

CHAPTER 5: OUTCROPS AND SAMPLES

Chapter 5

Outcrops and Samples

A total of ten outcrops were investigated for this study. These outcrops are from different locations and represent the formations which occur in Labuan Island. Figure 5.1 is a map of Labuan showing the locations of those outcrops.

5.1 Sedimentary Sequence

The island is made up entirely of sedimentary rocks. These rocks are Lower to Middle Miocene in age and can be correlated to these of onshore west Sabah, Brunei, and northern Sarawak (Liechti et al., 1960; Wilson, 1964; Potter et al., 1984; Koopman, and Schreurs, 1996). Wilson, 1964 divided Labuan rocks into three main units: Temburong Formation, Setap Shale and Belait Formation. Lee (1977) subdivided these formations into smaller informal units. Mazlan, (1997) regrouped Layang Layangan Unit I of Lee (1977) which forms lower part of Belait Formation located below the prominent strike ridge from Tg. Layang Layangan to Tg. Kubong with Temburong Formation. Tongkul (2001) regarded and mapped Temburong Formation of Wilson (1964) and Lee (1977) as Setap Shale (see Table 3.1). A major unconformity at the base of Belait Formation can be correlated with the mainland onshore areas and dated as Early Miocene by Liechti, et al. 1960. The marine sequences of Setap Shale and Temburong Formation beneath the unconformity are highly deformed whilst the fluvial to shallow marine deposits of Belait Formation are mildly deformed.

Since the geology of the Island have different divisions for the sediments, this current study will be done on individual units from the different locations visited in this study.

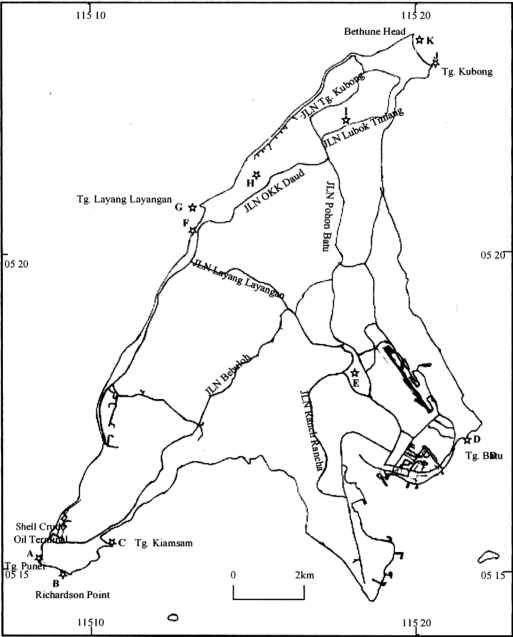


Figure 5.1: Map of Labuan Island shows locations of the outcrops

5.2 Outcrops

5.2.1 Tg. Punei unit

The Tg. Punei unit or proximal turbidite unit of Lee (1977) is exposed at the coast along the south western part of the Kiamsam Peninsula, extending from the recently constructed Shell Oil Terminal. Wilson (1964) mapped this unit as part of the Crocker Formation and Tongkul mapped it as Setap Shale.

The Tg. Punei unit (Figure 5.2) consists of thickly interbedded conglomerate, sandstone, siltstone and silty shale together with some thick massive strongly folded, slumped shale and mudstone with big quartzite and sandstone slump balls. The slumped silty shales and mudstone are generally dark colored and the bedding is distorted and strongly folded (Lee, 1977). The shale appears to be chipped and cracked, and traces of the bedding generally are destroyed, due to weathering and tectonics. The siltstones are generally hard and contain trace fossils and coal fragments in some places (Plate 5.1).

The sandstone of the unit occurs in beds of varying thickness from a few centimeters to over one meter. They exhibit fining upwards with increasing amount of silt, clay and lignitic content. The sandstone beds show graded bedding with coarse gravels at the bottom (Plate 5.2). Both the bedded shales and mudstones at the top of turbidite sequences and the massive slumped shales and claystones have very variable sand and silt content in different parts of the exposed section. The sandstone beds also exhibit wedging characteristics, with some of these beds changing in thicknesses as one traces them along their strikes. The environment of deposition for this unit was interpreted as proximal turbidite of Temburong Formation by Lee (1977).

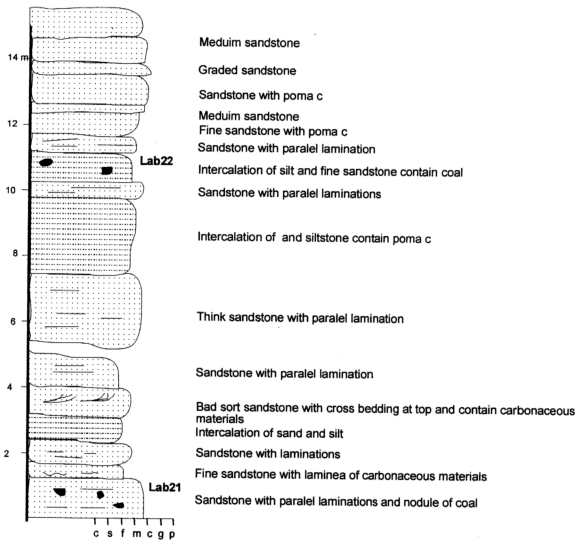


Figure 5.2: Sedimentological log of out crop of Tg. Punei unit near to Shell Crude Oil Thermal at the SW of Labuan Island.



Plate 5.1: Gray siltstone with trace fossils and rounded coal pebbles in Tg. Punei unit (Location A on Figure 5.1)



Plate 5.2: Graded bedded of conglomerate to fine sandstone with lens of coal in Tg. Punei unit SW of the Island (Location A on Figure 5.1)

5.2.2 Richardson Point unit

This is quite an extensive unit on Labuan making up large areas of the older core rocks forming the Labuan Anticline, in particular, a large part of the Kiamsam Peninsula and most of the southern part of the Ranche Ranche.

The largest well exposed outcrop is at the southern coast of the Kiamsam Peninsula (Figure 5.3). Wilson, 1964 correlated this unit with the Temburong Formation on the main land of Borneo while Tongkul (2001) grouped it within Setap Shale. The beds of this unit strike north south with dips of 75 to 85 towards the west (Plate 5.3). They show graded bedding from medium sand at the base to silt and shale at the top. Folds are present in this turbidite unit (Plate 5.4).

This unit is more argillaceous in character than the Tg. Punei located adjacent of it. It consists of regular interbedded thin, fine to very fine sandstone, siltstone and shale with argillaceous rocks being more dominant. The shales are rather silty, dark brown grey to dark grey in color, generally laminated, and contain sand and silt streaks and plant fragments. The mudstones are dark gray and massive (Plate 5.5). The fine sandstone and siltstones are grayish and seem cleaner than those of Tg. Punei unit. The siltstones also contain carbonaceous laminations. The beds in this unit vary in thickness from 10 to more than 30 cm. Many of the beds are organically burrowed and trace fossils are abundant and varied. Lee (1977) interpreted this unit as distal turbidite.

One outcrop near to Jalan Ranche Ranche (Locality E in Figure 5.1) (Plate 5.6) also consist of thin beds of medium, fine sandstone with intercalations of shale and mudstone. They dip steeply (85°) to west. The sandstone is well sorted and is not strongly cemented, and is sometimes friable. Fine parallel laminae are present in the siltstone and fine sandstone. This unit was probably represents of deposition in a turbidite environment.

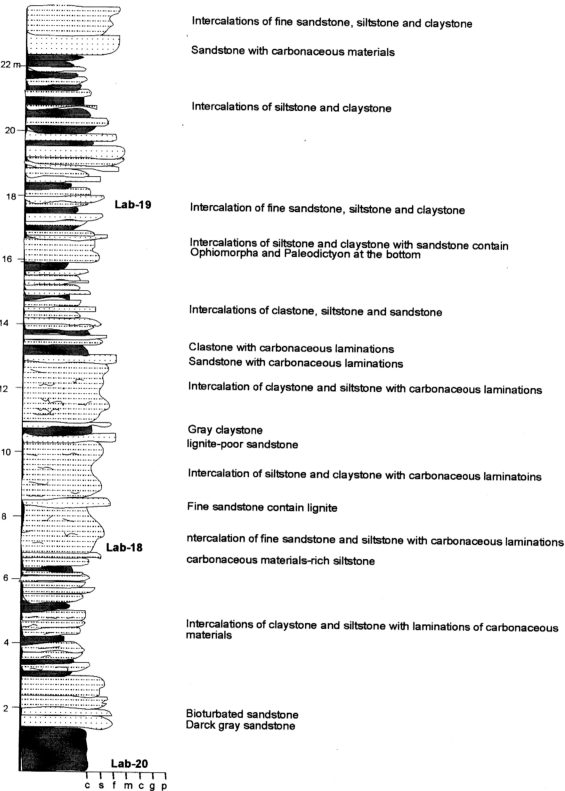


Figure 5.3: Sedimentological log of outcrop of Richardson Point unit, SW of Labuan Island



Plate 5.3: Massive gray mudstone in Richardson point unit SW Labuan Island. (Location B on Figure 5.1)

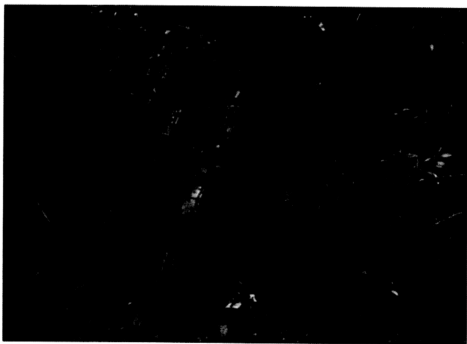


Plate 5.4: Argillaceous unit showing steeply dipping beds of shale, siltstone and fine sandstone with carbonaceous materials in Ricardson point unit), SW Labuan Island. (Location B in Figure 5.1)



Plate 5.5: Fold within Richardson Point unit at the SW of Labuan Island

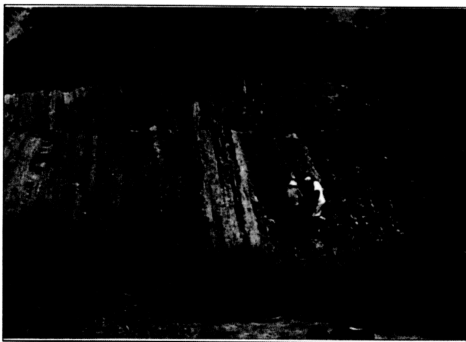


Plate 5.6: steeply dipping beds of shales, siltstones and fine to medium sandstone near to the Jalan Ranche Ranche. (Location E on Figure 5.1)

5.2.3 East Kiamsam sandstone unit

The East Kiamsam sandstone unit of Lee (1977) is a localized unit exposed at the southern extremity of the Kiamsam Peninsula from Richadson Point eastwards to Tg. Kiamsam. Wilson, 1964 placed it with the Tg. Punei unit in the Crocker formation. Lee (1977) separated it from the Tg. Punei unit of the Temburong Formation according to variations in lithology and bedding characteristics. However, he described it as consisting of large slumped or faulted blocks.

This unit is massive-bedded clean sandstone. Shale is not observed, probably due to their being eroded away by the strong wave action of the sea in this part of the peninsula. However, the sandstones are silty and clayey, very poorly bedded to massive thick bedded, gray in color, friable, consolidated but poorly cemented. They are poorly sorted but better than sandstones in the Tg. Punei unit of the Temburong Formation, the grain size ranges from very fine to medium sand. The beds are strongly fractured. Fossils were not observed, even though Lee (1977) found large foraminifera in thin section of sandstone. Carbonaceous laminations were observed in two beds of very fine sandstone interbedded with medium sandstone (Plate 5.7).

Lee (1977) proposed that these sandstones were first deposited on an unstable slope and then redeposited in a deeper water environment by sedimentary slumping.

5.2.4 Temiang unit

According to the previous studies, the dark gray shale and siltstone on Jalan Lubok Temiang probably belongs to Setap Shale. In this location the dark shale and siltstone were exposed by digging under the surface (Plat 5.8). The exposure is made up entirely of dark shale and siltstone which is very rich in organic matter and contains coal pebbles. The Setap Shale in Labuan Island was probably neritic shale which was deposited in a quiet open marine environment (Lee, 1977).



Plate 5.7: Grey siltstone, showing laminations of organic matter and micro-Faults in East Kiamsam Sandstone unit at Tg. Kiamsam (Location C on Figure 5.1).

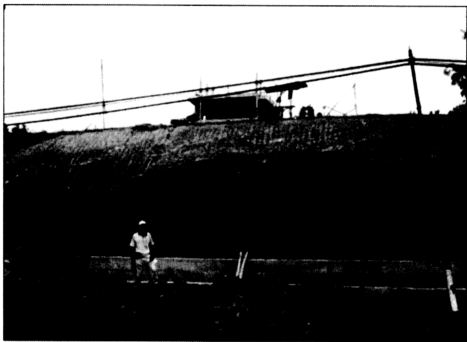


Plate 5.8: Massive gray shale with thin sandstone beds in Temaing unit at Jalan Lubok Temiang (Location I on Figure 5.1)

5.2.5 Tg. Batu

This outcrop occurs on the eastern flank of Labuan anticline. The outcrop consists of sandstone at the base overlain by intercalations of claystone and siltstone (Figure 5.4). The dips of this unit are about 20° SE. The sandstones at the base are gray, quite poorly sorted, very fine grained, grading upwards to medium grained and contain plant fragments. There is a massive sandstone containing *Ophiomorpha* at the top of the unit. The sands are thick bedded and show medium scale low angle trough cross bedding with sharp curved erosive bases in the lower portion of the unit.

The intercalations of shale, siltstone and fine sandstone are cut by sand channels. The shales are usually dark gray and silty and often sandy, show increasing content of sand and silt streaks upwards.

Lee (1977) who studied the sequence from Tg, Batu to Memedai and Kg. Pantai, interpreted the thick sands as probably bar sands and the shales were deposited below wave base to the wave zone and shoreface upwards to possibly offshore bar.

5.2.6 Layang Layangan units

The Layang Layangan units (Lee, 1977) are well exposed as coastal outcrops at Tg. Layang Layangan, and along Jalan OKK Daud at Ladan Andy, on the west flank of the Labuan anticline. This unit underlies the conglomerates of the Belait formation, which form a prominent strike-concordant ridge that can be traced from Kubong Bluff to Tg. Layang Layangan.

This sequence is shown in Heybroek's (1954) map as part of the Belait Formation, but Mazlan (1994) interpreted it as part of Temburong Formation. However, Lee (1977) regarded it as the transition between the Setap shale and Belait Formation.

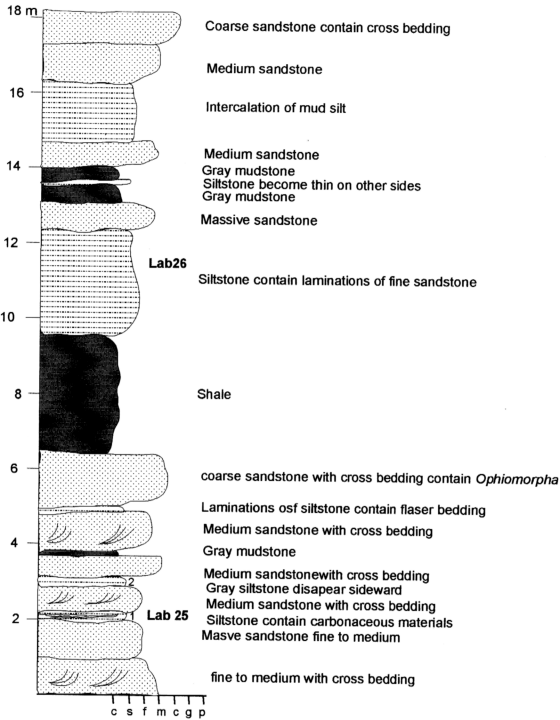


Figure 5.4: Sedimentological log of Tg. Batu unit at the east of the Island

5.2.6.1 Layang Layangan units at Tg. Layang Layangan

The exposure of Layang Layangan at the coast near to the Tg. Layang Layangan (Figure 5.5) was divided into two smaller units by Lee (1977).

Layang Layangan unit I

The lower part of this unit is characterized by lenticular (Plate 5.9) or tabular-shaped sandstone bodies with hummocky cross bedding intercalated with mudstone. They also show graded bedding, slumping features (Plate 5.10) and climbing ripples. The beds of sandstone are generally thin to thick, medium grained and have common carbonaceous bands and laminae, and coal pebbles. This unit is characteristic by load and flame structure occurring in the interbeds of carbonaceous sandstone and silty mudstone.

The upper part of this unit is characteristic by ripple marks (plate 5.11) and small cross-beds. Rhythmically thinly bedded fine sandstone with shale is common in this unit. The shales and mudstone of this unit are generally sandy and silty. They are dark colored with various shades of gray. It contains abundant carbonaceous laminations. Two faults are visible in this unit (Figure 5.2 & Plate 5.12).

Sedimentary features suggest the environment of this unit was delta fringe or delta slope for the lower part and intervening tidal flat deposits between the channels in delta complex for the upper part (Lee, 1977).

Layang Layangan unit II

This unit forms part of a prominent strike-concordant ridge that can be traced from Tg. Kubong to Tg. Layang Layangan. The base of this unit is medium to very coarse grained pebbly sandstones and conglomerates (Plate 5.13). The sediments are thickly bedded, and show large scale trough cross bedding indicating deposition mainly by

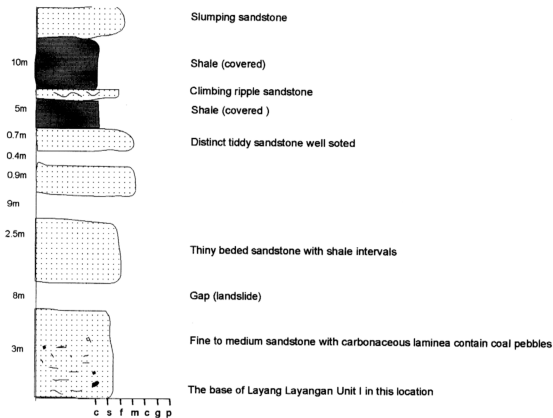


Figure 5.5: Sedimentological log of Layang layangan units at Tg. Layang Layangan

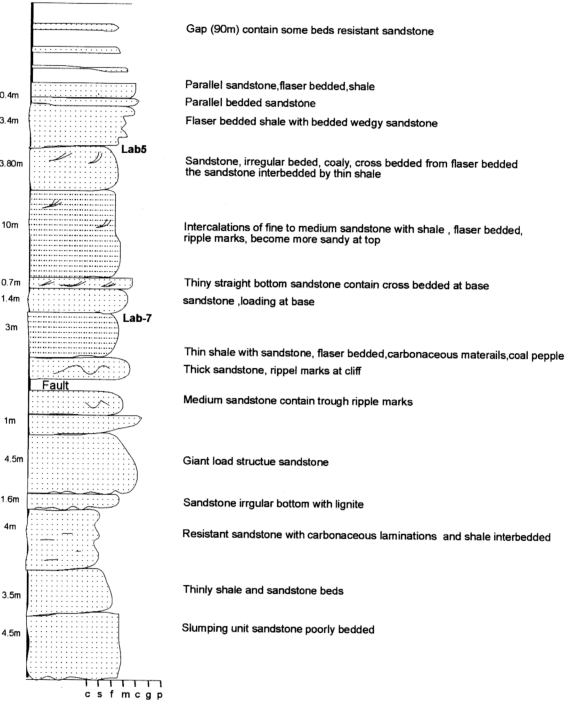


Figure 5.5: Continued

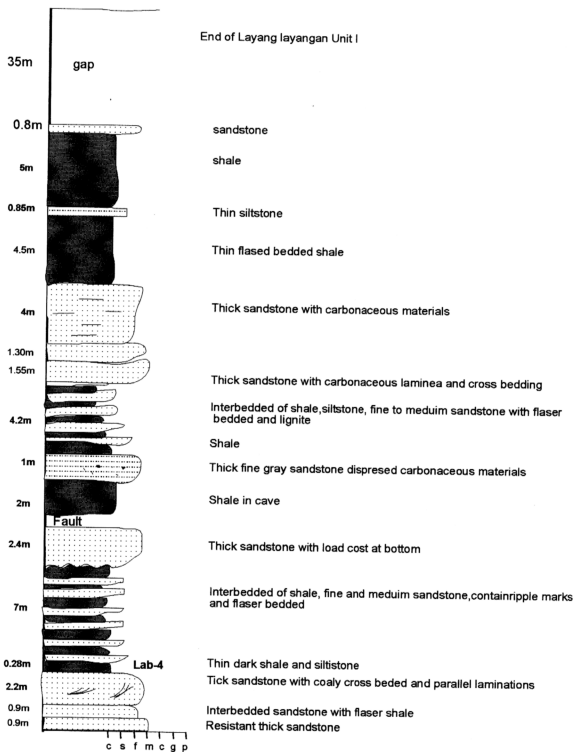


Figure 5.5:Continued

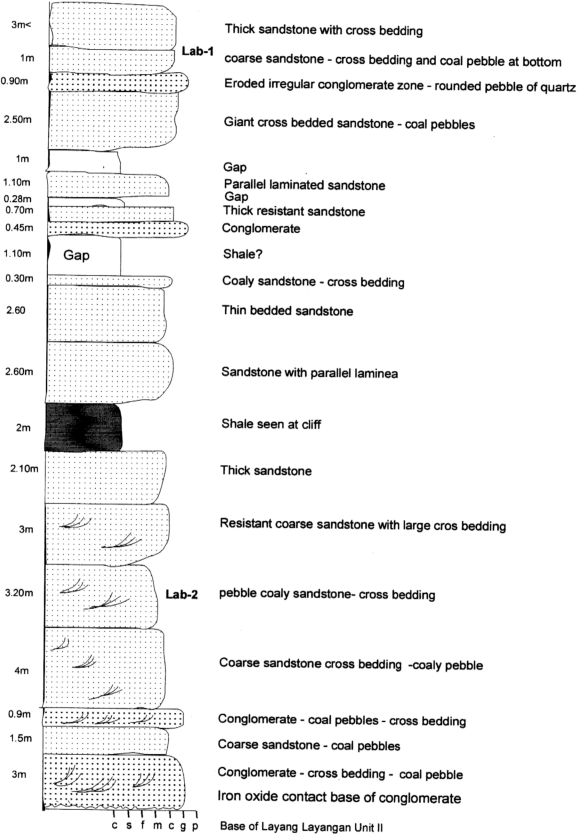


Figure 5.5:.....Continued

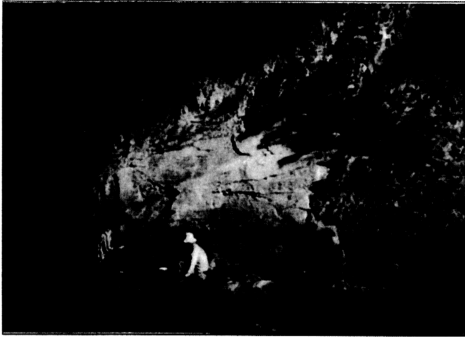


Plate 5.11: Steeply dipping sandstone with ripple marks in Layang Layangan unit I at Tg. Layang Layangan.



Plate 5.12: Faults in Layang Layangan unit I at Tg. Layang Layangan

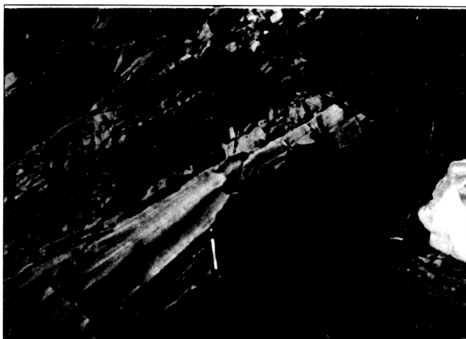


Plate 5.9: Channelized sandstone beds with parallel laminations of carbonaceous materials in Layang Layangan unit I at Tg. Layang Layangan.

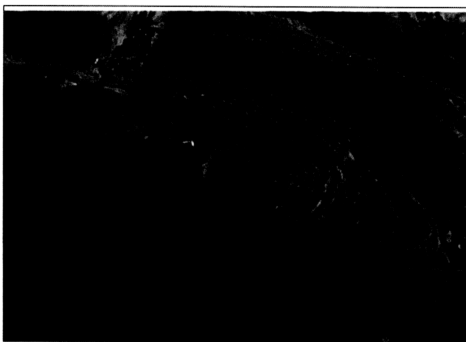


Plate 5.10: Slumped sandstone beds with carbonaceous material and coal pebbles in Layang layangan unit I at Tg. Layang Layangan



Plate 5.13: Conglomeratic sandstone of Layang Layangan unit II at Tg. Layang Layangan showing channel features with erosive bases.

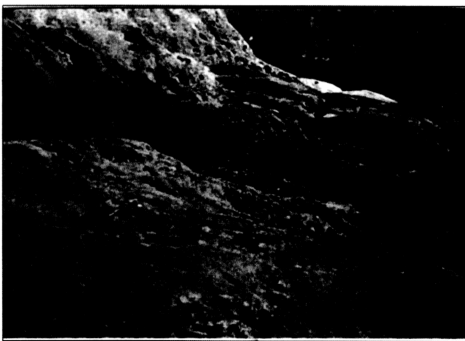


Plate 5.14: Cross bedded conglomeratic sandstone with rounded coal pebbles in Layang Layangan unit II at the top of the Tg. Layang Layangan exposure.

unidirectional traction currents. Interbedded with these conglomeratic rocks are generally medium to fine grained sandstone and minor mudstones. The beds of this unit contain well-rounded coal fragments (Plate 5.14). Thick coarse sandstone beds with medium scale cross bedding are typical of fluvial or valley fill deposits (Wilson, 1964; Lee, 1977; Mazlan, 1994). This probably represents a series of channels building over each other.

5.2.6.2 Layang Layangan unit at OKK Daud

The outcrop at Ladang Andy on Jalan OKK Daud (Figure 5.6 & Plate 5.16) shows an argillaceous appearance similar to the outcrop of Layang Layangan unit I at Layang Layangan. The beds in this outcrop are moderate to steeply dipping. There is a fault in this outcrop (Plate 5.16).

The sequence in this location is made up of interbedded mudstone, siltstone and sandstone. The sandstones are fine to medium grained and some are coarse grained. They show ripple marks and are cross-bedded (Plate 5.18) including hummocky cross-bedding. The basal sandstone contacts vary from flat to channelised (Plate 5.17). Load structures are present, not common in this outcrop. These beds of sandstones vary from thin to thick (10 cm to more than 50 cm) and have common carbonaceous laminae and coal fragments. The mudstones are usually silty and mostly thick bedded. They are dark gray in color and have coal fragments. The siltstone beds are generally less than 20 cm thick and carbonaceous laminae are common in these beds. Other than the coaly material, fossils were not observed in this study.

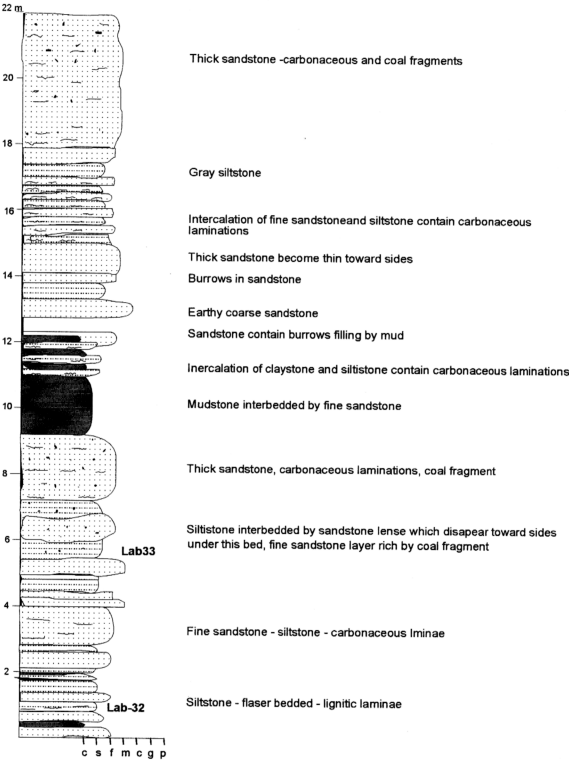


Figure 5.6: Layang Layangan unit I at Ladan Andy on Jalan OKK Daud

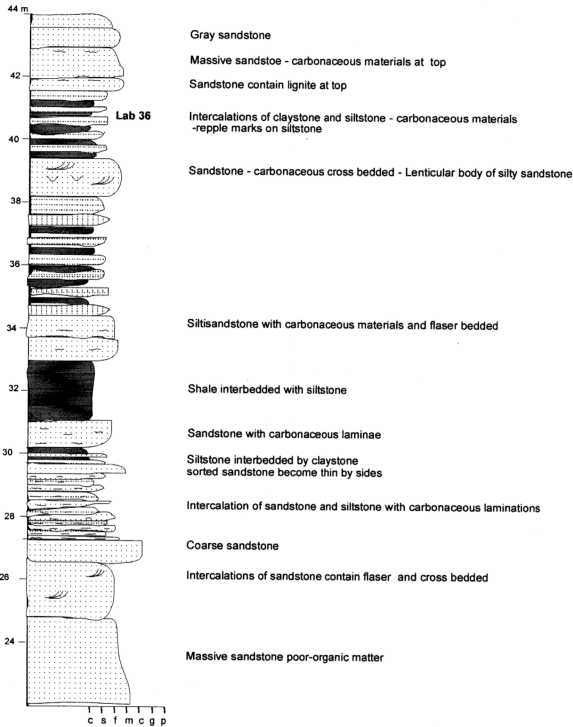


Figure 5.6:Continued

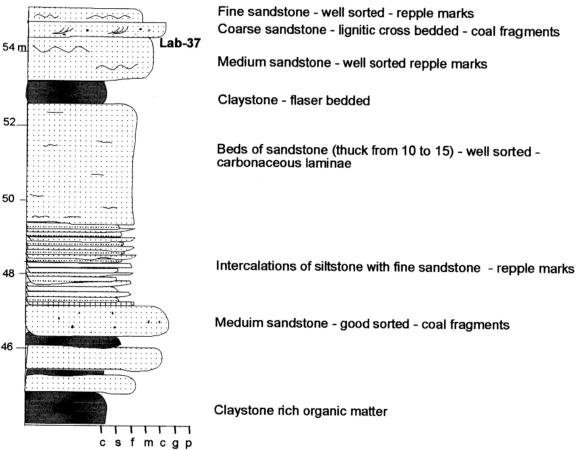


Figure 5.6:Continued



Plate 5.15: Argillaceous sequence of Layang Layangan unit I at Ladan Andy (Location H on Figure 5.1) on Jalan OKK Daud.

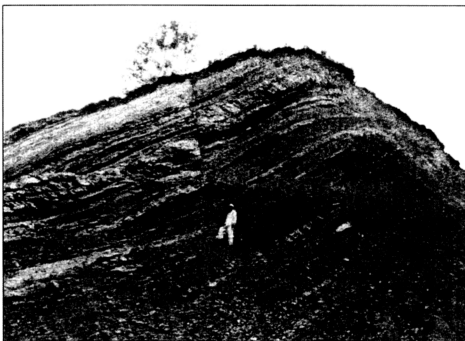


Plate 5.16: Intercalations of shale, siltstone and sandstone. Layang Layangan unit I at Ladan Andy (Location H on Figure 5.1) on Jalan OKK Daud. The sandstone on the left show channel features. There is a fault in the middle

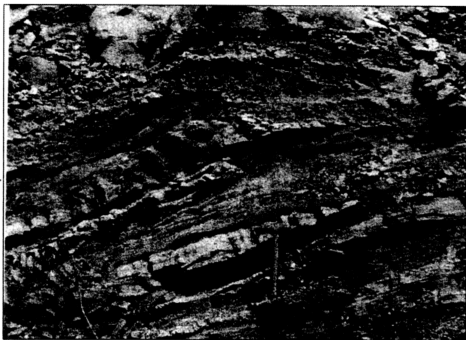


Plate 5.17: Channelized sandstone within argillaceous beds in Layang Layangan unit I at Ladan Andy (Location H on Figure 5.1) on Jalan OKK Daud.



Plate 5.18: Cross bedded coarse sandstone with coal on surfaces of cross beds underlain by fine to medium ripple marked sandstone in Layang Layangan unit I at Ladan Andy (Location H on Figure 5.1) on Jalan OKK Daud.

5.2.7 Tg. Kubong unit

This unit is Layang Layangan unit II of Lee (1977) in the north of the island. The outcrop of this unit (Figure 5.7) consists of generally fining-upward sandstone that dips to the NW by 15°. The basal Belait of Mazlan (1997) at Tg. Kubong is of medium to very coarse-grained pebbly sandstone. The sediments are thickly bedded, and show large-scale cross bedding (Plate 5.19). They are fluvatile channel units, each unit begins with coarse sandstone and ends with shale or siltstone. The sandstones generally are coarse, medium and fine grained and contain medium to large cross bedding. Graded bedding from coarse to fine sandstone is found repeated in this outcrop. At the base of the massive sandstone, there are lenses of coal, which are from 3 cm to 20 cm thick and 50 cm to 300 cm a long. The deposits at this outcrop are equivalent to the Tg. Layang Layangan unit II of Lee (1977) and were deposited in river channels (Wilson, 1964; Lee, 1977; Mazlan, 1994).

5.2.8 Bethune Head unit

The fluvial sequence of the basal Belait Formation (Tg, Kubong) passes upwards (northwards) into shallow marine deposits at the Bethune head (Mazlan, 1997). In these coastal exposures, the gently dipping shale and sandstone sequence exhibit, a stepped-like cuesta topography whereby the more resistant sandstones form the northward slope of the cuestas. The sequence consists of almost cyclic alternation of coarsening-upward shale-sandstone units (Mazlan, 1997).

There are good exposures near to Bethune head (Figure 5.8), with thin beds of sandstone, siltstone and shale. The beds dip consistently to the north at low angles of about 20°. The sandstone is fine and contains laminations of carbonaceous material.

The siltstone is usually found as thin beds intercalated with shale. There is bioturbated, siltstone containing vertical burrows (Plate 5.20), at the top of this outcrop.

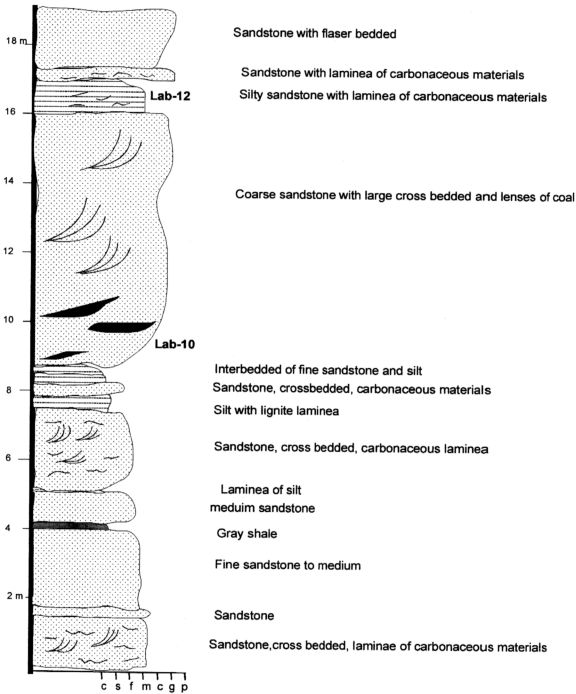


Figure 5.7: Sedimentological log of Layang Layangan unit II at Tg. Kubong

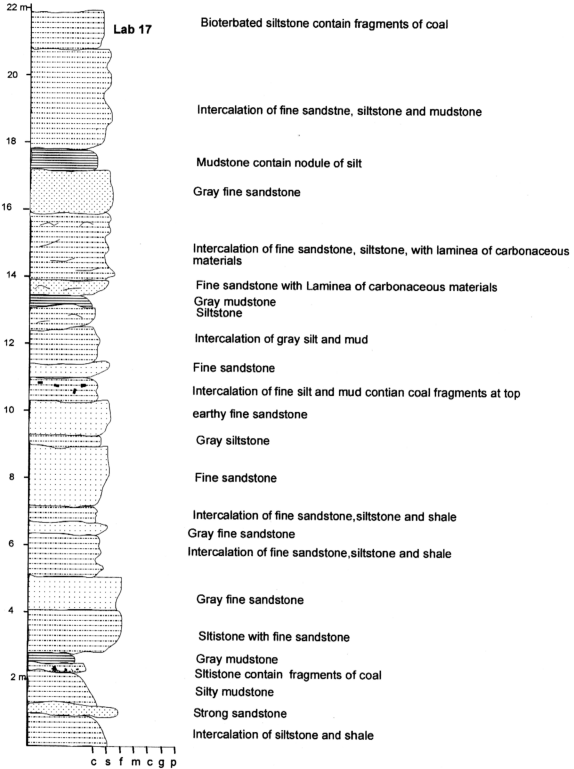


Figure 5.8: Sedimentological log of outcrop near to Bethune Head at the north of Labuan Island



Plate 5.19: Trough bedded coarse sandstone with large lenses of coal, Layang Layangan unit II at north of the Island at Tg. Kubong.

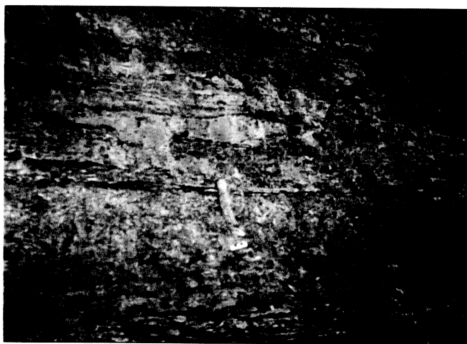


Plate 5.20: Bioturbated shale and siltstone with vertical burrow in the Bethune Head unit north of Labuan Island

5.3 Samples

Fresh and unweathered samples were dug out (about 30 cm) from outcrops and placed into canvas bags. The locations of these samples are shown in the stratigraphic sections. The samples labeled *20, Lab 18 and Lab 19* (Plates 5.23, 5.24 and 5.25) were collected from outcrop located in the (Figure 5.2) south west of Labuan Island at Richardson point (Location B on Figure 5.1). They belong to the Temburong Formation of Wilson (1964) and Lee (1977) or to the Setap Shale according to Tongkul (2001). The sample *Lab 41* (Plate 5.26) was collected from an outcrop near to Jalan Ranche Ranche that probably belongs to the same unit.

Samples *Lab 21* (Plate 5.21) and *Lab 22* (Plate 5.22) were collected from the outcrop (figure 5.3) at the southwest of the island near to the Shell Crude Oil Terminal (Location A on Figure 5.1). They are from the Temburong Formation (Wilson, 1964; Lee, 1977) or Setap shale (Tongkul, 2001).

Sample *Lab 23* (Plate 5.27) was collected from an outcrop at Tg. Kiamsam (Location C on the Figure 5.1). This sample is from the Temburong Formation (Wilson, 1964), East Kiamsam Sandstone (Lee, 1977) or Setap shale (Felix, 2001). Sample *Lab 39* (Plate 5.24) was probably from the Setap shale and its locations on Jalan Lubok Temiang (Location I on Figure 5.1).

Samples numbered *Lab 4* (Plate 5.32) and *Lab 7* (Plate 5.31) are from the coastal outcrop (Figure 5.4) near to Tg. Layang Layangan (Location F on Figure 5.1), and *Lab 33, Lab 36, Lab 37* (Plates 5.33, 5.34, 5.35) were collected from outcrop (Figure 5.5) at Ladang Andy on Jalan OKK Daud. All of these samples are under the conglomerates of the Belait Formation which form the prominent strike-concordant ridge that can be traced from Kubong Bluff to Tg. Layang Layangan. They make up the Lower Belait Formation of Wilson (1964), Lee (1977) and Tongkul (2001), or Temburong Formation according to Mazlan (1994 & 1997).

Samples *Lab 1* and *Lab 10* (Plates 5.36 and 5.37) were taken from the unit which forms the prominent strike- ridge from Tg. Layang Layangan to Kubong Bluff. Sample *Lab 1* is from outcrop (Figure 5.4) at Tg. Layang Layangan west of the Island (Location G on Figure 5.1), and sample *Lab 10* from outcrop (Figure 5.6) at Tg. Kubong north of Labuan Island (Location J on Figure 5.1).

Samples *Lab 12* and *Lab 17* (Plates 5.38 and 5.39) are also from outcrops (Figures 5.6 and 5.7 respectively) north of the Island (Locations J and K on Figure 5.1). All the samples (*Lab 1*, *Lab 10*, *Lab12*, and *Lab 17*) belong to the Belait Formation (Wilson, 1964; Lee, 1977; Mazlan, 1994 & 1997; and Tongkul, 2001)

Samples *Lab 25* and *Lab 26* (Plates 5.29 and 5.30) were collected from outcrop (Figure 5.8) in the east Labuan Island (Location D on Figure 5.1). They belong to Belait Formation according to Wilson (1964); Lee (1977) and Tongkul (2001).

There are summarized in Table 5.1.

Sample number	Lithology	Formation	Environment (Lee, 1977)	Location
Lab 26	Shale	Belait Formation at Tg. Batu		Tg. Batu
Lab 25	Sandstone			
Lab 17	Siltstone + coal	Bethune Head of Bel.For.	Shallow Marine	Near to Bethune Head (K)
Lab 12	Siltstone	Tg Kubung Unit & Tg. Lay. Lay. Unit II of Belait Formation	Fluvial Deposits	Tg. Kubong (I)
Lab 10	Coal			
Lab 1	Coaly Sandstone	Lyang Layangan unit I (Belait Formation (Lee, 1977), Temburong Formation (mazlan, 1994)	Tidal flat between channels; Delta slope	Tg Layang Layangan (G)
Lab 37	Coaly Sandstone			Jalan OKK Daud (H)
Lab 36	Shale			
Lab 33	Siltstone			
Lab 4	Shale			Tg. Layan Layangan (F)
Lab 7	Coal	Setap shale		Jalan Lubok Tmiang (I)
Lab 39	Siltstone			
Lab 41	Shale	Belait Formation		JLN Ranch Racha (E)
Lab 23	Siltstone	East Kiansam Sandstone	Proximal Turbidite	Tg. Kiansam(C)
Lab 21	Coal	Tg. Punei Unit (Temburong F. of Lee, 1977), (Setap. Shale of Tongkul, 2001)		Near to Shell Crude Oil Terminal (A)
Lab 22	Calcareous Coal			
Lab 20	Shale	Richardson Point Unit Temburong F. of Lee, 1977), Setap Shale of Tongkul(2001)	Distal Turbidite	Richardson Point (B)
Lab 18	Siltstone			
Lab 19	Siltstone			

Table 5.1: Description of selected samples analysed in this study (letters A, B... K show locations on figure (5.1)

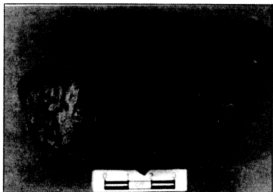


Plate 5.21: Hand specimen of sample Lab 21 of coal

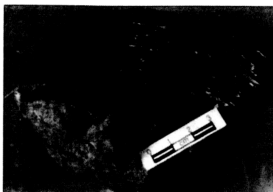


Plate 5.22: Hand specimen of sample Lab 22 showing calcareous coal ball with burrows

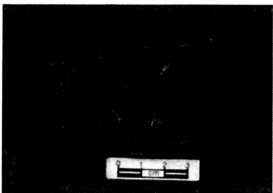


Plate 5.23: Hand specimen of sample Lab 20 showing massive gray mudstone

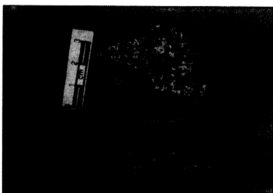


Plate 5.24: Hand specimen of sample Lab 18 showing siltstone with patches of carbonaceous materials

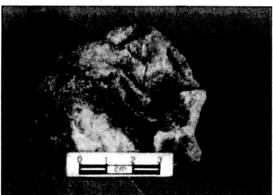


Plate 5.25: Hand specimen of sample Lab 19 showing carbonaceous material mixed with siltstone

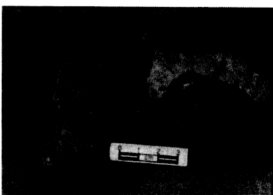


Plate 5.26: Hand specimen of sample Lab 41 showing shale with small laminations of organic matter



Plate 5.27: Hand specimen of sample Lab 23 showing siltstone with parallel laminations organic matter.



Plate 5.28: Hand specimen of sample Lab 24. Light gray Siltstone with patches of carbonaceous material and coal pebbles.

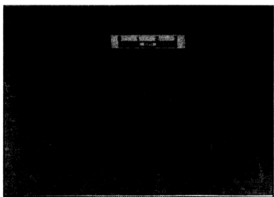


Plate 5.29: Hand specimen of sample Lab 25 showing fine sandstone with coal fragments.

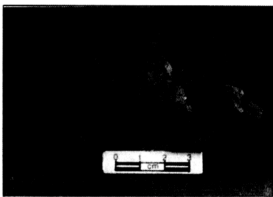


Plate 5.30: Hand specimen of sample Lab 26 showing light grey mudstone.

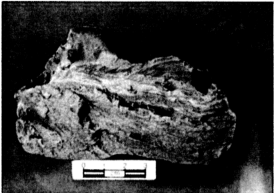
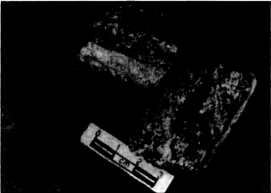
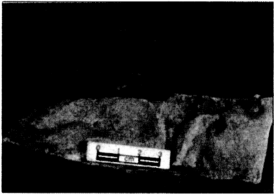


Plate 5.33: Hand specimen of sample Lab 33. showing band of siltstone intercalate with mixture of siltstone, clay and carbonaceous materials

Plate 5.34: Hand specimen of sample Lab 36 showing light gray mudstone with bioturbated surface.



Plate 5.35: Hand specimen of sample Lab 37. Siltstone rich in coal fragments and other carbonaceous materials.

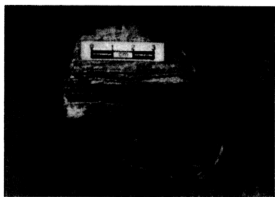
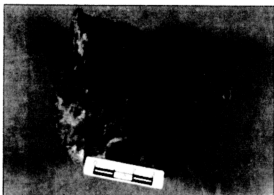
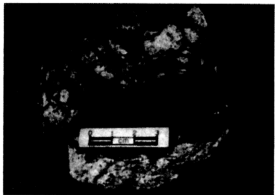


Plate 5.38: Hand specimen of sample Lab 12 showing fine sandstone with parallel laminations of organic mater changing to siltstone at the top.

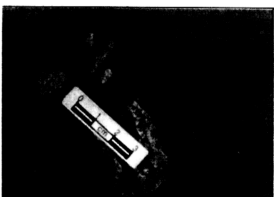


Plate 5.39: Hand specimen of sample Lab 17 showing friable siltstone with thin layer of coal at the top.