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Sedimentary sequence in the subsurface of the Pekan coastal plain, Pahang

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Abstract: The Pekan coastal plain in which the Pahang river delta is located is made up of a thick sequence of unconsolidated sedimentary sequence of an unnamed formation. Drilling programmes carried out in the area show that the unconsolidated sequence was deposited during two major periods of sedimentation that took place in two different setting. The lower sequence which has been interpreted to have been deposited during the Pleistocene period consists of entirely continental sediment. The continental sequence can be devided into several packages according to their depositional trends and the boundary of each package is marked by an apparent depositional break. The sea-level rise during the early Holocene period have resulted in deposition of a series of marine/ marine-influenced sediments at the top of the sequence.

Abstrak: Dataran pantai Pekan yang di dalamnya terletak delta Sungai Pahang dibentuk oleh satu jujukan sedimen takterkonsolidasi yang tebal yang setakat ini tidak begitu jelas nama formasinya. Program penggerudian yang dilakukan di kawasan tersebut menunjukkan bahawa sedimen takterkonsolidasi tersebut telah dimendapkan pada period yang berlainan dan berlaku di dalam setting yang berbeza. Jujukan bawah yang telah ditafsirkan telah dimendapkan semasa Pleistosen terdiri daripada sedimen daratan. Jujukan sedimen daratan tersebut boleh dibahagikan kepada dua pakej pemendapan yang setiap satunya di pisahkan dari pada yang lain oleh rumpang pemendapan. Peningkatan paras laut semasa awal Holosen telah mengakibatkan pemendapan satu siri sedimen lautan/dipengaruhi lautan di abahagian atas jujukan.

INTRODUCTION AND PREVIOUS WORK

The Pekan coastal plain (Fig. 1) represents one of the largest coastal deposits in Malaysia. Many workers (Nossin, 1965a, b; Koopmans, 1972; Bosch, 1988; Tjia, 1992; Mazlan & Kamaluddin, 1991) have undertaken studies of this coastal plain. Many of these works were concentrated on the morphology and genesis of the beach ridges/shorelines that are prominent along the coastal region (Nossin, 1965a, 1965b).

The latest work on the Quaternary geology of the Peninsular Malaysia was by Bosch (1988) who suggetsed the lithostarigraphic classification and naming of the sediments Holocene and Pre-Holocene age based on the surficial deposits and shallow tube wells drilling. A summary of facies description from the study is shown in Table 1.

Bosch (1998) concluded that sea-level fluctuations during the late Pleistocene and Holocene age exerted significant effect on the shaping of the coastal plain along the coast of Malay Peninsula. The main mechanism was through the control on the sedimentation processes. Based on studies by Tjia (1992), the relative sea level had fluctuated many times; a big drop was observed during the late Pleistocene (~150 m) followed by late Holocene rapid sea level rise and highstand at +5 meter above the present day mean sea level around 5,000 yrs BP and the subsequent drop to the present level. These fluctuations have resulted in the erosion and deposition of various coastal plain deposits. Remnants of paleoebeaches/shorelines can be seen outcropping on the present coastal plain, some kilometers landward of the present day shoreline and at different elevations attesting to the time that they were deposited (Bosh, 1988; Tjia, 1992). The present Pahang River delta proper is probably the result of progradation of different lobes in response to the stabilisation of the relative sea level around 2,000 years ago.

This paper will try to reclassify the Quaternary sedimentary sequence of the Pekan coastal plain based on subsurface data obtained from wells drilled in the area.

PHYSICAL SETTING

The Pekan coastal plain consists of several morphological features welded together to form a complex physiography.

The Coastal plain: The Pahang river delta is a part of the Quaternary coastal plain complex deposited in an embayment or funnel shape depression that stretches from bedrock promontory at Tg. Tembeling, located to the north of Kuantan in the north to Sg. Rompin in the south. The coastal plain is fronted by a series of beach ridges 1 to 2 meters high that are generally parallel to shoreline separated by swales filled by mangroove marshes, brackish *nypa* or fresh water swamp. Landward the coastal plain terminates against the steep slope of pre-Pleistocene deposits and Upper Paleozoic metasediments and granitoid bedrock outcrops. In between, except for remnants of

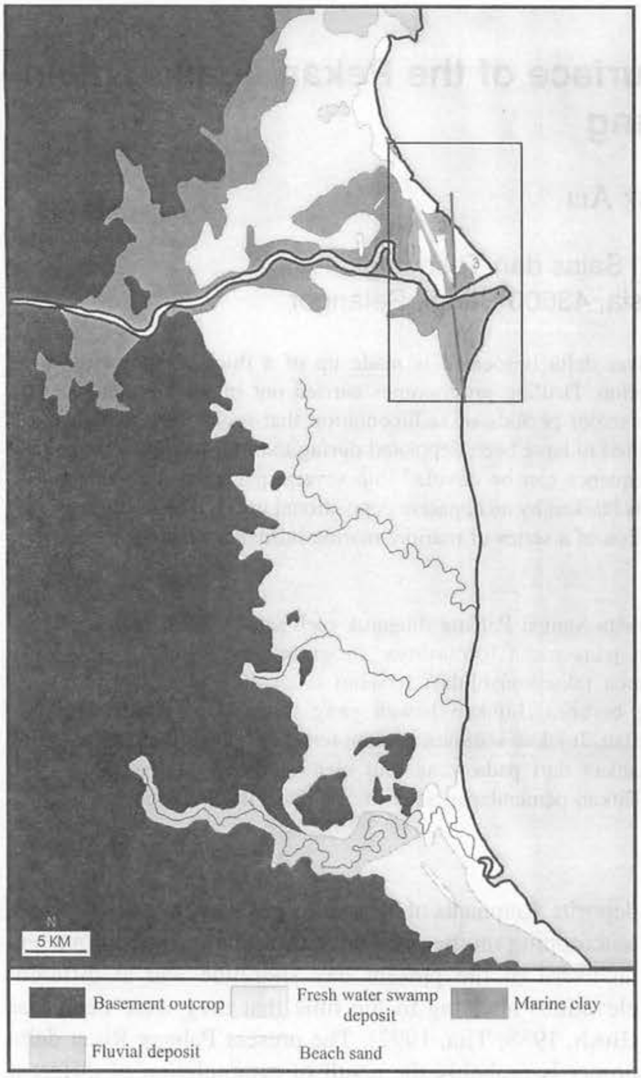

Figure 1. Pekan coastal plain.

Table 1. Lithostratigraphy classification of Quaternary deposits (after Bosch, 1988).

HOLOCENE NAME	DESCRIPTION	ENVIRONMENT
GULA FORMATION 1) Matang Gelugor Member	Clay, silt and sands with minor amount of gravel, shells and corals	Marine
2) Bagan Datoh Member	Sand, gravel shells and corals	Beach ridges/ chenier/ shoreline
3) Teluk Intan Member	Sand, clay and silt	Offshore marine
4) Port Weld Member	Sand, clay and silt	Inshore-lagoonal, estuarine, deltaic, tidal flats.
	Clay and silt	Mangrove
BERUAS FORMATION	Clay, silt, gravel and peat	Terrestrial; deposited after the most recent major low sea-level

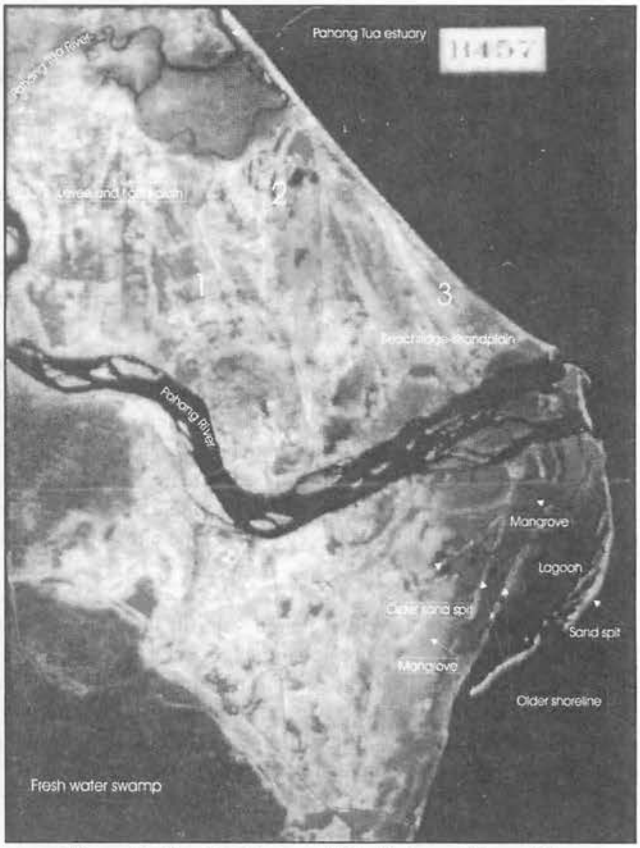

Figure 2. Satellite image of the Pahang River delta.

"older beach ridges/shorelines deposits" and rivers such the Pahang river itself, the coastal plain is generally very smooth and dominated by fresh water swamp.

The Delta: The Pahang river delta complex is located in the middle of this wide funnel-shaped coastal plain as shown in Figure 2. It covers the area from Sg. Penor in the north to Sg. Miang in the south. Landward, the delta proper terminated around 25 km west of Pekan town where the Pahang river flows across the freshwater dominated coastal plain.

STUDY APPROACH

The approach employed for this study can be divided into three stages of work; data acquisition, analyses and integration.

Stage1: Data acquisition (surface and subsurface)

Surface data: surface data was collected to delineate the distribution of the present day sedimentary sub-enviroments of the delta. Initial information was gathered by studying topographic maps, aerial photographs, LANDSAT and SPOT images. To confirm the interpretation, numerous site investigations were conducted. Based on this analysis, a sedimentary facies map was generated.

Subsurface data: in order to get a better understanding of the stratigraphy, a total of fourteen (14) boreholes were

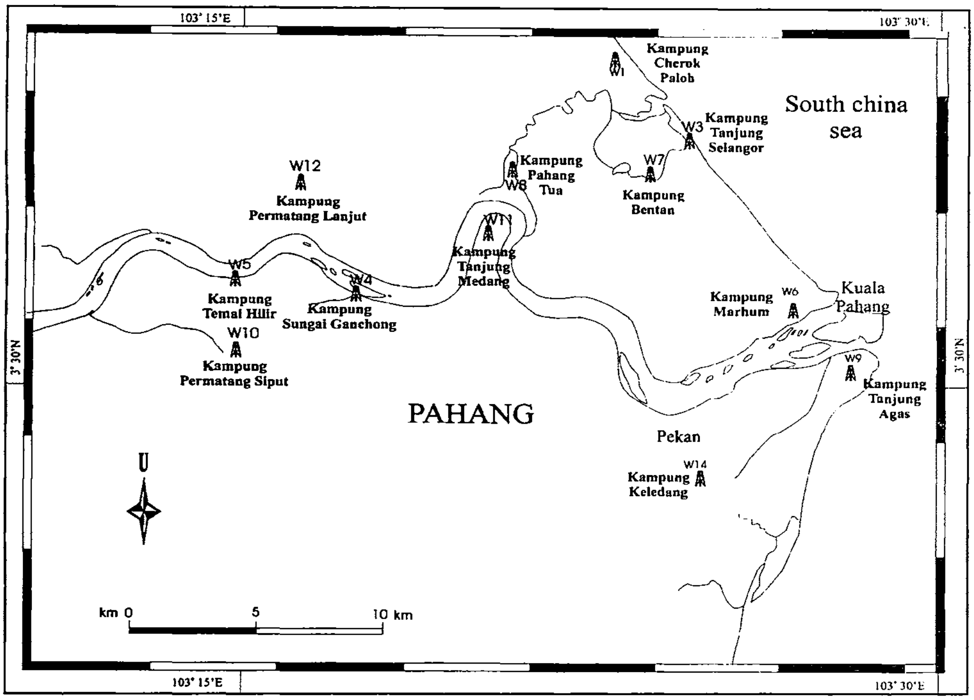

Figure 3. Borehole location.

drilled where continuous core samples were taken (Fig. 3). Drilling was completed using either Mazier or percussion methods down to the estimated basement rock. For the Mazier method, the cores were extracted at three (3) meter per sample while the Percussions method allowed for core sampling of one (1) meter at a time. Recovery from both of the methods vary from 20 percent in loose coarse-grained sediments to 100 percent in muddy to clayey sediment. The location of these boreholes were based on surface investigations, and a total of nineteen (19) water well data drilled by the Geological Survey Department. In this study, logistics control the sequence in which the boreholes were drilled. For, calibration of the depth and facies, a series of shallow seismic data was acquired around selected boreholes, aprroximately 0.5 km on each sides. This was done by using dynamite as the source and a series of 100Hz geophones as receivers.

Stage 2: Data analysis

The cores samples were logged in the field before transported back to the storage room. In general, the core samples in the upper 30 meters were good, however quality and recovery became less satisfactory at greater depth depth especially when the sediments were dominated by coarser-grained materials. The correlation between drill holes was then done and calibrated to the processed seismic data.

SEDIMENTARY SEQUENCE IN THE SUBSURFACE

Subsurface facies identification, classification and description are based on sediment cores obtained from the drilling programme.

Sedimentary packages

In most cases, technical difficulties do not permit drilling to reach the bedrock which form the bottom base or reference datum for the Quaternary sediments. Therefore only one reference level is available, i.e. the ground surface. Definite, correlatable lateral markers are also lacking. For these shortcomings, a practical approach to group the sedimentary strata penetrated by the bore holes are by obvious physical packaging. In this method, two distinct major sedimentary packages are identified in the sedimentary intervals, i.e. an upper (package A) and a lower package (package B) as shown in Figure 4. The boundary is taken at the last transgressive facies of marine/ saline mud.

Package A of the upper package is made up of :

(a) Sediments presumably being the product of the last high stand and its subsequent drop and consist of fossiliferous dark grey saline lagoonal clay and blocky to upward fining well sorted medium to fine beach ridge and strand-plain sand to be referred to as the Holocene sediments, and

(b) Sediments of the present meandering Pahang River which consist of upwards fining granule to coarse sand to silt point bar deposit, and carbonaceous laminated and occasionally fine cross laminated silt and very fine sand of levee deposits and crudely laminated mud of flood plain deposits to be referred to as Recent sediments. It is about 35m at its thickest location at the eastern end.

Package B or the lower package is made up of subsequences of predominantly blocky to crudely upward fining gravel to coarse and medium angular sand intercalated by light gray to white non-marine (continental) clay. This lower sequence will be referred to as late Pleistocene and older sediments.

Package A is assumed to be of Holocene and Recent sediments and are related to the present day Pahang River delta system and its associated environments, especially that of the Recent sediments. This age assumption will be discussed later. Package B is assumed to be of pre-Holocene or Pleistocene and older sediments and do not appear to be related to the present day Pahang River delta complex depositional system. The two packages are separately described.

Package A: Holocene and Recent sediments

Recent sediments

Recent sediments are those of the existing fluvial regime consisting of the present day river channel, its levee and flood plains and their deposits; and those of the beaches, beach ridges, strand plains, river-mouth spits and lagoons and their deposits. Their facies is penetrated by the bore holes but they have already been described earlier.

Holocene sediments

The Holocene sediments are characterised by the saline and beach deposits and are the product of the last high stand and the subsequent drop in sea level. Three facies could be identified.

Facies A1: Grey fossiliferous clay sediments

This is clay facies and is characterised by its distinct dark colour which ranges from light grey to grey, and dark grey depending on the percentage of dark-coloured clay minerals, mainly illite, and fine carbonaceous materials in the sediments. Examples of the facies are at W1 Cherok Paloh at depth 31 m to 15 m, W3 Tg Selangor at depth 30 m to 13 m, W4 Kg Ganchong at depth 20 m to 5 m and W5 Temai Hilir at depth 14 m to 11 m. Internally there are fine laminations, streaks and occasionally micro-ripples of very light grey to whitish silty materials. The clay may also be greenish as at W4 Kg. Ganchong.

Tiny burrows of <2 mm diameter are occasionally present. There are intervals that appears to be structureless or massive and could have been the result of intense bioturbation rather than the product of very rapid deposition from suspension. Tiny, thick, ornamented gastropod shells measuring less than 3 mm long and very small fragments of thick shells are present at certain intervals in the mud.

Examples of this facies is at bore holes W3 Tg Selangor at depth 28 m to 12 m, W6 Kg Marhum at depth 34 m to 9 m, W4 Ganchong at depth 19 m to 6 m and W5 Kg Temai Hilir at depth 16 m to 9 m. At W6, there are occasional coarse to medium thin sand layer intercalations. The facies at these localities ranges from about 7 m to 25 m thick. It is thick and of about the same thickness along strike sections on the eastern part near the present coast and thins out westwards along dip sections, traceable as far inland or west as at bore hole W4 Kg. Ganchong and W5 Temai Hilir which is about 26 km from the river mouth. It does not seem to be present at Kg Temai Hulu which is already 30 km inland.

This facies sits sharply on upward-fining cobbly very coarse to fine clayey sand of fluvial channel character and is overlain by bell-shaped to blocky very coarse to fine clean sand of facies A2.

Sedimentary structures in the clays suggest low energy environment of deposition with occasional ripples. The shells suggest saline water condition. The environment in which this facies was deposited is likely to a lagoonal setting rather than that of lower shore face. The thin sand intercalations at W6 could represent wash over sands.

Facies A2: Coarse to medium, clean, flat-bedded to low angle bedding blocky sequence sand.

This facies is characterised by its clean, almost clay-free nature of the sand. It is generally about 10 m thick. It is medium to coarse sand in the basal sequence, coarsening upwards into cobbly very coarse sand and subsequently fining again into coarse sand, forming bell-shaped sequence, or it could be variable or blocky in vertical sequence.

It is present at bore holes near the present coastline, namely W1 Cherok Paloh, W3 Tg. Selangor, W7 Kg. Bentan, W6 Kg. Marhum and W9 Tg. Agas but is not encountered in bore hole W4 Ganchong. From surface study this facies seems to disappear west of Kg Jambu and is not present at Kg Benta. Kg Jambu is located on Jalan Pulau Keladi and is about 11 km from the present river mouth.

Sand grains are subangular to subrounded, consist mainly of quartz and granule fragments of dark chert, schist and vein quartz.

Internally, horizontal to low-inclined bedding is discernible, suggesting flat-bedding or low angle foreset bedding. This bedding feature is visible because of the presence of horizontal grain size banding.

The clean nature of the sand and the flat to low angle bedding indicate very high energy environment, and together with the variable or blocky vertical sequence and that it overlies low energy saline clays, the facies is best interpreted to be that of beach ridges with wash-over and possibly that of strand-plain sands.

Facies A3: Black to brown laminated to structureless carbonaceous mud and silt.

This facies consists of black mud and silt and is laminated in the lower part and grading into brownish silt in the upper part. It is characterised by the presence of variable amounts of carbonaceous matter and macerated plant fragments in the form of laminae in the lower part and disseminated particles in the upper part. It is well represented in bore holes W4 Ganchong from depth 5 m to 0.5 m and at W5 Temai Hilir from depth 11 m to 3 m. At both localities, it is found to overly Facies A1.

Based on the lithology, sedimentary structures and its associated facies, this facies is interpreted to be that of flood plain and fresh water swamp.

This upper sequence could be interpreted to be related the last high stand and its subsequent lowering of the sea level.

Package B: Pleistocene and older sediments

Pleistocene sediments are encountered in all the bore holes, at least down to the depth of nearly 240 m in the eastern part of the coastal plain area at bore hole W7 Kg Bentan which is located about 2.5 km from the coast to about 80 m in the western part of the area at W5 Kg Temai Hilir which is about 26 km from the river mouth. At bore holes near the coastline in the east, it was encountered at the depth of about 25 m downwards. Since none of the bore holes near the coastline reached the bedrock proper, the total thickness of the Pleistocene and older sediment package is not known for certain. The shallow seismic data run across the bore hole indicates that the bedrock surface is an irregular erosional surface at the depth of around 270 m to 300 m, suggesting a thickness of the sedimentary package to be about 245 m to 275 m. The package wedges westwards and the bedrock shallows to a depth of about 80 m at the bore hole W5 Kg. Temai Hilir where hard rock chips were encountered at a depth of about 80 m. Shallow seismic data here confirms this depth of about 82 m. The bedrock and the sedimentary package appear at the surface further west at Kg Batu Balik which is about 45 km from the river mouth.

Although the Pleistocene and older sedimentary package is thick, it is made up basically of two facies types, namely very thick to thick intervals of gravelly, very coarse to coarse angular sand ranging from 5 m to 15 m thick passing up or alternating with thin, less than 1 m to 3 m thick, white, kaolinitic clay intervals and consists of a number of blocky to upward-fining, thick, coarse to very coarse cobbly and pebbly, poorly sorted clayey sand passing up into thick white kaolinitic clay.

Reddish mottled clay beds representing paleosoil horizons indicating subaerial exposure occured at several levels. Near to the coastline at W3, W6 and W7, one paleosoil bed occurs at about 40 m depth and the other at about 100 m depth. The upper paleosoil bed seems to appear at a slightly different depth as one moves to the west, thus appearing at 55 m depth at bore hole W4 Kg. Ganchong. These paleosoil horizons could represent important stratigraphic markers.

Although several sub packages could be envisaged from the seismic profile, only two sub packages could be clearly identified from the sediment log record to the depth penetrated by the bore holes; they are denoted as sub package Ba for the upper sub package and sub package Bb for the lower sub package. The boundary of the sub package is the erosional base of gravelly sand of the upper sub package and the top of red-mottled structureless mud interval of the lower sub package, as seen at depth 87 m at W3 Tg. Selangor and at depth 50 m at W4 Ganchong.

The facies types of the two sub packages are similar in general sense. However, the two sub packages will be described separately.

Sub package Ba, the upper sub package

Two facies are identified, namely the sand facies and the clay facies.

Facies Ba1: Gravelly, very coarse to coarse clayey white sand.

This facies consists generally of upward-fining, very coarse to coarse sand and occasionally medium sand, generally about 4 m to 6 m thick but ranging from 2 m to over 20 m thick. Examples of this facies is at W3 at depth 86 m to 30 m, W4 at depth 50 m to 30 m, W6 at depth 99 m to 25 m and W7 at depth 84 m to 12 m. Thin upward-fining sequences are at W6 at depth 70 m to 48 m. Some consist of several stacked-up upward-fining sequences compounding to over 20 m thick as at W3 at depth 86 m to 64 m. Not all exhibit upward-fining character. There are occasionally those that do not show grading tendency and are rather blocky or variable vertical grading as at W3 at depth 64 m to 52 m.

The base of the facies is erosional. The basal parts of most sequences are cobbly or even pebbly. The cobble and pebble clasts are well rounded to rounded and occasionally subrounded and are made up of fragments of greyish white vein quartz, dark grey chert and black schist. The majority is vein quartz. The largest pebbles recovered are up to 3 cm in long diameter. Larger pebbles come up as broken rock chips because they were crushed during percussion drilling.

Very coarse sand grains are quartz, vein quartz and rock fragments. Medium sands are mainly quartz. Sand grains are angular to subangular. The sand grain and clast voids are invariably filled by white kaolinitic clay; the sands are therefore invariably poor to very poorly sorted. This suggest that the main source rock for the facies is from granitoid bodies.

Since most of the cores are retrieved by percussion method, internal sedimentary structures are not discernible and interpretation has to be based mainly on textural features.

The overall features of the facies indicate that the very coarse pebbly sands were deposited rapidly by shallow, fast flowing current, and suggesting braided to straight channels or even ephemeral streams.

Facies Ba2: White kaolinitic clay

This facies consists of white kaolinitic structureless clay occuring on top of facies Ba1 gravelly, very coarse to coarse clayey white sand and is encountered in all the bore holes. It ranges in thickness from less than 1 m to 3 m thick. At a number of bore holes, e.g. W3 at 100 m depth, W5 at 55 m depth and W6 at 100 m depth, parts of the white clay are red-mottled ferric oxides or hematite, suggestive of being paleosoil horizons.

White kaolinitic clays are the product of continental fresh water deposition. Paleosoil horizon indicates exposure to the atmosphere, good drainage, leaching, weathering of the clay and soil development. All these could be indicative of flood plain environment.

Facies Ba1 and Ba2 generally form well-developed upward-fining sequence ranging from about 2 m to over 10 m thick, as at bore hole W6 and W4. Individual facies Ba1, however, could be stacked-up, thus compounding into multiple upward-fining sequences and at the same time forming a major upward-fining suquence, as at bore hole W7 and W3.

The general interpretation of sub package Ba or the upper portion of the Pleistocene and older sediments is that they are the product of deposition in fast and swift flowing straight to braided channels with their associated flood plains.

Sub package Bb, the lower sub package

Three facies are identified.

Facies Bb1

This is similar to facies Ba1 in that it consists of upward-fining very coarse sand sequence passing up into facies Bb2 white kaolinitic clay. However, it is made up generally of several stacked-up upward fining, very coarse to coarse sand, generally about 6 m to 10 m thick but ranging from 2 m to over 20 m thick. Occasionally individual upward-fining sequences do occur. Blocky sequence are more common, that is, those that do not show grading tendency and are rather blocky or variable vertical grading.

The base of the facies is erosional. The basal parts of most sequences are pebbly. The pebble and cobble clasts are well rounded to rounded and occasionally subrounded and are made up of fragments of white vein quartz, gray chert and black schist. The largest pebbles recovered are more than 3 cm long. There are probably more and larger pebbles in the basal part of this facies since many broken rock chips were recovered. The rock chips represent parts of larger clasts that had been broken up during percussion drilling.

Occasionally pebbles and cobbles may form the dominant component of the facies, as at W4 at depth 112 m to 89 m.

Similar to facies Ba1, very coarse sand grains are made up of quartz, vein quartz and rock fragments. Medium sands are mainly quartz. Sand grains are mainly angular. The sand grain and clast voids are invariably filled by white kaolinitic clay. The sands are invariably poor to very poorly sorted.

The overall features of the facies indicate that the very coarse pebbly sands were deposited rapidly by shallow, fast flowing current, and suggesting straight or braided channels or even ephemeral streams. The dominantly pebbly interval at W4 is more akin to deposition by out-wash process.

Facies Bb2

This facies is similar to that of facies Ba2 in that it consists of white kaolinitic structureless clay occuring on top of facies Bb1 gravelly, very coarse to coarse clayey white sand and is encountered in all the bore holes. It also ranges in thickness from less than 1 m to 3 m thick. Examples of the facies re at bore hole W3 at depth 15 m abd 113 m to 108 m, W4 at depth 121 m to 114 m, 89 m, 83 m to 80 m and 63 m, W5 at depth 70 m and 62 m, W6 at depth 194 m, 168 m, 153 m, 145 m and 131 m. The lower part of a number of these clay intervals are greyish to black due to the presence of carbonaceous materials and plant fragments. At a number of bore holes, e.g. W3 at 100 m depth, W5 at 55 m depth and W6 at 100 m depth, parts of the white clay are red-mottled ferric oxides or hematite, suggestive of paleosol horizons.

White kaolinitic clays are normally considered to be the product of continental fresh water deposition; paleosol horizon indicates exposure to the atmosphere, good drainage, leaching, weathering of the clay and soil development. All these are indicative of flood plain environment. Carbonaceous materials and plant fragments came fron the vegetated part of the flood plains.

Facies Bb2 generally forms the thinner upper part of upward-fining sequence with the thicker lower part, and the sequence ranges from about 4 m to over 6 m thick, as in bore hole W3, W4, W5 and W6. More individual facies Bb1, however, are stacked-up, compounding into multiple upward-fining sequences as thick as 40 m as at W3.

Facies Bb3: Red-mottled and rootleted bed

This facies consists of greyish white clay, generally thick to very thick, ranging from 4 m to over 15 m. Examples of the facies are at W3 at depth 100 m to 86 m (14 m), W4 at depth54 m to 50 m (4 m), W6 at depth 114 m to 98 m (15 m) and W7 at depth 97 m to 83 m (14 m). The lower portion of the facies interval is generally ferric oxide red-mottled (W3 and W4). Occasionally there are plant remains and rootlets? In this lower portion. The upper portion consists of structureless white clay.

This facies differ from facies Bb2 by being very thick, occurring at the top of sub package Bb, and the presence of rootlets?, indicative of definite vegetated condition. It forms a good local stratigraphic marker.

The overall feature of facies Bb3 is indicative not only of flood plains condition but that the flood plain existed for a much longer duration, suggesting a low-stand situation.

STRATIGRAPHY AND CONCLUSION

The ages and exact stratigraphy of the sedimentary packages could not yet be assigned for certain because there no radiocarbon dating has been done with the samples. At the present stage, the relative age of the packages is attempted by comparing the sedimentary sequence and the facies characteristics with the one described by Bosch (1988). As a result it seems that the upper sequence which is dominated by marine (or marine influenced sediments) can be included in the Gula Formation. Whereas the lower continental deposits are equivalent to the Beruas Formation as described in Bosch (1988). The stratigraphy of the

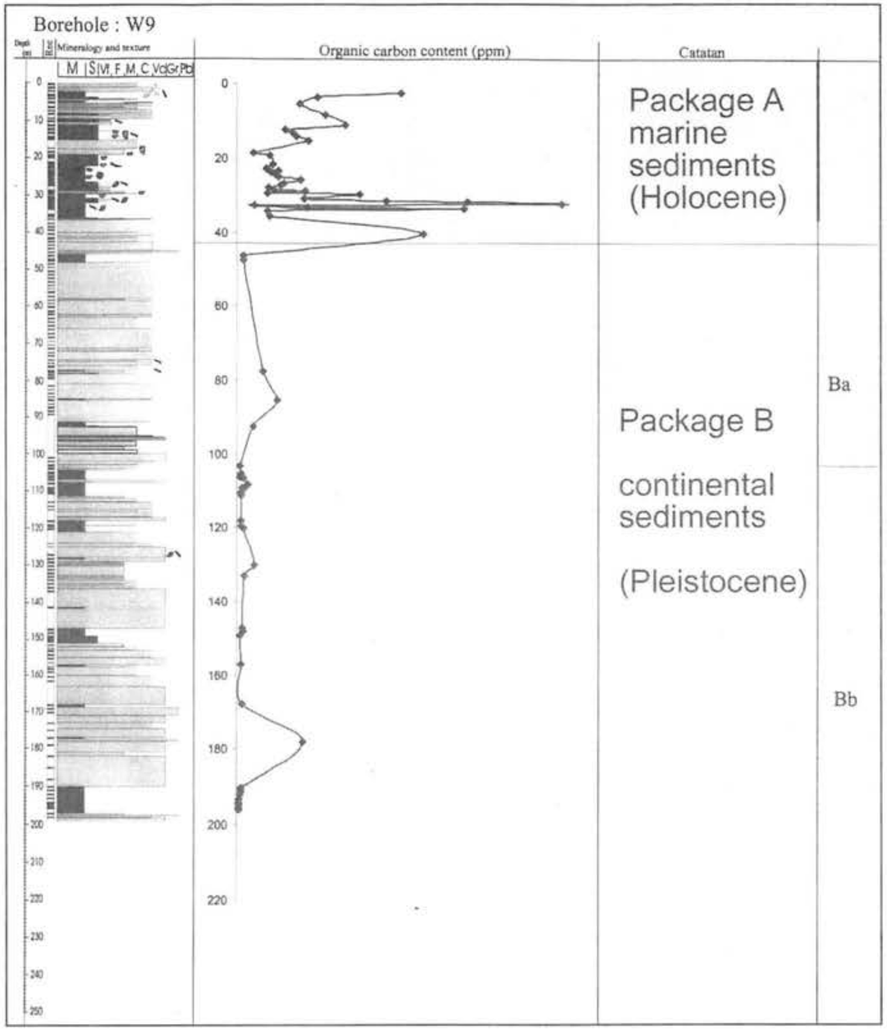

Figure 4. Sedimentary sequence and packages in the subsurface of the Pekan coastal plain.

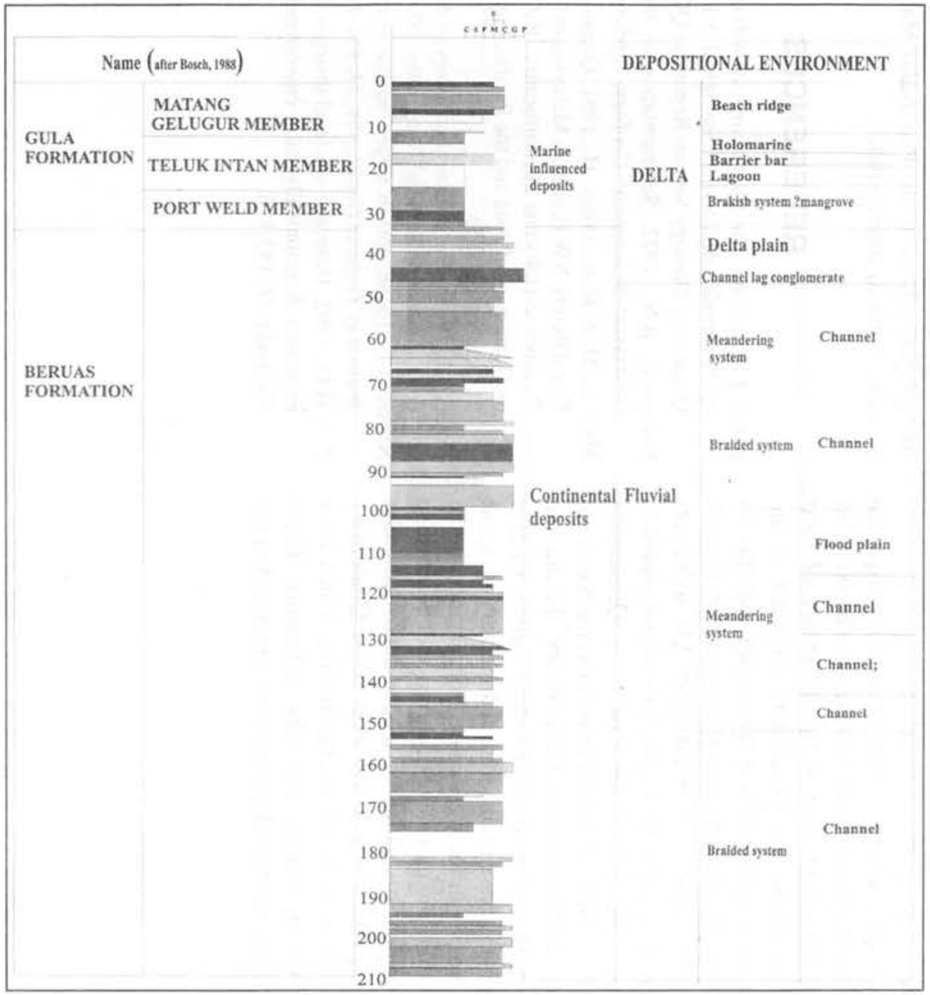

Figure 5. Quaternary formations and interpreted depositional environment.

whole sequence is presented in Figure 5.

The stratigraphic scheme for the Quaternary sequence of this part of the Malay peninsula however, can be excluded from the existing scheme due to the difference of their geographical locations. The Quaternary sequence of the east coast are separated from their west coast sequence as facies are not exactly. The physical environment of the east coast and the west coast are very different. The sediments that were deposited in the west coast are not subjected to high energy regime. Whilst the east coast Quaternary sediment were deposited under the more extreme condition with variable weather condition. Furthermore, the internal physical factors that controlled the sedimentation are also different which gave rise to different sedimentary facies as compared to the one in the west coast. For instance, in the east coast are, there are extensive occurrence of beachridge and strandplain deposits which have been deposited under high energy regime whereas the west coast Quaternary sediments are more of a low energy regime which have been represented by muddy and silty sediments. These differences qualify the two deposits to be seperated in the stratigraphic scheme of the Peninsular Malaysia and has to be looked into in future studies.

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