and was generally believed to be the transition between Setap and Belait formation (Lee, 1977, p. 74). In the preceding paragraphs, it was argued that the base of the Belait Formation marks the Te5 unconformity and that the sequence south of the conglomeratic ridge should be included in the Temburong formation. Therefore, the Layang-Layangan units are also interpreted herein as part of the Temburong Formation.

Outcrops of the Layang-Layangan units at Tg. Layang-Layangan and along Jln OKK Daud (Fig. 5) show variable strike directions and degree of structural deformation, suggesting that the strata were already deformed prior to the deposition of the overlying Belait Formation. In most places, the beds are moderate to steeply dipping  $(50^{\circ}-70^{\circ})$  to N or NW, while in some places, they are tightly folded (Figs. 6 and 7). Overturned beds were observed near Taman Layang-Layangan (Fig. 8). The highly variable bedding attitude and higher degree of deformation compared to the Belait rocks provide strong evidence for an unconformity between the Layang-Layangan units (Temburong Formation) and the Belait Formation.

## SEDIMENTOLOGY OF LAYANG-LAYANGAN UNITS

The Layang-Layangan units are best exposed in the coastal outcrops leading to Tg. Layang-Layangan (Fig. 5). They are overlain by conglomerate with coal pebbles, similar to those in



**Figure 4.** Exposure of contact between grey shales (here regarded as part of the Temburong Formation) and overlying conglomerate of Belait Formation. Location: Chimney near Tg. Kubong (Locality "A" in Figure 5). Ruler is 1 m long.

the Belait Formation at Kubong Bluff. The contact between the two formations is not well exposed at Tg. Layang-Layangan.

The Layang-Layangan sequence (Fig. 9) consists of siltstone and shale with thin sandstone beds, passing upward into heterolithic sandstone and mudstone intercalation. Sandstones in the lower part are lenticular and exhibit a distinctive, lowangle, undulating parallel stratification, resembling "hummocky cross-stratification" (Dott and Bourgeois, 1982) (Fig. 10). Sandstones in the upper part are tabular or sheet-like, and show trough cross-stratification and small-scale current or wave ripple lamination (Fig. 11). Lee (1977, p. 75) noted a general increase in grain size northwards (upwards).

The thickening and coarsening-upward trend, and the upward change from low-angle parallel stratification to angle-of-repose cross-stratification, suggests a shallowing-upward depositional environment, similar to that reported in the Kubong Bluff area. Undulating parallel stratification is most commonly reported in shallow marine sediments deposited below fairweather wave base (e.g. Johnson and Baldwin, 1986). Further support for this interpretation is the abundance of softsediment deformation features such as load structures, small growth faults, and rotated and slumped sandstone blocks in muddy matrix (Fig. 12), which also suggest deposition on a sloping surface.

Several shale samples from the Layang-Layangan units taken by the author were found to be devoid of foraminifers. Lee (1977) interpreted the lack of fossils as indicative of "a Belait rather than a Setap age". This, however, may be due to paleoenvironmental conditions, and may not have any age significance.

The shallowing-upward sequence in the Layang-Layangan units was probably produced by shoreline progradation. The fluvial conglomeratic rocks forming the cliffs at Tg. Layang-Layangan could have resulted from rapid base-level lowering due to relative sea level fall (Fig. 13). This accelerated relative sea level fall may be due partly to the structural growth of the Labuan anticline in late Miocene times (Bol and Van Hoorn, 1980).



**Figure 5.** Map of northern Labuan showing the location of outcrops studied by the present author, including those of the Layang-Layangan units (labelled "A" to "D") as mentioned in the text.



**Figure 6.** Road-cut exposure of Layang-Layangan beds showing a highly asymmetrical fold with apparent vergence towards to east. Also shown are slump zones and a continuous bed containing load structures. Location: Along Jln OKK Daud, near Taman Layang-Layangan (Locality "B" in Figure 5).



**Figure 7.** Asymmetrically folded thinly bedded sandstone. Location: Behind rotan factory, along Jln OKK Daud (Locality "C" in Figure 5).

### CONCLUSION

It is proposed that, in the northern part of Labuan, the Setap Shale Formation according to Brondijk's (1962) definition does not exist. Only two formations can be recognized: Belait Formation. which comprises conglomerate, sandstone, shale, and coal, underlain unconformably by Temburong Formation, which comprises conglomerate, sandstone, shale, and coal, underlain unconformably by Temburong Formation, which is essentially a thinly bedded sandstone-shale sequence (Fig. 14). The Layang-Layangan units are interpreted as part of the Temburong Formation because they are more strongly deformed than the Belait and occurs below the Te5 unconformity. The unconformable boundary between Belait and Temburong is marked by the base of the conglomerate which forms the prominent strike-ridge extending from Kubong Bluff to Tg. Layang-Layangan.

As depicted in Heybroek's map (Wilson, 1964), the Belait Formation also crops out in the eastern part of Labuan. Correlation between these Belait outcrops with those in the northern part of the island remains unclear and should be investigated. Wilson (1964, p. 70) had reported Setap Shale containing *Globigerinatella* of late Te5 to Tf1 age near Tg. Batu in the southeastern end of the island (Fig. 3), apparently conformable with the Belait. Lee (1977, p. 80), however, could not confirm the presence of Setap Shale in this area. More detailed mapping and paleontological work are needed to improve our understanding of the stratigraphy of Labuan.



**Figure 8.** Overturned beds of sandstone and shale with *Ophiomorpha* near Taman Layang-Layangan. Beds dip to the south (Locality "D" in Figure 5). Hammer is 33 cm long.



**Figure 9.** Sedimentological log of the Layang-Layangan units in the coastal exposure leading to Tg. Layang-Layangan, showing a general thickening- and coarsening-upward sequence of strata. Note the difference in the stratification types between the lower and upper parts. Thickness of beds in cm.



**Figure 10.** Examples of undulating parallel stratification resembling hummocky cross-stratification (HCS) in the Layang-Layangan units at Tg. Layang-Layangan. A. Argillaceous, thinly-bedded sequence showing a lenticular bed of very "clean" fine-grained sandstone with HCS. Beneath that sandstone bed are slumped sandstone blocks in argillaceous matrix. Geologist is 1.6 m high. B. Strike view of "hummock" (pencil pointing way-up to NW) in thinly laminated sandstone. Note the low-angle truncation surfaces separating cross-stratified sets. Also present are load and flame structures in thin muddy layers (lower right). Pencil is 15 cm long.



Figure 11. Heterolithic sandstone-mudstone intercalation with waveformed ripples on bedding surfaces, representing the main facies in the upper part of the Tg. Layang-Layangan sequence. Hammer is 33 cm long.



Figure 12. Examples of soft-sediment deformation features in the Layang-Layangan units, indicative of deposition in relatively deep water and on steep slopes. A. Randomly oriented sandstone blocks in argillaceous matrix (debris flow?). Tg. Layang-Layangan. Hammer is 33 cm long. B. A slump fold in outcrop along Jln. OKK Daud. Beds above and below are undeformed (see Figure 7). Locality "C". Pencil is 15 cm long. C. Small-scale synsedimentary growth faults and rollover features in sandstone at Jln. OKK Daud. Locality "C". Pencil is 15 cm long.

15 cm

ML3-30

30 cm

ML3-33

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**Figure 13.** Cartoon illustrating the interpretation of the sequence of events which may have produced the Te5 unconformity on Labuan. 1. Shallow marine sedimentation during progradation of shoreline, producing the coarsening-upward sequence of Layang-Layangan units. 2. Compression deformation and growth of the Labuan Anticline resulted in relative sea-level fall, and the Te5 unconformity.

AGE	Leichti et al 1960	Wilson (1964) after Brondijk 1962	This study
MIDDLE	BELAIT FORMATION	BELAIT FORMATION	BELAIT FORMATION Unconformity LAYANG-LAYANGAN UNITS
7 OLIGOCENE - LOWER MIOCENE	SETAP SHALE	SETAP SHALE ?	TEMBURONG FORMATION

Figure 14. Proposed stratigraphical subdivision of Labuan based on this study.

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