GEOLOGY OF SUBONG AREA, GUA MUSANG AND PETROLOGY OF ITS GRANITOID ROCK

by

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DECLARATION

I declare that this thesis entitled Geology of Subong Area, Gua Musang and Petrology of Its Granitoid Rock is the result of my own research expect as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : _______________________________

Name : Siti Salina Binti Sulong

Date : _______________________________

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Geology of Subong Area, Gua Musang and Petrology of Its Granitoid Rock

ABSTRACT

Geological mapping of 25 km^2 with the scale of 1:25000 were conducted in the Subong area, Gua Musang, Kelantan, Malaysia. Geographically, this area located at between 4° 56’ 7.63” to 4° 58’ 48.69” North latitude and 101° 55’ 3.97” to 101° 57’ 47.33” East longitude. The objectives of the research are to produce an updated geological map and specifically the petrology of granitoid in the Subong area. Unit lithology in the research area can be divided into three main units. Description sequentially from the oldest to the youngest lithology units are as follows Slate Unit, Limestone Unit, Granite Unit and Alluvium Unit. The study area is part of Gua Musang Formation with age ranging from Permian to Quartenary. The geomorphology of the study area, Subong area can be divided into two units of morphology which is medium and low relief morphology unit. In the study area, the main geological structures that occurred in the area such as lineament features, joint structure and fold structure. For the study of granitoid rock, two granite samples were analyzed from the result of X-ray Flourescence (XRF) Spectrometry analysis and Inductively Coupled Plasma Mass Spectometry (ICP-MS). The grantoid that is found in the study area is classified as granodiorite. It is classified as I-type and shows a metaluminous characteristics as the value of A/CNK is less than 1.

Geologi di Kawasan Subong, Gua Musang dan Petrologi Batuan Granitoid

ABSTRAK

Pemetaan geologi 25 km^2 dengan skala 1:25000 telah dijalankan di Kawasan Subong, Gua Musang, Kelantan, Malaysia. Secara geografi, kawasan ini terletak di antara 4° 56’ 7.63” to 4° 58’ 48.69” latitude utara dan 101° 55’ 3.97” to 101° 57’ 47.33” longitude timur. Objektif kajian ini adalah untuk menghasilkan peta geologi yang telah dikemaskini dan lebih khusus ialah petrologi batuan granitoid di kawasan Subong. Unit lithologi di kawasan kajian boleh dibahagikan kepada tiga unit utama. Penerangan secara berturutan dari yang paling tua kepada kepada unit lithology termuda adalah seperti berikut Slate Unit, Batu Kapur Unit, Granit Unit, dan Alluvium Unit. Kawasan kajian ini adalah sebahagian dari Formasi Gua Musang yang berumur dalam lingkung usia Permian hingga ke Kuaternary. Geomorfologi kawasan ini boleh dibahagikan kepada dua unit morfologi iaitu unit batuan morfologi sederhana dan unit batuan morfologi rendah. Di kawasan kajian, struktur geologi utama yang berlaku di kawasan adalah seperti ciri lineament, struktur kekar dan struktur lipatan. Untuk kajian petrologi dan penetapan tektonik batuan granitoid, data dari uji kaji X-ray Flourescence (XRF) Spectrometry dan Inductively Coupled Plasma Mass Spectometry (ICP-MS) telah dianalisis. Jenis batuan granitoid yang dijumpai di kawasan kajian adalah jenis granodiorite. Ia diklasifikasikan sebagai jenis-I dan menunjukkan ciri metaluminous dengan bacaan A/CNK kurang dari 1.

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mm	Millimeters
km	Kilometer
wt %	Weight per cent
°	Degree

LIST OF ABBREVIATIONS

XRF	X Ray Fluorescent
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
REE	Rare Earth Elements
SiO_2	Silicon Dioxide
TiO_2	Titanium Oxide
Al_2O_3	Aluminium Oxide
FeO	Iron Oxide
MnO	Manganese Oxide
MgO	Magnesium Oxide
CaO	Calcium Oxide
Na_2O	Sodium Oxide
K_2O	Potassium Oxide
P_2O_5	Phosphorus Pentoxide

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Gua Musang is a district that is situated in the southern Kelantan, Malaysia that is known for its geological potential and history. A regional scale of geological mapping had been conducted gives the overview of the geology in Gua Musang. To study the details of the geology at Subong area, a detailed geological mapping as well as petrology analysis needs to be done at the specific study area.

This research is conducted for better understanding the geology of the research area. This involves with the geological mapping of the research area that cover up an area of about 5x5 km^2 in the scale of 1:25,000. Geological mapping will focus on the study of geomorphology, structural geology, stratigraphy, sedimentology and other geological aspects that is studied from field observation and outcrop description.

This research is also specified on the petrology of granitoid rocks in Subong area, Gua Musang. Granitoid is a phaneritic plutonic rock that formed in the area where continental crust undergo the orogeny processes such as the subduction of continental arc or collision of sialic masses. Formation of granitoid requires thermal disruption. Granitoid rock is light in colour and dominated by quartz and feldspar minerals.

This study is conducted due to the limited scientific research about the granitoid rock at that specific area. Two approaches are applied which involves the petrography and petrology analysis to identify the elemental composition, origin and rock classification. The use of polarized microscope for observation of thin sections and X-ray Flourescence (XRF) spectrometry will be implemented for this study. The geological mapping and petrology analysis will help a better understanding of the geology of Subong area.

1.2 Study Area

1.2.1 Location

This research is focusing in Subong and its surroundings, where it located in Gua Musang, Kelantan, Malaysia. It is situated at the south of Kelantan, Gua Musang district, whereas, Kelantan is located at the northeast of Peninsular Malaysia. Geographically, this area located at the coordinate of latitude ranges from 4° 56' 7.636" N to 4° 58' 48.697" N and longitude from 101° 55' 3.978" E to 101° 57' 47.33" E. The research area covered an area of 5 km width x 5 km height with the total area of 25km^2.

The base map is prepared and digitized by using ArcGIS 10.2 software. The topography of the study area is covered with hilly topographic unit which display the mean elevation of 76-300 meters (Hutchinson and Tan, 2009). This area is used for vegetation purposes as it contributed in villager's economy. Generally, the highest elevation of the hill is 240 meters. Figure 1.1 shows the study area in Kelantan map and Figure 1.2 shows the base map of study area. There is one main road known as Jalan Jelawang-Gua Musang at the east part of the study area.

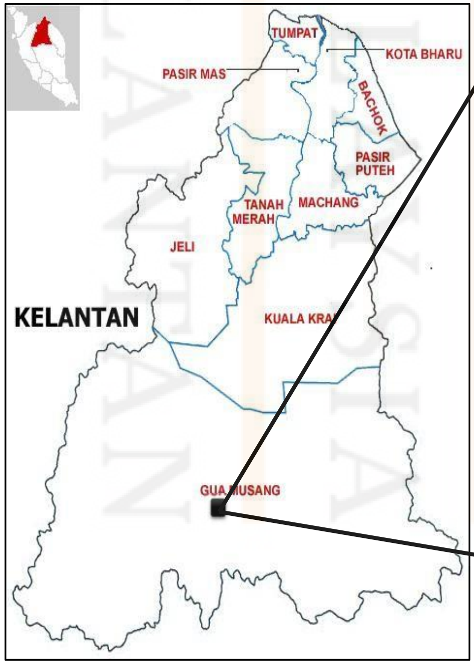

Figure 1.1: The location of study area in Kelantan map.

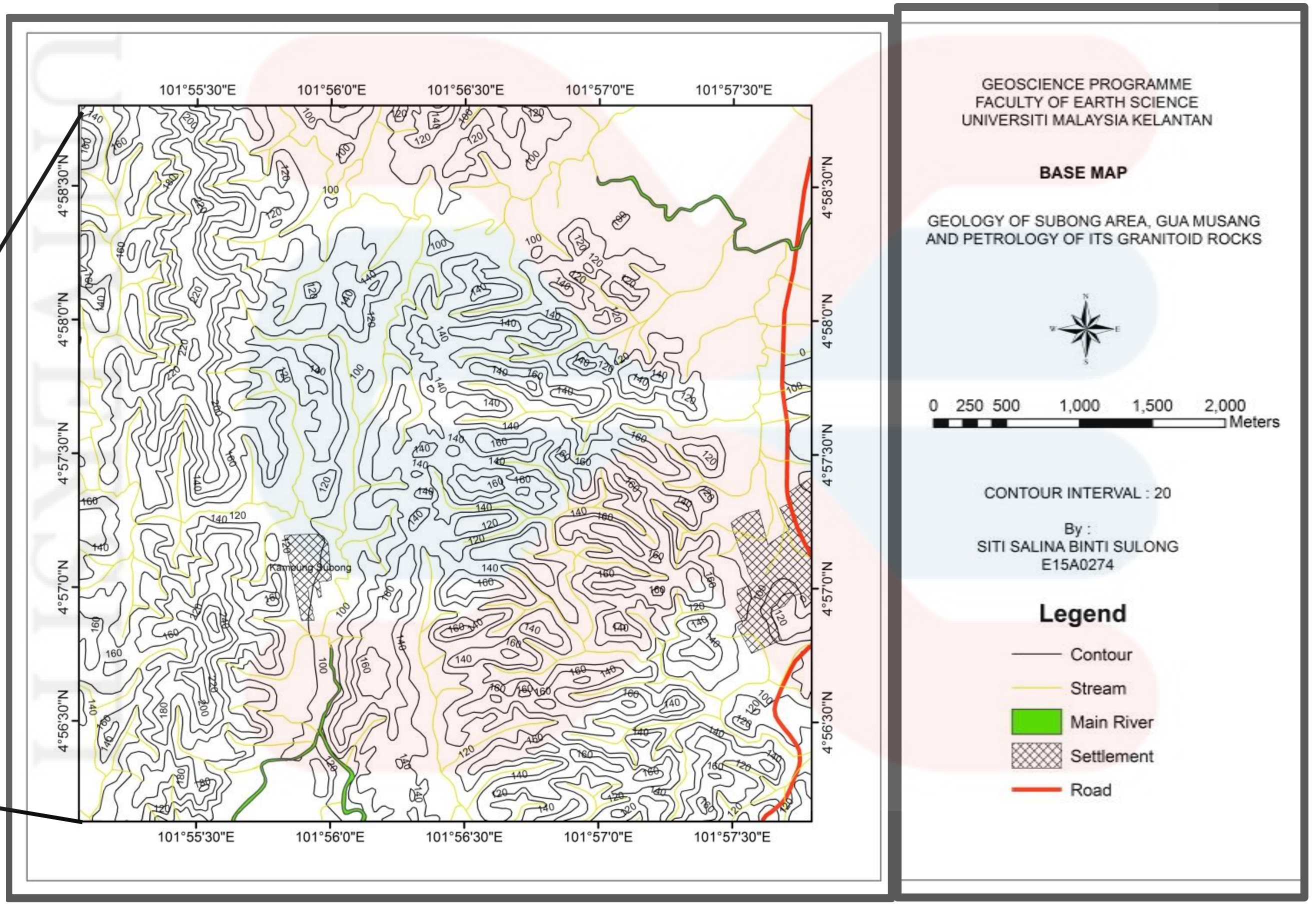

Figure 1.2: The base map of the study area.

1.2.2 Road connection

Road connection is referring to the accessibility of road for transportation to reach the study area. Subong area is located 16.4 km away from Bandar Gua Musang and can be reached by two-wheeled and four-wheeled vehicles. The study area can be access by the main paved road which is known as Jalan Jelawang-Gua Musang and also unpaved roads or off-roads. It usually takes about 25 minutes' drive via Jalan Jelawang- Gua Musang which situated at the east part of study area. Figure 1.3 shows the road connection from Bandar Gua Musang to Subong area.

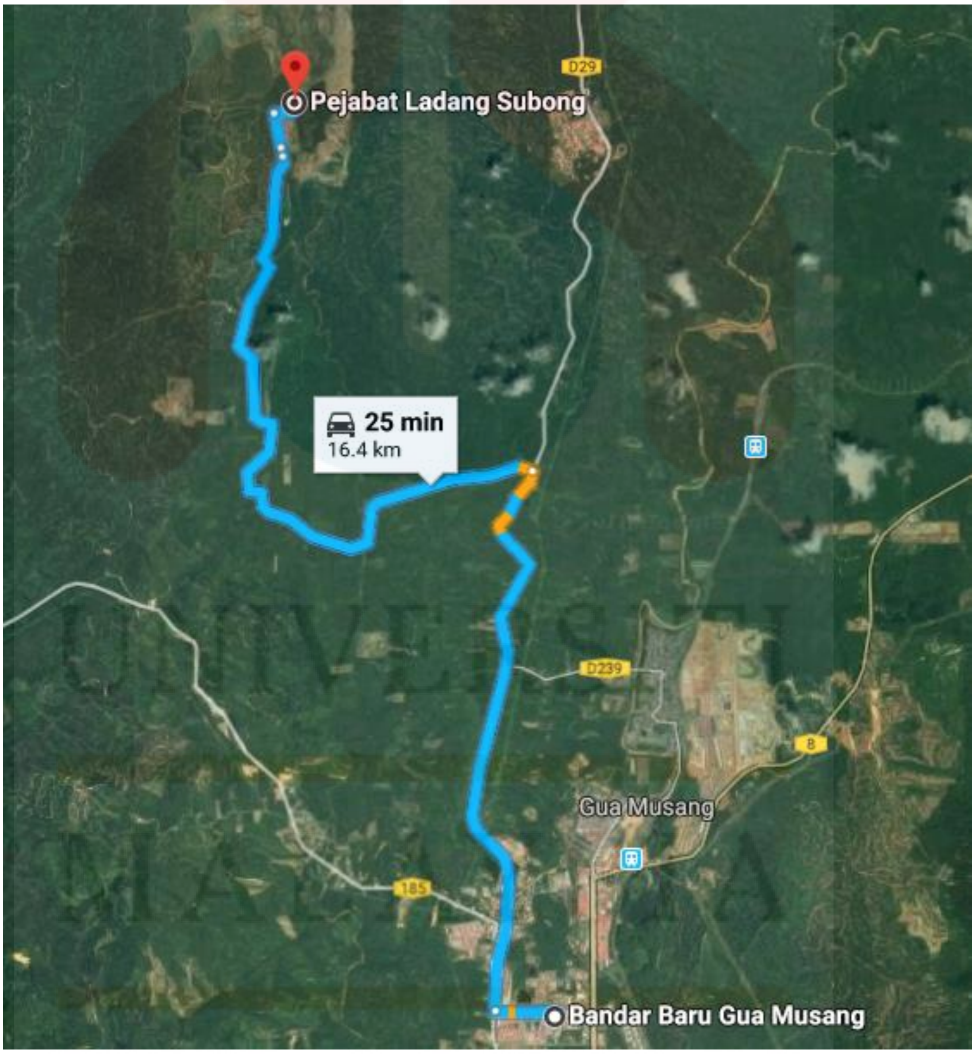

Figure 1.3: Road connection from Bandar Gua Musang to Subong area.

1.2.3 Demography

Demography is a statistic study on population growth. Population growth can be described as a value that showing population rate over particular time and are used to analyse the population density for a selected area. Table 1.1 shows the total population of Gua Musang. According to Statistic Departments of Malaysia (2010), Gua Musang has a population of 86,189 peoples.

Table 1.1: Total Population in Gua Musang by Ethnics

Total Population in Gua Musang by Ethnics						
Area/Ethnic	Malay	Chinese	Indian	Other Ethnic	Non-Malaysian	Total
Batu Papan	1512	883	132	16	51	2594
Bertam	1131	1	1	0	9	1142
Chegar Bongor	398	24	0	4	68	494
Gua Musang	15285	2217	155	118	645	18420
Kerinting	128	1	15	0	13	157
Limau Kasturi	893	5	0	7	70	975
Paya Tupai	352	0	0	0	12	337
Other	44 581	739	47	12586	4117	6207
					Total	86189

(Source: Statistic Departments of Malaysia, 2010)

People distribution in Subong area is notably not very highly populated as in Bandar Gua Musang. Most of people distributions in the study area are concentrated at the eastern part as there is a major road connection. The western part of the study area is less populated as this area is hilly area.

1.2.4 Land Use

The major land use at Subong area is for agricultural and plantation purposes. Most of the land in this area being used for plantation purpose mainly emphasize on oil palm at the northern part of the study area. Other than that, other features of the land use serves as construction purposes such as shop, housing area, clinic, school and others. From surveys and observation made, there are variety of infrastructure such as shops, government amenities as well as local authority and municipal facilities located along the roadside of Jalan Jelawang- Gua Musang. Another type of land use is the residential area in which the villagers live.

1.2.5 Social Economic

Social economic is the position of a person in a group of people who are determine by the type of economic activity, education and income. The social economic of the people at the study area are mainly the plantation and agriculture. With the available huge land resources, plantation and agriculture has become a choice where the people are depending on this as their main source of income. The high demanding markets of palm oil encourage the people to increase the production of the palm oil.

Besides that, business activities also been carried out by the people in the study area. Some local people open a small stall that selling out daily necessities for village people there. Besides that, some local people in this study area open a small restaurant that selling food, drinks and some fruit for the people that passed by that area.

1.3 Problem Statement

Preliminary studies that have been conducted shows that the published and updated information regarding the geology of study area which is Subong area, Gua Musang is very limited. To have a better understanding on geology of that particular area, geological mapping is conducted in order to record and explain the geological data in proper documentation through a geological map in scale (1 : 25,000) and report writing.

The categorization of the rock unit in regional scale at Kelantan state under Gua Musang Formation had been done by the previous researchers. To have a good understanding on particular characteristics of rock unit under Gua Musang Formation in a locality specification of 5x5 km^2 area, the research study is focusing on petrology study of granitoids in the specification part of the research.

The needs for this research arise when the application of the I- and S- type classification system of granitoids cannot represent a significant number of the Malaysian granitoid attributes. (Ng et al., 2015). This present study are contradictory with the previous division of Malaysian granitoid of the Southeast Asian tin belt that divides the granitoids in the Eastern province that situated to the east of the Bentong-Raub suture zone are for the most part being classified as I-type which formed above an east-dipping Paleo-Tethyan subduction zone. Meanwhile, the granitoid in the Main Range province that situated to the west are classified as S-types which formed due to the crustal thickening and collision between the Sibumasu and Indochina-East Malaya blocks. This research will study the specific classification of granitoids in Subong area, Gua Musang.

1.4 Objectives

a) To update the geological map of research area with the scale of 1:25,000.

b) To study the petrology and tectonic setting of granitoid rock in the study area.

1.5 Scope of Study

The research is focusing on general geology and petrology study of granitoid rock within the Subong area, Gua Musang where it is classified under Gua Musang Formation. To achieve the aims of this study, petrography and geochemistry approaches will be applied to identify the elemental composition, origin and rock classification. Geochemistry analysis will be conducted through the analyzing data of major, trace and rare earth elements that are obtained from the X-ray (XRF) spectrometry and Inductively Coupled Plasma Mass Spectometry (ICP-MS). Petrography analysis which involves the microscopic examination of thin section will helps in description and systematic classification of rocks.

1.6 Significance of Study

This research is conducted to provide an updated geological map of Subong and its surroundings. The detail information of the geological aspects such as geomorphology, structural geology, stratigraphy and others of the specific locality within an area of 5x5 km^2 in a scale of 1: 25,000 will be obtained. From the petrology study, the data about the compositions, textures, occurrences and classification of granitoid rocks can be obtained. It helps in providing the scientific evidence of granitoid rock in specific locality. The better understanding of the petrology of the granitoid rocks are able to be acquired for the future references.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review on the existing past studies need to be done before conducting a research as it will help in understanding the overview about the research's content and knowledge about the study area and the topic itself. In this chapter, a detail review regarding the geological of the study area and petrology study on granitoid will be discussed based on the previous research which had been conducted at the study area. Geological study of research area will covered the aspects of the regional geology, tectonic setting, stratigraphy, historical and structural geology.

2.2 Regional Geology and Tectonic Setting

2.2.1 Peninsular Malaysia

Peninsular Malaysia is an integral part of the Eurasian Plate (Hutchinson, 2009) and situated to the north of present active subduction zone of the Sunda arc. The classification of Peninsular Malaysia into two tectono-stratigraphic terranes that form part of the Eurasian Terrane which incorporates the East Malay or the Eurasian plate-Indochina blocks and the Sibumasu or Shan Thai blocks.

The genesis of the Central Belt and the Bentong-Raub Suture is due to the rifting of Indochina and Sibumasu terrane of the north-east margin of the ancient Gondwana plate tectonic in the Late Permian-Early Triassic (Campi et al, 2002). This can be proven from the stratigraphic, paleontological and paleomagnetic evidence. After that, the development of continental lithosphere and island arc succession occurred in front of it. Next, the collision between continental lithosphere and island arc succession with the accumulation Asian landmass and circuit along the Bentong-Raub Suture is occurred. The significant N-S- or NW-SW- trending left-lateral strike-slip fault, dilatational Riedal and subsidiary shears associated with these faults were formed as a result from the collision event. Distribution of continental blocks, fragments, terranes and principle suture of Southeast Asia is shown in Figure 2.1.

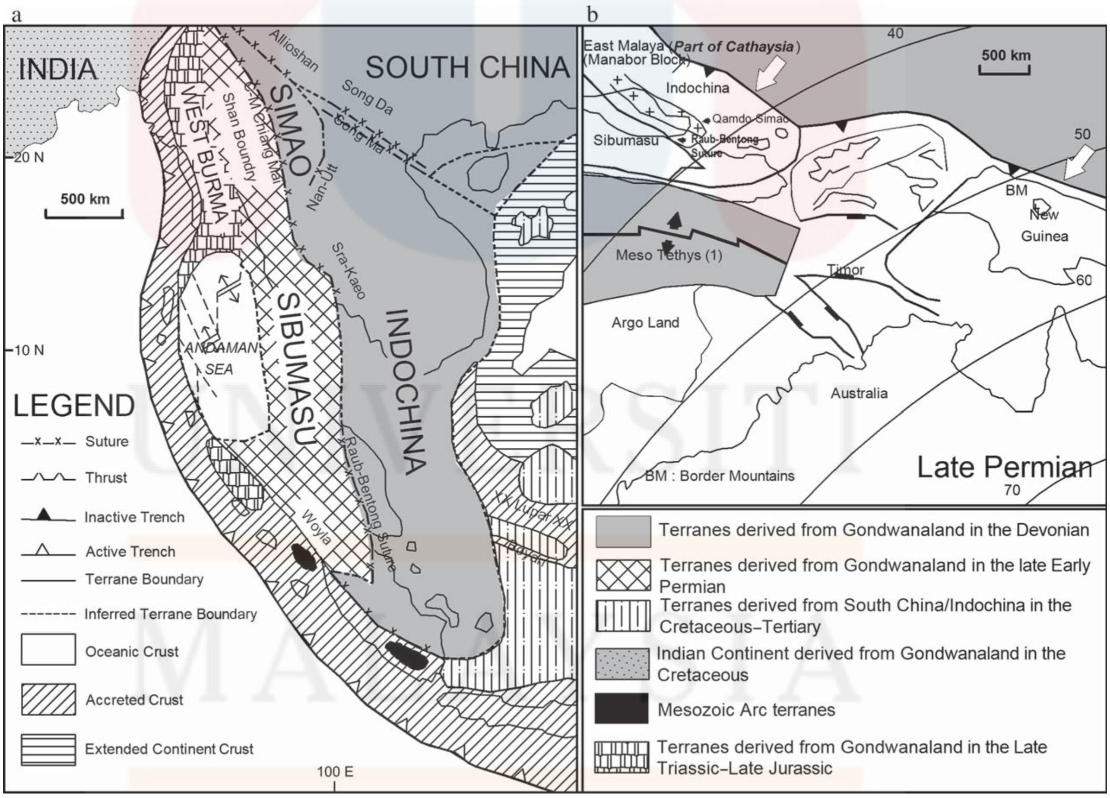

Figure 2.1: Distribution of continental blocks, fragments, terranes and principle suture of Southeast Asia

The Bentong-Raub suture represents the Palaeo-Tethys in Peninsular Malaysia that runs generally in southwards extension of the Nan-Uttaradit and Sra Kaeo sutures of Thailand (Hutchinson, 2009). The Palaeo-Tethys opened in the Lower Devonian, caused by separation of Sibumasu from Gondwanaland, and closed in the Triassic, caused by the Indosinian orogenic collision with the Indochina Block that was earlier sutured to Eurasia. The suture zone contains of schist, cherts with small serpentine bodies, argillite, olistostrome and melange. It is also zone of parallel steeply dipping N-S faults with several periods of reactivation (Ariffin & Hewson, 2007). The division of Eastern Belt and Central Belt occurred due to the lies of Gold Belt in the East Malay/ Indochina Block. Figure 2.2 shows the Permo-Triassic Indosinia Orogeny based on forearc basin subsidence and segmentation model.

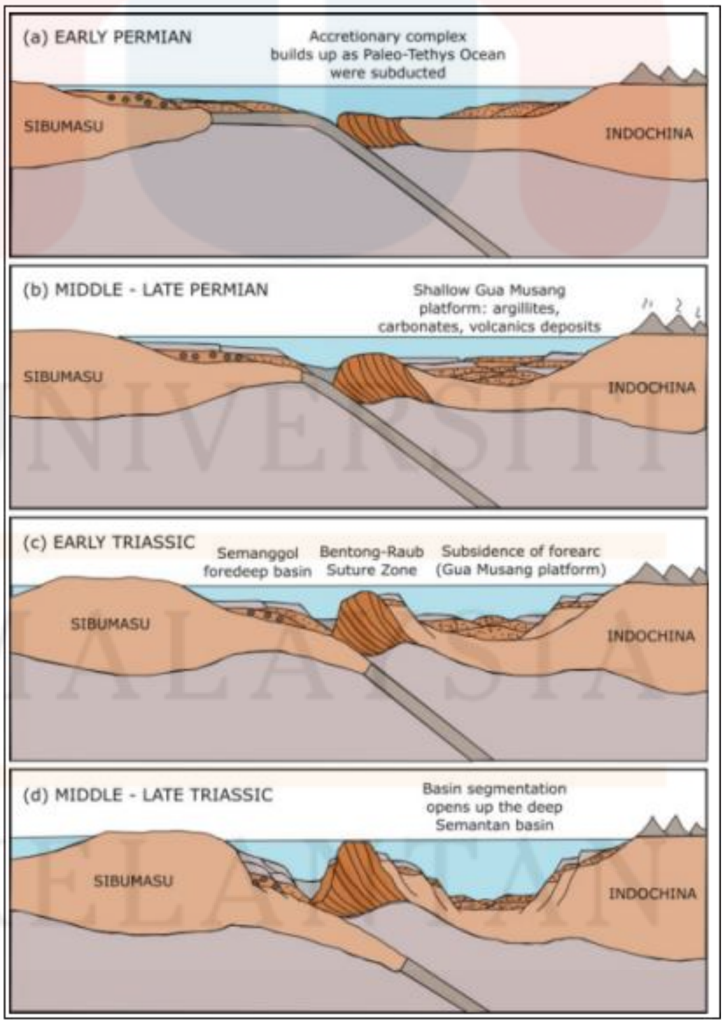

Figure 2.2: The Permo-Triassic Indosinia Orogeny

2.2.2 Kelantan

Generally, Kelantan located at the northeast of Peninsular Malaysia (Nasaruddin & Bahar, 2013). It covers an area of 15,099 km^2 confront with the South China Sea to the north-east, and bordered by Narathiwat Province of Thailand to the north, Terengganu to the south-east, Perak to the west, and Pahang to the south. Kelantan is located at the coordinate of latitude ranges from 4° 33’ N to 6° 14’ N and longitude from 101° 20’ E to 102° 41’ E. Kelantan is divided into ten districts which are Tumpat, Kota Bharu, Pasir Mas, Bachok, Tanah Merah, Machang, Pasir Puteh, Jeli, Kuala Krai and Gua Musang.

The distribution of rocks in a north-south trend in the Kelantan state can be classified into four main types, including sedimentary or metasedimentary rocks, granitic rocks, unconsolidated sediments and extrusive rocks (Pour & Hashim, 2017). Figure 2.3 shows the geological map with distribution of rocks in Kelantan state. Geological formation of Kelantan can be divided into three main chronologies which are Paleozoic, Mesozoic, and Cenozoic which ranges from Lower Paleozoic until Quartenary (Hutchinson & Tan, 2009).

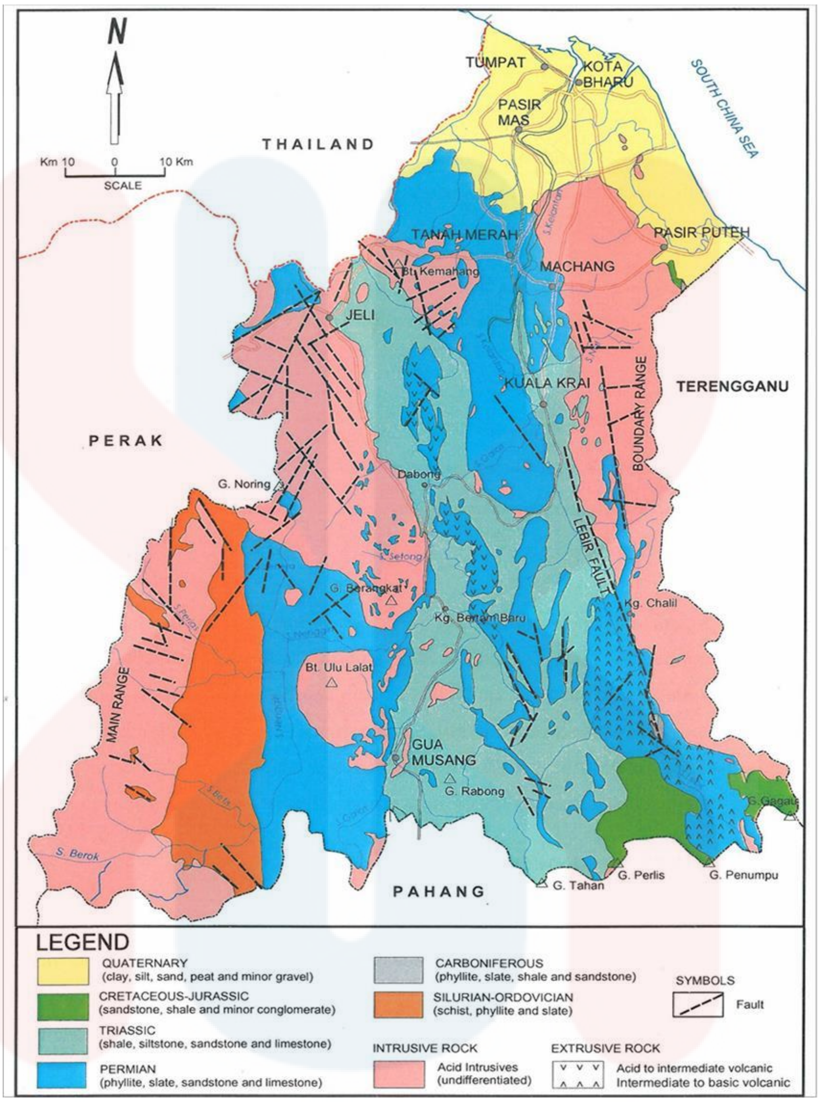

Figure 2.3 : Geological map with distribution of rocks in Kelantan

A) Paleozoic

The Paleozoic formation is found in the Central Belt. The Upper Paleozoic sediments consists of argillaceous, volcanic, calcareous and arenaceous rocks of the Raub Group, Gua Musang Formation, Aring Formation and Kepis Beds and shows the typical shallow marine depositional environment in which the active submarine volcanism is starting in Late Carboniferous and peak at Permian and Triassic in geological time (Peng, 2009).

A) Mesozoic

The large part of newly-formed landmass of Peninsular Malaysia were encountered with the uplifting and subaerially exposed at the beginning of Mesozoic Era. Marine sedimentation was centered in two areas which are the northwestern Kodiang-Semanggol depocentre and the Gua Musang-Semantan depocentre in the Central Belt. During Triassic time, the extensive occurrence of tuff and associate tuff, tuffaceous siliciclastic and conglomerate can be seen in the Gua Musang-Semantan depocentre which indicates the volcanic activities and basinal instability were active during the life span of the basin (Abdullah, 2009).

B) Cenozoic

The Quaternary sedimentary deposits are representing the Cenozoic formation which can be classified as a Pleistocene and Holocene deposit. The Pleistocene is comprises of Simpang Formation meanwhile the Holocene is comprises of Gula Formation and Beruas Formation. The Quaternary Period is represented by extensive deposits of unconsolidated to semi-consolidated boulders, gravel, sand, silt, and clay that underlie the coastal and inland plains (Raj et. al, 2009).

2.2.3 Gua Musang, Kelantan

Gua Musang lies within the central belt of Peninsular Malaysia that extends from Kelantan to Johor between the eastern foothills of the Main Range. This formation is part of the Gua Musang-Semantan depocentre that lies east of the Bentong-Raub Suture. According to Hutchinson and Tan (2009), in the western part of the Central Belt are Upper Paleozoic rocks of the Gua Musang and Aring Formations in south Kelantan and Taku schist in east Kelantan. It is predominated by argillaceous strata and volcanic rocks with subordinate arenaceous and calcareous sediments deposited in a shallow-marine environment.

2.3 Stratigraphy

Division of north-south tectonostratigraphic zones of Peninsular Malaysia into three belts which are the Western Belt, Central Belt, and Eastern Belt shows the significant differences in the stratigraphies, volcanism, magmatism and evolution of geological structure (Metcalfe, 2013). Figure 2.4 shows the simplified geological map of Peninsular Malaysia that shows the division of the belts.

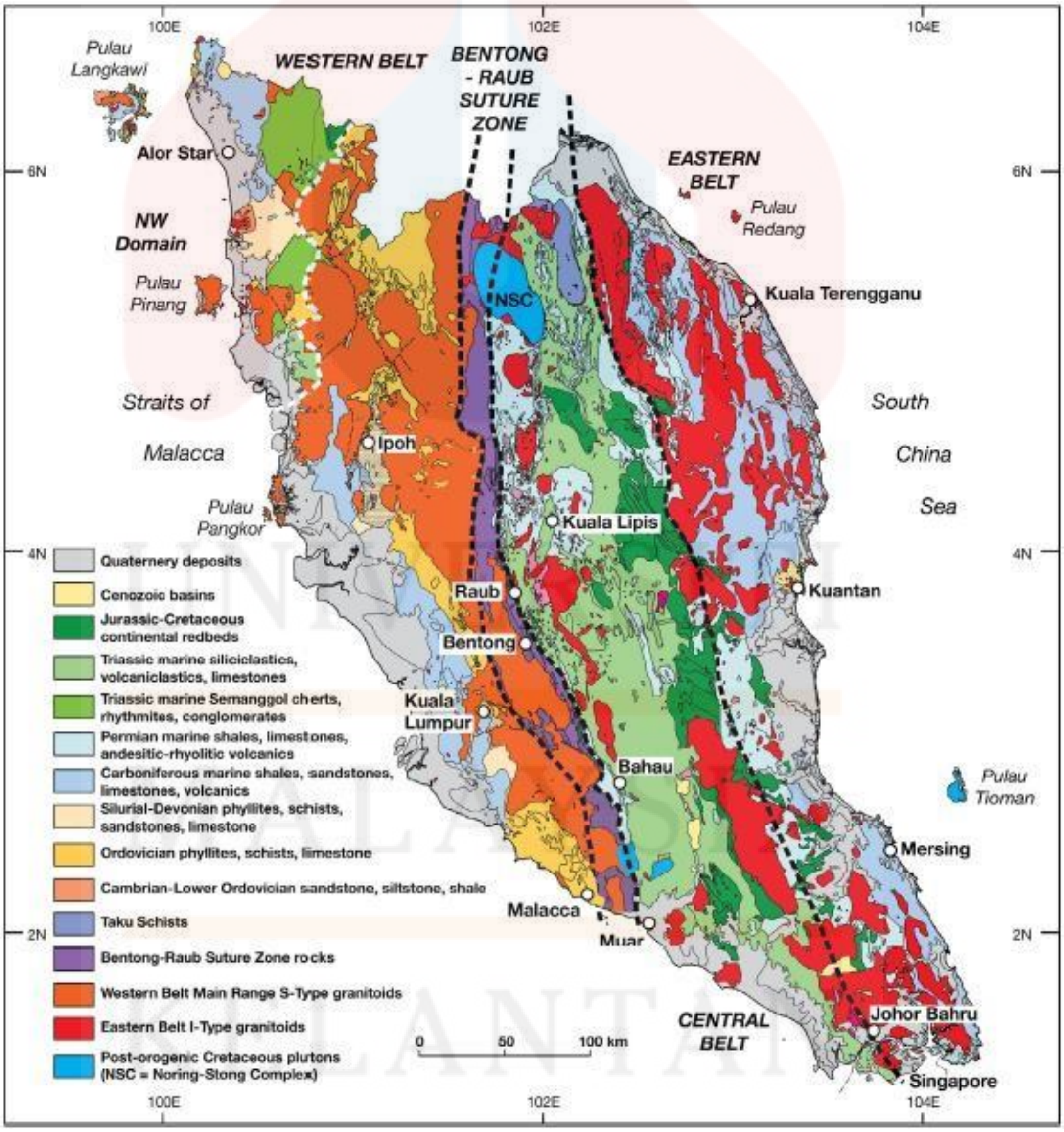

Figure 2.4: The geological map of Peninsular Malaysia

The Permian strata of the Central Belt are very well developed in southern Kelantan and northern Pahang. Most of them belong to the Permo-Triassic Gua Musang Formation which consists of mainly of three facies, which are limestone, volcanic and argillaceous facies. (Mohamed, K. R., et al., 2016).

In Kelantan, formations that had been identified are Aring Formation, Taku Schist Formation, Gua Musang Formation, Telong Formation, Gunung Rabong Formation, Nilam Marble Formation and Koh Formation. Specifically, Gua Musang area comprises of Gua Musang Formation and Gunung Rabong Formation.

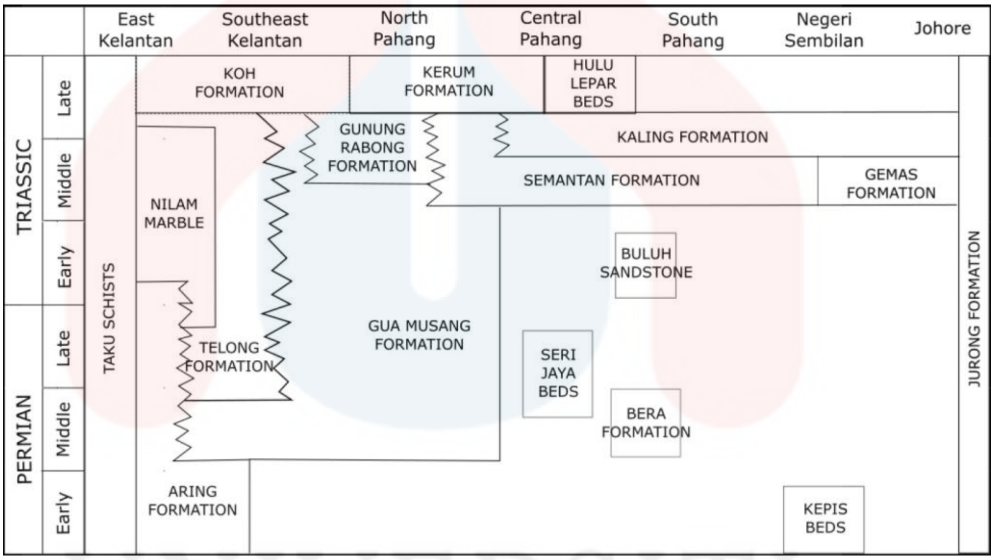

Figure 2.5: Permo-Triassic stratigraphic correlation chart of Central Belt Peninsular Malaysia

Gua Musang Formation stretches to north Kelantan and southwards to north Pahang and is overlain unconformably by Gunung Rabong Formation. The age of this formation is Middle Permian to Late Triassic. The upper part of Gua Musang formation interfingers with Semantan Formation, Telong Formation, and Gunung Rabong formation. Four lithology had been identified which is calcareous facies, argillaceous facies, arenaceous facies and the volcanic facies. The depositional environment of this formation is a shallow marine shelf deposit with an active volcanic activity. (Mohamed, K. R., et al., 2016).

Gunung Rabong Formation is an argillaceous succession of age Middle Triassic to Upper Triassic which exposed between Gua Musang and upper reaches of Sungai Relai-Sungai Aring. At the southern area, the lithology is alternation of shale and quartzite and minor conglomerate, meanwhile, black shale and crystal tuff is dominant at the northern area. Figure 2.6 shows the stratigraphy of Gua Musang area.

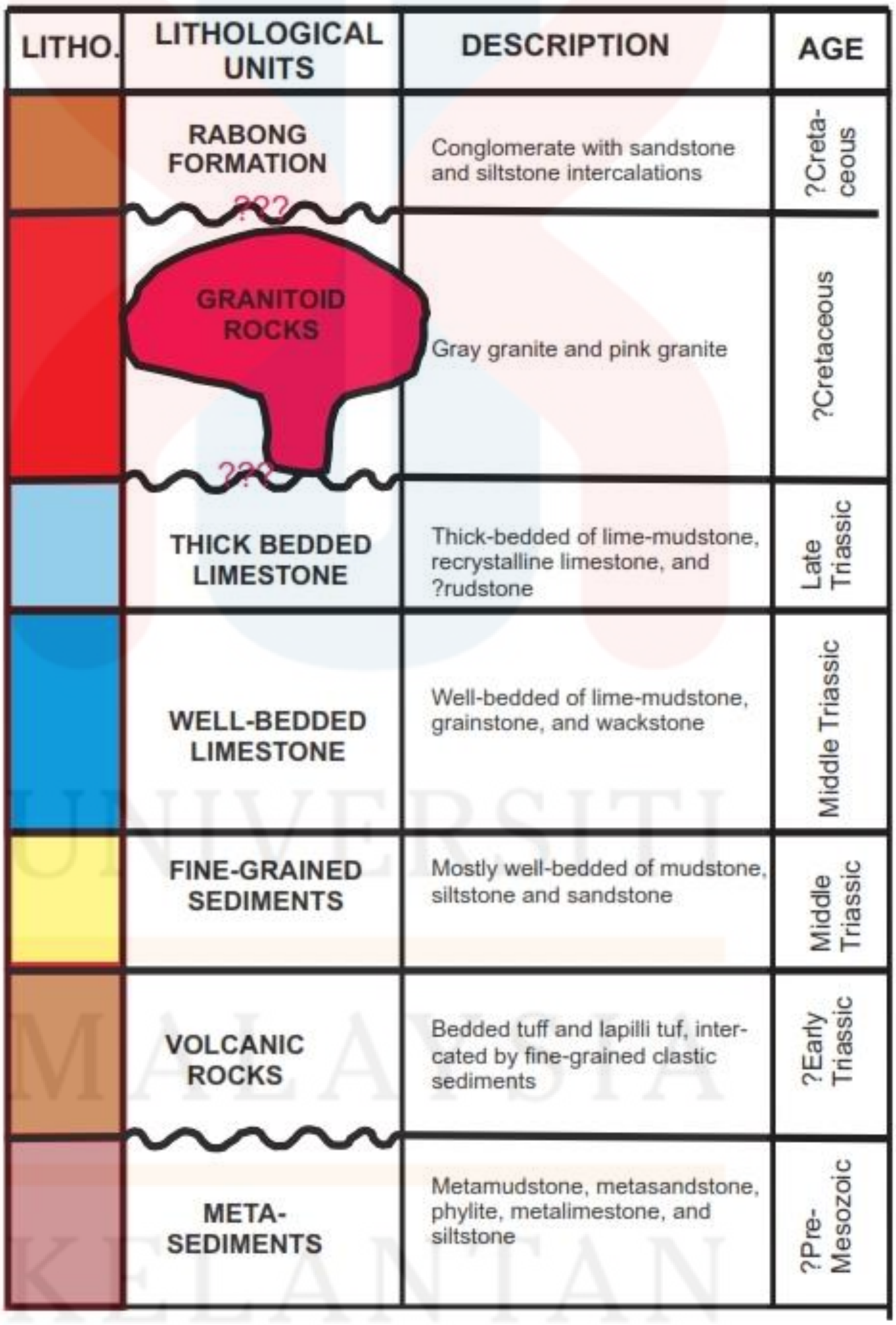

Figure 2.6: The stratigraphy of Gua Musang area.

2.4 Historical Geology

The Peninsular Malaysia is a part of Eurasian plate and also a part of Southeast Asia, which is known as Sundaland (Hutchinson and Tan, 2009). Sundaland is a subaerially exposed Asian continent with southeastern extension to which the Peninsular is connected by the Isthmus of Kra, which is the narrowest part of the Malay Peninsular located in the southern Thailand with only 64 km wide. Sundaland comprises few region such as the Malay Peninsular, Sumatra, Java, Borneo and Palawan.

During the low sea level stands in the Pleistocene, this region that are located on the shallow water Sunda Shelf were exposed. The Peninsular has been mostly present throughout the Cenozoic and thought to been relatively stable tectonically as the earth processes are mainly epeirogenic uplift and tilting, fault movement and local gentle downwarps. (Dapper, 1989).

As the Paleo-Tethys Ocean and Sibumasu terrane were subducted obliquely under the Indochina volcanic arc, the accretionary complex continues to grow while argillo-carbonate sediments were deposited within the shallow marine Gua Musang platform. Concurrently, pyroclastics or volcanics input were being supplied by the volcanic arc nearby, hence the presence of volcanics within Gua Musang Group. Shallow marine sedimentation progressed throughout the Permian until the Early Triassic (Mohamed et. al., 2016).

2.5 Structural Geology

According to article of Geology of the Batu Melintang- Sungai Kolok transect area along the Malaysia-Thailand border (2006), Peninsular Malaysia was formed as a result of collision between Sinoburmalaya to the west and Eastmal-Indosinia blocks to the east. The Bentong-Raub Suture which represented the collision zone, are also represents the Palaeo-Tethys in Peninsular Malaysia (Hutchinson and Tan, 2009). The suture zone can be traced northward into Thailand and southward into the Banka and Billiton Islands. Rock deformation in the Malay-Thai Peninsula that occurred during the Late Triassic are originated from the result of these collision blocks and large-scale tectonic event.

As stated by Mustaffa Kamal Shuib (2009), distributions of the Main Range Granite in the NNW-SSE direction of Peninsular Malaysia are separating the Eastern and Western province. The major faults occurred in the N-S, NW-SE, NNE-SSW, and E-W direction influenced the variation of the surface topography and the coastlines. The Peninsular's fault that occurred in the direction of NW-SE are parallel to the structural grain of part of Sumatra, Indonesia. Meanwhile, the N-S major fault is parallel to faults in central Sumatra. The division of the Peninsular into three different belts which are Western, Central and Eastern Belts are due to the N-S to NNW-SSE structural grain. The general NNW-SSE structural trends are resulted from three main deformation phases which are an Upper Triassic-Lower Jurassic transpression, Upper Cretaceous and Tertiary strike-slip, and the Upper Triassic-Lower Jurassic orogenic event.

2.6 Petrology of Rock

Petrology is the scientific study of rocks that deals with their composition, texture, and structure, their occurrence and distribution, and their origin in relation to physicochemical conditions and geologic processes. It includes the subdisciplines of experimental petrology and petrography. This research is mainly focusing on the classification of granitoid rocks in Subong, Gua Musang and its surrounding.

2.6.1 Petrology of Granitoid Rocks in Peninsular Malaysia

According to Ghani et al (2013), north-south elongate provinces are proposed due to the distinct petrological and geochronological characteristics of the granitoids at the Southeast Asian tin belt. The division of granite belt that had been modified by Cobbing et al. (1989) are categorized into the four division which are the Eastern, the Main Range, the Northern and the Western Province. The Central and Eastern Belt of Peninsular Malaysia had been unified into an Eastern Province due to the quite similar characteristics.

The Eastern and Main Range Granite provinces are separated by the Bentong-Raub suture, and are well exposed in Peninsular Malaysia. Eastern provinces is dominated by the I-type granites that formed during the Middle Permian to Late Triassic meanwhile the Main Range provinces is comprises of the S-types granites that formed during a Triassic to Early Jurassic. Each of the granite types shows a mineralogically different.

However, Ng et al. (2015) and Ghani et al. (2013) argues the I- and S-type designation of the distribution of the Malaysian granitoids by stating that the Main Range is consist of the transitional I/S-types of granites.

Gua Musang that is located at the Central Belt are classified as Eastern Province and believed to have the distribution of I-type granites. Petrographic analysis will be conducted at Subong, Gua Musang to specifically study the type of granites in that particular area.

2.6.2 Distribution of Rare Earth Element (REE) at Peninsular Malaysia

The Peninsular Malaysian granites are classified into two main groups based on the Rare Earth Element (REE) patterns. According to Hassan and Hamzah (1998), it can be divided into groups with anomalous Europium (Eu) values and a group that lack or with small Eu anomaly. A group with anomalous content of Eu shows the “bird-wing” REE pattern that is distributed at the West Coast Triassic, part of Central and East Coast Provinces. The non-anomalous or with small Eu anomaly is observed on the Cretaceous granites of the West Coast, Gua Musang granites, and granite patches from the East Coast Provinces. The non-anomalous Gua Musang granites can be correlated to the Cretaceous granites of the southern Peninsular which exhibit a resemblance with the Noring granite. The distribution of the non-anomalous East Coast granite can be related to the I-type granite which is believed to originate from an oceanic or primitive mantle source which has a poor plagioclase source.

The Cretaceous southern Peninsular granite is derived from a primitive mantle source. For the group with anomalous ones in the Province, it shows the resemblance with the Main Range and is from S-type. The presence of anomalies indicates that the parental materials from a sialic basement that is readily high in plagioclase feldspar that undergo the partial melting or fractional crystallization or both.

The composition of REE in West Coast Province shows a general enrichment of Light Rare Earth Element (LREE) components and low Heavy Rare Earth Element (HREE) components with $(La/Yb)_{cn}$ values range from 2.59 to 10.79. It shows the low ∑REE content which is ranges from 110-232 ppm and clearly displays negative Eu anomalies. The West Coast Province area extends from the granite batholiths from Langkawi Island in the North to that of Batu Pahat in the south. In Central Province, it extends through Gunung Benom to Stong Complex in the northern-most end. Generally, it composed a rather high ∑REE content which is 205 to 282 ppm and enrichment of LREE components with $(La/Yb)_{cn}$ values 11.82 to 68.66. It shows hardly noticeable negative Eu anomalies. In East Coast Province, it has been subdivided into two subprovinces. Subprovince A consists of batholiths that extend from Kuantan to Kelantan and show a mixed S and I affinity. Meanwhile for Subprovince B, it covers area that extends from south east Johor and Singapore and exhibits I-type characteristics.

2.6.3 Classification of Granitoid Rock.

Petrogenetic classification of granitoids is based on mineralogical, chemical and tectonic classification which is influenced by the origin and tectonic setting of the granitoid magmas. According to Bernand Barbarin (1990), the information regarding the changes of tectonic setting with time and space are able to be defined through the distinct characteristics and act as geotectonic tracers.

In mineralogical classification, the IUGS classification will be implemented through the application of QAPF diagram which is named according to the percentage of felsic minerals such as quartz, alkali feldspar and plagioclase feldspar. The mineralogy reflects the major-element compositions. From the result collected, the data will be plotted on QAPF diagram (Streckeisen, 1991). Although the application of this diagram is simple and inexpensive, but it overlook the compositional variation apart from those that affect the feldspar abundances and unable to address the minor phases which may bring important petrologic implication (Frost et al., 2001).

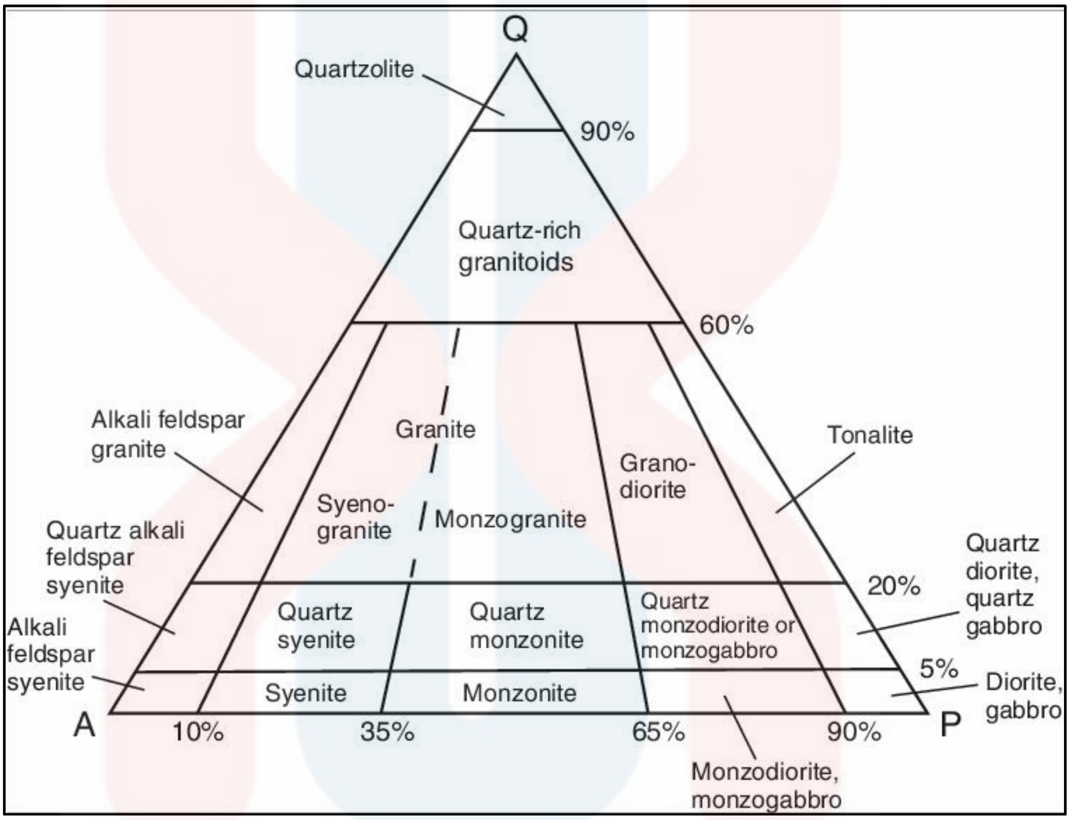

Figure 2.7: QAPF ternary diagram

Chappel and White (1974) introduced an alphabetic (SIAM) classification that takes the consideration of the origin of the granitoid precursor. S-type granitoids are formed due to partial melting of sedimentary potolith that are common in collision zones. Generally, peraluminous granite can be identifying with the presence of muscovite, biotite and higher silica content.

I-type granitoids are derived from the partial melting of igneous rock due to the upwelling of mantle material to higher levels. These are metaluminous granites with the presence of hornblende or alkali amphiboles biotite.

A-type granitoid are emplaced in either within plate anorogenic settings or in the final stages of an orogenic event. It is characterized by the high silica content, and presence of flourite. G. Nelson Eby (1992) states that quartz syenite, subalkalic-peralkalic granite, rhyolites and comendites are the rocks under this classification.

Lastly, M-type granitoids are derived from the fractional crystallization of basaltic magma and are relatively plagioclase rich. It associated with gabbros and tonalite and displays the characteristics of subduction zone.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter is focusing on the materials used to run the research and the methodology which applied for data collecting and data analysis. In conducting geological mapping, we need a method for retrieval and processing of data. Systematic research stages is important with the aim that these geological mapping can run smoothly by following the time that has been planned. The stage of the study is presented in the form of a flow chart in Figure 3.2.

In order to achieve maximum results in this research, there are several systematic and planned stage were carried out which included preliminary studies, field studies, laboratory work, data processing, data analysis and interpretation and thesis write-up.

3.2 Materials

In order to perform geological mapping, a complete set of mapping equipments is required. This includes the use of Garmin Global Positioning System (GPS), notebook, geological compass, hand lens, hydrochloric acid (HCL), chisel-head hammer, meter tape and base map. Figure 3.1 shows list of materials used for geological mapping.

Figure 3.1: List of materials used for geological mapping (Source: Google Images)

GPS is a satellite based navigation system composed of satellite, monitoring stations, and GPS receiver. GPS device receives signals to ascertain the device's location on Earth. Hammer is used for splitting and breaking rocks in order to obtain a fresh surface. Brunton compass is used to make an accurate degree and angle measurement in the field. Next, hand lens is used to make the first interpretation of rock samples in the field before further analysis is performed in the laboratories. The properties of the sample such as rock type, texture, identifiable mineral and other physical properties can be determined. Hydrochloric acid (HCL) is used to identify the reaction of rocks in order to differentiate between carbonate rocks.

3.3 Methodology

Methods that have been used for this research divided into preliminary study, field study, laboratory work, data analysis and interpretation, and report writing.

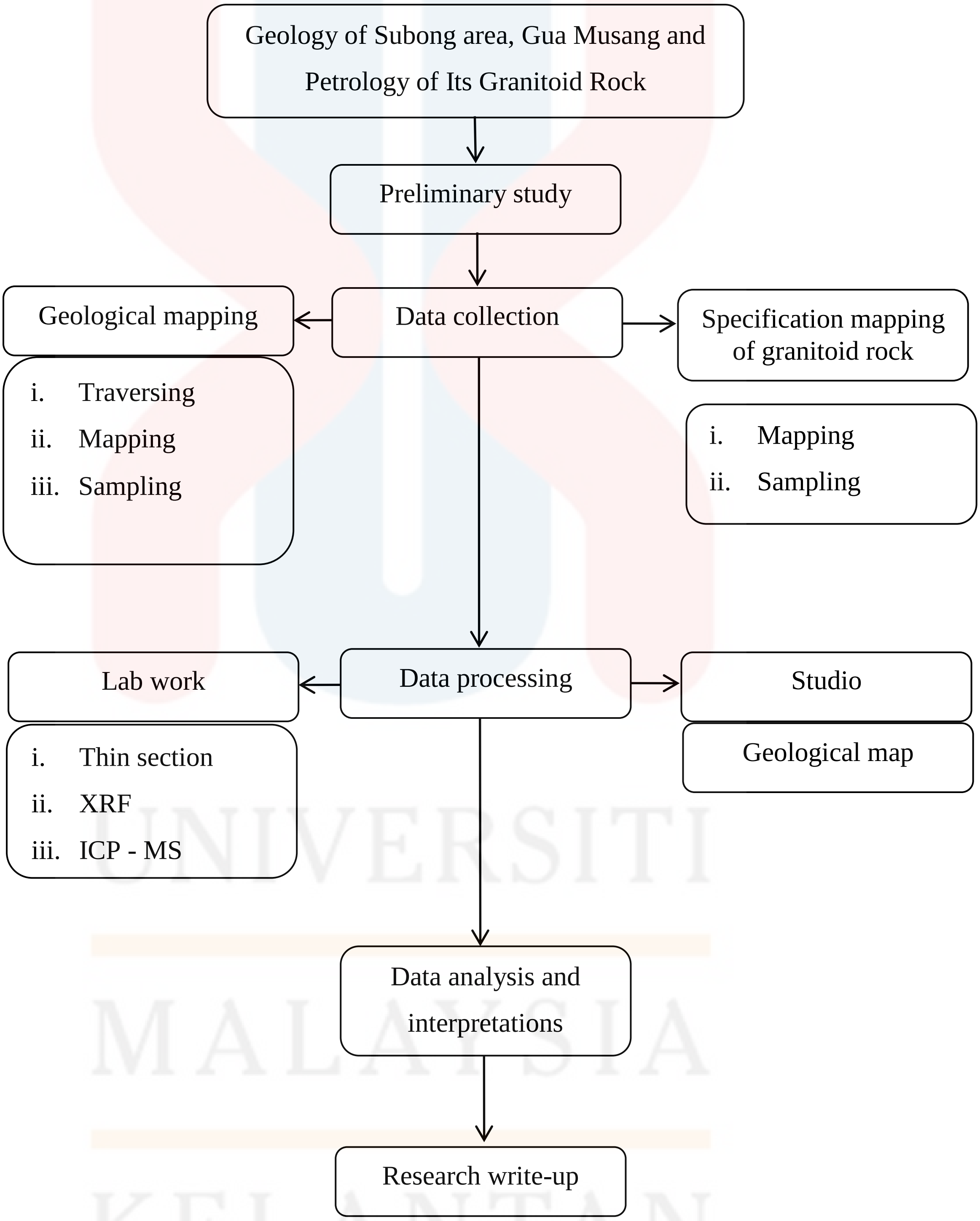

Figure 3.2: Flow chart method and research phase

3.3.1 Preliminary Study

Preliminary study can provide initial overview of the topic selected. This study can be done through the observation of topographic map, base map, discussion with supervisor and other references from the online articles, journals, e-book, proceedings and thesis. Through satellite image and base map, the information about the lineaments, geomorphology, and other aspects can be observed to identify the geology of the area. Intensive reading has been done to get the general overview about the distribution and petrology of granitoid rocks.

3.3.2 Field Study

Data collection is conducted through field studies and comprises of two main aims which are for the general geological mapping and specification mapping of granitoid rock. Geological mapping is the process of selecting and identifying the geological elements of the selected interest area in order to prepare a detailed geological report and a map (Njue, 2010). The field work is including the interpretation of geological boundaries, analyzing the rock distribution, and study of geological structure. Besides that, the data collection for the specification of granitoid rock, it involve geological mapping as well with more focusing in fresh rock sampling of granitoid rock.

3.3.3 Laboratory Work

The laboratory investigation will be carried out which are field data and petrographic analysis. The method of X-ray Flourescence (XRF) spectrometry and Inductively Coupled Plasma Mass Spectrometry (ICP - MS) also were used for elemental determination.

A) Field Data Analysis.

Field data analysis is the process of constructing and updating geological map on scale 1:25,000 of study area with the help of ArcMap 10.2 software. Other software also used such as GeoRose and Stereonet.

B) Thin section

Petrography analysis of thin section provides the detailed information of the arrangement of the constituents and interrelation of each particular feature. The preparation of thin section involves few steps starting from sectioning, vacuum impregnation, grinding and polishing.

For thin section preparation, bulk sectioning process is required to create a section approximately 3mm thick. The samples need to be in a clean and vacuum impregnating for pores filling and mechanically support the specimen materials. To have a smooth surface and free of gross deformation, the surface of interest were grinded. The types and characteristics of material such as hardness were taken into consideration in choosing the grinding and polishing abrasives. A proper grounding procedure will exhibit an evenly reflective surface. Next, a glass slide is added onto the chip to the lapped face of the slab with epoxy. The specimen required a clean and dry condition. The top surface of specimen was mounted and the air bubbled were removed. Carborundum powder was used in grinding process until a desired thickness is achieved. Besides that, the samples were polished on a polishing machine until a decent polish is achieved for petrography analysis. Lastly, the prepared thin sections were observed under petrographic microscope for optical characteristics observation of mineral present in each rock samples.

C) X-ray Flourescence (XRF) spectrometry

XRF spectrometry is a non-destructive chemical analysis that works on wavelength-dispersive spectroscopic principles. XRF method is applicable for analyzing the bulk chemical analyses of major and trace elements (Wirth and Barth, 2018). The XRF analysis was conducted in laboratory of University of Malaya.

The sample should be able to display the nature and overall composition of the entire material to be representative of rock mass of interest. To avoid the modification in sample composition during transport and storage, the information of the origin and history of the sample was required. Next, the sample needs to be in clean and dry conditions to avoid the probability of contamination occurrence. Rock crusher was used to crush and powder the rock sample into an ideal grain size of $< 60\mu$m. The binding aid and the pressing the mixture by a press pellet compressor under 20 kpa were carried out to produce a homogeneous sample pellet. The binding aid is usually a cellulose wax mixture and combines with the sample in a proportion of 20% - 30% binder to sample. The samples then were analysed by XRF machine. The result of a major and trace element were recorded and detected with ppm and ppb values.

D) Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

ICP-MS is an analytical technique that allows more sensitive detection in determining a wide range of extremely low detection limit of atomic elements below one part in 10^{12} (part per trillion). Mass spectrometer will be detecting the ion that has been separated by ICP source (Wolf, 2005). This technique is highly recommended for trace elemental analysis as it offers a high speed of analysis, accurate detection limit and isotopic sensitivity potential (Batsala et. al., 2012). ICP-MS analysis has been carried out at Universiti Malaysia Pahang.

Generally, working standard solutions were prepared from primary standard solutions and in-house stock standard solutions. Before starting the instrument and stabilizing the material, the sample introduction system was checked. Standardization blanks, working standard solution drift control samples, and quality control samples were used to measure the unknown samples. The correction of the data was done by considering the standardization blanks, drift correction, and dilution factor application. The results were normalized to the internal reference standard.

3.3.4 Data Analysis and Interpretation

The data obtained from the laboratory work will be analyses and interpreted. From the result of XRF and ICP-MS analysis, the distribution of rare earth element, major and trace element were interpreted. ArcGIS software is used for geological map creation and mapping purpose for identification of geological aspects.

3.3.5 Research Write-Up

All the analysis of the field studies data will be documented as a complete report which includes introduction, research objectives, literature review, materials and methodology, data analysis and result, and conclusion. The purpose of this report write-up is to help future researchers or readers to review and understand about the topic for future improvement and suggestion for the better ways in handling the research in the same field study.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter is discussing about the geology and provides the detail geological information about Subong area, for example geomorphology, lithostratigraphy, petrology, geological structures, and geological history based on the field observation, sampling and analysis of the data in the study area. Few maps such as the geomorphological map, traverse and observation map, and drainage map were provided in order to understand the characteristics of the study area. All the geological information and data that have been collected from the field were studied in order to create a detailed geological map for the specific study area and to achieve the research objective. All of the results were plotted and recorded on the geological map with the exact scale of 1:25,000.

4.1.1 Accessibility

Accessibility explained the approachability and ease to reach a place with respect to another place. Accessibility also determined by people and affects infrastructure, transport policies, and regional development. In Subong area, there is a direct geographic relationship between the land use system and road network. The roads act as connecting networks to all the locations. There are two types of road which is the main paved roads that can be accessed by big vehicles, and also unpaved road which only can be access by small vehicles such as motorcycles or four by four vehicles. The main paved roads which known as Jalan Jelawang-Gua Musang connects Gua Musang town in the south to the Subong area. The unpaved road is used to access the palm oil and rubber plantation area. The telecommunication systems in the study area are quite accessible, but yet is still depends on local influence which some location that might have low coverage in the telecommunication systems.

4.1.2 Settlement

Settlement includes the places and areas that are settled by people that formed a community. The main villages that covered and located in the study area are the Kampung Sungai Terah that located at the east and the Kampung Subong that is located at the west of the study area. Most of the community in the village works in managing rubber and palm oil plantation. The population at the Subong area is dominated by the Malay race with a small percentage of other races such as Chinese, Indian and others.

4.1.3 Vegetation

In this study area, almost entirely, are dominated by the forestry of vegetation which is palm oil and rubber plantation. It is approximately 70% of the study area is dominated of palm oil plantation and the other rest of 30% is dominated by the rubber plantation. The residents of Subong area are dependent on oil palm and rubber plantation. The distribution of the vegetation can be observed at Figure 4.1.

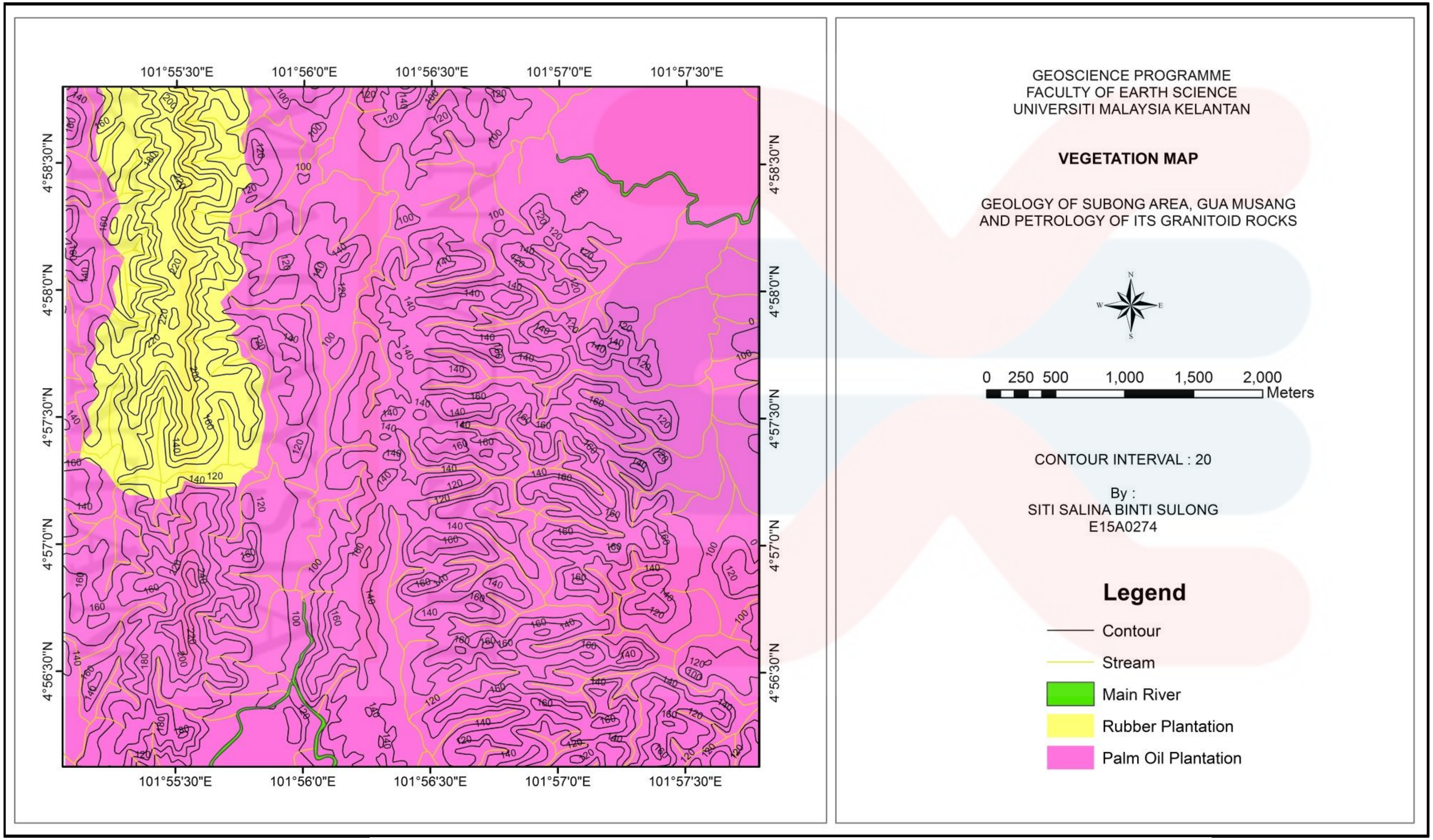

Figure 4.1: The distribution of rubber and palm oil plantation in the study area

4.1.4 Traverse and Observation

Traversing and observation methods are applied during mapping processes in order to collect geological data, rock sampling and measuring. A well-planned traverse route was set before going to the field in order to make the geological mapping processes success and efficient. The whole geological fieldwork process for the study area takes approximately 6 days to complete and collect the geological data.

The observations were made during the traversing by observing the every change of the fixed patterns of lithologies and geological structures. All the observation was recorded in a field notebook and the traverse route was track by using GPS. The traverse route was then plotted in the map in the Figure 4.2.

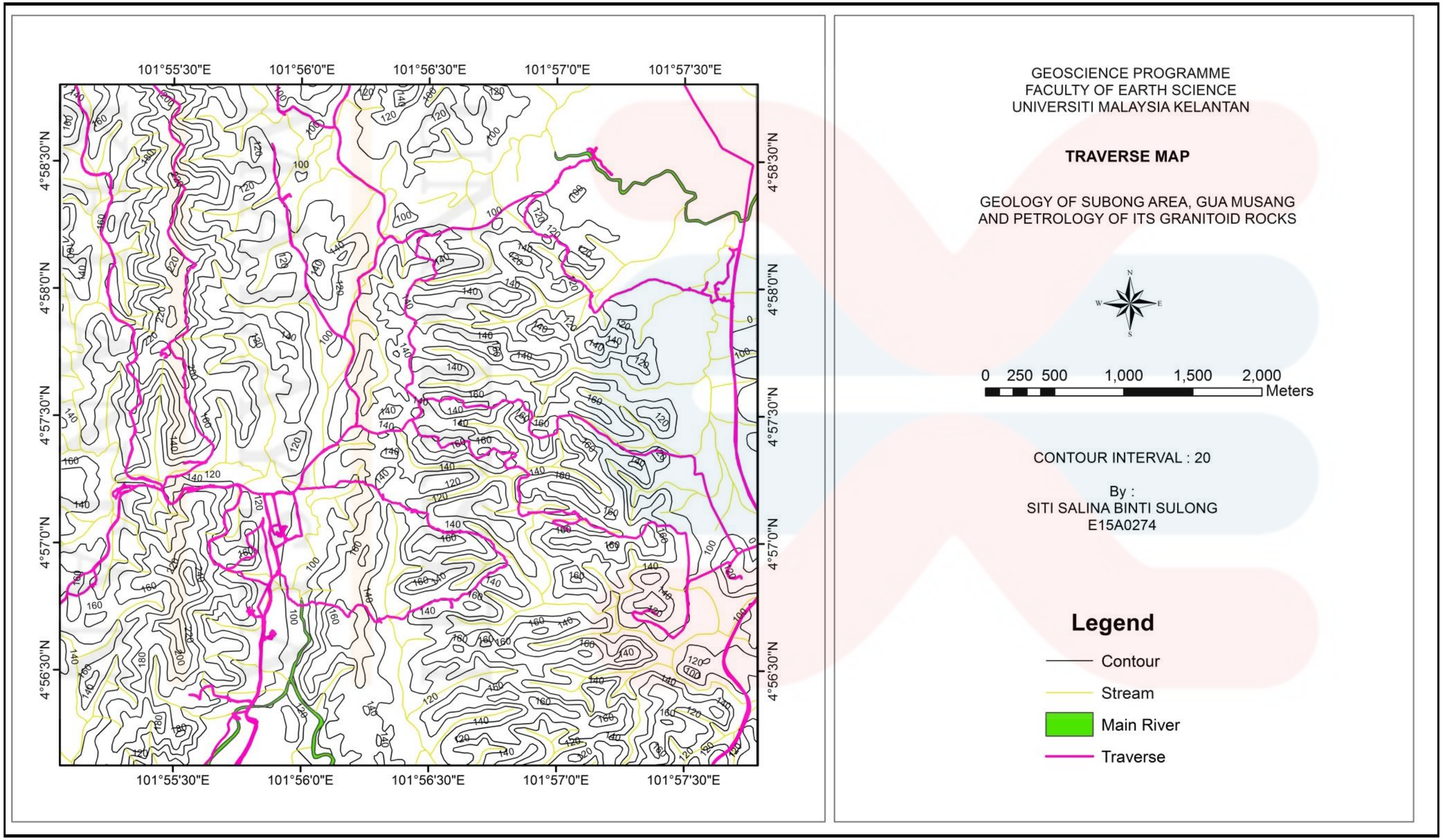

Figure 4.2: Traverse route during field studies.

4.2 Geomorphology

Geomorphology is defined as the science that study of the landform on the earth surface which covers the topic of landform genesis, the weathering pattern and the description of the rivers in the study area. The study of the landforms also allows the geologist to study the history and development of the landforms. The geomorphology of the study area is classified according to the standard geomorphologic classification by Van Zuidam (1985).

Van Zuidam (1985) described geomorphology as the study of descriptive geomorphological landforms and processes and their relationships between landforms and processes in spatial arrangement. The classification is influenced by several factors such as process, study area, type of lithology and the influence of geological structure. In this section, the geomorphologic classification, weathering processes and drainage patterns is described.

4.2.1 Geomorphologic classification

According to Van Zuidam (1985), geomorphological landform is characterized based on relief elevation. The significance of classifying the landform based on its relief elevation is to describe about the condition of the morphology and morphogenetic landforms. Table 4.1 shows that the classification of geomorphological landform based on relief elevation. According to the state of the landform, Subong area can be classified into two units of morphology which is medium and low relief morphology unit. Medium relief morphology unit is comprises the low hill and hill landform while the low relief morphology unit consists of low-lying plain landform. Figure 4.5 shows the relief elevation map.

Table 4.1 Classification for Relief Elevation

Relief/ Landform	Elevation (meters)
Lowland	< 5
Low-lying plain	5 – 100
Low hill	100 – 200
Hill	200 – 500
High hill	500 – 1500
Mountain	1500 – 3000
High mountain	> 3000

(Source: Van Zuidam, 1985)

For medium relief morphology unit, it displays the properties of topographic relief from moderate to high and topographic texture from moderate to rough and slope slightly sloping to moderately steep. The top of the hill which situated at the south-west part (240 m) and the ridges of the hill along the north-west part (220 m) exhibit the characteristics of hilly morphology. It is mainly composed of igneous rock such as granite. For the south-east part of the study area, it is classified as the low hill landform as it at the elevation of 100 to 200 meters and is dominated by metasedimentary rock such as slate.

Figure 4.3: Hill morphology at the study area.

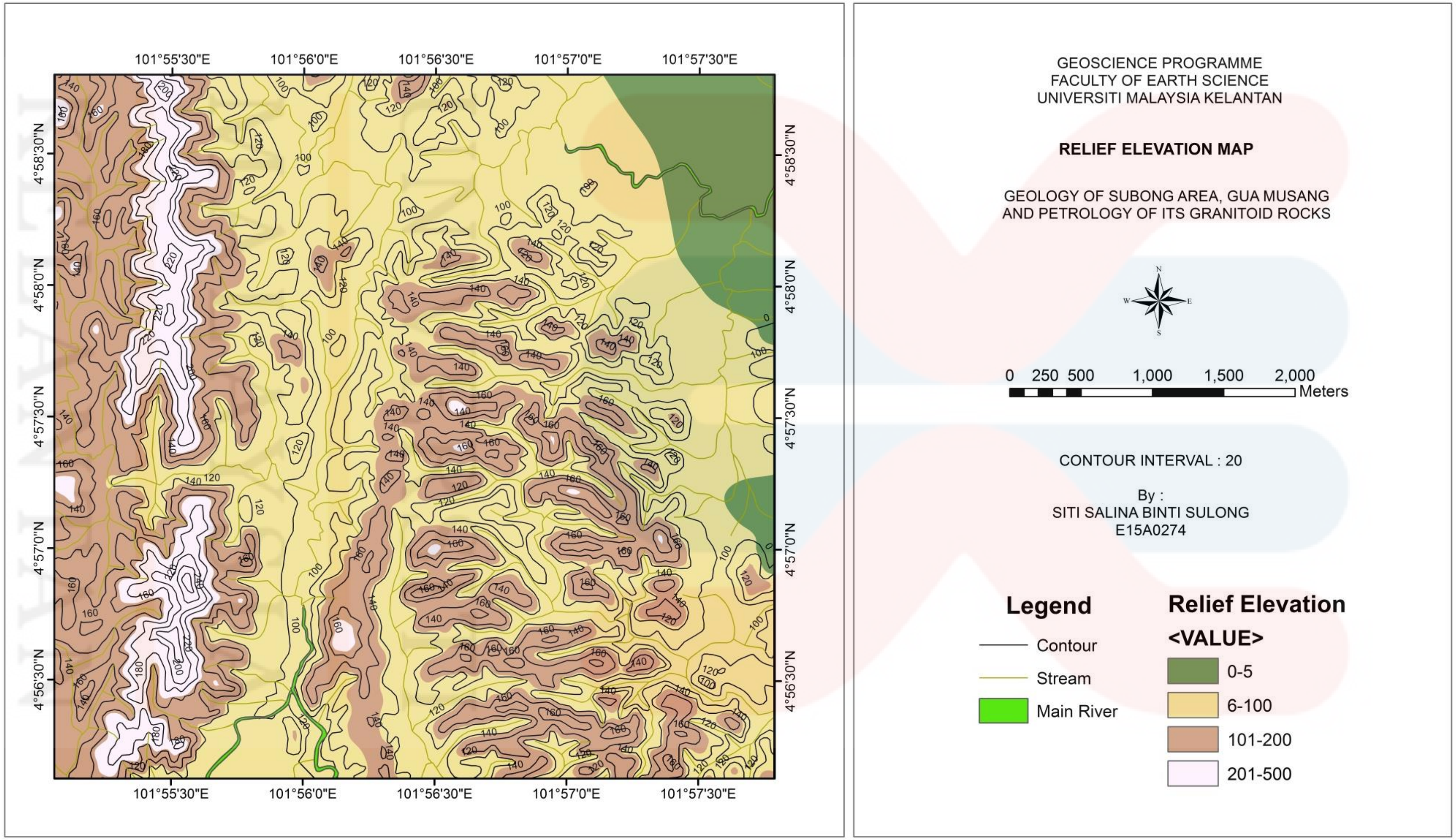

Figure 4.4: Relief Elevation Map

On the north-eastern part of the study area, it is classified as low relief morphology unit or low-lying plain landform as it displays the properties of low topographic relief and smooth topographic texture. The area is at the elevation from 5 to 100 meters from sea level. It is composed of sedimentary rocks such as limestone. Most of the residential areas are concentrated along the roads for easier connection.

4.2.2 Weathering

The occurrences of weathering can be observed in the study area. Figure 4.5 shows the exposed outcrop that has been undergoing a weathering process. As a result, the sample obtained at the outcrop is not fresh and some of the outcrops have been changed into soil and sediments. This is also was related to the tropical climate in Malaysia which hot and humid throughout the years.

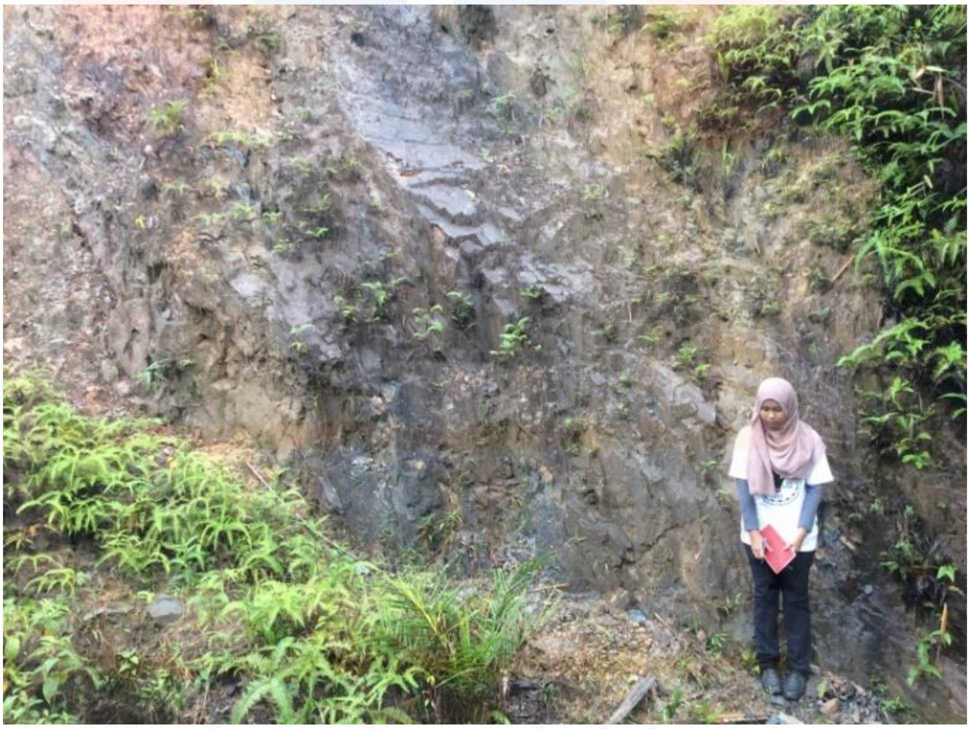

Figure 4.5: Physical weathering at the study area.

Besides that, chemical weathering can be identified in the study area. Figure 4.6 shows the formation of holes on the surface of the limestone rock at Gua Subong. This indicates the transportation of dissolved material which leaves a void on the rock surface due to the dissolution processes. The formation of holes and pits also occurred due to the water dropped from the ceiling of cave which composed of acidic solutions.

Figure 4.6: Dissolution on limestone at Gua Subong

4.2.3 Drainage pattern

In geomorphology, drainage systems or river systems are the pattern developed by the streams, lakes and rivers in the particular drainage basin where water discharge naturally to developed a pattern and a certain alley on the surface. According to Thornbury (1969), the rivers form networks that may be described by several geometrical and topological properties. The development of river flow patterns in the study area is controlled by few factors such as slope, structural control, and geomorphology of a basin river flow patterns, vegetation and climatic conditions.

Based on field observation, there were two types of drainage pattern of Subong area which are dendritic and trellis drainage patterns. The flow pattern of dendritic occupies about 60% of the study area that extends relative from the north to the west. It displays a structure like branching pattern of tree roots where most contributing streams are jointed together into the branches of the main river. Dendritic drainage formed "V" shaped valley, and the rock type of the surrounding rocks are generally igneous rock that are non-porous, impervious and highly resistance to the erosional processes.

Next, the trellis drainage patterns can be observed at the east and occupies about 40% of the study area. A trellis drainage pattern occurs when subparallel stream erode a valley along the strike of less resistant formation. It develops in folded topography and indicates parallel valleys of weak rock between ridges of resistant rock. The rock types of the surrounding area are metasediments and sedimentary rock such as slate, shale and limestone.

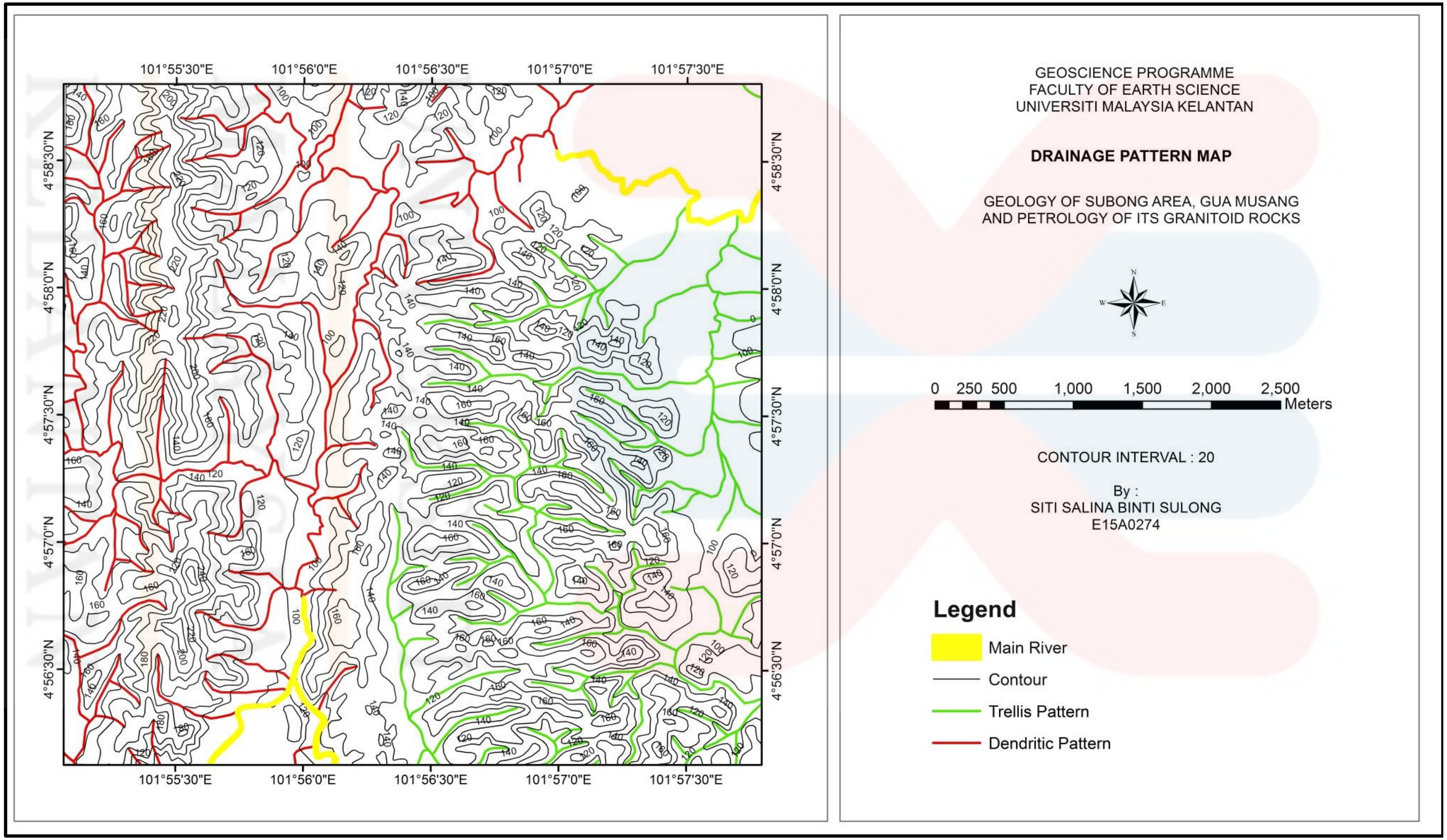

Figure 4.7: The drainage pattern in the study area.

4.3 Lithostratigraphy

The study area is mainly composed of igneous, sedimentary and metasedimentary rock. Lithologically, the study area is classified into four main lithologic units; the slate, limestone, granite and alluvium units. The units are determined based on their dominant distributions lithology. All the details of each unit are all recorded in the geological map.

4.3.1 Stratigraphic position

Generally, lithology of the study area consisted of four main lithologic units which are slate, limestone, granite and alluvium units. The stratigraphic is based on lithostratigraphic units and is presented sequentially from the oldest to the youngest. The stratigraphic column is presented in Figure 4.8 showing the relationship between the units in the study area. The slate unit was classified as the oldest units, and is located in the eastern part of the study area. The second oldest rock unit is the limestone unit that located at the north-east of the study area. Next, the granite unit is classified as the third oldest rock that situated at the western part in the study area. The alluvium unit is the youngest with the period Quaternary.

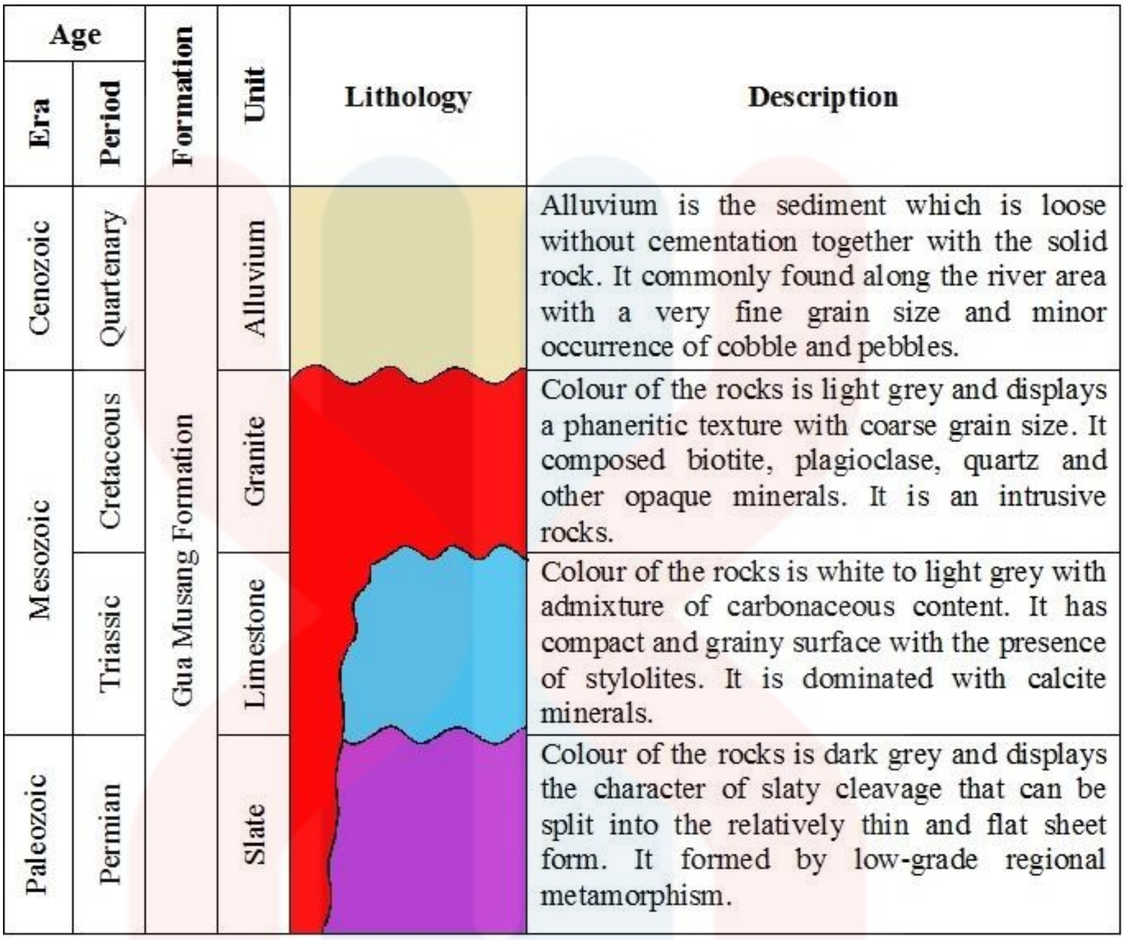

Figure 4.8: Stratigraphic column of study area.

4.3.2 Unit explanation

In describing the lithologic units, it is important to know the sequence of the lithology rock unit starting from the oldest rock unit to the youngest lithologic rock unit, together with the horizontal distribution and vertical distribution. It is also explained in terms of the distribution of each lithology, dimensions of the rock units and relationship between the units. Petrographic analysis of each lithologic unit is important in identifying the minerals and its compositions. Figure 4.9 shows the distribution of the lithology unit in the study area.

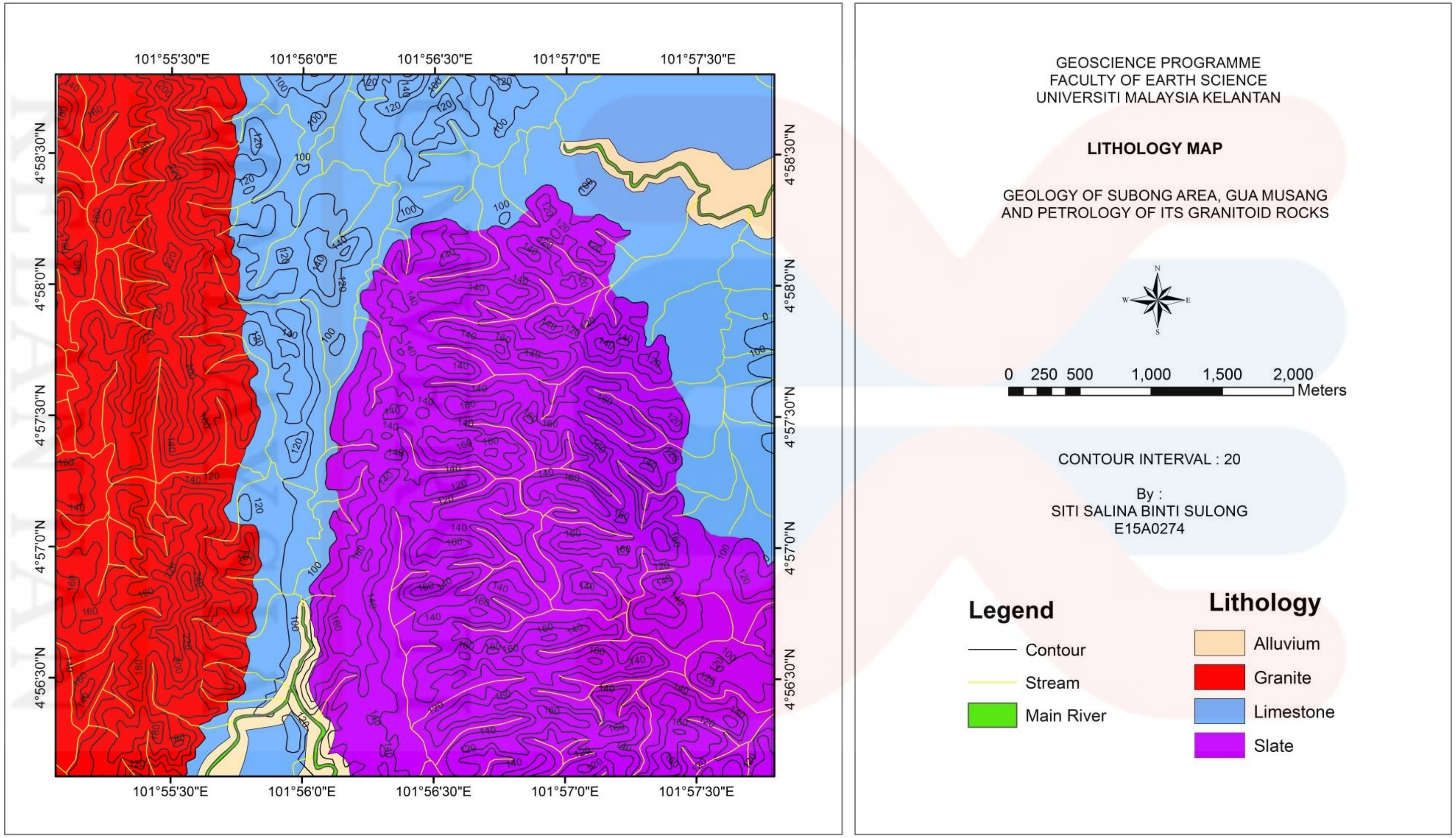

Figure 4.9: Lithology Map of the study area.

4.3.2.1 Slate Unit

The slate unit was the oldest unit and widely distributed at the eastern part of study area. According to Kamal Roslan, Nelisa Ameera and Che Aziz (2016), the slate unit which identified under metasediment lithology (argillaceous facies) along with shale, slate, phyllite and siltstone is identified under Permian age. Slate is a fine-grained, foliated metamorphic rock that formed by the alteration of shale and mudstone by low-grade regional metamorphism. It is dark grey in colour and displays the character of slaty cleavage that can be split into the relatively thin and flat sheets form. Slate is categorized as a product of low grade metamorphism as it formed under low temperature and low pressure.

The formation of slate is influenced by the regional metamorphism in the area that consists of shale, mudstone, or volcanic rock that rich in silica that can act as protolith rock. In the study area, it is identified that the protolith of the slate came from the shale based on the mineral compositions in slate which are almost the same with shale. With the conditions of low pressure and temperature with time, the shale is eventually undergoes metamorphism processes to form slate. Figure 4.10 shows the slate outcrop that was found along the Jalan Jelawang- Gua Musang.

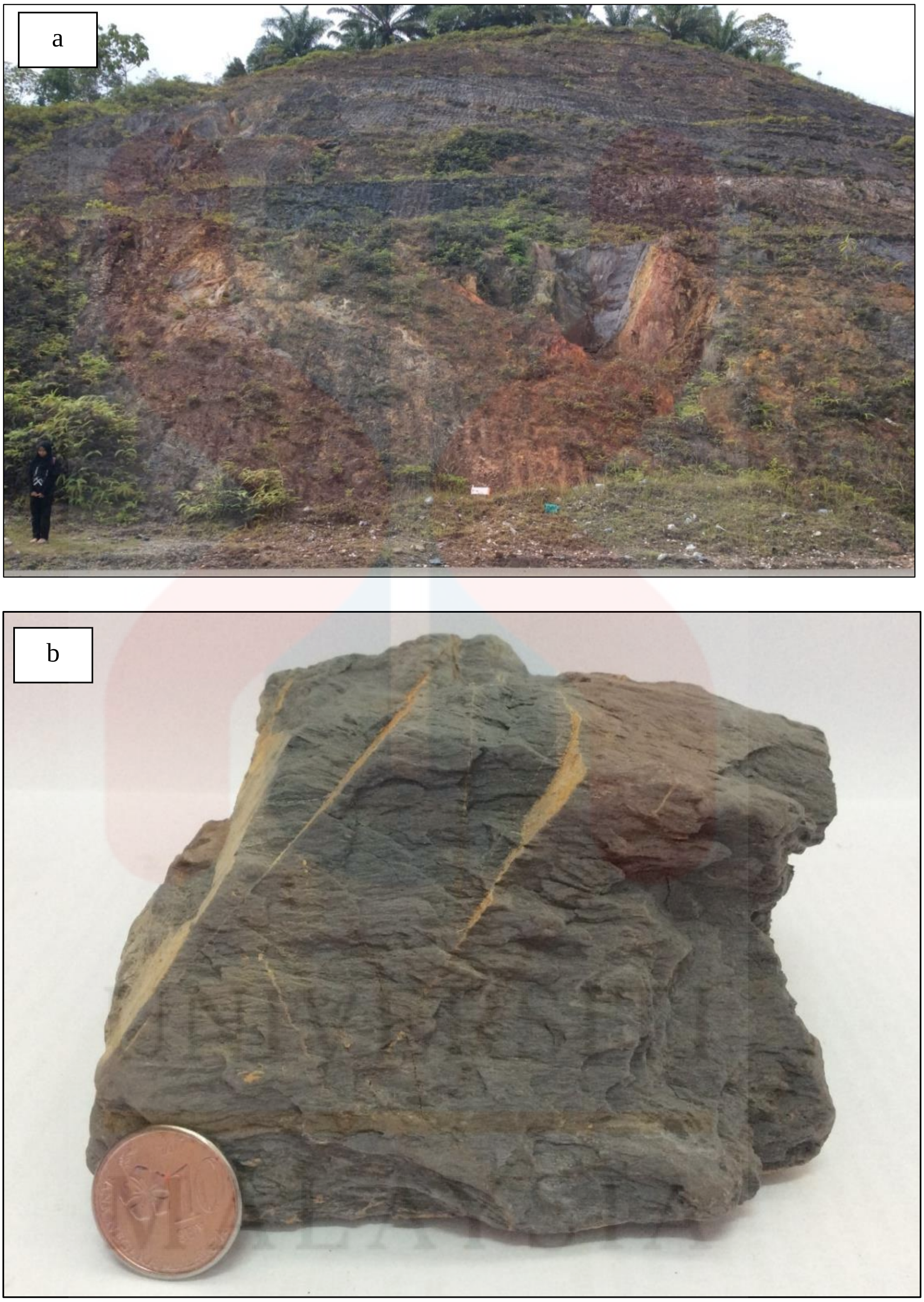

Figure 4.10: (a) The field observation of slate outcrop along Jalan Jelawang- Gua Musang. (b) The hand specimen of the slate.

Under the microscope observation of Figure 4.11, the plain polarized light (PPL) shows whitish brown colour, while cross polarize light (XPL) shows dark greyish colour. It is in fine grain size and displayed the hypocrystalline characteristics. Under XPL, the foliation can be observed based on crystal orientation which indicates that the rock is undergoes low grade metamorphism processes. It is quite difficult to identify its mineral composition due to the effect of weathering processes. The thin section also displays a low relief characteristic with a no significant crystal structure.

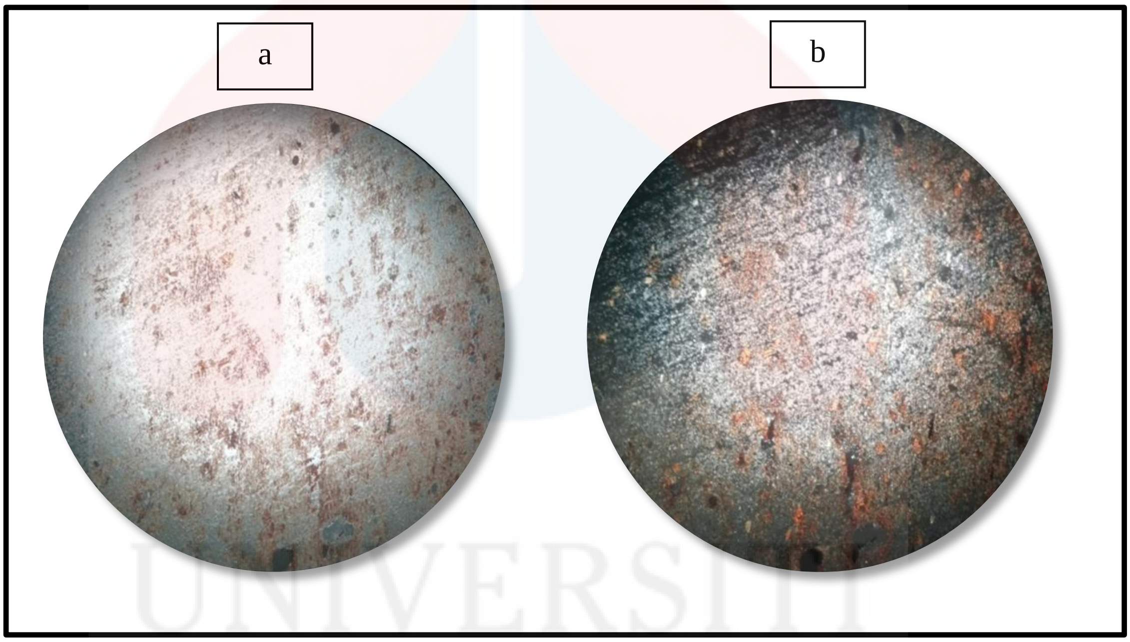

Figure 4.11: Thin section of slate under plain polarize light (PPL) on the (a) and cross polarize light (XPL) on the (b). Both of thin section is under 4x10 magnification.

4.3.2.2 Limestone Unit

The limestone unit is widely distributed at the north-east of the study area. According to Kamal Roslan, Nelisa Ameera and Che Aziz (2016), it is stated that the limestone unit was aged Late Triassic.

Limestone is a sedimentary rock that builds up mostly by calcite minerals. The limestone found in Figure 4.12 is classified as a carbonaceous limestone. It shows light grey in colour from admixture with carbonaceous content without any trace of fossil appearances. It has a compact and grainy surface which can be observed on Figure 4.13.

Figure 4.12: The limestone outcrop

Figure 4.13: Hand specimen of limestone

In terms of mineral compositions, limestone is dominated with calcite mineral. Calcite minerals can be identified as it displays colourless in colour under both microscope. Figure 4.14 shows the limestone under PPL and XPL.

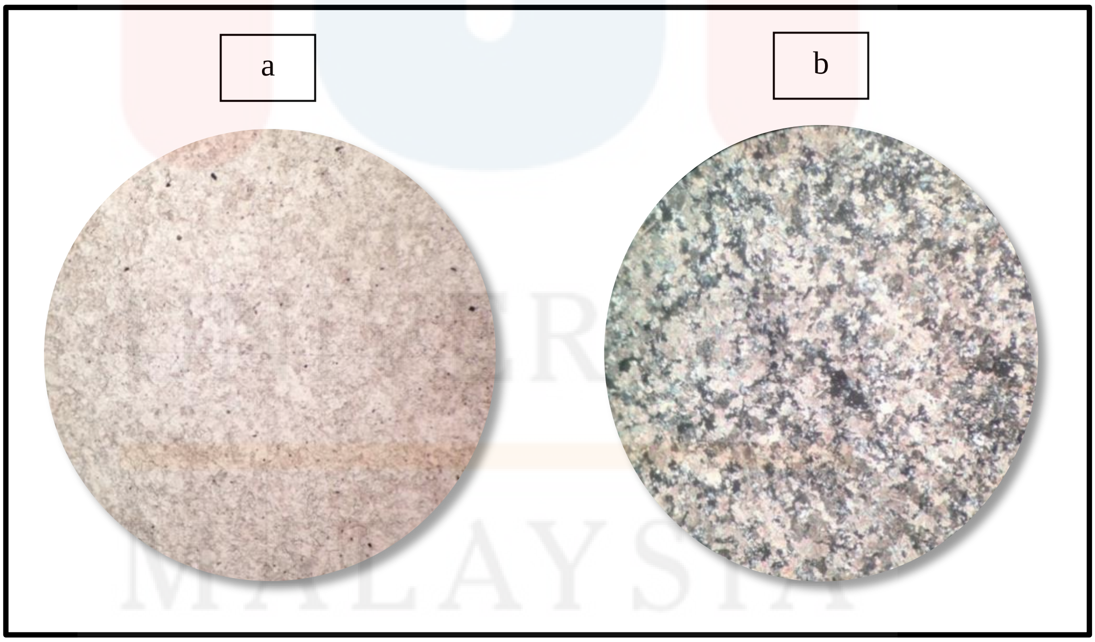

Figure 4.14: Thin section of limestone under plain polarize light (PPL) on the and cross polarize light (XPL) on the (b). Both of thin section is under 4x10 magnification.

There is a presence of secondary sedimentary structure known as stylolites on the surface of the outcrop as shown in Figure 4.15. It displays the undulated surface resulting from localized stress-driven dissolution of some minerals of the rock and commonly occurred in carbonates rock (Rolland, 2012). This structure formed due to pressure dissolution that occurred due to overburden pressure. The veins were filled with insoluble residues such as clay particles, oxides and organic matters during the progressing overburden pressure. According to Norman (2015), decreasing of the porosity, permeability and reduction of bed thickness of the host limestone is viewed as the effect of stylolitization.

Figure 4.15: The presence of stylolites on the surface of limestone outcrop.

4.3.2.3 Granite Unit

This unit is widely distributed at the west of the study area. Granite is the igneous rock that comes from volcanoes activity which is the plutonic type and is classified as the intrusive rock as it formed from the slow crystallization of magma beneath the earth interior. The granite form in this study area is believed as the intrusion and it is belong under Cretaceous age. Figure 4.16 shows the river where the granite is distributed along it and the hand specimen of the granite.

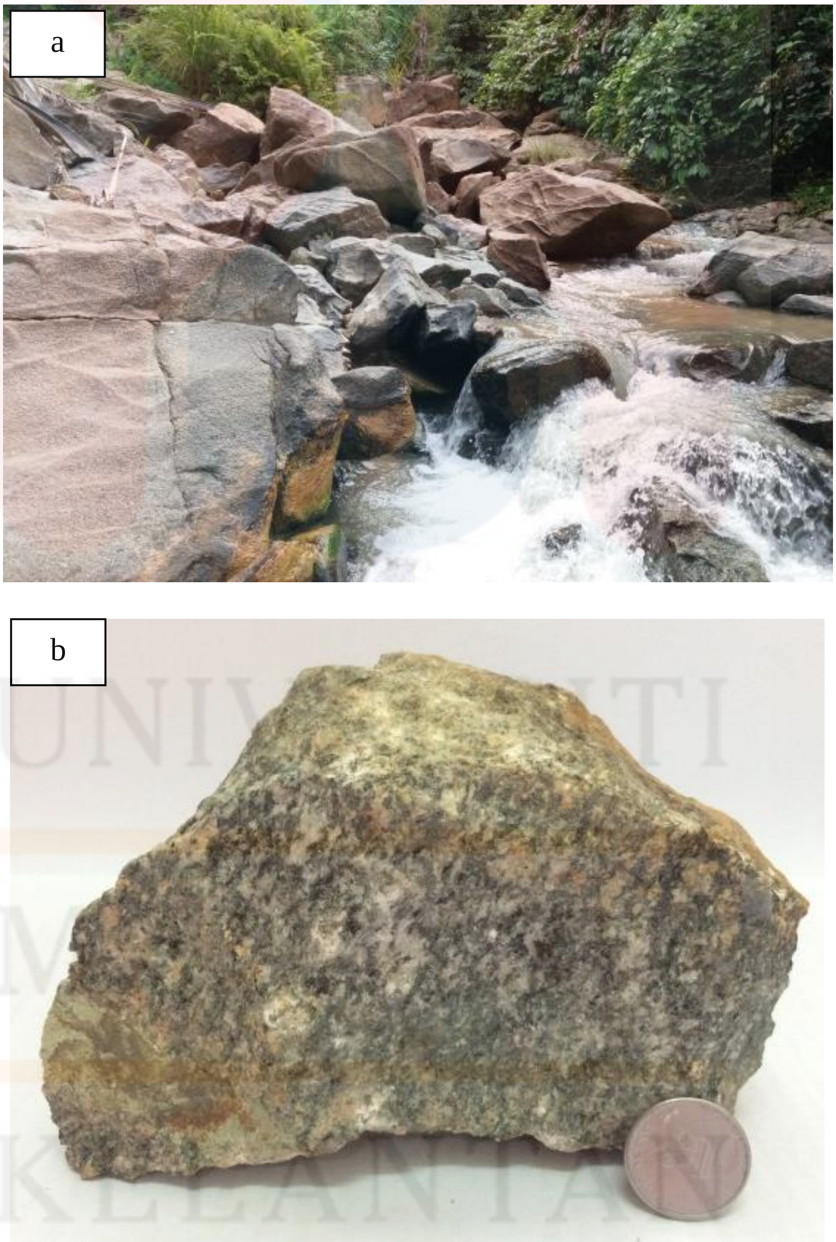

Figure 4.16: (a) The field observation of granite outcrop along river. (b) The hand specimen of the granite.

Under the microscope, it shows that most of the grains are bounded by only a few well-formed crystal faces or known as hypidiomorphic. It is also shows the inequigranular texture as the crystal sizes is in different sizes. Mineral composition composed of biotite (40%), plagioclase (30%), quartz (20%) and opaque mineral (10%).

For the biotite (biot) mineral, it shows light brown colour under PPL with low relief, and light green and light red under XPL with high relief. Biotite shows no twinning under XPL. It is in the subhedral crystal shape with extinction of 40°. It is also has a low birefringence under XPL. For plagioclase (Pl) mineral, it is colourless and low relief under PPL and low birefringence under XPL. It is has subhedral crystal shape and albite twinning with extinction of 47°. For quartz (Qtz), it is colourless and low relief under PPL and low birefringence in XPL. It has subhedral shapes and extinction angle of 22°.

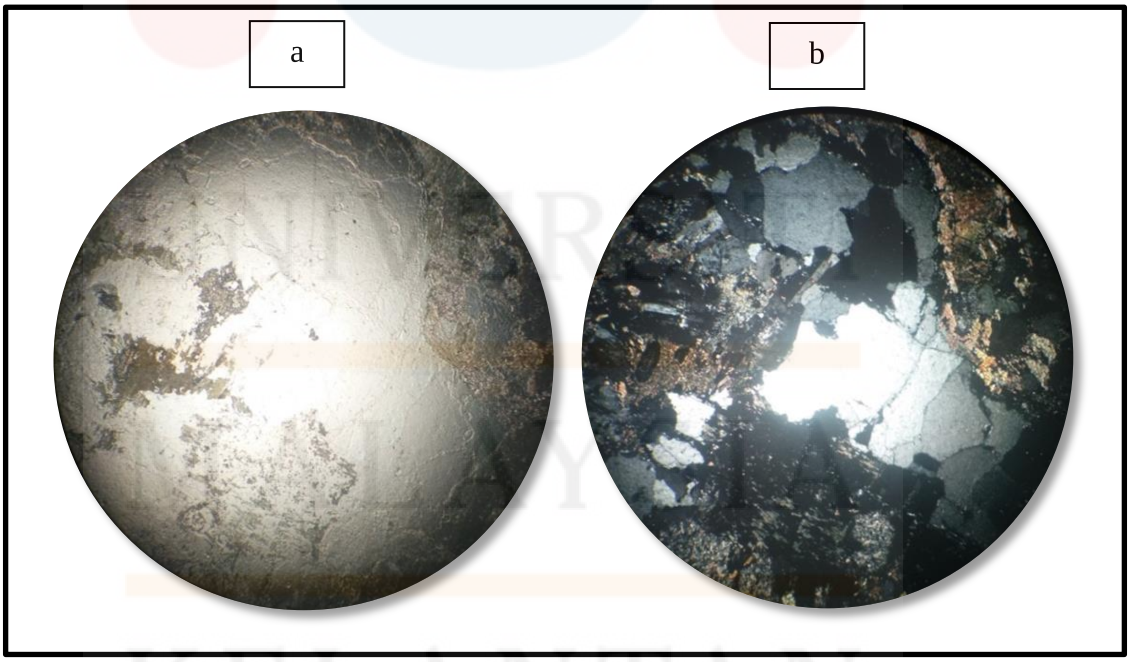

Figure 4.17: Thin section of granite under plain polarize light (PPL) on the (a) and cross polarize light (XPL) on the (b). Both of thin section is under 4x10 magnification.

The sample has been classified using QAPF diagram and their modal composition indicated that of both of the sample are classified as granodiorite. Granodiorite is a phaneritic-textured intrusive igneous rock which composed of more plagioclase feldspar than orthoclase feldspar.

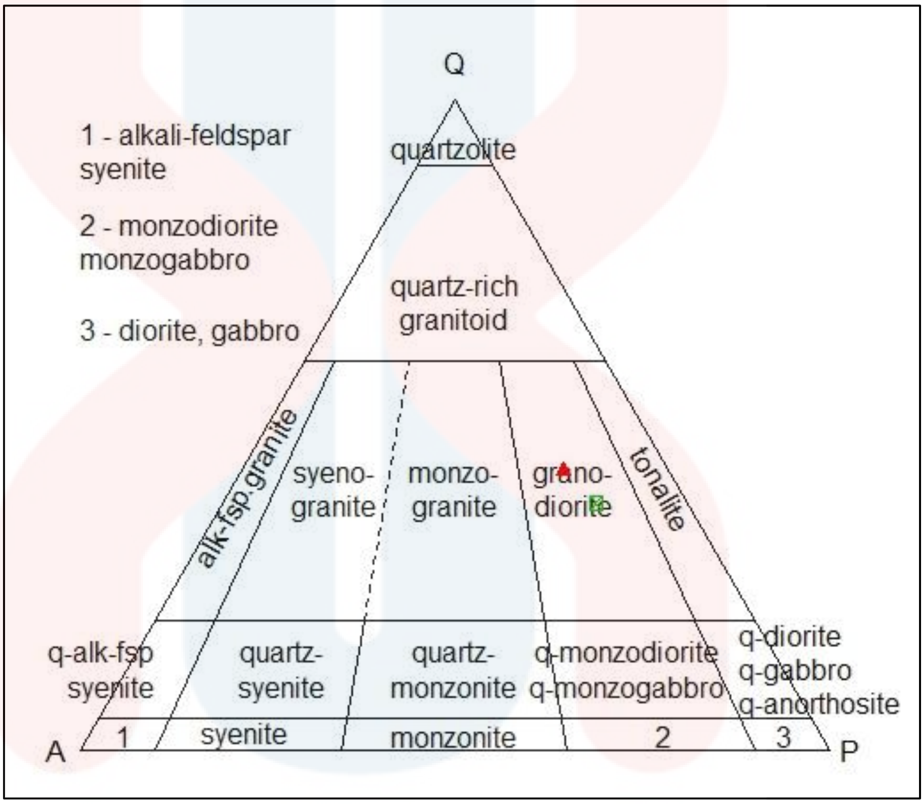

Figure 4.18: QAPF diagram used for granite classification

4.3.2.4 Alluvium Unit

Alluvium is the sediment that commonly distributed in the river area. It is identified in along of Subong area with a very fine grain size with the minor occurrence of cobble and pebbles. Alluvial is the sediment which is loose without cementation together with the solid rock. It is resulted from the weathered rock that has been eroded and transported which known as alluvial sediment.

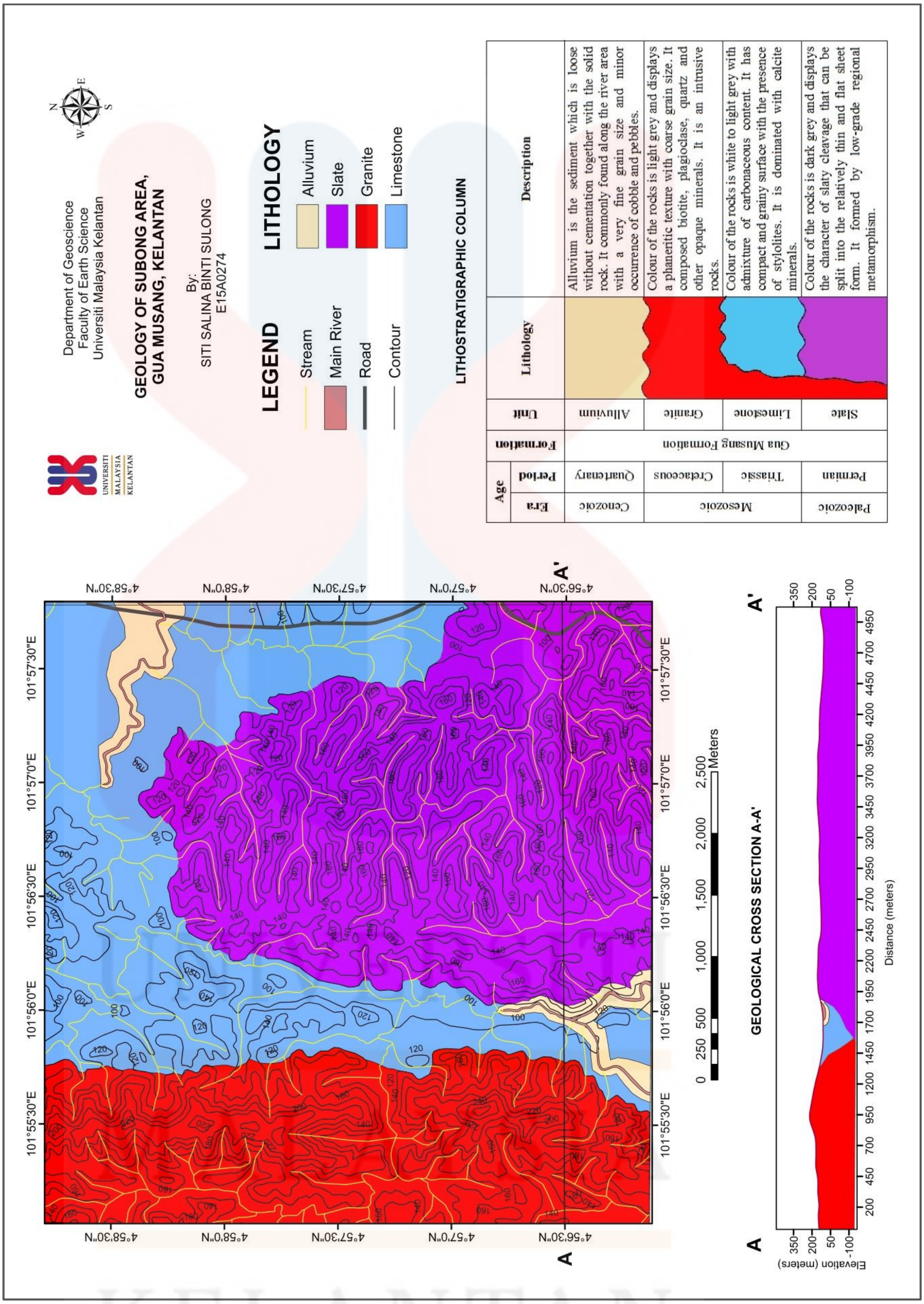

Figure 4.19: Geological Map of study area

4.4 Structural Geology

Structural geology is a scientific discipline that is explained about processes and the outcome of rock deformational with respect of the distribution of rock units. It is also the processes that results in the formation of geologic structures and how these structures can affect the rocks. The regional structure normally associated with the local structures, thus it is important to map out the local structure during the fieldwork.

The local structures are also related with the lineament which has been mapped during the preliminary studies stage. The discussion of the geological structure of the study area included geological structure patterns that were found in the field such as identifying the type of structure, regional stratigraphic studies and interpretation formation mechanism of geological structure. The geological structures that can be observed in the study area consisted of:

4.4.1 Lineament Analysis

4.4.2 Joint Structure

4.4.3 Fold Structure

4.4.1 Lineament Analysis

A lineament is described as the linear earth surface reflection of tectonic faults and fractures in the bedrock that emphasized on the earth surface by drainage, topography, and vegetation, which can be identified by photointerpretation method. Photointerpretation method that was applied is by using Terrain Google Maps, topography map and remotely sensed data. Lineament analysis is one of the methods of identifying the deformation zones in the bedrock and indicator of geological structures including faults, folds, and other deformation.

It is important to conduct lineament identification during preliminary stage. The lineaments segments that trace out from the satellite imageries are roughly 500 m to 5 km long and mostly found at the valleys, ridges, and rivers according to the topography of the study area as shown in the Figure 4.20. In the study area, the lineaments can be classified as the fault-correlated lineaments and rivers and valleys lineaments. The fault-correlated lineaments which represent by the yellow lines extended over greater geographical distances and represent complex regional structural patterns. It is believed that there is an occurrence of strike slip fault along the lines due map observation of the offset of the river patterns. The black lines are representing the rivers and valleys lineaments.

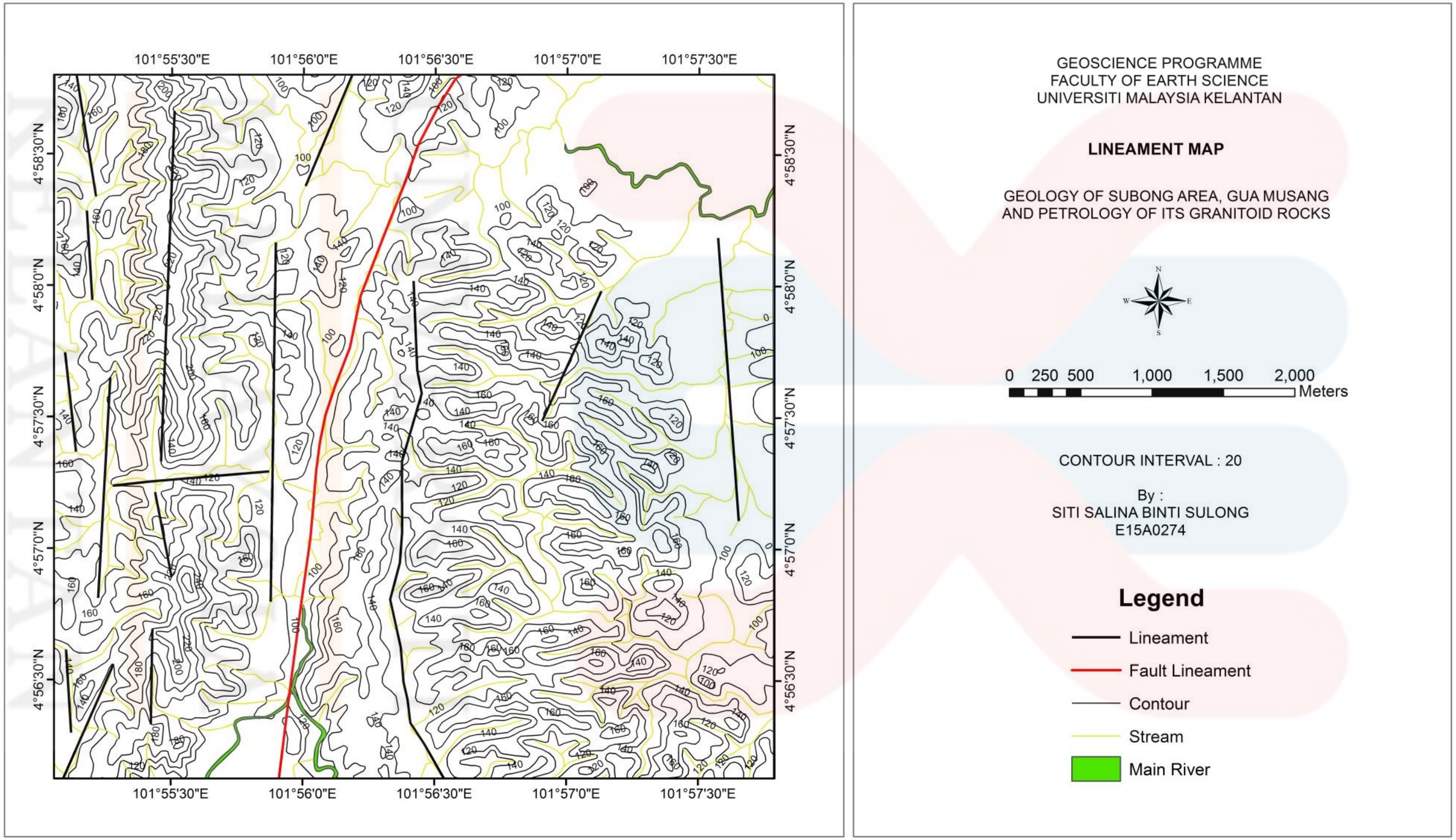

Figure 4.20: Lineament map of study area

4.4.2 Joint Structure

Joint is a planar discontinuity that involves no displacement of adjacent blocks. It is formed during the exposure of rocks due to erosion of overburden and the effects of contraction and expansion due to cooling and decompression respectively. Joint analysis was conducted at the river where the granite outcrop is distributed along the river as shown in Figure 4.21. It is located at coordinate of 04° 57’ 13.3” N and 101° 55’ 20.49” E. The result of measurement was interpreted by using the method Georose Diagram (Figure 4.22) to determine the direction of the general force direction and magnitude of the main force direction. The major direction of force, σ^1 is dominated at the 60°-70° North.

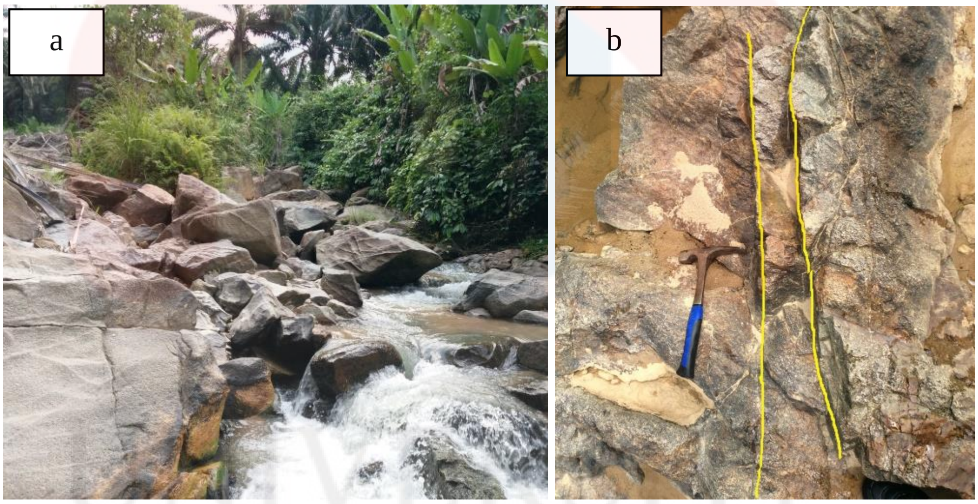

Figure 4.21: (a) The location of joint analysis and (b) Joint in granite outcrop.

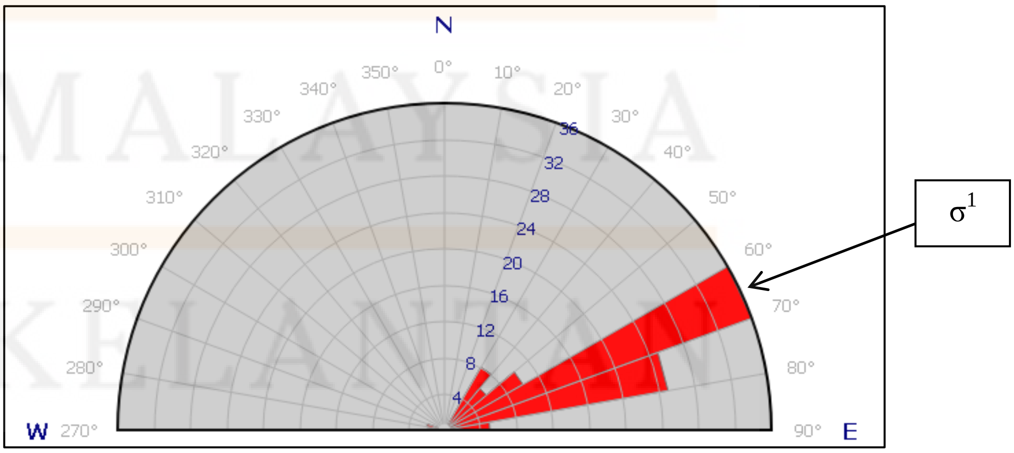

Figure 4.22: Joint analysis on granite by using GeoRose Diagram

4.4.3 Fold Structure

Folding is a formation of bending and curving of originally flat or planar surfaces due to shortening that altered the competent and less competent layer of rocks. The formation of fold indicating that various condition of stress, pressure and temperature that body of rock encounters.

The mechanisms that involve in fold formation are buckling and bending. Buckling is fold due to the pressure is parallel to the surface meanwhile bending is a fold that the direction of pressure is vertical to the surface. The minor fold that is observed is shown in Figure 4.23. It is occurred on the mica schist outcrop which embedded on the ground.

Figure 4.23: Minor fold occurred at mica schist outcrop.

4.5 Historical Geology

The study area was divided into four different lithological units which started from the Pre-Mesozoic to Quartenary. This study area is categorized under Gua Musang Formation with the depositional setting of shallow marine shelf deposit with an active volcanic activity. The depositional environment of the metasediment unit was believed deposited at warm, quiet and shallow marine region during the Pre-Mesozoic period. The metasediment unit is formed which consist of argillaceous facies made up of shale, siltstone, phyllite and sandstone. The main lithology found in this unit is slate.

Besides that, in the Early Triassic, it is believed that this area has been experienced volcanic activity. In this period, the carbonate is unable to be deposited because of the murky water condition caused by the volcanic eruption that disturbs its depositional activity. The volcanic eruption has resulted the release of volcanic debris that fallout evenly that prevent the deposition of carbonate rock. After the volcanic debris fully deposited, the water turns to be calm and clear again that allowed the deposition of carbonate. The major distributed carbonate at Gua Musang shows that this area was exposed to the depositional environment which near to a volcanic source within volcanic arc setting. During the Cretaceous period, there is an occurrence of volcanic activity which leads to the creation of high marine topography from the limestone deposited in the environment of shallow marine.

CHAPTER 5

PETROLOGY OF ITS GRANITOID ROCK

5.1 Introduction

This chapter is focusing on petrology and geochemical studies in determining any possible differences in the distribution of major, trace and rare earth elements along with the study of chemical variations in order to achieve a better understanding of their texture, petrogenesis and evolution. A total of 4 samples of granite at Gua Musang were analyzed for major, trace and REE elements by using X-Ray Fluorescene (XRF) and Inductively Coupled Mass Spectrometry (ICP-MS).

Geochemistry analysis of the granitoid rocks were carried out by analysing five samples from Gua Musang, Kelantan. Three samples, labelled NSS 001 and NSS 002 is collected from Panggung Lalat, Gua Musang, meanwhile NSS 003 and NSS 004 is collected from Subong, Gua Musang. The data are compared and relate to each other as it is believed are from the same source and origin.

Geochemistry makes use of major element data in three principle ways which are in rock classification, in the construction of variation diagrams and as means of comparison with experimentally determined rock compositions, whose conditions of formation are known. In addition, major elements are used together with trace element, in the identification of the tectonic setting of igneous and sedimentary rocks.

5.2 Major Element Chemistry

The selected analyses of the samples are listed in Table 5.1. All major elements are being normalized 100% to reduce the loss or error of weight elements. Generally, the plutonic rocks marked the contact abundance major elements which are ranges from SiO_2, Al_2O_3, MgO, FeO, CaO, K_2O, Na_2O, P_2O_5, TiO_2, MnO.

Table 5.1 Major element oxide (wt %) from the samples collected

	Panggung Lalat		Subong	
	NSS 001	NSS 002	NSS 003	NSS 004
SiO_2	59.6131	47.3843	59.5180	64.1025
TiO_2	0.4961	0.5750	0.6473	0.2573
Al_2O_3	17.1959	16.0202	13.9866	17.3558
FeO*	6.6758	9.5762	8.0871	3.6811
MnO	0.1516	0.2890	0.1358	0.0653
MgO	3.5072	10.4034	5.5782	1.3327
CaO	7.0454	13.5705	8.0688	6.9280
Na_2O	2.8161	1.1377	2.2436	3.2147
K_2O	2.2797	0.8179	1.4305	2.7875
P_2O_2	0.2186	0.2254	0.3036	0.2746

The range of SiO_2 of Panggung Lalat is lower (47.38 – 59.61 wt %) compared to Subong granite (59.51 – 64.10 wt %). This shows that the Subong granites are more siliceous. Contents of other elements for Subong granite are typically 0.25 – 0.64% TiO_2, 13-98 – 17.35% Al_2O_3, 3.68 – 8.08% FeO, 0.06 – 0.13% MnO, 1.33 - 5.57% MgO, 6.92 – 8.06% CaO, 2.24 – 3.21% Na_2O, 1.43 – 2.78% K_2O and 0.27 – 0.3% P_2O_5.

Selected major elements using Harker variation diagrams for the Panggung Lalat and Subong granite are shown in Figure 5.1. The linear correlations of some of the major elements indicate that these characteristics are related to their source and thus can be incorporated while discussing their petrogenetic history. In general, the plots shows clear trend of decreasing TiO_2, Al_2O_3, MgO, CaO, and FeOt with increasing SiO_2 content. These trends demonstrate that fractional crsytallization may have been an important process in the evolution of this granite suite. The Subong granite have a higher content of major elements compared to the Panggung Lalat granite.

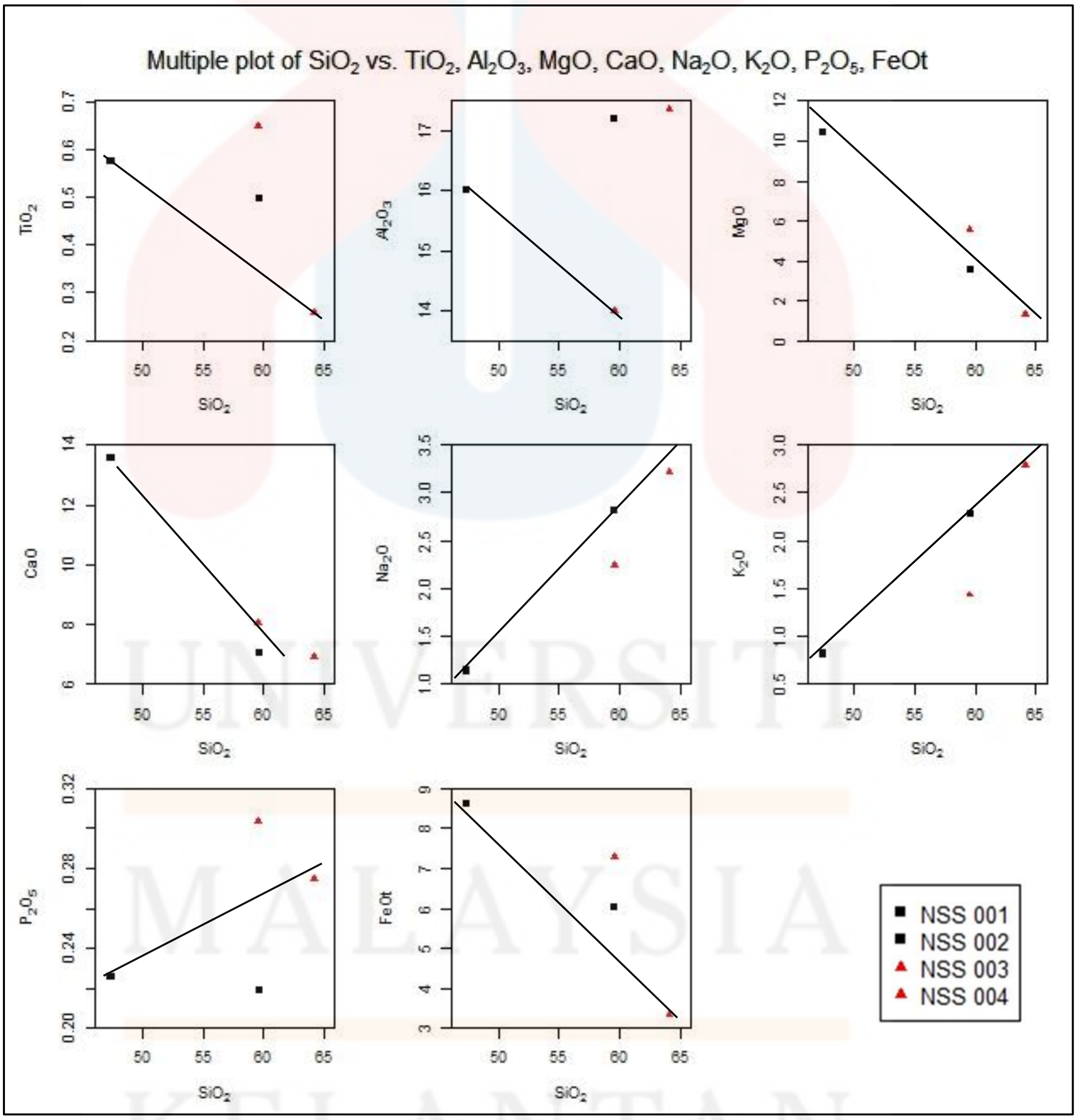

Figure 5.1: Major element Harker diagram of the Subong and Panggung Lalat granite.

Two trends stand out in this diagram and the Subong samples are separated to those of the Panggung Lalat granite. These results show a higher P_2O_5 content of the Subong granite compare to the Panggung Lalat granite at a given SiO_2 concentration. The sample with 59% SiO_2 from Subong has 0.3% P_2O_5 compared to the Panggung Lalat granite which only has 0.218% P_2O_5 with the same SiO_2 content. On the other hand, the Subong granite have a high CaO with the same SiO_2 content compared to the Panggung Lalat granite.

Based on the Figure 5.2 of the FeOt/MgO versus SiO_2 (Miyashiro, 1974), three of the samples are plotted in the calc-alkaline field. This interpretation is also corroborated by K_2O versus SiO_2 classification diagram in Figure 5.3 where all of the samples are plotted between the field of calc-alkaline series and high-K calc-alkaline series. To further support the result, when plotted on an AFM diagram (Figure 5.4), reveal calc-alkaline nature. From these interpretations, it can be concluded that the granite samples are mainly calc-alkaline affinity.

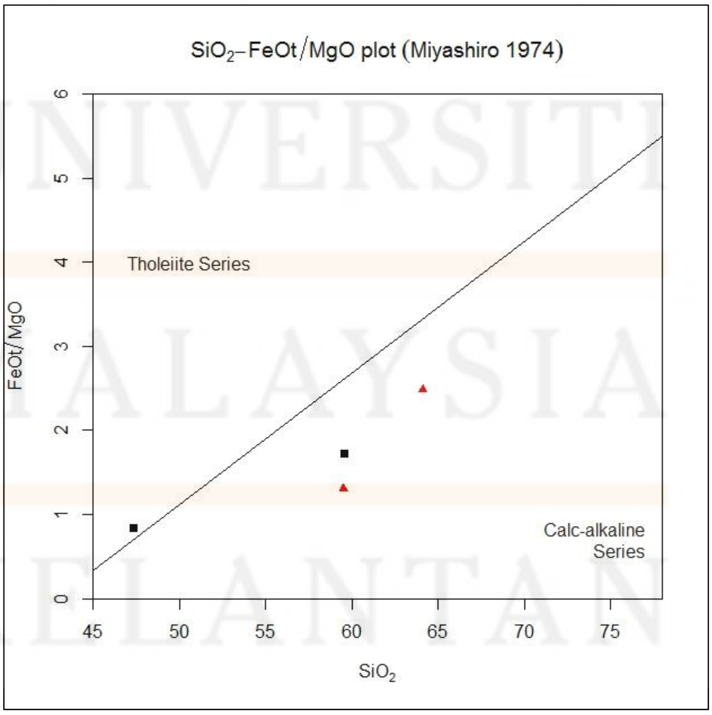

Figure 5.2: FeOt/MgO versus SiO_2 (Miyashiro 1974)

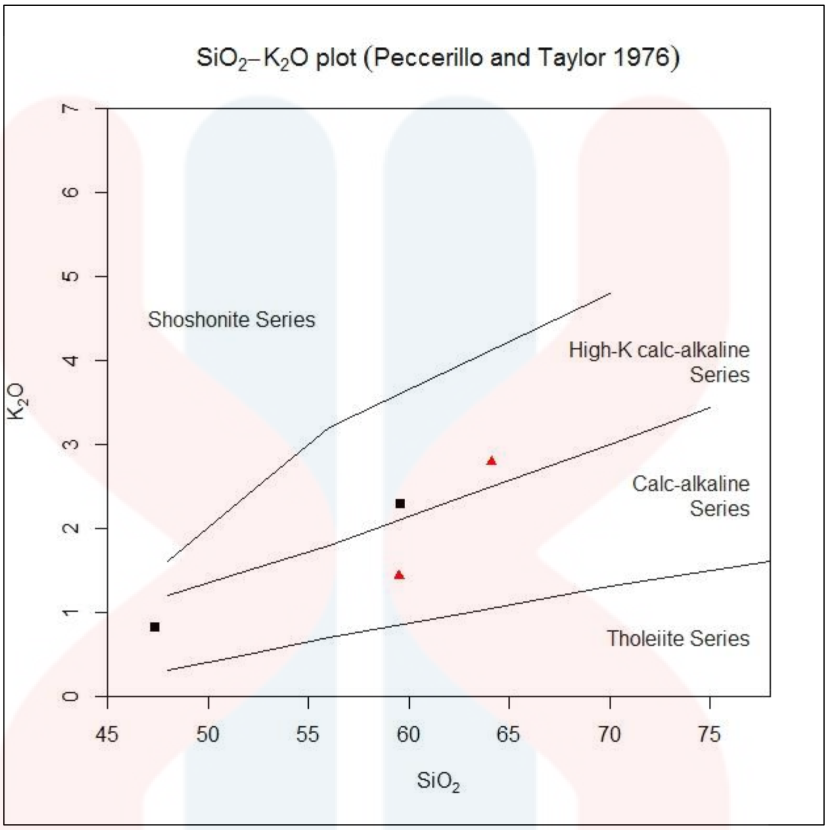

Figure 5.3: K_2O versus SiO_2 diagram (Peccerillo and Taylor 1976)

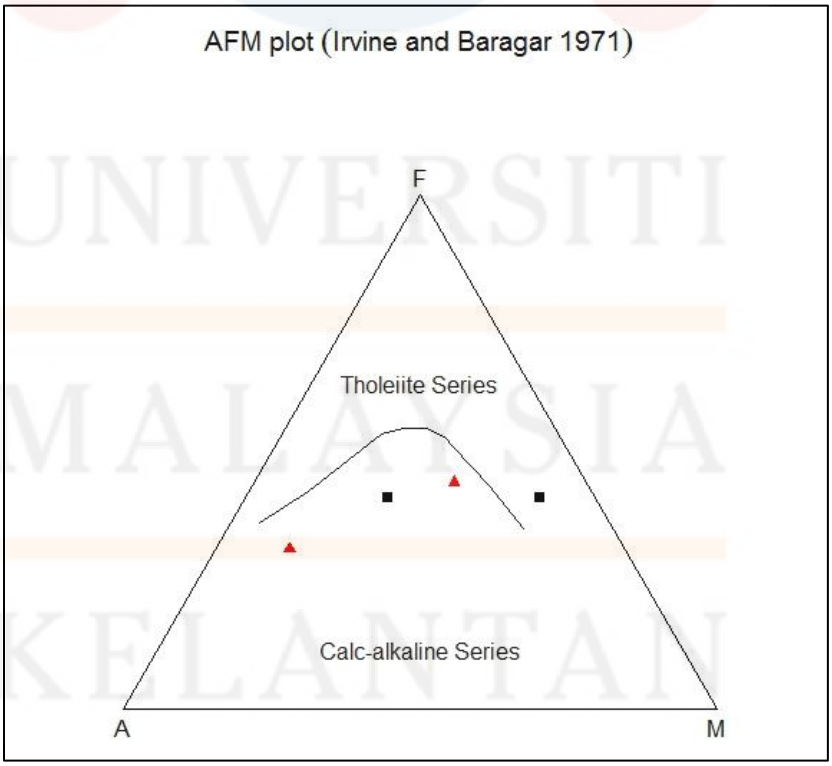

Figure 5.4: AFM plot

Most extensively used parameter to denote the nature of granitic magma has been molecular proportions of the ratio $Al_2O_3/(CaO+Na_2O+K_2O)$, abbreviated as A/CNK which divided the granitoid rocks into peraluminous when A/CNK>1.0 and metaluminous when A/CNK<1.0 depending upon the alumina saturation. Having A/CNK values less than 1 (Figure 5.5), the granites are classified as metaluminous in nature.

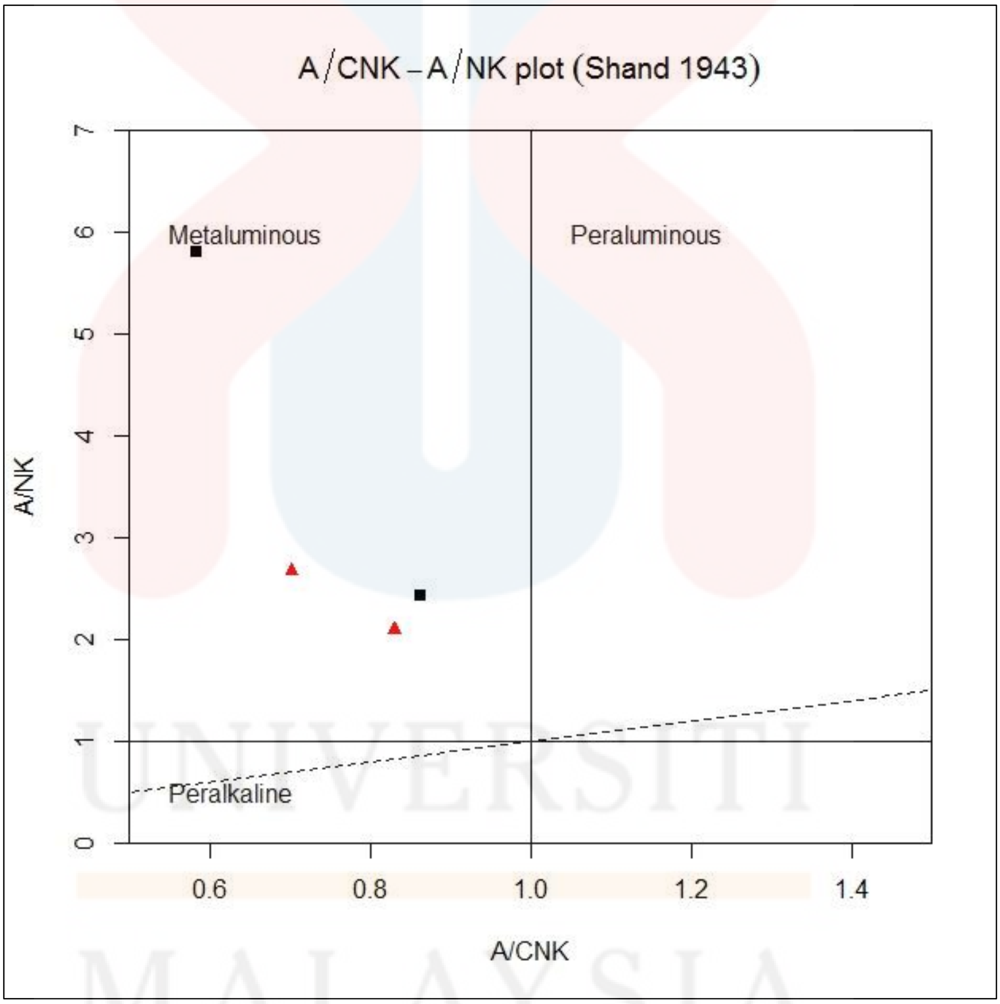

Figure 5.5: A/CNK vs A/NK plot of granites.

On Na_2O vs K_2O plot (Figure 5.6), Subong granites are plotted in the I-type field of Chappell and White (1984). I-type granitoid derived due to partial melting of igneous protolith. Deep seated igneous or metaigneous rock of lower continental crust subjected to partial melting due to upwelling of mantle material to higher levels. Generally metaluminous granite, expressed mineralogically by absence of peraluminous minerals like muscovite and are characterised by presence of hornblende/ alkali amphibole and biotite

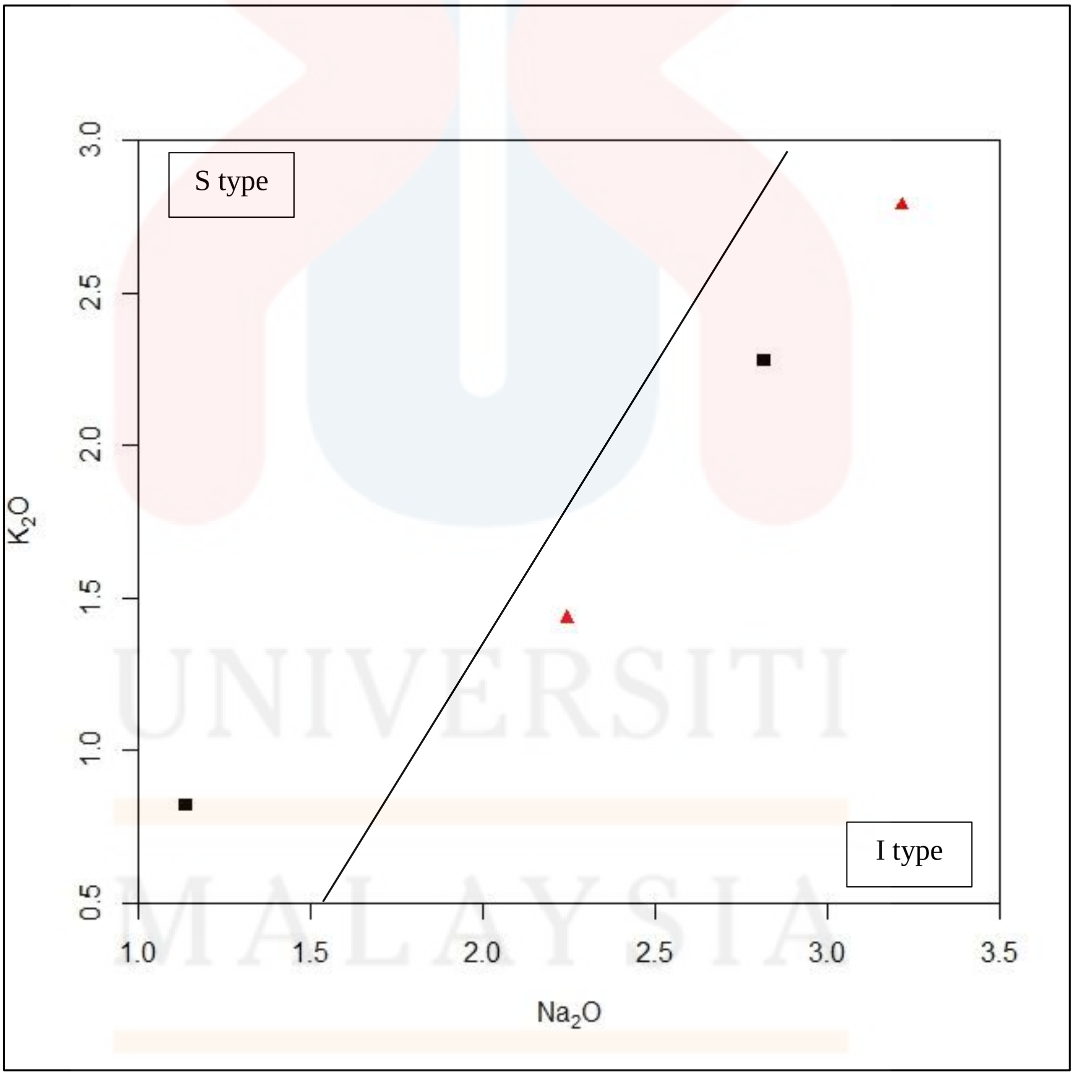

Figure 5.6: Na_2O vs K_2O for classification of granitoids.

5. 4 Rare Earth Elements

Two granite samples were collected for rare earth elements detection by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) methods. Content of REE in the samples is shown in Table 5.2 in unit ppm.

Table 5.2 REE element in sample NSS 003 and NSS 004

Samples	NSS 003	NNS 004
LREE		
Lanthanium (La)	2.0000	28.7000
Cerium (Ce)	44.9000	59.5000
Praseodyium (Pr)	0.5832	0.6973
Neodymium (Nd)	24.6000	27.0000
Samarium (Sm)	5.3000	4.8000
∑LREE	**77.3832**	**120.6973**
HREE		
Europium (Eu)	0.0932	0.0691
Gadolinium (Gd)	4.6000	4.0000
Terbium (Tb)	0.0648	0.0518
Dysprosium (Dy)	0.3362	0.2591
Holmium (Ho)	0.0638	0.0484
Erbium (Er)	0.1661	0.1274
Thulium (Tm)	0.0223	0.0173
Ytterbium (Yb)	0.1377	0.0993
Lutetium (Lu)	0.0194	0.0145
Thorium (Th)	1.0000	1.3000
Yttrium (Y)	1.5000	1.1000
∑ HREE	**8.0035**	**7.0869**

The rare earth elements have very similar chemical properties and are generally considered to be resistant to fractionation in supracrustal environments. Distribution of REE can be used as an indication in defining the parental materials of certain rock. The rare earth element (REE) patterns of these two types of granitic rocks are presented in Figure 5.7. In general, the REE can be classified as light rare earth element (LREE) and heavy rare earth elements (HREE). The REEs content of the batholiths phases are strongly LREE enriched with an average value of 99.04025 ppm. The HREE concentrations are low with an average value of 7.5452 ppm.

In this plot, both of the samples have a similar pattern which indicates that both of the granites experienced a similar process in their origin. The significant depletion of Eu anomalies displays a sharp negative Eu. The depletion of Eu is indicating plagioclase fractionation. Petrographic data shows the presence of dominant plagioclase in the samples.

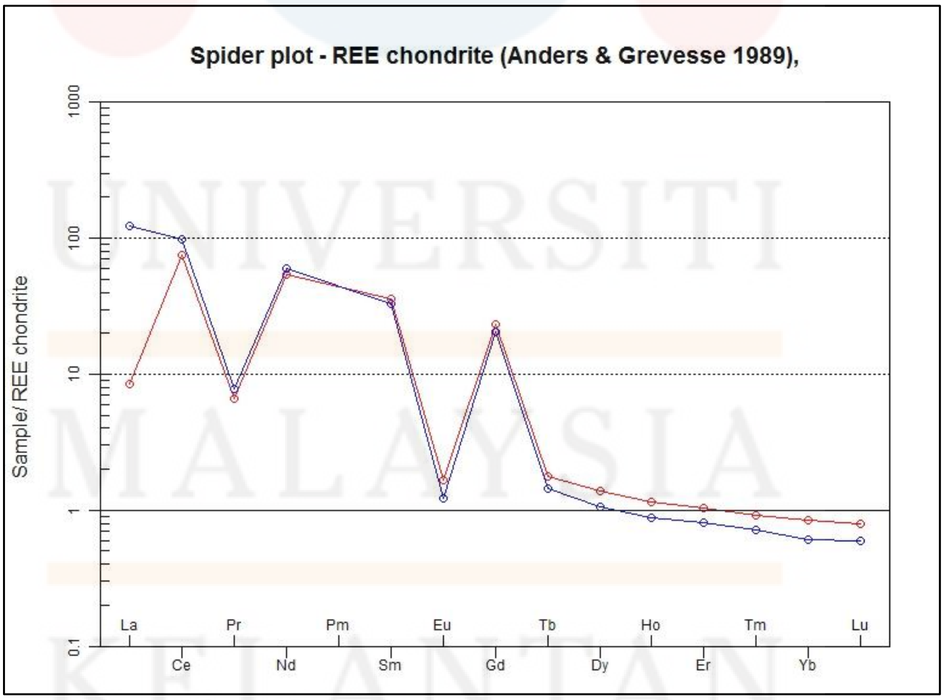

Figure 5.7: Chondrite-normalised REE abundances for the granitoids.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The objectives of this research were achieved and the results were documented in this thesis. The geology of the Subong area can be classified into two units of morphology which is medium and low relief morphology unit. Medium relief morphology unit is comprises the low hill and hill landform while the low relief morphology unit consists of low-lying plain landform. The drainage patterns consist of dendritic and trellis pattern due to the type, landform and geological structure. Unit lithology in the research area can be divided into three main units. Description sequentially from the oldest to the youngest lithology units are as follows Slate Unit, Limestone Unit, Granite Unit and Alluvium Unit. The study area is part of Gua Musang Formation with age ranging from Permian to Quartenary. The geological structure developed in the research area is lineament, joint and fold structure.

A petrological study has been conducted to study the granitoid formation. Petrology is comprised of two main different context which are petrography and geochemistry analysis. To identify the lithology, petrography and geochemistry analysis should complement each other as it can be correlated to the geological ancient of the study area. Based on petrography analysis, it can be concluded that distribution of granite in Subong area as a granodiorite based on its composition.

Based on the analysis of major element, Subong granite are more siliceous. Plotting of FeOt/MgO versus SiO_2 diagram, K_2O vs SiO_2 diagram and AFM diagram shows that the Subong granite are in the calc-alkaline field. Next, A/CNK – A/NK diagram is plotted to determine the alumina saturation content in these granite. The results shows that the granites are classified as metaluminous due to the A/CNK values less than 1. As for the conclusion, classification of type of granitoids by using Na_2O vs K_2O diagram shows that it is classified as I-type. REE analysis shows that both of the Subong samples have a similar pattern which indicates that both of the granites experienced a similar process in their origin.

6.2 Recommendation

The analysis for the geochemistry is needed to improve in terms of data analysis where more advanced and precise methods could be used to obtain more accurate data. A detail elaboration and discussion needs to be conducted. The future researcher is needed to study further in depth of origin magma, tectonic setting, and their formation.

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