GEOLOGY AND SEDIMENTOLOGY OF SANDSTONES IN TELUK KALUNG AREA, KEMAMAN, TERENGGANU

by

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DECLARATION

I declare that this thesis entitled, “Geology and Sedimentology of Sandstones in Teluk Kalung Area, Kemaman, Terengganu” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ________________________________

Name :________________________________

Date : ________________________________

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Geology and Sedimentology of Sandstones in Teluk Kalung Area, Kemaman, Terengganu

ABSTRACT

Teluk Kalung is located at the southern part of Terengganu. It is known as an oil-and-gas based industry. It is also part of Sungai Perlis Beds which age about 359.2 to 299 million years ago which intruded by Jengai Granite 251 million years ago. The lithostratigraphy that had been observed in this study area consists of sandstone units, shales units, metasediments units, granitoid body and superficial deposits. There are Carboniferous plant fossils found to be preserved in the shales units in this study area; the Pteridosperm plants which are *Rhacopteris* sp., *Sphenopteris* sp. and *Sphenopteridium* sp. All of these plants fossils lived in warm and humid near-shore environment. The sedimentology study shows that the past depositional environment for the sedimentary rocks in this study area was deposited in marginal-marine environment. Meanwhile, the origin of the minerals in the sandstone of the study area originated from the sediments of recycled orogeny and craton interior based on the provenance study of the sandstones.

Geologi dan Sedimentologi Batuan Pasir di sekitar Kawasan Teluk Kalung, Kemaman, Terengganu

ABSTRAK

Teluk Kalung terletak di bahagian selatan Terengganu. Ia sangat dikenali sebagai industri berasaskan minyak dan gas. Ia juga merupakan sebahagian daripada Lapisan Sungai Perlis yang berumur kira-kira 359.2-299 juta tahun lalu yang telah dicerobohi oleh Granit Jengai kira-kira 251 juta tahun yang lalu. Berdasarkan pemerhatian yang telah dijalankan sepanjang kajian ini, litostatigrafi yang terdapat di kawasan kajian ini adalah terdiri daripada unit batu pasir, syal unit, unit metasedimen, badan granitoid dan superfisial. Terdapat fosil tumbuhan Karbon didapati disimpan dalam unit syal di kawasan kajian ini; tumbuh-tumbuhan Pteridosperm iaitu *Rhacopteris* sp., *Sphenopteris* sp. dan *Sphenopteridium* sp. Semua fosil tumbuh-tumbuhan ini merupakan hidupan yang hidup dalam persekitaran berhampiran pantai yang mempunyai klimat panas dan lembap. Kajian sedimentologi menunjukkan bahawa persekitaran pengenapan masa lalu untuk batu-batu sedimen di kawasan kajian ini telah disimpan dalam persekitaran marginal-marin. Sementara itu, asal-usul mineral dalam batu pasir kawasan kajian berasal dari sedimen daripada orogeni yang dikitar semula dan dalaman craton berdasarkan kajian provenans untuk batu pasir di kawasan kajian tersebut.

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LIST OF ABBREVIATIONS

km	Kilometre
m	Metre
cm	Centimetre
Mm	Millimetre
GPS	Global Positioning System
GIS	Geographic Information System
HCL	Hydrochloric acid
N	North
E	East
S	South
W	West
PPL	Plain Polarized Light
XPL	Cross Polarized Light

LIST OF SYMBOLS

%	Percentage
°	Degree
‘	Minutes
“	Seconds
φ	Phi
σ_1	Maximum forces
σ_3	Minimum forces
μ	Micro

CHAPTER 1

INTRODUCTION

1.1 General Background

The selected study area for this research study is in Teluk Kalung which is located at the western part of Kemaman. Teluk Kalung is known as an industrial town of Kemaman. This area is also known for its heavy metal and petroleum industry. The total area of Teluk Kalung is around 39.62 km^2. The total population of Teluk Kalung is around 6958 in 2010. In this area, there is beach along the eastern part of Teluk Kalung. The exact location of the beach is 4.286 N and 103.477 E.

Teluk Kalung and Chukai are two neighborhood town that which is connected by the Jalan Kemaman-Dungun as the main road used by the local residents. Chukai is the main town in the district where most government facilities is available there. In Teluk Kalung, there are two beaches as the recreation areas which are Pantai Marina and Pantai Teluk Kalung.

1.2 Problem statement

The geological map of this research's study area in the ratio of 1:25000 is not up to date plus the latest geological mapping for this study area that is supposedly conducted by authorities is still in pending status as stated in the Geological Society of Malaysia website. The previous geological map for Chukai district was published almost 30 years ago, in 1990 by Director of National Mapping of Malaysia. So, this problem must be solves by constructing this research study and produce an updated geological map of this particular area in scale of 1:25000.

For the research gap, the specific study about sedimentology and provenance of sedimentary rocks at Teluk Kalung has not been conducted by any researcher. In order to fulfil the gap, this research must be conducted in order to give details information about sedimentology and provenance of sedimentary rocks at Teluk Kalung.

1.3 Research objectives

For this research study, there are three main objectives need to be achieved:

a) To enhance a geological map of the study area with the scale of 1:25,000 ratio.

b) To determine the sedimentology of sandstones units in Teluk Kalung area.

1.4 Study area

For this research study, we collected several data such as location, demography, landuse, social economic, and road connection or accessibility in Teluk Kalung. All of these data have been collected from trusted sources such as Jabatan Pengairan dan Saliran Daerah Kemaman, Jabatan Perangkaan Negeri Terengganu.

1.1.1 Location

The study area for this research is from Teluk Kalong to Bukit Kuang. It is encompassed with coordinates of 04° 17' 53" N, 103° 25' 18" E to 04° 15’ 42” N, 103° 28’ 37” E as shown in the Figure 1.1. The total area selected for this research study is 30 km^2 equal to 6 km from north to south and 5 km from east to west.

1.1.2 Demography

According to Jabatan Pengairan dan Saliran (JPS) Kemaman, the people distribution data in Kemaman from the year 2000 until 2010 was estimated to exponentially increase. From the year 2000, the total population of Kemaman is 141,400 and in 2010, the total population of Kemaman had increased to 181,100 as shown in Table 1.2. Meanwhile, total people distribution based on age group of Teluk Kalung as recorded by Jabatan Perangkaan Negeri Terengganu (JPNT) in 2010 is shown in Table 1.1. Total people distribution in Teluk Kalung is 13,483.

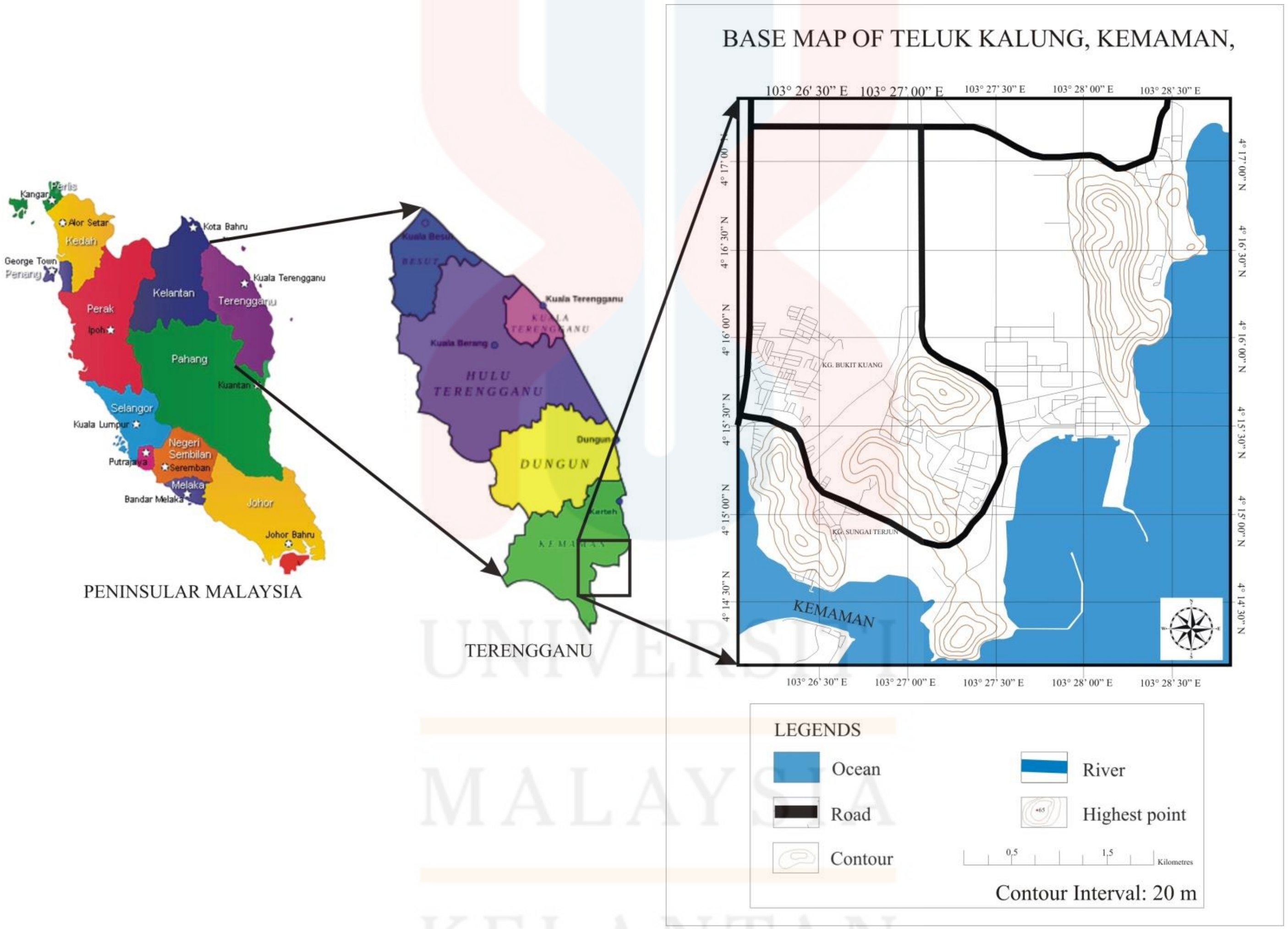
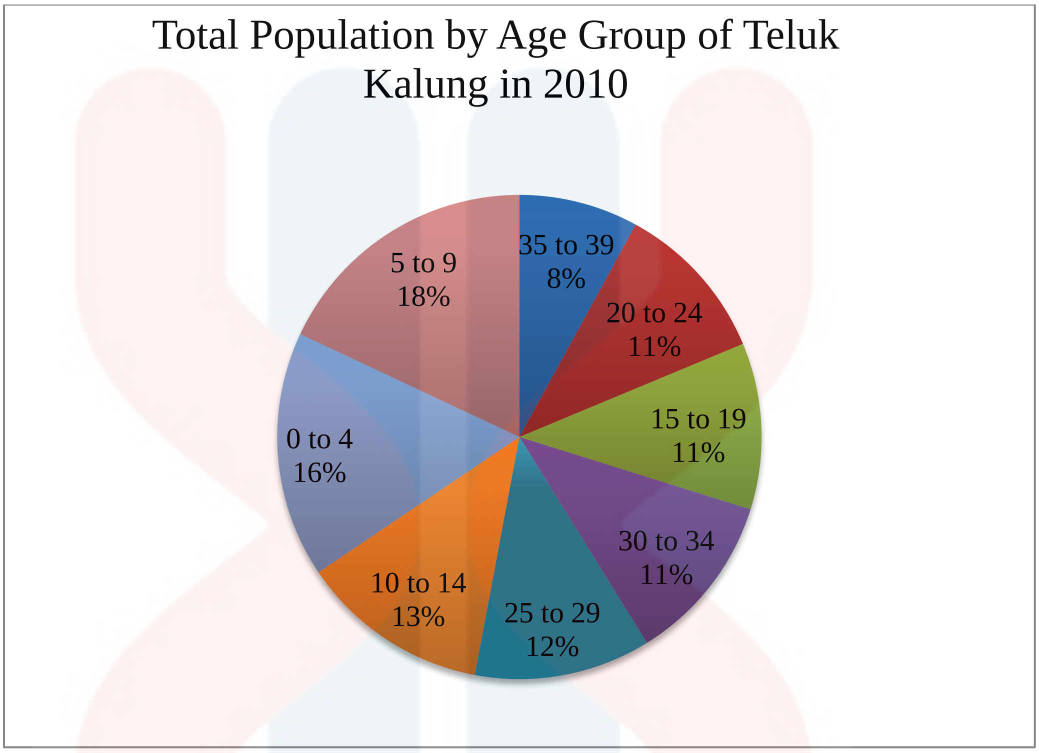


Figure 1.1: Base map of Teluk Kalung

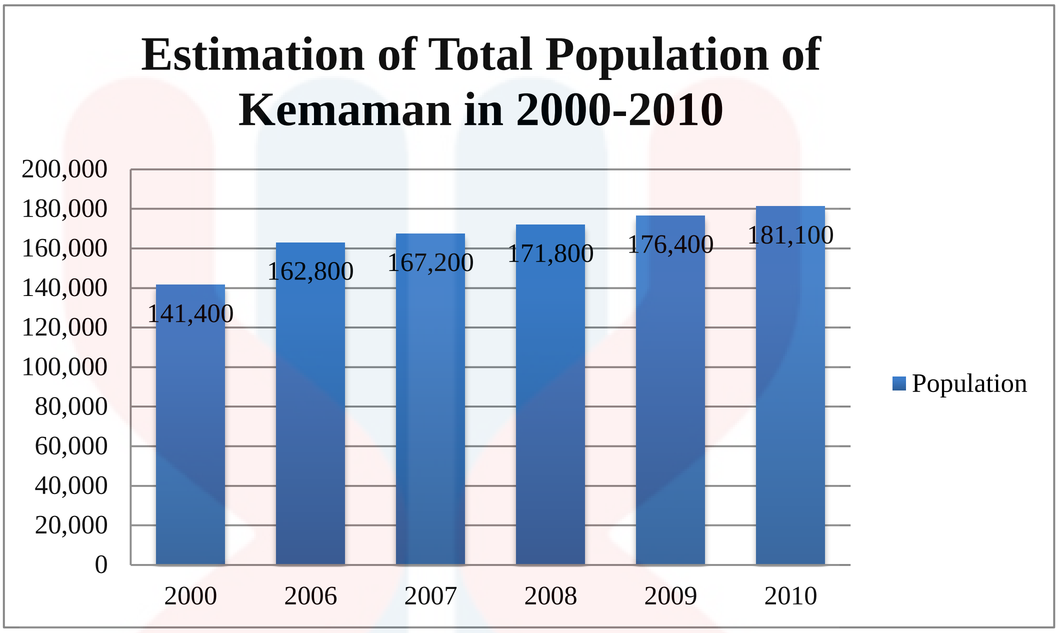
Table 1.1: Percentages of total population of Teluk Kalung by age group (Jabatan Perangkaan Negeri Terengganu, 2010)



1.1.3 Rainfall

In general, the climate of Teluk Kalung is similar to the climate of East Coast of Peninsular Malaysia that is tropical monsoon. The average annual rainfall of Teluk Kalung is around 2879 mm every year. The average annual temperature for Teluk Kalung is 26.5°C.

Table 1.2: The bar chart showing the estimation of total population of Kemaman in 2000-2010 (Jabatan Pengairan dan Saliran Daerah Kemaman)



1.1.4 Landuse

Based on the data recorded by Jabatan Pengairan & Saliran of Kemaman District (2010), the total area for Kemaman is 253,559.90 hectares and divided into 12 subdivisions of the districts. Teluk Kalung is one of the subdivisions in Kemaman. The total area of Teluk Kalung is 3,962.30 hectares with five villages. The division of landuse of Teluk Kalung can be seen in Table 1.3. In Kemaman, the total land use for agriculture is 73,344.3 hectares which equal to 28.9% of total area for Kemaman. The total area for industrial land use is 2,960 hectares which takes only 1.2% which most of them took place in Teluk Kalung.

1.1.5 Social economic

The social economic in this study area is mostly oil and gas industry. There are about hundreds of oil and gas companies operating in this study area such as Halliburton, Schlumberger, CariGali, Huntsman and a lot more. The residents of Teluk Kalung area are mostly works in this oil and gas industry. There is a supply base located in the Teluk Kalung named Kemaman Supply Base (KSB). This is the centre of the industrial activities of the oil and gas company (Figure 1.1).

1.1.6 Road connection

The main road that connects Teluk Kalung and Bandar Chukai is Jalan Kemaman-Dungun. The main road is paved road and has a lot of traffic lights. Most of local people and outsiders used this road as the main road but there are also few alternative roads in the villages and industrial areas. The alternative roads usually used by industrial worker that want to avoid traffic in early morning (Figure 1.1).

1.5 Scope of the study

Scope of the study for this research focused on the sedimentology and provenance of sedimentary rocks at Teluk Kalung by analysing the lithology, sedimentary structures, colour, geometry of the rock, the grain sizes analysis and facies analysis in this research study. This research also focused on the study about origin tectonic setting of the formation of sedimentary rocks at Teluk Kalung.

Table 1.3: The data of landuse in Kemaman district (Jabatan Pengairan & Saliran Daerah Kemaman, 2010).

Type of land use	Total area (hectares)	Percentages (%)
Agriculture	73,344.3	28.9
Building	9,126.6	3.6
Industrial	2,960.0	1.2
Forest reserve	76,389.0	30.1
Others	91,739.0	36.2

1.6 Research importance

The importance of this research study are to provide an updated geological information such as geological map regarding to the study area for further study or research academic purposes. By conducting this research study, the data about the composition, texture and structure of the sedimentary rock of Teluk Kalung can act as parameter to its sedimentology and provenance. So, this research study can provide better understanding about the sedimentology and provenance of the sedimentary rocks that exist in Teluk Kalung to the readers.

1.7 Chapter's summary

The study area is located at Teluk Kalung, Kemaman. In this research, the main objectives are to construct an updated geological map of the study area with the scale of 1:25000 and to determine the sedimentology and provenance of the sedimentary rocks at Teluk Kalung. The importance of this research study is to provide a detailed geological map regarding to the study area for future research academic purposes and provide better understanding about the sedimentology and provenance of the sedimentary rocks that exist in Teluk Kalung to the readers.

CHAPTER 2

LITERATURE REVIEWS

2.1 Regional Geology and Tectonic Setting

Peninsular Malaysia is a part of Sundaland that also includes Borneo, Java and Sumatera. Sundaland is a part of submerged southeastern extension of Asian continent in which the Peninsular Malaysia is connected with the Isthmus of Kra. Peninsular Malaysia has 130,268 km^2 of total land area (John, 2009).

Geographically, Sundaland area includes Peninsular Malaysia, Sumatra, Borneo, Java and Palawan. All of these regions are all located on the shallow sea of Sunda Shelf that was originally exposed as land during low sea level stands in Pleistocene Period (Metcalfe, 2011).

According to Charles (2009), Peninsular Malaysia is an integral part of the Eurasian Plate, the South-East Asian part of Sundaland. The rock formation of North-West of Peninsular Malaysia showed no interruption occurs until it across the Border of Thailand but the formation was named differently. Sibumasu block in Peninsular Malaysia correlated with Peninsular Thailand. For instant, Machinchang

Formation in Langkawi is equivalent and correlated with Tarutao Formation, southern Thai island.

Based on Metcalfe's tectonic model, the collision between Sibumasu block and East Malaya block generate a suture line which known as Bentong-Raub Suture. Thus, the large part of western coast of Peninsular Malaysia are belong to Sibumasu block meanwhile the smaller part of eastern coast are belong to East Malaya block (Metcalfe, 2001).

Peninsular Malaysia is divided into three main belts named as Western Belt, Central Belt and Eastern Belt. The boundary between the Western and Central Belt was drawn by connecting the serpentinite bodies that mainly found in Kuala Pilah area and Bentong-Raub area. This boundary was marked and named as Paleo-Tethys Suture or famously known as Bentong-Raub Suture (Ibrahim Abdullah, 2004).

2.2 Historical geology

Terengganu is located in the east part of Eastern Belt of Peninsular Malaysia. The dominant rock of Terengganu is mostly Carboniferous sedimentary rocks including metasediments and also granite (Khoo and Tan, 1983). The Sungai Perlis Beds are named after the Sungai Perlis, Ulu Paka in Terengganu. The age of this formation is Lower Carboniferous to Upper Permian (Lee Chai Peng et al, 2009).

2.3 Stratigraphy

2.3.1 Stratigraphy of Peninsular Malaysia

There are three main belts in Peninsular Malaysia which are Western Belt, Central Belt and Eastern Belt. Paleozoic rocks covered almost 25% part of Peninsular Malaysia. Based on *Stratigraphic Lexicon of Malaysia* by Lee Chai Peng *et al* (2004), there are 42 formations that have been identified and mapped into geological map of Peninsular Malaysia but there are few new formation have been added.

The Peninsular Malaysia have been divided into three belts by characterised it by different stratigraphy features. As we know, the Peninsular Malaysia divided into three main belts which are Western Belt, Central Belt and Eastern Belt as shown in Figure 2.1 (Lee Chai Peng et al, 2009).

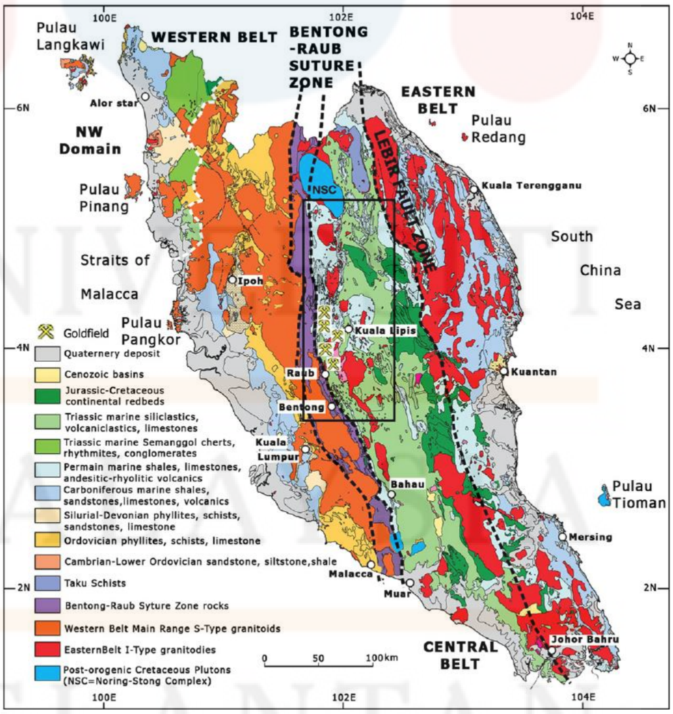


Figure 2.1: Division of three main belts in Peninsular Malaysia (Charles, 2009).

Western Belt includes the west part of Peninsular Malaysia which exposed in Langkawi, Kedah, Perak, Perlis, Selangor, Negeri Sembilan and Malacca. According to Lee Chai Peng *et al* (2009), Western Belt consist mostly rocks from Late Paleozoic. Outcrops that exposed in the Northwestern Domain of the Western Belt; in Langkawi, Kedah and Perlis are the most complete sequence of Paleozoic sedimentary rocks ranging from Late Cambrian to Late Permian. These outcrops are mainly deposited in shallow marine shelf environment of Machinchang and Jerai Formations, Setul Group, Timah Tasoh and Chepor Formations, Singa and Kubang Pasu Formations and Chuping Limestone that dipping eastwards to Mahang and Sungai Patani Formations. Western Belt has the oldest formation in Peninsular Malaysia which are Machinchang Formation and Jerai Formation. Both of these formations are believed to form in Middle Cambrian (Khoo and Tan, 1983).

The Central Belt stretches from Kelantan to Johor between the eastern foothills of the Main Range (Titiwangsa Range); marking as its western boundary. Central Belt boundary is marked by the Lebir Fault in the north down to the western boundary of Dohol Formation in the south Lee Chai Peng *et al* (2009). The main lithology of Central Belt is clastic sedimentary rocks, volcanic igneous rocks and limestones from Permian-Triassic. There is also deposition of pre-Early Devonian of coarse clastics, argillaceous sediment chert and other rock types occurred in the marginal belt that formed the foothills of the Main Range Granite. Previous research also found ultramafic bodies in the foothills belt which forcing the foothills to undergo regional metamorphism. Taku Schists and adjacent areas occupy the northern part of the Central Belt. The regional metamorphism exposed mainly schists, amphibolites and phyllites (Khoo and Tan, 1983).

Based on *Geology of Peninsular Malaysia* by Hutchinson and Tan, Eastern Belt consists dominantly of Paleozoic sediments which ranging in age of Carboniferous to Permian distributed from east Kelantan until Terengganu and from east Pahang to east Johor. Eastern Belt is hugely covered by Carboniferous and Permian clastic sedimentary rocks and volcanic rocks. During Permian Period, Eastern Belt experienced a phase of regional metamorphism, folding and uplift of continent followed by the deposition of an older series of continental deposits, for instant Murau and Redang Conglomerates. During Early Triassic, an event of orogenic uplift have occurred and followed by deposition of gentle dipping younger beds of continental deposits that might have uplifted in the Early Cretaceous (Khoo and Tan, 1983). Ibrahim Abdullah (2004) summarized that the northern part of Eastern Belt consists of the Carboniferous meta-sediments, igneous rocks and Jurassic-Cretaceous continental deposits.

2.3.2 Stratigraphy of Terengganu

Terengganu is located in the east part of Eastern Belt of Peninsular Malaysia. The dominant rock of Terengganu is mostly Carboniferous sedimentary rocks including metasediments and also granite. Terengganu have several formations that have been identified and formally recorded in the Geological Society Malaysia.

a) Sungai Perlis Beds

The Sungai Perlis Beds are named after the Sungai Perlis, Ulu Paka in Terengganu. The age of this formation is Lower Carboniferous to Upper Permian as shown in Figure 2.2. The thickness of the formation is around 1,500 m and mostly is argillaceous sedimentary rocks. Type areas for Sungai

Perlis Beds are catchment of Sungai Perlis, Sungai Jengai, Sungai Angka and Sungai Paka (Chand Fateh, 1978).

The formation consist interbedded carbonaceous slate, argillite, phyllite, variably metamorphosed siltstone and sandstone. The other minor lithology also present such as schist and minor lenses of quartzite, metaconglomerate and calc-silicate hornfels. Based on previous study, there is a lacking of fossil species identification that had been identified (Lee Chai Peng et al, 2009).

b) Redang Beds

The Redang Beds was named after Pulau Redang. The bedrock is unconformably lying above the Pinang Beds. Redang Beds consists the infamous Tumbu Kili Conglomerate- metaconglomerate with interbeds of black slate, quartzite and politic hornfels (Lee Chai Peng *et al*, 2009). Based on the study from Khoo *et al*, (1988), Redang Beds are interpreted to be continental fluviatile or deposited near shore. The previous research found several species of plant fossils such as Pecopteris sp., Calamites sp., Taenopteris sp., Cordaites sp.. all of these species are known as Redang Floral; its age is from Carboniferous to Permian (Khoo, Yaw, Kimura, Kim, 1988).

c) Pinang Beds

Pinang Beds in one of the stratigraphy unit found in Terengganu. It is named informally for the non-fossiliferous metasediments lying unconformably under the fossiliferous Permian Redang Beds on Pulau

Pinang- small island of Pulau Redang. The lithology of Pinang Beds consists of quartzitic calcite hornfels, pelitic hornfels, and slate. It was interpreted that the depositional environment of the Pinang Beds to be deeper than nearshore (Lee Chai Peng et al, 2009).

d) Charu Formation

There are another layer called as Charu Formation located in southern part of Terengganu and northern part of Pahang. Charu Formation also known as Cherul Formation. Based on the fossil findings, the age of the formation might be in between of Low Carboniferous to Permian. The dominant sedimentary rocks that lie in this formation is Carboniferous-Permian clastics sedimentary rock and carbonate rocks aged of Permian (Chand Fateh, 1978).

e) Gagau Group

The other stratigraphy unit existed in Terengganu is Gagau Group. Gagau Group was first introduced by Rishworth (1974). The Group was named after Gunung Gagau and this Group consists two distinctive formations; the Older Badong Conglomerate underlying Lotong Sandstone. The entire sequence of sedimentary rocks of Gagau Group ranges from the basal Gagau unconformity up to the recent erosional surfaces of Lotong Sandstone (Abdullah, 2009). There is some plant fossils found in Gunung Gagau area and the age of the plant fossils is around Late Jurassic to Early Cretaceous. Badong Conglomerate deposited above the basal Gagau unconformity and it is overlie by the Lotong Sandstone. The conglomeratic sediments are either massive or bedded and might to be occur in wedge-shaped bodies or laterally continuous beds. The conglomeratic bodies' thickness varies from thick accumulations in the hollow space of the Gagau basal to thinly bed or even absent over higher relief surfaces. In the other hand, Rishworth (1974) have stated the estimation of the bed's thickness; approximately 600 m to the northwest, 400-500 m in the southwest and 20-100 m in southeast.

f) Bukit Keluang Formation

Bukit Keluang Formation famously known for its conglomeratic bodies. Bukit Keluang Formation was named after the locality of the Bukit Keluang Conglomerate. According to Rishworth (1974), Bukit Keluang Formation was part of Gagau Group which contain of fining upward sequence of clastic sedimentary rocks. The sequences of formation consist of conglomerate in the lowest part, followed by sandstone and shale on the upper part of the sequence. Based on previous research, they have discovered plant fossils in Bukit Bubus and Bukit Dendong which give a powerful clue about the age of the Bukit Keluang Formation.

2.4 Structural Geology

The characterisation of the structure deformation can describe the flow path of the particles during the deformation occur and can infer the direction and the magnitude of the inner forces involved in the driving deformation. Structural geology is one of the main geological features that important to the Earth Science field.

Based on RADARSAT image, North-South fault zones are clearly observed as it acting as N-S negative lineament flanking granite batholiths. These faults are Besut Faults, Kampung Buloh Fault and Ping-Teris Fault Zone and some in Negeri Sembilan. According to (Tjia, 2000), the total traceable length of the faults is 150km approximately. These faults are sinistral strike-slip faults. They cut across the Permian-Upper Triassic granites (Shuib, Major Faults, 2009).

The Besut and Kampung Buloh fault zones are striking toward north-south and they dip steeply to east. At the southern end of these fault zones, it seems to be interrupted with NNW-SSE trending lineaments. They cut along and bound the Lawit and Kapal granite bodies. This deformation indicates that they are at least post Late Triassic.

Ping-Teris fault seem to strikes toward north-south and the fault pattern is sub-vertical. Ping-Teris fault cut through Carboniferous slate and phyllite giving rise to phyllonitic fault zone with contorted quartz veins (Tjia, 2000). The fault zones had undergone three phases of deformations. Due to dextral strike slip movement, drag folds and contorted quartz vein formed.

The other fault in Terengganu is in Pulau Kapas. In Pulau Kapas, the Kapas Conglomerate bounded to the north by an E-W normal fault. The fault is 100 m length and it is trending toward north-south. The Kapas Fault zone forms the western boundary of a continental deposit of probable Permian age; Kapas Conglomerate. Pulau Kapas had undergone several times of deformations and caused regional metamorphism. The Carboniferous metasediments in the Kapas Fault zone show the evidence of repeating movement of refolding. The evidence of the first phase of faulting is the soft sediments deformational structures in the Kapas Conglomerate.

Then, a drag fold formed and it was along the N-S bounding faults. The third wave deformation episodes is the dextral strike-slip fault movement that reactivated the N-S faults (Shuib, 2003).

Based on previous research, there are some dykes found in Teluk Kalung such as dolerite, lampophyr, and aplite along Tanjung Gemok to Tanjung Penunjuk. Xenolith also found in that area.

2.5 Sedimentology

Sedimentology rocks covered two per three of the Earth's surface. Sedimentary rocks have a special genetic features as their textures, structures, composition and fossils content act as the indicator to their past depositional environment and life forms in the ancient life. Sedimentary rocks are the valuable to us, geologist because they provide clues to the evolution of the Earth environment and living thing through time (Boggs, 2009).

For sedimentology, there are six aspects that need to be consider in analysing sedimentary rocks such as the lithology, texture of the sedimentary rocks, the sedimentary structures, the colour of the rocks, the geometry and relationship of the beds or rock units and the nature, distribution and fossil preservation that contained in the sedimentary rocks (Tucker, 2009). All of these aspects are important to determine the facies association and the depositional environment.

2.6 Petrography

Petrography is the branch of geology that concerned with the classification and description of the rock by observing mineral composition of the rock based on the physical analysis especially using microscopic observation. The physical analysis of the rock or macroscopic observation is done by observing the outcrop in the field by describing the physical appearance of the rock such as colour of the rock, the size of the grain, and the rock texture. Meanwhile for microscopic analysis, it's includes the analysis of the thin section under microscope (Boggs, 2009).

For sedimentary rocks, the size of the grains plays an important role for the classification of sediments and sedimentary rocks. Udden-Wenworth scale and Atterberg scale are widely used to identify the grain sizes. The Udden-Wenworth scale deals with logarithmic and geometric of the grains while the Atterberg scale covers the geometric, decimal and cyclical. Udden-Wenworth scale often used in sedimentology and petrology meanwhile the Atterberg scale is usually used in geotechnical, civil engineering, hydrogeology and engineering geology (Haldar & Tisljar, 2014). The Udden-Wenworth grain size scale as shown in Figure 2.2.

For sandstones, the most accurate classification is by petrographic. Commonly, this classification triangle that proposed by Pettijohn *et al* as shown in Figure 2.3 is useful for sandstones. There are four common types of sandstones which are quartz arenite, arkose, litharenite and greywacke. Furthermore, the observation of quartz, feldspar and lithic fragments are necessary for point counting purposes. Based on the result of point counting, the nomenclature for the sedimentary rocks will be obtained by plotting the values of point counting in the triangle of Quartz-Feldspar-Lithic Fragments (QFL) (Tucker, 1981).

Millimeters (mm)		Micrometers (µm)	Phi (φ)	Wentworth size class		Rock type
	4096		-12.0	Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0	Cobble		
	64		-6.0	Pebble		
	4		-2.0	Granule		
	2.00		-1.0	Very coarse sand	Sand	Sandstone
	1.00		0.0	Coarse sand		
1/2	0.50	500	1.0	Medium sand		
1/4	0.25	250	2.0	Fine sand		
1/8	0.125	125	3.0	Very fine sand		
1/16	0.0625	63	4.0	Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0	Medium silt		
1/64	0.0156	15.6	6.0	Fine silt		
1/128	0.0078	7.8	7.0	Very fine silt		
1/256	0.0039	3.9	8.0	Clay	Mud	Claystone
	0.00006	0.06	14.0			

Figure 2.2: Udden-Wenworth grain size scale

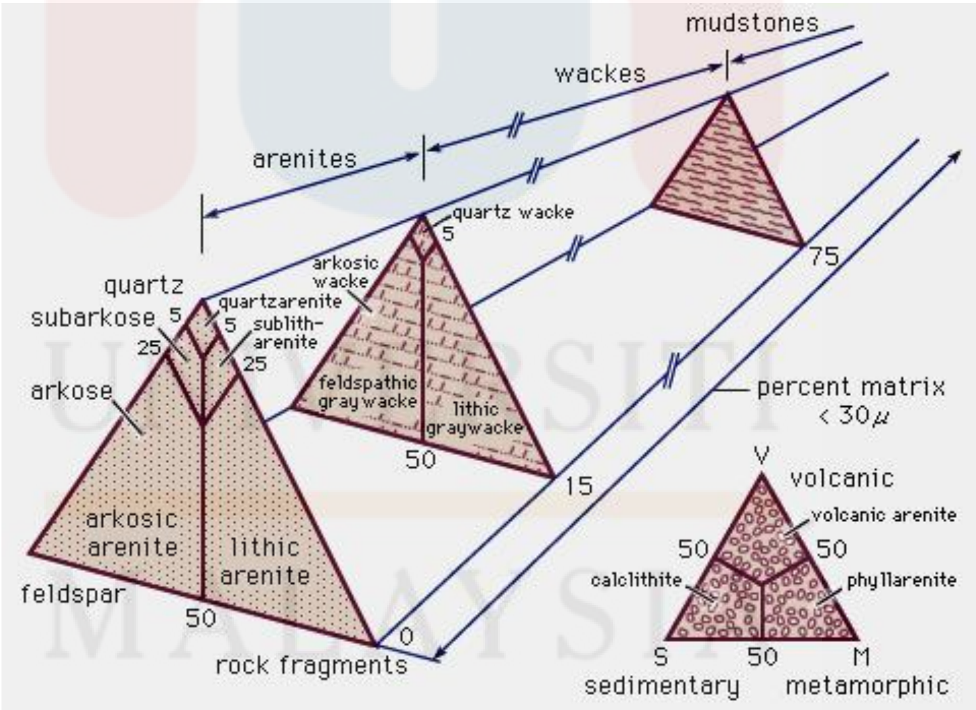


Figure 2.3: Pettijohn classification of sandstones (Haldar & Tisljar, 2014)

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

In order to conduct this research, there are several methods that are relevant to be used to gain the result of the research. The methods are preliminary research, materials, field studies, laboratory investigation, data analysis and interpretation, and report writing. Each of them plays an important role in completing this research.

3.2 Preliminary research

When a researcher wants to conduct a research, they have to do background study related to the research. The main purpose of preliminary research is to obtain sufficient and efficient information about the research by referring to the primary and secondary resources. Primary resources are the first-hand documentation or original documentation that has direct evidence about a topic under investigation. Mostly the primary resources are available in the original format for example research studies, diaries and letters. Meanwhile, the secondary resources are from textbooks, magazines and academic journals. This kind of resource is a type of document that written after an event has occurred and it is offer different perspectives, analysis, and conclusions of those documents.

By doing preliminary research, it enable the researcher to understand better how to conduct the research and it also can lead the researcher to set a goal or objectives for the research study. By reading or revising a lot of resources when doing preliminary research, the researcher can figure out the missing elements in the previous study so that the researcher can make a research gap. Furthermore, the researcher starts to dig out what the element that can attract the audience to read their paper by filling out the missing elements of the previous research.

3.3 Materials

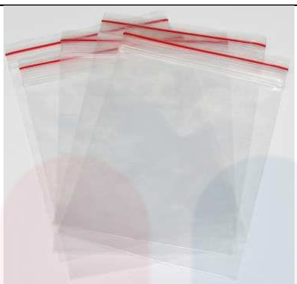
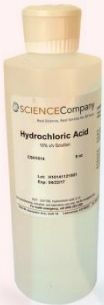
The materials that will be used to conduct this research are geological hammer, geological compass, geological map of the study area, hand-held GPS, dilute hydrochloric solution, measuring tape, hand lens, digital camera, and zip-lock sample bag.

Table 3.1: Materials used for the research study

Tools	Name & Function
	Name: Geological compass • Measure the strike and dip of the bedding, joints, fractures and other tectonic structures • Show direction of North • Measure the azimuth of the outcrop

	Name: Geological hammer • Most suitable tools to pick a sample from the outcrop
	Name: Hand-held GPS • Gives information such as coordinates and elevation for current location • Store traverse data and can be transfer in ArcGIS software

	Name: Measuring tape • Useful for measuring the thickness of bedding for lithology logs purposes
	Name: Digital camera • Capture the view of the outcrop and the geomorphology of the area • Capture the picture of samples
	Name: Hand lens • Provide a close view of mineral composition by using naked eyes • Suitable to use during the fieldwork

	Name: Zip-lock sample bag • Samples are put into the sample bag to avoid any damage to the sample for future reference
	Name: Field notebook • Record important information such as location of the outcrop, type of outcrop, structural geology and geomorphology of the study area.
	Name: Dilute HCL solution • Gives reaction when the samples have the presence of calcite minerals
	Name: Geological map • Provide a bigger view of the study area • As reference while traversing the map

3.4 Methodology

For every research study, there are several steps that need to be followed in completing the research. For this research, there are eight steps that play an important role to complete the research; preliminary research, problem statement identification, determine the objectives, field studies, laboratory investigation, conclusion and recommendation and lastly, report writing as shown in Table 3.2.

3.5 Field studies

As a geologist, geological field mapping is necessary in completing a research study by collecting various amounts of data from the field. The main point about fieldwork is being able to observe what you see and record it in detail. The data that we collected in the field work are lithology analysis, structural geology, geomorphology, and sedimentology.

a) Traversing

For this research study, traversing is the most suitable method to control the boundary of the geological mapping as there is no clear geological map about the study area. Traversing method is the best method because it enables the better view of the ground of the field and also exposes more detailed information such as structure of the outcrop (Barnes & Lisle, 2004). The purpose of traversing is to cover the study area of this research by 5X5 km per square. By traversing, the exact coordinates of lithology boundary can be obtain by using GPS and the coordinate then can be key-in into ArcGIS to get the picture of the lithology boundary in the map of study area in the scale of 1:25000.

b) Lithostratigraphic analysis

Lithostratigraphy analysis is an analysis about the lithostatigraphic unit that exist on the study area of the research. There are six aspects that we need to consider when constructing a field work such as the lithology of the study area, the texture of the rock – referring to the features and arrangements of the grains in the sediment, the sedimentary structures that exist in the bedding, the colour of the sediments or rocks, the geometry of the rocks and the preservation of fossils in the sedimentary rocks (Tucker, 2009).

By analysing the lithostratigraphic of the bedding, the information such as conformity, superposition, hiatus, and contact between the units of lithology can be identified. These informations are important to make a facies analysis.

c) Morphological mapping

The only way for the morphological mapping for this research to be done is by going to the field and observes the landform. Landform itself is vary in shape and size. Morphological mapping purpose is to identify the basic landform units in the field. By observing the geomorphology of this study area, the information of depositional environment can be determine as a result of the morphological mapping (Huggett, 2007).

d) Structural analysis

Structural analysis is an observation about the structure of the rocks such as faults, joints, folds and fractures. It is a study about the deformation and forces that acting on the rocks. The structure of the rocks can be observes along with traversing the study area. The strike and dips reading is important in determine the forces that deform the rocks structure. Then, a Rose diagram must be constructed to gain the direction of the force that acting on that particular area.

e) Sampling

For this research study, sampling is one of the important methods as it can provide detailed information for the facies analysis and also the mineral composition of the sample. The way to done this method was by rock picking using geological hammer or coring. For this research study, the sample of the rock were taken by breaking down the pieces of the outcrop by using a geological hammer. The samples taken are fresh and from *in situ* rock for thin section purposes.

The size of the samples taken was bigger than a size of fist that is efficient for sedimentological laboratory purposes. For each samples taken, the detail data recording was jotted down in the field note and the samples were labelled to avoid any confusion during laboratory work.

3.6 Laboratory investigation

a) Preparation of thin section

There were various methods of laboratory investigation used for this field of study but for this research study, preparing thin section was the best method to be done. For petrographic study, the samples of sedimentary rocks were prepared. The steps of preparing thin section were sectioning, vacuum impregnation, grinding and polishing of the samples.

By preparing thin section, the detailed information about the mineral composition was determined once the thin sections were done. The thin sections then were analyse under polarised microscope in order to determine the grain size, sorting, porosity, rock fabric and minerals abundances of each sample.

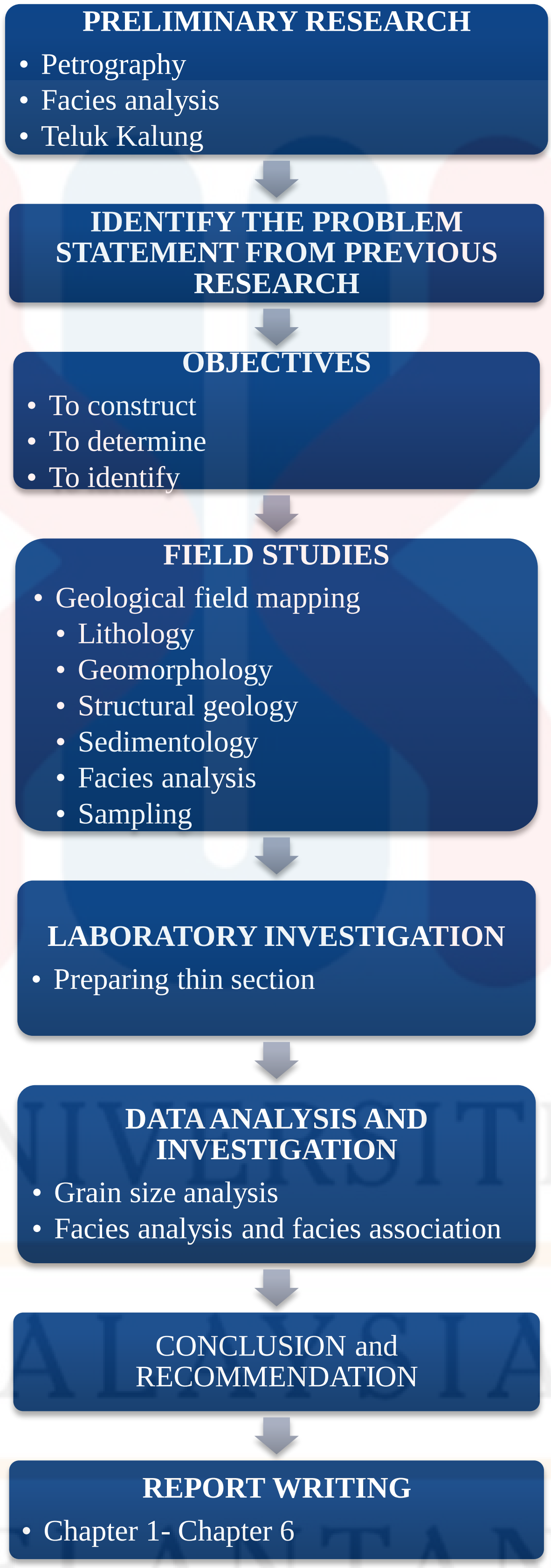


Figure 3.1: Research flow chart

3.7 Data analysis and interpretation

Data analysis and interpretation purpose is to obtain useful and usable data by conducting the research study.

3.7.1 Grain size classification and provenance

Grain size is the basic descriptive element in all sedimentary rocks. Udden-Wenworth grain size scale is widely used in describing the grain size of sedimentary rocks. The Udden-Wenworth grain size scale consists of seven grades of sediments which are clay, silt, sand, granules, pebbles, cobbles, and boulders. For sandstones, the first approximation observation of the grain size can be done by observing using hand lens. The clasts of conglomerates and breccias can be measured directly by using a measuring tape. For poorly cemented sedimentary rocks, sieving method is more suitable technique to analyse the grain size (Tucker, 1981). Grain size analysis is crucial to distinguished between sediments of different environments and facies. It also gives information on the depositional process and the flow conditions during the sediments deposition.

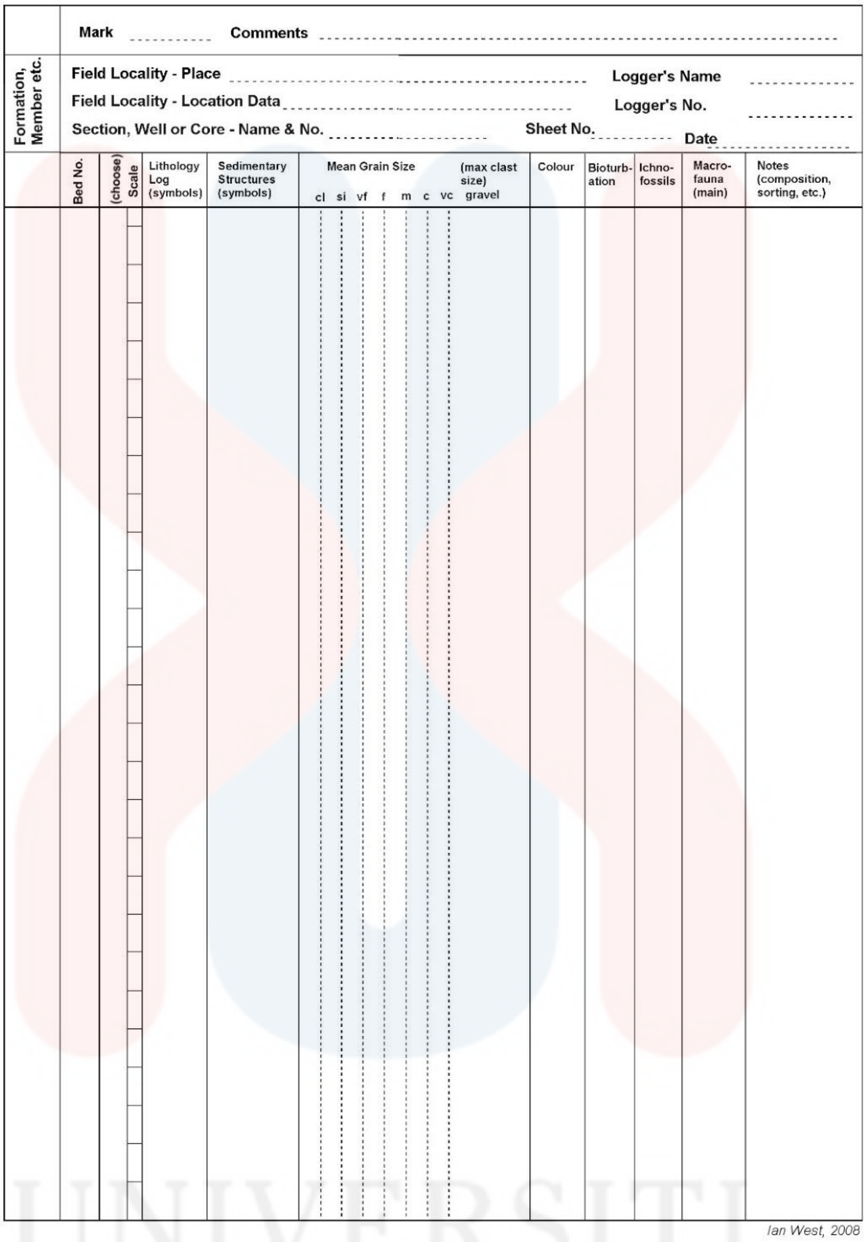
The presence of quartz, feldspar and lithic fragments through are necessary when observing the thin section under polarised microscope. The observation of minerals under polarised microscope is useful for point counting purpose. Each minerals; quartz, feldspar and lithic fragments is counted for every point by sketching the image of thin section observed in the graph paper. Based on the result of point counting, the percentage value of point counting for each mineral is calculated and plotted in the provenance triangle. From the plotting, the result will show the tectonic environment of formation for the sedimentary rocks observed.

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class		Rock type
	4096		-12.0	Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0	Cobble		
	64		-6.0	Pebble		
	4		-2.0	Granule		
	2.00		-1.0	Very coarse sand	Sand	Sandstone
	1.00		0.0	Coarse sand		
1/2	0.50	500	1.0	Medium sand		
1/4	0.25	250	2.0	Fine sand		
1/8	0.125	125	3.0	Very fine sand		
1/16	0.0625	63	4.0	Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0	Medium silt		
1/64	0.0156	15.6	6.0	Fine silt		
1/128	0.0078	7.8	7.0	Very fine silt		
1/256	0.0039	3.9	8.0	Clay	Mud	Claystone
	0.00006	0.06	14.0			

Figure 3.2: Grain size scale for sediments and sedimentary rocks (Tucker, 1981).

3.7.2 Sedimentology analysis

Sedimentology analysis is an analysis that allows the interpretation of the depositional environment of the lithostratigraphic units by determined their sedimentary structures such as the geometry and the primary structure of the bedding. A stratigraphic column has to be constructed to enable the researcher to analyses the facies and their associations. Facies is defined by their sedimentology characteristics; the lithology, colour, texture, geometry, fossils, sedimentary structures and paleocurrent pattern (Tucker, 2009).



Mark .... Comments ....

Formation, Member etc.

Field Locality - Place .... Logger's Name ....

Field Locality - Location Data .... Logger's No. ....

Section, Well or Core - Name & No. .... Sheet No. .... Date ....

Bed No.	(choose)	Scale	Lithology Log (symbols)	Sedimentary Structures (symbols)	Mean Grain Size cl si vf f m c vc	(max clast size) gravel	Colour	Bioturb-ation	Ichno-fossils	Macro-fauna (main)	Notes (composition, sorting, etc.)

Ian West, 2008

Figure 3.3: The lithology log sheet that important for jotting down the lithology log data (Robert, 2015)

3.8 Report writing

There are six main chapters for this final year project's report. This report must be clear and precise for the reader to read the content with some geological background. This report writing must contain precious information related to the title of the research project. This report writing must be done before the end of seventh semester.

Each chapter contain its own precise information such as Chapter 1 is the introduction of this research study which states the problem statement, objectives, scope of the study and research importances to the reader and society. Chapter 2 is the literature review part where the researcher has to study the previous study related to their research and rewrite the information that they have studied. Chapter 3 is the materials and methodologies part that will be used during the research study. Chapter 4 is the most important part which is the outcome that the research gets from the methodologies that they used. There is a lot of information gained from the methodologies used. Chapter 5 is the specification of the study which this chapter explain the detailed information about the specific study of the research study. Lastly, Chapter 6 concluded the overall research study and also the recommendation about the study.

CHAPTER 4

GENERAL GEOLOGY OF TELUK KALUNG, KEMAMAN

4.1 Introduction

General geology of this research site investigation such as geomorphology, stratigraphy, structural geology and historical geology data have been collected as it is important to determine its geological processes and evolution that affected the morphology of the area. This chapter emphasize the detail field observation and mapping which contributing such important information that required in this research. Based on Figure 4.1, the traversing method had been done in order to collect the essential data to achieve the objectives of this research. Figure 4.1 shows the accessibility of the study area, the culture in the study area by traversing the study area.

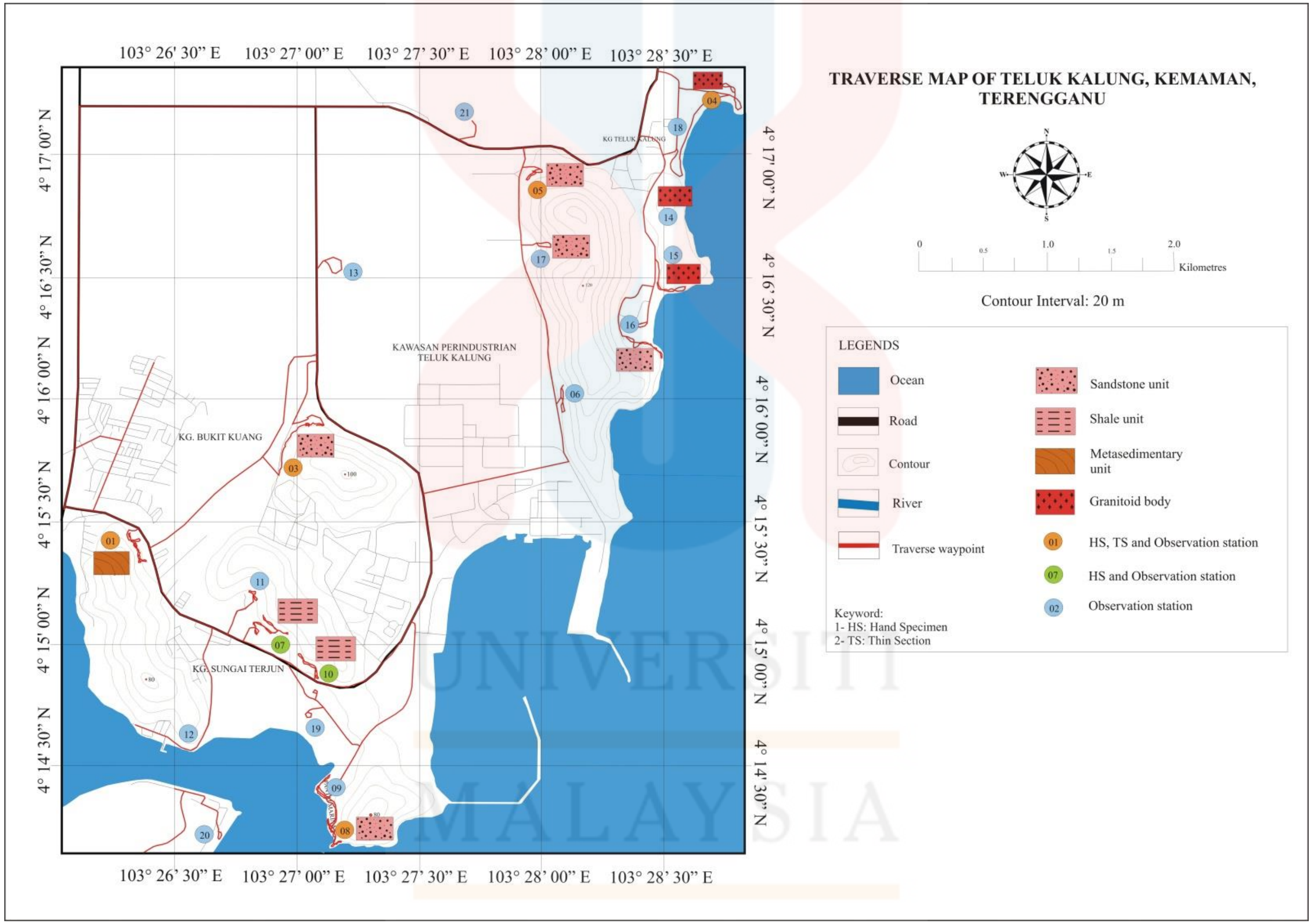


Figure 4.1: Traverse map and the station in the map.

4.2 Geomorphology of Teluk Kalung area

Geomorphology analysis is an analysis based on the physical features of the landform which related to the geological structures of the landform to gain precious information such as the geological event that occurs on the landform and its evolution. The only way to appreciate the landform is by go to the field and see them. Landforms vary enormously in shape and sizes as some might appear as karst topography, volcanoes, coastal plain and fluvial. In this research, landform features such as the topography, drainage, positive and negative lineaments and weathering process are essential for geomorphology analysis.

4.2.1 Morphology of Teluk Kalung area

The morphology of this study area dividied into two units of morphology which are low relief and high relief morphology. In these morphology units, it includes of few morphology element such as lowland (Figure 4.2, 4.3, 4.4), lowland inland (Figure 4.3), low hills and also coastal plain (Figure 4.5). The highest elevation for this study area is about 139 meter above the sea level as shown in the topography map in Figure 4.6. In this area, industrial activities dominated the land use which causing most of the land are excavated and discovered then it became lowland due to the industrial construction and development. Based on the Figure 4.6, the contours are mostly seen in the SE part in the map which this contour area is dominated by the non-industrial activities which is the residential area and the recreation area. The classification of the topography of the study area is classified based on the Van Zuidam's morphology element table as shown in Table 4.1.

The coastal plain landform dominated the east part of the map in Figure 4.6. There are two types of coastal plain that exist in this study area which are the coastal deposition and coastal erosion. The coastal deposition is the landform of the beaches where there is the laying down of material on the coast by the sea. This deposition occurs when the waves lose its energy and it also occurs when there are a large inputs of sediments made into the coastal system. In the study area, the landform caused by the coastal deposition is long shore drift. The coastal erosion is a result from the high energy waves, large fetch, high exposure and limited deposition.

Table 4.1: Van Zuidam's Morphography Element (Zuidam, 1985)

ABSOLUTE ELEVATION	MORPHOGRAPHY ELEMENT
<50 meter	Lowland
50 meter – 100 meter	Lowland inland
100 meter – 200 meter	Low hills
200 meter – 500 meter	Hills
500 meter – 1500 meter	High hills
1500 meter – 3000 meter	Highlands
>3000 meter	High mountains

Figure 4.2: Low relief morphology in Teluk Kalung area with coordinates of 4°14'46.19''N, 103°27'6.07''E.

Figure 4.3: The panoramic view of lowland and lowland inland morphology in Teluk Kalung area with coordinates of 4°14'59.90"N, 103°26'52.68"E.

Figure 4.4: The residential area in lowland morphology in Teluk Kalung area in panoramic mode

Figure 4.5: The panoramic view of coastal plain morphology in Teluk Kalung area

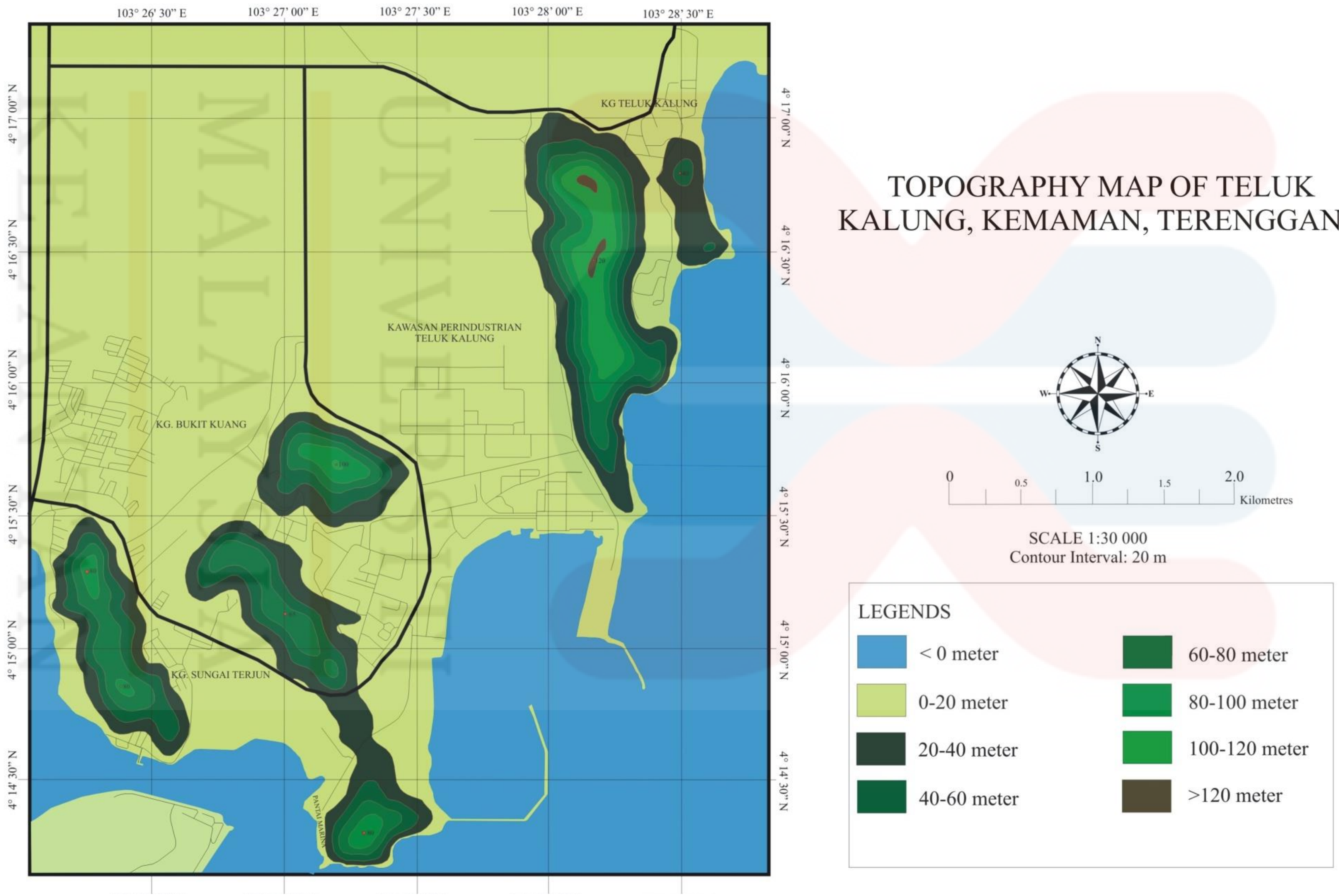


Figure 4.6.: Topography map of this study area

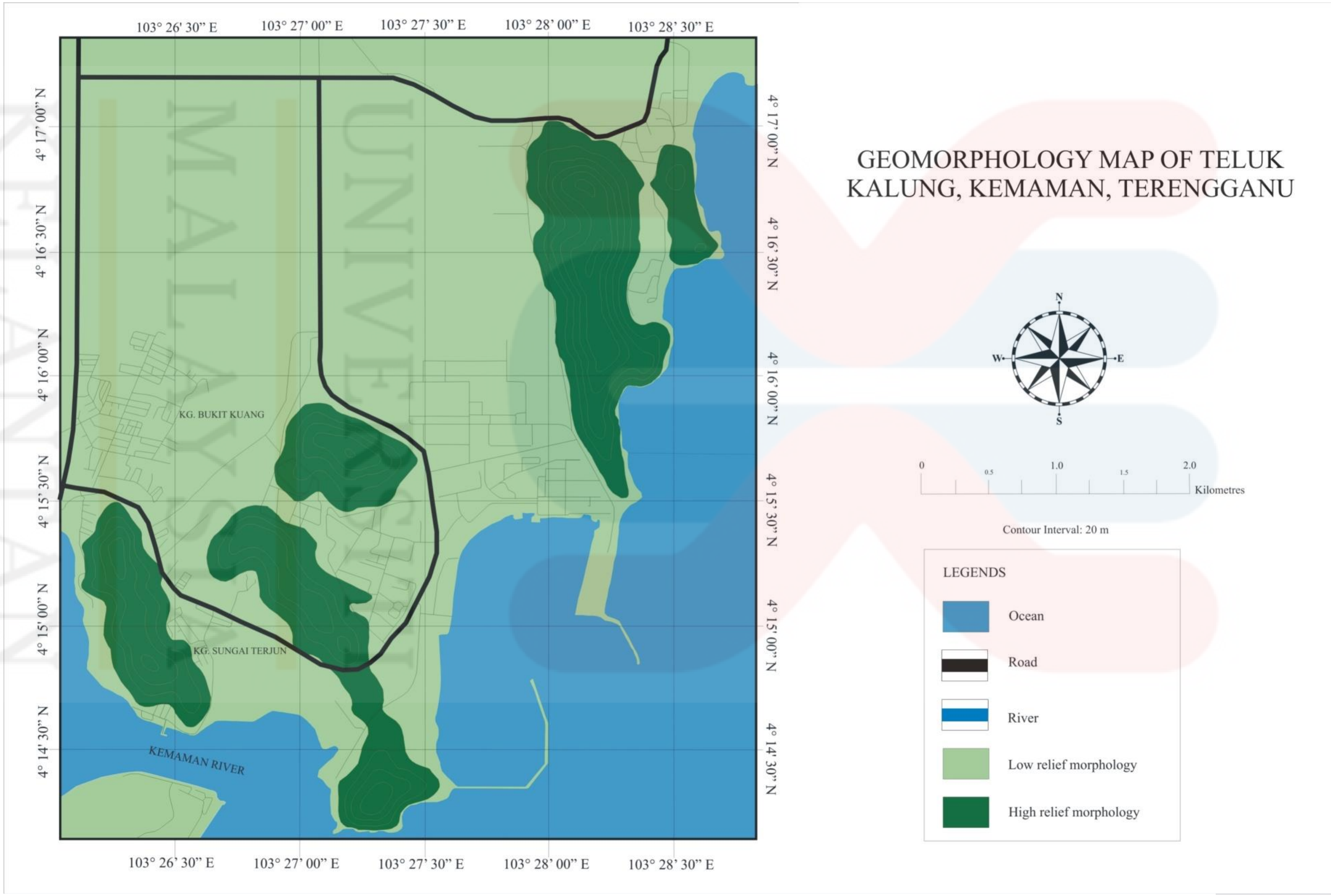


Figure 4.7: Geomorphology map of the study area that show the low relief and high relief morphology

4.2.2 Drainage of Teluk Kalung area

The drainage existed in this study area is river estuary as shown in drainage map (Figure 4.9). River estuary is semi-enclosed coastal body of water which have connection with open sea. Estuary does receive freshwater runoff and limited salt intrusion flowing from rivers and stream. In this study area, the South China Sea progressively enters the river and the topography of the estuary is similar with the river valley. This type of estuary is most common type in such humid climates. The characteristic of the drowned river valley is typically large. It appeared as wedge shaped in the cross sectional part and this river is broadening and deepening toward the sea. Figure 4.8 shows the view of the river estuary from the ground level.

Figure 4.8: The drowned river valley in Teluk Kalung area with coordinates of 04 14’ 33” N, 103 26’ 30” E.

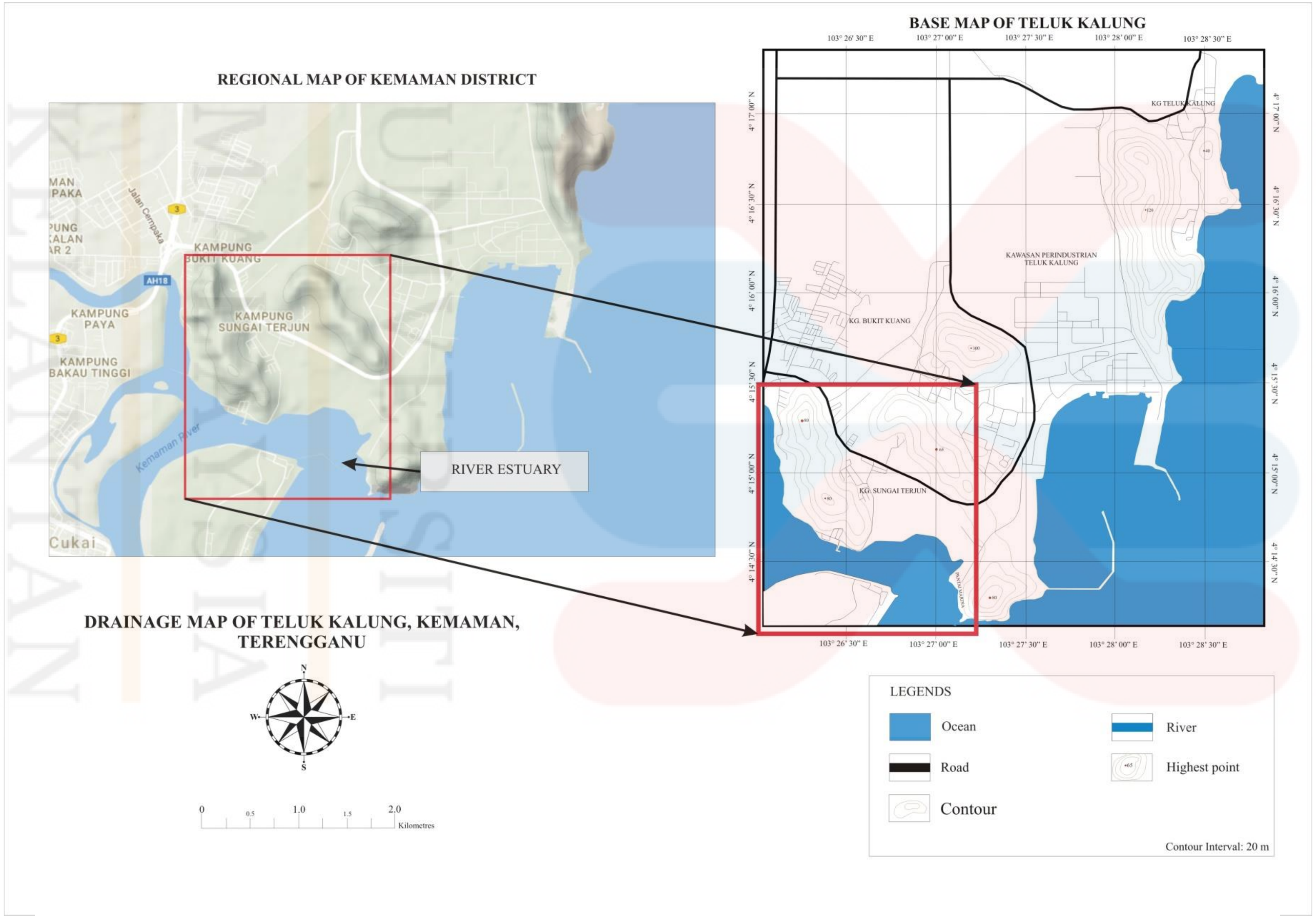


Figure 4.9: Drainage map of Teluk Kalung area which showing the river estuary locality in the regional map

4.2.3 Weathering process of Teluk Kalung area

Weathering process that acting on the rock bodies comes in various ways whether in physical weathering, chemical weathering and biological weathering. Weathering process does affect the rock in physical or chemical characteristics. The rate of weathering process can be accelerated by few factors such as the climate of the region, the temperature and thermal expansion that acting on the rock.

a) Physical weathering

Physical weathering is a weathering process that breaks the rock into smaller pieces without changing any chemical composition of the rocks. In this study area, the physical weathering process does break the rocks along its joint and fracture. The joints are the result of mechanical physical weathering (Figure 4.10).

Figure 4.10: The jointing set in the rock bodies is one of the result of the physical weathering.

There are some rocks that undergo salt crystallization which caused the rock to form structure like honeycomb structure in Figure 4.11. It is common structure for rocks along coast lines. Honeycomb structures in rock can occur when there are salt water or wind that dominates the rock bodies.

Figure 4.11: The honeycomb structure in sandstone body as a result of physical weathering.

The mechanism for this weathering is salt heaving which the salt is deposited on the surface of the rock by salt water spray or by wind. In order to allow the salt to settle on the rocks, the moisture must be present so that the salt solution can evaporated and it will begin to crystallize within the pore spaces in the rock bodies. The salt crystals pry the mineral grains apart and started to enlarge the pore spaces in the rocks.

b) Chemical weathering

Chemical weathering is a weathering process that breaks the rock by changing its chemical properties. Chemical weathering has various types such as oxidation, hydrolysis, and carbonation. Chemical weathering agents are rain water, seawater, and groundwater. The rate of chemical weathering can be rapidly occur when the climate are warmer and humid; this condition will accelerate the chemical reaction between the mineral grains.

Chemical weathering is the most weathering process that affecting the physical appearances of the rock in the study area especially in the coastal plain morphology. This is because the rocks are exposed to the sea water and the temperatures of the coastal plain are warmer which allowing the chemical weathering to change the rocks' properties. There are a few types of chemical weathering that occur in the study area such as oxidation (Figure 4.12).

Figure 4.12: The oxidation that weathered the sandstones in Pantai Marina.

4.3 Stratigraphy Of Teluk Kalung area

The stratigraphy of this research area consists of Sungai Perlis Beds sedimentary rocks and metasedimentary rocks and also Jengai Granite. The correlation of the formation has been confirmed by observing the types of lithology that exist in the study area and also strengthen by the plant fossils discovery. All of these information are compulsory to determine the formation of the study area and the depositional environment of these units. Sungai Perlis Beds is older than Jengai Granite that intruded the regional of Teluk Kalung (Ong Yeoh Han, 2009). The distribution of these lithologies can be seen in the geological map in Figure 4.46.

Table 4.2: The lithostratigraphic column of the study area, Teluk Kalung (Lee Chai Peng *et al*, 2009)

AGE	FORMATION	UNIT	LITHOLOGY	EXPLANATION	FOSSILS	DEPOSITIONAL ENVIRONMENT
Qtrny. to recent	SUPERFICIAL DEPOSITS	Marine deposits		Contains marine deposits which are coarse sand to fine sand, silt-size sediments, clay-size sediments and also coral pieces from the sea		Marginal-marine environment
Late Permian to Early Triassic	JENGAI GRANITE	Granitoid body		Contains of 3 types of granite which are biotite granite, alkali feldspar granite and monzogranite.		
Lower Carboniferous	SUNGAI PERLIS BEDS	Metasediments		Contains of dominated metasedimentary rocks with sandstones.		Marginal-marine environment
		Shale		Contains of dominated shales interbedded with sandstones, metasedimentary rocks such as slate and phyllite.	Consists of Pteridosperm plant fossils: 1) *Rhacopteris* sp. 2) *Sphenopteris* sp. 3) *Sphenopteridium* sp.	Marginal-marine environment
		Sandstone		Contains of dominated sandstones with minor siliclastic sedimentary rocks such as siltstones, mudstones, and shales.		Marginal-marine environment

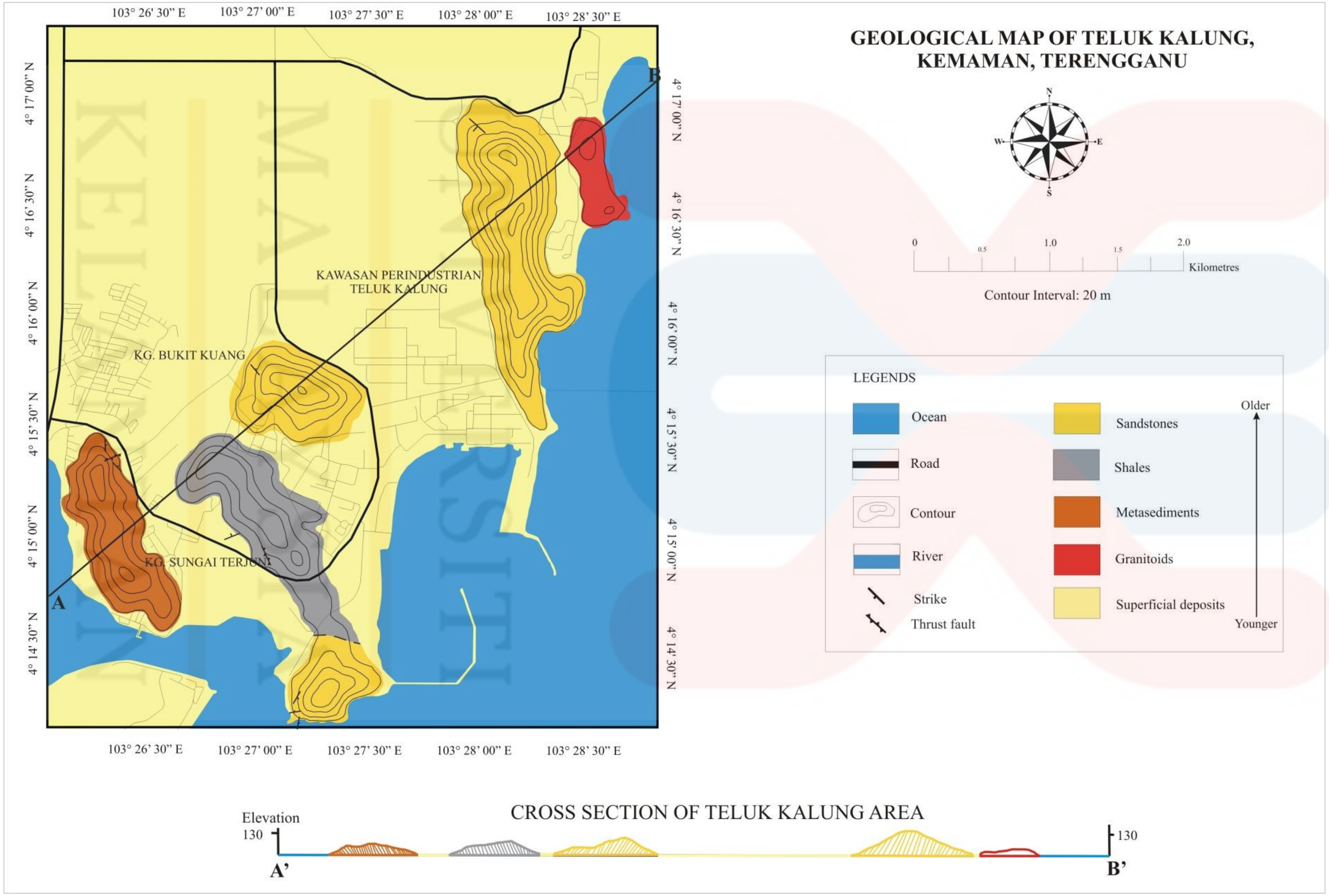


Figure 4.13: The geological map of Teluk Kalurng area that show the distribution of the lithostratigraphic unit in the study area

4.3.1 Lithostatigraphy Units In Teluk Kalung area

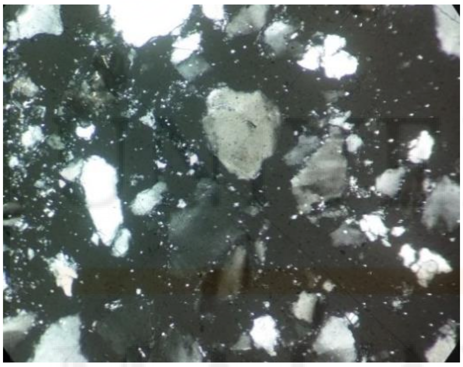
a) Sandstone unit

Sandstone is a clastic sedimentary rocks that consists of sand-size grains minerals, lithic fragments and may consists organic materials. Sandstones found in this study area have various types of grain size, colours and textures. Sandstones' grain size range between very coarse sand (0.5 mm - 1.0 mm) to very fine sand (0.0625 mm – 0.0310 mm) according to Wentworth Size Class.

The sandstone unit that had been observed in locality 16NAD03 (Figure 4.14) shows some physical characteristics that can be seen by naked eyes such as the colour, textures, and grain size. From the physical characteristics observation, the colour of the sandstone (16NAD03) is brownish for its appearance colour due to the weathering but the actual colour is light brown. The texture of the sandstone is smooth. The grain size of the sandstone is medium sand grain. The thickness of this unit is about 45 meter in long as the sandstone-dominated hill cutting outcrop is exposed along the hill side.

Figure 4.14: The lithic arenites interbedded with very fine siltstones bedding located in locality 16NAD03.

Table 4.3.-: Lithic arenites under 10X magnification microscope. The composition of this minerals are quartz mineral (C4, F3, H3) and lithic fragments (A5, H1, I2).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
2											**2**											**2**
3											**3**											**3**
4											**4**											**4**
5											**5**											**5**
	XPL											**PPL**										

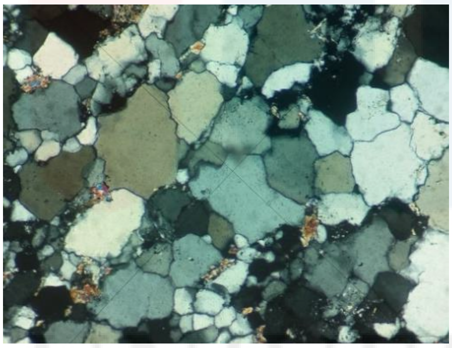
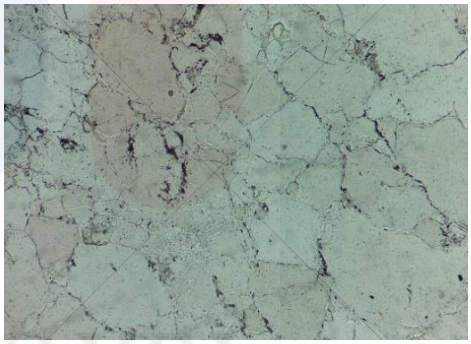
The microscopic observation for this sandstone shows that this sandstone comprises of quartz minerals (58%) and lithic fragment (42%) as shown in petrographic table; Table 4.3. The shapes of the minerals are mostly sub angular. The sortation of the mineral grains is poorly sorted. The grain size of the minerals is about 1/8 mm to ¼ mm. Based on these observation, the naming of the sandstone is tuffaceous sandstone. Detailed discussion about the sedimentology and its depositional environment will be discussed in Chapter 5.

Next, in locality 16NAD04, the sandstones units observed is slightly differ with previous locality, 16NAD03. The colour of the fresh specimen is light grey. The texture of the sandstones is sandy due to its grains size. The grain size of the sandstone is medium sand grain. The size of the bedding is about 5 meter in width and 4.5 meter in height (Figure 4.15).

Figure 4.15: The outcrop of metasandstone interbedded with quartz arenites located in locality 16NAD04

The microscopic observation of this sandstone also had been done. The mineral composition of this sandstone is quartz (98%), pyroxenes (1%) and matrix (1%) as shown in Table 4.4. The sortation of the mineral grain is well sorted. The grain size of the minerals is about ¼ mm to ½ mm. Based on these observation, the naming of the sandstones is quartz arenites according to Pettijohn Classification (1975). Detailed discussion about the sedimentology and its depositional environment will be discussed in Chapter 5.

Table 4.4: Quartz arenites under 10X magnification microscope. The composition of this minerals are quartz mineral (D3, F4, J2), pyroxenes (C5, G4) and lithic fragments (H5).

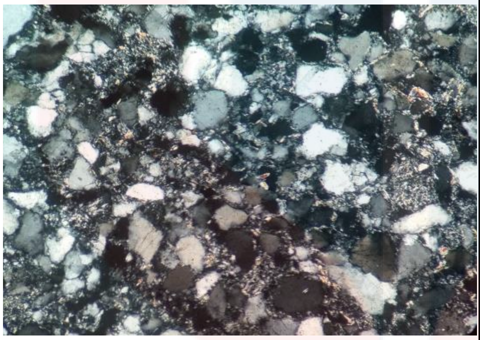
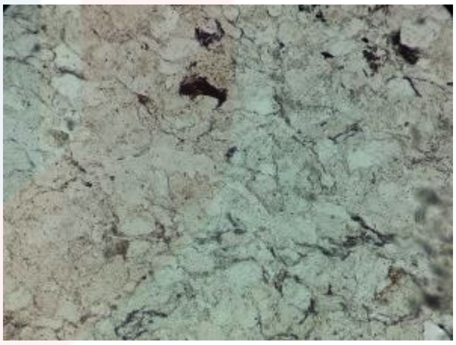
	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
2											**2**											**2**
3											**3**											**3**
4											**4**											**4**
5											**5**											**5**
	XPL																			*PPL*		

Next, in locality 16NAD08, the sandstones observed is differs with other sandstones. The colour of the fresh specimen is light greenish grey. The texture of the sandstones is smooth due to its grains size. The grain size of the sandstone is fine sand grain. The bedding of the sandstones is interbedded with shales in Figure 4.16. The microscopic observation of this sandstone also had been done.

The mineral composition of this sandstone is quartz (75%), and lithic fragments (25%) as shown in Table 4.5. The sortation of the mineral grain is well sorted. The grain size of the minerals is about ¼ mm to ½ mm. Based on these observation, the naming of the sandstones is lithic arenites according to Pettijohn Classification (1975). Detailed discussion about the sedimentology and its depositional environment will be discussed in Chapter 5.

Figure 4.16: The outcrop of lithic arenites interbedded with shales located in Locality 16NAD008

Table 4.5: Lithic arenites under 10X magnification microscope. The composition of this minerals are quartz mineral (E2, G3, H5) and lithic fragments (D2, I3).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
2											**2**											**2**
3											**3**											**3**
4											**4**											**4**
5											**5**											**5**
	XPL																			*PPL*		

b) Shales unit

Shale is a fine-grained siliciclastic sedimentary rocks. It contains more than 50 percent of siliciclastic grain less than 0.062mm in diameter. They are dominantly made up of silt-size and clay-size particles. Shales are differ with mudstones as it show fissility or lamination in its bedding compared to mudstones. Shales are an indicator to depositional environment as shales are formed from marine environments where they deposited on the seafloor. It also can form in lakes or quiet water in rivers, lagoonal, tidal flat and deltaic environments. The shales unit found in this study area is mostly interbedded with siltstone, sandstone, phyllite, and carbonaceous slate which the shales is the dominant lithology in the bedding. The shales in this study area have several physical characteristics that have been observed.

The shales unit that had been observed in locality 16NAD07 (Figure 4.17) shows some physical characteristics that can be seen by naked eyes such as the colour, textures, and grain size. From the physical characteristics observation, the colour of shales is light grey. The grain size of the shales is silt size to clay size shales and the percentage of clay-size particles in the shales is about 55%. The texture of the shales is smooth due to the grain size. The outcrop of this shales unit also contain sandstone, phyllite and carboneceous shales. The thickness of this unit is estimated to be about 45 meter in long according to the lithology log that have been recorded during the field observation. There are plant fossils found in this bedding units which is *Sphenopteridium* sp. (Figure 4.18) and *Sphenopteris* sp (Figure 4.19). These Pteridosperm plants live on nearshore in the past environments (Ohana, Kimura and Khoo, 1991).

Figure 4.17: The outcrop of the interbedded light grey shales with sandstone and phyllite in locality 16NAD07

Figure 4.18: *Sphenopteridium* sp. found in shales bedding

Figure 4.19: *Sphenopteris* sp. that found in the shales bedding

Another shale unit have been observed in locality 16NAD010 (Figure 4.20) which shows some physical characteristics that can be seen by naked eyes such as the colour, textures, and grain size. From the physical characteristics observation, the colour of shales is black. There are plant fossils found in the bedding of this shales unit which is *Rhacopteris* sp. shown in Figure 4.21. The grain size of the shales is silt size to clay size shales and the percentage of clay-size particles in the shales is about 70%. The texture of the shales is smooth due to the grain size. Based on the observation, the naming of shales is mudshales due to percentage of clay-size constituent. This mudshales unit is interbedded with sandstones and mudstones. The thickness of this unit is estimated to be about 20 meter long.

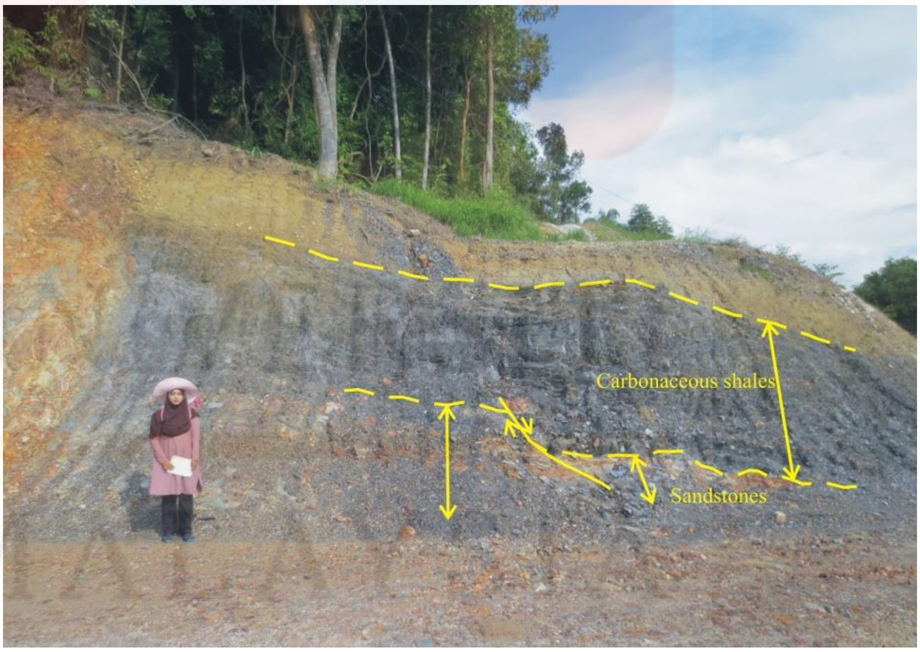


Figure 4.20: The outcrop of carbonaceous shales interbedded with sandstones in locality 16NAD010

Figure 4.21: The plant fossils, *Rhacopteris* sp.found in the shales bedding

c) Metasedimentary units

Metasedimentary rocks is a metamorphosed sedimentary rocks due to several factors such as tectonic event, the regional metamorphism and contact metamorphism. In this study area, there are some metasedimentary rocks such as quartzite, slate and metasandstone. Each of them lies within sedimentary rocks bedding.

Quartzite unit is originally from sandstone which had gone through metamorphism by alterating its composition by the heat, pressure and chemical action during metamorphism process. This quartzite found in a fault zone where the compressional forces are strong that metamorphosed the sandstone into quartzite. The quartzite that had been observed in locality 16NAD001 (Figure 4.22) shows some physical characteristics that can be seen by naked eyes such as the colour, textures, and grain size. From the physical characteristics observation, the colour of quartzite is light grey (Figure 4.23). The grain size of quartzite is coarse grain. The texture of the quartzite is coarse due to the grain size. The microscopic observation of this quartzite shows the composition of this quartzite is more than 90% of its mineral particles is quartz (Table 4.6). Based on the microscopic observation, the interlocking between the quartz mineral can be seen and this interlocking minerals does strengthen the rocks. This quartzite unit also composed of carbonaceous shale and quartz arenites which is black and light grey in colour. The thickness of this unit is about 15 meter long.

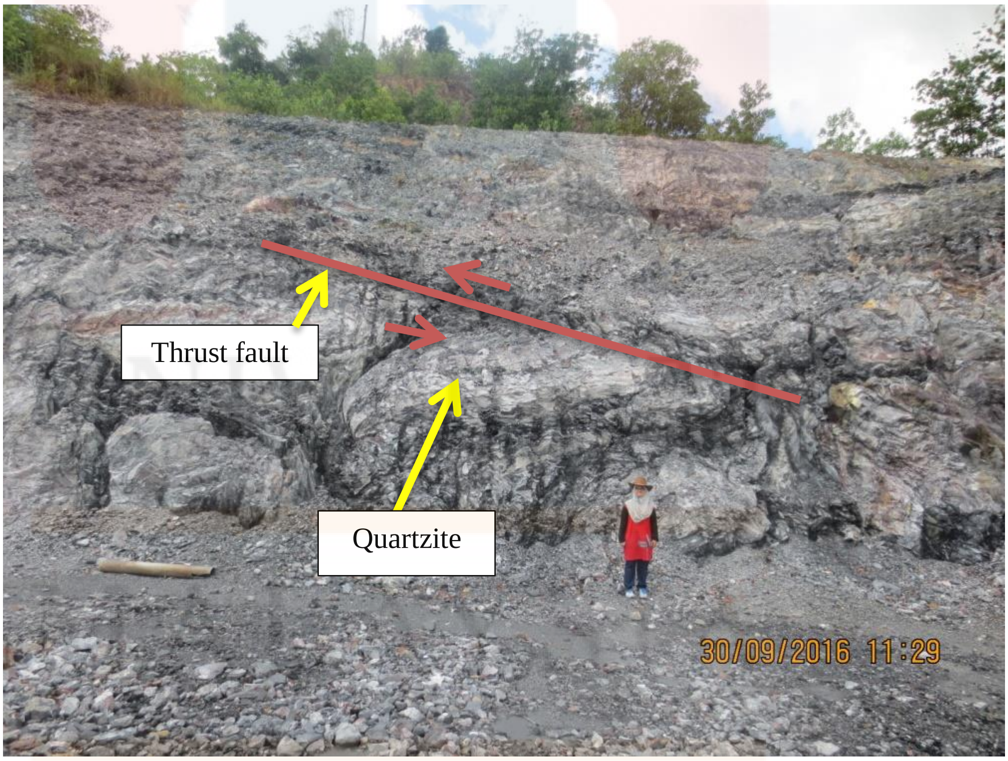
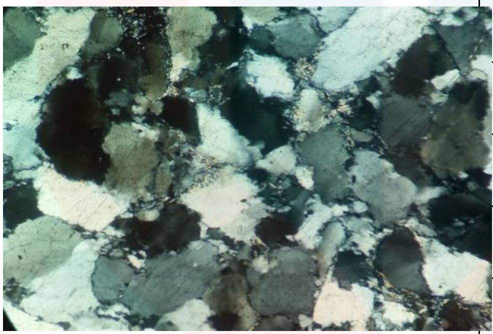


Figure 4.22: The quartzite in thrust fault zones.

Figure 4.23: The colour of fresh hand specimen of quartzite is light grey

Slate is a fine grained metamorphic rock that has foliation features. Slate is created by the alteration of shales or mudstone by low grade metamorphism. The foliation in slate is caused by the parallel orientation of platy minerals in the rock which gives the fissility features to the rock. Composition of slates is mainly of clay minerals or micas, depending on the grade of metamorphism that have been through. The distribution of slate in the study area is in locality 16NAD001 (Figure 4.24) and 16NAD007 (Figure 4.25). Based on the fresh specimen of slate in the study area, the micas minerals give a low shiny colour to the slate. The thickness of the unit is about 25 meter in long.

Table 4.6: Quartzite under 10X magnification microscope. The composition of this minerals are quartz minerals.

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											1											1
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Some of the slate also contains hematite as the outcrop of the slates have red stain of iron oxide (Figure 4.25). The colour of the slate found in the study area is dark grey which indicates that the amount of iron and organic materials are high in the rock bodies.

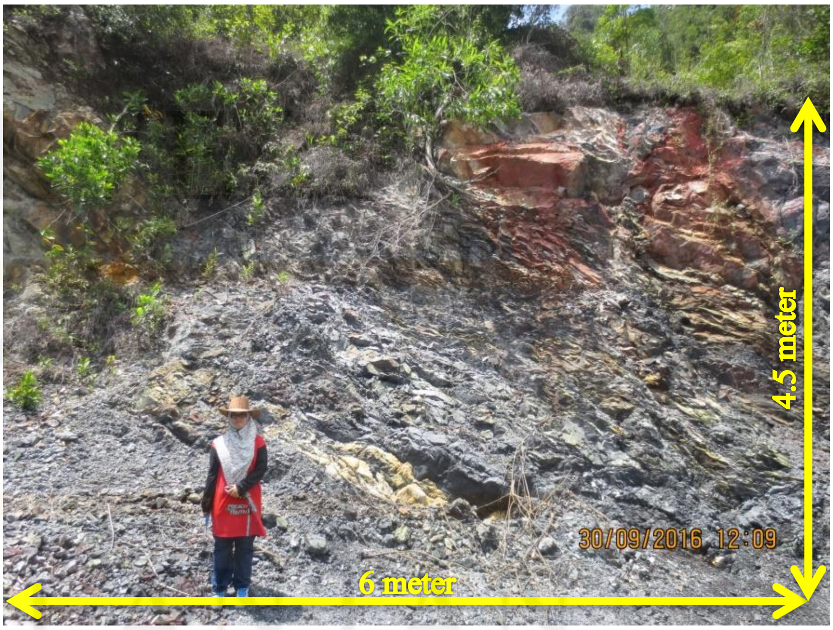


Figure 4.24: The outcrop of slates interbedded with metasandstones with width of about 6meter and 4.5 meter in height in locality 16NAD001.

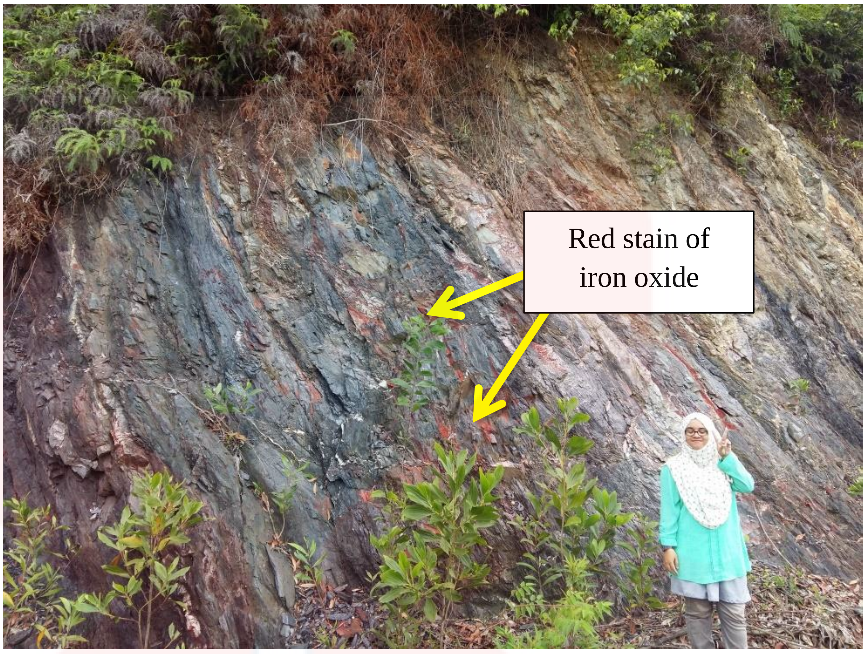


Figure 4.25: The red stain in the slates rock bodies in locality 16NAD007

Metasandstone is a rock derived from sandstone which metamorphosed due to some condition such as heat, pressure and chemical action. The locality of metasandstone in the study area was found in locality 16NAD001. The fresh hand specimen of metasandstone is dark grey in colour due to heavy metals composition that affecting the colour of the metasandstone (Figure 4.26). The grain size of the metasandstone is from medium sand size to fine sand size. The rock show upward sequence from its grains size sortation. The thickness of this outcrop is about 45 meter in long.

The composition in the metasandstone is mostly consists of quartz (88%), heavy metals (9%) and lithic fragment (3%) based on the microscopic observation in Table 4.7. From the microscopic observation (Table 4.7), the alignment of the minerals can be clearly seen under microscope as the minerals are flattened and elongated forming an alignment in mineral sortation as a result of metamorphism. The alignment of flattened minerals shows the direction of the maximum stress that have undergone by the rock.

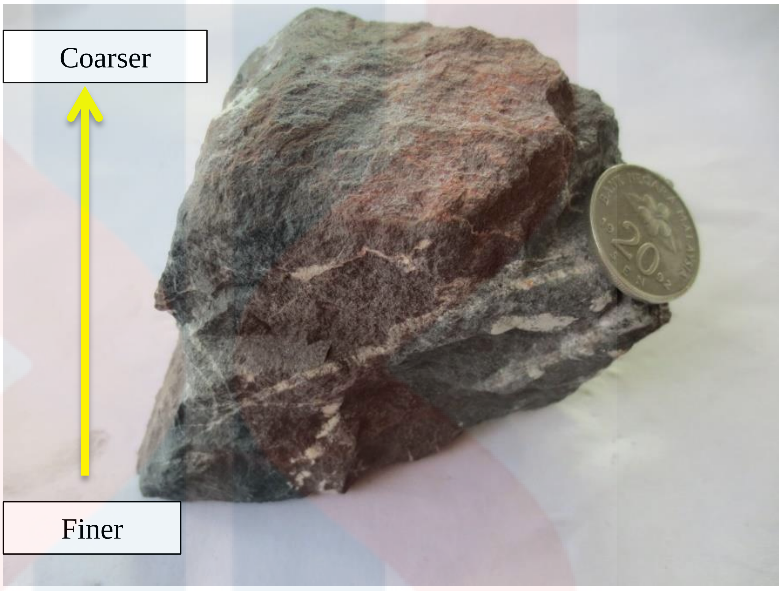
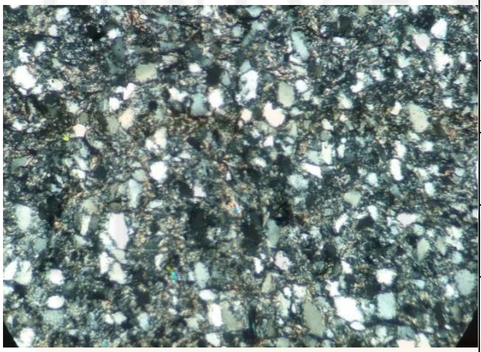
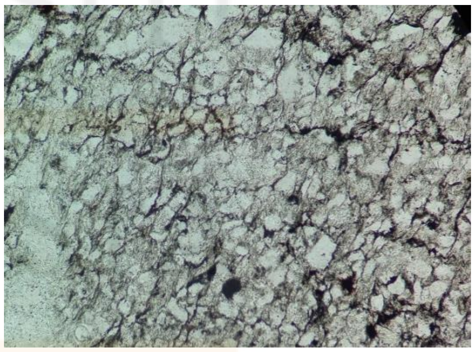


Figure 4.26: The fresh hand specimen of metasandstone that show the grading in the grain sizes.

Table 4.7: Metasandstone under 10X magnification microscope. The composition of this minerals are quartz minerals(A2, D4 under cross polarize), heavy metals (F5, H3 under plain polarized), and lithic fragments (E2, B3 under cross polarized).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
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d) Granitoid body

In Teluk Kalung, there are three types of granitoid body found which have different in their physical appearances and mineral composition. These three granitoid body found in along the shoreline of locality 16NAD004. The distribution of granitoid body cover the northern east part of the study area. The physical characteristics of the granitoid bodies are vary according to its colour, texture, mineral identification and mineral size. The microscopic observation also had been done to determine the name of the granitoid body.

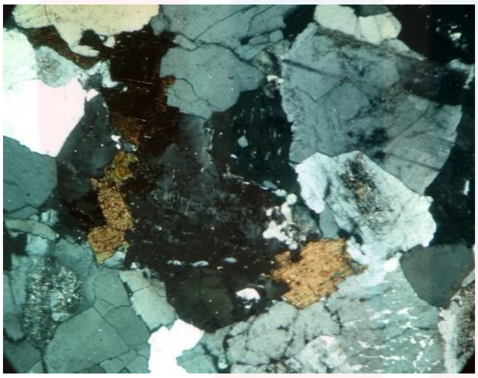
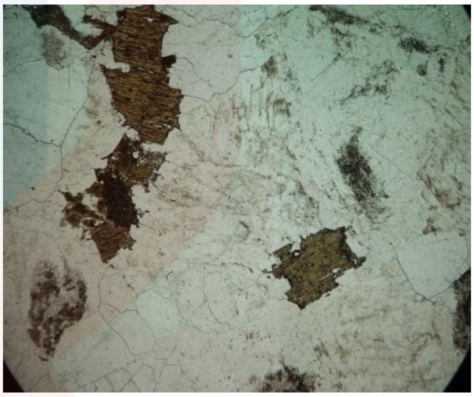
i) White granite

The physical appearances of the granites such as colour, textures, mineral and mineral size had been observed (Figure 4.27). The colour of the first granite is white. The texture of this granite is phaneritic as the mineral grains can be clearly seen by naked eyes. The phaneritic textures also mean that the granite is able to crystallize slowly underneath the Earth crust without being exposed to the atmosphere during its crystallization process. The minerals that can be observed by naked eyes are quartz (clear white), alkali feldspar (pinkish), plagioclase (milky white) and biotite (dull black). The dominant mineral in the granite body is biotite. The grain size of the granite is coarse grained.

The microscopic observation of this granite shows some other information such as the angularity of the minerals, the interlocking of the minerals and the percentage of the minerals in the rock. Based on Table 4.8, the mineral such as quartz, plagioclase, alkali feldspar and biotite can be seen. The angularity of the minerals is sub angular. The minerals are interlocking each other. The percentage of quartz is 50%, plagioclase is 5%, alkali feldspar is 30%, and biotite is 15% . The biotite is the accessory minerals in the granite. The naming of the granite is biotite-granite as the granite contain biotite as its accessory minerals to differ it with other granites.

Figure 4.27: The fresh hand specimen of the granite.

Table 4.8: Biotite granite under 10X magnification microscope. The composition of this minerals are quartz (A2,B2), alkali feldspar (H5), and biotite (C4 and G5).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
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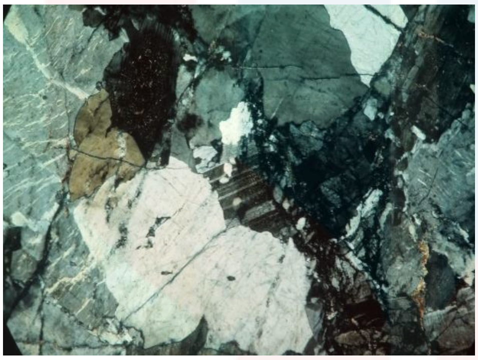
ii) Pinkish granite

The physical appearances of the granites such as colour, textures, mineral and mineral size had been observed (Figure 4.28). The colour of the granite is pinkish white. The texture of this granite is phaneritic as the mineral grains can be clearly seen by naked eyes. The phaneritic textures also giving means that the granite is able to crystallize slowly underneath the Earth crust without being exposed to the atmosphere during its crystallization process. The minerals that can be observed by naked eyes are quartz (solid white), alkali feldspar (pinkish), plagioclase (milky white) and biotite (dull black). The dominant mineral in the granite body is alkali feldspar. The grain size of the granite is coarse grained.

The microscopic observation of this granite shows some other information such as the angularity of the minerals, the interlocking of the minerals and the percentage of the minerals in the rock. Based on Table 4.9, the mineral such as quartz, plagioclase, alkali feldspar and biotite can be seen. The percentage of quartz is 45%, plagioclase is 3%, alkali feldspar is 49%, and biotite is 3%. The biotite is the accessory minerals in the granite. The naming of the granite is alkali feldspar-granites as alkali feldspar is dominant minerals in the granite.

Figure 4.28: The fresh hand specimen of the granite.

Table 4.9: Alkali feldspar granite under 10X magnification microscope. The composition of this minerals are quartz (F2), alkali feldspar (B3), plagioclase (G3) and biotite (C3).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
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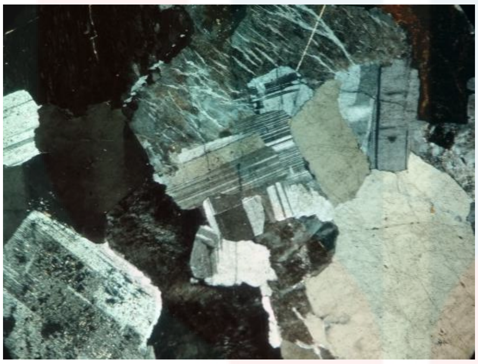
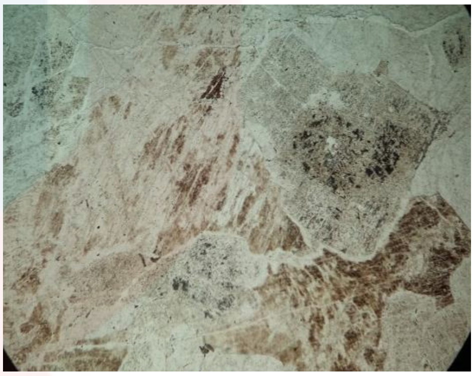
iii) White pinkish granite

The physical appearances of the granites such as colour, textures, mineral and mineral size had been observed (Figure 4.29). The colour of the granite is pinkish white. The texture of this granite is phaneritic as the mineral grains can be clearly seen by naked eyes. The phaneritic textures also means that the granite is able to crystallize slowly underneath the Earth crust without being exposed to the atmosphere during its crystallization process. The minerals that can be observed by naked eyes are quartz (solid white), alkali feldspar (pinkish), plagioclase (milky white) and biotite (dull black). The dominant mineral in the granite body is alkali feldspar. The grain size of the granite is coarse grained.

Figure 4.29: The fresh hand specimen of the granite.

The microscopic observation of this granite shows some other information such as the angularity of the minerals, the interlocking of the minerals and the percentage of the minerals in the rock. Based on Table 4.10, the mineral such as quartz, plagioclase, alkali feldspar and biotite can be seen. The angularity of the minerals is subangular. The percentage of quartz is 40%, plagioclase is 35%, alkali feldspar is 20%, and biotite is 5%. The biotite is the accessory minerals in the granite. The naming of the granite is monzogranite after the plotting of the minerals percentages in the quartz, alkali feldspar and plagioclase triangle have been done.

Table 4.10: Monzogranite under 10X magnification microscope. The composition of this minerals are quartz (I4), alkali feldspar (E2), and plagioclase (F3).

	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J	
1											**1**											**1**
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e) Superficial deposits

The superficial deposits are normally referred as the unconsolidated sediments that are deposited less than 2.6 million years ago. In this study area, there are beach ridges that extend from the north part of the map until the southern part of the map. The constituents materials of the beach ridges in this study area is commonly of coarse to fine sand, silt-size sediments, clay-size sediments and also the dead coral pieces that deposited parallel to the shoreline (Figure 4.30). The age of these superficial deposits is from Quarternary to recent as these sediments are keeps being transported and deposited along the shoreline because of the wave.


Figure 4.30: The Quaternary deposits in Locality 16NAD08

4.4 Structural Geology

4.4.1 Lineament Analysis

The lineament is the expression of underlying geological structures such as fault and folding. The structures such as fractures zones, shear zones and igneous intrusion also give rise to the lineament. Usually a lineament shows a fault-alligned valley, a straight coastline, a series of fault or fold-alligned hills or combination of these features. Lineament also can let us interpret what type of lithology might exist in this particular area by observing the lineament features in the map for mapping planning. For example, limestone karst topography will show a sharp edges lineament in the topographical map which give mean that the lithology of the particular lineament are hard or maybe there are some tectonic event that have construct the lineament features.

In this study area, the collection of the lineaments data have been done by mapped the lineaments that exist across the study area and compared it with the pattern of known structural or tectonic features that can be observed during the mapping session. In Figure 4.32, the lineaments of Teluk Kalung area were mapped in the lineament map and the observation of the lineament has been done by measuring the strike of the lineaments. The lineament in this study area shows the pattern of strike toward NE as shown in rose diagram in Figure 4.31.

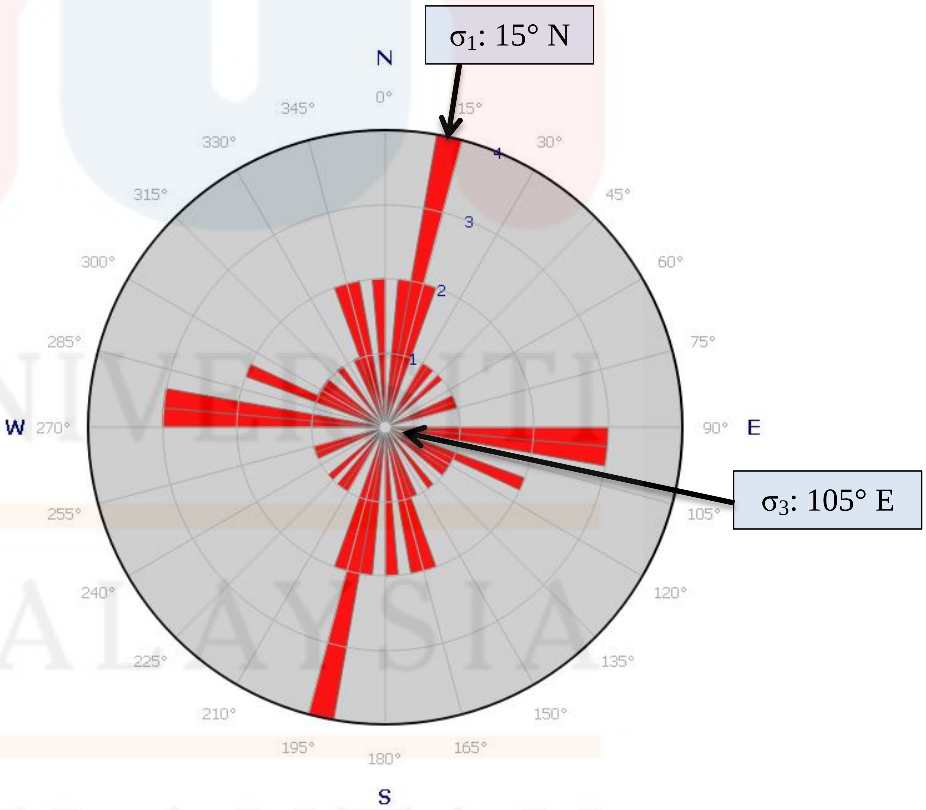

Figure 4.31: The total strikes of the lineament that shows that the maximum forces is coming from the direction of 15°N and the minimum forces is coming from 105° E

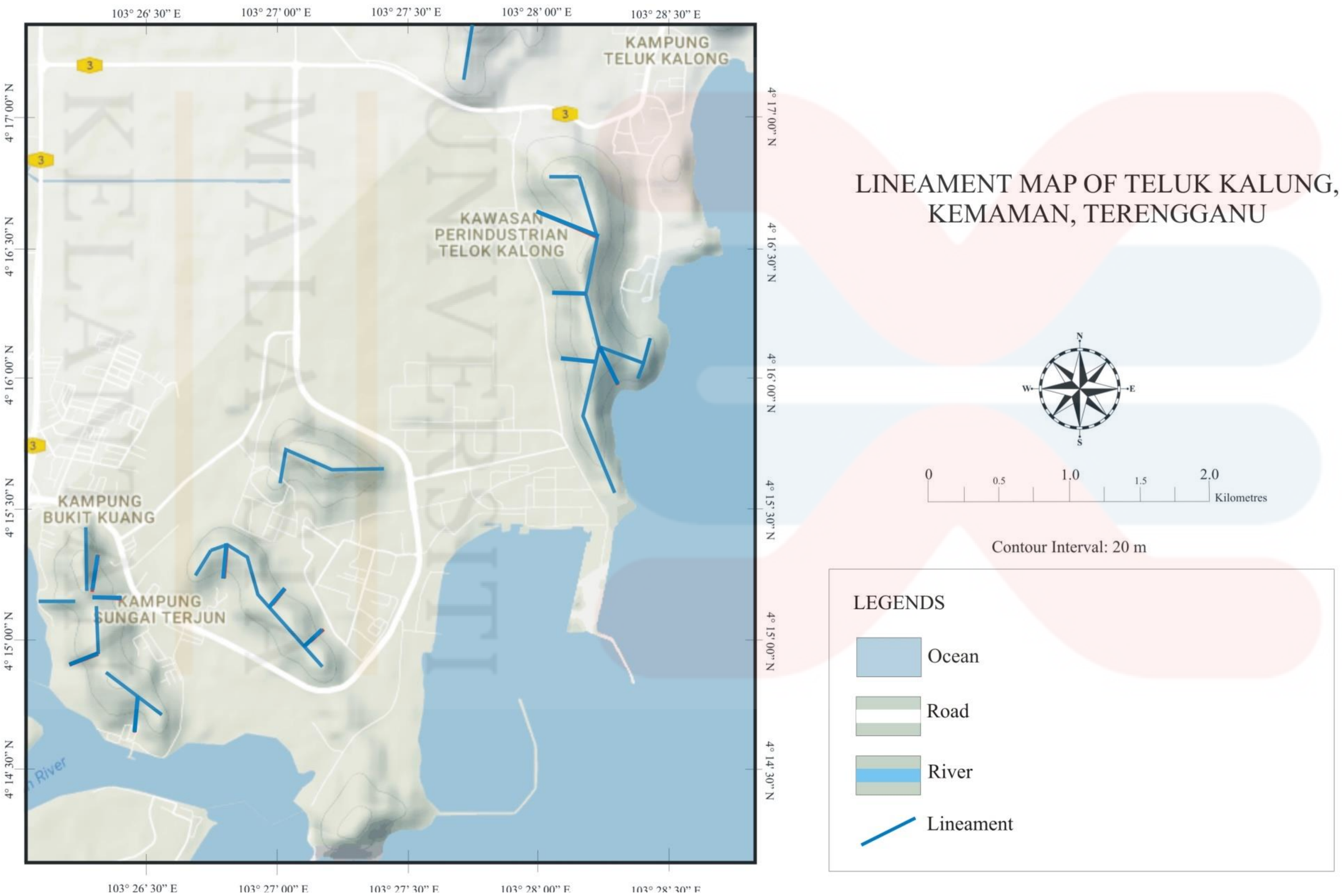

Figure 4.32: The lineament map of Teluk Kalung area

4.4.2 Fold

The folding structures are mostly found in most bedding in Teluk Kalung. The range of folding comes in minor to major folding. From field observation, the rocks in Teluk Kalung have been intensely folded into complex series of anticlines and synclines. It is striking toward NNW-SSE according to Ong Yeoh Han, Wong Ting Woon (2009). The folding structures are effecting the geomorphology of the Teluk Kalung area especially in Pantai Marina. In locality 16NAD08; Pantai Marina, the bedding are intensely folded and it is difficult to analyse its folding pattern as some of the rocks in Pantai Marina are eroded in large scale from in-situ parent rock due to the waves erosion and some of the rock bodies is submerged in the sea water.

Types of folding exist in the study area are anticlines, synclines, tight fold, recumbent fold and drag fold. Anticline is a type of fold that formed due to compressional forces of tectonic events. It is an arch-like shape folding that has the oldest strata at its core. Anticline can be recognized and differentiates with other structures as it has curvature structures which convex up. The hinge of the anticlines is located at the highest points of the curvature. The anticlines of the study area formed the V shaped hills but some part of the V shaped hills had been excavated because of the manmade activity (Figure 4.33).

The anticlines can be described with other name such as tight anticlines and open anticlines. Tight anticlines is an anticlines that has less than 30 degrees of the angles between the limbs. The tight anticlines in locality 16NAD007 have about 15 degree to 25 degree between the limb opening (Figure 4.34). Open anticlines is a fold that have the angle between the limb opening about 70-120 degrees. In the study area, this type of fold is found in beach area which is in Locality 16NAD008 (Figure 4.35).

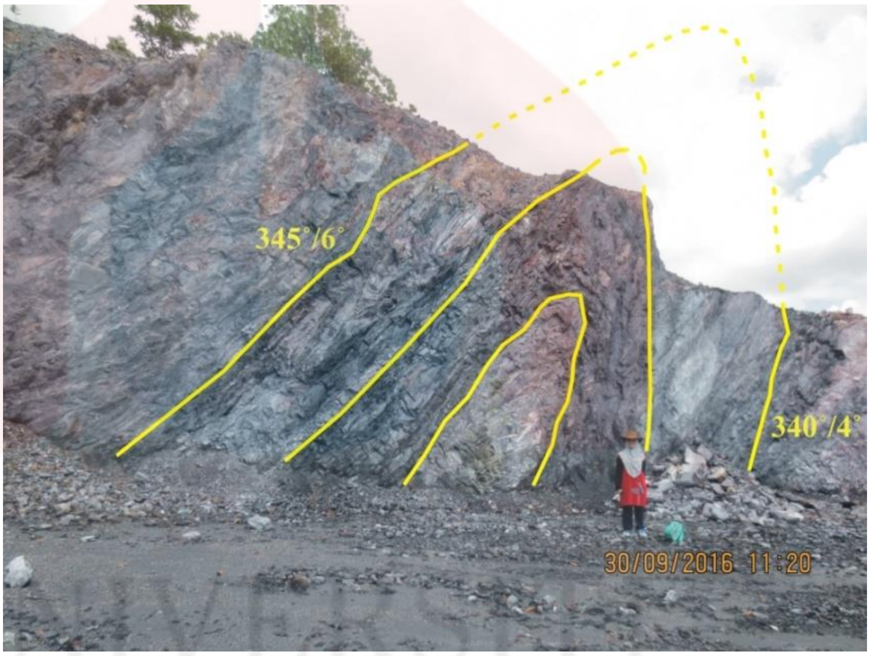

Figure 4.33: Anticline in locality 16NAD01

Recumbent synclines also seem to be recognized in this study area. Recumbent synclines is differ with tight anticlines by the angle of limb opening and its maximum hinge lines. A recumbent fold has an essentially horizontal axial plane and its axial plane is not symmetrical. As the fold is facing upward, the naming of the fold is recumbent synclines (Figure 4.36).

Drag folds in this study area are found in fault zones. Drag fold is a deflection markers which adjacent to a fault. There are two type of drag fold which are normal and reverse drag. Both are differ in their movement of drag depends on the elasticity of the strata, the movement of fault and the topological irregularities represent by the fault zones. In this study area, the type of drag fold recognized is normal drag which is easily to recognized phenomenon (Figure 4.37). Normal drag is refers to markers that are convex in the slip direction made by the thrust fault movement.

Figure 4.34: Tight anticline in locality 16NAD07

Figure 4.35: Open anticline in locality 16NAD08

Figure 4.36: The recumbent synclines in locality 16NAD010

Figure 4.37: Drag fold is marked by the yellow dash lines and the thrust fault is marked by the yellow straight line.

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4.4.3 Fault

Fault is the prove of sudden movement or break in the rock bodies caused by tectonic movement or forces. There are several types of fault that exist in the Earth which are normal fault, reverse fault, strike-slip fault and thrust fault. All of these fault types are differ based on its breaking angles. In this research area, fault rarely found rather than folding structures. Most faults found in this study area is thrust fault. Faults are found in locality 16NAD010 which is the thrust fault does break the bedding of interbedded sandstone and shale (Figure 4.38).

Thrust fault is a type of fault that breaks the rock strata that have gone through movement where the lower stratigraphic position are pushed up over the higher strata. The older rocks are above the younger rocks due to the forces of the tectonic activity. Thrust fault are also normally recognized with low dip angles which almost 20 degrees from the horizontal position. Based on Figure 4.36, we can clearly see the angle of the thrust fault is about 25˚ to 35˚. There also drag folds associates along the fault lines as the result of the movement of the fault. Thrust fault in the study area does occur in large scale which takes up to 6 metres in length but it also occur in small scales which about 70-130 centimetres as shown in Figure 4.39.

Figure 4.38: The thrust fault in interbedded shales and sandstone with strike and dip of 61˚/12˚

Figure 4.39: The small scale of thrust fold with dip angle of 21˚

4.4.4 Joint and Vein Analysis

a) Joint analysis

Joints is a continuity fracture in a layer of a rock or a body of a rock that lacks any visible or measurable movement that parallel to the fracture surface plane. Joints are mostly found in sandstone body rather than shale body because the sandstone is well consolidated, lithified and more resistant to the physical weathering and hydrothermal action (Figure 4.40). Joints are more prominent in the beach area as the outcrops are exposed to the physical weathering by the wave which resulting in joint development. Joint can occur as joint sets and systems. They vary in their appearance, dimensions and arrangement.

Joints are classified based on the process that is responsible for their formation or their geometry. The geometry of the joints refers to the orientation of the joints based on the rose diagram. There are three types major types of joints which are non-systematic joints, systematic joints and columnar jointing. The types of joint that are recognized in the study area are non-systematic joints and systematics joints. Non-systematic joints is joints that are parallel in form, spacing and orientation in which mean the joints are develop when they are not readily grouped into distinctive joint sets. In Figure 4.41, the joints are form in irregular pattern showing that the forces that acting on the rock comes in various direction. It might formed during the deformation process that folded most the beds in this locality which is Locality 16NAD008; beach area. The mechanical weathering might play roles too in the joints formation as they break the rock body. The rose diagram of the non-systematic joints shown in Figure 4.41 shows that the orientation of the non-systematic joints is facing in various directions.

The other type of joint that are recognized in this study area is systematic joints. Systematic joint is a planar, parallel joints that occur regularly in some distances. They formed a family of joints that are recognized as joint sets. In Locality 16NAD008, the joints reading have been taken along the beach. The joints reading shows that the orientation of the joint are mostly parallel to each other in the rock body. Figure 4.42 – 4.45 shows the joints sets with rose diagram that show the orientation of the joints that directs towards 110˚-120˚, 105˚-110˚ and 165˚-170˚.

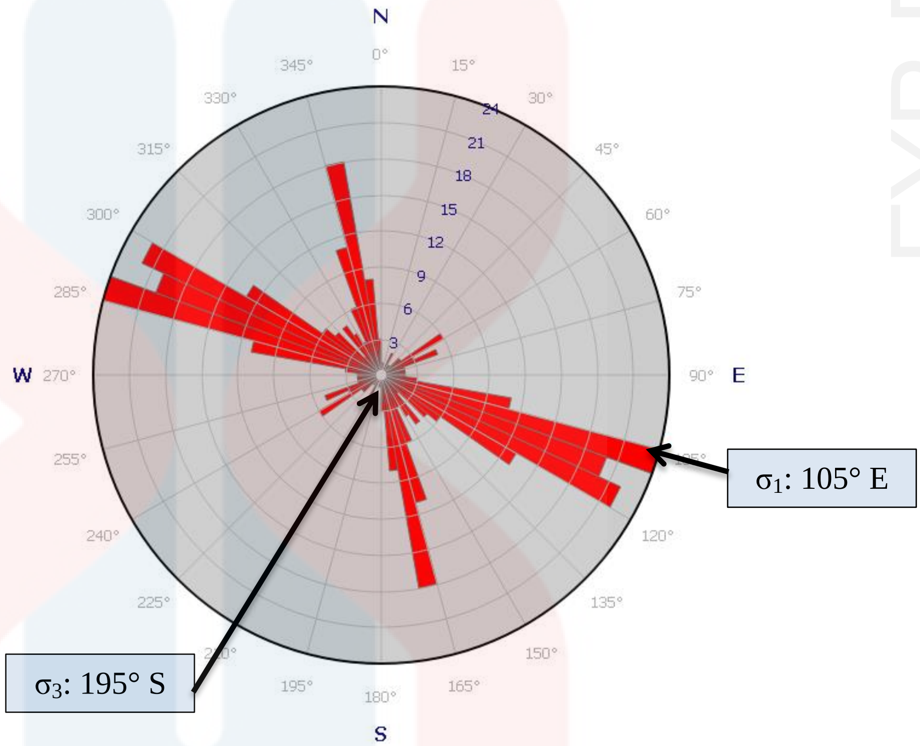

Figure 4.40: The rose diagram for the total joint reading taken for this study area shows that the maximum forces, σ_1 is coming from 105° E and the minimum forces, σ_3 is coming from 195° S.

Figure 4.41: The joint are more likely to develop in sandstone body compared to shales body.

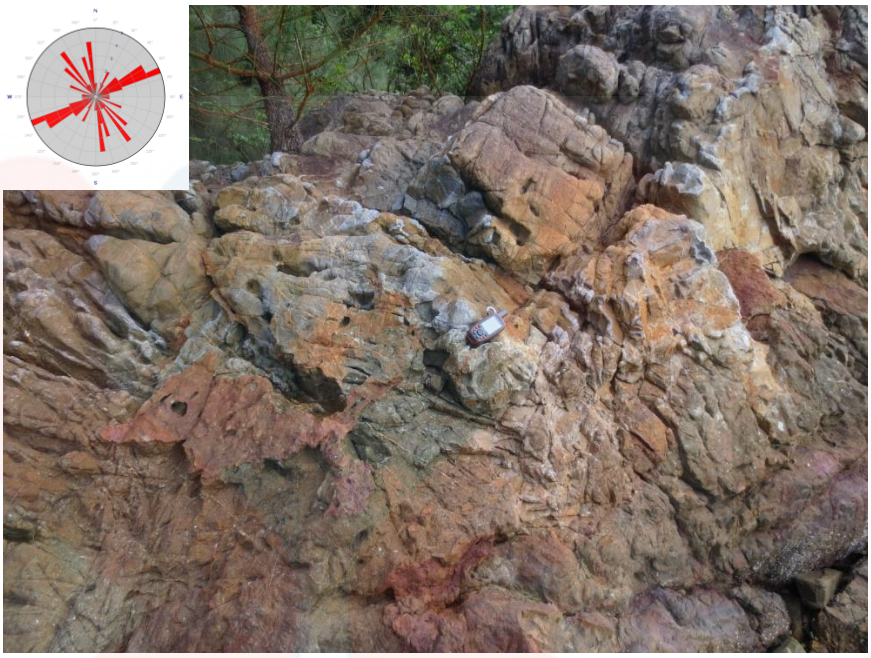

Figure 4.42: The non-systematic joints in the sandstone body with a rose diagram that shows the direction of the forces acting on the rock body comes in various directions

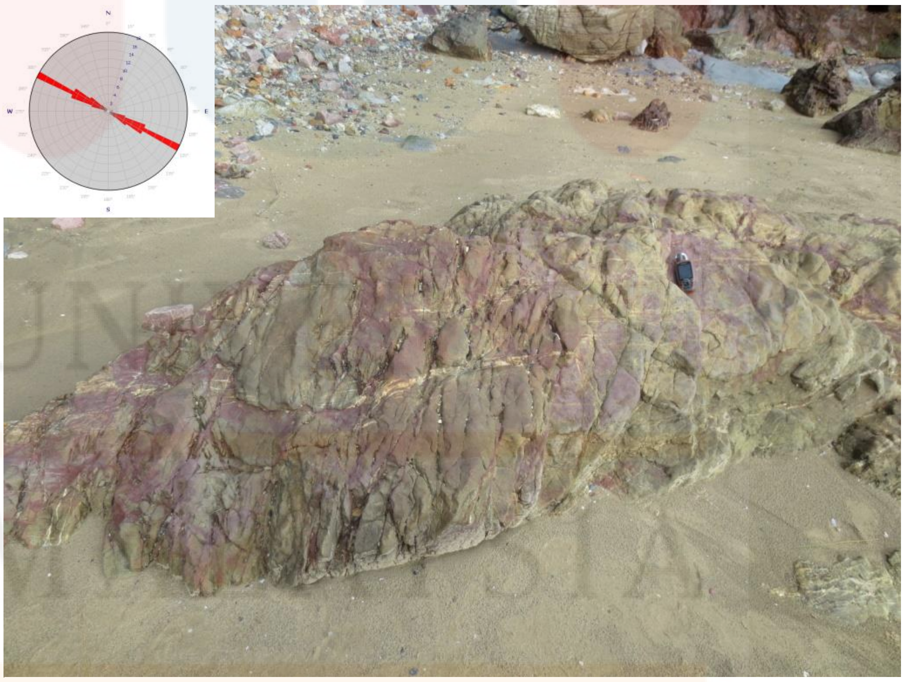

Figure 4.43: The sandstone body with azimuth of 75˚ N that has systematic joints with rose diagram that shows the direction of maximum forces (σ_1) comes from E 110°.

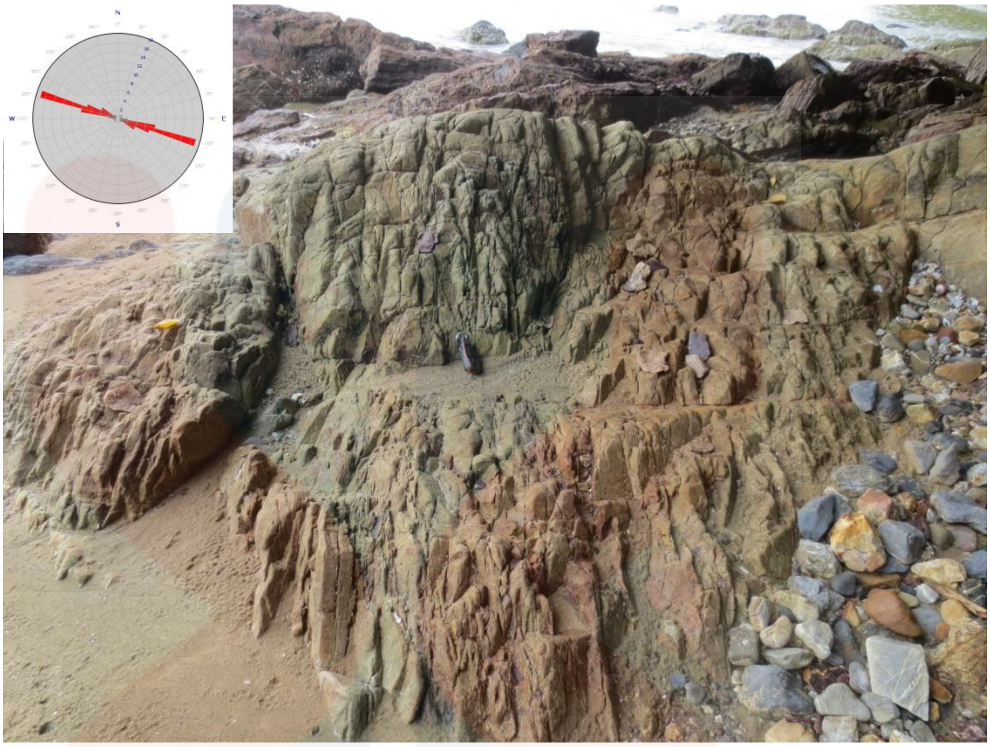

Figure 4.44: The sandstone body with azimuth of 69˚ N that has systematic joints with rose diagram that shows the direction of maximum forces (σ_1) comes from E 105°.

Figure 4.45: The sandstone body with azimuth of 92˚ N that has systematic joints with rose diagram that shows the direction of maximum forces (σ_1) comes from SE 165˚.

b) Vein analysis

When joints formed, the break in the rocks tend to open pores spaces in the rock bodies which will allow the fluids to enter the pore spaces and leaving the minerals behind after the fluids drained out. A vein will form after the fracture is filled with aqueous solution in the rock body that then deposited through deposition. The process of the vein formation involved with hydrothermal action. Veins are typically to be related with the crystal growth of the minerals in the walls of planar fractures in the rock. Based on the observation in the study area, the mechanism of vein formation is from open space filling. Once the fractures are formed in the rock, it will be filled with the hydraulic solution. The minerals that filled the pore spaces in the rock bodies in the study area is quartz minerals as a results of hydrothermal deposits. The growth of quartz minerals in these cracks are supported with high temperatures and pressures. Quartz vein in the rock body in Teluk Kalung show random orientations based on the rose diagram of the quartz vein strikes reading in Figure 4.45.

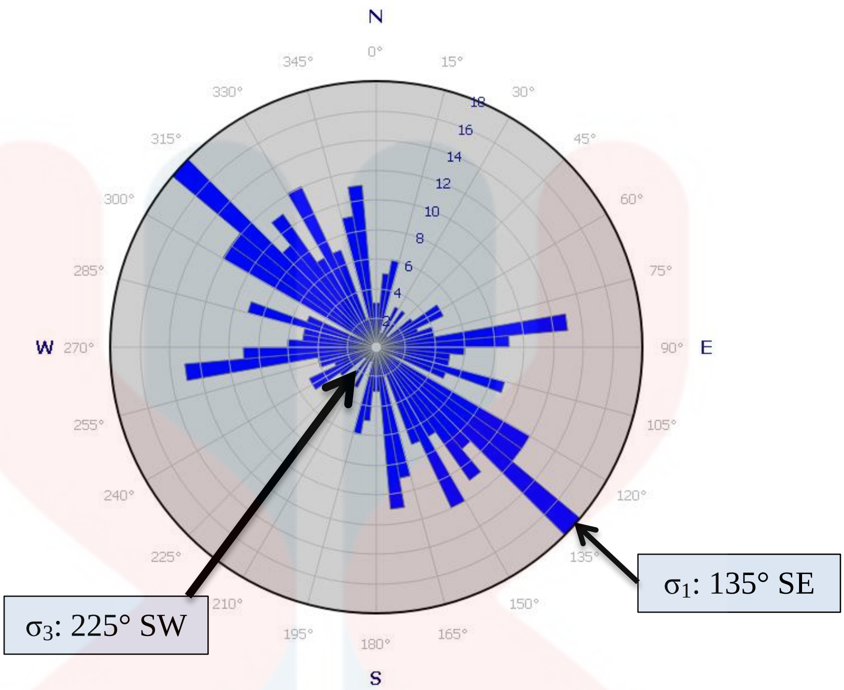

Figure 4.46: The rose diagram for the total vein reading taken for this study area shows that the maximum forces, σ_1 is coming from 135° SE and the minimum forces, σ_3 is coming from 225° SW.

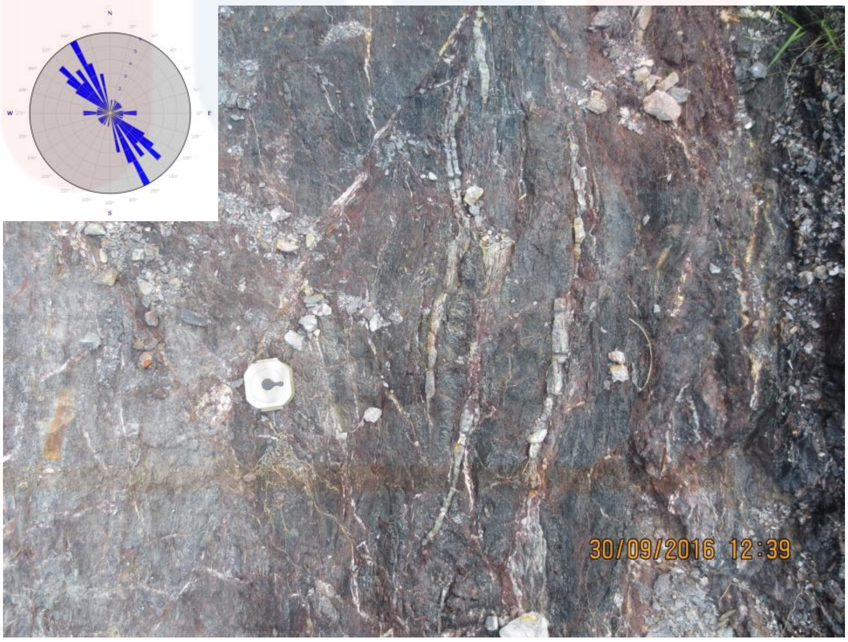

Figure 4.47: The quartz vein in metasandstone body in locality 16NAD001 showing the random orientation based on the rose diagram.

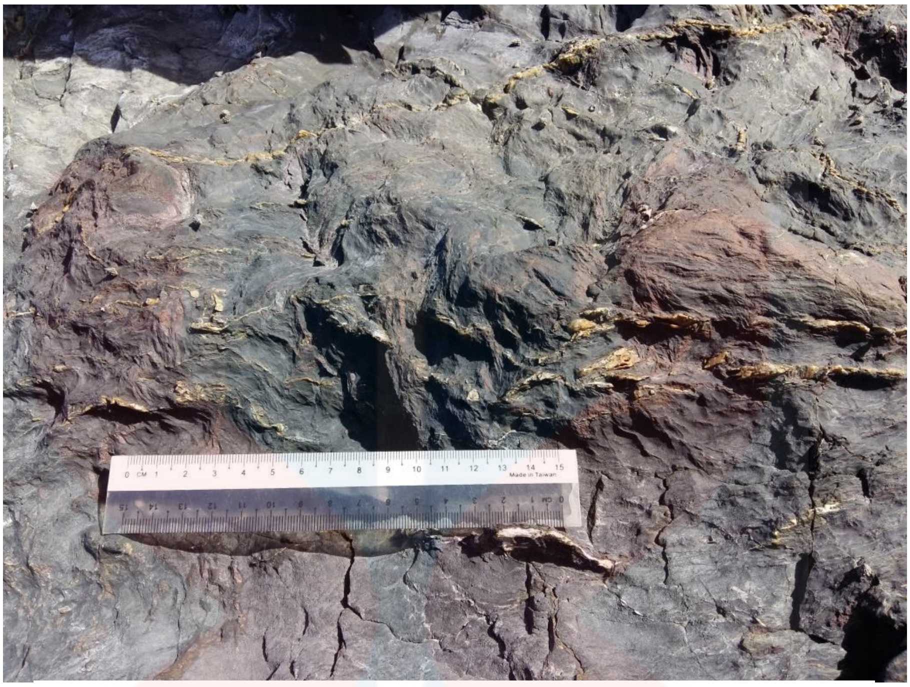

Figure 4.48: The quartz vein in sandstone in locality 16NAD08

4.5 Historical Geology Of Teluk Kalung Area

Teluk Kalung area is part of Kuantan Group which is Sungai Perlis Beds. The age of this beds is about 359.2 million years to 299 million years ago. The plant fossils found in this bed is a Euramerican plants which are *Rhacopteris* sp., *Sphenopteridium* sp. and *Sphenopteris* sp.. These species are very important to the study of migration of floral element from Asia to Euromarican and it is believe that this plant is from Upper Carboniferous deposits (Šimůnek, 2009). This trigonocarpoid pteridosperm fossils found in Teluk Kalung locality is isolated pinnules which is spreading all over the surface of the carbonaceous shale. The size of the pinnules is about 2-3 cm. These plants may transported through wind and water as the body part of this plants founded is isolated pinnules. Based on Zbyněk Šimůnek (2009), riverbanks or near shore might be the natural habitat for these plants. Vegetation of riverbanks grew on elevated, well drained substrates with a high nutrient level supply. These plants only substrates only during floods and the presence of some pteridosperm plants.

The sediments that deposited in Teluk Kalung area 359.2 million years ago which formed the sandstones were originated from the recycled orogeny and craton interior. It is believed that a volcanic region give rise to the sediments of the sandstones as the petrographic observation of the sandstones show that the quartz minerals in the sandstones have embayment or engulfment features which indicates that the minerals are originated from volcanic region. It is also suggested that the Kuantan Flora terrain was extended toward volcanic landward and it has similar lithologies with mainland Terengganu which was a festoon of volcanic islands (Jennings & Lee, 1985).

CHAPTER 5

SEDIMENTOLOGY OF SANDSTONES UNITS IN TELUK KALUNG, KEMAMAN

5.1 Introduction

The main specification of this research is the study of sedimentology of sedimentary rocks in Teluk Kalung. Field observations and mapping had been carried out in order to collect essential data such as types of lithology, sedimentary structures and lithology logs. After the field observations carried out completely, there are a few of lithology that are found to be deposited in Teluk Kalung area such as sandstone unit, shale unit, metasediment unit and also intrusive igneous rocks. Sedimentology study which including the provenance study had been done on sandstone unit of Teluk Kalung area.

5.2 Sedimentology of Sandstone Unit

Previously in Chapter 4, the detail explanation about its physical characteristics such as colour, mineral grain size, textures and also the microscopic observation had been discussed earlier. In this chapter, the detailed discussion will be more on the lithology log interpretation, sedimentary structures to interpret the depositional environment of the sandstone unit that lies in Teluk Kalung area. Sandstone unit covered about 60% of this study area. As mentioned before, sandstone unit is the oldest bed lies in Teluk Kalung which age in Lower Carboniferous. Even though this bed is the oldest bed in this study area, the nature of the outcrop is still well present as it is exposed by the continuous man made hill cutting due to the industrial activities. There are two distinctive sandstone units that are differ based on their depositional environment.

The bedding of tuffaceous sandstone and siltstone shows an abrupt contact which directly distinguished these two strata. The abrupt contact between strata means there are minor interruption occurs during the deposition (Figure 5.1). The lithology log of this sandstone unit has been taken during the field observation in Locality 16NAD03 shown in Figure 5.3. Based on the lithology log, the sandstone is interbedded with siltstone. The total thickness of the sandstone unit observed is about 7 meter.. The grain size of the sandstone does not show any grading in the bed, meanwhile the siltstone bed show grading features in its grain size. The sedimentary structures in this bedding are not very visible as some of the surface already eroded or washed away. Based on the observation on the lithology log sheet A, the depositional environment of this sandstone unit maybe deposited in terrestrial environment as the grain sizes of this sandstones unit ranging from sand-size grain to silt-size grains.

Meanwhile, in Locality 16NAD08, the lithology log of the sandstone unit also recorded in the lithology sheet B (Figure 5.4). The lithology log shows that the interbedded of sandstone and shale are deposited in wave dominated environment where there are cross lamination in sandstone beds. It indicates that the sediments of the sandstones was deposited in the low flow regimes. The sedimentary structures in the sandstone unit are mostly visible in the sandstone unit in Locality 16NAD08 (Figure 5.2). The sedimentary structures observed in these sandstone unit such as the tabular cross-lamination, hummocky cross lamination, parallel lamination, flute cast, boudinage, balls and pillow structures and tafoni structure.

Figure 5.1: The laminated bedding of tuffaceous sandstone and siltstones in Locality 16NAD03

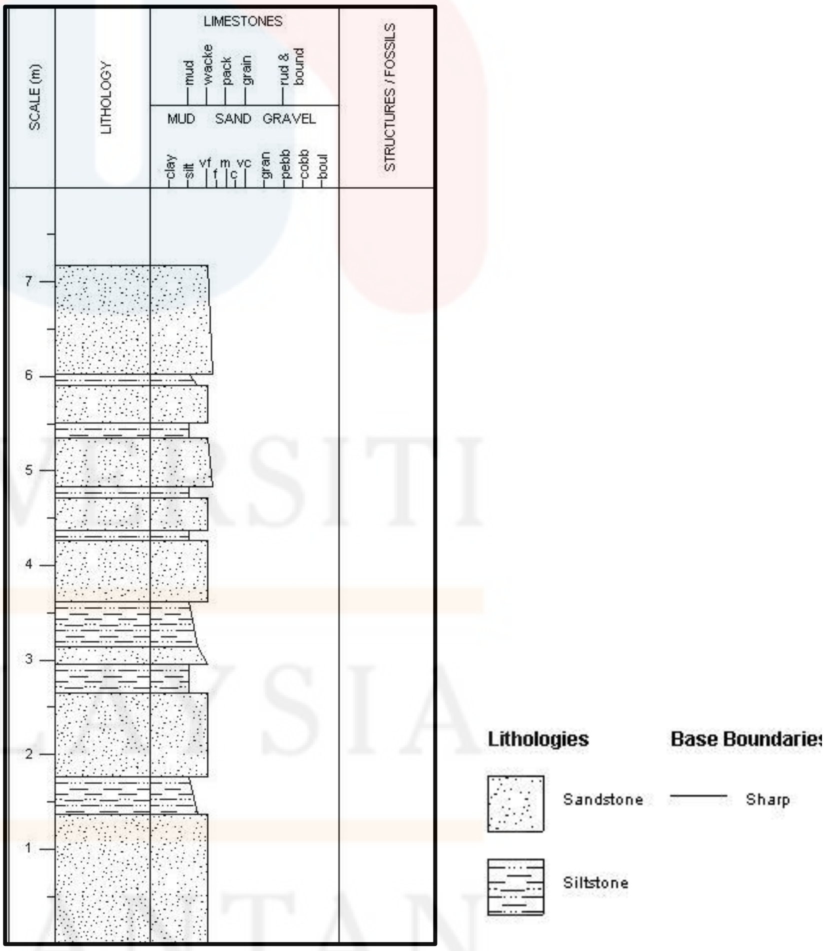

Figure 5.2: The lithology log (Sheet A) of Locality 16NAD03

Figure 5.3: The bedding of interbedded sandstone and dark grey shales in Locality 16NAD08

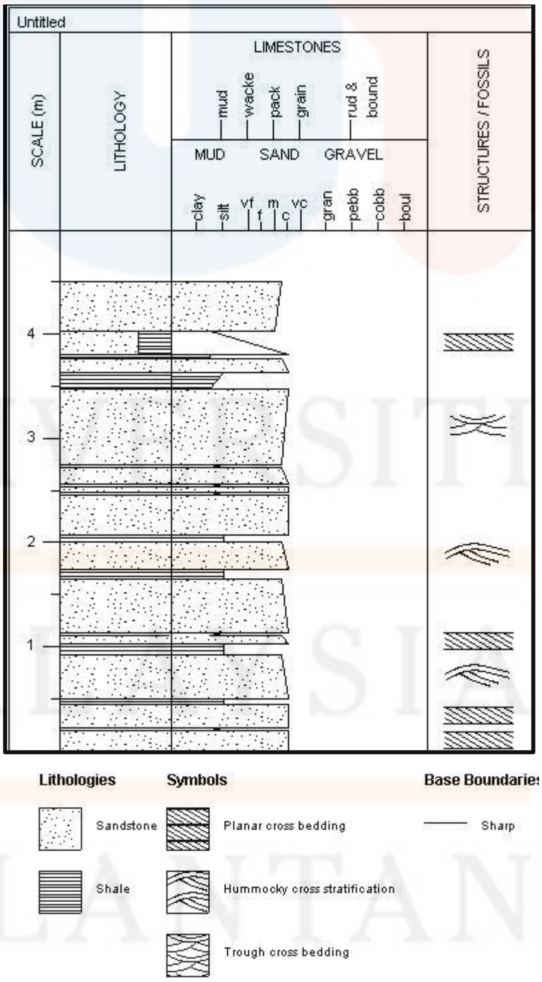

Figure 5.4: The lithology log (Sheet B) from the sandstone unit in Locality 16NAD03.

Cross bedding or cross lamination is an inclined layer that indicates the past environment of the bedforms is deposited in inclined surfaces. It also indicates that there were flowing medium in the depositional environment such as water or wind. The flowing medium can cause these sand sediments to form a crest and then the force of the fluid forced the sediment to fall down the downstream side of the dunes. The repeating avalanches eventually forming this sedimentary structures. There are few types of cross bedding found in the sandstones units which are tabular cross bedding (Figure 5.5) and planar cross stratification (Figure 5.6). Tabular cross beds in this sandstone beds in ranging from 5 cm to 75 cm in thickness. Tabular cross bedding is mainly formed by the migration of ripple and dunes during the lower-flow regimes. It is typically found in sandstones body. Hummocky cross stratification is normally found in sandstone to coarse siltstone. The occurrence of the hummocky cross beds is generated by the strong energy of large storm waves in the ocean during the deposition of the sediments. During the ancient times, the hummocky cross stratification was likely to occur in shallow marine environments, on the shore face and shelf by the waves.

Parallel lamination also found in the both sandstones and shales body in this sandstone unit (Figure 5.7 and Figure 5.8). The parallel lamination develops when the fined grained sediments settled in quiet water such as in deep marine environment. Lamination in sandstones is often formed when the wave energy separated the grains of the sediments which is normally occur in coastal environment.

Another sedimentary structures observed in this sandstones unit is flute cast (Figure 5.9). Flute cast is the elongated welts or ridges that have bulbous nose at the end of the structures. It flares out in the other direction and merges gradually with the bed surface (Boggs, 2009). It is usually found in soft sediments such as shales and mudstones. This structures show the direction of the paleocurrent flow. The flutes casts is commonly found in turbidite sequences but they also present in shallow marine environment sediments.

Figure 5.5: The tabular cross beds in the sandstone beds in Locality 16NAD08

Figure 5.6: The planar cross stratification in the sandstone beds in Locality 16NAD08

Figure 5.7: The parallel lamination in sandstone body in Locality 16NAD08

Figure 5.8: The parallel lamination of shales body in Locality 16NAD08

Figure 5.9: The flute cast in the shales body.

Next, the sedimentary structures found in the sandstone unit is ball and pillow structures (Figure 5.10 and Figure 5.11). Normally, these structures is found in lower part of sandstones beds that overlies shales. In this study area, the sandstones pillow are found in the shales beds not far from the sandstones bed. The shape of the sandstones balls found is hemispherical and gently curved, it might have undergo the deformation process that have curved the edge of the sandstone balls. This sedimentary structures are believed to happen due to the breakup of unconsolidated sediments or semiconsolidated sediments possibly caused by shocking as the study area had undergone several times of deformations.

Lenticular bedding also is a part of the sedimentary structures found in the sandstone unit of the study area (Figure 5.12). Lenticular bedding a structure formed by the interbedded of mud and sandstones in which displaying a pattern of discontinuous sand lenses. It is believed that during the formation of the bedding, the mud is deposited on top of the lenses of sands due to the slack water which means the velocity of the water was decreased to zero. It is differ with flaser bedding as the lenticular bedding is mud-dominated bedding with some lenses of sands compared to flaser bedding which is vice versa.

Figure 5.10: The sandstone ball in the shale beds

Figure 5.11: The sandstone pillow in the shale beds

Figure 5.12: The sandstone lenses marked with yellow dash line in the shale beds showing the lenticular bedding

5.3 Provenance of Sandstones in Sandstones Units

Provenance of sandstones is a study about the origin of the sediments in the sedimentary rocks. The purpose of the provenance study is to provide the evidence of the erosion history that take over the parent rocks of the sedimentary rocks. The method used to interpret the provenance of the sandstones is using petrographic study. The petrographic analysis includes point counting on the quartz, feldspar and lithic minerals by calculating the percentages of each minerals and then the percentages value for each minerals is plotted in the provenance triangle. For this study, there are three samples of sandstones were analysed by point counting method (Table 5.1) and the percentages value for each minerals was mapped in the provenance triangle in Figure 5.13. The result of the point counting method shows that the samples of sandstones in Teluk Kalung area originates from continental block and recycled orogeny.

Table 5.1: The percentage of the QFL minerals obtained after point counting calculation.

Sample	Quartz (%)	Feldspar (%)	Lithic fragments (%)	Total (%)	Name of rock
1	42	0	58	100	Quartz arenites
2	96	0	4	100	Lithic arenites
3	72	0	28	100	Lithic arenites

i) Sample 1; Quartz arenites

Samples 1, quartz arenites is identified to be originates from the continental block provenances. Continental block provenances are located in the continental masses which bordered by one side of passive continental margin and the other side is by an orogenic belt or convergence plate zone. Based on the provenance triangle in Figure 5.13, the sample 1 consists of ancient craton source rock. The source rocks of this block consists of plutonic igneous, metamorphic and sedimentary rocks and also few volcanic rocks. Eroded sediment from these sources normally consists of quartzose sand, feldspar with high rations of potassium feldspar to plagioclase feldspar, metamorphic and sedimentary rock fragments. This sediments that eroded from the sources rocks were likely to be transported to the marginal ocean basins or local basins within the continent (Boggs, 2009). Based on Figure 5.14, the quartz minerals in the quartz arenite sample shows the embayment features which indicate that the quartz minerals might be recycled from volcanic rocks.

ii) Sample 2 and 3; Lithic arenites

Next, Sample 2 and 3(lithic arenites) consists of sediments grains that originated from recycled orogeny provenances. The quartz minerals that originates from recycled orogeny is normally not stable due to its maturity of the minerals. The recycled orogeny provenances are the convergence plate zone that collide with major plates that causing uplifting sources area along the collision suture belt. Sedimentary and metamorphic rocks are typically present along the continental collision margins. The detritus that derived from these source rocks commonly consists of abundant of sedimentary-metamorphic rock fragments (Boggs, 2009). Lithic arenites are likely composed of unstable materials which the formation of the sandstones was influenced by deposition of high relief source areas. The quartz minerals in both samples is poorly sorted and poorly rounded as seen in Figure 5.15 and 5.16.

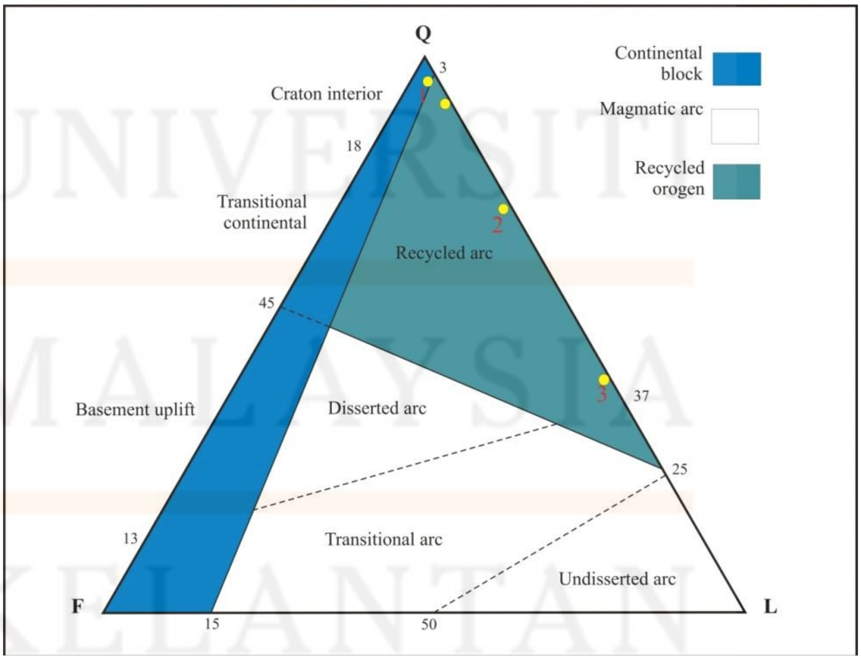

Figure 5.13: The plotted data in the provenance triangle show the results of point counting method.

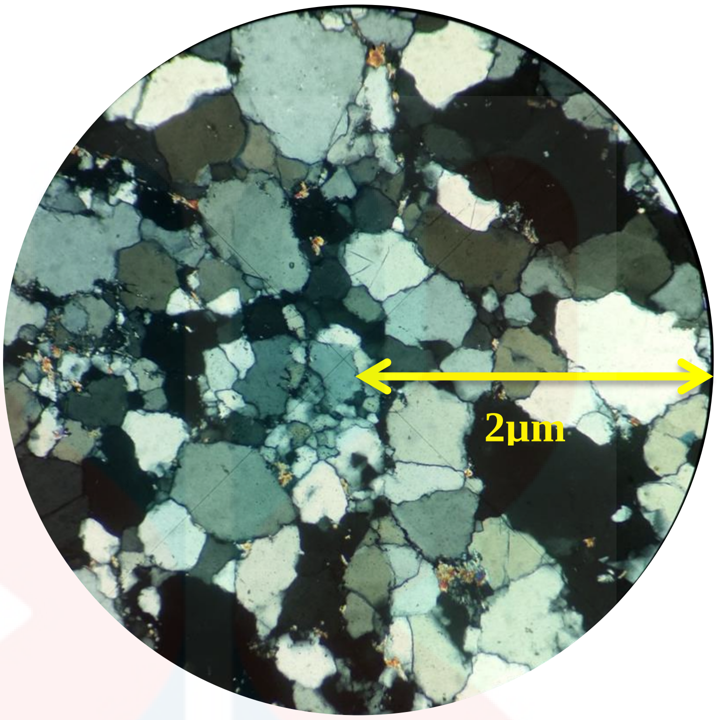

Figure 5.14: Sample 1 (quartz arenites) consists of more than 90% of quartz minerals and the minerals are texturally submatured because the grain is subangular.

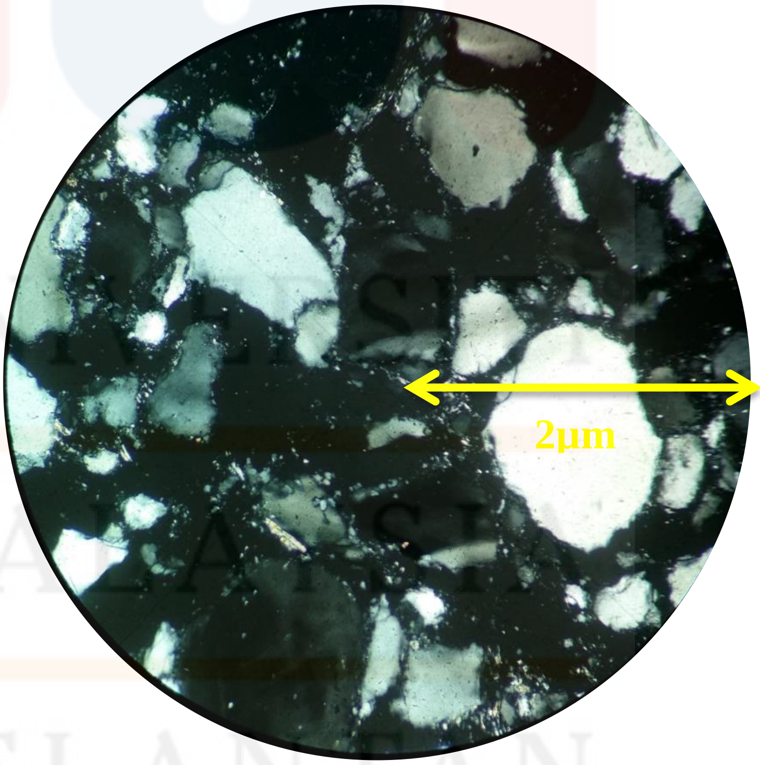

Figure 5.15: Sample 2 (Lithic arenites) consists of more than 20% of lithic fragments for this spot and poorly sorted.

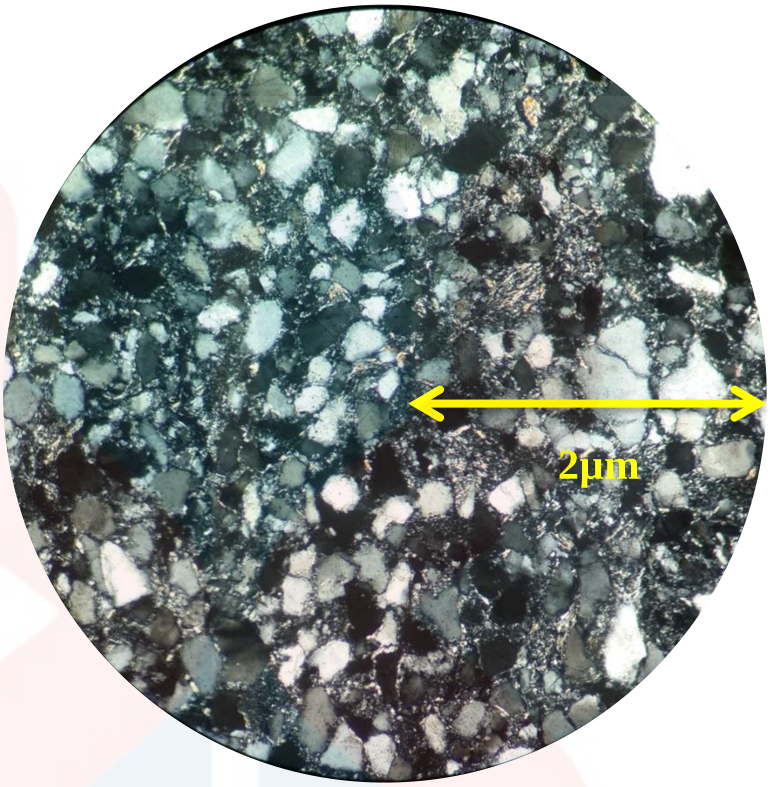

Figure 5.16: Sample 3 (Lithic arenites) consists of more than 10% of lithic fragments and poorly rounded.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Overall, we can conclude that the formation that lies in the study area; Teluk Kalung are Sungai Perlis Beds which comprise of sandstone unit, shales unit and metasedimentary units and underly by Jengai Granite which consist of biotite-granite, alkali feldspar granite and monzogranite. The Quartenary deposits of the Teluk Kalung still in the continous transportation and deposition process which it started from the age of Quartenary to recent. The age of the Teluk Kalung area is from Lower Carboniferous to recent.

In Chapter 5, detailed discussion about the sedimentology and provenances of the sandstones units. The sandstones unit found in this study area are deposited in beach environment and deltaic environment based on the study of the sedimentary structures and lithology log interpretation of the sandstone units. Both of sandstones unit still in the same depositional environment group which is marginal-marine environment.

The origin of the sediments in the sandstones of the sandstone units comes from the recycled orogeny and craton interior based in the plotted percentages value of each quartz, feldspar and lithic fragments in the provenance triangle. The results of the plotted value in the provenance diagram can be considered as valid answer as the quartz minerals in these sandstones samples shows some features such as the quartz minerals in quartz arenites (Sample 1) show embayment features which means that the quartz are originated from volcanic source rocks in the ancient craton. Another example is the quartz minerals in the lithic arenite (Sample 2) consists of metamorphic rock fragments that show wave like features when observed under the polarised microscope.

6.2 Recommendations

The suggestion for further study in this study area is the diagenesis of the siliciclastic sedimentary rocks which can provide detailed information about the condition that caused metamorphism in the Teluk Kalung area by observing the diagenetic process of the sedimentary rocks and its effect on the sedimentary rocks afterward. The diagenesis study also gives foundation about the mineralogical changes in the sedimentary rocks after diagenesis process. The study about the diagenesis of the siliciclastic sedimentary rocks in this area never been proposed by any researcher before, so it is quite interesting to do the diagenesis study of the siliciclastic sedimentary rocks of this study area.

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APPENDICES

a) Total strikes reading for joint analysis

Angle (°)	Frequency	Angle (°)	Frequency
0-15	0	181-195	0
16-30	2	196-210	2
31-45	0	211-225	0
46-60	8	226-240	8
61-75	8	241-255	8
76-90	4	256-270	4
91-105	14	271-285	14
106-120	66	286-300	66
121-135	24	301-315	24
136-150	11	316-330	11
151-165	20	331-345	20
166-180	29	346-360	29

b) Total strikes reading for vein analysis

Angle (°)	Frequency	Angle (°)	Frequency
0-15	14	181-195	14
16-30	4	196-210	4
31-45	4	211-225	4
46-60	9	226-240	9
61-75	12	241-255	12
76-90	26	256-270	26
91-105	16	271-285	16
106-120	14	286-300	14
121-135	42	301-315	42
136-150	27	316-330	27
151-165	20	331-345	20
166-180	23	346-360	23