GENERAL GEOLOGY AND PETROLEUM SOURCE ROCK EVALUATION IN GUA PANJANG AREA, GUA MUSANG, KELANTAN

by

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DECLARATION

I declare that this thesis entitled General Geology and Petroleum Source Rock Evaluation in Gua Panjang area, Gua Musang, Kelantan 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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ABSTRACT

Gua Musang is a district in Southern Kelantan which located in the central belt of the Peninsular Malaysia that held many hidden geological gems. Formed during the late Permian-Triassic period, Gua Musang formation is covered with argillaceous, calcacerous, volcanic and arenacous rocks. As the largest district in Kelantan, Gua Musang holds many beautiful karst morphology that covered most of the region. The research is to confirm the previous geological information by the conduction of geological mapping in the study area of Gua Panjang that is located in the sub-district of Gua Musang. Argillaceous and calcareous rock units are both rich in organic content as they are formed from accumulation of undisturbed dead organisms. Petroleum source rock evaluation through identification of organic matter richness is a conventional geochemical method which uses recoverable solvent under not very high temperature. The method used in the research is the Soxhlet extraction method over a duration of 24 hours.Targeted organic-rich rock samples of coal and claystone collected from the study area were tested to identify the potential of petroleum source rock. Both rock samples indicate very excellent potential of petroleum source rock as they yielded a range from 675 028 to 855 708 ppm of extracted organic matter (EOM). Although these rocks contain high yield of EOM, the potential of petroleum source rock is unclear as further analyses are needed to support and confirm the findings.

GEOLOGI UMUM DAN PENILAIAN BATUAN SUMBER PETROLEUM DI KAWASAN GUA PANJANG, GUA MUSANG, KELANTAN

ABSTRAK

Gua Musang merupakan sebuah daerah di Kelantan Selatan yang menyimpan nilai geologi tersembunyi di semenanjung tengah. Terbentuk semasa tempoh Permian-Triassic lewat, Formasi Gua Musang dipenuhi dengan batuan lempung, batuan berkapur, hasil gunung berapi dan batuan pasir. Sebagai daerah yang terbesar di Kelantan, Gua Musang mempunyi banyak morfologi karst yang cantik yang meliputi sebahagian besar rantau ini. Kajian ini adalah untuk mengesahkan maklumat geologi yang sedia ada melalui kaedah pemetaan geologi di kawasan kajian Gua Panjang yang terletak di Bandar Gua Musang.Unit batuan lempung dan berkapur kaya dengan kandungan organik kerana mereka terbentuk daripada pengumpulan organisma mati. Penilaian batuan sumber petroleum melalui penentuan kuantiti bahan organik adalah satu kaedah geokimia yang konvensional di mana pelarut organik digunakan pada suhu tidak terlalu tinggi. Kaedah yang digunakan dalam kajian ini adalah kaedah pengekstrakan menggunakan alatan Soxhlet sepanjang 24 jam. Sampel batuan organik iaitu batuan arang dan batu lumpur yang di ambil dari kawasan kajian telah diuji untuk mengenal pasti potensi sebagai batuan sumber petroleum. Kedua-dua sampel batuan menunjukkan potensi yang sangat baik sebagai batuan sumber petroleum dengan menghasilkan jumlah bahan organik yang diekstrak (EOM) dari 675 028-855 708 ppm. Walaupun batuan ini mengandungi nilai EOM yang tinggi, potensi sebagai batuan sumber petroleum adalah kurang jelas kerana analisis selanjutnya diperlukan bagi menyokong dan mengesahkan penemuan tersebut.

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LIST OF ABBREVIATIONS

N	North
E	East
Mm	millimeter
GDP	Gross Domestic Product
TOC	Total Organic Carbon
GPS	Global Positioning System
DCM	Dichloromethanol
EOM	Extracted Organic Matter
mg	milligram
Kg	Kilogram
g	gram
PPM	Parts Per Million
2D	2-Dimension

LIST OF SYMBOLS

σ	Sigma
%	Percentage
=	Equal
x	Unknown value of x

CHAPTER 1

INTRODUCTION

1.1 General background

Geology is the study of the Earth, including the materials that it is made of, the physical and chemical changes that occur on its surface and in its interior, and the history of the planet and its life forms (Graham R. Thompson, 1997). In order to understand how oil is produced and generated from within the earth, one must first understand how it can be generated from the rock itself. Delineation and identification of potential source rocks depends on the studies of the organic-rich sediments that had been deposited in the past. Source rock refers to the formation in which oil and gas originate. These oil and gas are generated when large volume of microscopic plant and animal material are deposited in the marine, deltaic or lacustrine (lake) environments. The organic material can either be deposited in these environments or being transported into the environment by rivers, streams or the sea.

Source rock potential analysis is a research conduction in which to determine the potential of a rock in becoming a source rock. An excellent source rock is one that can generate economic amount of oil. The oil produced from source rock is generally called petroleum, which is natural occurring hydrocarbons, whether in the form of gaseous, liquid or solid. To identify a rock as a source rock, the characteristics of a rock which can generate oil must be understood. The rock must be off fine-clastic (silt and/or clay) sediments. This is to protect the organic matter from being destroyed during the burial by creating an anoxic environment. Types of sedimentary rocks that are important in the production of hydrocarbon are Sandstones, Carbonates, Shales and Evaporites (Rodgers, 2014)

The area of research is in Gua Musang, which is in the southern part of Kelantan. Kelantan is one of the 11 states in the Peninsular Malaysia and is located in the central belt. The time frame for formation of Gua Musang is from the Middle Permian to Upper Triassic (Leman M. S., 1993) and mapped by Yin (1965). According to Lithology Map of Kelantan in Figure 1.1, Gua Musang is mostly covered by sedimentary rocks of shales, limestones, sandstones and siltstones which make it a possible area for the formation of source rocks. Metamorphic rocks are also present in some parts of Gua Musang, in small amount. This research is to determine the amount of organic matter present in the potential source rock from the following type of rocks.

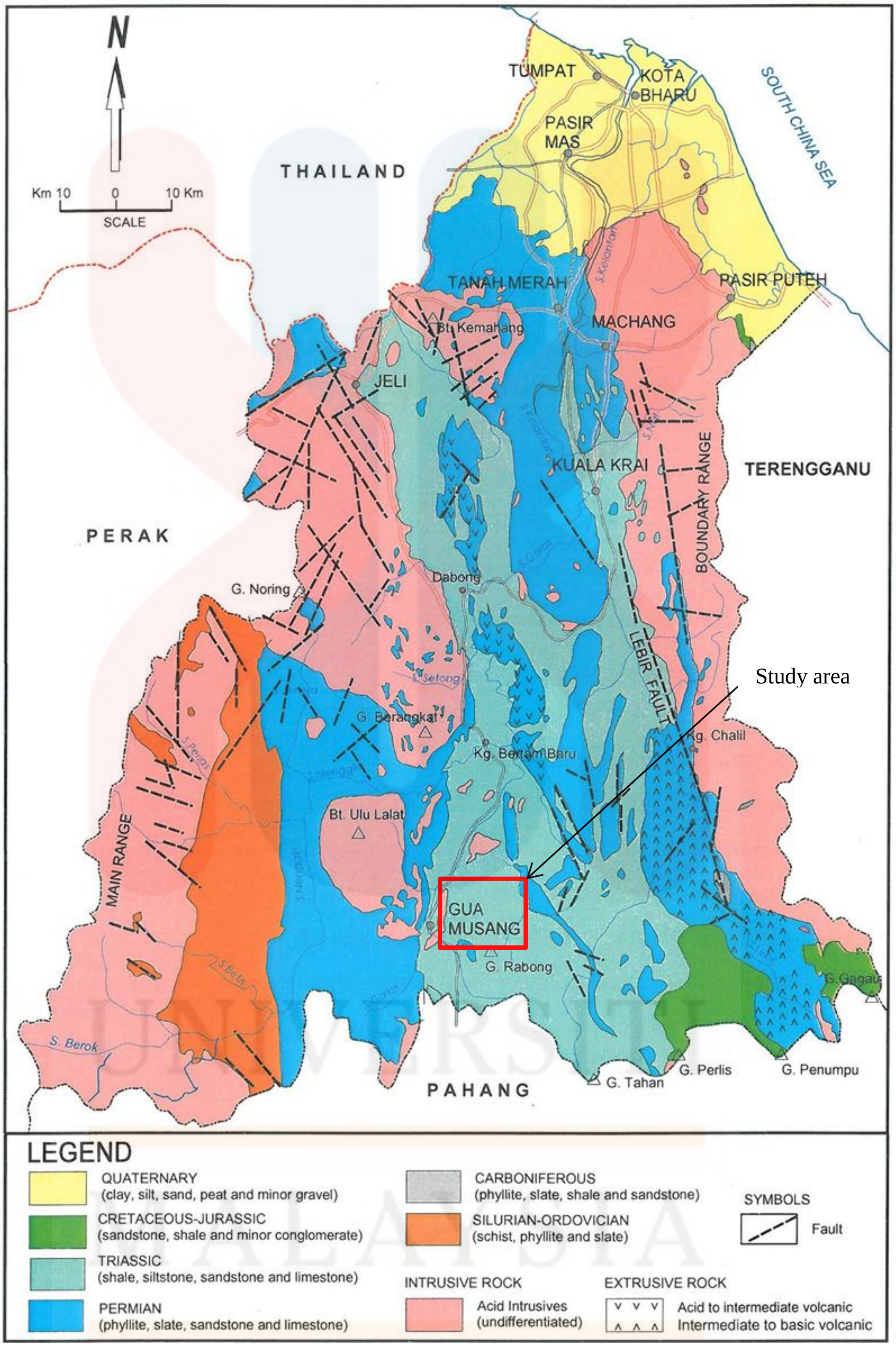

Figure 1.1 : Lithology map of Kelantan

(Source : Department of Minerals and Geoscience Malaysia (2003) Quarry Resource Planning for the State of Kelantan. Osborne & Chappel Sdn. Bhd)

1.2 Problem Statements

A source rock can be broadly defined as any fine-grained, organic-rich rock that is capable of generating petroleum, given sufficient exposure to heat and pressure. From the study area, the lithologies are off sedimentary rocks that include sandstone, shale, limestone and siltstone. These are all potential source rocks given that they fulfil all the conditions to be able to generate hydrocarbons.

Also, thermal maturity of the rocks is difficult to be accurately determined. Thermal maturity in this research refers to the source rock exposure to heat over time. Immature rocks are ones with potential in becoming source rocks but not during that specific timing because the condition is infavorable. As the rocks are buried deeper within the earth, the exposure they have to heat increases. The precise depth of the burial rocks and the amount of heat exposure towards the rocks are difficult to identify.

The map and information regarding the study area are very limited as some of the areas in Gua Musang have developed but not yet been recorded. Also, the general geology analysis is to identify the geological information of the area such as geomorphology, lithology and structural features. The study area in Gua Panjang is covered mostly with thick vegetation with limited access to main roads, which makes it even more difficult to locate the potential source rock using the geological mapping method. The lack of significant discoveries in Gua Musang is what caused the lack of economic potential exploration.

1.3 Research Objectives

The research objectives are ;

a) To update the geological map of the study area with scale of 1 : 25000

b) To study the organic richness of the potential source rock in the study area

1.4 Study Area

Kelantan is located in the central belt of the Peninsular Malaysia and it is bordered by Narathiwat Province of Thailand to the north, Terengganu to the south-east, Perak to the west, Pahang to the south and to the west of Kelantan is the South China Sea. The study area is located in area of Gua Panjang or also known by the locals as Gua Nenek, near the Bandar Gua Musang. It can be reached by modest transportation with only 20 minutes from the town. The study area covers a box of 5 km x 5 km of Gua Panjang area and the base map can be referred to in Figure 1.2.

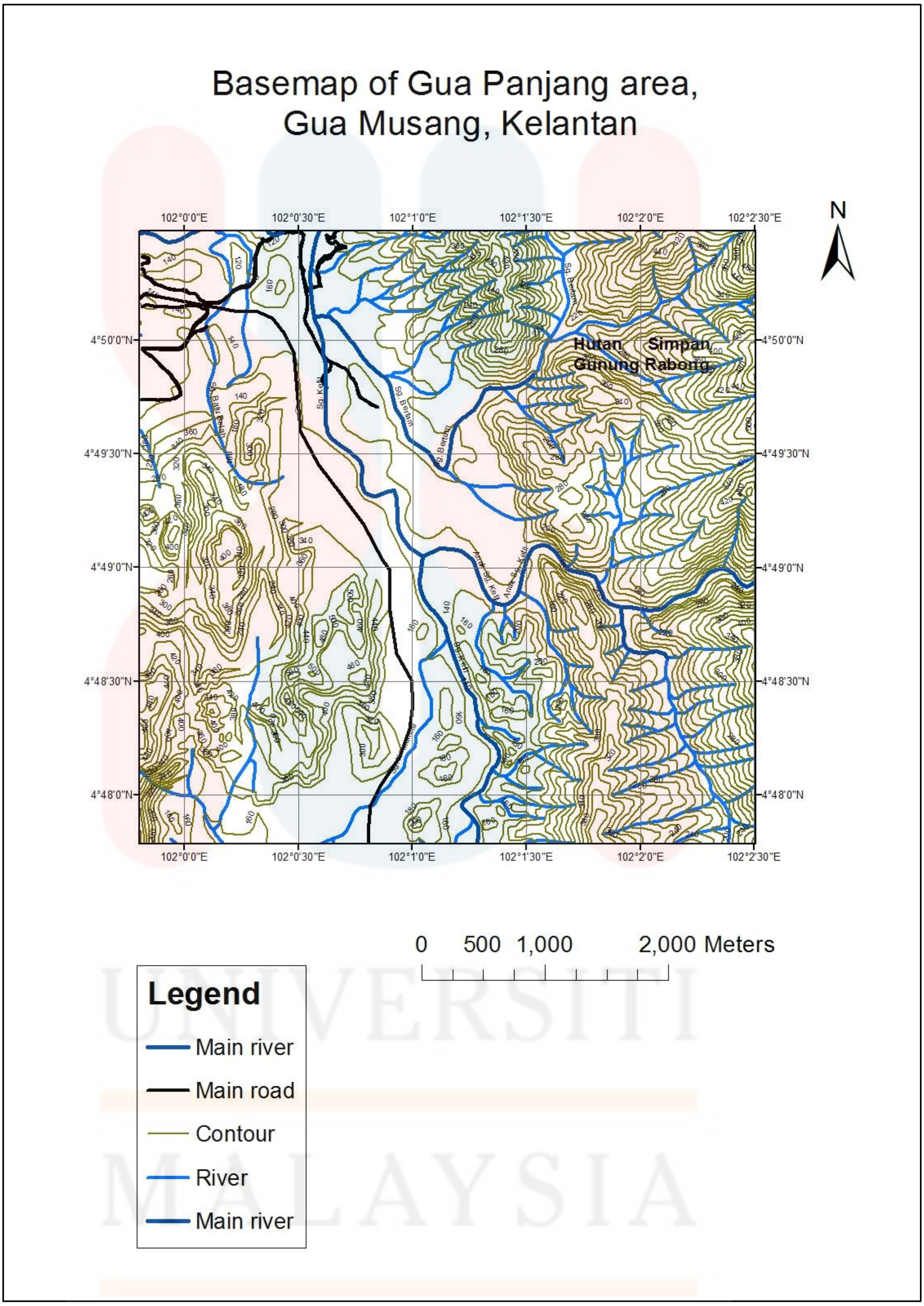

Figure 1.2 : Basemap of study area

1.4.1 Location

Gua Panjang, Gua Musang is located near the Bandar Gua Musang with approximately 10 km from the town and 130 km from University Malaysia Kelantan Jeli campus. To get to the study area from Bandar Gua Musang, one must take the first exit on the roundabout before heading south to Kuala Lumpur. If coming from the south, the roundabout must be exited on the third exit. The study area can be accessed through Chin Teck Plantation Estate which is a private estate. The main river in the area is the Sungai Ketil which extends from the north to the south and there is only one main road in the study area and one railway route that connects the south to the north of Malaysia. The line is for the national train company, KeretaApi Tanah Melayu (KTM) Sdn Bhd. About 70 % of the study area is covered with vegetation of palm trees, and the rests are rubber plantation and preservation forest of Gunung Rabung.

1.4.2 Demography

Gua Musang is divided into three sub-districts which are Chiku, Galas and Bertam. The total population of the whole Gua Musang District is 86,189 people as in the year 2010. There are three major ethnic groups in Gua Musang which are Malay, Chinese and Indian with Malay population having the highest number of 64,253 which covers 74.5 % people in Gua Musang. This is followed by Chinese with 3,870 people, Indian with 350 people and the rest are others including non-Malaysian citizens. Figure 1.3 shows the population number based on ethnicity in representation of a bar graph. Sub-district Galas has the highest population of 36,955 people as it covers the most developed town in the whole Gua Musang district that is the Bandar Gua Musang. Table 1.1 shows the population in Gua Musang Kelantan.

The factor of location and distribution of facilities influenced the different compositions of residents in the north and south of Kelantan. In the early 80s, there were 719,827 people living in the north, compared to only 139,543 in the south, for a ratio of 6:1. This effectively means that Southern Kelantan makes up 83% of the state landmass but was home to only 16% of residents in the state (KESEDAR, 2016).

Table 1.1 : Total population by ethnic group in Gua Musang, Kelantan

Jadual 20.1 : Jumlah penduduk mengikut kumpulan etnik, daerah/mukim dan negeri, Malaysia, 2010 (samb.)
Table 20.1 : Total population by ethnic group, district/mukim and state, Malaysia, 2010 (cont'd)

Negeri : KELANTAN
State

Jajahan/Daerah/Mukim *Jajahan/District/Mukim*	Jumlah *Total*	Warganegara Malaysia *Malaysian citizens*							Bukan warganegara Malaysia *Non-Malaysian citizens*
		Jumlah *Total*	Bumiputera			Cina *Chinese*	India *Indians*	Lain-lain *Others*	
			Jumlah *Total*	Melayu *Malay*	Bumiputera Lain *Other Bumiputera*				
GUA MUSANG (samb./*cont'd*)									
Chiku	**26,093**	**23,514**	**23,423**	**22,925**	**498**	**40**	**14**	**37**	**2,579**
Relai	26,093	23,514	23,423	22,925	498	40	14	37	2,579
GUA MUSANG	**86,189**	**81,204**	**76,823**	**64,253**	**12,570**	**3,870**	**350**	**161**	**4,985**
Galas	**36,955**	**35,312**	**31,084**	**30,981**	**103**	**3,808**	**329**	**91**	**1,643**
Bandar Gua Musang	20,047	19,369	15,944	15,848	96	3,100	287	38	678
Batu Papan	1,834	1,706	1,687	1,687	-	9	-	10	128
Gua Musang	163	160	160	160	-	-	-	-	3
Ketil	1,818	1,660	1,617	1,617	-	14	25	4	158
Pulai	2,203	2,069	1,422	1,418	4	617	16	14	134
Renok	10,890	10,348	10,254	10,251	3	68	1	25	542
Bertam	**23,141**	**22,378**	**22,316**	**10,347**	**11,969**	**22**	**7**	**33**	**763**
Kuala Sungai	563	524	524	524	-	-	-	-	39
Limau Kasturi	2,322	2,022	2,009	2,009	-	6	-	7	300
Ulu Nenggiri	20,256	19,832	19,783	7,814	11,969	16	7	26	424

(Source : Department of Statistics Malaysia (web))

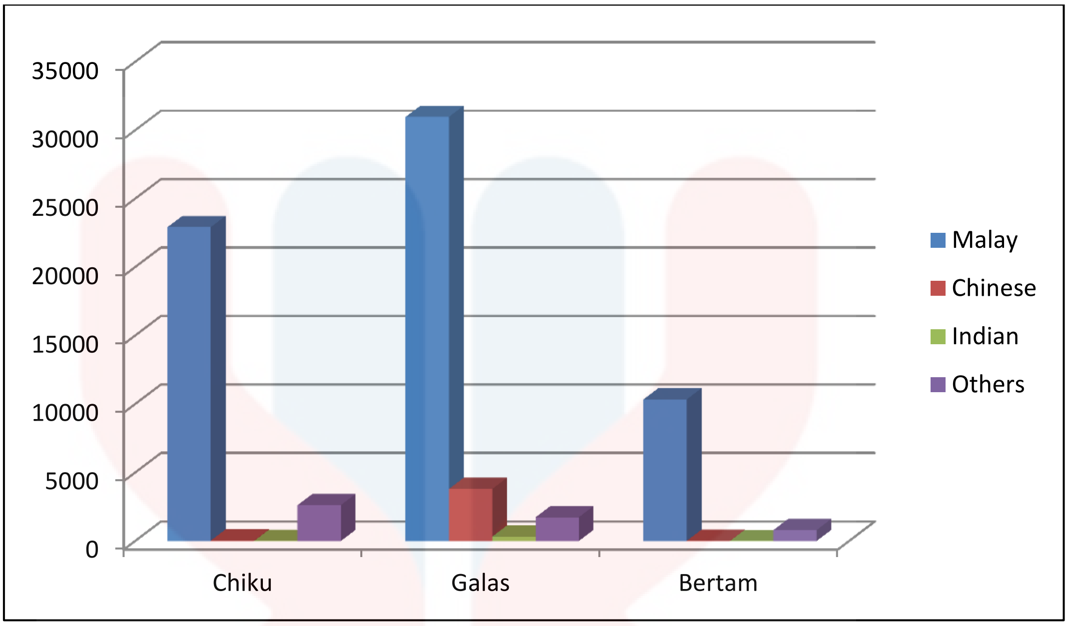

Figure 1.3 : Graph bar of the population in Gua Musang according to ethnicity

1.4.3 Rainfall

The annual average rain distribution in the state of Kelantan is 291.27 mm per month. In the district of Gua Musang, the annual total rain for the year 2014 is 3220 mm that is average compared to Gunung Gagau district with total rain exceeding 5000 mm. The least rain-affected district is Laloh with total rain of 2417.0 mm. February is the least rained month in Gua Musang with only 3.0 mm of rain and December recorded the most rained month with rain total of 591.0 mm. The second most rained month is August with more than 600 mm total rain. It can be said that Gua Musang experiences rain in monthly basis with frequent rains toward the end of the year. Appendix A shows the percentage of annual average rain in Kelantan for the year 2014 and Figure 1.4 shows the pie chart of the rain distribution.

From the pie chart, it can be said that Laloh experienced 2417.0 mm of rain in 2014, followed by Dabong with 2666.0 mm, then Gua Musang with 3220.0 mm of rain. Aring was rained with 3620.0 mm in 2014 with difference of 1286.0 mm from Jeli. Lastly Gunung Gagau experienced 5850.0 mm rain in 2014. These are all arranged in ascending order respectively.

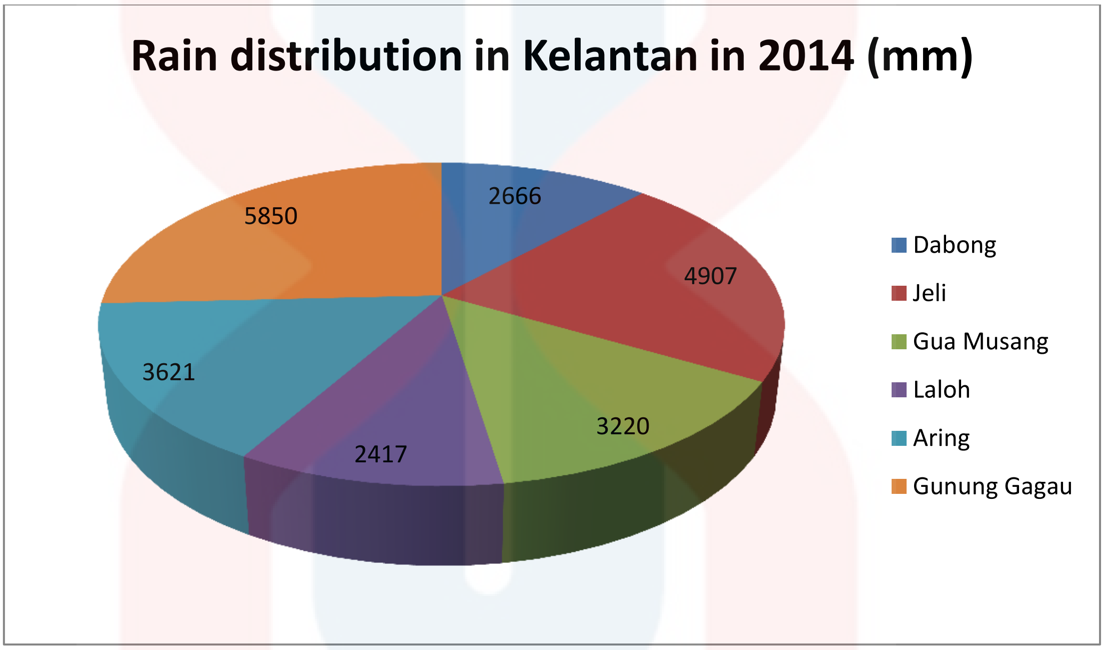

Figure 1.4 : Pie chart of rain distribution in Kelantan for the year 2014

1.4.4 Landuse

The region of Southern Kelantan borders Thailand to the north, Perak to the west, Pahang to the south, and Terengganu to the east. This is effectively three quarters (3/4) of the landmass for the state of Kelantan, 1.234 million hectares, covering the Territory of Gua Musang (797,976 ha.), Kuala Krai Territory (335,689 ha.) and Tanah Merah Territory (72,273 ha.).

Southern Kelantan is a hilly area with almost 50% of the land at gradients of more than 25° and just 10% with gradients of less than 15°. Despite the large landmass, only 20% of the land has potential to be developed for the agricultural sector. (KESEDAR, 2016)

Gua Musang District is located in the south of Kelantan and is quite separated from the central state administration in Kota Bharu. The South Kelantan Development Authority (KESEDAR) and the Federal Land Development Authority (FELDA) are the two main agencies that develop land schemes in the district of Gua Musang, Kelantan. A large part of the schemes under the FELDA was planted with oil palm trees (84.7%) while the rest was planted with rubber trees.

Oil palm tree is widely cultivated in only four land schemes: Paloh 1, Paloh 2, Paloh 3, and Chalil. In the other land schemes oil palm is cultivated on a small scale. Rubber is mostly grown in the Meranto, Sungai Terah, New Renok, Jeram, Tekoh, Limau Kasturi, and Sungai Asap land schemes. The overall land area the FELDA oil palm plantation in Gua Musang was 10,552.50 hectares in 2008 and 8,867.23 hectares in 2009. Comparatively, in 2008 there was a total of 432.52 hectares of rubber plantations, which decreased to 180.66 hectares by April of 2009 (Fauzi Hussin, 2012).

Despite the agriculture development in Gua Musang, most of the region in Gua Musang are still kept untouched. Forest are generally thick and some of them are even preserved as Hutan Rizab negeri Kelantan.

Figure 1.5 shows the landuse in the study area of Gua Panjang which include preserved forest of Hutan Rizab Gunung Rabong, Chin Teck Palm Oil Plantation estate, thick forest and small settlement within the estate.

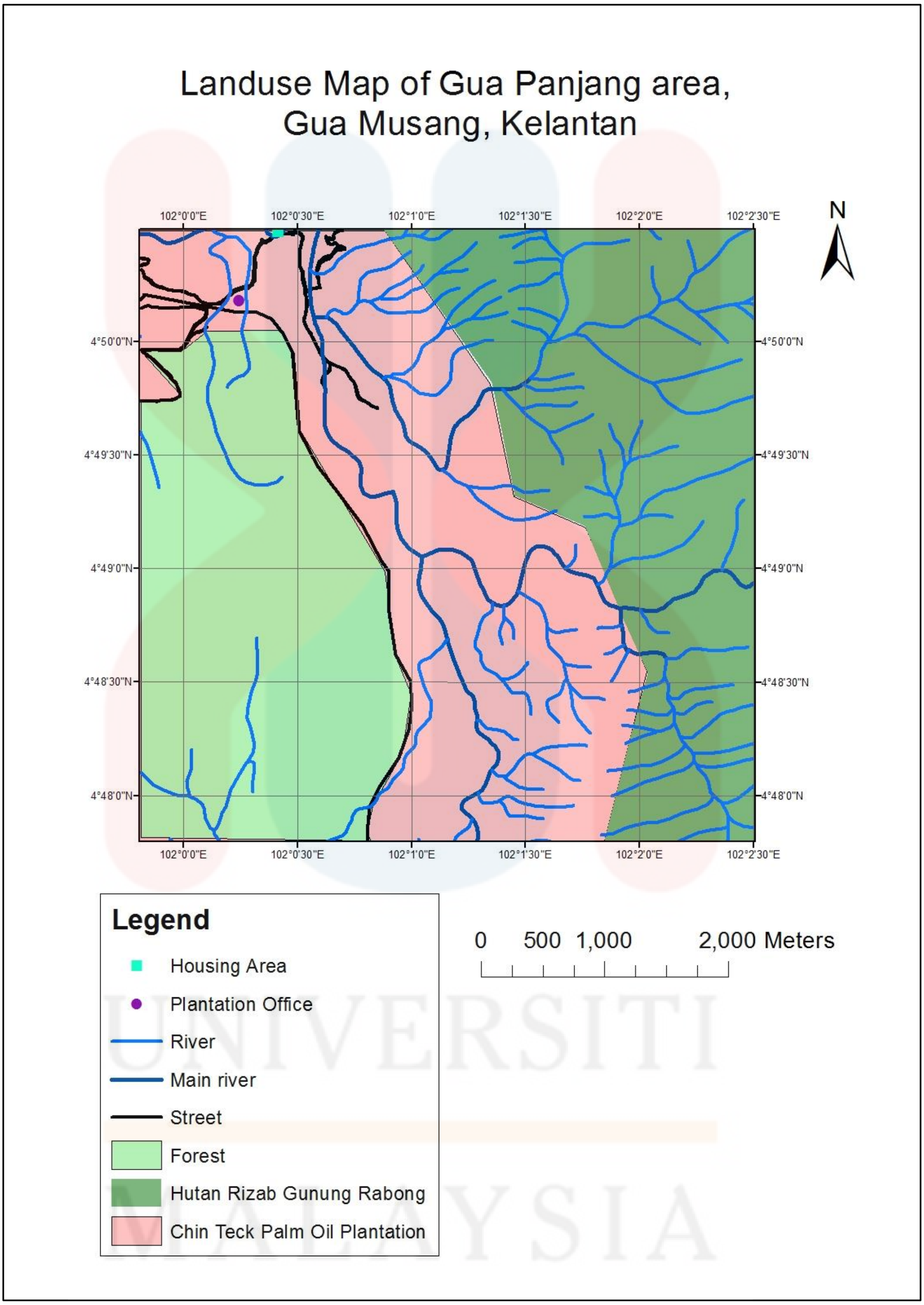

Figure 1.5 : Landuse map of study area

1.4.5 Social Economic

Kelantan, which has an area of roughly 1.5 million hectares, remained the poorest state in Malaysia in the early 1980s, with the lowest GDP per capita in the country at approximately RM1,740.00 and boasted only 46% of the national percentage at RM3,758.00. Kelantan was the poorest state in Malaysia in the early 80s, and Southern Kelantan was the poorest of the poor, with an average monthly income of just RM259 (1985). This was linked to almost 80% of residents relying on the agriculture sector.

Gua Musang is an area where most people are from the settler community. Each settler is given a total of ten acres for the farm and a house. Therefore, the settlers' main occupation and income come from palm oil and rubber. The income derived each month covers the cost of living expenses and schooling for their children. Hence the social economic conducted in Gua Musang is mostly agricultural-based. Although recently the district of Gua Musang has slowly develop its business-sector through the many shop-lots established, especially in Bandar Gua Musang.

Table 1.2 shows the acreage of the oil palm plantations and the total production of the Gua Musang FELDA land scheme. In 2008, the total oil palm production varied according to the size of the planted area. Although Chiku 1 had a smaller area compared to Kemahang 1 the production higher at 28,611.92 tonnes. The least amount of farm produce was from the Aring land scheme with 11,586.64 tonnes. In 2008, Felda Gua Musang had a high total yield of 158,904.32 tonnes. Figure 1.6 shows the palm-oil plantation as the social economic activity.

Table 1.2 : Acreage of oil plantations in FELDA Gua Musang

Scheme	Acreage of crops (hectare)		Production (M/tonnes)
	Planted	Harvested	
Kemahang 1	1957.15	1957.15	23,877.15
Chiku 1	1806.04	1806.04	28,611.92
Chiku 2	1204.74	1204.74	20,665.12
Chiku 3	788.40	788.40	12,261.56
Chiku 5	1217.63	1217.63	17,104.71
Chiku 6	832.56	832.56	13,886.43
Chiku 7	1106.85	1106.85	19,226.22
Perasu	806.67	806.67	11,684.57
Aring	832.46	832.46	11,586.64
Total	10552.5	10552.5	158,904.32

Source: FELDA Gua Musang office, June 2009.

(Source : FELDA Gua Musang office)

Figure 1.6 : Field photograph of the economic activity (oil palm plantation) in the study area

Coordinate : N 04°50’30.071 E 102°2’30.113

1.4.6 Road connection / Accessibility

There are two federal routes, 8 and 185 which intersect near Gua Musang. Route 8 leads to the state administrative center of Kota Bharu northwards, while route 185 connects Simpang Pulai near Ipoh in Perak in the west to Kuala Jenderis in Hulu Terengganu in Terengganu in the east. Due to Gua Musang vast landmass, the road connection between the villages and some areas is severely bad.

The area of Gua Panjang can be reached by bituminous road and slight off-roads. It takes about twenty minutes to reach study area from the Bandar Gua Musang. Also, Gua Panjang can be reached from road directing Gua Musang-Kuala Lumpur highway. The surrounding areas in the location of study can be access by non-bituminous road or small roads which is through the estates and small villages. Most of the roads are in bad conditions and are not really suitable for normal vehicles. Figure 1.7 shows the road accessibility in the study area which include the main road or the street and the small roads inside the plantation estate.

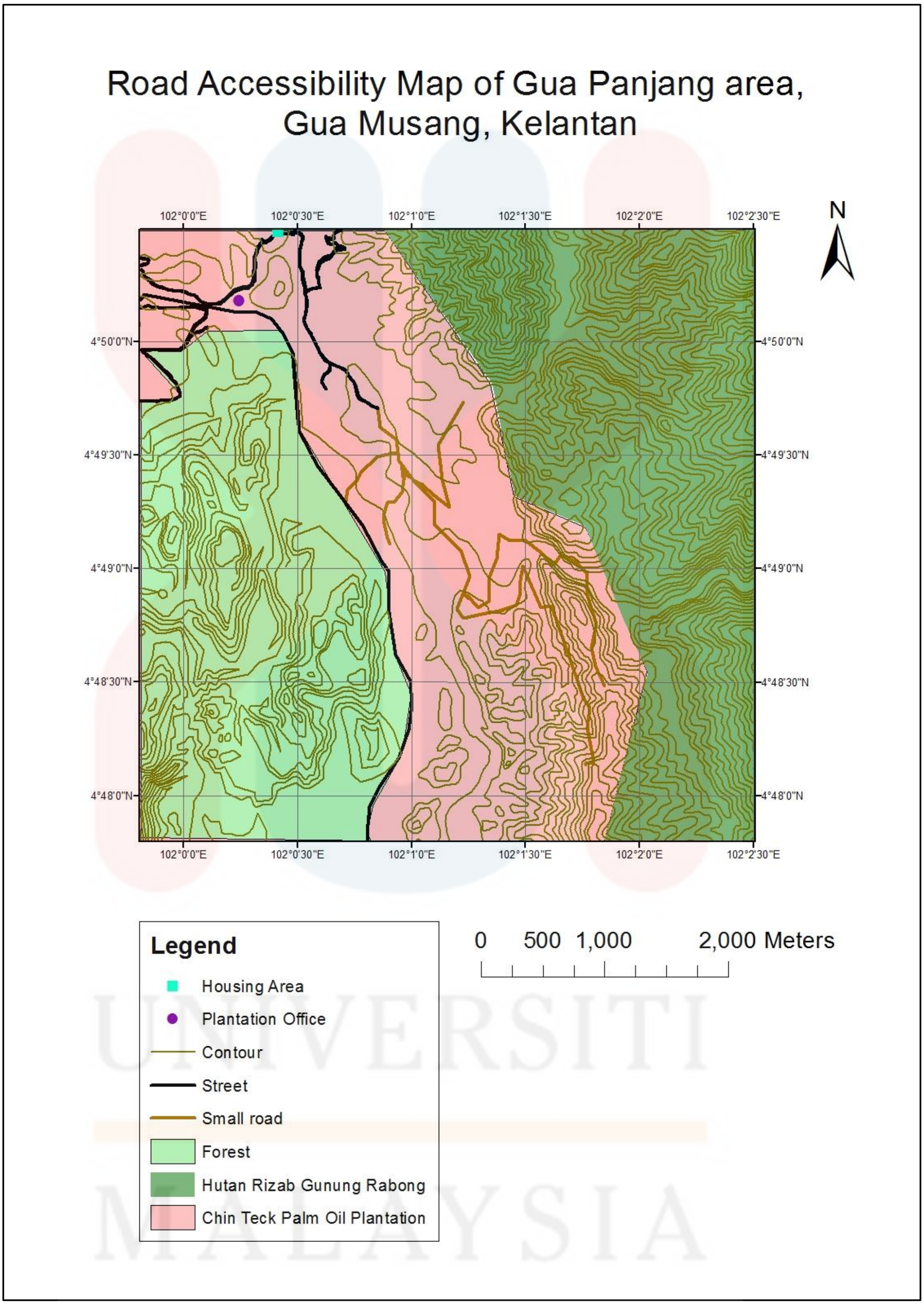

Figure 1.7 : Road Accessibility Map

1.5 Scope of study

For the general geology research, a basic geological mapping was conducted to observe the study area. Samples are taken from the study area and analyzed through petrographic analysis to determine the exact minerals that are present in the rocks and hence further ensured the type of rock observed. Geomorphology and the geological structures are noted and marked to improve the geological map.

The scope of study is related to general geology and petrographic analysis of the rocks in the study area. Also, the specification of the study is related to organic material in the potential petroleum source rock. The objectives of this research are to produce improved and updated geological maps of the study area, to determine the lithology of rocks in the study area, the structural geology and geomorphology of the area as well as to investigate the organic material containing in the potential petroleum source rock in the study area.

For the petroleum source rock evaluation, samples are collected and tested with organic geochemical analyses. Through the data acquired, the data is interpreted based on the Extracted Organic Material (EOM) calculated from the experiment. The result helped to identify the detail of the organic content of the potential petroleum source rock.

1.6 Research Importance

From the research, updated geological maps are produced, which contains additional roads, vegetation areas and new town or populated areas. Geological information regarding the area can help in exploring the area for future developments.

Meanwhile, for the petroleum source rock evaluation, the organic material helps in identifying the potential of the petroleum source rocks. Source rocks are crucial in order to determine the potential economic value a place has. This research can help the society to appreciate and acknowledge the value a rock has to offer. Also, the economy of the locals and the nations are improved if the rocks do have high potential as petroleum source rock.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss on the literature review of previous studies that had been conducted regarding any related topic to the research. The purpose of literature review is to justify the methodological choices to situate with the current study within a wider disciplinary conversation. This chapter will cover about Regional Geology and Tectonic Setting, Regional Stratigraphy, Structural Geology, Sedimentology and Source rock analysis.

2.2 Regional Geology and Tectonic Setting

According to Hutchinson (1989, 1996) , the Peninsular of Malaysia is an integral part of the Eurasian plate that is on the South- East Asia called Sundaland. The Peninsular is then subdivided into three belts which are the Western belt, Central belt and the Eastern belt. The Main Range is the most prominent and continuous of the mountain ranges in Peninsular and extends from southern Thailand. (Hutchison, 2009). The eastern part of the Main Range is considered to be the boundary between the Central and Western belts and the boundary between the Central and Eastern belts is the western foothills of the elongate granitic plutons of Terengganu, Pahang and Johor.

The peninsular has completely emerged throughout the Cenozoic Era and is considered to be tectonically stable. That is, the activity is confined to epeirogenic uplift and tilting, some fault movement and local gentle downwarps (Stauffer, 1973).

Gua Musang is located within the south of the state of Kelantan which is situated in the central belt of the Peninsular. The central belt undoubtedly had been subjected to major north-south trending faulting (T.T. Khoo, 1983). These major faults have influenced the development of tectonic of the peninsular. The central and eastern parts of the Peninsular have more widespread of upper Palaeozoic rocks than in the western part which is confined to Lower Palaeozoic outcrops (Yee, 1983).

Massive plutonic acid magmatism occurred during the late Triassic and late Cretaceous in the Central Belt and a large acid to andesitic volcanism occurred in the Permian and Triassic. After the cratonization of the peninsular Malaysia, volcanic activities continued to be manifested in the late Mesozoic, early Tertiary and Pleistocene in the Central and Eastern belts.

2.2.1 Stratigraphy

The geological formation of Kelantan ranges from Lower Paleozoic until Quaternary and can be divided into three main chronology which are the Paleozoic, Mesozoic and Cenozoic. The Central Belt is largely underlain by rocks of the

Mesozoic and Permian (Yee, 1983). The bulk of the Upper Paleozoic sediments consist of marine Permian strata that occur as linear belts flanking Mesozoic sediments in the Central Belt. Raub group which consists of rocks of the Calcareous Series that aged from Carbo- Permian stretches along the belt from Kelantan southwards to Bentong in south Pahang. In Kelantan, formations included within this group are the Gua Musang formation and Aring formation that is located in the South of Kelantan. Gua Musang is located within the Gua Musang Formation in the central zone. The central zone of the Peninsular is bordered on the west by the Main Range granite and Lower Palaeozoic sediments of the Bentong group (Yee, 1983). The oldest sediments recorded in the central zone are sporadic outcrops of Carboniferous limestone (Yee, 1983). The upper Palaeozoic sediments of the central zone consist of four facies which are the argillaceous, volcanic, calcareous and arenaceous.

The Gua Musang formation consists of calcareous-argillaceous sequence of crystalline limestone with interbedded argillites and subordinate sandstones and volcanics (Yee, 1983). The shales are commonly grey but can vary to black when carbonaceous. The sandstones include greywacke, protoquartzites and orthoquartzites but metaquartzites are the most common. The volcanics vary in composition from rhyolitic to andesitic and include tuffs, lavas and agglomerates. A Late Carboniferous to Triassic age is indicated by fossils presence. The formation is the lateral equivalent of the Aring formation which is pyroclastic. It can also be considered to be synonymous with the Telong formation of Aw, who estimated a thickness of about 650 m for the unit in South Kelantan.

2.2.2 Structural Geology

The Taku Schists and adjacent areas occupy the northern part of the Central Belt and suffered uplift, recumbent style folding and regional metamorphism during the late Triassic. In the rest of the Central Belt, the late Triassic orogenic uplift has terminated marine sedimentation. Continental deposition began afterwards and continued up to the early Cretaceous. During the late Cretaceous, the continental deposits were uplifted and gently folded (Tan, 1983).

2.2.3 Historical Geology

The Central Belt of Peninsular Malaysia is covered predominantly by Permian-Triassic clastics, volcanics and limestones (Tan, 1983). During the pre-early Devonian deposition, coarse-clastics, argillaceous sediments chert and other rock types occur in the marginal belt forming the foothills of the Main Range Granite.

The Upper Paleozoic formation of Gua Musang is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous facies. The depositional environment in Gua Musang is off usually shallow marine with irregular active submarine volcanism starting in the Late Carboniferous and reaching its peak in the Permian and Triassic. The oldest sediments recorded in the central zone are sporadic outcrops of Carboniferous limestone.

In Gua Panjang, occurrences of algal boundstone, wackestone, packestone and oolitic grainstone were reported (Hussin, 1990). The limestones in Gua Panjang ranges from Late Permian to Anisian or possibly Scythian. According to (Hada, 1966), the Triassic succession contains ammonites belonging to the *Meekoceras* *gracilitatus* zone, and conodonts like *Hindeodella*, *Neoprioniodus biscuspidatus* and *Hibbardella*. The relationship between the Permian and Triassic succession is observed as unclear in Gua Panjang.

2.3 Geochemical analysis

2.3.1 Organic matter richness

A source rock is generally defined as any fine-grained, organic-rich rock that is capable of generating petroleum, given that it is mature enough under sufficient temperature and pressure (Rojas, McCarthy, Niemann, Palmowski, Peters, & Stankiewicz, 2011). Organic richness refers to the quantity and type of organic matter contained within a rock. In order to determine the potential of a rock to generate petroleum, the thermal transformation of organic matter needed to be taken into account.

Organic content in a rock is controlled greatly by biological productivity, sediment mineralogy and oxygenation of the water column and sediment. Biologic contributions to organic content range from hydrogen-poor woody fragments to hydrogen-rich algal or bacterial components (Rojas, McCarthy, Niemann, Palmowski, Peters, & Stankiewicz, 2011). The organic matter is subjected to many chemical and biological processes as it settles down the water column to sediment interface. Oxygen, water Eh and pH play major role in the productivity of organic matter as biodegradation and oxidation reduce organic richness of the sediments. Commonly, Type I and Type II Kerogen are derived from lacustrine and marine source rocks are the best kerogen and capable of generating liquid hydrocarbons (Hakimi, Abdullah, & Shalaby, 2012). Type III Kerogens are mostly contained with woody materials and are gas proned (Rubble, Lewan, & Philip, 2001). Type IV Kerogen composed primarily of inert material and has no potential generating hydrocarbons. Coals usually are dominated by Type III kerogen and are gas proned (Mustapha & Abdulllah, 2013)

According to the article Basic Petroleum Geochemistry for Source Rock Evaluation by (Rojas, McCarthy, Niemann, Palmowski, Peters, & Stankiewicz 2011), many organic-rich source rocks are argillaceous and carbonate (typically marls) that can contain up to 30 % total organic carbon (TOC). The boundary between a fair and a poor clastic source rock is commonly defined at approximately 0.5 percent total organic carbon content (Tissot, 1978). Carbonates with as little as 0.3 percent TOC is considered to be fair source rocks. Good clastic source rocks generally contain greater than 1.0 percent TOC and good carbonate source rocks have TOC value greater than 0.5 percent.

According to the classification by (Peters & Cassa, 1994), potential source rock with bitumen more than 1000 ppm value is a good source rock. An excellent source rock is one that has the value of bitumen more than 4000 ppm. On the other hand, a poor potential source rock has the value of bitumen less than 500 ppm.

Gua Musang area is mostly covered with argillaceous facies, volcanic, calcareous and arenaceous facies (Yee, 1983).

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter will discuss the materials and methodologies involved during the conduction of the research. These include the materials and methods used, the preliminary studies, the field of study, the laboratory investigations and how the data is analyzed and interpreted. This workflow is further divided into two parts which are the general geological research of the study area and the organic material analysis through geochemical analysis. The materials and methods involved in the research are described in details in this chapter.

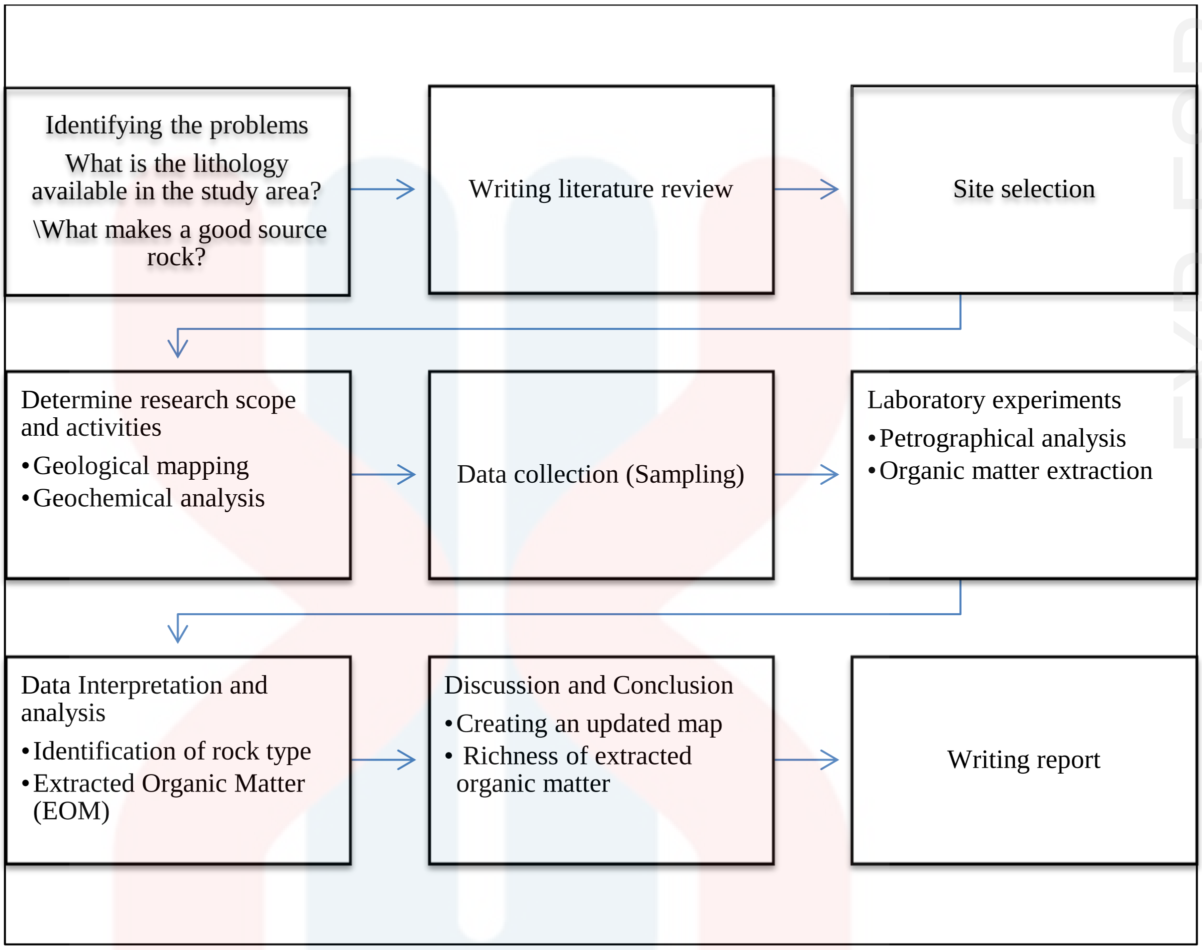

Figure 3.1 : Overview of the research

3.2 Materials

3.2.1 Mapping material

a) Base map / Topological map

The term basemap is often used in GIS and refers to a collection of GIS data and/or orthorectified imagery that form the background setting for a map. The function of the basemap is to provide background detail necessary to orient the location of the map. Information can be added to a basemap by overlaying other information on top of it. Basemaps contain reference information that may provide different geospatial information based on what the cartographer is trying to communicate. For example, the drainage pattern of the study area, the lithologies and the watershed.

Topographic maps are detailed, accurate graphic representations of features that appear on the Earth's surface. These features include:

- cultural: roads, buildings, urban development, railways, airports, names of places and geographic features, administrative boundaries, state and international borders, reserves
- hydrography: lakes, rivers, streams, swamps, coastal flats
- relief: mountains, valleys, contours and cliffs, depressions
- vegetation: wooded and cleared areas, vineyards and orchards.

Topographic maps usually show a geographic graticule and a coordinate grid, so you can determine relative and absolute positions of mapped features.

b) Geology Hammer

A geologist's hammer, rock hammer, rock pick or geological pick is a hammer used for splitting and breaking rocks. In field geology, they are used to obtain a fresh surface of a rock in order to determine its composition, nature, mineralogy, history and field estimate of rock strength.

Figure 3.2 : A geological hammer

c) Global Positioning System Device (GPS).

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit. GPS was originally intended for military applications, but in the 1980s, the system is made available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

Figure 3.3 : Global positioning System (GPS)

d) Compass

A compass is an instrument used for navigation and orientation that shows direction relative to the geographic cardinal directions, or "points". Compass enables users to determine bearings accurately and to pinpoint locations to within a few meters. There are two types of compasses used in the conduction of the research, which are the Brunton compass and Suunto compass.

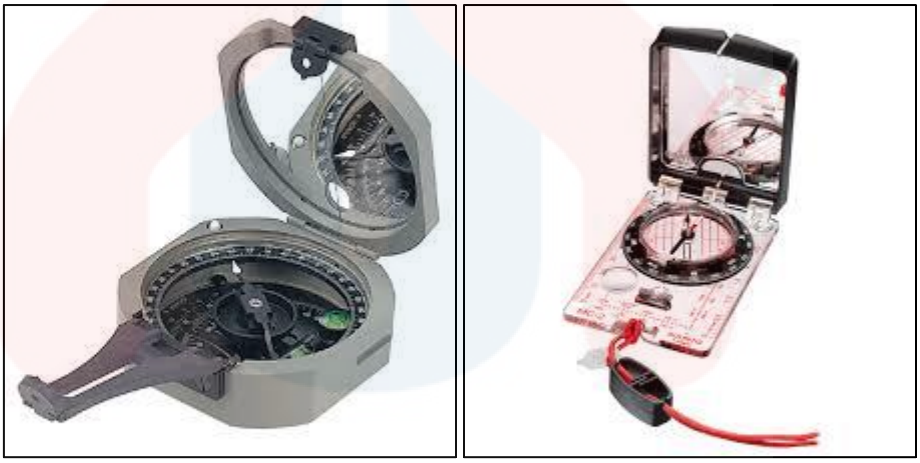

Figure 3.4 : Brunton and Suunto compass

e) Field notebook

Field notebook is used for recording all the data collected during the conduction of the research.

f) Hand lens

Geologists working in the field, lab or office often need to closely examine rocks, sediments, soils, sand, minerals and other materials with tiny features. A hand lens provides a quick and easy way to perform that work.

Figure 3.5 : A 10x hand lens

g) Hydrochloric acid (HCl)

A dilute hydrochloric acid (5 – 10 %) is used to conduct the acid test to the investigate the presence of carbonate minerals such as calcite and dolomite.

Figure 3.6 : Bottles of hydrochloric acid

h) Sample bags

Geological sample bags are to keep the rock samples in a proper storage so that the samples are not exposed to any conditions which by means can affect the geochemistry analysis of the research.

3.2.2 Thin Section Material

a) Polarizing microscope

The microscope is used to determine the optical properties of the minerals. Plus, it helps in determining the size of the minerals present by using the scale on the lens.

b) Glass slides

The glass slides are used in laboratories to hold the specimens underneath microscope for observation. Glass is the chosen material because it allows light from the microscope to easily pass through and illuminate the specimen. The glass slide containing the specimen is placed between the two stage clips on the microscope.

c) Grinder

A grinder is a type of machine that use an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the work piece via shear deformation. A grinder provides the functions of rubbing, pre-grinding, thin section, grinding and polishing.

d) Epoxy

Epoxy is a type of durable glue that provides high grade bonding properties that are far superior to the most of ordinary paste-style glues. The use of epoxy is for mounting detached grains of minerals for optical study.

3.3 Methodology

3.3.1 Preliminary Researches

Preliminary researches are early studies regarding the conduction of the research and before any actions or steps are taken further. Before any steps are taken, the research needs to be studied in details to plan a well-calculated step and to avoid any mistakes or loss so that the research can reach its objectives and to eliminate any inefficiency. Related information and data are obtained from previous thesis, journal articles and other resources like websites and books.

Articles from peer-reviewed journals go through a process of review by one or more experts in the subject area. Peer-reviewed journal articles can also be called refereed journal articles. The Library catalogue includes most of the journal articles available in the Library databases.

Internet is another vital resource to obtain information regarding the research. There are several hundred search engines, Web directories, and subject specific collections on the Internet. Also, there are many solid academic resources available on the Net, including hundreds of on-line journals and sites set up by universities and scholarly or scientific organizations.

3.3.2 Field studies

Field study is the research that is conducted in the field or study area. During the conduction of this research, field works were conducted to collect primary data using suitable method to fulfill the research objectives. The method used in field study is geological mapping. Geological mapping was conducted to gather information about the lithology, structural and petrographic aspect of the study area . All data were collected and analyzed before completing a new and updated geological map of the study area.

Mapping Technique

i. Traverse Mapping

Traverse mapping is a method of mapping used to observe the topographical and set by passing the points of interest in the study area. This method is usually used in a large scale of study area and less detailed data will be gathered. This mapping method approaches only the possible access point or location in the study area such as roads, tracks, streams and ridge crest. Traverse mapping involve simply walking along the predetermined route or traversing using a suitable vehicle where it can be accessed.

Sampling

Samples are taken during the field studies from selected outcrops that can be found in the study area. The samples are collected using the geological hammer and sample bags. The samples are then labeled based on its location in the study area. Then, the samples are observed using the hand lens before being taken to the laboratory for petrographic analysis.

3.3.3 Laboratory work

The methods used to evaluate the organic matter in the potential source rock are described below.

a) Petrographic Analysis

Thin section of the rock samples collected is studied under an optical polarizing microscope. Petrographic analysis is useful in providing information about the mineralogy features of the rocks. Figure 3.1 shows the step in preparation of thin section.

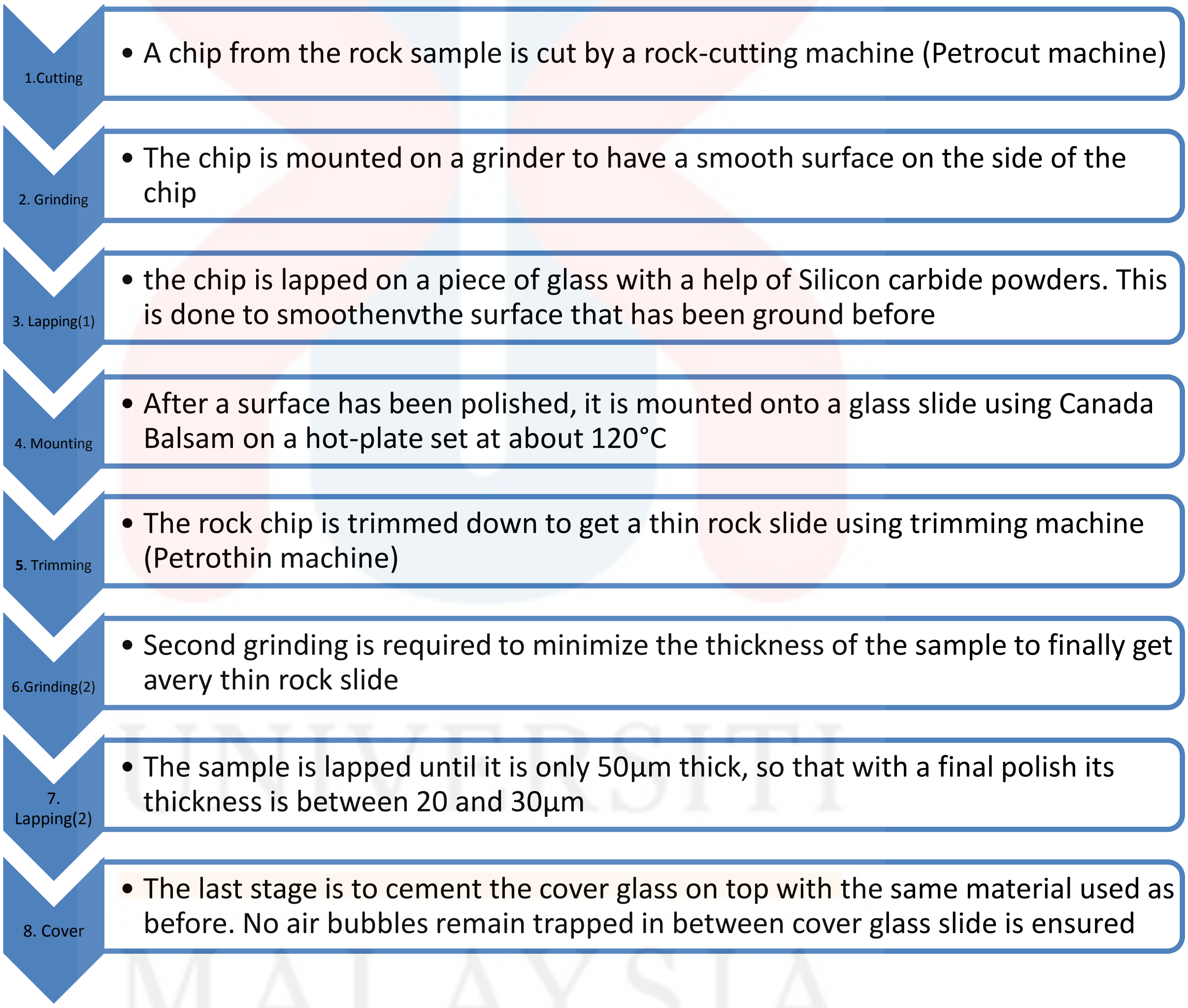

Figure 3.7 : Preparation of thin section

b) Geochemical Analyses

Geochemical analysis carried out in this research is the bitumen extraction. Selected samples of coal and clay were extracted using conventional Soxhlet extraction methods to determine the percentage bitumen/ asphalt and the extracted organic matter (EOM).

Figure 3.8 : Field photograph of clay and coal samples collected

i. Bitumen extraction using Soxhlet extraction method

Soxhlet extraction is used as a method to recover the bitumen or by definition, the soluble in organic solvents from the rock samples. The Soxhlet extractor, named after its designer, is used to keep a continuous supply of fresh solvent to a sample being extracted. Extraction method usually starts with sample preparation. The dirt and any suspected extraneous materials on the rock samples collected from the field are washed or its surface is scrapped to remove the dirty portions or materials. The samples are then wrapped in tinfoil and put in drying oven (in this case 'dirty drying oven') at 110°C to dry properly. Disaggregation (pulverization) and homogenization of the samples are usually achieved with the aid of pestle and mortar. The samples are ground approximately for 10 minutes each. 25 grams of the pulverized samples are weighed into a test-tube using a weighing machine.

The sample is then placed in a thimble and put into the main chamber of the extractor. The extractor is then set up on top of a glass flask containing the solvent to be used. On top of the extractor is placed a reflux condenser. Figure 3.9 shows the soxhlet extraction apparatus set-up. As the solvent boils in the flask, the vapour travels up the extractor, through the vapour tube and up into the condenser where it is converted back into a liquid. This liquid, which is completely free from dissolved components, drips into the main chamber on top of the sample. This continues until the level of solvent in the chamber reaches the highest level of the return tube. When the solvent reaches this level, it starts a siphon which empties the main chamber through the return tube back into the flask. After many cycles which usually takes several hours, the flask will contain the extract products dissolved in the solvent with the solid material left in the timble. The solid material is usually discarded after the experiment and the solvent too is removed typically by means of a rotary evaporator, yielding the extracted compound. Some of the experiment apparatus and processes are shown in Appendix B.

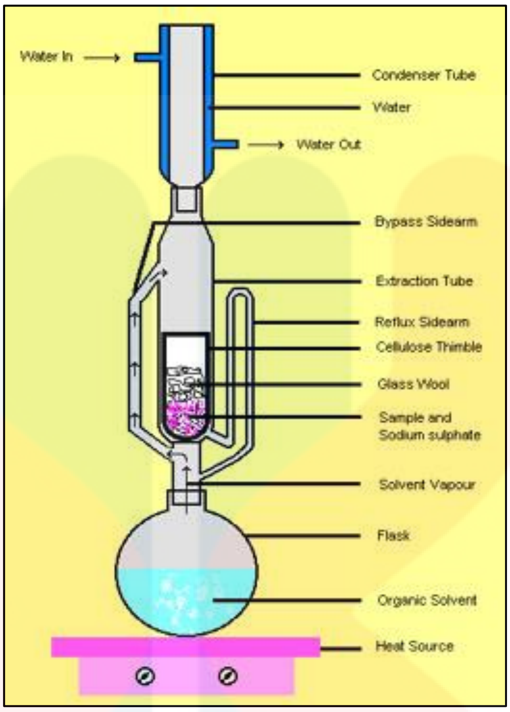

Figure 3.9 : Soxhlet extraction apparatus set-up

(Source : (Benning & Bergeron, 2016))

3.3.4 Data Processing

The thin section slides are observed under the optical polarizing light microscope with cross-polarized light and plane-polarized light. The minerals size, texture, colour and abundance are noted and further recorded for identifying the rock type of samples collected.

For the extraction experiment, the extraction is left for 24 hours for the cycle to continue until there is extracted product dissolved in the solvent of the round bottom flask. Then, the result is collected and interpreted.

3.3.5 Data Analysis and Interpreting

The results obtained from the experiment are recorded and then further analyzed for interpretation. After the extraction, the two fractions which are the materials remained with the solid and the material dissolved in the organic solvent. By definition, kerogen is organic matter that is insoluble in organic solvents and acids and bitumen is organic matter that is soluble in organic solvents and acids, refer figure 3.10 (The Summons Lab)

Petrographic analysis is conducted through observation under the microscope. The minerals present are referred to several references and narrowed down to identify the rock type,

Figure 3.10 : Example of extracted bitumen

(Source : summons.mit.edu)

The yield, the mass of extractable organic matter (EOM) expressed as follows.

Table 3.1 : Table of extraction result

Sample	Standard	Coal	Claystone
Mass of thimble + cotton			
Mass of rock sample (D)	25.000 g	25.000 g	25.000 g
Mass of thimble + cotton + sample (C)			
Mass of thimble + cotton + extracted rock (E)			
EOM (F) g = (C-E)			
EOM = F x 1000000 / D (PPM)			

1000 PPM = 1000 mg / kg
= 1 mg / g
10 000 PPM = 1 Wt %

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is the study of the geological science of the study area. In this chapter, the general geology of the study area going to be described are the geomorphology, stratigraphy, structural geology and historical geology. These general knowledge are very crucial in understanding the whole geological aspect of an area.

Gua Musang is located in the southern part of Kelantan which covers an area of about 7979 km^2, Gua Musang is the largest district in Kelantan that is bordered by the state of Pahang to the south, Terengganu to the east and Perak to the west. In 1976, Gua Musang was given the status of a Sub-District before being upgraded to full district in September 1997. Gua Musang is the ninth district in the state of Kelantan and is divided into three parliaments which are Galas, Bertam and Chiku. Gua Panjang area is located not far from the Bandar Gua Musang, which lies in the Galas parliament that is the most populated parliament in Gua Musang.

As in 2010, Galas has the population of 36,955 people that is the most populated sub-district in Kelantan. In the study area, the settlement is very limited as the area is covered with thick forest and mountainous area. All the settlements in the study area are focused in the palm oil plantation estate as it is the major economic activity of the locals.

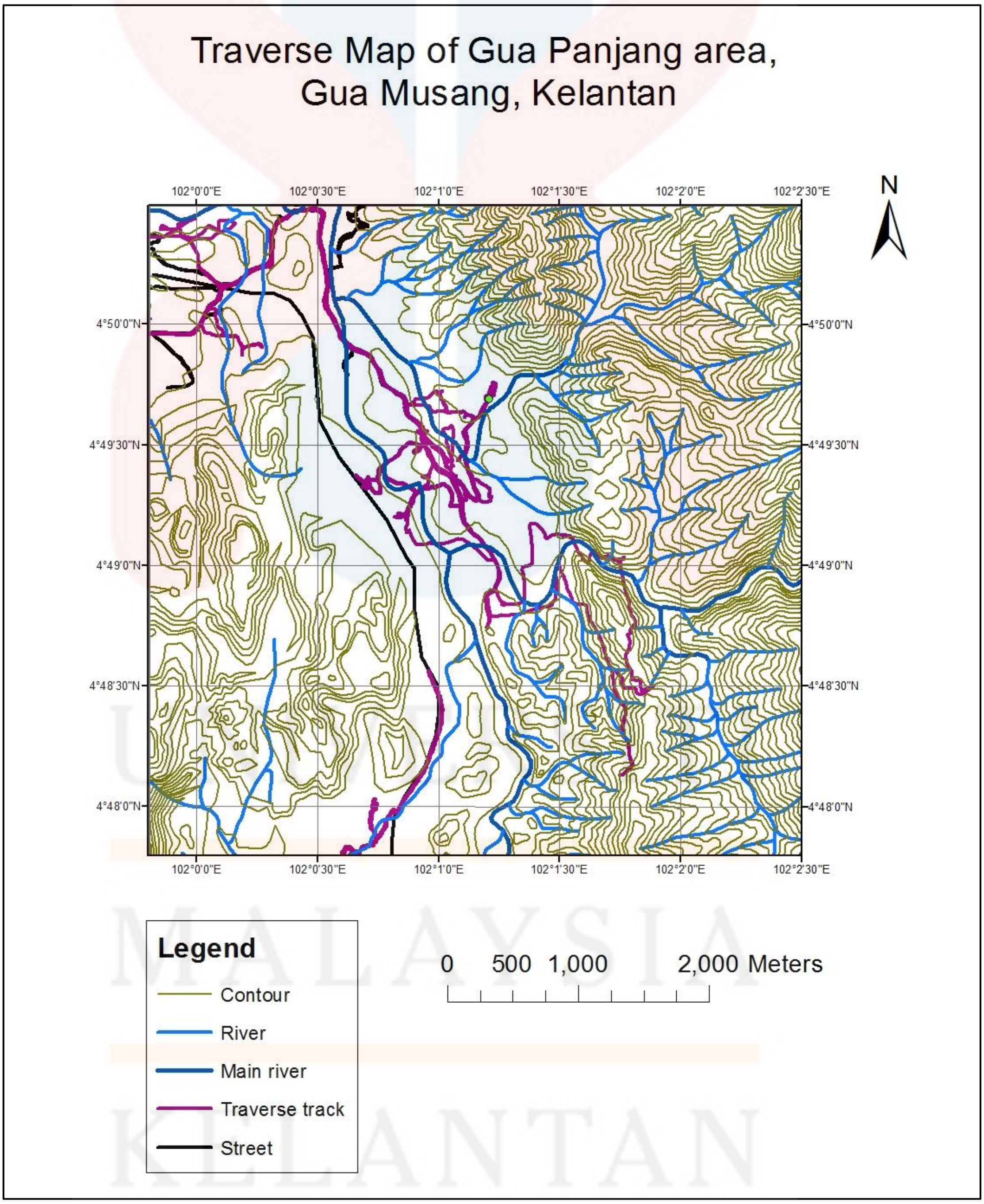

Figure 4.1 : Traverse Map

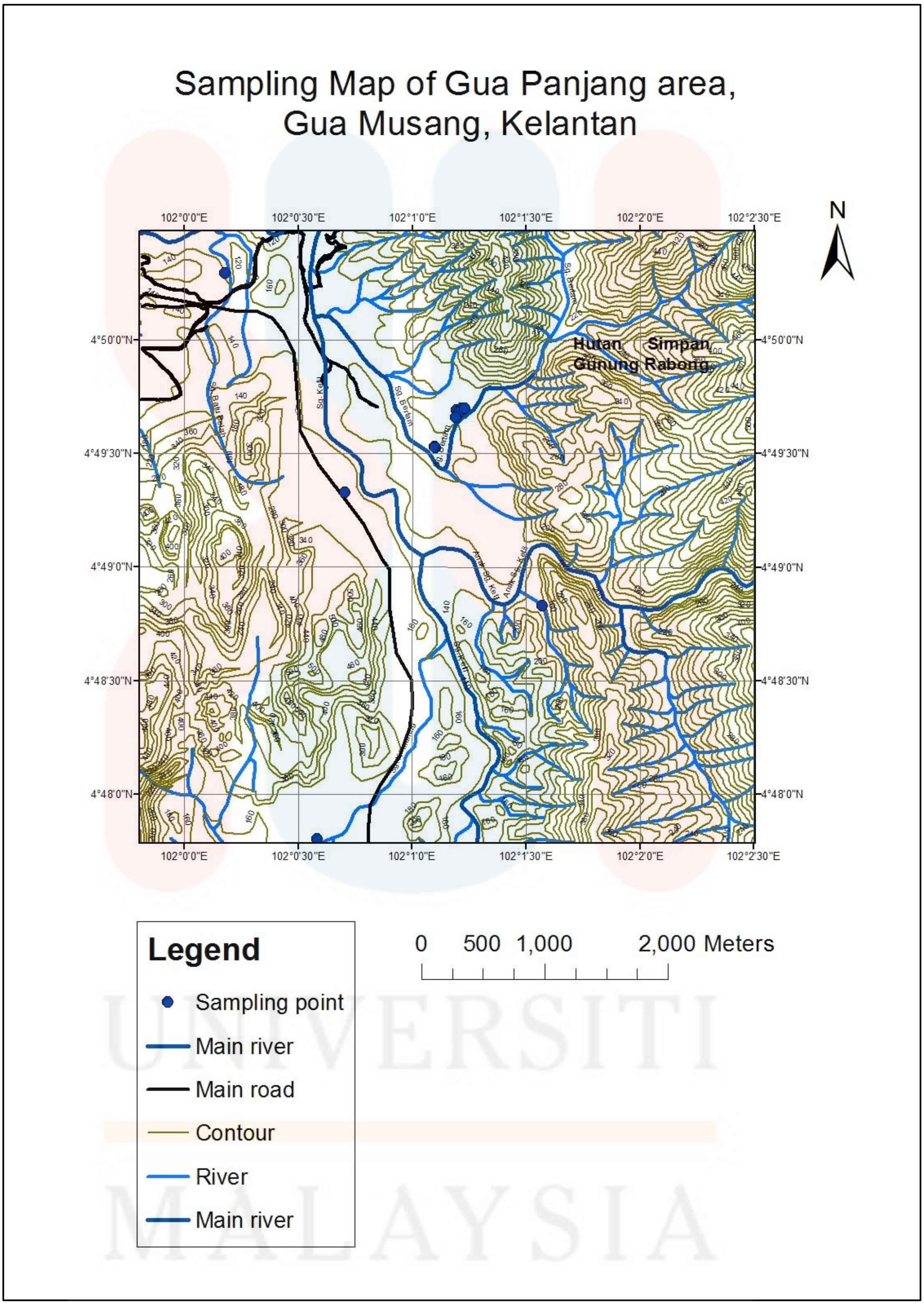

Figure 4.2 : Sampling map

4.2 Geomorphology

The word geomorphology derives from three Greek words which bring the meaning of the Earth, its form and the discourse. Geomorphology is therefore 'a discourse on Earth forms'. It is the study of Earth's physical land surface features, its landforms which include rivers, hills, plains, beaches, sand dunes, and myriad others. It investigates the landforms and the processes involved in the formation of those landforms. Many landforms have a long history, and their present form does not always relate to the current processes acting upon them. The nature and rate of geomorphic processes change with time, and some landforms were produced under different environmental conditions, surviving today as relict features (Huggett, 2007). In modern geomorphology, the three study chief aspects of landforms are form, process and history. The golden rule was the dictum that 'the present is the key to the past'.

The geomorphology of the study area includes karst morphology that lies greatly across the palm plantation. It is formed through the dissolution of limestone and some other rock like dolomite and mineral gypsum. Karst morphology can be characterized through the presence of caves, stalactites and stalagmites, and sea notches. Karst features are very thick, mechanically strong and contain massive joints that can be observed at great distance. The rock bodies of limestone and metalimestones are scattered around the area near the limestone hill. This is because rockfalls, block slides and rock slides are very common in karst morphology as there are many bare rock slopes and cliffs. The solution too acts as effectively sideways as downwards, causing the undercutting of the rocks.

The karst morphology in the study area is bare karst as it is largely exposed to the atmosphere. Some small limestone landforms produced through dissolution is the pinnacle karst that stands up to approximately 2m with wide about the same length at the base. These pinnacles are sometimes exposed to soil erosion and become highly weathered. Limestone cave observed in the study area exhibit common karst features like stalactite and sea notch. The presence of mineral travertine that shines when light hits its surface is small in Gua Panjang. Gua Panjang known by the local as Gua Nenek shows elongated opening which suit its name that means long cave through direct translation from Bahasa Melayu.

Figure 4.3 : Field photograph of the geomorphology in study area

Figure 4.4 : Field photograph of Gua Panjang

Figure 4.5 : Field photograph of stalactite in Gua Panjang

4.2.1 Topography

Topography is the study about the detailed map of the surface features on the land. It includes the mountain, hills, creeks, and other bumps and lumps on a particular hunk on earth. The study area covers 25 km^2 of the area near Gua Panjang in Gua Musang Kelantan. Sungai Ketil is the main river in the study area with most of the area is covered with palm-oil plantations and preserved forest.

The highest elevation point in the study area is in the preserved forest of Hutan Simpan Gunung Rabong, with height exceeding 500 m. This is a mountainous area. The study area is mostly covered with topography of mountainous and hills. The hilly area with elevation not more than 300 m is filled with palm-oil plantation. The topographical map can be referred to in Figure 4.6 and Figure 4.7.

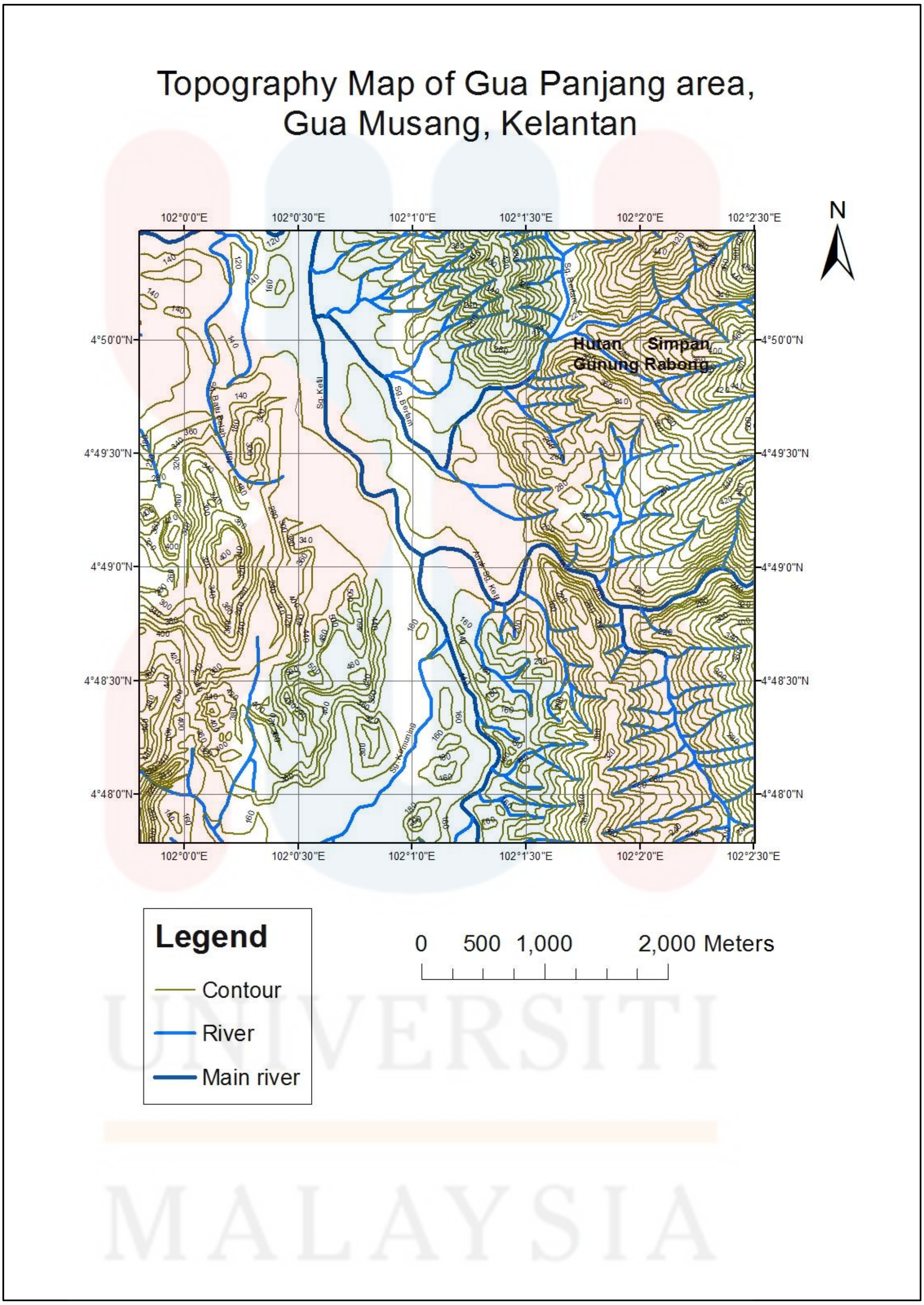

Figure 4.6 : Topography Map of study area

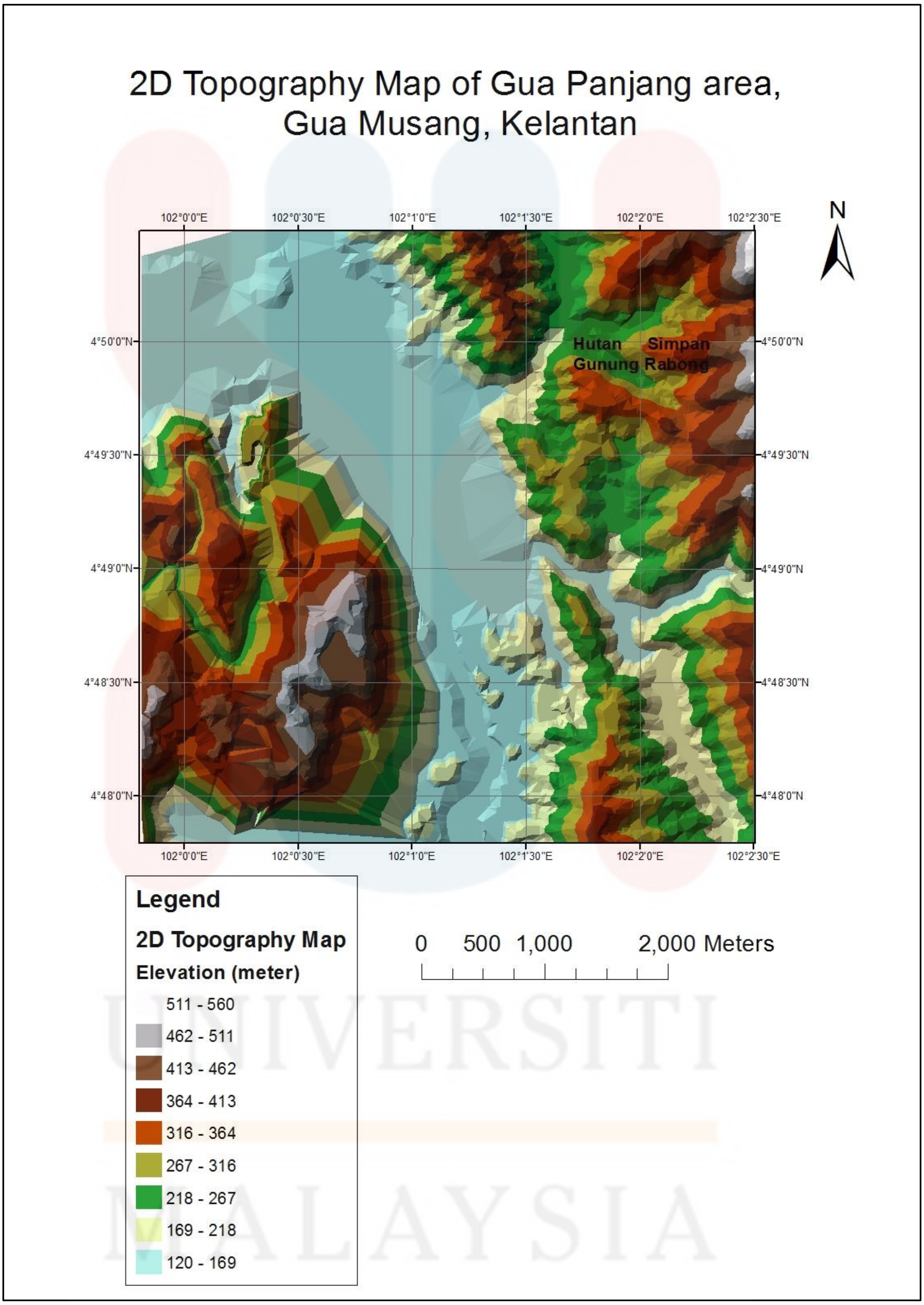

Figure 4.7 : 2D Topography Map of study area

4.2.2 Drainage system

Drainage system or river system is the pattern formed by streams, rivers and lakes in a particular drainage basin. A system can be considered as a network when the nodes (stream tips and junctions) are joined by links (stream). Drainage systems vary and often a pattern can be seen on the topo sheet. The system achieves a particular drainage pattern of its network of stream channels and tributaries over time as determined by local geologic factors. Drainage patterns are classified on the basis of their form and texture. Their shape or pattern develops in response to the local topography and subsurface geology. Drainage channels develop where surface runoff is enhanced and earth materials provide the least resistance to erosion. The texture is governed by soil infiltration, and the volume of water available in a given period of time to enter the surface (Ritter, 2003)

An area drained by a single river is called a drainage basin or catchment area. It includes the various streams, tributaries and sub-tributaries that join to create a network of the river. Thus the main river of an area along with its tributaries forms a drainage pattern. It is logical that water will flow from higher to lower area and while doing so, it will cut through the surface of the land. Fewer drainage channels will develop where the surface is flat and the soil infiltration is high and the fewer number of channels, the coarser will be the drainage pattern.

In the study area, the main river is the Sungai Ketil which elongates and forms the pattern which can be seen as dendritic and parallel drainage patterns. Dendritic drainage pattern is the most common form of pattern and it looks like the branching pattern of tree roots. It develops in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction the tributaries take. The tributaries joined larger streams at acute angle that is angles less than 90 degrees.

Meanwhile, parallel drainage pattern formed where there is an obvious slope to the surface. This can be seen on the topomap in Figure 4.6, as the drainage pass through high elevation contours towards the north and south of the study area. A parallel pattern also develops in regions of parallel, elongate landforms like outcropping resistant rock bands. The highly resistant rock band in the study area is sandstone that contains the mineral quartz that is very resistant to weathering. All forms of transitions can occur between parallel, dendritic, and trellis patterns throughout the system.

The small streams and tributaries eventually connect to the main river of Sungai Ketil.

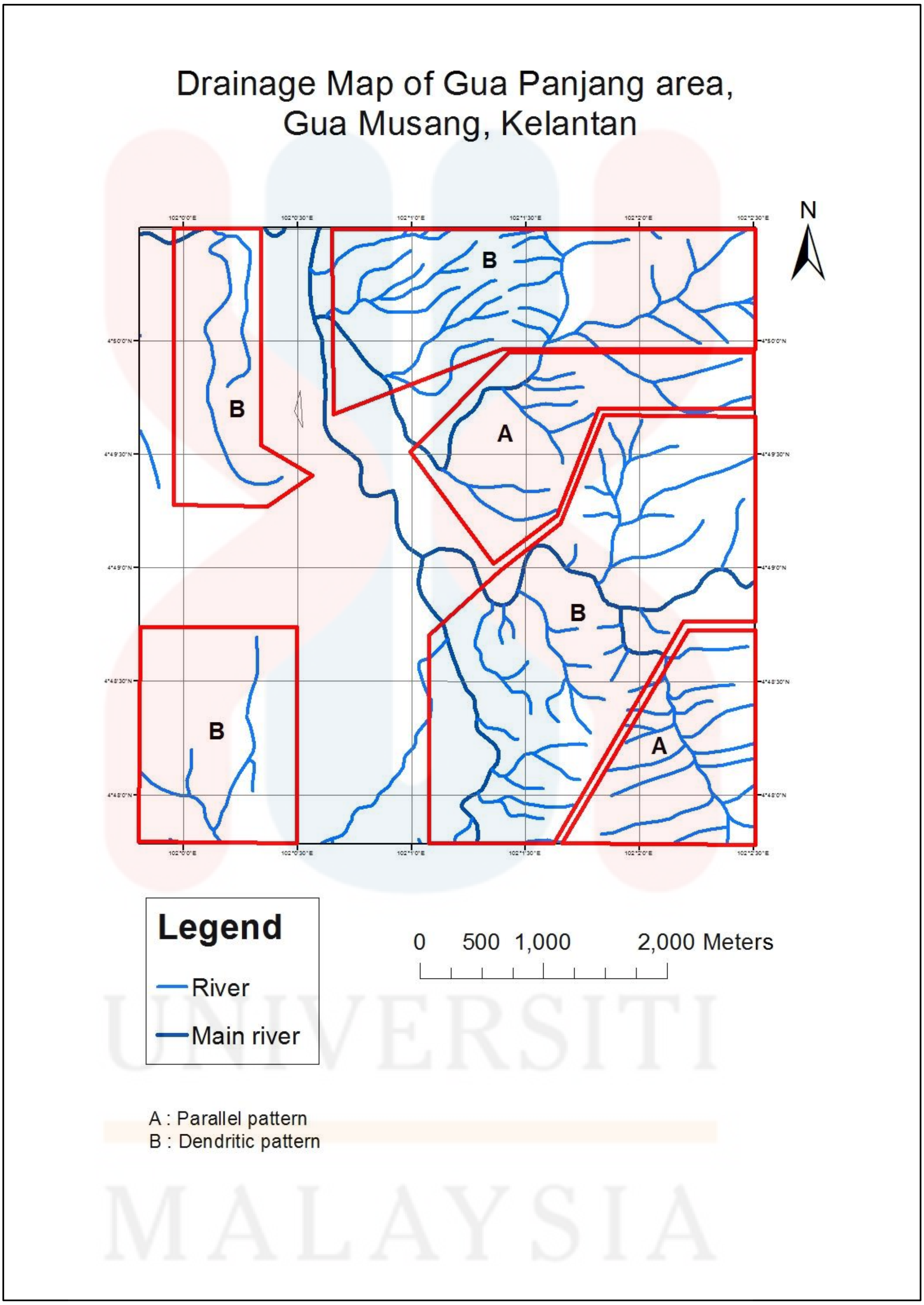

Figure 4.8 : Drainage Map of Gua Panjang

4.2.3 Weathering process

Weathering is the decomposition and disintegration of rocks and minerals at the Earth's surface. Weathering itself involves little or no movement of the decomposed rocks and minerals. This material accumulates where it forms and overlies unweathered bedrock (Thompson & Turk, 1997). The process of weathering usually is followed by erosion process which erodes the weathered materials from the rocks. There are three types of weathering, which are physical weathering, chemical weathering and biological weathering. All of these weathering processes are aided by the action of rainwater, extremes of temperature, and biological activity. It covers all the processes that altered or changed the physical and chemical properties of rocks which are exposed to these mechanisms.

Figure 4.9 : Field photograph of weathered Limestone (1)

From Figure 4.9 and Figure 4.10, it can be seen that the limestone outcrops experienced biological weathering and physical weathering. This occurred when the lichen formed on the rocks. Lichens are formed as a result of the presence of water and air. Physical weathering occurred as the physical appearance of the rocks changes due to the action of rainwater and high temperature over long period of time. As the physical weathering cracks the rock, creating more exposed area for the lichen to grow which further induce the biological weathering.

The pinnacles structure of the limestone outcrop in Figure 4.9 is completely covered by lichen. The structure is commonly exposed by soil erosion.

Figure 4.10 : Field photograph of weathered Limestone (2)

4.3 Stratigraphy

Gua Musang Formation is part of the Permian – upper Triassic lithostratigraphic units. The lithologies include argillaceous and calcerous rocks interbedded with volcanic and arenaceous rocks (Leman M. S., 2004). From the geological mapping conducted in the study area, the lithologies of rocks are able to be confirmed through field observation and petrographic analysis.

4.3.1 Lithostratigraphy

Lithology of rocks refers its physical characteristics which include colour, rock type, mineral composition and grain size. Lithostratigraphy deals with the stratigraphic relation among the strata that can be identified through the determination of lithology. The law of Superposition is the general law in which the lithostratigraphic units obey. According to this law, in any succession of strata, not disturbed or overturned since deposition, younger rocks lie above older rocks.

The most common lithology that can be found in the study area is the carbonate rocks of limestone and metalimestone. These carbonate rocks are dominated by the mineral calcite. Some areas are dominated with argillaceous rocks that vary from mudstone to siltstone.

The hand specimen collected as shown in Figure 4.11 is a marbleized limestone that shows a non-foliated fabric. This fabric usually brings about the meaning of an isotropic fabric. That is the minerals present are of the same type of mineral. The marbleized limestone is collected from an outcrop near the main river of Sungai Ketil with coordinates N 04° 49’ 19.5’’ E 102° 01’ 49.6’’. The colour of the rock is cloudy white or chalky. Marble is formed when limestone is exposed to high temperature and pressure over long period of time. The hand specimen exhibits rough surface with high hardness. It also has very few impurities as marble that contains impurities will develop a more grayish, pink or yellowish in colour. The marble acted on HCl when it is poured on its surface. This is because marble acts as a neutralizer to the acid and as an indicator of the presence of carbonate mineral like calcite.

Figure 4.11 : Marble hand-specimen

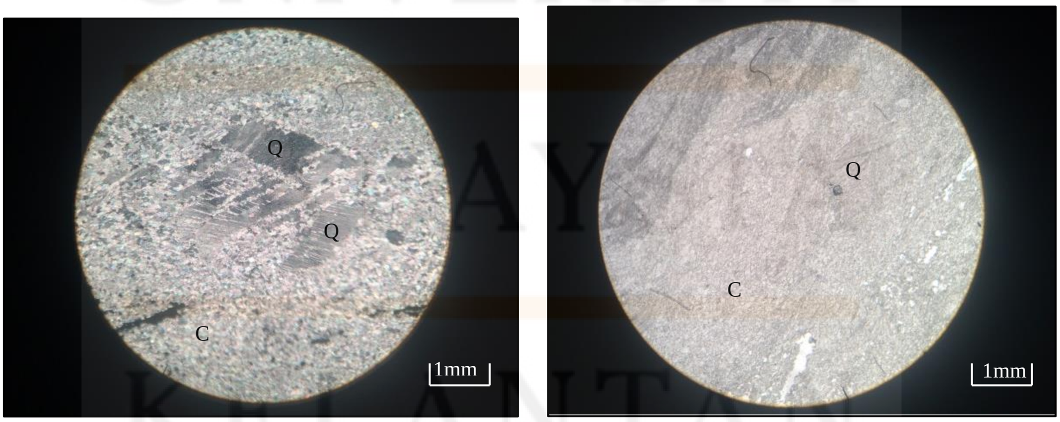

Figure 4.12 : Photomicrograph of marble under (a) cross-polarized light, (b) plane-polarized light with magnification 10x

From Figure 4.12, it can be seen that the calcite minerals labelled C fill the groundmass of the rock specimen. The minerals size is influenced by the rate of metamorphism acted upon the limestone. The greater the metamorphism, the larger the recrystallization of mineral calcite. Sometimes, calcite can only be seen as sugary sparkle of light reflecting from their tiny cleavage faces when the rock is played in the light. This showed that the metamorphism grade acted upon the marble is low. Other mineral present on the marble thin section is Quartz (Q).

Figure 4.13 : Metalimestone hand specimen

Figure 4.13 shows a hand specimen of an almost similar rock unit as in Figure 4.12.It is a metamorphosed limestone, which means it is still undergoing metamorphism to transform into a marble. The metalimestone shows the colour of milky white with medium-sized grains. The rock has a rough surface and great hardness. The fabric is similar to marble in Figure 4.11 that is isotropic fabric. It can be said that the minerals present are calcite minerals.

Metalimestone is formed from a limestone. Limestone is an organic sedimentary rock that forms from the accumulation of past living organisms like shell, coral, algal, and fecal debris. It can also be a chemical sedimentary rock formed through precipitation of calcium carbonate. When a limestone is exposed to great temperature and pressure, the calcite mineral inside of it recrystallizes and grows larger given the exposure to these factors is continuous and great.

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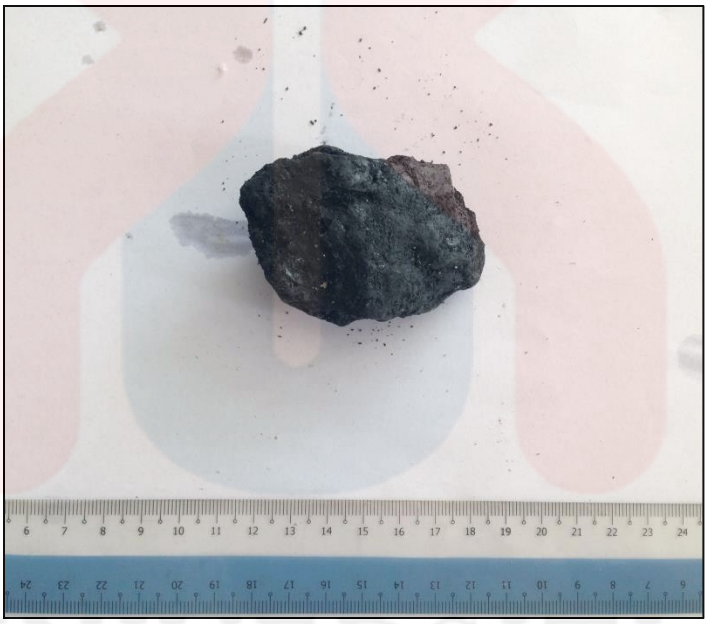

Figure 4.14 : Coal sample

From the geological mapping conducted during the research, a coal unit was found. Coal is organic sediment formed through the accumulation of dead plants in the forests and grasslands. Anoxic condition for when the accumulation is buried inside, causes the decomposition of the dead materials to stop and organic matter is preserved. The coal sample (Figure 4.14) was collected in area covered with roots of large trees by the river banks with coordinate of N 04°49’ 36.1’’ , E 102°01’ 12.5’’.

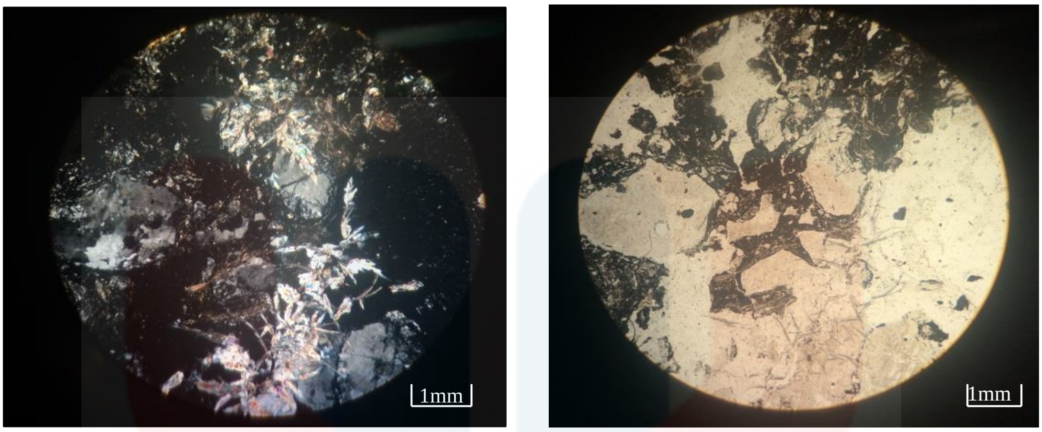

Figure 4.15 : Photomicrograph of coal under (a) cross-polarized light, (b) plane-polarized light with magnification 10x

Based on Figure 4.15, the dark region indicates the coal material, but it is mostly opaque under the microscope. The loop-shaped orange-yellow objects are the flattened large spores of plants.

Figure 4.16 : Claystone sample

Claystone sample in Figure 4.16 shows almost similar characteristics as coal,that is very fined sediments with grains size of clay. Claystone consists up to fifty percent clay and its minerals are integral to mudrocks. The formation of clay can come from soil, volcanic ash, and glaciation. Feldspar, amphiboles, pyroxenes, and volcanic glass are the common source of clay minerals.

Figure 4.17 is a Slate hand specimen that exhibits the appearance of brown-red colour. The reddish appearance is possibly due to the present of iron and organic material in the rock. The slate has foliation texture with fine-grained minerals. The minerals in slate are formed from fine-grained sediments such as mudstone and shale through low-grade metamorphism. When these rocks are compressed by external force and heated, tiny new flakes of mica grow, and tend to line themselves up at right angles to the direction of compression. The slate observed has low roughness surface and intermediate hardness.

Figure 4.17 : Red Slate hand specimen

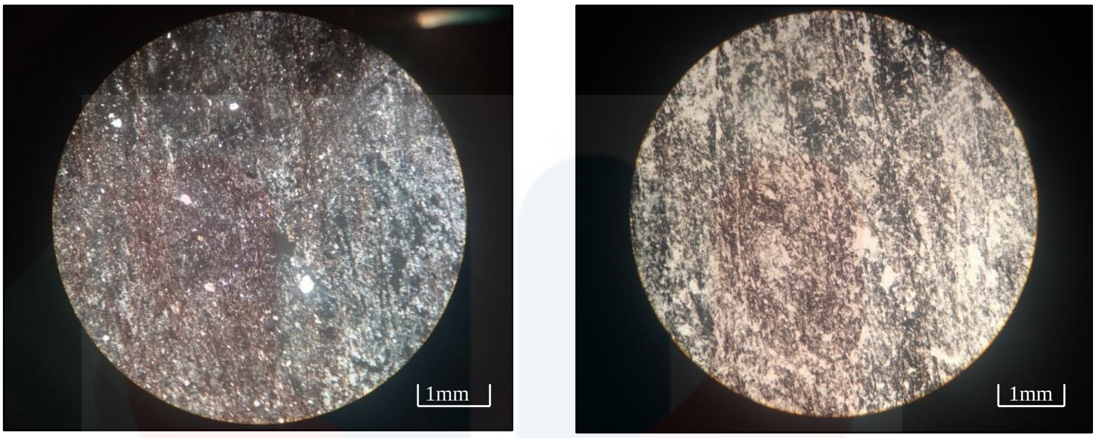

Figure 4.18 : Photomicrograph of red slate under (a) cross-polarized light, (b) plane-polarized light with magnification 10x

Figure 4.18 shows the red slate under microscope with cross and plane polarized light. The individual quartz crystals can be seen as the tiny white points while containing other minerals like micas as a result of metamorphism of clay minerals in shale. Slate can also contain small amounts of feldspar, calcite, pyrite and hematite. Parallel mineral grain alignments give the rock an ability to break smoothly along planes of foliation. From the figures, it can be seen that the slate does not show perfect parallel orientation.

The geological map of the study area (Figure 4.19) is produced based on the rock units found and with reference to (Leman M. S., 2004) and (Yee, 1983).

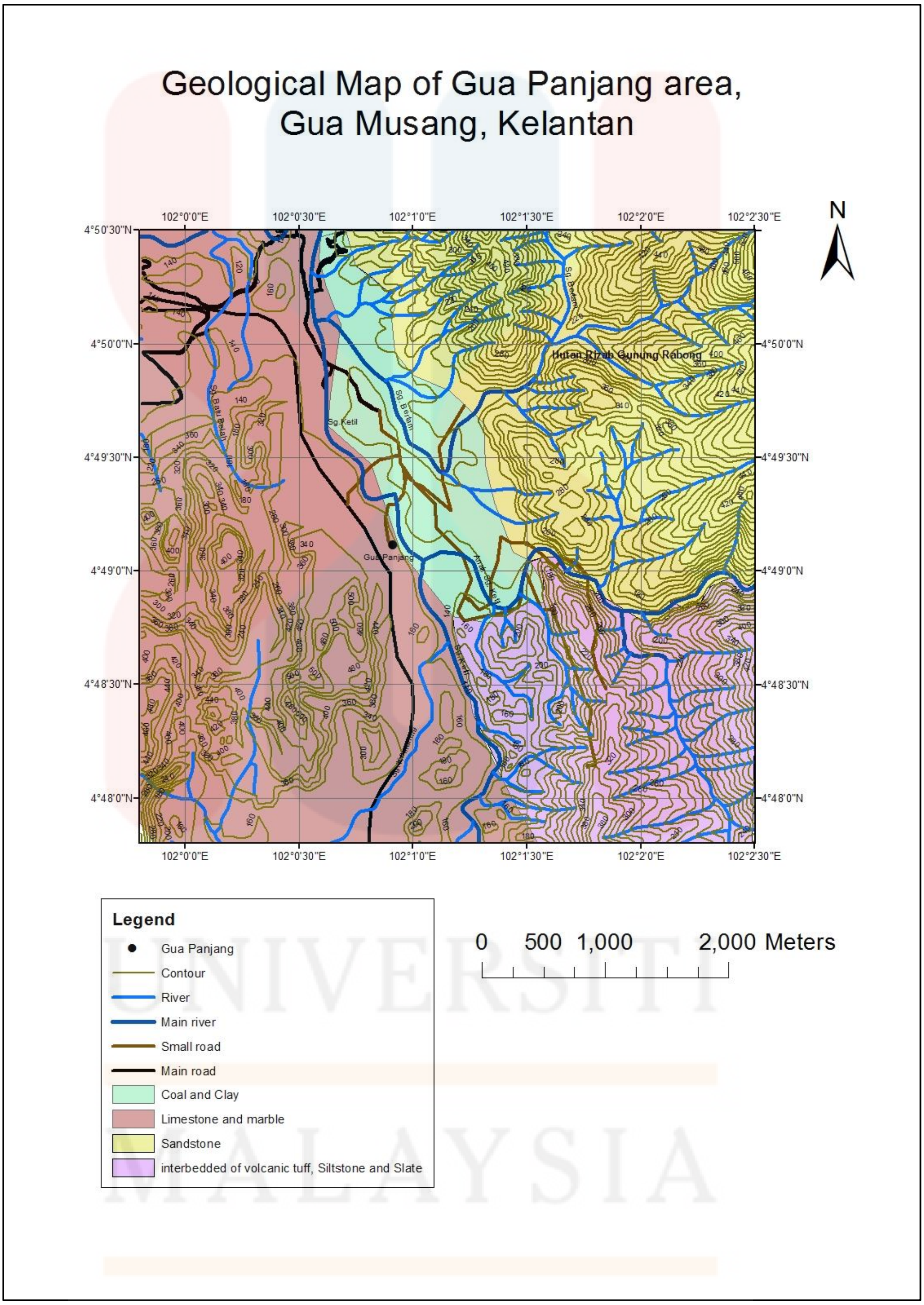

Figure 4.19 : Geological map of study area

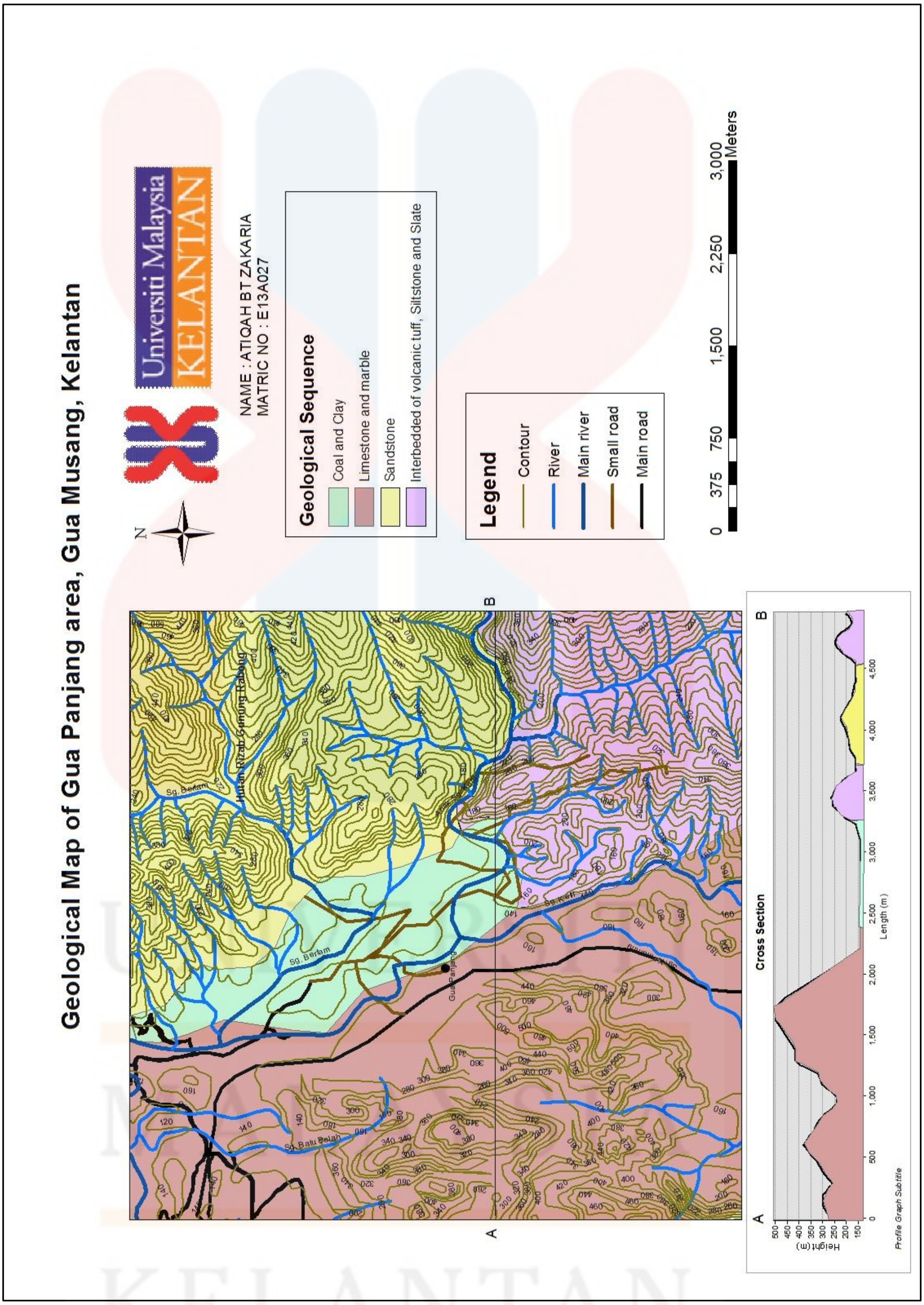

Figure 4.20 : Cross section of study area

4.3.2 Lithostratigraphic Column

The lithostratigraphic units in Gua Musang are commonly stratified and tabular in form. The lower boundaries of Gua Musang formation is not precisely known, but the upper boundary is overlain by the Koh Formation and interfingering with Semantan Formation, Telong Formation and Gunung Rabong Formation.

ERA	PERIOD	LITHOLOGY
CENOZOIC	QUARTENARY	Alluvium
	TERTIARY	
MESOZOIC	CRETACEOUS	
	JURASSIC	
	TRIASSIC	Coal and Claystone Marble Limestone
PALEOZOIC	PERMIAN	Sandstone, Siltstone, Slate
	CARBONIFEROUS	Volcanic tuffs

Table 4.1 : Lithostratigraphic column

The lithostratigraphic column constructed in Table 4.1 is with reference to (Yee, 1983) and (Leman M. S., 2004) and from the geological mapping conducted.

4.4 Structural Geology

Structural geologic feature that can be found in the study area is the folding structure. A fold is a structure produced when an originally planar surface becomes bent or curved as a result of deformation. Folds are an expression of a different type of deformation which produces gradual and more continuous changes in a rock layer, both in its attitudes and internally, as the rocks accommodates to changes in shape. The main elements of the geometry of the folds shape are, the hinge, which is the zone of maximum curvature of the surface, and secondly, the limbs, which are the areas between the hinges.

Folds structure observed in the study occurred by the combination of plastic deformation and brittle fracture. This is because the folds exhibit many tiny fractures and joints. Both folds arch upward which indicate that they are both anticline fold. Even though an anticline is structurally a high point in a fold, it does not always form topographic ridges. The folds observed here (Figure 4.20 and Figure 4.21) are located by the river banks with elevation of 140 m. The coordinate is 102˚ 01’ 11.611’’ E, 4˚49’39.893’’ N.

Figure 4.21 : Field photograph of folding structure

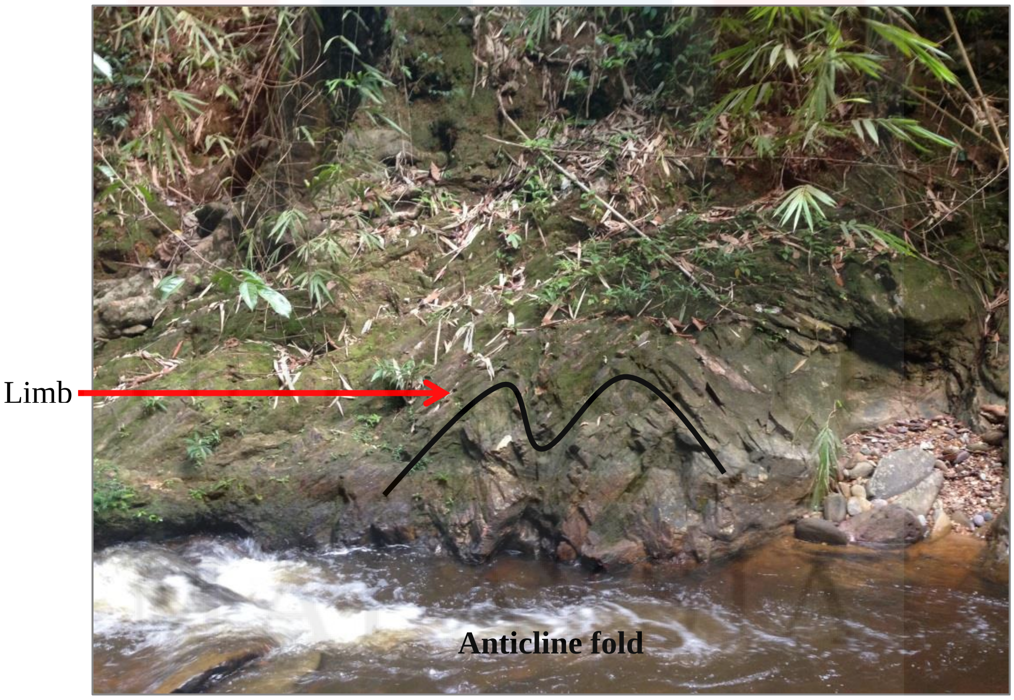

Figure 4.22 : Field photograph of folding structure

4.4.1 Lineament Analysis

Lineament is defined as a line feature or pattern interpreted on satellite images or over a distant view of the earth's topographical. The lineament indicates the geological structure like faults and fractures over the regional area.

The lineament analysis was conducted on the study area with the aid of a 2D-topography map (Figure 4.22). The lineament lines were observed based on relief features on the map. From the lineament lines, rose diagram is constructed to identify the direction of force acting upon the area. Based on Figure 4.23, $\sigma 1$ signifies the direction of the strongest force acting on the area which has created the lineament feature in the study area. Directly perpendicular to $\sigma 1$ is the $\sigma 3$ which symbolizes the direction of the weakest force acting upon the area. These forces drove the formation of lineament feature that is related to geological structure such as faults.

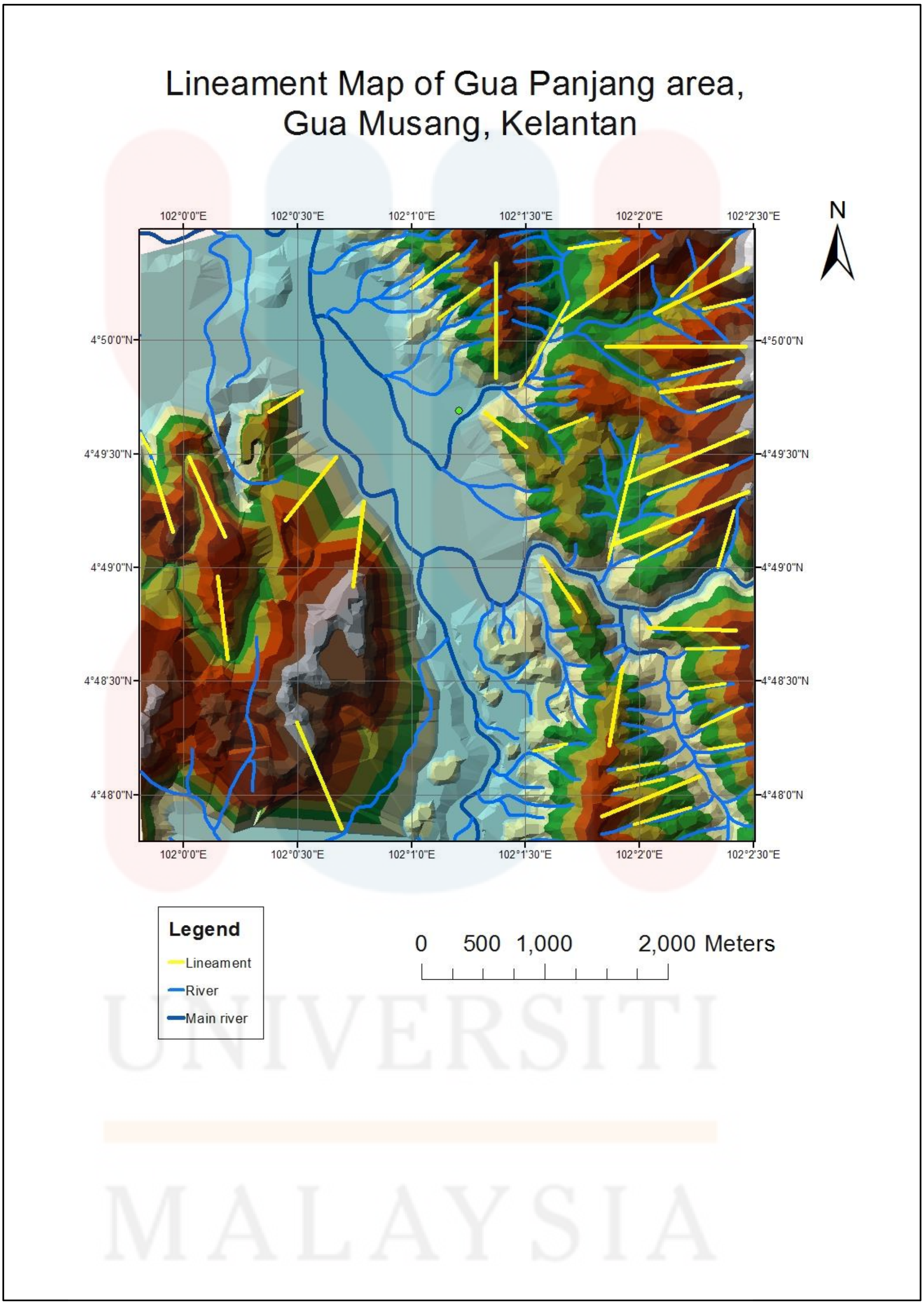

Figure 4.23 : Lineament Map

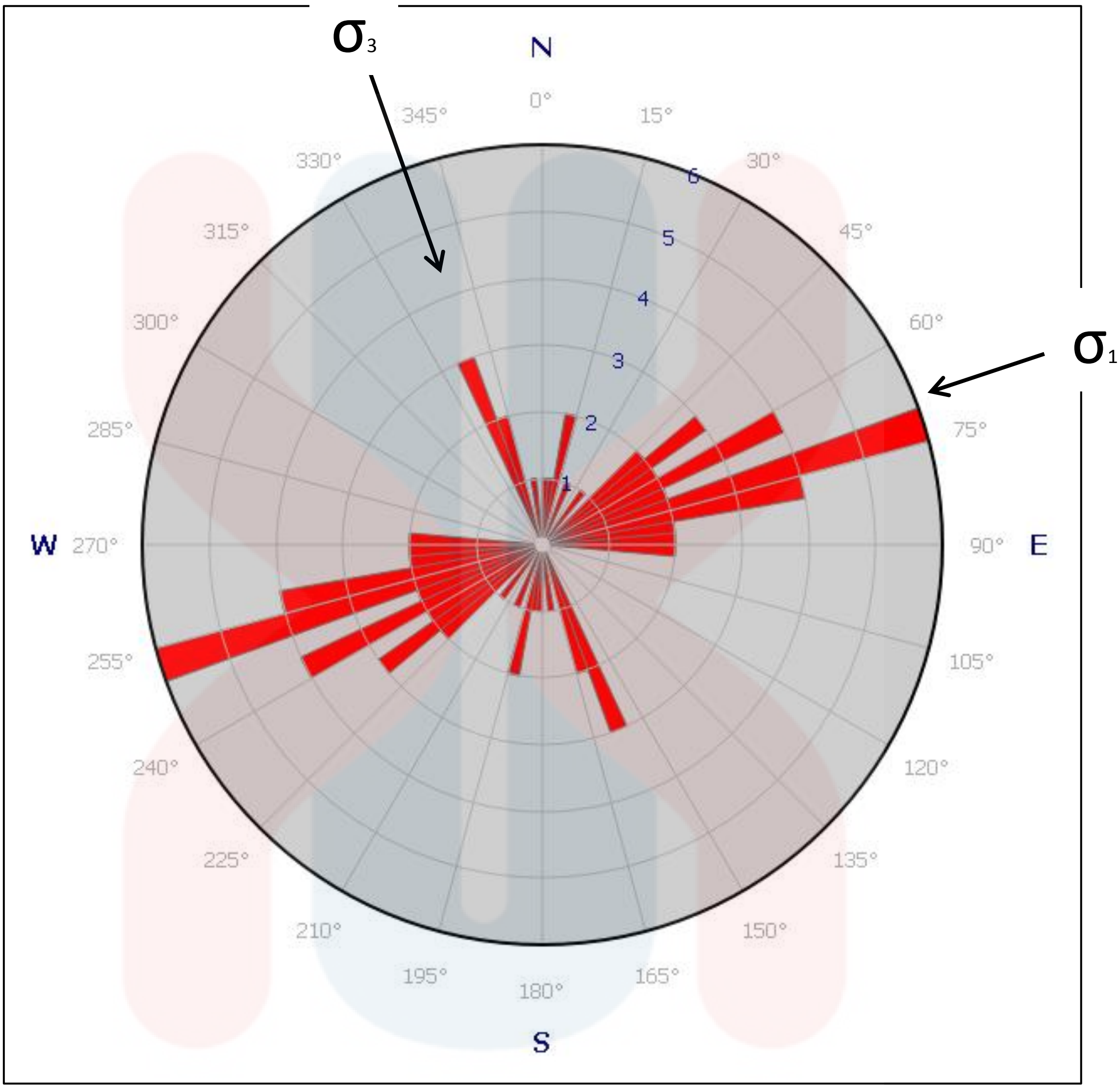

Figure 4.24 : Rose diagram of lineament

4.4.2 Joint Analysis

Joints are when individual fractures extend together in the same area and have similar orientation. Fractures are surfaces along which rocks or minerals have broken, in this manner producing two free surfaces where none existed before. Several ways in which a joint set can develop are through systematic joints, non-systematic joints, linear joints, sheet joints and columnar joints.

Systematic joints are roughly planar, parallel to each other and usually regularly spaced while non-systematic joints are curved and irregular. Linear joints form when two different joint sets occur in the same rock and are found almost everywhere in rocks and can sometimes show up as linear fractures, or lineaments. Sheet joints or exfoliation joints are curved fractures which is a characteristic of intrusive igneous rocks. Lastly, columnar joints are typical of extrusive igneous flows and shallow tabular intrusive igneous rocks. These fractures separate the igneous rock into pentagonal to hexagonal columns.

The joints observed in the study area are over an outcrop of Marble and Siltstone. The joints are systematic joints as they are mostly planar and parallel to each other. From the Rose diagram constructed for Structure 1 (Figure 4.24), it can be said that the strongest force signifies by σ1 acting upon the rock came from the direction in between 330° - 345°. This is the direction in which the greatest force came from. σ3 is the weakest force that acted upon the rock which contributed to the formation of the joints on the marble outcrop. The direction of σ3 is in between the angle 60° and 75°. Rocks are considerably weaker in tension than in compression.

For structure 2 where the joint analysis was conducted, the strongest force, σ1 acting upon the rock came in the direction of 15° - 30°. Meanwhile the weakest force, σ3 acting on the siltstone outcrop came from the direction 285°-300°. The joints observed on this structure exhibits planar geometry. The joints are associated with folds.

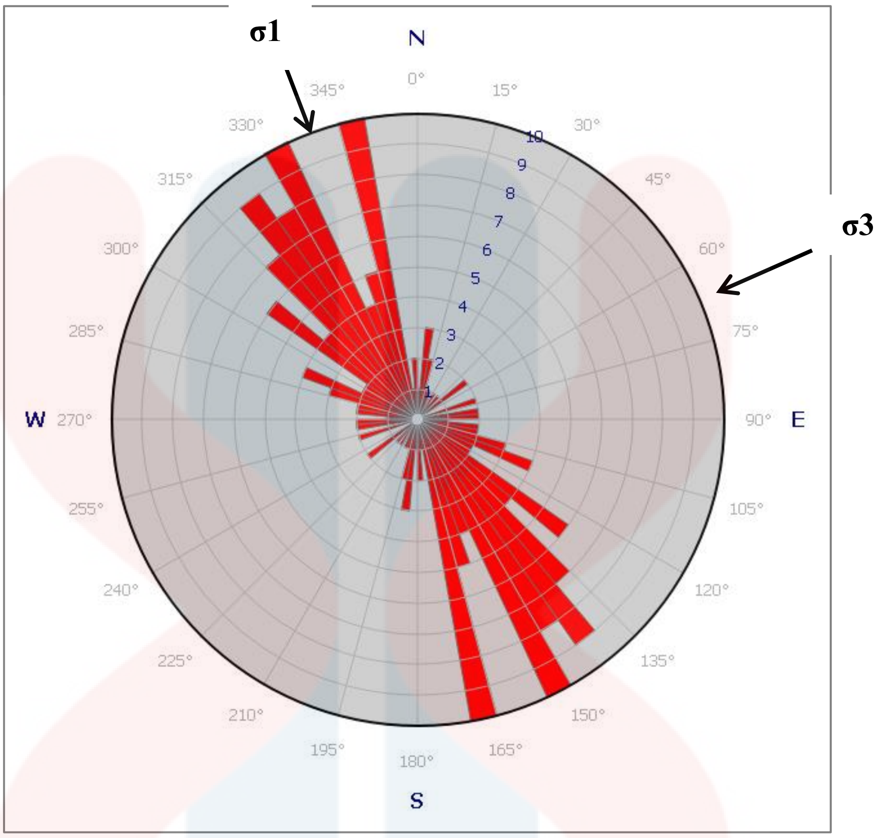

Figure 4.25 : Rose diagram of Joint Analysis at Structure 1

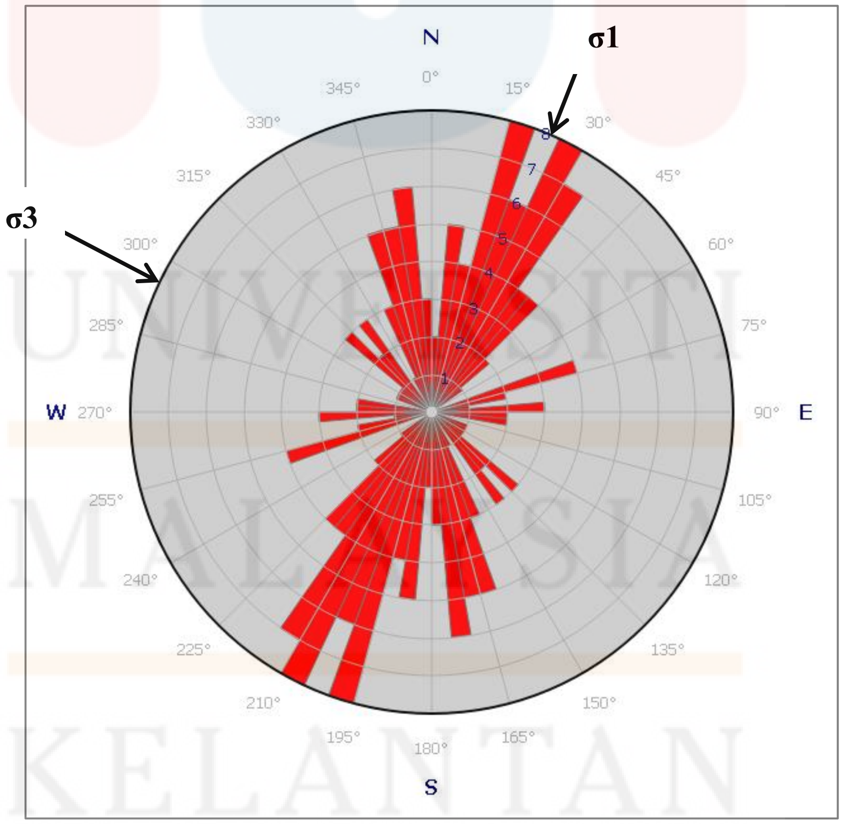

Figure 4.26 : Rose diagram of Joint Analysis at Structure 2

4.5 Historical Geology

Gua Musang which is located in the central belt of the Peninsular Malaysia is classified in the Gua Musang formation. The origin of the name Gua Musang, came from the name of the town in south Kelantan. This formation is of the era of Mesozoic with age of middle Permian to Upper Triassic (Leman M. S., 2004). The formation forms a continuous north-south trending belt, extending beyond the international boundaries to neighboring country of Thailand in the north. Gua Musang Formation is dominated by shallow marine clastics and carbonates with little interbedded of volcanic rocks. The depositional environment is shallow marine shelf deposit with active volcanic activity. The volcanic activities were recorded as submarine volcanism and irregular during the late carboniferous of Paleozoic era and reached its peak during Permian- Triassic.

Although the oldest recorded sediment in the central zone is the carboniferous limestone, the limestone observed in the study area of Gua Panjang ranges from the age of Permian to Triassic. Hence, the volcanic products are what made the oldest unit in the study area followed by argillaceous sediments, calcareous, metamorphosed limestone, organic sediments and alluvium.

CHAPTER 5

PETROLEUM SOURCE ROCK EVALUATION

5.1 Results and Discussion

5.1.1 Organic matter richness

Source rocks are the result from the combination of physical, biochemical and geologic processes that culminate in the formation of fine-grained sedimentary rocks containing carbon and hydrogen-rich organic matter. This organic matter can be extracted through various extraction methods, but the solvent extraction method has been used to isolate and characterize soluble and insoluble bitumen fractions since the beginning of source rock analysis.

The Sohxlet extraction method was carried out on two samples collected in the study area consisting of claystone and coal. The coal sample possesses high extracted organic material (EOM) with 855 708 ppm .While the clay sample shows a slightly lower value of EOM from coal sample, with 675 028 ppm (refer Table 5.1). The EOM calculated from the experiment is used as a maturity indicator of the potential source rock. From the data collected, it is likely that the coal and clay can become possible source rock as the content of organic matter within the rock is great. According to the classification by (Peters & Cassa, 1994) in Appendix C, rocks that contain more than 1000 ppm bitumen extracted could become potential source rocks. Meanwhile, for hydrocarbon content, value more than 600 ppm makes good source rocks.

Table 5.1 : Extraction result

Sample	Standard	Coal	Claystone
Mass of thimble + cotton	46.4478	42.0455	37.1336
Mass of rock sample (D)	25.000	25.000	25.000
Mass of thimble + cotton + sample (C)	71.4478	67.0455	62.1336
Mass of thimble + cotton + extracted rock (E)	24.6832	45.6528	45.2579
EOM (F) g = (C-E)	46.7646	21.3927	16.8757
EOM = F x 1000000 / D (PPM)	187 0584	855 708	675 028
Wt %	187.0584	85.5708	67.5028

The EOM in coal and mudstone samples was calculated through the mass recorded of the empty thimble with cotton and for when the thimble and cotton after extraction. There is a difference in mass for when the thimble is removed after extraction. A known mass of the samples was added to the mass of empty thimble and cotton to identify the mass of the thimble before extraction. The rock samples were seen to be lost after the extraction as it dissolved in the solvent. This is known as the bitumen extracted because bitumen is soluble in organic solvents and acids while kerogen is insoluble in organic solvent.

Generally, the total organic extract from all the samples yield a range from 675 028 to 855 708 ppm. The organic richness in coal sample collected from the study area exceeds the average amount of an organic-rich potential source rock. The coal sample could be a more convincing petroleum source rock as it yielded a high gross of EOM. The clay sample also demonstrates a significant amount of EOM yield. However, it is noted that the EOM contains a complex mixture of hydrocarbons and non-hydrocarbon components especially within the thermally immature samples, which therefore affect the determination of source rock quality.

From Figure 5.1, the EOM yield from coal sample exceeded the clay sample by 180 000 ppm. That is by 18% more from the clay sample. The Soxhlet extraction dissolved the organic matter within the coal and clay rock sample to remove the soluble kerogen decomposition products into the solvent mixture of Dichloromethane (DCM) and Methanol (MeOH). Not very high temperature was used for energetic gain of the whole system and it was recorded that the technique would extract with rate of 90% of the kerogen present.

Organic matter richness within coal and clay samples may have been related to the depositional environment during which a suitable type of organic matter is deposited in the sediment and preserved over a long period of time. The geological settings of these depositional environments coupled with other external factors like climate will affect the redox potential of the sediments during deposition hence giving different degree of oxidizing or reducing conditions.

According to (Muhamad & Awang Jamil, 2010), environments close to fluvial influence will receive more high land plant or terrigenous organic matter compared to algal organic matter and vice versa. This, coupled with favourable anoxic condition will increase organic matter preservation and resulting in higher quality source rock.

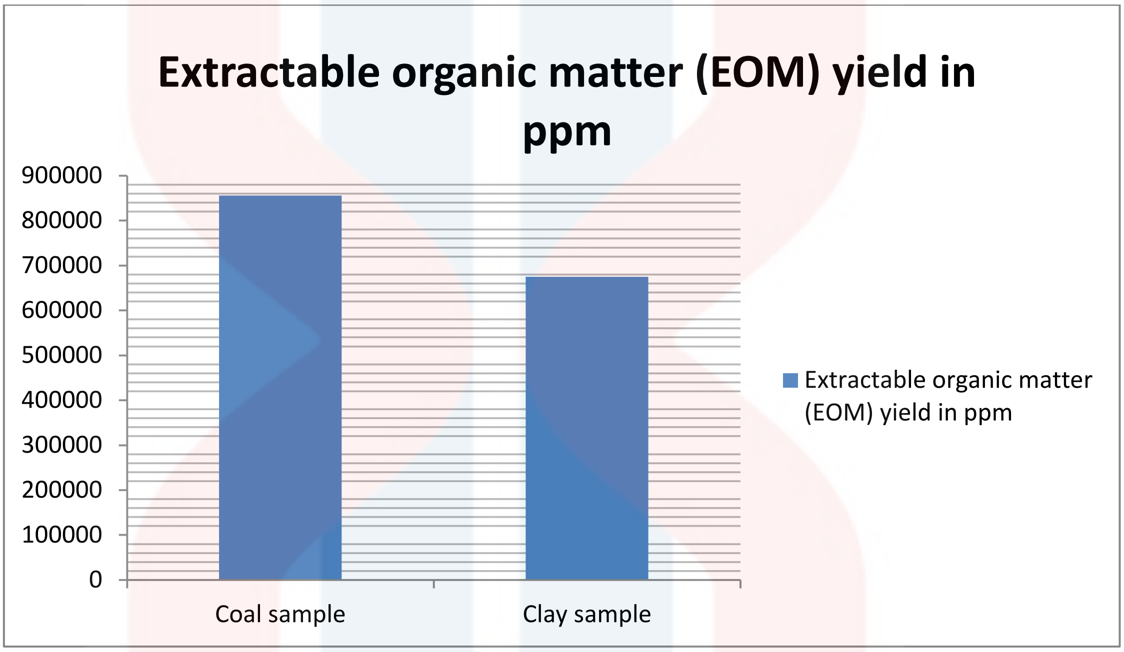

Figure 5.1: Graph of Extratable Organic Matter (EOM) from analyzed source rock

Also, throughout the conduction of the whole experiment, many errors and contamination might have occurred. There are several factors which can affect the rate of yield of EOM. These factors are described below.

The rate of extraction of organic matter depends on the type of organic solvent chose for the experiment. The bitumen will be easily extracted if the force of attraction between the bitumen and the solvent is great than that between the solvent molecules or of the dissolution of the solvent. The solvent is crucial as they can solubilized and extract small, unbound molecules and attack the kerogen structure present in the rock sample matrix. Solvent can break the bond within the sample by electron donor-electron acceptor interactions and hydrogen bonding.

The time of extraction affect the yield of organic matter in the experiment. The extraction was conducted for 24 hours with a pause in the hour-12. The pause may have affected the yield as the water may have condensed into the solvent of extracted organic matter. According to a study by (Nassef, Soliman, Abou Al-Alla, & Eltaweel, 2015), as the time of extraction increases the yield increases too up to a time of four hours.

Particles size too is a vital parameter in determining the amount of organic matter yielded. Generally, the larger surface area exposed will increase the rate of EOM yielded. This is because, the smaller the size of the particles the greater the interfacial area between the solid and the liquid and therefore the rate of transfer of material. The optimum particle size for efficient extraction is 1.0 mm.

The conduction of the experiment is held in a protected environment to secure from any contamination. However, contamination might have occurred unexpectedly. The usage of contaminated gloves and apparatus may have influenced the result of extracted organic matter (EOM).

The reason behind the inaccuracy of the results obtained from the experiment is the discounted of the thickness and areal extent of the outcrop. The coal and clay samples collected are from the same bedding structure. The presence of these lithologies is very limited in the study area. The maturity of the organic matter is unclear because further analyses like vitrinite reflectance measurement and pyrolysis were not conducted.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

In conclusion, the objectives of the research to update the geological map and study the organic richness of potential petroleum source rock in the study area are achieved. Updated geological maps with scale of 1: 25 000 are produced to highlight the topography of the area, the drainage system, lineament and the geological details. The major lithology that can be observed in the study area is the calcareous sedimentary rock, Limestone. Minor lithologies include volcanic tuff, marble and argillaceous rock of siltstone. There are also coal and clay presence in the study area but very limited. Gua panjang area in Gua Musang does not have major structural features but is blessed with vast karst morphology which is the main geological attraction in Gua Musang.

The organic richness of the potential petroleum source rock in the study area can be said as great only with further analyses to improve the data. The coal sample shows to be an excellent potential as petroleum source rock as it yielded great amount of EOM through a conventional Soxhlet extraction method. However, advanced method should be applied to confirm this finding such as identifying the total organic carbon (TOC) of the sample through Rock-eval pyrolysis and thermal maturity through vitrinite reflectance measurement.

6.2 Suggestion

Further research and analyses should be conducted in Gua Musang, Kelantan to improve the geological data available in greater details. The organization should collaborate with the Jabatan Mineral dan Geosains Malaysia to update the geological data for future references which can be rewarding for both parties. The geological mapping of the research could be improved with proper transportation provided for students to conduct geological mapping. Some of the areas could not be accessed with normal 4-wd transportation due to the roads were too small and unsafe to pass through. Preserved forest is inhabitant with wild animals which can be hazardous at times. Gua Musang can be made as a tourist attraction for the beautiful karst landforms it holds.

Future petroleum source rock evaluation in Gua Musang, Kelantan should be done over a regional aspect rather than in a small area of study. Further investigation should be made in Gua Musang to identify the petroleum potential it has to offer by using advanced technology equipment to improve validity of the results obtained.

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APPENDICES

APPENDIX A : Table of percentage of annual average rain in Kelantan for 2014

PERATUS JUMLAH HUJAN TAHUNAN
NEGERI KELANTAN BULAN 31 DISEMBER 2014

BIL	NAMA STESEN	BULAN												JUMLAH
		JAN	FEB	MAC	APR	MEI	JUN	JULAI	OGOS	SEPT	OKT	NOV	DIS	
1	Kota Bharu @ Jeti Kastam	80.0	2.0	30.0	6.0	127.0	146.0	74.0	239.0	121.0	264.0	837.0	994.0	2,920.0
2	Tumpat @ Pengkalan Nangka	69.0	1.0	58.0	8.0	75.0	118.0	138.0	140.0	137.0	278.0	660.0	803.0	2,485.0
3	Pasir Mas @ Kasar	135.0	0.0	39.0	0.0	75.0	193.0	148.0	166.0	112.0	367.0	586.0	959.0	2,780.0
4	Machang @ Kusial	316.0	6.0	58.0	40.0	117.0	195.0	221.0	283.0	237.0	280.0	487.0	1686.0	3,926.0
5	Bachok @ Serdang Gunung Barat	45.0	0.0	30.0	1.0	152.0	312.0	120.0	237.0	165.0	216.0	1021.0	970.0	3,269.0
6	Pasir Puteh @ Bkt. Gedombak	262.0	1.0	60.0	21.0	122.0	176.0	234.0	314.0	443.0	197.0	816.0	1236.0	3,882.0
a.	**PURATA PANTAI**	**151.17**	**1.67**	**45.83**	**12.67**	**111.33**	**190.00**	**155.83**	**229.83**	**202.50**	**267.00**	**734.50**	**1108.00**	**3,210.33**
b.	**PURATA PANTAI TERKUMPUL**	**151.17**	**152.83**	**198.67**	**211.33**	**322.67**	**512.67**	**668.50**	**898.33**	**1,100.83**	**1,367.83**	**2,102.33**	**3,210.33**	**267.53**
1	Dabong	178.0	0.0	16.0	0.0	146.0	129.0	56.0	427.0	258.0	227.0	262.0	967.0	2,666.0
2	Jeli	432.0	6.0	225.0	245.0	368.0	251.0	198.0	446.0	301.0	451.0	442.0	1542.0	4,907.0
3	Gua Musang	136.0	3.0	196.0	169.0	225.0	215.0	90.0	618.0	489.0	313.0	175.0	591.0	3,220.0
4	Laloh	152.0	8.0	74.0	98.0	199.0	73.0	151.0	282.0	172.0	148.0	354.0	706.0	2,417.0
5	Aring	174.0	5.0	251.0	144.0	206.0	251.0	130.0	306.0	495.0	545.0	233.0	881.0	3,621.0
6	Gunung Gagau	171.0	22.0	208.0	59.0	461.0	192.0	317.0	341.0	562.0	252.0	579.0	2686.0	5,850.0
c.	**PURATA PENDALAMAN**	**207.17**	**7.33**	**161.67**	**119.17**	**267.50**	**185.17**	**157.00**	**403.33**	**379.50**	**322.67**	**340.83**	**1228.83**	**3,780.17**
d.	**PURATA PENDALAMAN TERKUMPUL**	**207.17**	**214.50**	**376.17**	**495.33**	**762.83**	**948.00**	**1,105.00**	**1,508.33**	**1,887.83**	**2,210.50**	**2,551.33**	**3,780.17**	**315.01**
e.	**PURATA KESELURUHAN**	**179.17**	**4.50**	**103.75**	**65.92**	**189.42**	**187.58**	**156.42**	**316.58**	**291.00**	**294.83**	**537.67**	**1168.42**	**3,495.25**
f.	**JUMLAH PURATA TERKUMPUL**	**179.17**	**183.67**	**287.42**	**353.33**	**542.75**	**730.33**	**886.75**	**1,203.33**	**1,494.33**	**1,789.17**	**2,326.83**	**3,495.25**	**291.27**
g.	**Peratus = Purata x 100 / 2700**	**6.64**	**0.17**	**3.84**	**2.44**	**7.02**	**6.95**	**5.79**	**11.73**	**10.78**	**10.92**	**19.91**	**43.27**	**129.45**
h.	**PERATUS PURATA TERKUMPUL**	**6.64**	**6.80**	**10.65**	**13.09**	**20.10**	**27.05**	**32.84**	**44.57**	**55.35**	**66.27**	**86.18**	**129.45**	**129.45**

(Source : Department of Statistics Malaysia (web))

APPENDIX B : Photographs of apparatus used during the Soxhlet extraction experiment

APPENDIX C : Geochemical Parameters Describing the Petroleum (Quantity) of an Immature Source Rock

Petroleum Potential	Organic Matter TOC (wt. %)	Rock-Eval Pyrolysis S_1[a]	Rock-Eval Pyrolysis S_2[b]	Bitumen[c] (wt. %)	Bitumen[c] (ppm)	Hydrocarbons (ppm)
Poor	0–0.5	0–0.5	0–2.5	0–0.05	0–500	0–300
Fair	0.5–1	0.5–1	2.5–5	0.05–0.10	500–1000	300–600
Good	1–2	1–2	5–10	0.10–0.20	1000–2000	600–1200
Very Good	2–4	2–4	10–20	0.20–0.40	2000–4000	1200–2400
Excellent	>4	>4	>20	>0.40	>4000	>2400

[a]mg HC/g dry rock distilled by pyrolysis.

[b]mg HC/g dry rock cracked from kerogen by pyrolysis.

[c]Evaporation of the solvent used to extract bitumen from a source rock or oil from a reservoir rock causes loss of the volatile hydrocarbons below about n-C_{15}. Thus, most extracts are described as "C_{15+} hydrocarbons." Lighter hydrocarbons can be at least partially retained by avoiding complete evaporation of the solvent (e.g., C_{10+}).

Source : (Peters & Cassa, 1994)