Holocene Sea-level Change and The Development of Perak Coastal Plain, Perak, West Malaysia

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Abstract- This paper focuses on the geomorphology, sedimentology and stratigraphy of Perak coastal deltaic-plain in relation to Holocene sea level change. Based on analysis of topographic maps and aerial photographs, Perak River has undergone five stages of evolutions before its current river course. The first course (I) runs in a westerly direction near Kg Tg. Blanja. The second (II) and third (III) course stream towards southerly direction. The forth (IV) course branch from the recent river. The fifth flows along Kg. Ulu Dudap towards southerly direction. The first course develop may has been influenced by the Quaternary and Holocene development of the coastal plain. The river shifting towards southerly direction resulted in partial silting of the estuary. The Perak River has been shifted several times and finally followed the direction of the current river.

Shallow boreholes from seventeen (17) locations within the area of Parit- Lumut- Bagan Datoh- Langkap in south of Perak has been analyzed. These data show that the Perak coastal plain sedimentary succession can be divided into three major intervals. The oldest interval A (Simpang Formation) was deposited within fluvial environment during the Pleistocene age. The second interval B (Gula Formation) was deposited within a marine environment possibly related to a sea level transgression. The third interval C forms terrestrially; it shows similar characteristics as to Beruas Formation, marked by the occurrences of peat and gravel sediments. It records a phase sea level drop.

Keywords: Geomorphology, sedimentology, stratigraphy, transgression, regression.

I. INTRODUCTION

This study focuses on the sedimentology and stratigraphy of the Quaternary coastal-deltaic sedimentary succession of Perak. It is an attempt to unravel the controls on the evolution of the river and the sedimentation on the coastal-deltaic plain of the larger part of south Perak. The emphasis is on the impact of Holocene relative sea level change on the development of Perak River and the coastal plain. Borehole data were analyzed to identify the depositional sequences and their relationships to the Holocene sea-level fluctuation.

II. QUATERNARY GEOLOGY

A. Holocene Sea level Change in Southeast Asia.

Sunda Shelf is situated in the Southeast Asia; it forms a large submerged extinct continental shelf of mainland Asia. Sunda Shelf was exposed during Last Glacial Maximum (LGM) when the sea levels were estimated to have been approximately 116 m lower than modern mean sea level (MSL) [1-3] as shown in Fig. 1.

Peninsular Malaysia is located in the middle of the Sunda Shelf. It is characterized as a dry area during the LGM when the sea-level 116 m below the present day sea-level. A ‘savanna corridor’ did exist through the continent of Sundaland and formed a bridge between Malay Peninsula and major islands in of Indonesia [4]. Heaney [5] described the existence of a wide ‘savanna corridor’ extending down the Malaysian Peninsula through Borneo and into Java. These situation shows that the Perak coastal plain could be located in the middle of the dry ‘savanna corridor’ during the Last Glacial Period.

The Quaternary is characterized by repetition in climate change. Holocene transgression is a sharp rise in global sea-level, recorded from lowland areas around the world. Evidence includes erosive and depositional features such as raise marine terraces, submerged peak layer, mangrove sediments, marine notches, emerged coral reef and marine mollusks [6].

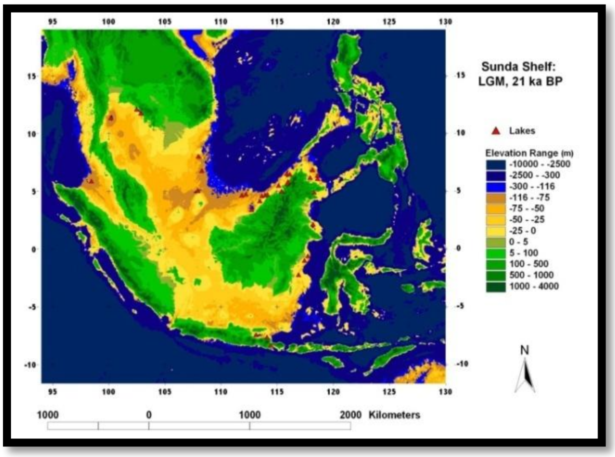

Fig. 1: Sunda Shelf; LGM, 21 ka BP -116m below present day sea level [12].

The sea-level change has strongly influenced the distribution of the sediments in the coastal plain of Peninsula Malaysia since the last 15,000 years ago. A very fast rise in sea-level between 12,000 years B.P occurred, when sea is about 70m below its present level. Only after 6,000 years B.P, it reaches its present level.

A slight rise afterward brought sea-level to its highest point between 5,000 and 4,000 years B.P about 3.0-3.5m above present level [7]. Tjia [8] studied abrasion platforms, sea-level notches and oyster bed in Peninsula Malaysia. Based on the sea-level curves shown in Fig. 3, it shows two high stands at 5000 and 2800 ^{14}C yrs BP [9].

The Southeast Asian deltas have been controlled mostly by the fluctuation in sea level and partly by sediment supply and subsidence history. Sands and gravels comprising Old Alluvium in Malaysia and Singapore, termed of Simpang Formation in Perak [10] appear to have been deposited under more seasonal climatic conditions such as alluvial fan or braided river deposit. A drowned delta in the Strait of Malacca indicates the depth at which the lower shoreline is about 146m below present [11].

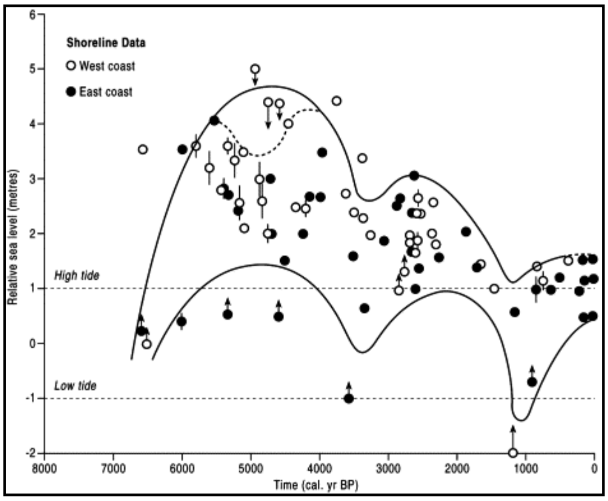

Fig. 3: Holocene sea-level envelope for Peninsula Malaysia [8]-[9]

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B. *Quaternary Geology of Perak State.*

Holocene transgression has greatly affected the evolution of the peninsula coastal plains [4] and could have influenced the geomorphologic and stratigraphic changes of the Perak River. In addition, the condition of the Sundaland's paleoenvironment changes through times since the Last Glacial Period must have influenced the characteristics of Perak River.

The only dated indicators for high sea level during Holocene along the coast of Perak and Selangor can be found around Seberang Perak area at an elevation of 5.0 m above present sea level by Bosch [7]. Tjia [8] state that in Peninsula Malaysia and Thailand, sea level peaked at +5 m at 5 ka and at ca. +4 m at 6 ka. Evidence for channel switching from mangrove mud to fresh water peat swamp environment has been document for some river such as Perak River in Western Malaysia [13].

III. STIUDY AREA

Perak located at the west of Peninsular Malaysia which bordered by the Strait of Malacca to the west. Its other borders are shared by the state of Kedah and Thailand's Yala Province to the north, Kelantan and Pahang to the east and Selangor to the south Perak. It is the second largest Malaysian state on Peninsula Malaysia after Pahang. The coastal plain area is located in the lower part of the Perak river, which is situated on the south of Perak state.

This study focuses on the floodplain and coastal area of Perak which dominantly exposed at the south (Fig. 4). The Quaternary deposits have a very wide distribution at this area. They covered 80 per cent of the Perak coastal plain area.

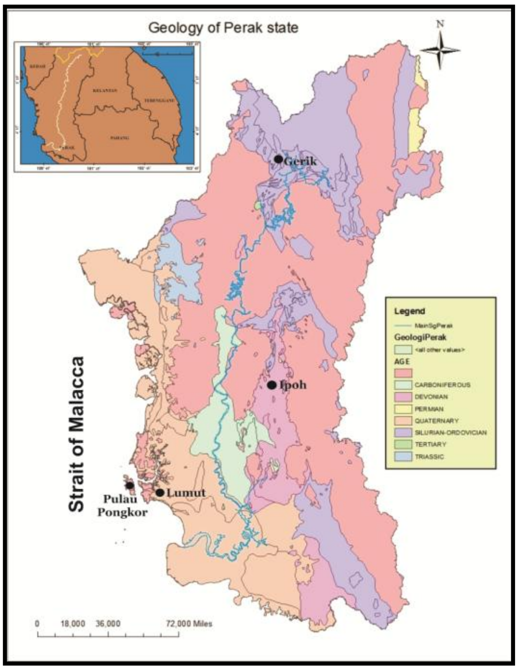

Fig. 4: Map of study area, Perak at the west of Peninsula Malaysia [JMG, 2011].

IV. RESULTS

A. *Development of Perak Coastal Plain*

The development of the Perak coastal plain can be interpreted through the studies of old river courses and old beach ridges and boreholes data of the Quaternary section.

The old river courses have been studied by Koopmans [13] using aerial photographs. Traces of the strong meandering old river courses show the abandoned position of Perak River in the past. This evidence shows the development and changes of the Perak River through time.

The first course (I) joins the Perak River near Kg. Tg. Blanja with the sea, running in a westerly direction and draining into the sea. The second old river courses (II) can be traced near Ayer Tawar trending North-South and the third old river courses (III) extend from Kg Teluk Manis in southerly direction. The fourth old river courses (IV) branch from the recent river course about three kilometers of Kg. Pasir Puteh. The fifth old river courses (V) runs along Kg. Ulu Dudap towards southerly direction. No age determination of the different old river courses of the river was altered by Koopmans [13] as shown in Fig 5.

The systems of the old river courses designated (III), (IV) and (V) were younger than those of (I) and (II). The younger river course seem to have high natural levels about 1-3m and still show clearly depressed valleys filled by stationary water. The older valleys banks are flattened and barely visible [13].

The first course develop may has been influenced by the Quaternary and Holocene development of the coastal plain. The river shifting towards southerly direction resulted in partial silting of the estuary. The Perak River has been shifted several times and finally followed the direction of the recent river [13].

Fig. 5: I-V is Old River courses of the Perak River, as interpreted from aerial Photograph modified from Koopmans, 1964 [15].

Old beach ridges were observed using the aerial photographs by Koopmans [13]. The sediment can be differentiate by the sorting and grains size of the sands. The sandy beach is well-sorted and course to very course based on Wenthworth scale. The grains are angular to subangular and composed almost entirely of quartz [13].

There are 3 zone of beach ridges have been traced, one of it developed over Pantai Remis, Kampung Tuntong and Kampung S. Hut to the north. This sandy beach ridge is about 4km wide and the most inland ridge was found north of Kampung Padang. These older ridge is about 19km from the coast near Badak River. The second one was found extending from Kampung Permatang, Kampung Parit, Kampung Batu 8 and 9 over Paya Burong to Badak River. The younger zone intersects the older one near Lekir and parallel to the present coastline. It is about 400m inland from the coast and about 0.8 to 3 km broad. The both younger and older beach rides have the same elevation about 3-6km above MSL (Modern Sea Level). Flitch [14] in his study believes that their elevations are above the sea level due to the recent emergence of the land in East Pahang. Nossin [15] stated that simple eustatic changes also can be the reason of the features. There is no evidence of the tectonic movement as suggested by Fitch and proven by Scrivenor [16] indicates that it is impossible the changes of the sea level is caused by earth movement in the stable Sunda Shelf.

B. The Holocene siliclastic wedge of the Perak coastal-deltaic plain.

The coastal areas of Perak are covered by Quaternary sediments. This Quaternary sediment thins towards the foothills, but may thicken up to 105m towards the lower coastal plain.

The investigation of the sedimentation Quaternary sediment pile is based on borehole data. The borehole data covers the coastal area and the lower part of Perak River. There are five main types of lithologies from the borehole data analysis; peat, clay, silt, sand and gravel. The borehole depth ranges from 4 meters to 105m meters. The deepest borehole by Dorsihah [17] is located at Titi Gantung about 105 meters.

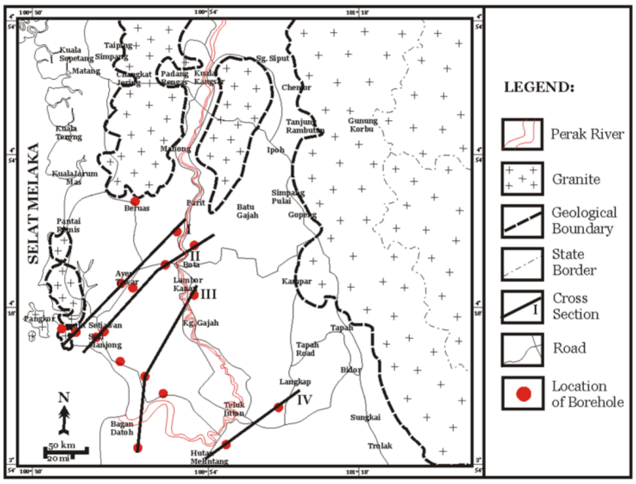

Fig. 6: Map shows the location of the available borehole data in south of Perak and the cross section.

Four cross sections and correlation panels have been constructed as shown in Fig. 6 to observe the coastal plain development in south Perak. The cross sections have allowed the overall correlation of the Quaternary stratigraphy in the study area. It is an attempt to analyse the development of the coastal plain areas, as well as to study the impact of Holocene sea level change in coastal plain of Perak.

The first cross section (I) as shown in Fig. 7 is trending from NE to SW through Parit, Ayer Tawar and Lumut areas as shown in Fig. 6. The borehole at Ayer Tawar [18] reached the bedrock at 78m depth. The other two wells are located around Parit and Lumut which are about 23 to 35m depth respectively, described by Wong [18] and Ismail [19]. Several massive sandy layers can be found below 8m at Ayer Tawar and 4m at Parit but none at Lumut. A superficial gravel layer can be found near Parit at about 10m depth.

One borehole in Air Tawar shows the occurrences of a two thick peat layers (~1-2 m) at about 18 meters and 24 meters below the present sea level [18]. In the same borehole, plant remains can be found in a tiny sandy clay layer about 10 meters below the present sea-level. A few layers show occurrence of the plants remains that can be found in this borehole. The sediment of Ayer Tawar consists of clay sediment at the bottom followed by interbedding of sands, clayey sediment and massive sandstone before reached the bedrock. These layers can be interpreted as terrestrial deposits based on plant remains, absence of shell fragments and association with peat layers.

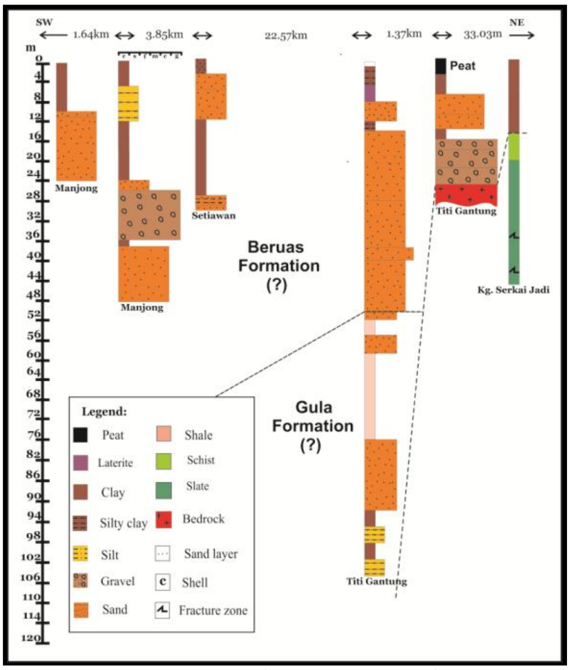

Fig. 7: Stratigraphy correlation of cross section I is from Parit towards southeast arounds Lumut based on data from Ismail [19] and Wong [18].

The second (II) cross section as shown in Fig. 8 is trending from NE towards SW through Kg Serkai Jadi, Titi Gantung, Setiawan and Seri Manjong. Metamorphic bedrock can be found around Kg. Serkai Jadi [20] while granitic bedrock is recorded at Titi Gantung by Abdul Rashid Bachik [21]. In the same area, Dorsihah [17] described a 105 m deep borehole without reaching the bedrock. A thick shale layer from the same borehole data was recorded between 52 to 76m depth. This stratigraphic log also has shown the occurrences of clayey, silty and red sandy sediment. The boreholes near Setiawan and Manjong consist of clayey, silty, sandy and gravelly sediment [20]. It is similar to the terrestrial deposits.

The third (III) cross section as shown in Fig. 9 is trending from NE towards the SW due to the boreholes data available. The cross section line started from the Kg Gajah to Kg Permatang and end up at Bagan Datoh [9] as shown in Fig. 7. The bottom layer dominantly consist of silty sediments, several layers of clay with occurrences of plant remains, shells and humic. This layer was referred as Gula Formation by Bosch [7]. The Port Weld Member overlain the Gula Formation and characterized by abundant of plant remains in the clay and silty layers [7]. A massive sand layer and shell fragments occurred in a section referred as Matang Gelugor Member by Bosch [9]. There are silty, clayey and sandy layers with plant remains and a peat layer deposited in the NE area near Kg. Gajah. This was mentioned by Bosch [9] as Beruas Formation.

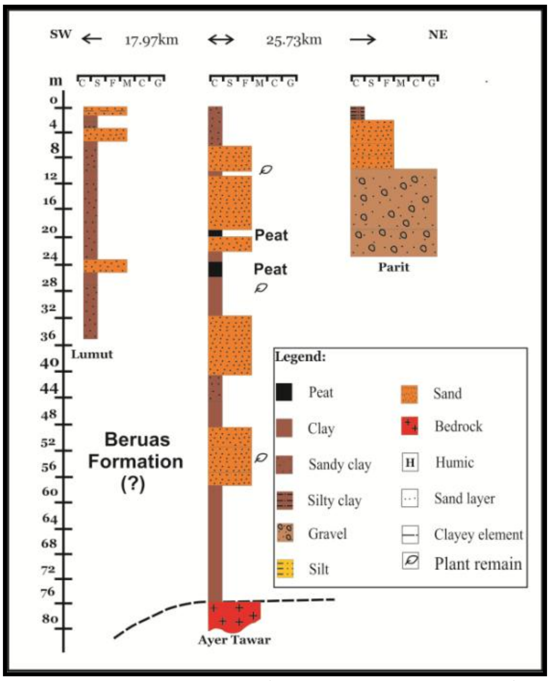

Fig. 8: Stratigraphy correlation of cross section II starting from Kg Serkai Jadi towards Manjong based on data from Dorsihah [17], Wong [18], Mohd. Irwan [10], and Abdul Rashid [21].

The forth (IV) cross section as shown in Fig. 10 connected the two areas at the south of Perak coastal plain from SW to S of Teluk Intan [7]. The bottom part is characterized by silty layers and it is represent the terrestrial sediments by Bosch [9]. It is overlain by clayey sediment with abundant of humic and layers of silt. These sediments were referred as to Teluk Intan Member and Port Weld Member by Bosch [7] which is similar to marine deposits. The peat layers are common at the top section of this area. It is show the terrestrial environment in general or Pengkalan Member in particular as mentioned by Bosch in 1986 [7].

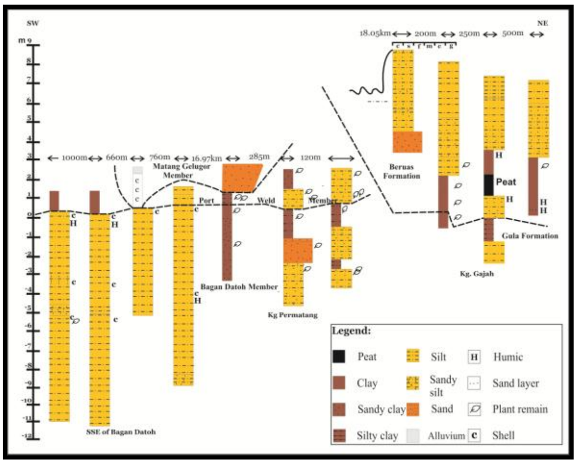

Fig. 9: Stratigraphy correlation of cross section III from Kg Gajah towards southeast of Bagan Datoh based on data from Bosch [7].

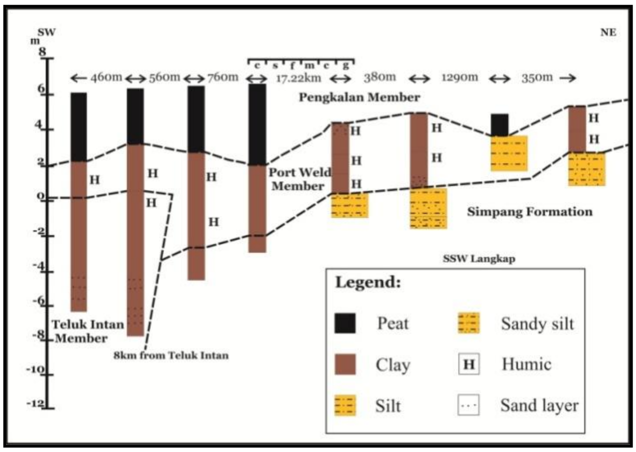

Fig. 10: Stratigraphy correlation of cross section IV located at the south of Perak coastal plains based on data from Bosch [7].

V. DISCUSSION

Data from the analyzed boreholes showed that the coastal plain in south of Perak is covered by Quaternary deposits. Table 1 summarizes the stratigraphic organization of the different depositional units. The stratigraphy of the area can be divided into three stratigraphic intervals. The bedrock can be found only in the north of coastal plain and the older Quaternary deposit which is of Pleistocene age can be found around Langkap and Teluk Intan in the south; this is formally known as Simpang Formation. The younger units of Gula Formation and Beruas Formation are widely distributed in the study area. These units are classified based on lithology, age (fossils) and stratigraphic association (environment of deposition). [7], [22]-[23].

TABLE 1
QUATERNARY STRATIRAPHY OF PERAK COASTAL PLAIN [7], [22]-[24]

Quaternary epoch	Interval	Environment/ lithology	formation
Holocene	C	Clay, silt, sand, gravel and peat	Beruas Formation • Pengkalan member: Paludal/ freshwater/ peat swamp with high pollen diversity and low to high spore value.
	B	Clay, silt and sand	Gula Formation • Matang Gelugor Member: shallow marine coastal with pollen generally absent. • Port Weld Member: mangrove pollen diversity low to moderate and low spore value. • Teluk Intan Member: inshore with moderate to rich pollen content and high spore value. • Bagan Datoh Member: offshore with moderate pollen content and low spore value.
Pleistocene	A	Clay, silt, peat, sand, gravel, and peat	Simpang Formation • Terrestrial; fluvial processes.

In 1986, Bosch [7] mentioned that Simpang Formation can be found around Langkap area and its underlying the marine deposits which referred as Teluk Intan Member and Bagan Datoh Member. The Simpang Formation is interpreted to have been deposited during the Last Glacial Maximun and when the sea level was at its lowest point (100-120 m below present).

Figure 11 illustrates the stratigraphic relationship between the different depositional units within the study area. The Gula Formation underlies the Beruas Formation. This stratigraphic relationship was recorded by Bosch [7] at upper coastal plain around Lambor Kanan. The lower part of the section was dominated by marine deposits. The Gula Formation possibly represents a transgressive depositional phase, related to a period of relative sea-level rise during the about 5000-4000 years BP [12].

The Bagan Datoh Member represents the shallow marine offshore environment which is a part of the Gula Formation. When the sea level started to drop, the Port Weld Member developed in this area. It is shown by the development of mangrove environment in this area.

In Kg Gajah, the stratigraphic log shows the Gula Formation underlying the Beruas Formation. The Beruas Formation was deposited during the sea level fall, from the maximum high stand to the present level which results in a regression. The gravel layers have been found in this area and it indicates the terrestrial deposits of Beruas Formation [7].

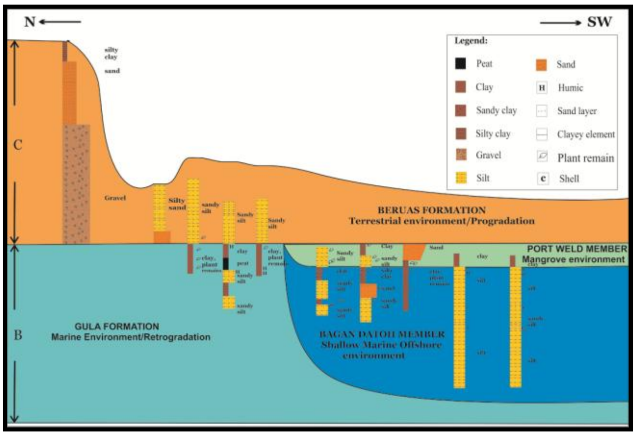

Fig. 11: Stratigraphic cross section of Perak coastal plain from north to southwest.

VI. CONCLUSION

The Quaternary sedimentation trend of the Perak coastal plain shows the occurrences of three different stratigraphy units. The stratigraphy of the intervals is shown in Figure 11:

1. The first interval A referred as to the Simpang Formation. It is the oldest formation in this area deposited during Pleistocene age when the sea level estimated to be -116 m below present day sea level [12]. The formation has been interpreted as terrestrial deposit.

2. The second interval B, referred as to Gula Formation, was deposited during Holocene age when the sea level rises to the high stand (4000-5000 years BP) about 5 m above present sea level [7]-[9]. The retrogradation of the coastline occurred during the period of sea level transgression and marine sediments were deposited.
3. The third interval C is the youngest unit in this area and deposited within a terrestrial environment during a period of sea level fall. It occurred when the sea level drop back to the present sea level around 3500 years BP.

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