EVALUATION OF RESERVOIR ELEMENTS IN WEST KELANTAN DELTA

By

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13916

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CERTIFICATION OF APPROVAL

The Evaluation of Reservoir Elements in Western Kelantan Delta
Depositional Environment

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A project dissertation submitted to the
Petroleum Geoscience Programme
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SOFEA AMIERA BINTI ABDUL RAHIM

ABSTRACT

The location of the study area is in a delta which is located on the east coast and in the north easternmost of Peninsular Malaysia. It is located in the Kelantan state which is situated within two districts area of Kelantan; Tumpat and Kuala Krai. The general geology of the study area is a wave-dominated delta that consists of Quaternary sediments.

The objective of the research is to do evaluation of the reservoir elements in term of porosity and thermal conductivity and their relationship with depth. A review of these elements has been done by doing the soil analysis. This analysis is important for reservoir characterization or description since the results will lead to the reservoir's quality determination. Three samples are gathered from different location to determined their lithology and develop lithology map by comparing with the well log data. The porosity and thermal conductivity profiling produced from geological model (Petromod software) are then used for the reservoir's quality determination.

ACKNOWLEDGEMENT

Alhamdulillah, all praises and thanks to Allah, the Lord and Sustainer of the worlds for allowing this project to be completed. I hope He blesses and accepts this effort and rewards us with that which is good in this world and the next. The completion of this work would not have been achieved without the invaluable help and assistance of several parties. Firstly, I would like to express my deepest gratitude towards my supervisor, A.P. Wan Ismail Wan Yusoff for his willingness not only to accept but also his dedication to guide me throughout the course of it. This work has also benefitted from the selfless help by my co-supervisor, Dr. Abdull Halim Abdul.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

The location of the study area is in a delta which is located on the east coast and in the north easternmost of Peninsular Malaysia. It is located in the Kelantan state which is situated within two districts area of Kelantan; Tumpat and Kuala Krai. It is the only delta exists in the Kelantan state that situated between latitude of 06° 11”N and 06° 13”N and longitude of 102° 10”E and 102° 14”E (Nazaruddin & Armugam, 2012)

The general geology of the study area is a low lying coastal plain that composed of a 10km outer belt of barrier and deltaic deposits backed by a 30km wide alluvial plain. The surface of the alluvial plain is often disturbed by abandoned levees and meander scrolls. It is recorded that there is upper layer of sand, with a downward succession by sandy clay and clay in 15m deep unbottomed borehole near the beach. It is believed that the Kelantan delta is a wave-dominated delta that consists of Quaternary sediments (Sa & Boon, 2011).

The soil samples are taken from different sites of the study area for lithology determination and soil analysis. The lithology column is produced to see the variation of the lithology. Well log data will also be analyzed for the lithology variation to construct the lithology column. As for the soil analysis, it is done to describe the reservoir characteristics. Reservoir elements consist of porosity, thermal gradient, thermal conductivity, pore pressure and etc. For this research, the elements of evaluations are focused on the porosity and thermal conductivity corresponding with depth. These relationships are analyzed on the basis of the porosity and thermal conductivity profiling. From the soil and well log analysis, the estimation on the reservoir quality can be done.

1.2 Problem Statement

There are lacks of studies on the porosity with depth and the thermal conductivity with depth on the onshore Peninsular. These studies are required to evaluate the reservoir elements; porosity and thermal conductivity corresponding with depth in the onshore of the Peninsular. The profile produced from the study can be compared with the Malay Basin's profile. The comparison between the onshore and offshore profile helps to evaluate the reservoir's potential of hydrocarbon accumulation.

1.3 Objectives and Scope of Study

There are three objectives of conducting this project:-

i To study the variation of lithology profile in various geomorphology

ii To study the relationship between the thermal conductivity and porosity with depth

iii To determine the reservoir quality based on the thermal conductivity-depth, porosity-depth profile, thermal conductivity-porosity relationship and lithology column

The scope of study for this research is to do evaluation on the reservoir elements by doing the soil and well log data analysis and compare them with the porosity and thermal conductivity profiling. The laboratories data of the samples obtained are analyzed to evaluate the porosity and thermal conductivity distribution of the samples. The well log data are also analyzed for the lithology variation to construct the lithology profile. Then, the distribution of these two elements is used in porosity and thermal conductivity profiling to produce porosity versus depth and porosity versus thermal conductivity profile. These profiles will be used to determine the quality of the reservoir in the study area.

1.4 Relevancy of Study

The evaluation of the reservoir's quality plays as an important role in oil and gas industry especially for the hydrocarbon exploration. By comparing the data between the deep reservoir and shallow reservoir, the industry could figure out the link between both to determine the reservoir's quality.

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

2.0 LITERATURE REVIEW AND/OR THEORY

2.1 Geological Setting of Peninsular Malaysia

According to the map of the geological domains of Peninsular Malaysia, the study area, the West Kelantan delta is a part of the central and east domain (see FIGURE 1 and FIGURE 32). The Peninsular Malaysia is composed of four geological domains which are Northwest, West, Central and East domain. It is extended in north-northwest (NNW) direction following its main structural trend that was developed during Late Triassic-Early Jurassic deformational period (Tjia, 1999).

The boundaries between the four domains of Peninsular Malaysia are based on the Bentong-Raub suture zone that runs generally North-South and the Lebir lineament which is also known as the Eastern Tectonic zone (see FIGURE 1). The differences between these geological domains are depended on the variation in structural trend and style, mineralization types, dominant lithology and facies, and paleogeography.

Based on the study by Bosch (1986), using the aerial photograph interpretation, it is defined that the sediments within the Kelantan delta are unconsolidated sediments of Quaternary deposits. According to the simplified geological map of the Malay Peninsula shown in appendix 1 in FIGURE 33, it is assumed that the sediments are sourced from the Eastern Belt I-type granitoids (Metcalfe, 2013). These deposits are classified by Bosch (1986) into three formations which are the Gula formation, the Beruas formation and Simpang formation (Geology of The Melintang-Sungai Kolok Transect Area Along The Malaysia-Thailand Border, 2006).

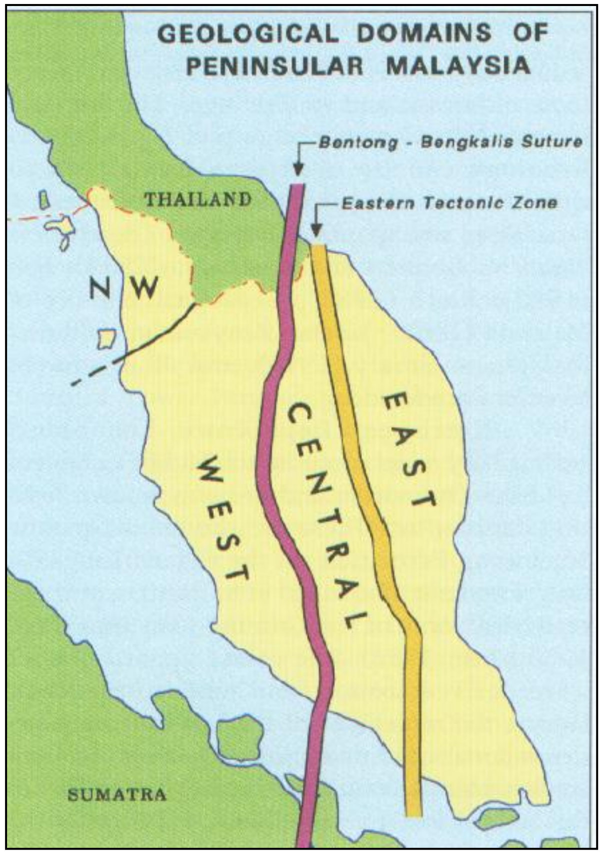


FIGURE 1: Geological domains of Peninsular Malaysia

2.2 Geological Setting of The Kelantan Delta

According to the Hydrographic Directorate, Royal Malaysian Navy (2003), the maximum tidal range recorded in Kelantan delta is 1.2m. The main source of sediments is from the Sungai Kelantan which the sediments from the banks consists of the gravel, sand and silt-content that varies according to the environmental setting. The present delta form is made up of the abandoned cuspate delta and a modern fan shaped delta which they are located respectively at Sungai Pengkalan Datu which is an abandoned distributary of Sungai Kelantan and Sungai Besar. The sequence of the Kelantan delta evolution can be seen in the FIGURE 34 in appendix 2 (Sa & Boon, 2011).

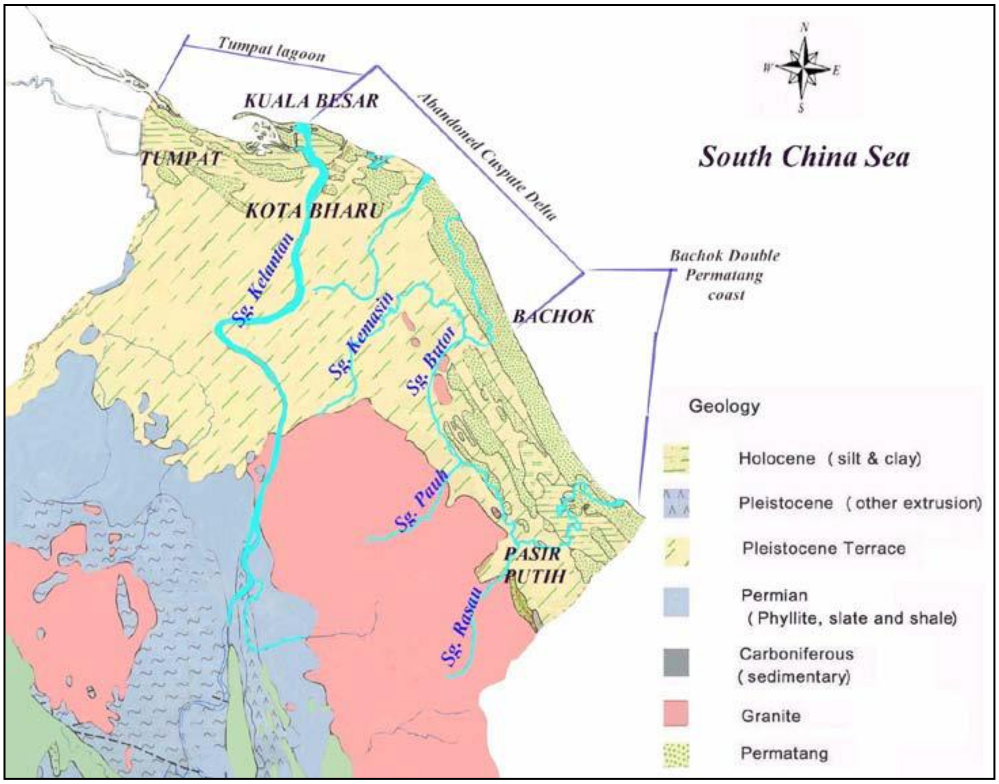


FIGURE 2: Background map of Kelantan delta

In the northern area of Kelantan, the outer barrier extends from the Bachok coast towards Pengkalan Datu meanwhile in the southern part, it is formed by different beach ridge series. For the inner barrier, it is well developed in the southern area but is absence in northern area of Kelantan due to the erosion by the meandering rivers. The meander scrolls and abandoned levees meander across the coastal plain where the inner barrier once existed.

2.3 Thermal Conductivity & Porosity

Thermal conductivity is one of the thermal properties of the rock that is important for understanding of the heat flow in the rock (Robertson, 1988). It is defined as a rate at which energy transfer across a unit area under the potential of a unit temperature gradient perpendicular to area. It is expressed in the units of $W(m^{o}K)^{-1}$ and it is influenced by the fluid, rock type and porosity. Basically, the heat is derived from the radioactive decay and it is transferred within the rocks usually by conduction for most of the surface rocks (Yusoff, 1993).

The porosity of the reservoir is depended on the burial depth due to the effects of the increasing overburden rock that lead to the compaction and cementation. It is expected that the overall low porosity is in the older strata; deeper depth of burial (Ehrenberg, October, 2009).

The porosity is defined as the ratio of the volume of voids to the total volume and can be measured by doing soil analysis. The analysis is focused on the measurement of the weight and the volume of the soil sample (Das, n.d.). The calculation of porosity and thermal conductivity are as shown:-

$$K = XY^{Vsh}Z^{\emptyset}$$

$$\emptyset = \frac{Bulk\ volume - Matrix\ volume}{Bulk\ volume}$$

$$Volume = \frac{Mass}{Density}$$

Where,

K= Thermal conductivity,

X, Y & Z= Constant

V_{sh}= Volume of shale

$\emptyset$= Porosity

Table 1: Thermal conductivity calculation based on thermal facies

Thermal facies	Parameter units	X	Y	Z
1	$\frac{Vsh < 20\%}{\emptyset < 35\%}$	6.86	0.99	0.98
2	$\frac{Vsh\ = or <\ 20\%\ and < 41\%}{\emptyset < 34\%}$	6.43	0.99	0.98
3	$\frac{Vsh = or > 41\%\ and < 61\%}{\emptyset < 34\%}$	10.59	1.00	0.96
4	$\frac{Vsh\ = or > 61\%}{\emptyset < 34\%}$	5.83	0.99	1.00
5	$\frac{Vsh < 26\%}{\emptyset = or > 34\%}$	13.14	1.09	0.91
6	$\frac{Vsh = or > 26\%\ and\ < 41\%}{\emptyset = or > 34\%}$	12.95	1.03	0.93
7	$\frac{Vsh = or > 40\%}{\emptyset = or > 34\%}$	15.24	1.01	0.94

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

3.1 Project Activities

Input
- Review and study
- Collecting soil samples (fieldwork)
- Gather well logs data from Mineral and Geology department

Process
- Soil analysis
- Well log analysis

Output
- Lithostratigraphic column
- Porosity-depth profile
- Thermal conductivity-depth profile
- Thermal conductivity-porosity-lithology intergration (reservoir quality)

3.2 Gantt Chart

3.2.1 Timeline For Final Year Project 1

No.	Detailed/Week (starting from 13 Jan 2014)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■	■												
2	Preliminary Research Work		■ △	■ △	■ △	■ △									
3	Submission of Extended Proposal						▲	△							
4	Proposal Defense								■ △	■ △					
5	Project Work Continues										■ △	■ △	■ △		
6	Submission of Interim Draft Report													▲	
7	Submission of Interim Report														▲

■ Process △ Weekly meeting ▲ Key milestone

3.2.2 Timeline For Final Year Project 2

No.	Detailed/Week (starting from 1 June 2014)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continues														
2	Submission of Progress Report														
3	Project Work Continues														
4	Pre-SEDEX														
5	Submission of Draft Final Report														
6	Submission of Dissertation (Soft Bound)														
7	Submission of Technical Paper														
8	Viva														
9	Submission of Project Dissertation (Hard Bound)														

Process Weekly meeting Key milestone

3.3 Review and Studies

Some reviews and studies are done to get better idea of the project and enhance more knowledge on the area study. The available information is gained from the materials and references as below:-

i Consultation with the Supervisor

ii Reading materials; thesis, journals, books, field reports and articles from websites)

3.4 Data Collection and Compilation

The main data required for the project are the porosity and thermal conductivity data which are gained from the soil sample analysis. The soils are collected from three different sites of the study area meanwhile the well log data are obtained from the Minerals and Geosciences department. Both data are important for the description of the lithology.

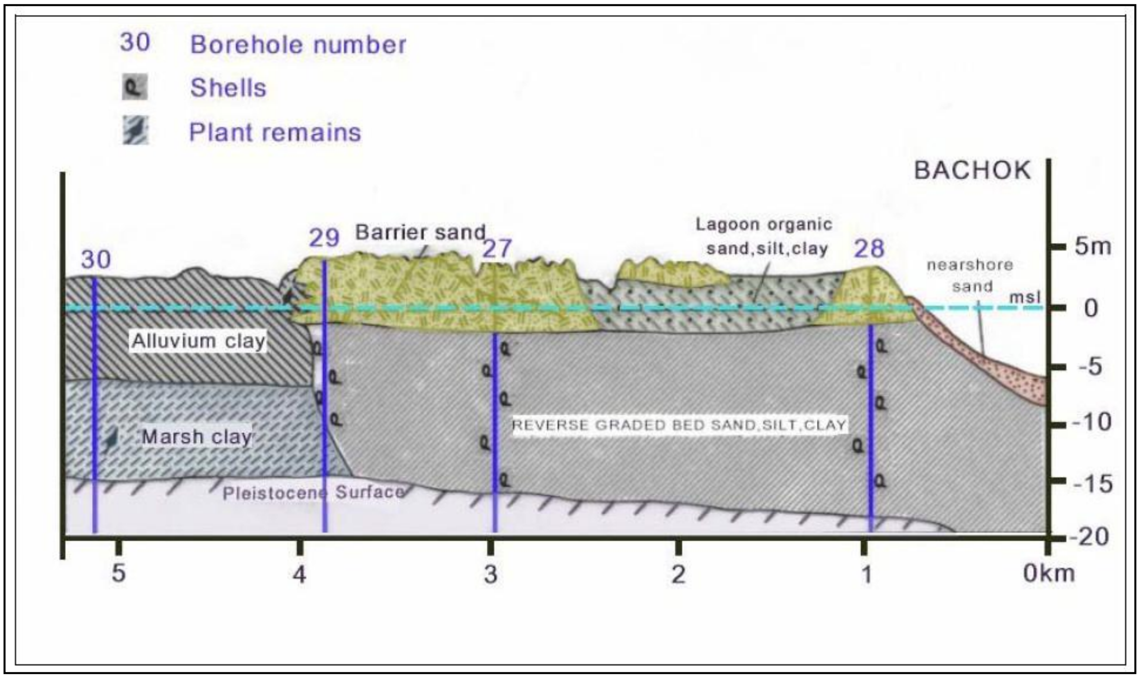


FIGURE 3: Example of lithostratigraphic section of Bachok

3.5 Data Analysis

Based on the soil analysis, the Porosity-Thermal conductivity profiling is produced. This profile concept is to be used in evaluating the reservoir quality. An example of the profile concept is used to make comparison with the profile produced. The example of the profile concept can be seen in the FIGURE 4 and FIGURE 5.

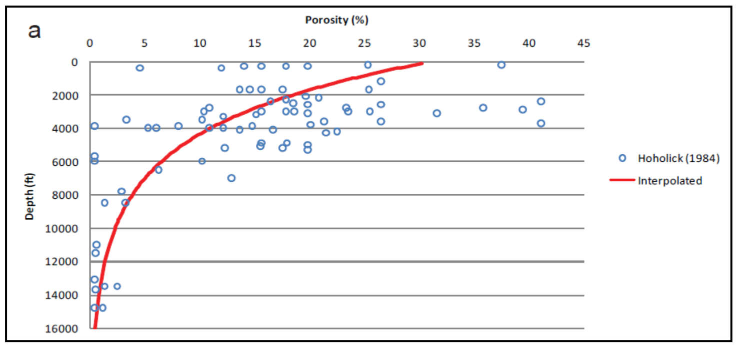


FIGURE 4: An example of porosity-depth profile (Hoholick, 1984)

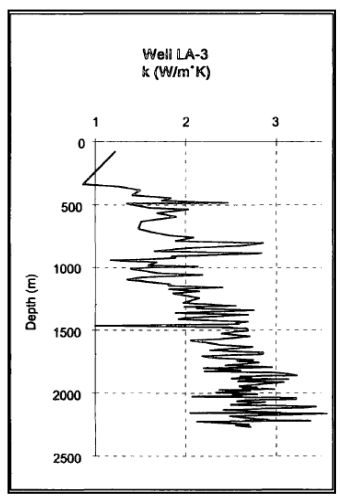


FIGURE 5: The example of thermal conductivity-depth profile (Yusoff, 1993)

CHAPTER 4

RESULTS AND DISCUSSION

4.0 RESULTS AND DISCUSSION

4.1 Variation of Lithology Profile in Various Geomorphology

4.1.1 Lithology Profile Based on The Samples Collected

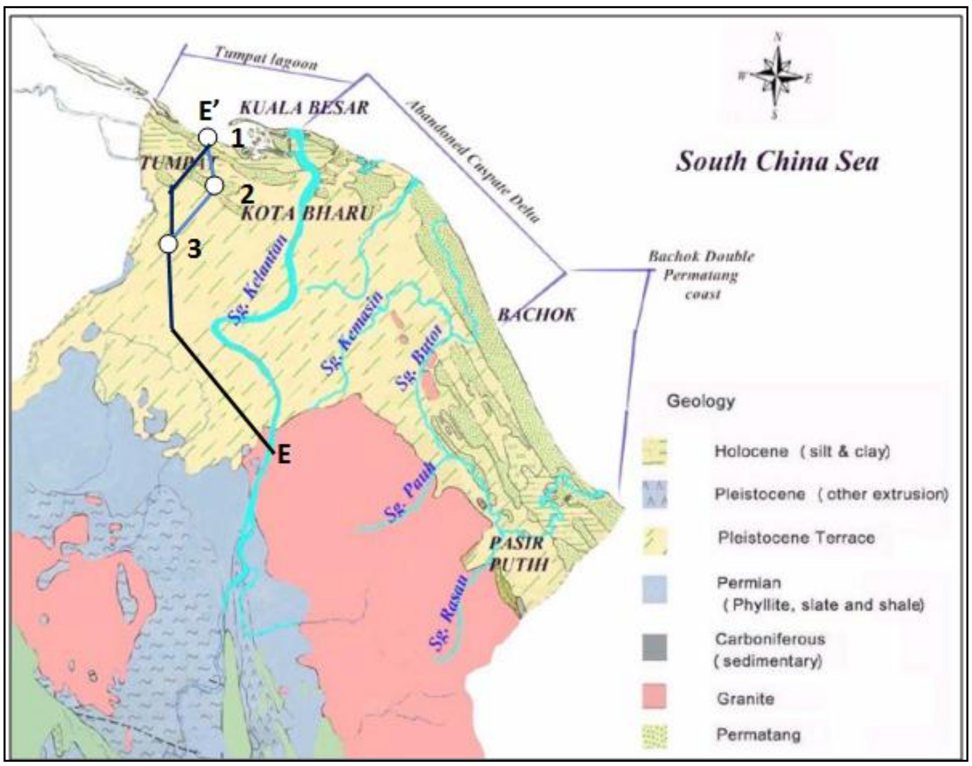


FIGURE 6: The geomorphology map of Kelantan delta (modified from Geostudies, 2011). E-E' cross section represent the lithology correlation from E point to E' point. Circle mark shown is the site of collecting soil sample for lithology column determination (Sa & Boon, 2011)

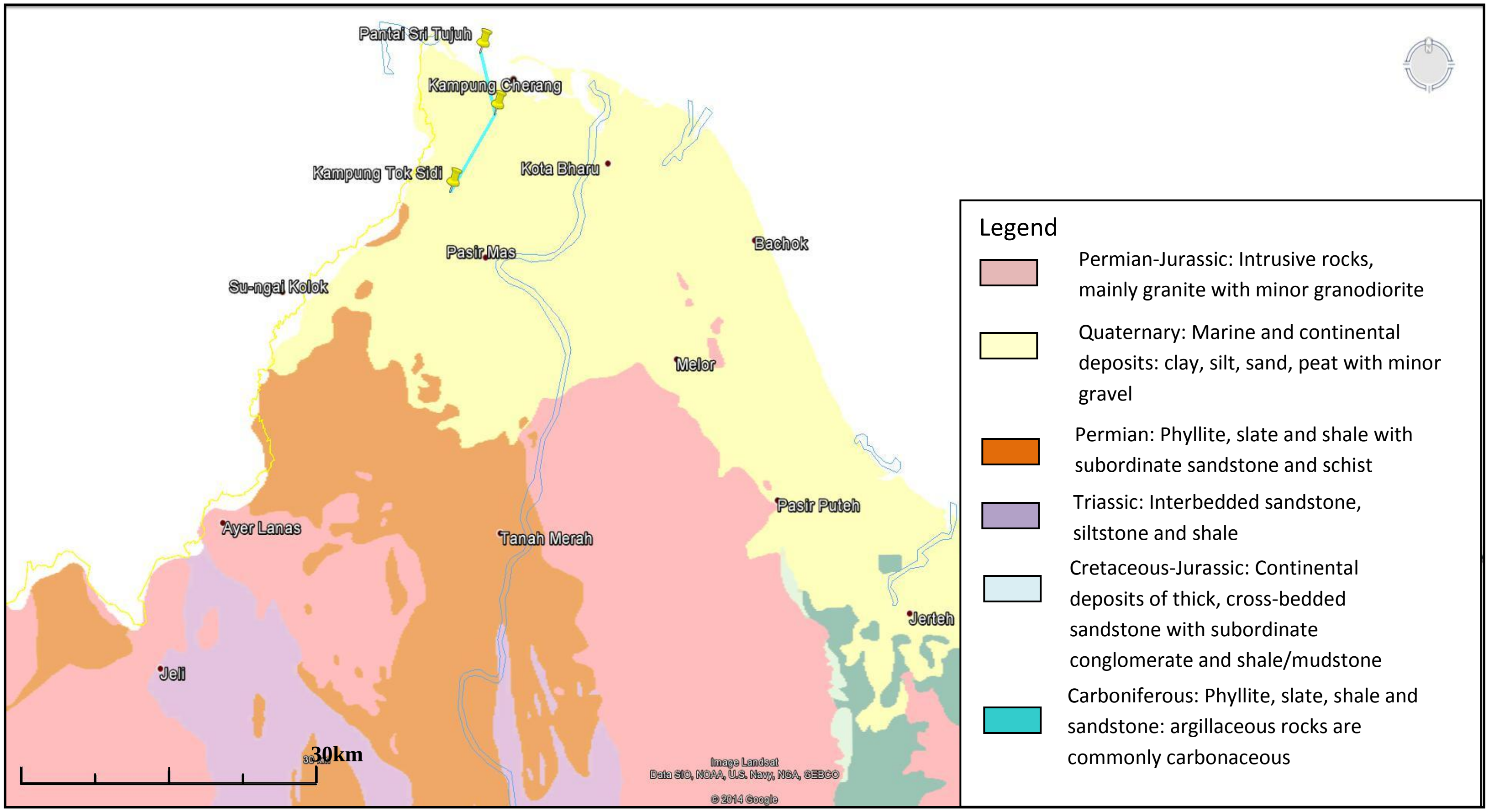


FIGURE 7: Lithology map of Kelantan delta

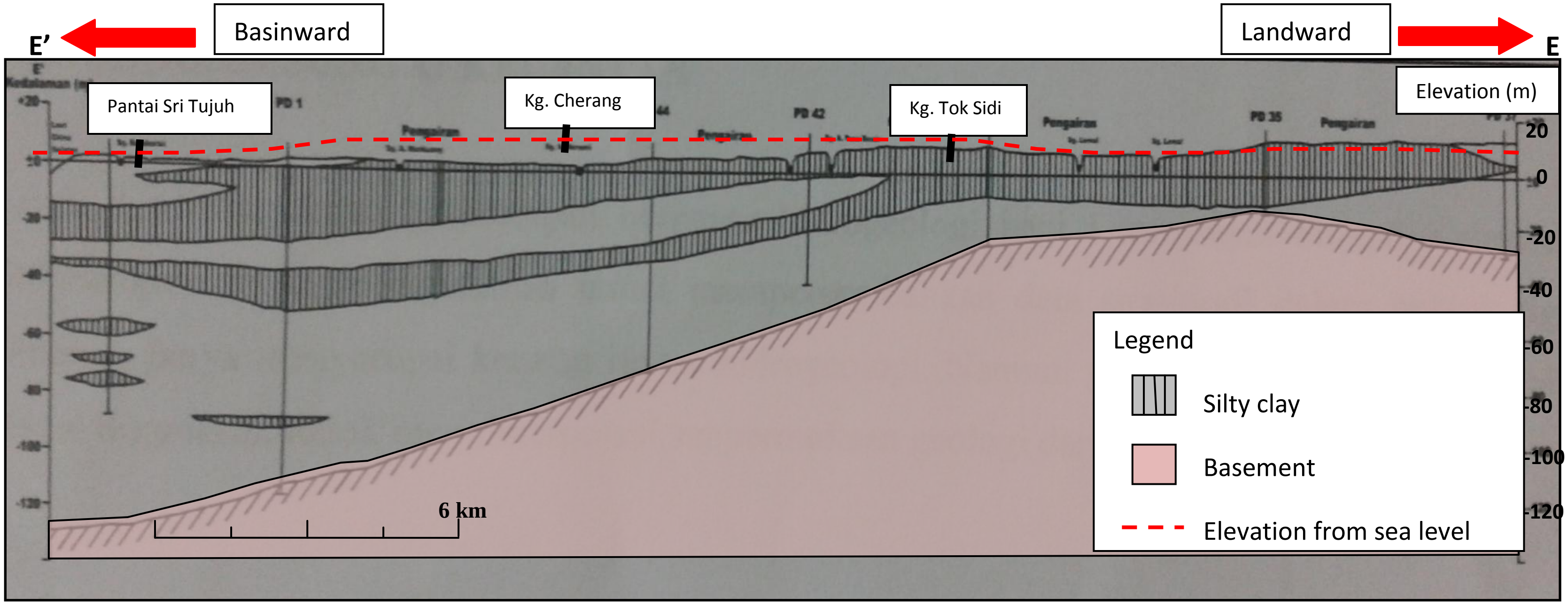


FIGURE 8: Lithology column of cross section E-E'(modified from Mineral and Geosciences Department study, n.d.).

As can be seen in the FIGURE 6, the three white circle marks shown in the geomorphology map indicates the site of the sample collection which is in the Pantai Sri Tujuh; location 1, 2 is in Kg. Cherang offset (about 10km) and location 3 is Kg. Tok Sidi area. The samples collected from these areas have been interpreted in cross section FIGURE 8 (Akhir & Ahmad, n.d.). The elevation above sea level in each location varies where in location 1, the elevation is 2m, 8m in location 2 and 9m in location 3. The lithology column modified shows that there is a variation of lithology from location 1 to 3; sand to clay distribution. The variation of the lithology occurred with respect to the change of environment as shown in the figures below.

FIGURE 9: Sand sample taken from the beach at Pantai Sri Tujuh

FIGURE 9a shows the depositional environment of the first site of sample collection which is in the beach. The sample collected is sand with fine-grain as can be seen in the FIGURE 9b. The assumption is that the beach in the East Kelantan delta which is coarse-grain sediments are eroded, transported and deposited in Tumpat area. Due to the transportation factor, the grain becomes finer in West Kelantan delta. The red arrow and line indicates the interbedded sand with carbonaceous silt and erosion of the beach as shown in FIGURE 10.

FIGURE 10: Erosion and interbedded of the sediments

FIGURE 11: Silty sand samples taken from Kg. Cherang

FIGURE 11 shows ridge depositional environment where the sample collected is fine and compacted silty sand. The presence of the Nibung root indicates that the location is nearby swale depositional environment, a shallow trough between ridges that run parallel to the shoreline.

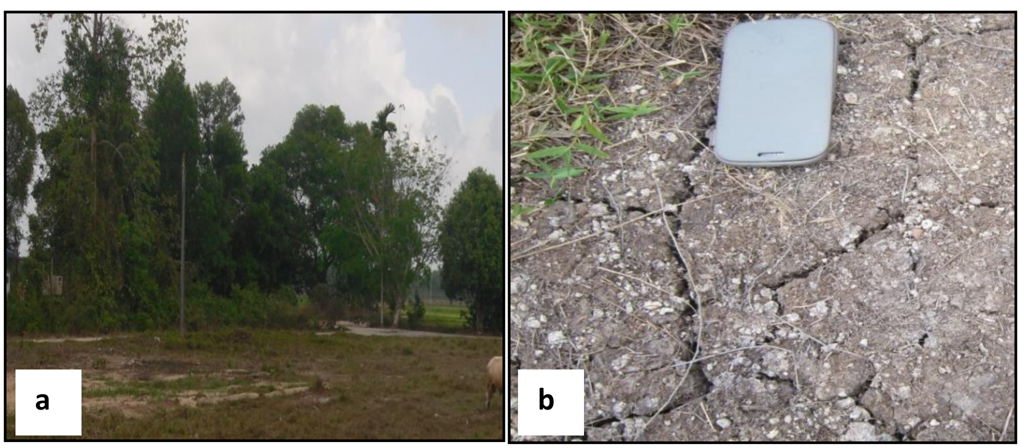


FIGURE 12: Mud samples collected from Kg. Tok Sidi area.

FIGURE 12a shows the sample collected nearby paddy field is mud sample. The mud crack feature shown in FIGURE 12b indicates that the area used to contain water. Mud or clay lithology found in the area represents the swampy depositional environment.

4.1.2 Lithology Determination and Interpretation Based on Well Log Analysis

Samples collected are compared with the well log data of boreholes nearby the sites which are obtained from the Mineral and Geosciences department (Projek Bekalan Air Kelantan Utara, 1993). The well log data used for the comparison is gamma ray (GR) log data and this comparison is to confirm the lithology variation from one location to another. The log curve will be only focused in the shallowest part because the samples collected from the site are shallow in depth that is ranged from 0 to about 2m deep.

Sample taken from Kg. Tok Sidi is compared with the data from Kampung Kota borehole which is approximately about 15 km far from the site. According to the GR log curve from the borehole, it shows high curve in the shallowest part indicating that there is presence of clay. Based on the core description shown in FIGURE 14 it describes the shallowest part as the silty clay which is tallied with the sample collected from Kg. Tok Sidi.

The bell shape log shown by the Kg. Kota GR log data indicates that it is trangressive shelf which the pattern is fining upward. Silts and clays predominate during the flood basins of the deltaic plains. In most deltas, these sediments are buried with peat and contain large amount of logs, wood and fine grained plant materials. Generally, fine-grained materials are filled in the upper part of the channel and coarsening downward similarly as shown in the log.

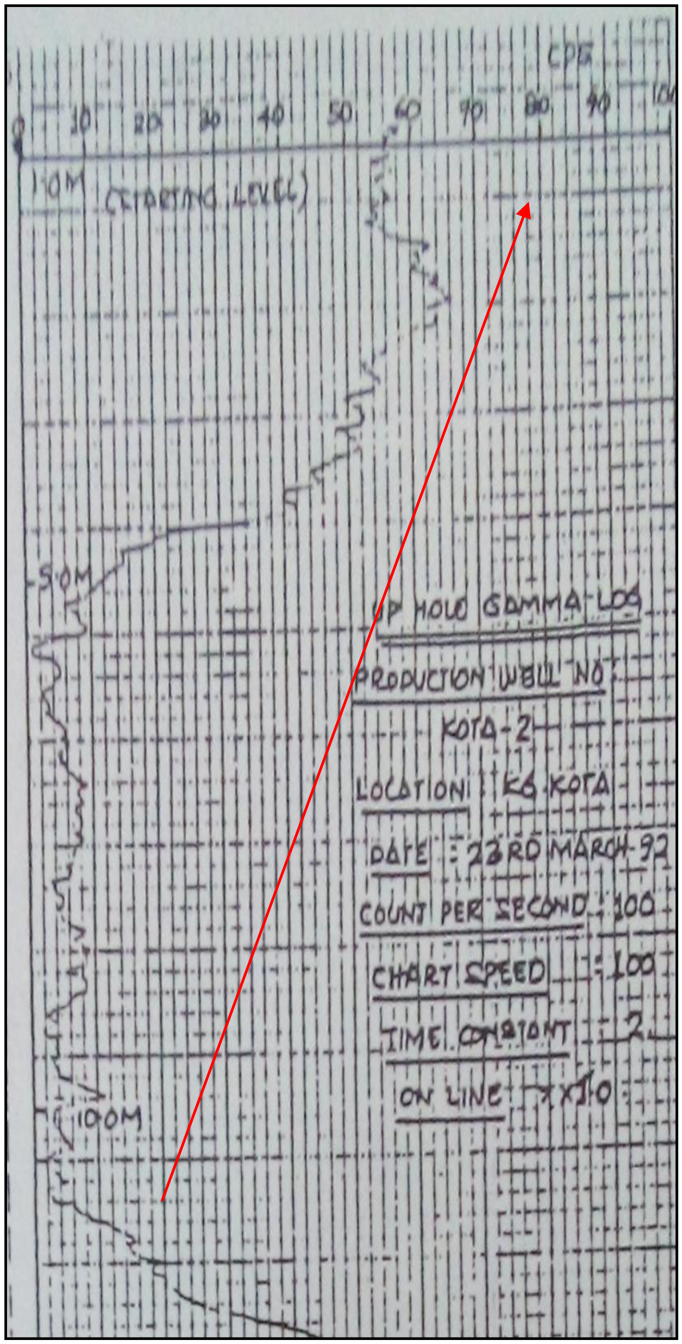


FIGURE 13: GR log data from Kg. Kota borehole

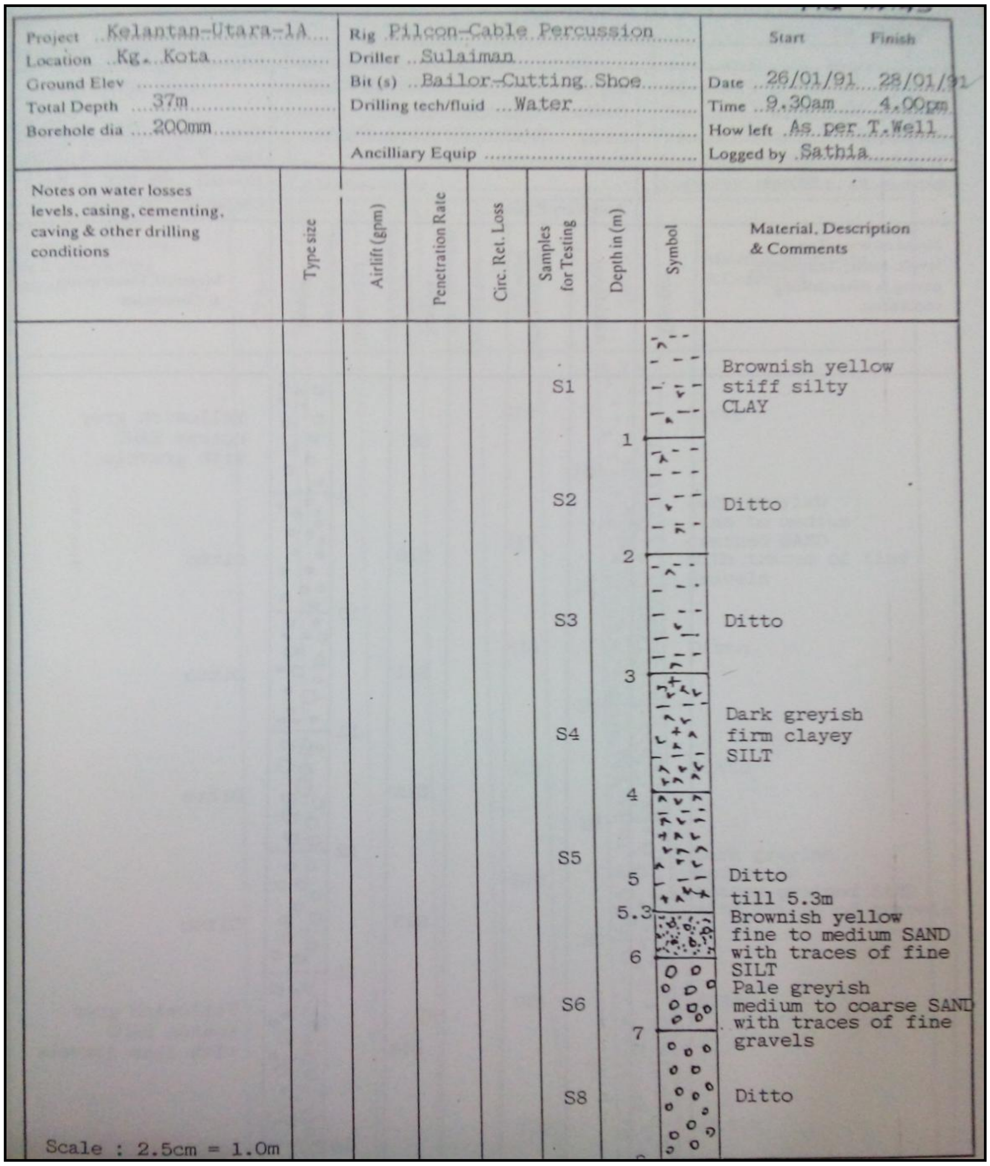


FIGURE 14: Lithology description of Kg. Kota borehole

As for the sample collected from Kg Cherang, it is compared with the GR log and lithology description from Kg. Teluk borehole which is about 2 km faraway. Based on the GR log, it shows high curve but lesser than the curve from Kg. Kota borehole. This means that there is still presence of clay in the shallow part but with lesser amount. The cylindrical log pattern shown for Kg. Teluk indicates channel-fill. In channel-fill, it is most common to have interbedded of sands, silts and clay which the potential of source rock and reservoirs are interbedded alternately.

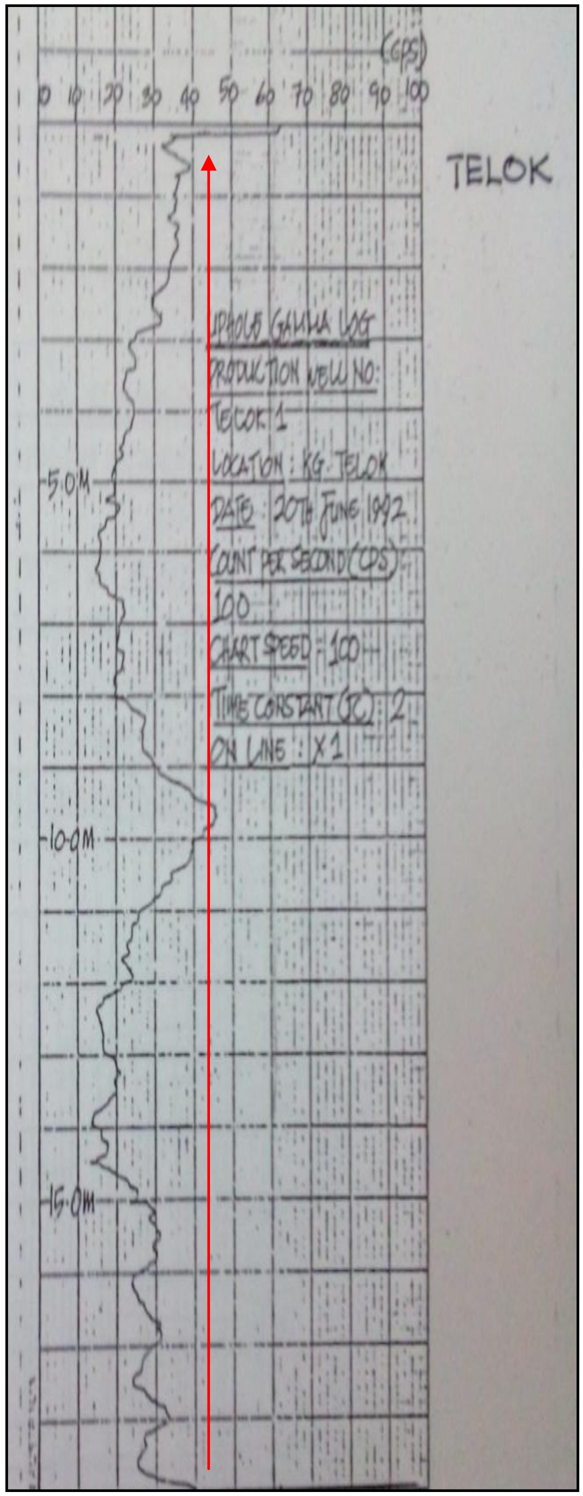
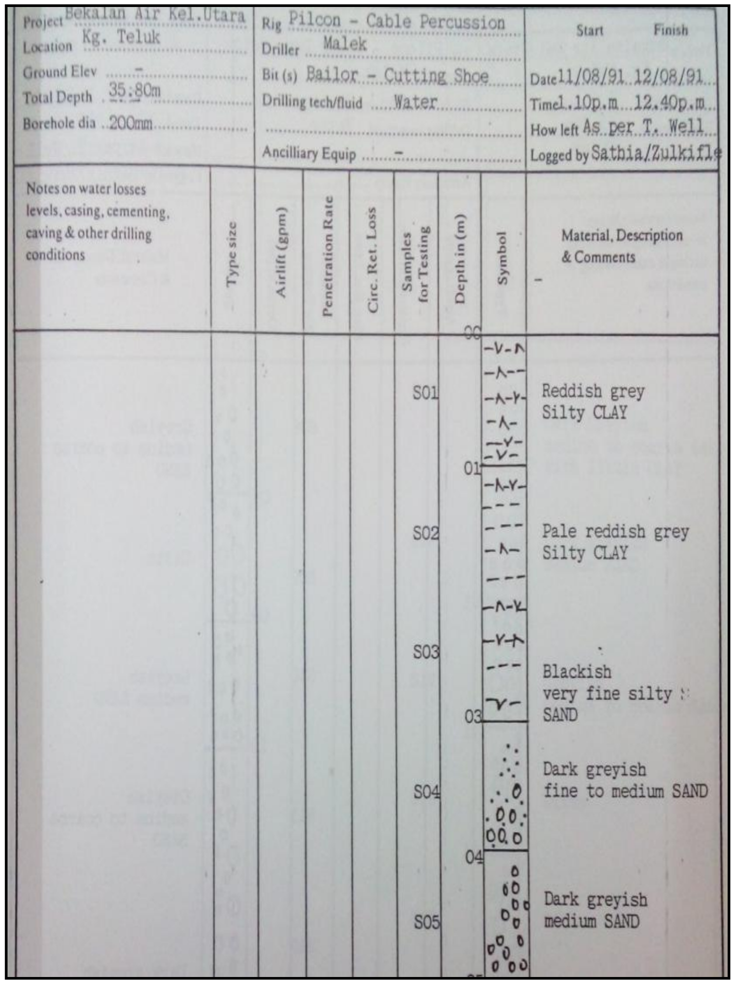


FIGURE 15: GR log data of Kg. Teluk borehole



Project Bekalan Air Kel.Utara
Location Kg. Teluk
Ground Elev –
Total Depth 35.80m
Borehole dia 200mm

Rig Pilcon – Cable Percussion
Driller Malek
Bit (s) Bailor – Cutting Shoe
Drilling tech/fluid Water
Ancilliary Equip –

Start Finish
Date 11/08/91 12/08/91
Time 1.10p.m. 12.40p.m.
How left As per T. Well
Logged by Sathia/Zulkifle

Notes on water losses levels, casing, cementing, caving & other drilling conditions	Type size	Airlift (gpm)	Penetration Rate	Circ. Ret. Loss	Samples for Testing	Depth in (m)	Symbol	Material, Description & Comments
						00		–
					S01			Reddish grey Silty CLAY
						01		
					S02			Pale reddish grey Silty CLAY
					S03			Blackish very fine silty SAND
						03		
					S04			Dark greyish fine to medium SAND
						04		
					S05			Dark greyish medium SAND

FIGURE 16: Lithology description of Kg. Teluk

In contrast, the sample collected from Pantai Sri Tujuh is confirmed for its lithology by comparing the sample collected from Pantai Mek Mas, one of the locations in the East Kelantan delta. This is because there is unavailability of GR log data from location nearby. In Pantai Mek Mas location, the sample collected is sand with coarse grain. The difference of the sand size is in agreement with the theory that the beach in East Kelantan delta is partly the original site of deposition and it is eroded by the wave, transported and deposited in the West Kelantan delta causing the grain to be fine. The sediment is also transported from the Kelantan river from the source in the upstream.

FIGURE 17: Coarse-grain sand interbedded with carbonaceous silt in Pantai Mek Mas

FIGURE 18: Fine-grain sand interbedded with carbonaceous silt in Pantai Sri Tujuh

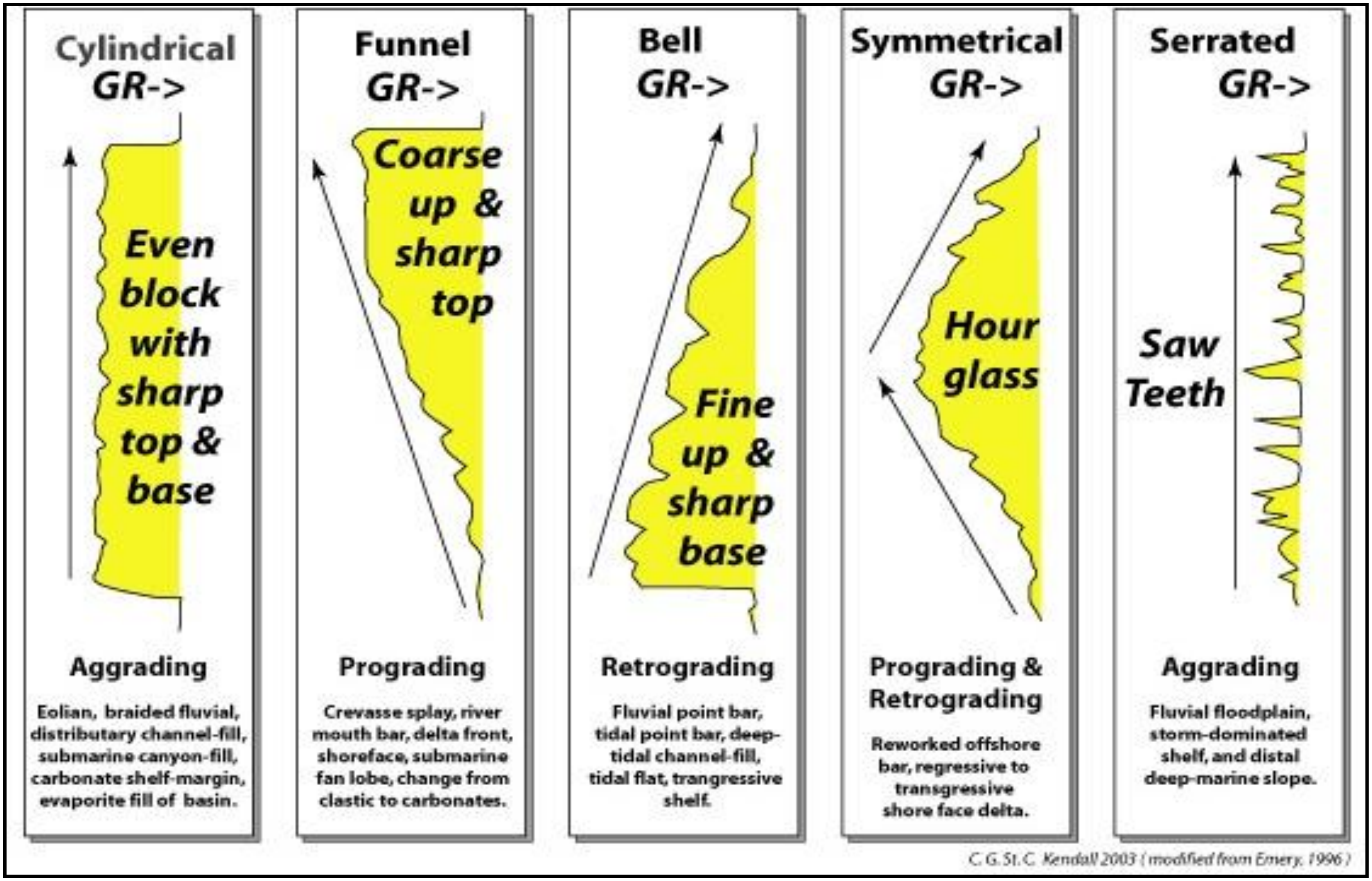


FIGURE 19: General Gamma Ray response to variations in grain size (after Kendall, 2003)

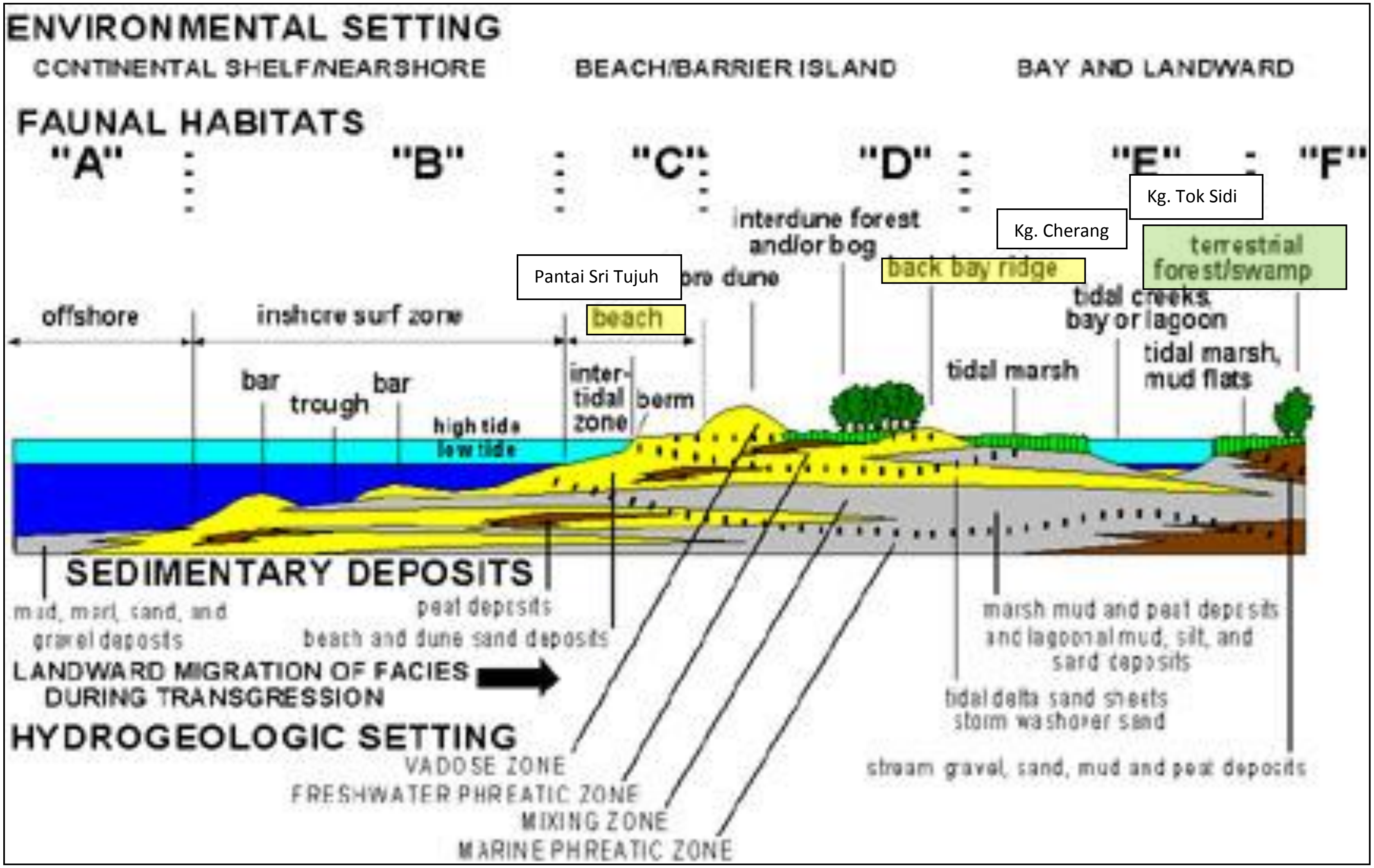


FIGURE 20: Comparison of environmental setting model with the cross-section E-E' based on the log interpretation

4.2 Grain Size Distribution

4.2.1 Results From Sieving Analysis

TABLE 2: Results of sieving analysis for Kampung Cherang

Sieve aperture (mm)	Weight retained (g)	Weight retained (%)	Cumulative weight retained (g)	Cumulative percent retained (%)	Grain size (phi)
2	2.17	1.09	2.17	1.09	-1
1	15.11	7.56	17.28	8.65	0
600µm	45.99	23.00	63.27	31.65	0.74
425µm	35.92	17.96	99.19	49.61	1.23
300µm	37.88	18.94	137.07	68.55	1.74
150µm	48.57	24.29	185.64	92.84	2.74
63µm	11.12	5.56	196.76	98.40	3.99
44µm	2.87	1.44	199.63	99.84	4.51

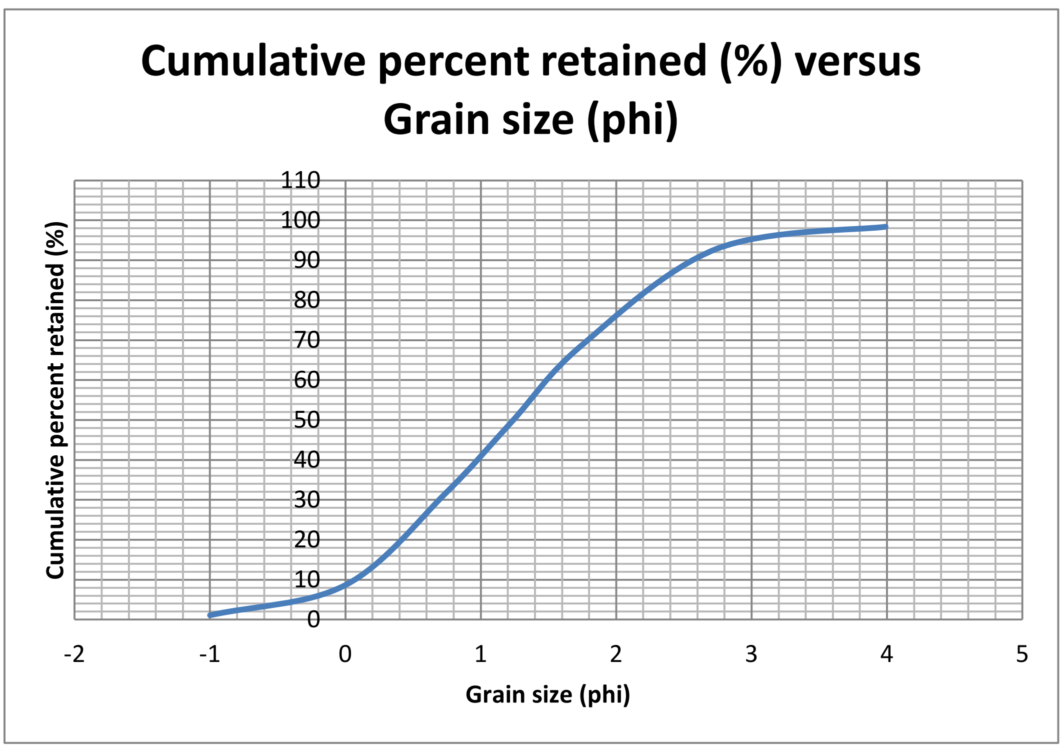


FIGURE 21: Graph of Analysis of Kampung Cherang data

TABLE 3: Results of sieving analysis for Kampung Tok Sidi

Sieve aperture (mm)	Weight retained (g)	Weight retained (%)	Cumulative weight retained (g)	Cumulative percent retained (%)	Grain size (phi)
2	84.37	42.19	84.37	42.19	-1
1	38.31	19.16	122.68	61.35	0
600µm	27.95	13.98	150.63	75.33	0.74
425µm	10.06	5.03	160.69	80.36	1.23
300µm	7.87	3.94	168.56	84.3	1.74
150µm	8.86	4.43	177.42	88.73	2.74
63µm	8.87	4.43	186.29	93.16	3.99
44µm	13.08	6.54	199.37	99.7	4.51

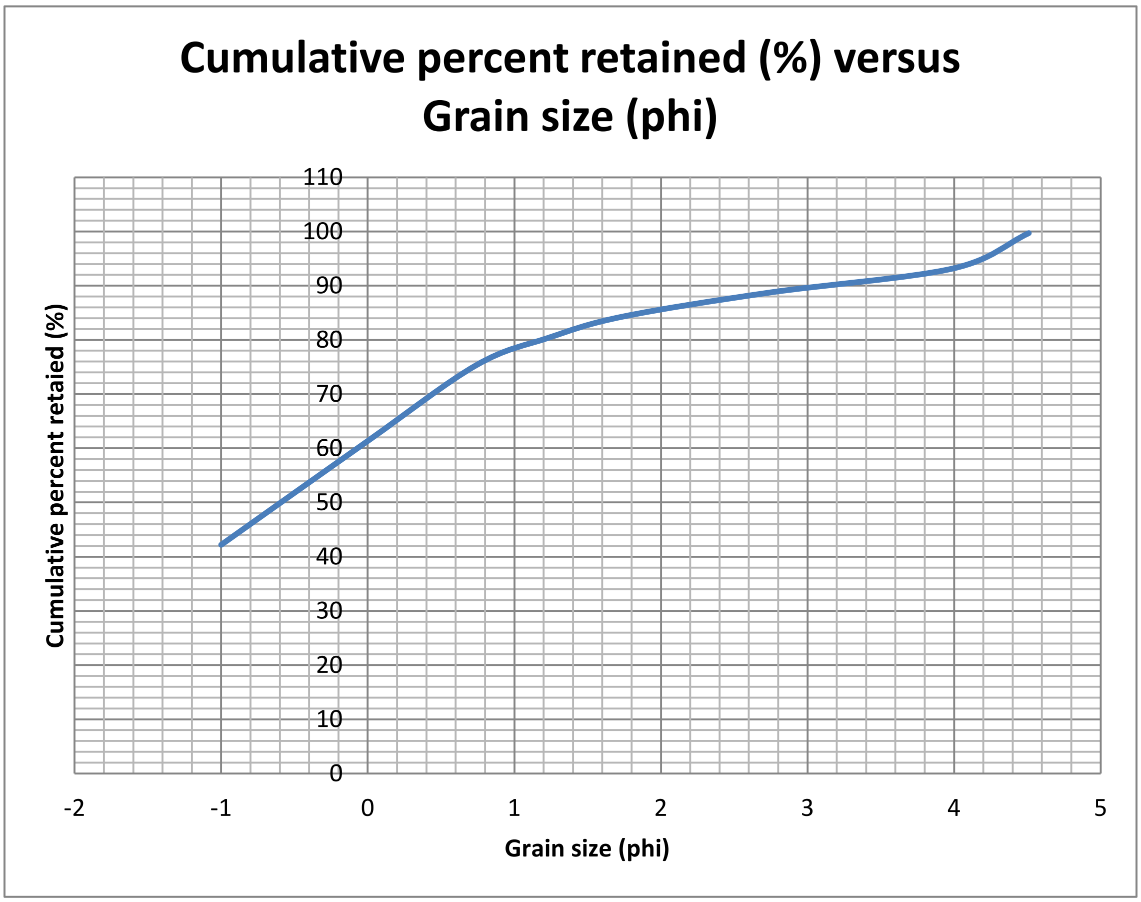


FIGURE 22: Graph of Analysis of Kampung Tok Sidi data

TABLE 4: Results of sieving analysis for Pantai Sri Tujuh

Sieve aperture (mm)	Weight retained (g)	Weight retained (%)	Cumulative weight retained (g)	Cumulative percent retained (%)	Grain size (phi)
2	0.19	0.10	0.19	0.10	-1
1	1.12	0.56	1.31	0.66	0
600µm	20.84	10.42	22.15	11.08	0.74
425µm	45.37	22.69	67.52	33.77	1.23
300µm	76.6	38.3	144.12	72.07	1.74
150µm	54.1	27.05	198.22	99.12	2.74
63µm	1.54	0.77	199.76	99.89	3.99
44µm	0.21	0.11	199.97	100	4.51

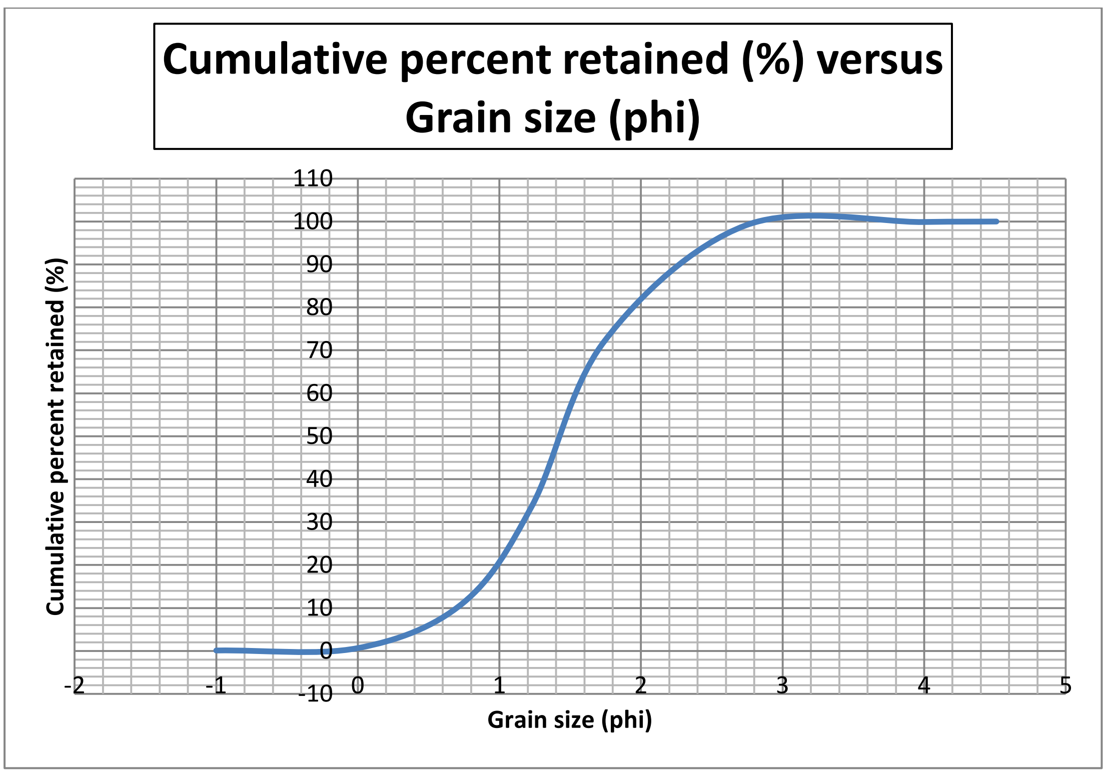


FIGURE 23: Graph of analysis for Pantai Sri Tujuh

4.2.2 Statistical Parameter For Mineral and Geosciences Data and Sieving Analysis

$$Mode = the\ most\ frequent\ size\ category$$

$$Median = 50\%\ above\ and\ 50\%\ below\ this\ category$$

$$Graphic\ mean = \frac{\emptyset 16 + \emptyset 50 + \emptyset 84}{3}$$

$$Inclusive\ graphic\ standard\ deviation = \frac{\emptyset 84 - \emptyset 16}{4}$$

FIGURE 24: Calculation of statistical parameter

TABLE 5: Results calculated from the graph and bar chart

Statistical parameter	Kg. Cherang sample	Kg. Tok Sidi sample	Pantai Sri Tujuh
Median (phi)	1.2	-0.6	1.4
Graphic mean (phi)	1.27	0.4	1.47
Inclusive graphic standard deviation (phi)	0.50	0.45	0.3

TABLE 6: Grain size based on graphic mean

Boulder	-12 to -8 phi
Cobble	-8 to -6 phi
Pebble	-6 to -2 phi
Granular	-2 to -1 phi
Very coarse grained	-1 to 0.0 phi
Coarse grained	0.0 to 1.0 phi
Medium grained	1.0 to 2.0 phi
Fine grained	2.0 to 3.0 phi
Very fine grained	3.0 to 4.0 phi
Coarse silt	4.0 to 5.0 phi
Medium silt	5.0 to 6.0 phi
Fine silt	6.0 to 7.0 phi
Very fine silt	7.0 to 8.0 phi
Clay	8.0 and smaller

TABLE 7: Grain sorting based on inclusive graphic standard deviation

Sorting	Phi value
Very well sorted	Under 0.35
Well sorted	0.35 to 0.50
Moderately well sorted	0.50 to 0.71
Moderately sorted	0.71 to 1.0
Poorly sorted	1.0 to 2.0
Very poorly sorted	2.0 to 4.0
Extremely poorly sorted	Over 4.0 phi

Based on the TABLE 7 and TABLE 6, it shows that samples taken from Pantai Sri Tujuh has very well-sorted and the finest grain compared to others. Eventually, it is believed that the variation of the grain size and sorting of these sediments is due to the transportation factor which is from the source in the upstream to the beach.

4.3 Reservoir Properties and Qualities

Based on the output results from Kg. Teluk and Kg. Kota, it is concluded that both Kg. Cherang and Kg. Tok Sidi have potential reservoir in deeper parts assuming that they have comparable lithology succession. For Pantai Sri Tujuh, it is unclear to determine the reservoir potentials in the deeper part as there is only one data obtained for the area relating to the reservoir elements. In addition, there is no data from any location nearby to investigate on the reservoir elements of Pantai Sri Tujuh. The porosity values expected for Kg. Cherang and Kg. Tok Sidi are about 41%-57% which is considerably high for hydrocarbon accumulation. The thermal conductivity value varies from about 1-2 W/m/K, believed due to the variation of mineral composition of lithology and fluid flow.

The results of pressure and maturity are also included to strengthen the evidence of the potential reservoirs in the deeper part. The data are plot on the graph of porosity versus depth and thermal conductivity versus depth for T well (Central Malay basin) to compare the reservoirs on the onshore and offshore. From FIGURE 29 and FIGURE 30, they show that the data for porosity and thermal conductivity with depth in the onshore (West Kelantan delta); Kg. Tok Sidi, Kg. Cherang and Pantai Sri Tujuh area are deviated to some extend from the trend in the offshore (Central Malay basin) which is T well. It is expected that the deep reservoir in the onshore are probably having similar reservoir properties and quality with the offshore based on the extrapolation of data from the results.

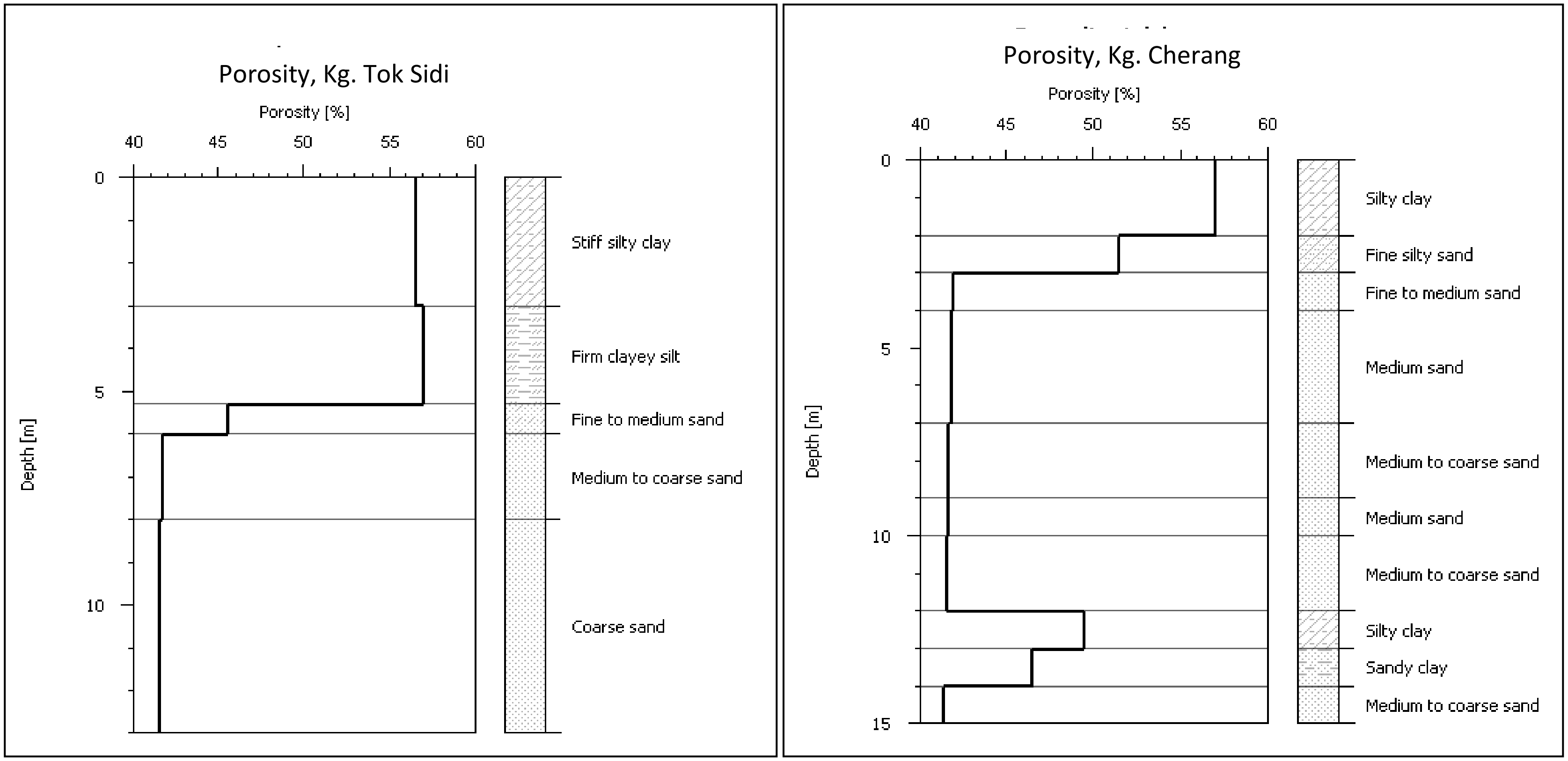


FIGURE 25: Depth versus porosity plots for Kg. Tok Sidi and Kg. Cherang

FIGURE 25 shows high values in porosity for both locations, indicating that there is possibility of reservoir potential especially in clay lithology. This is because clay has finer grain which giving more spaces between the grain. However, this only applies for uncompacted clay that lies on the surface or near the surface. As can be seen from the trend, the porosity values decrease with depth due to the compaction factor. As compaction occur, the pores collapse thus reducing the pore spaces between the grains.

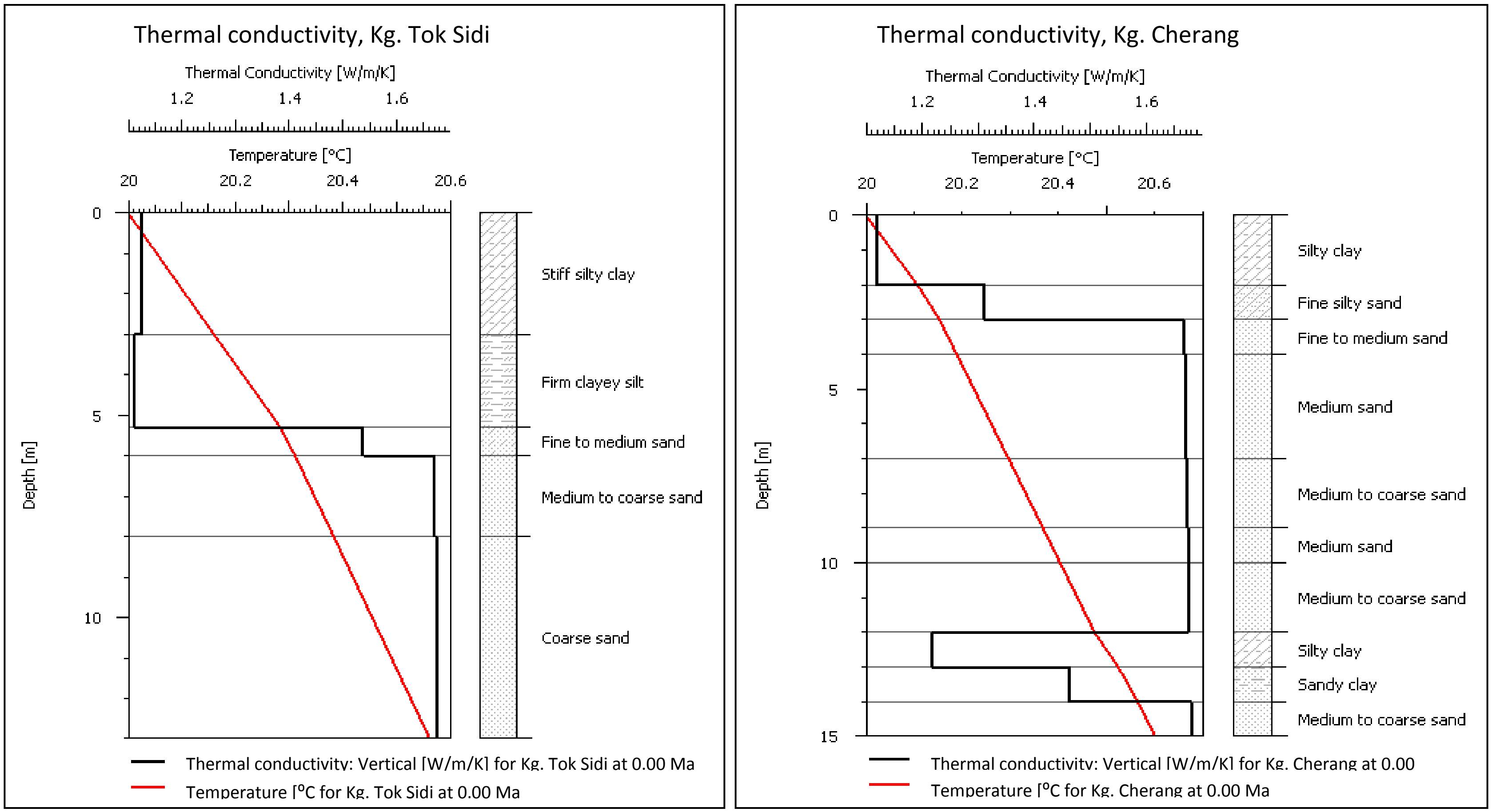


FIGURE 26: Depth versus thermal conductivity and temperature plot for Kg. Tok Sidi and Kg. Cherang

FIGURE 26 shows the variation of thermal conductivity and temperature with depth plot due to lithology variation. It is shown that clay lithology has the lowest value of thermal conductivity which is inversely proportional to porosity value. The sand of the field area has the highest value, estimated of 1.55-1.76 while the clay is estimated to have value below than 1.1. This variation occurs as different lithology consists of different mineral composition. Each mineral have its own heat flow unit. Quartz mineral has high value of heat flow unit thus, giving high value of thermal conductivity. The amount and type of fluid in pores and water bounded in clays contribute partly to the gross thermal conductivity of the samples.

For the temperature curve, it is observed that temperature result in Kg. Tok Sidi shows concave trend, this trend indicates that there is prominent vertical fluid flow. There is possible sealing property in this area due to the thick shale or clay sediments shown in the shallow part. Meanwhile, in Kg. Cherang, the temperature curve shows two pattern which are concave and convex pattern. The concave pattern is observed in the shallow part while in the deeper part, the temperature result shows convex pattern. This indicates that there are two types of fluid flow; prominent lateral and vertical fluid flow. Based on the temperature curve shown, it is expected that there is prominent vertical fluid flow in shallow part and prominent lateral fluid flow in the deeper part.

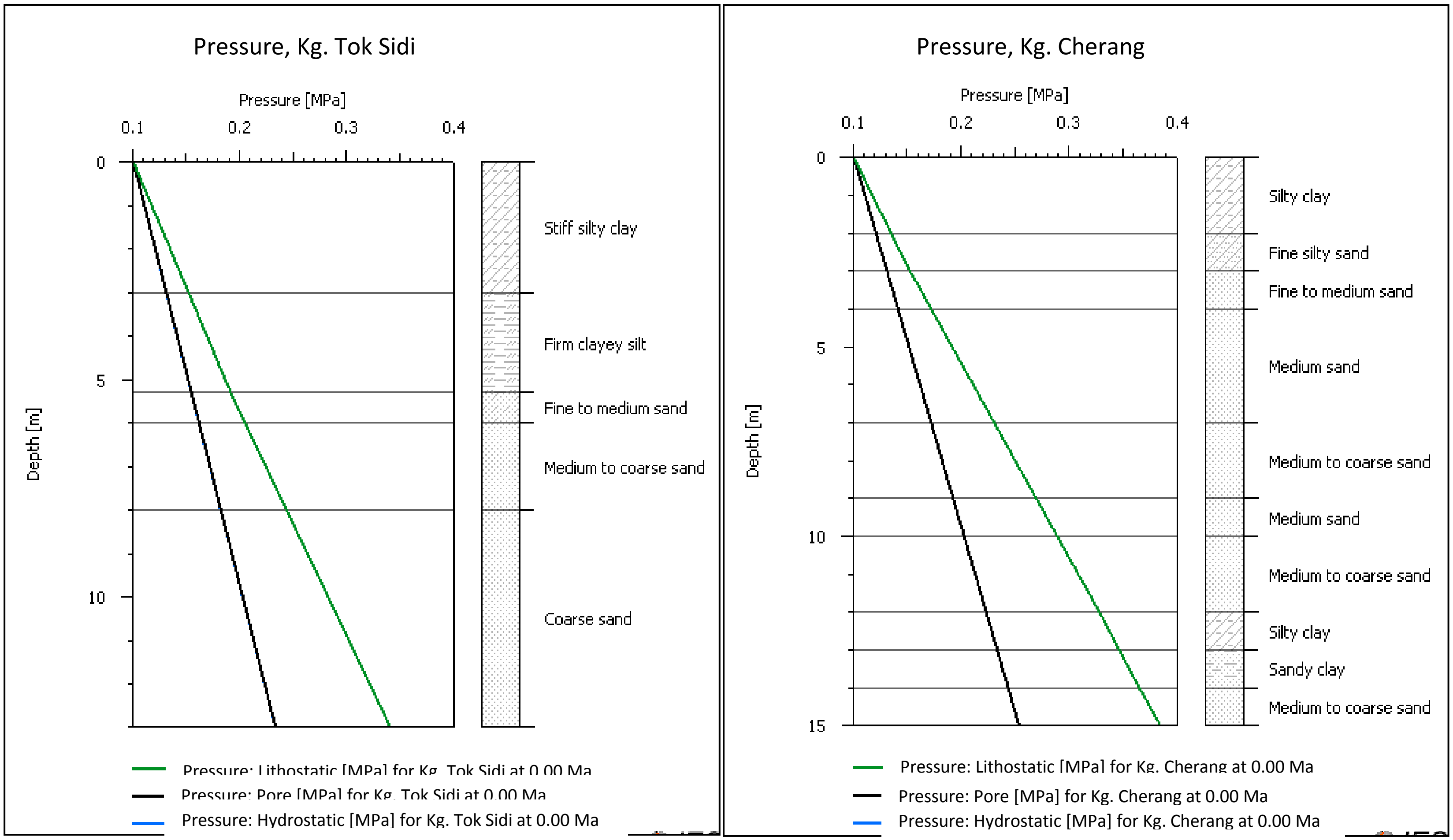


FIGURE 27: Depth versus pressure plot for Kg. Tok Sidi and Kg. Cherang

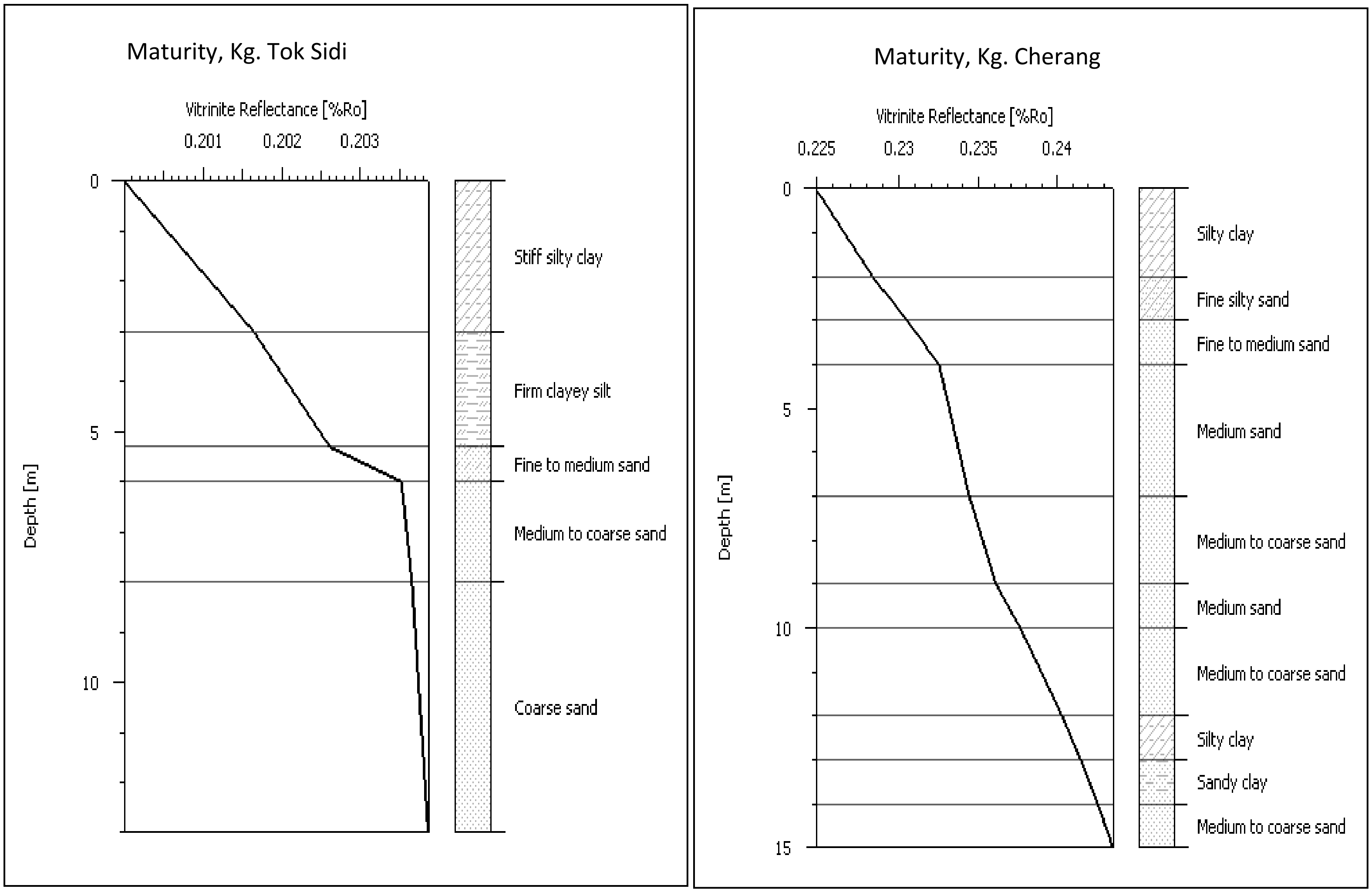


FIGURE 28: Depth versus maturity plot for Kg. Tok Sidi and Kg. Cherang

Standard range for reservoir maturity is 0.5-1.3. Value below than 0.5 represent immature reservoirs indicating that it is not the right timing for the reservoir to become potential target. Meanwhile, value more than 1.3 represent the overmatured reservoir hence, it is not suitable as potential reservoir.

Based on the results shown in FIGURE 28, the reservoirs within depth of 0 to about 15 m are indicated as immature because the temperature (see in FIGURE 26) and pressure (see in FIGURE 27) are not enough to bake the reservoirs. However, it is expected that reservoirs in Kg. Cherang area can reach maturity earlier than in Kg. Tok Sidi based on the gradient trend shown. There is no overpressure shown as the pore pressure follows the hydrostatic pressure trend. However, it is expected that there is possible mature reservoir in deeper part based on the trend of the results and from the succession where it shows the presence of seal rock and possible reservoir interbedded alternately.

The variation in porosity with depth can be determined from the thermal conductivity variation with depth. Normally, the thermal conductivity is likely to increase with burial depth if the compaction plays as the main factor. In Central Malay Basin, it has been observed that the average thermal conductivity increases with depth. Central Malay Basin has undergone a normal sedimentation history and relatively normal compression zone which often disturbed by the overpressured zones that occur only at depth near the bottom of the well.

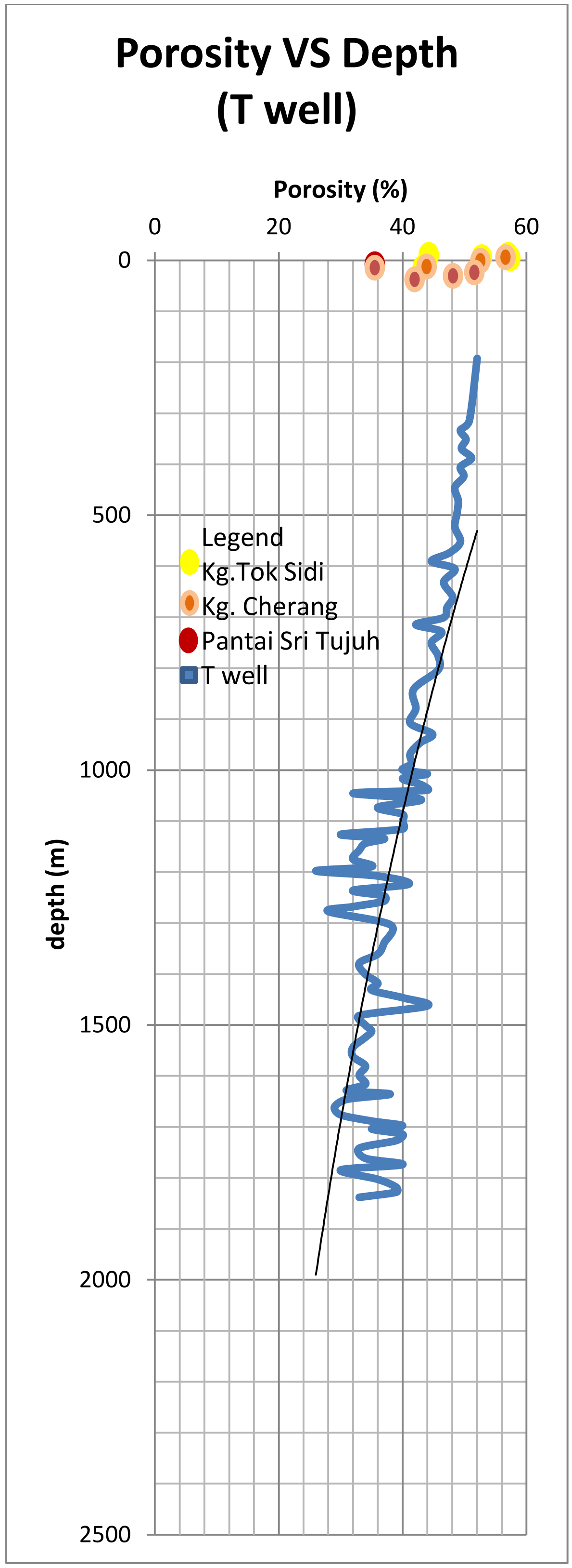


FIGURE 29: Graph of porosity versus depth for onshore (Kelantan delta) and offshore (Central Malay basin)

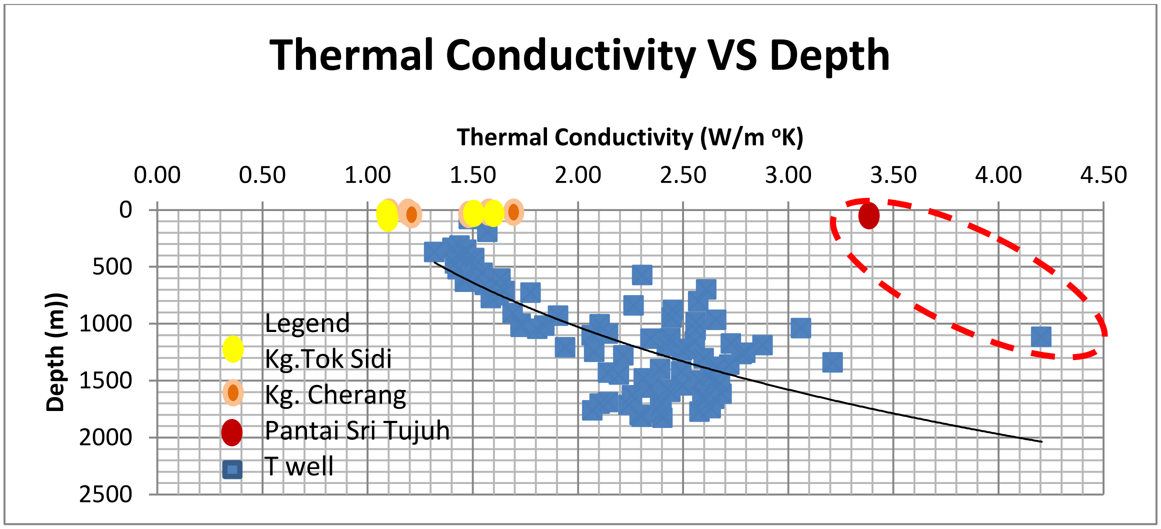


FIGURE 30: Graph of thermal conductivity versus depth for onshore (Kelantan delta) and offshore (Central Malay basin)

The onshore data are plot on the graph of depth versus porosity and depth versus thermal conductivity for T well which represents the offshore data (Central Malay Basin). The purpose of this plot is to compare the reservoirs in the onshore and the offshore. Based on both profiles, they show consistent trend of porosity and thermal conductivity for onshore and offshore. Hence, it is expected that the deep reservoirs in onshore are possible to have similar trend with the offshore data based on the extrapolation of data from the results.

For Pantai Sri Tujuh, there is only one value for both porosity and thermal conductivity so, it can only represent as localized area. In thermal conductivity versus depth profile, it is observed that Pantai Sri Tujuh value have similar trend with one point plotted as shown by the circle marked in FIGURE 30. It is assumed that both are possible similar lithology which is almost 100% sand lithology. The rest points plotted are mixture of sand and clay.

4.3.1 Summary of The Reservoir Quality and Properties

Samples/Parameter	Porosity in shallow part, 0-5m (%)	Porosity in deeper part, 5-≤2000m (%)	Thermal conductivity in shallow part, 0-5m $W(m^oK)^{-1}$	Thermal conductivity in deeper part, 5-≤2000m $W(m^oK)^{-1}$
Kg Tok Sidi (silty clay)	56-57	42-35	1.0-1.06	1.04-3
Kg Cherang (sandy clay)	42-57	41-35	1.55-1.78	1.2-3
Pantai Sri Tujuh (sandy beach)	35	-	3.42	-

The summary shows that the porosity value for Kg. Tok Sidi and Kg. Cherang are still considerably high even in the deeper part. This is based on the extrapolation of data using the offshore data, T well. Thus, it is expected that there us reservoir potential in deeper part of the study area. For Pantai Sri Tujuh, it is inconclusive due to the limitation of data.

CHAPTER 5

CONCLUSION

5.0 CONCLUSION

From the results, thermal and porosity-depth profile and lithology column are developed which these profiles are important for the determination of reservoir's quality. It is shown that variation of lithology are according to the variation of geomorphology. High sand lithology are found near shore while high clay distribution are in swampy area.

The thermal conductivity and porosity with depth profile are consistent with the lithology-depth profile where different lithology shows correct profile of the thermal conductivity and porosity with depth. The profiles also show consistent relation between onshore and the offshore. It is expected that the reservoir's elements and quality in deeper part of the onshore have similar trend with the offshore based on the extrapolation of the data.

In order to confirm or get better view of the reservoirs' potential of the area, it is suggested to drill deeper to get more data on the onshore and thorough analysis. It is strongly believed that good reservoir characterization contributes to the volume of reserve calculation.

REFERENCES

Akhir, A. M. (n.d.). *Model Konsep Lembangan Sungai Kelantan.* Kelantan: Jabatan Mineral dan Geosains.

Clauser, C. &. (n.d.). Thermal Conductivity of Rocks and Minerals. 106.

Cristian, R. &. (n.d.). *Carbon Dioxide Storage Capacity in The Upper Cambrian Basal Sandstone of The Midwest Region: A County-Based Analysis*.

Das, B. M. (n.d.). Weight-Volume Relationships, Plasticity, and Soil Classification. In *Fundamentals of Geotechnical Engineering* (pp. 38-45). Nevada: CENGAGE Learning.

Ehrenberg, S. N. (October, 2009). Petroleum Reservoir Porosity versus Depth: Influence of Geological Age. *AAPG Bulletin* , 1281-1282.

The Malaysia-Thailand Border Joint Geological Survey Committee. (2006). *Geology of The Melintang-Sungai Kolok Transect Area Along The Malaysia-Thailand Border.*

Halim, A. (n.d.). *Prediction Of Soil Thermal Using Single Probe Method.* Tronoh.

Metcalfe, I. (2013). Tectonic Evolution of The Malay Peninsula. *Journal of Asian Earth Sciences* , 195.

Nazaruddin, D. A. (2011). *The Study on The Importance Ecotourism for Local Community Empowerment in The Kelantan Delta Area, Kelantan, Malaysia.* Kelantan.

Jabatan Mineral dan Geosains. (1993). Kelantan: *Projek Bekalan Air Kelantan Utara*.

Ramm, M. &. (1994). Porosity/Depth Trends In Reservoir Sandstones: Assessing The Quantitative Effects of Varying Pore Pressure, Temperature History and Mineralogy, Norwegian Shelf Data. *Clay Minerals* , 475.

Robertson, E. C. (1988). *Thermal Properties of Rocks.* United States: United States Department of The Interior Geological Survey.

Sa, T. T. (2011). *The Worls's Coasts: Kelantan, Malaysia.*

Tjia, H. D. (1999). Geological Setting of Peninsular Malaysia. In *The Petroleum Geology and Resources of Malaysia* (pp. 141-142). Kuala Lumpur: Petroliam Nasional Berhad.

Yusoff, W. I. (1993). Geothermics of the Malay basin, offshore Malaysm. 21.

APPENDIX 1

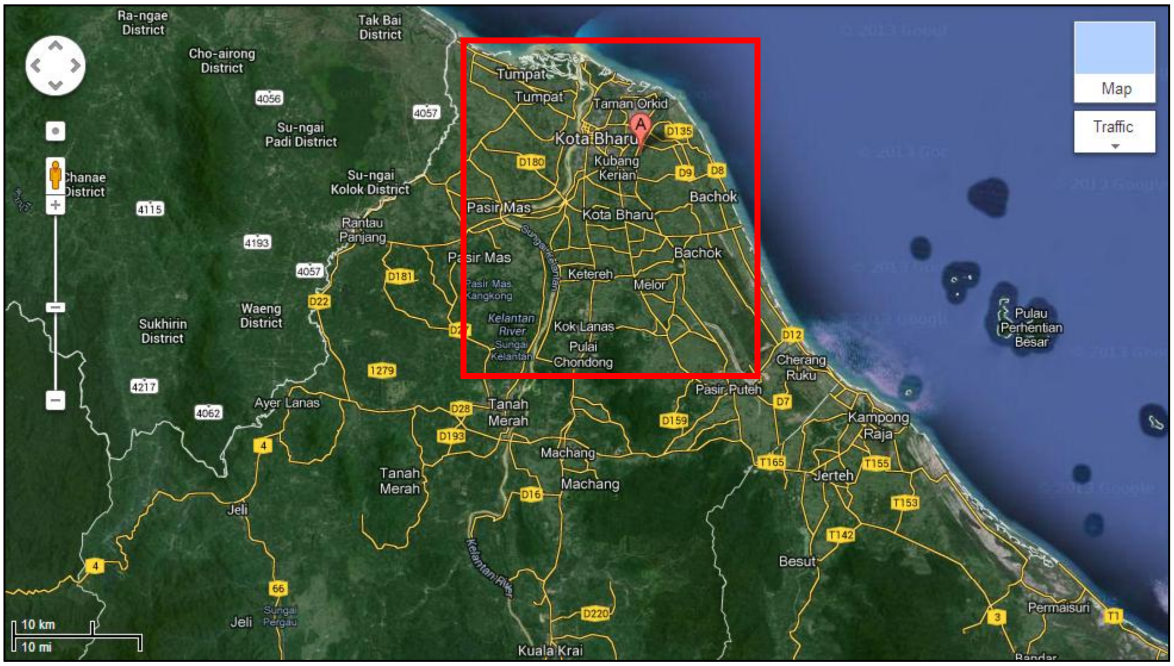


FIGURE 31: Location of the study area in Kelantan delta

APPENDIX 2

FIGURE 32: Sediments of Peninsular Malaysia. The red circle shows the location of the study area.

APPENDIX 3

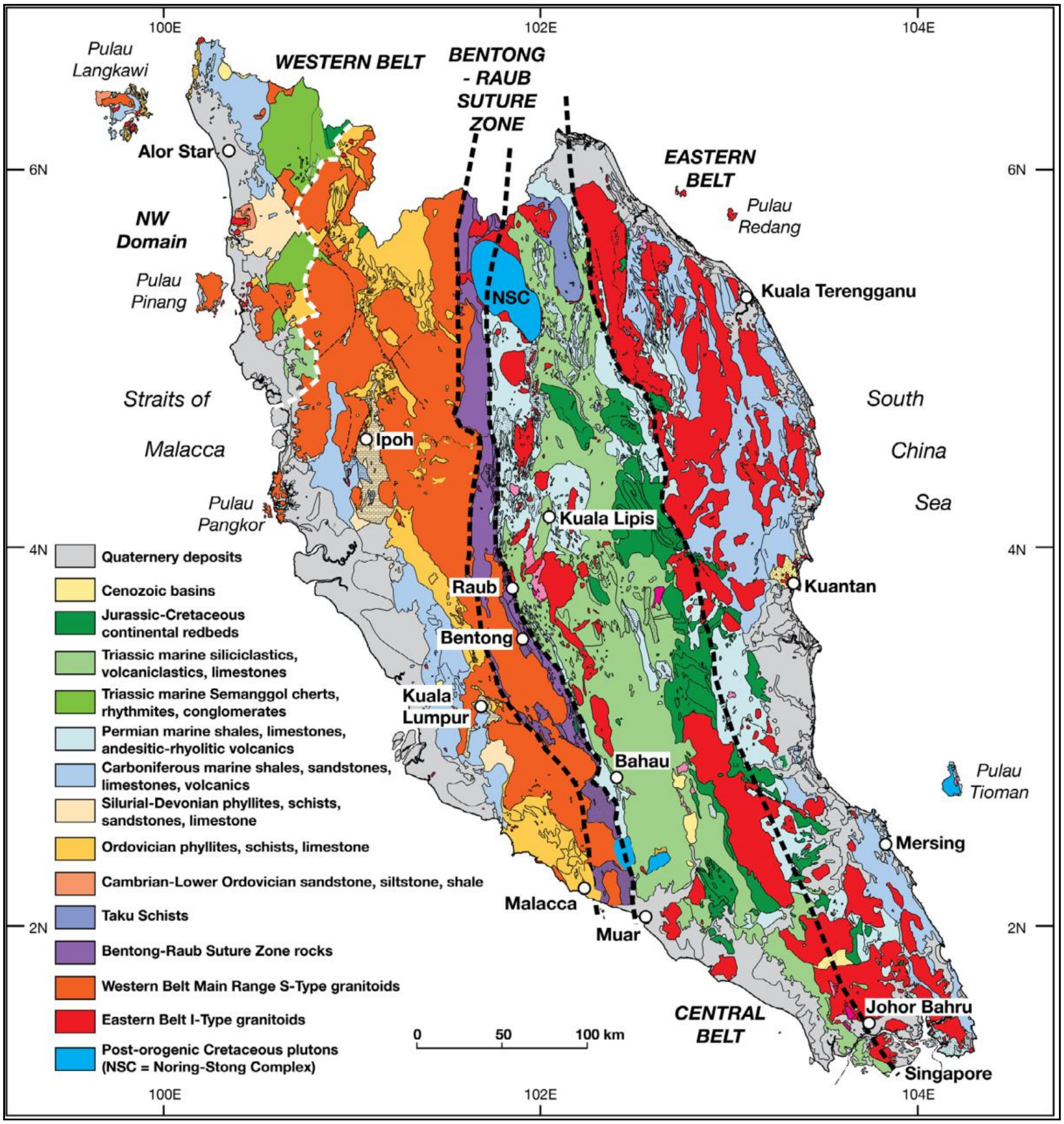


FIGURE 33: The simplified map of geological Malay Peninsula

APPENDIX 4

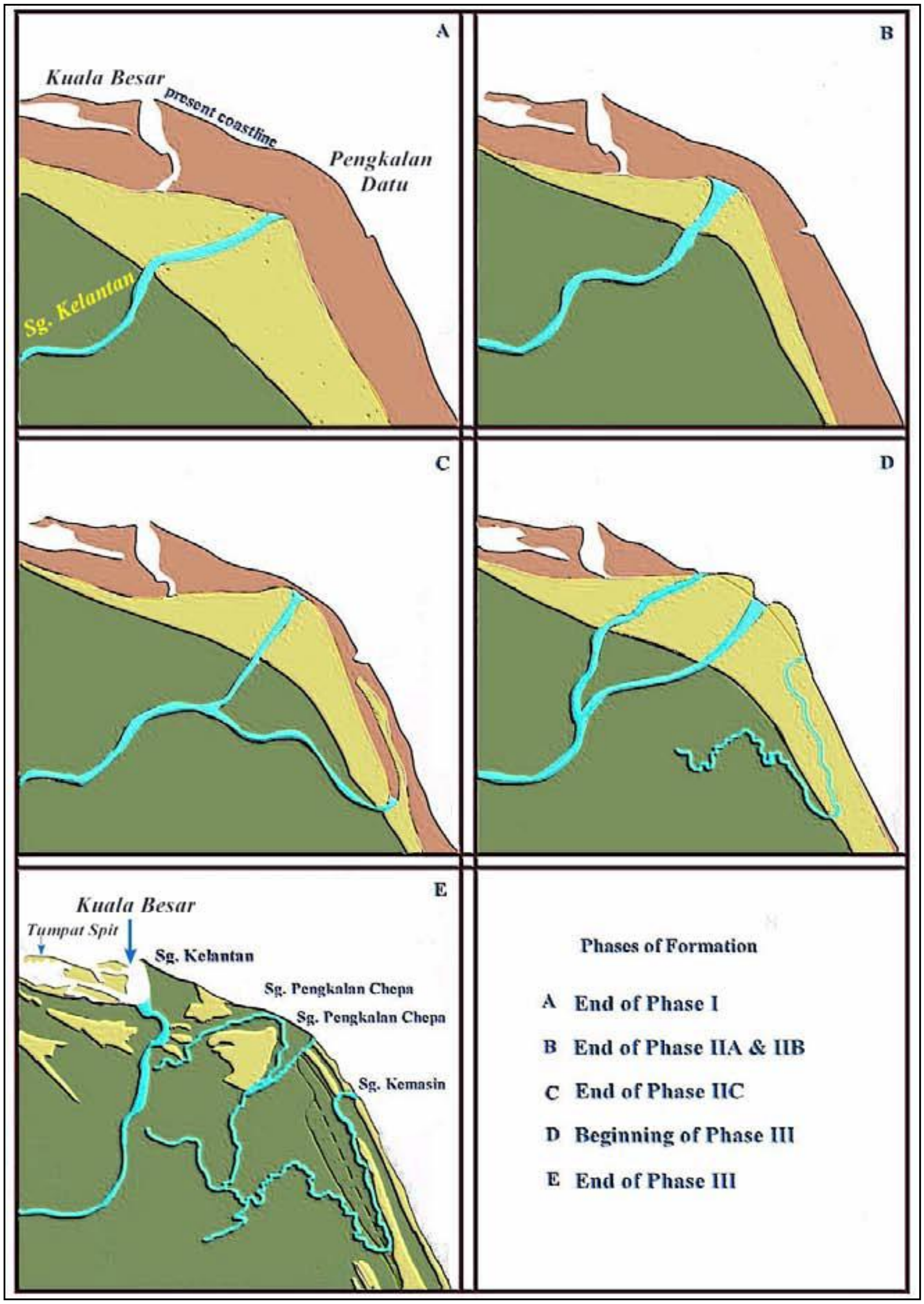


FIGURE 34: The delta evolution associated with the shifting river mouth

APPENDIX 5

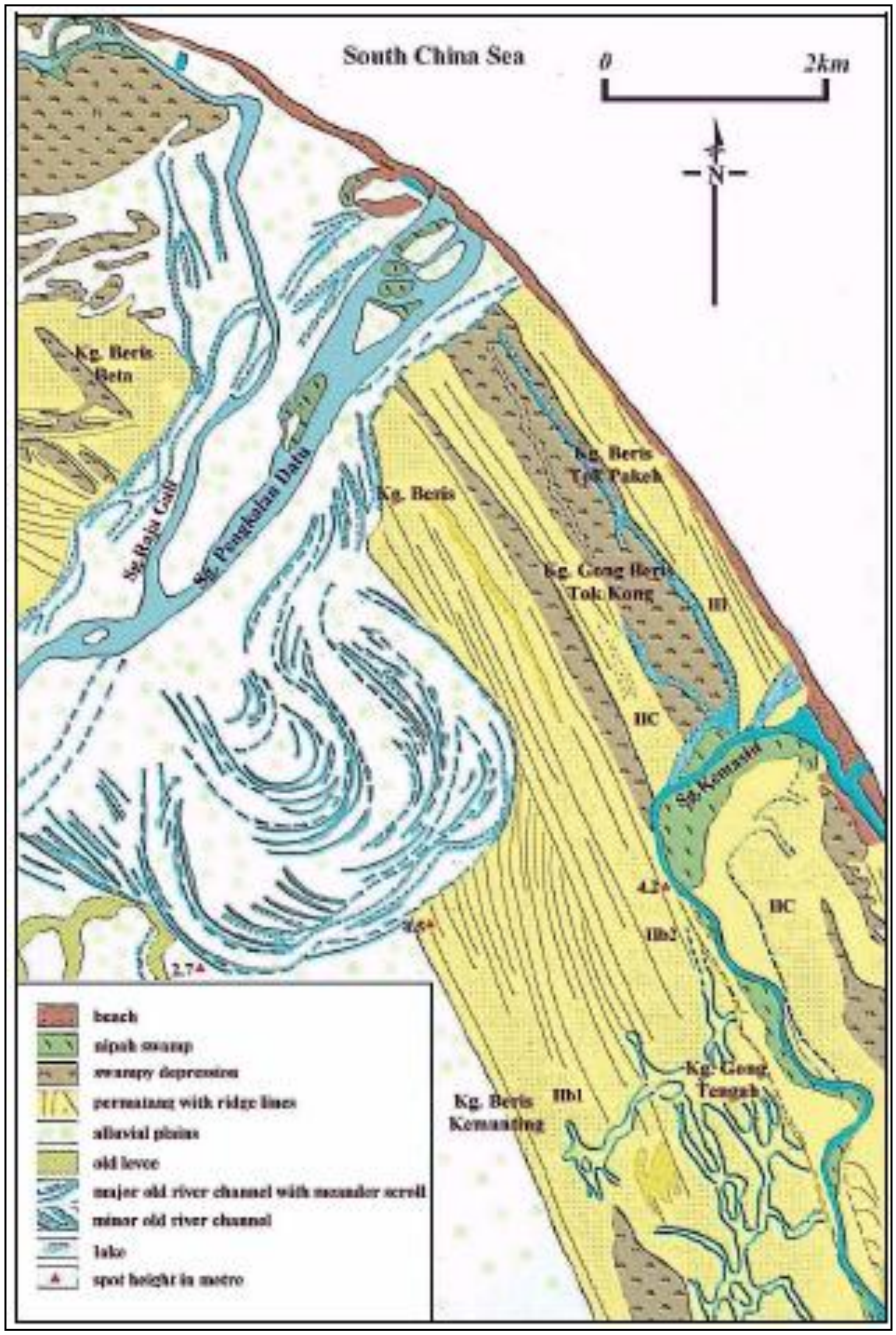


FIGURE 35:The geomorphology of northern area of Kelantan

APPENDIX 6

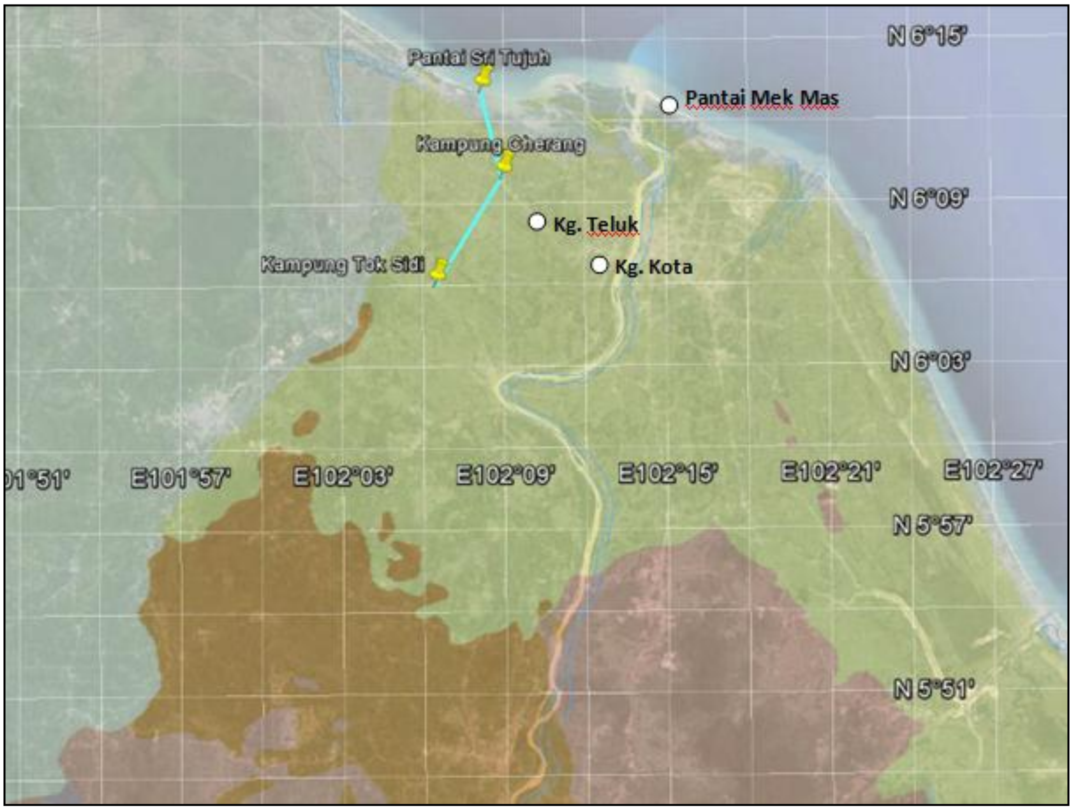


FIGURE 36: Lithology map overlay with Google Earth.