The Holocene Development of the Larut Matang Mangrove Forest Area and Its Associated Coastal Sedimentary Succession

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***Abstract* - This study investigates the impact of Holocene sea level change on the development of the Larut Matang Mangrove Forest area and its associate coastal sedimentary succession. Boreholes data from five sites within this study area were analyzed to correlate the sedimentary sequences corresponding to the fluctuations in the sea levels. Three different sedimentary units were identified based on their lithology, fossil content and stratigraphic association; these units can be matched to the Simpang Formation (Pleistocene), Gula Formation (Holocene), and Beruas Formation (Holocene).**

Interval I (Simpang Formation), a terrestrial deposits comprising of clay, sand and gravel, is interpreted to have been deposited by fluvial processes during the Pleistocene, possibly during the LGM (Last Glacial Maximum – 18,000 – 15,000 years ago). Interval II (Gula Formation) represents Holocene marine which mostly consists of clay, sand, gravel and some peat. This formation overlies the Simpang Formation, and it is interpreted as a transgression unit correlatable to the sea-level transgression and highstand from the sea-level curve estimated at 9,000 years ago. Interval III (Beruas Formation) is predominantly clay, silt and sand deposited by fluvial process interpreted to have been deposited due to the drop of sea level around 3,500 – 1,000 years ago.

Keywords – Larut Matang Mangrove Forest, Sea level changes, Holocene.

I. INTRODUCTION

Mangrove forests, which thrive in the intertidal zones of tropical countries, are the intersection between the land and the sea. This unique ecosystem can be found widely along sheltered coasts where they grow abundantly in saline soil and brackish water subject to periodic fresh-and salt-water inundation. With strong feet that hold the land beneath them, they are one of the most productive and biologically complex ecosystems on Earth [1].

This unique and complex ecosystem have their specific characteristics and morphological adaptations such as tough root systems, special bark and leaf structures to enable them to survive in their habitat's harsh conditions. The habitat is soft, silty and shallow, coupled with the endless ebb and flow of water providing very little support for most mangrove plants which have aerial or prop roots (known as pneumatophores, or respiratory roots) and buttressed trunks for gas exchange [1]. Another morphological adaptation, the viviparous, helps the trees to spread its offspring while they are still attaching to the parental trees [2].

Mangroves display unique biological characteristics; it is interesting to assess the extent to which these mangals can be used as indicators of sea-level rise or coastal changes. From recent reviews of mangrove by other researchers, it appears that these coastal ecosystems are so specialized that any minor variation in the tidal regimes may result noticeable mortality. Each species of mangrove has their own limit of tolerance with regard to salinity of the water and soil, as well as the inundation regime [3]. If any unexpected events happened, they might either readjust to the new conditions or succumb to the unsuitable conditions. Consequently, the use of remote sensing data for mangrove ecosystems offers excellent potential as a tool for monitoring coastal changes.

II. THE QUATERNARY GEOLOGY OF LARUT MATANG MANGROVE FOREST AREA

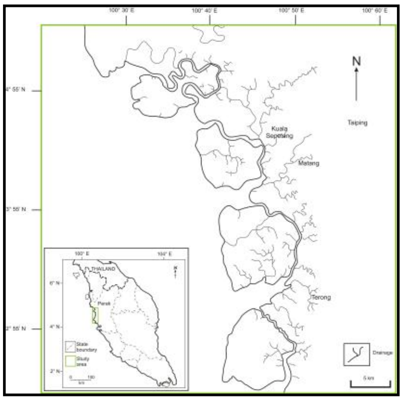

Fig. 1: Map of the Research Area.

Larut Matang is a coastal town located in the district of Matang, about 17 km from Taiping, in the state of Perak (Figure 1). The study area is located in the northwest of Peninsular Malaysia, bounded by latitudes 4º55' N and longitudes 100º21' E and 100º30' E. The shoreline in the study area is fringed by a continuous mangrove belt, separating the Strait of Malacca in the west and Larut Matang coastal plain in the east. The mangroves here form a part of the larger and laterally wider area stretching from Kuala Gula in the north to Panchor near Pantai Remis in the south. The mangrove-vegetated shoreline along Larut Matang formed part of the Matang Mangrove Forest Reserve which covers more than 40,000 hectares and it has been recognized as one of the most well managed mangrove swamps in the world.

The surrounding area is generally underlain by unconsolidated alluviums [4]. The alluviums are mainly peat with minor intercalations of clay and silt, sand, and gravel. Meanwhile, the underlying bedrock is predominantly sedimentary rocks (shale, mudstone and sandstone) and their metamorphic equivalents [5].

Based on previous studies of palynological and lithological characteristics of the Late Quaternary sediments in Peninsular Malaysia, there are six types of Quaternary depositional environments [6]. The depositional environments are interpreted and classified as presented in Table 1.

TABLE I
CLASSIFICATION OF LATE QUATERNARY DEPOSITIONAL ENVIRONMENTS AND THE CORRESPONDING LITHOLOGICAL CHARACTERISTICS (AFTER KAMALUDIN BIN HASSAN, 1989)

Depositional Environment	Descriptions
Shallow marine offshore (including tidal flat)	The lithology of the sediments deposited under this condition is homogenous and made up of clay, silt and sand. Shell and plant remains may be abundant or in moderate amounts.
Deltaic, lagoonal and estuarine	The sediments normally consist of clay, silt and sand. Gravel is sometimes present. Small to moderate amount of shell and plant remains may be present.
Mangrove	Clay and silt made up the sediment and occasionally peat is encountered. Small to moderate amount of plant remains and sometimes shell remains are present.
Back mangrove	Clay, silt and quite often peat constituted the sediment. Sand is often present and gravel is sometimes present. Small amount to abundant plant remains may be present. Shell remains are absent.
Freshwater swamp	Peat is basically the major component. Clay, silt and some sand and in places minor amounts of gravel are present.
Peat swamp	Peat is the only component present. Thickness may vary from less than a meter to more than 5 meters.

III. HOLOCENE SEA LEVEL CHANGE AND THE COASTAL SUCCESSION OF LARUT MATANG AREA

Sea level curves indicate that about 80,000 years ago the sea level around much of the world's coastline was slightly higher than it is now, but then it began to fall, and remain low during the Last Glacial Phase, between 80,000 and 6,000 years ago [7]. As we step back to the beginning of the Holocene period (around 15,000 years ago), the sea levels world-wide were then are some 120-150 meters below the present level. It is agreed that there was a relatively rapid rise in the sea level from the early Holocene [8]. Rapid rise of sea level from about – 53 m to +5 m at 10,000 BP to 5000 – 4000 BP has been interpreted by Geyh et. al. [9].

Since the last 15,000 years ago, Peninsula Malaysia is tectonically stable as it is above the sea level during that time. As the years passed by, the sea level rose to another 5 meters above the present level about 4,500 BP so that the mangroves on the seaward side of Matang, as we know today, were totally drowned. The sea level then slowly dropped about 1 mm per year to its present level [10]. There is evidence that mangroves were located many kilometers inland 4 – 5,000 years ago when the sea level was some 5 meters above the present level. It reveals that the Matang mangroves have been around for no more than 7,000 years, a very young age compared to the inland rain-forests [11].

Figure 2 shows the sea level curve from 21,000 BP to 4,200 BP [12]. Starting from 21,000 BP, the Last Glacial Maximum (LGM) reached its final phase and began to rise rapidly for the following years.

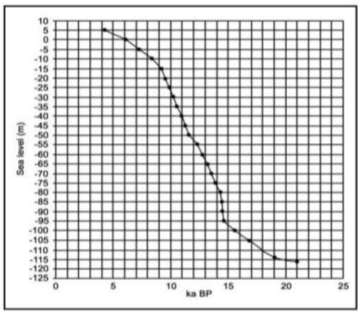

Fig 2: The sea level rise curve (Sathiamurthy and Voris, 2006)

Figure 3 below shows an age-altitude plot from the study in Malay-Thai Peninsula. It comprises 81 sea-level index points related to a past tide level together. According to Horton et. al. (2005), the plot of all index points from Southeast Asia confirmed the upward trend of Holocene relative sea level to a mid-Holocene high stand and subsequent sea-level fall to present [13].

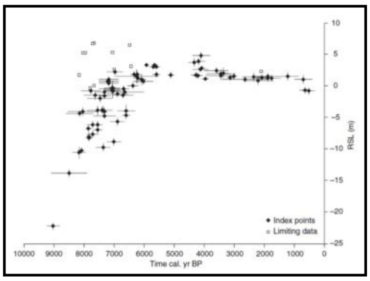

Fig. 3: Malay-Thai Peninsula relative sea-level index points (Horton et al, 2005)

From the inland shoreline limit around 5,000 years ago, the inland mangrove edge is interpreted as the position of the shoreline in the area (based on the peat) when the sea level is recorded at its highest, about 5m above the present [14]. The combined effects of the Holocene transgression, regression and sediment deposition resulted in coastal progradation and development of the coastal plain.

The fluctuations of the sea level during Holocene gave a sufficient time for vegetations to thrive and develop. This evolution brings valuable information on the provenance of the sediments and the environment of deposition as the sea level controls the life of the mangrove trees. This will also leave a trace on the shoreline morphology, and Kamaludin bin Hassan (1991) [15] had made a comparison by using the 1950's and 1966's aerial photographs in Pulau Kelumpang to indicate the coastline.

Figure 4 shows the comparison of the topographical maps of 50 years ago shows an expanding headland. Within the 16 years period, the corresponding mangrove gained was 5.45 km sq. every year. According to Kamaludin bin Hassan, the reason for the active accreting mangrove shore is mainly due to the high sediment supply brought in by the rivers draining the hinterland areas.

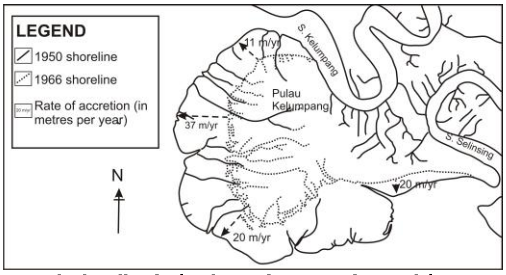

Fig. 4: The headland of Pulau Kelumpang depicted from 1950's and 1966's aerial photograph (Kamaludin, 1991)

IV. RESULTS

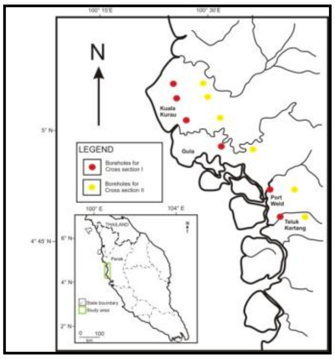

Fig 5 Cross section from North to South

Figure 5 shows the locations of boreholes that have been drilled in the study area. There are a total of 60 borehole logs analyzed from Kuala Kurau, Gula, Port Weld, Teluk Kertang and Kota Ngah Ibrahim. The correlations of the logs were made to see the stratigraphic profiles from North (Kuala Kurau) to South (Kota Ngah Ibrahim).

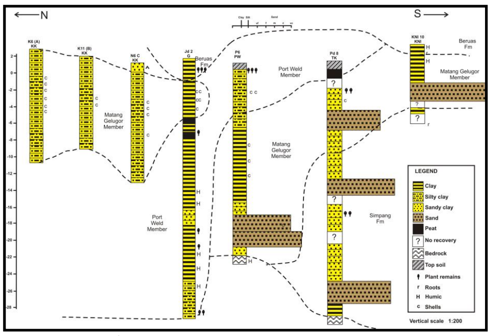

Fig. 6: Cross section I from North to South (Kuala Kurau – Kota Ngah Ibrahim, Matang) (Kamaludin, 1993; Suntharalingam and Teoh; Kamaludin, 1989 [18])

Based on the correlation as shown in Figure 6, the subsurface profiles show that the succession is dominated by clay. As we can see here, the correlation had delineated 3 formations in the area that are Simpang Formation, Gula Formation and Beruas Formation.

From Figure 6, the cross section shows three different units; lowest unit (Simpang Formation), middle unit (Matang Gelugor Member and Port Weld Member – both are Gula Formation) and top unit (Beruas Formation).

The lowest unit is dominating by sandy clay, and several sand units. According to Suntharalingam and Teoh [16], the lithology characteristic is similar to the Simpang Formation. This unit is then overlain by the younger unit deposited during Holocene; the Matang Gelugor unit. It is dominated by clay and this division shows the fining upward trend. Suntharalingam and Teoh define this as a marine clay unit. The presence of shells is a typical feature, thus this reveals that this unit was deposited in a marine environment.

Above this unit is the Port Weld member. This unit comprises of clay and several peat layers. The presence of peat layers and some plant remains is correlatable to the mangrove deposits suggested by Suntharalingam and Teoh [16].

The top unit of this cross section is characterizing by clay and a layer of plant material. This deposit is largely consists of flood plain deposits which closely resembles to Beruas Formations for its character of freshwater or a peat swamp.

From the correlation made from North (Kuala Kurau) up to South (Kota Ngah Ibrahim), we can see a very fascinating depositional environment. The Simpang Formation is the oldest units (Pleistocene) underlying the Matang Gelugor Member (Holocene). The Simpang Formation is interpreted to have been deposited by fluvial process in a terrestrial environment during Pleistocene when the sea level was well below the present [17]. During this time, the environment is interpreted as a terrestrial environment, and in the Holocene age, the Matang Gelugor Member overlain the Simpang Formation; which means that the sea level is rising by this time. Then the sea level dropped, thus the mangrove is starting to move seaward, and expending their territory. The depositional environment at this time is said to be mangrove environment (Port Weld Member). This unit is then overlain by sediments of Matang Gelugor Member. The Beruas Formation is deposited later by the fluvial process during the Holocene.

Another cross section for the study area was made (Figure 7). The Simpang Formation was overlain by Gula Formation and this is said to be a transgression deposition. By this time, the shoreline moves towards the ground, and resulting in flooding. Thus, the mangrove community was unable to survive in such environment. When the sea level starts to fall, the regression deposition occurs and this allows the mangrove community to develop.

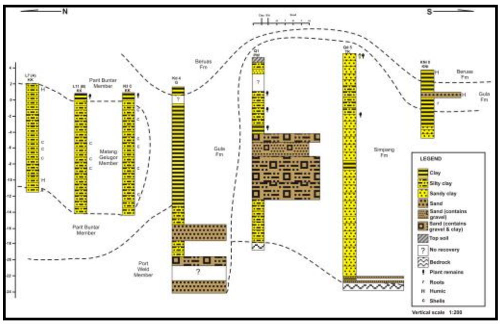

Fig. 7 Cross section II from North to South (Kuala Kurau – Kota Ngah Ibrahim, Matang) (Kamaludin, 1993; Suntharalingam and Teoh; Kamaludin, 1989 [18])

V. Discussion

Figure 8 is a summary diagram illustrating the relationship between the different sedimentary units captured in the boreholes within the study area. The oldest, terrestrial Simpang Formation (Pleistocene) is restricted to the southern part of the research area around Teluk Kertang and Port Weld. By matching this interval to the Quaternary sea level curve for Southeast Asia, the sediment is interpreted to have been deposited during the Last Glacial Maximum (LGM) around 18,000 years ago (Figure 2) when it was 100-120 m below present.

As the sea level rises through time, the coastline migrates inland and sediments such as clay, sand and gravel were deposited. This is the characteristic of the Gula Formation, which are well developed within the Kuala Kurau area. This transgressive succession overlies the Simpang Formation. This can be correlated to the sea level curve from Figure 3 which shows the sea level rising rapidly starting from 9,000 BP until 5,000 BP.

Between 3,500 – 1,000 BP, a minor fall in relative sea level was recorded in many parts of Asia. Coastline retreat (and sediment progradation) may have resulted in the deposition of the terrestrial clay, silt and some sand of the Beruas Formation. This section is only captured in the northern section around Kuala Kurau.

Table II below summarizes the development of the succession and their depositional environment in the order of age starting from Pleistocene (Simpang Formation) to Holocene (Gula Formation and Beruas Formation).

TABLE II
Late Quaternary Stratigraphy and the Characteristic Depositional Environment [After Kamaludin bin Hassan, 1989)

Quaternary Epoch	Interval	Depositional Environment	Description
Holocene	III	Terrestrial (Beruas Formation)	Lithology: Clay, silt and sand. Deposited by fluvial process. Pollen: *Eugenia, Macranga, Pandanus*
	II	Marine (Gula Formation)	Lithology: Clay, sand, gravel and some peat. Deposited in the littoral zone and estuarine to shallow marine environment Pollen: *Sonneratia, Palmae*
Pleistocene	I	Terrestrial (Simpang Formation)	Lithology: Clay, sand, some gravel. Lesser amount of peat. Deposited by fluvial process.

VI. Conclusion

The study area is underlain by three sedimentary units, and they can be correlated to the different stages of Quaternary sea level fluctuations (Fig. 8). These units are classified on the basis of lithology, fossil (age) and stratigraphic position (environment of deposition) as has been defined by Suntharalingam and Kamaludin [16 - 18].

1. The three different stratigraphic units which underlies the study area are formally referred to as the Simpang Formation (the oldest unit - Pleistocene), the Gula Formation (the younger unit - Holocene) and the Beruas Formation (the youngest unit - Holocene).
2. Interval I (Simpang Formation) consist of a terrestrial deposits comprising of clay, sand and gravel. The sediments of the Simpang Formation are interpreted to have been deposited by fluvial processes in a terrestrial environment during the Pleistocene, possibly during the LGM (Last Glacial Maximum – 18,000 – 15,000 years ago)
3. Interval II (Gula Formation) represents Holocene marine which mostly consists of clay, sand, gravel and some peat. This formation overlain the sediments of the Simpang Formation, and it is interpreted as a transgression phase. This unit can be correlated to the sea-level transgression and highstand from the sea-level curve at 9,000 BP (Figure 3).
4. Interval III (Beruas Formation) is predominantly made up of clay, silt and sand deposited by fluvial process during the Holocene. This terrestrial deposit is interpreted to have been deposited due to the drop of sea level around 3,500 – 1,000 years ago.

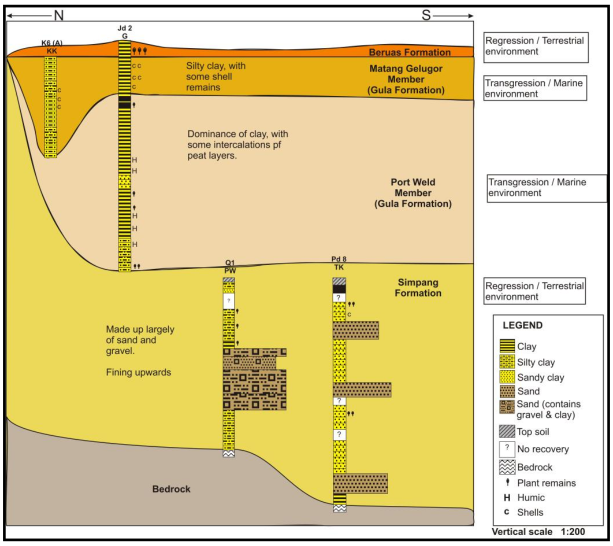

Fig 8: Stratigraphic cross section of the study area.

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APPENDIX

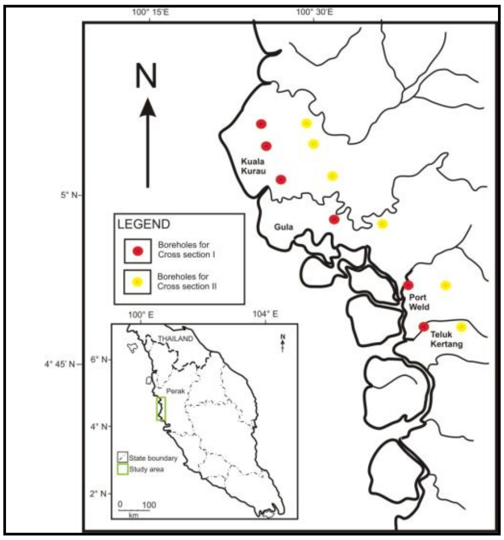
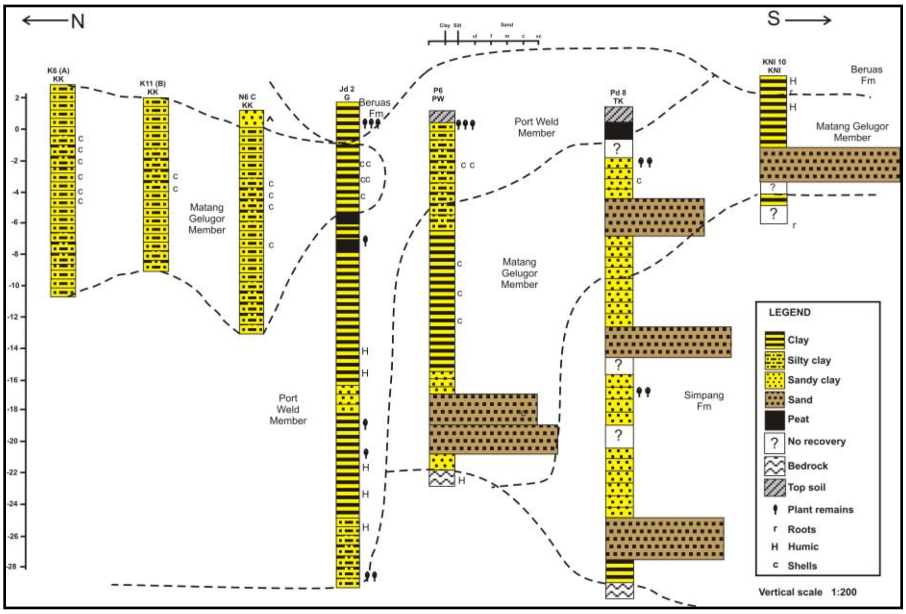


Fig 5: Cross section from North to South



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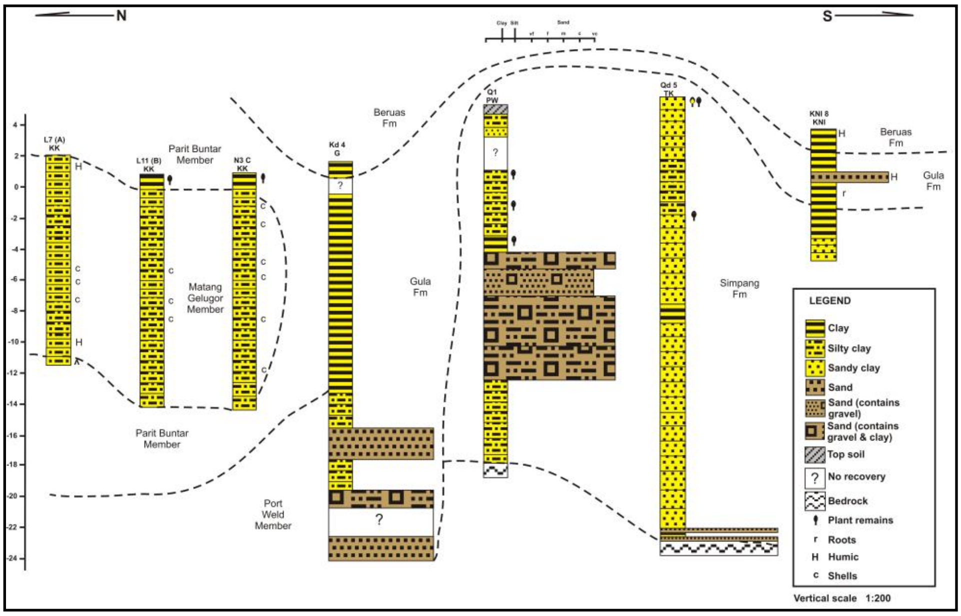

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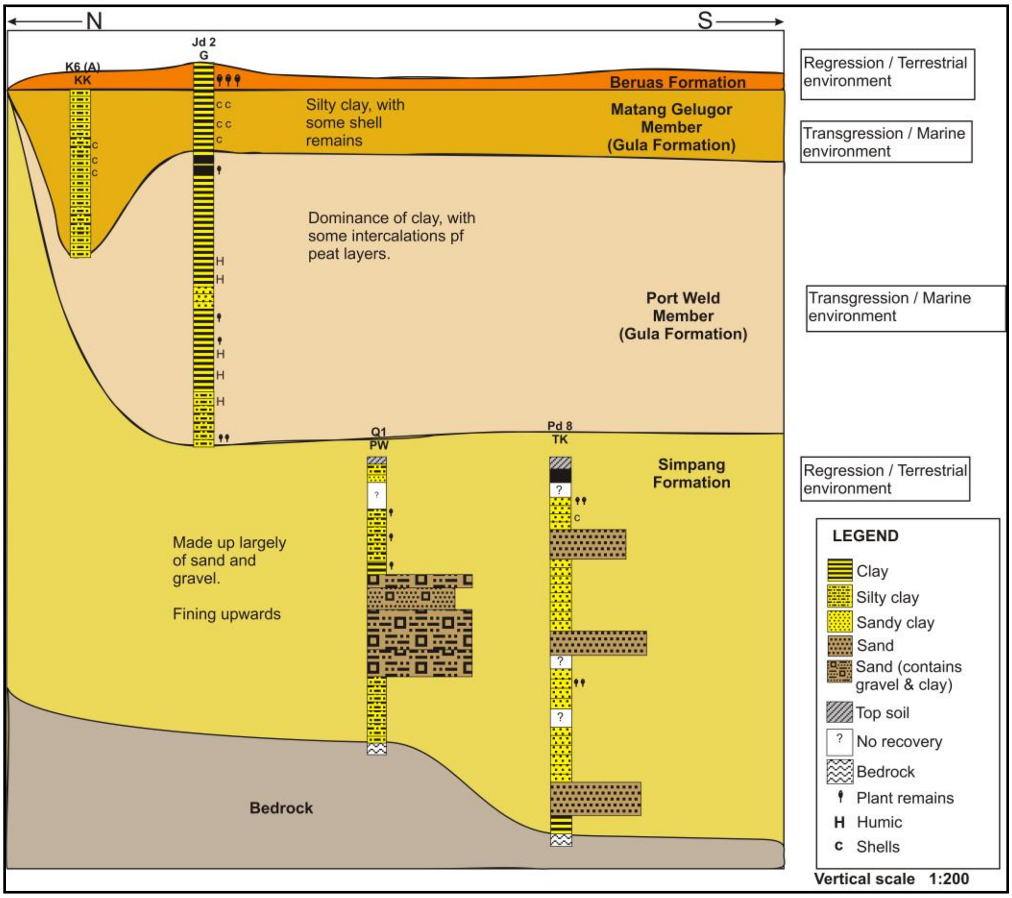

Fig 8: N-S Stratigraphic cross-section of the study area.