GEOLOGY AND GRANITOID GEOCHEMISTRY OF BANDAR UTAMA GUA MUSANG.

By

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A report submitted in fulfillment of requirements for the degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis is entitled Geology and Granitoid Geochemistry of Bandar Utama Gua Musang is 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.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient interms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honors

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Date : ………………………………….

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GEOLOGY AND GRANITOID GEOCHEMISTRY OF BANDAR UTAMA GUA MUSANG.

ABSTRACT

The study area is located at Bandar Utama Gua Musang, Gua Musang, Kelantan with the dimensions of 25 Km^2 of research area. This research paper is concerned with the objectives to produce the geological map of the research area with the scale of 1:25,000 and to analyze the petrography and geochemistry of the granitoid rocks in Bandar Utama Gua Musang for better understanding their petrogenesis. The geological information in the study area is collected through geological mapping process. The study area involved two formations which are Gua Musang Formation and Gunung Rabong Formation. Gua Musang Formation consists of meta sedimentary rock, volcanic tuff, limestone and granite whereas Rabong Formation consist of conglomerate. In addition, alluvium is the recent formation found at Galas River. All the findings and data are plotted in geological map. The structural analysis indicates that the principal stress or main compressive stress force (σ^1) is from the North-east and South-West direction. The geochemical analysis is done in four granitoid samples with code 18LALD1, 18LALD2, 18LALD3 and 18LALE15. The result shows that the granite in study area is S-type granite. LREE is dominant than HREE with Ce and Nd have the highest distribution value.

Keywords: Geological map; granitoid; petrogenesis; Gua Musang; geochemical analysis

GEOLOGI DAN GRANITOID GEOKIMIA DI BANDAR UTAMA GUA MUSANG

ABSTRAK

Kawasan kajian terletak di Bandar Utama Gua Musang, Gua Musang, Kelantan dengan keluasan kawasan kajian adalah 25 Km^2. Kajian ini memfokuskan beberapa objektif, untuk menghasilkan peta geologi kawasan kajian dengan skala 1:25,000 dan untuk menganalisis petrografi dan geokimia batu granit di Bandar Utama Gua Musang agar lebih memahami petrogenesisnya. Data geologi dalam kawasan kajian dikumpul melalui proses pemetaan geologi. Kawasan kajian terbahagi kepada dua formasi iaitu Formasi Gua Musang dan Formasi Gunung Rabong. Formasi Gua Musang melibatkan batu meta sedimen, tuff volkanik, batu kapur dan granit, manakala Formasi Gunung Rabong melibatkan batu konglomerat. Tambahan pula, villuvium adalah formasi yang paling termuda dimanya ianya terdapat di Sungai Galas. Keseluruhan hasil kajian dan data telah di plot dalam peta geologi. bumi. Analisa geokimia dilaksanakan di empat batu granit yang berkod 18LALD1, 18LALD2, 18LALD3 dan 18LALE15. Keputusan menunjukkan bahawa granit di kawasan kajian adalah kelas S granit. Unsur nadir bumi ringan lebih dominan berbanding unsur nadir bumi berat, dimana unsur Ce dan Nd mempunyai nilai unjuran yang tinggi.

Kata kunci: Peta geologi; granitoid; petrogenesis; Gua Musang; Analisa geokimia

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LIST OF ABBRIEVATIONS

ASI	Alumina Saturation Index
Al_2O_3	Aluminium Oxide
Ba	Barium
CaO	Calcium Oxide
Ce	Cerium
Dy	Dysprosium
Eu	Europium
Er	Erbium
FELDA	Federal Land Development Authority
Fe	Iron
FeO	Iron Oxide
Gd	Gadolinium
GRFR	Gunung Rabong Forest Reserve
GPS	Global Positioning System
HFSE	High Field Strength Element
HREE	Heavy REE
HnO_3	Nitric acid
Ho	Holmium
ICP-MS	Inductively Couple Plasma-Mass Spectometry
IUGS	International Union of Geological Society
KESEDAR	Lembaga Kemajuan Kelantan Selatan
K_2O	Potassium Oxide
La	Lanthanum
Ln	Lanthanoids
LREE	Light REE
Lu	Lutetium
MgO	Magnesium (ii) Oxide
Na_2O	Sodium Oxide
Nb	Niobium
Nd	Neodymium
ORG	Oceanic ridge granite

PPL	Plane Polarized Light
Pm	Promethium
Pr	Praseodymium
P_2O_5	Phosphorus Pentoxide
Q-A-P	Quartz-Alkali feldspar-Plagioclase
Rb	Rubidium
REE	Rare Earth Elements
RPT	Rancangan Pembangunan Tanah
Sc	Scandium
SiO_2	Silicon dioxide
Sm	Samarium
Syn-COLG	Syn-collisional graniite
Sr	Strontium
Th	Thorium
Tb	Terbium
VAG	Volcanicarc granite
WPG	Within plate granite
XRF	X-Ray Fluorescence
XPL	Cross Polarized Light
Y	Yttrium
Yb	Ytterbium
Zr	Zirconium
2D	Two-dimensional
3d	Tree-dimensional

CHAPTER 1

INTRODUCTION

1.1 General Background

This research is entitled Geology and Granitoid Geochemistry of Bandar Utama Gua Musang. In this research, the geology and granitoid geochemistry of Bandar Utama Gua Musang was studied since the detail information about granite at the study area is less and limited and not specific in local studies.

Geology is the scientific study of the Earth (Plummer et. al, 2013). The scientific study of the earth usually deals with study the earth materials which are rocks and minerals that make up the earth, the processes that happen in the earth and the structure that forms in the earth. Klein & Phillpots (2013) defines that a mineral is a naturally occurring solid, with an ordered atomic arrangement and definite chemical composition and almost all of the minerals are formed by inorganic chemical processes. The rock is defined as the naturally occurring consolidated mixture of minerals (Klein & Phillpots, 2013). Field study is conducted by cover 5×5 km of the study area and along with that, the rock distribution including its description also is being studied and analysed. Further analysis of the rocks was done at the laboratory by carrying out the petrography and geochemical analysis.

Generally, petrology is the science dealing with the description, classification, modes of occurrences and theories of the origins of rocks (Phillpots &

Ague, 2009). They further suggested that petrology studies fall into two general categories which are the identification and the classification of rocks, and the interpretation of these data and the generation of the theories of the origin of rocks. The identification and classification of rocks include the study of the minerals composition, texture and structure are called petrography. Petrography, the study of rocks in thin section, is primarily concern with the rock description and classification.

Then, the geochemical analysis was carried out by using the XRF (X- Ray Fluorescence) test and ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) test to run the elemental analysis on the rock samples. The interpretation of petrographic data combined with the study on petrochemical and geologic processes are generally called a petrogenetic study. A petrological study on the igneous rock also helps us to understand the tectonic setting of the magma generations better.

Thus, the study area can be understood by studying geology, the general geology, including rock units, stratigraphy, structural geology as well as its geomorphology. A more specific petrological study is done on the granitoid rocks. Results of this study will add geological information in the research area especially the tectonic conditions in which granitic rocks were formed and the rare earth elements (REE) distributions. Besides, data from both field and laboratory activities was used to produce the geological map of the study area and in identifying the rock's boundary at the research area.

1.2 Study Area

The study area extends from longitude and latitude of 101°58'0"E 4°54'30"N, 102°0'45"E 4°54'30"N, 102°0'45"E 4°52'15"N and 101°58'0"E 4°52’15"N.

1.2.1 Location

The study area is located at Bandar Utama Gua Musang, Gua Musang, Kelantan. Gua Musang is the largest district that located in the southern part of Kelantan as shown in Figure 1.1 while Figure 1.2 shows the basemap of the study area. Gua Musang is bordered by Pahang state at the south, Terengganu state to the east, Perak state to the west and the north by Kelantan district of Kuala Krai and Jeli. The study area is an area with a fast growing of development and facilities. Besides, even the study area is the main town of Gua Musang, it is still surrounded by the forest and mountainous landform.

1.2.2 Accessibility

The study area can be accessed by using the main road of Kota Bharu-Gua Musang and Gemas-Tumpat railway. Based on Figure 1.3A, by using a car, it takes about three hours to reach the Gua Musang from Kota Bharu when passing through the Kota Bharu-Gua Musang main road (blue line) whereas it takes about three hours and a half when passing through Rantau Panjang, Jeli and Dabong main road (grey line). Moreover, From Tanah Merah (Figure 1.3B) and Jeli (Figure 1.3C), the time taken to reach Gua Musang by using the car only takes about 2 hours and 19 minutes and 1 hour and 45 minutes respectively (blue line). Meanwhile, for the train, it takes about 6 hours from Tumpat to Gua Musang (red line) by passing through the Gemas-Tumpat Railway.

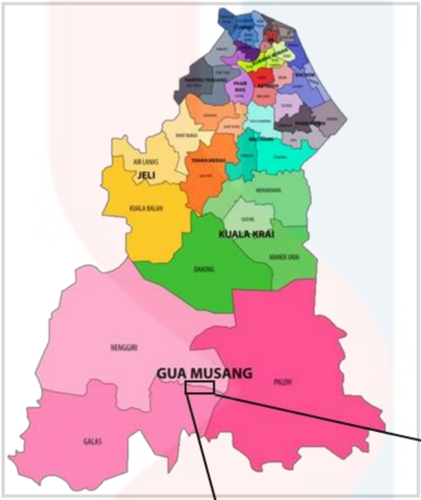


Figure 1.1 Location of Gua Musang at Kelantan

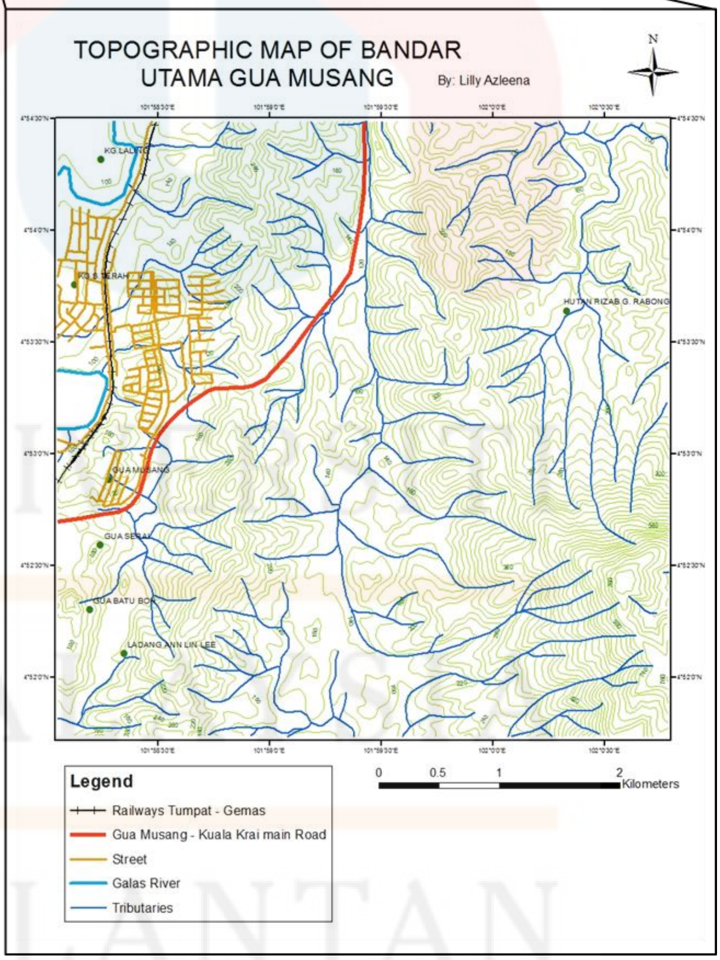


Figure 1.2 Base map of the study area.

Figure 1.3 Accessibility to Gua Musang. (A) From Kota Bharu to Gua Musang by using a car. (B) From Tanah Merah to Gua Musang by using a car. (C) From Jeli to Gua Musang by using a car. (D) From Tumpat to Gua Musang by using a train.

Source: (Google, n.d)

1.2.3 Demography

Table 1.1 represents the population of Kelantan state with ten administrative districts. This population data is based on 2000 census and total population may vary due to the rounding the values (Jabatan Kesihatan Negeri Kelantan, 2012). Gua Musang population is at the eight ranking of highest population among the 10 districts. Total Kelantan population in 2010 is 1,641,900 and gradually increased to 1,849,700 in 2014. The increase in population is due to the factors of birth rate, death rate and people migration that always change throughout the year. Based on Figure 1.4, the trend populations in Gua Musang show the annually increasing from 2010 population to 2014 population. It was about 2700 to 2800 census of annual increases in Gua Musang population.

Table 1.1 Population in Kelantan State

Source: Jabatan Kesihatan Negeri Kelantan (2012)

District	Year				
	2010	**2011**	**2012**	**2013**	**2014**
Bachok	142,100	146,000	149,900	153,800	157,700
Kota Bharu	509,600	522,000	534,500	547,200	560,100
Machang	101,300	103,900	106,400	109,000	111,700
Pasir Mas	212,000	217,300	222,800	228,300	233,600
Pasir Puteh	134,200	137,700	141,100	144,600	148,200
Tanah Merah	133,400	136,700	140,000	143,300	146,700
Tumpat	137,200	177,700	182,200	186,800	191,400
Gua Musang	103,300	106,000	108,800	111,700	114,500
Kuala Krai	120,800	123,700	136,500	129,500	132,400
Jeli	48,000	19,300	50,600	51,900	53,200
Kelantan (Total)	**1,641,900**	**1,690,300**	**1,772,800**	**1,806,100**	**1,849,700**

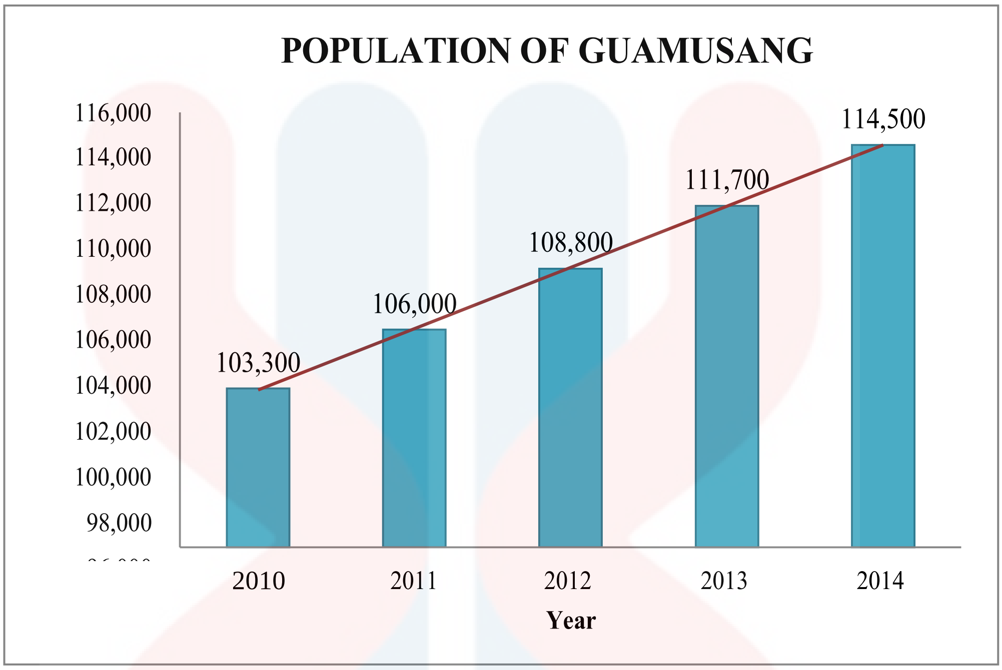


Figure 1.4 The trend of Gua Musang population

1.2.4 Landuse

In the central part including the Northern and Eastern part of the study area, the land is mostly covered by the palm oil plantations followed by rubber plantations and banana plantations. The landuse of plantations activities in Gua Musang is supervised by three main organizations which are Lembaga Kemajuan Kelantan Selatan (KESEDAR), Federal Land Development Authority (FELDA) and Rancangan Pembangunan Tanah (RPT).

With fast growing and developments of infrastructure and facilities, there are many government buildings such as schools, hospitals, police station, fire station, and any others is developed. Other than government building, there is also a private building that was built in purpose of educational activities like kindergarten and private institutions. Then, there are also public facilities like public phones, mosque, bus stations, main road, railway and others. Besides, construction of houses and buildings also is actively run. Moreover, there is a reserve forest that located at the southeastern part of the study area which is Gunung Rabong Forest Reserve (GRFR) with the peak's elevation of 700m to 740m above the sea level.

1.2.5 Socio economic

Most of the economy that is run by people in Gua Musang is a plant-based economy. Mainly, people developed the rubber plantation and palm oil plantation as their main economic activities. Palm plantations cover a huge area of Bandar Utama Gua Musang and it is the main source of income of people in Gua Musang. Moreover, agricultural activities like planting the banana tree and other vegetables and fruits also are done by people in Gua Musang.

Besides, people there also do their own business like running the grocery stores, stalls, supermarket and fruit stalls. The quarrying activities also are one of the people activities in Gua Musang to increase their economy.

Other than running the business, people also work as a teacher, police officers, firemen and hospital staffs. People in Gua Muang are also concern about their education since there are many educational institutes such as kindergarten, primary school, secondary school and private institutions is build.

1.3 Problem Statement

Based on the previous research, there was a less detailed or specific study about granitoid rocks that were carried out by localities in the interest area. Mostly, regional research of granitoid is done and it is so general. Moreover, detailed data about the geological information in Bandar Utama Gua Musang is less and limited since not many type of research had been carried out. With fast growing development in Bandar Utama Gua Musang, some of the hill is being excavated. Thus, the changes in the geomorphology and geological structures in the study area may vary.

Besides, although it is reported that the eastern province granitoid rocks are I-type granites, some opinion said that there is also a presence of S-type granites. This study is not so simple and needs detail petrography and geochemical study in the study area.

1.4 Research Objectives

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

ii. To analyze the petrography and geochemistry of the granitoid rocks in Bandar Utama Gua Musang for better understanding their petrogenesis.

iii. To investigate the distribution of rare earth elements (REE) in Bandar Utama Gua Musang granitoid rocks.

1.5 Scope of Study

The research interest area is cover 25 Km2 around Bandar Utama Gua Musang area with the dimension of 5 Km x 5 Km. The work includes geological mapping and petrological study of the granitoid rocks. Two-steps of work is conducted which are fieldwork and laboratory works. Fieldwork is intended for observing and collecting geological data including geomorphology, lithology, stratigraphy, sedimentology and geological structure. Besides, the laboratory work is intended for petrography study and rock geochemical analysis.

The rock samples are collected in order to proceed with the petrography analysis by using the geochemistry methods. In petrography study, the thin section is prepared and being observed under the polarized microscope to determine the rock properties and mineral characteristics within the rock samples. After that, the rocks then are named by using the data from the rock samples observation and availability of mineral in the thin section. Then, the geochemical analysis is aimed obtaining the major and trace element data of the rocks to study the affinity of magma and tectonic environments in which the rocks formed.

1.6 Significance of Study

The importance of this research is to provide more geological information specifically about the granitoid rocks by in the study area since most of the previous studies is done by regionally instead of by locality. Besides, since this research is carried out with more specific data and information about geology and petrology, it will help in understanding more about the origin and the history of the rock by correlating the rock with the formation characteristics at the study area. Nevertheless, this reference will be beneficial in the future as the reference for the academic purpose, especially for the geologist.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature review was completed by surveying, analysing and evaluating the journal articles, books, thesis and other published body resources that related to this research aims. All of the previous research and past studies about the regional geology, stratigraphy, structural geology, historical geology and petrography of the study area need to be understood and reviewed in this Chapter 2.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is an integral part of Eurasian Plate, the South-East Asian part of which is known as Sundaland (Hutchison, 1989, 1996). There are three main geological domains which are the Eastern Belt, Central Belt and Western Belt as shown in Figure 2.1. Gua Musang is located at the central belt of Peninsular Malaysia. The Central Belt stretches from Kelantan to Johor between the eastern foothills of the Main Range, forming its western boundary to its eastern boundary marked by the Lebir Fault in the north down to the western boundary of the Dohol Formation in the south (Peng, 2009). Besides, Peng (2009) said that the western part of Central Belt is Upper Palaeozoic rocks of Gua Musang and Aring Formations in south Kelantan and Taku Schist Formation in east Kelantan.

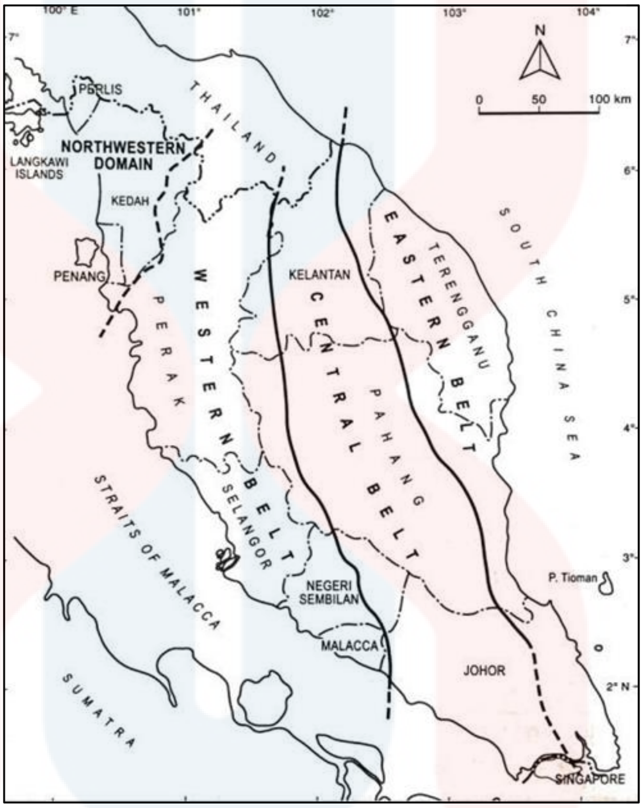


Figure 2.1 The geological domains of Peninsula Malaysia

Source: Peng (n.d)

Based on Figure 2.2, Peninsular Malaysia also is divided into two tectonic stratigraphy terranes which are from the Sunda Shelf known as the East Malaysia (Eurasian Plate Indochina) and Sibumasu (Shan-Thai) terranes, Main Range province or West Malaysia. These origins of terranes may possibly by rifting of the north-east margin of the ancient Gondwanaland landmass in the Late Permian to lately Triassic that responsible for the formation of the Central Belt and Bentong-Raub Suture (Ariffin, 2012). However, there is no detailed information about the tectonic setting of the granite formation at the study area either it is formed from the collision, subduction or during both of collision and subduction process.

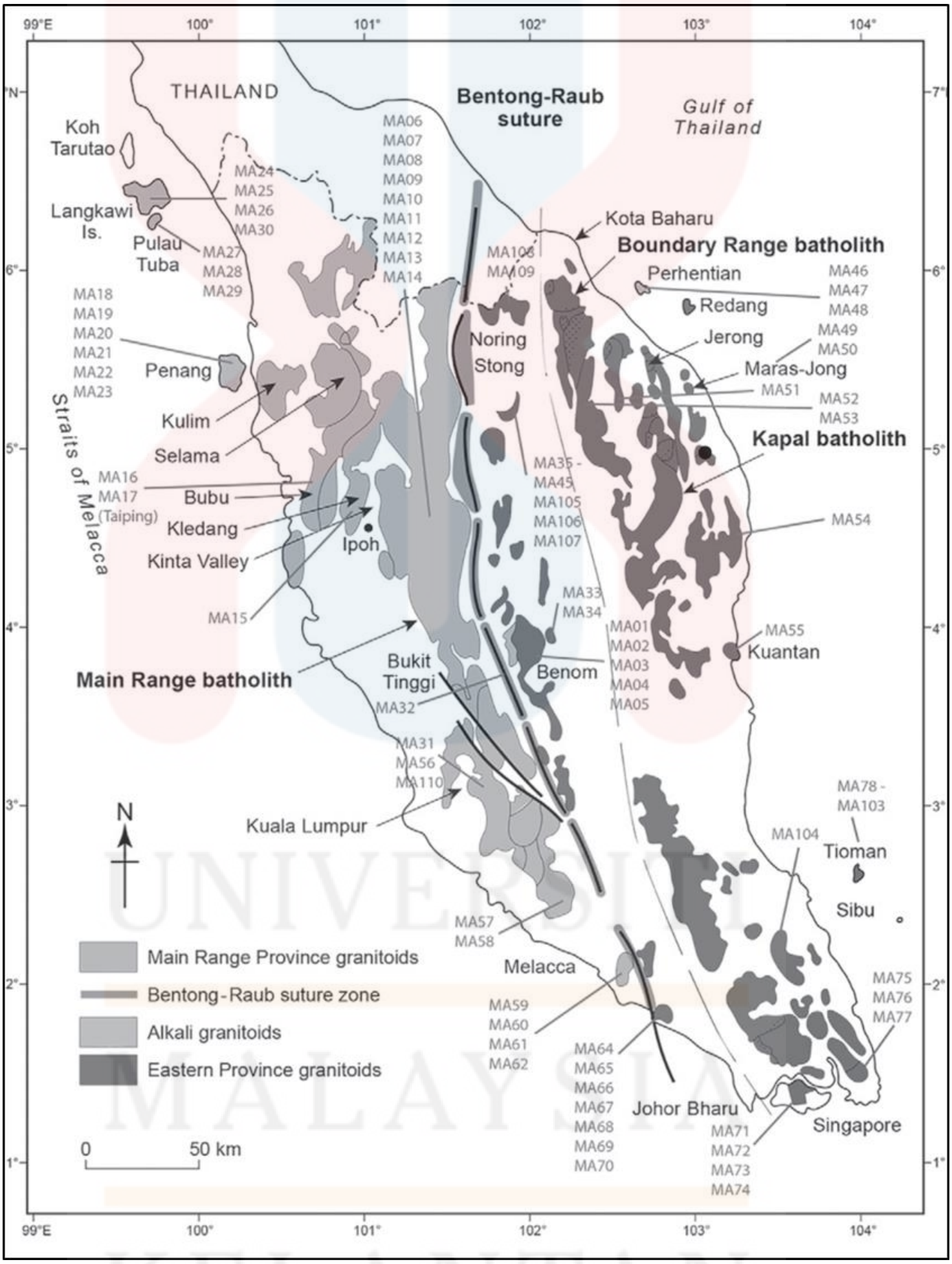


Figure 2.2 The Eastern Province granitoids and Main Range province granitoids separated by Bentong-Raub Suture

Source: Ng et. al, 2015a

2.3 Stratigraphy

Stratigraphy is defined as the relationship between the rocks and time. At one level, stratigraphy is about establishing a nomenclature for rock units of all ages and correlating them all over the world, but at another level, it is about finding evidence for climate change in the past or the plate tectonic movements (Nichols, 2009).

Gua Musang Palaeozoic Formation ranges from Middle Permian to Upper Triassic with 650m thick that comprises of crystalline limestone interbedded with thin beds of shale, tuff, chert nodules and subordinate sandstone and volcanic (Peng, 2009). There are two types of limestone which are the light grey calcitic limestone and grey to black recrystallized limestone (Peng, 2009). The light grey limestone is more hard, non-porous, brittle and splintery whereas the grey to black recrystallized limestone composed of small amounts of the carbonaceous, argillaceous and pyroclastic impurities. The limestone age in Gua Musang range from Permian to Lower Triassic.

Peng (2009) also stated that the thin-bedded, laminated and fissile shale is normally grey in colour but turns to black when carbonaceous and sometimes it associated with the bedded chert that have a colour dark grey to black. The arenites is usually metaquartzite but include the greywacke, protoquartzite and orthoquartzite. The argillaceous sandstone is fine to medium grained with angular quartz in limonitic and carbonaceous clay (Foo, 1983; Peng, 2009). The shale facies also range from Permian to Triassic.

The volcanics are composed of rhyolitic to andesitic variation, and include tuff, lava flows and agglomerate (Peng, 2009). The bulk has a crystal lithic tuff with fine to medium in grain size, occasionally interlaminated with dark grey tuffaceous shale and carbonaceous shale.

Abdullah (2009) stated that part of Gua Musang Mesozoic Formation comprises of Upper Permian-Triassic calcareous and argillaceous, shallow-water platform facies of the northern part of Gua Musang-Semantan Depocentre. The Mesozoic Formation is dominants at the central belt that formed continuous North-South trending belt extending beyond the international boundaries with Thailand in the north and Singapore (Jurong Formation) in the south (Shan, 2015).

However, in Gua Musang Formation stratigraphy, the stratigraphy is still incomplete and no past researches had classified the exactly Triassic and Permian successions because it is very difficult to classify them based on lithological characters. Besides, the distinction of the Gua Musang stratigraphy is depends almost entirely on fossil evidence (Abdullah, 2009).

Upper boundary of Gua Musang Formation is proposed to be overlapped by Gunung Rabong Formation without a distinct break (Abdullah, 2009; Yin, 1965). Abdullah (2009) stated that black shale and crystal tuff is dominant in the north whereas these rocks are replaced by the alterations of shale and quartzite and minor conglomerate to the south. Moreover, he said that the limestone occurs as a localized bed in shale. The Gunung Rabong Formation sediments have a strong similarity with the Triassic turbidites that found within Telong Formation and Semantan Formation (Abdullah, 2009; Kamal, 1996). In Mesozoic stratigraphy of Gua Musang, Lower Triassic limestones are lacks and the Middle Triassic limestone are dominant.

The carbonates of Gua Musang is said to be deposited in shallow water environment because there is strong Tethyan affinities that shows in faunal and floral composition of the Permian and Triassic limestone (Abdullah, 2009). The Lower Triassic limestone blocks, olistoliths and conglomerate are period of intensified shelf or platform stability. Besides, the Permian limestone is more extensive but, like the

Permian counterparts, the limestone occur as a discrete bodies separated by shale reflecting that the limestone is developed on remnants of the pre-existing Permian carbonate facies.

2.4 Structural Geology

The structural geology that can be found in Gua Musang is the major faults. This major fault can be classified into two classes which are Terrane-bounding faults (Bentong-Raub Suture Zone and Lebir Fault Zone) and the Terrane-crossing faults (Galas fault Zone).

The Terrane-bounding faults are the faults that formed a terrane by dividing the Peninsular (Mustafa, 2009). The Bentong-Raub Suture Zone can be found along the road of Gua Musang-Cameron Highlands as a deformed rock with a wide of 20 Km. There are seven tectonic units within this suture and their repeated occurrences resulting to the formation of imbricate structure (Tjia & Almashoor, 1996). The Lebir fault Zone can be found between Lebir River and the eastern of the Taku Schist near Kuala Krai expanding 10 Km wide (Mustafa, 2009). This Lebir fault Zone is interpreted as the dextral strike-slip terrane-bounding fault relating to the other major faults characteristics in Peninsular. Next, the terrane-crossing faults which are the Galas fault Zone that extends from Thailand to the Tembeling area with the trends from 300° to 340°. The Kemahang granite and Stong Complex is controls by this type of faults. All of these three faults can be seen through the satellite imagery.

Besides, there is a structure like folding that can be found in the Gua Musang area. For example, a refolded fold was found at the Gua Musang-Pulai junction where the sequence of well-bedded tuffaceous siltstone, sandstone, and minor lenses of limestone during the age of Permian to Middle Triassic are exposed.

2.5 Historical Geology

In Figure 2.3 below, it shows the Permo-Triassic Orogeny based on the forearc basin subsidence and segmentation model. According to the Mohamed et. al (2016), thick argillite and volcanic were deposited that adjacent to the Indochina volcanic arc during the Early Permian. The Paleo-Tethys subduction event caused the building of the accretionary complex. Gua Musang shallow marine environment was created by the thick argillites and volcanics during the Middle-Late Permian. This environment relates to the carbonate development and benthic fauna development. During the Early Triassic, forearc subsidence intensified in Gua Musang platform, creating more accommodation space for carbonate-argillite-volcanics deposition. The Paleo-Tethys Ocean is completely subducted as Sibumasu docked into Indochina. Middle-Late Triassic shows the event of oblique subduction of Sibumasu aided process of basin segmentation on the subsiding Gua Musang Platform, thus creating deep Semantan-Gemas basin.

The North-South Palaeo Tethys in Peninsular Malaysia is represented by the Bentong Raub Suture Zone that is characterized by the imbricated complex structure of pelitic schist, serpentinite, amphibole schist, melange-olistostrome and chert of Carbonaceous age including the undated post suture redbeds (Hutchison, 2014). The Palaeo Tethys history can be correlated with the oceanic cherts from the Late Devonian to the Late Permian. Sibumasu is characterized by the glacial pebbly mudstones of Carboniferous-Permian age, meanwhile the East Malaya and Indochina are characterized by the fusulinid limestones and cathaysian Gigantopteris flora.

According to the Heng et. al (2006), the geology of Kelantan central zone is composed of sediment and metasedimentary rocks that are bordered by Main Range granites to the west and Boundary Range granite to the east. The granite intrusive within the central zone is comprises of Senting batholiths, Stong Igneous Complex and Kemahang pluton.

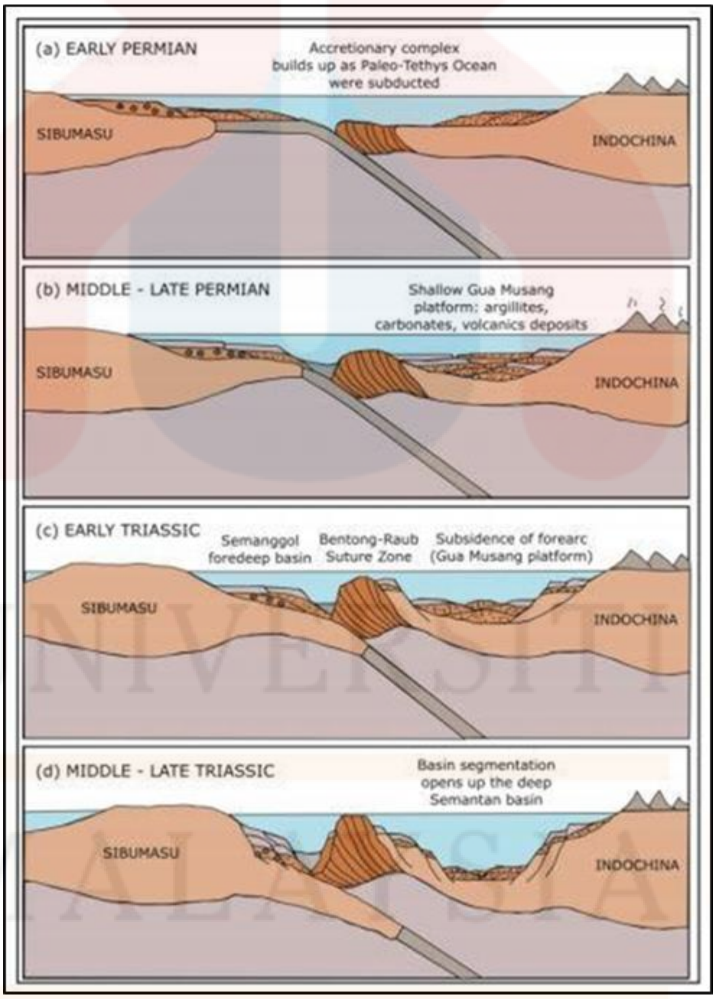


Figure 2.3 Permo-Triassic Orogeny based on the forearc basin subsidence and segmentation model.

2.6 Petrography and geochemistry

2.6.1 Petrography

Granite rock is the plutonic rock with less than 90% of mafic minerals. Based on the IUGS (international Union of Geological Society) classification in Figure 2.4, granites consist of a limited range of composition of quartz (Q), Alkali feldspar or K-feldspar (A) and plagioclase (P) magma series that may include tonalites, granodiorites, diorites, quartz monzonites, and granites. Thus, granitoid is the term that is used for the rocks that are rich in quartz and feldspar. The IUGS classification is used to identify the mineral, texture and for naming the rock.

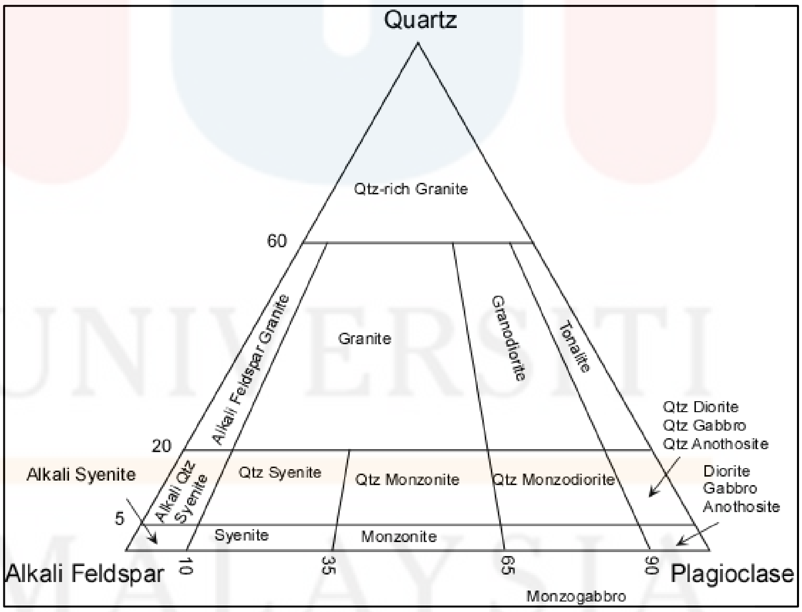


Figure 2.4 The IUGS (QAP) classification diagram.

The S-I-A-M classification of granitoid rocks is used to identify the chemical characteristics and tectonic setting of granitoid rocks. Chappell and White (1974) proposed that I-type granites are formed by igneous-sourced melt while the S-type granites are those who formed from a sedimentary-sourced melt. Further classification states that those who derived from partial melting of the mantle or relatively juvenile crust as M-type granites (White, 1979). These M-types of granites mostly generated at in island arc environments. Furthermore, the A-type granites are the alkali granites that formed in within–plate environments (Loiselle & Wones, 1979). The A-types granite also emphasizes the anorogenic tectonic setting, the relatively alkaline composition and the supposed anhydrous character of the magmas. Mineralogically, S-type granites are characterized by the presence of muscovite, andalusite, cordierite and garnet mineral whereas the I-type granites are characterized by the mineral presence like hornblende and sphene (Chappell & White, 1974). Next, A-type granites are characterized by the presence of fluorite. The M-type granites are the rock that relatively rich in Plagioclase. Ng. et al. (2015a) stated that the Eastern province granitoid were interpreted as pre- collision arc-related granites, while the Main Range or Western province granitoid were interpreted as collisional granites. Past studies showed that the collisional granite is characterized by high Rubidium (Rb) contents.

2.6.2 Geochemistry

(a) Major and Trace elements

The Aluminium Saturation index and Alkali Lime Index is used to discriminate the I-type granitoid and S-type granitoids.

Alumina Saturation Index (ASI) is divided into four subdivisions which is peraluminous, mataluminous, subaluminous and peralkaline (Figure 2.5). The

Alumina Saturation Index (A/CNK) is done by measuring the ratio of Al_2O_3/(CaO + Na_2O + K_2O) in terms of molar proportions where the Eastern and Western province of Malaysia granitoids can be distinguished. The I-type granitoids (Western belt) are essentially metaluminous and gradually become weakly peraluminous with an increase in silica contents whereas the S-type granitoids (Eastern belt) are typically peraluminous (Chappell & White, 1974; Azman Abdul Ghani et. al 2013b). Ng et al. (2015a) said that both provinces are following the trend index of I- type and S-type granitoids. They also said that the S-type Eastern province geochemical outliers show some of the Eastern granitoids are highly fractionated, while the metaluminous nature of Western province geochemical outliers can be explained by the presence of Hornblende-bearing rocks.

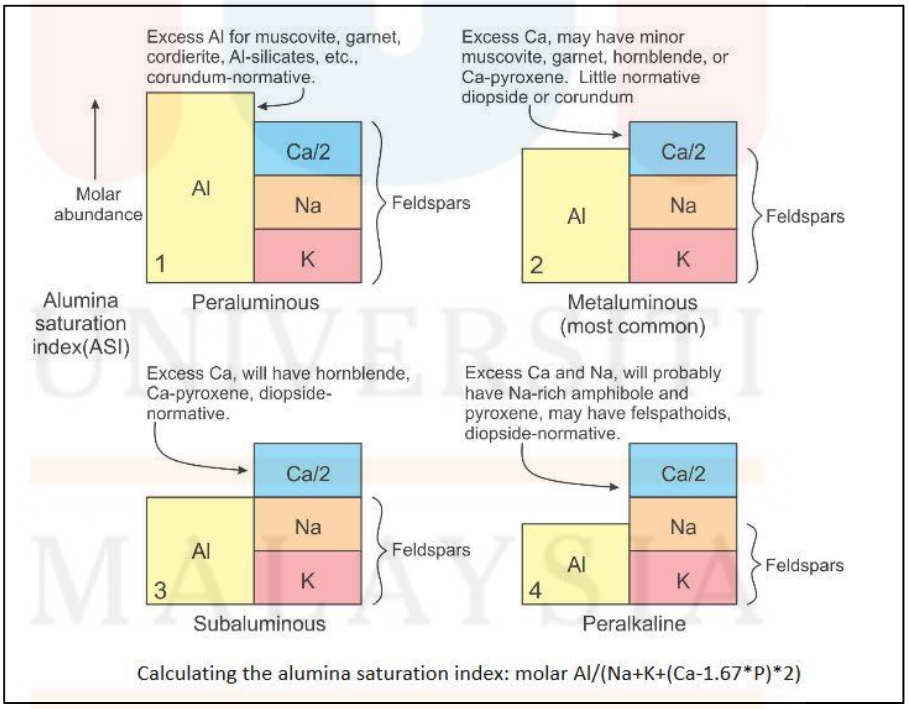


Figure 2.5 Alumina Saturation Index

Then, the geochemical analysis of Alkali Lime Index or Alkali Oxides Index, K-feldspar (K_2O) and plagioclase (Na_2O) ratio is discussed. There are four types of

Alkali Lime Index classification which are Alkalic, High-K Calcic-alkali, Calcic-alkali and Calcic or Tholeiite as shown in Figure 2.6. The I-type granites at the Eastern province tend to be more sodic in composition whereas the S-type granites at the western province are more potassic (Chappell & White, 1974; Ghani et. al, 2013b; Ng et. al, 2015a).

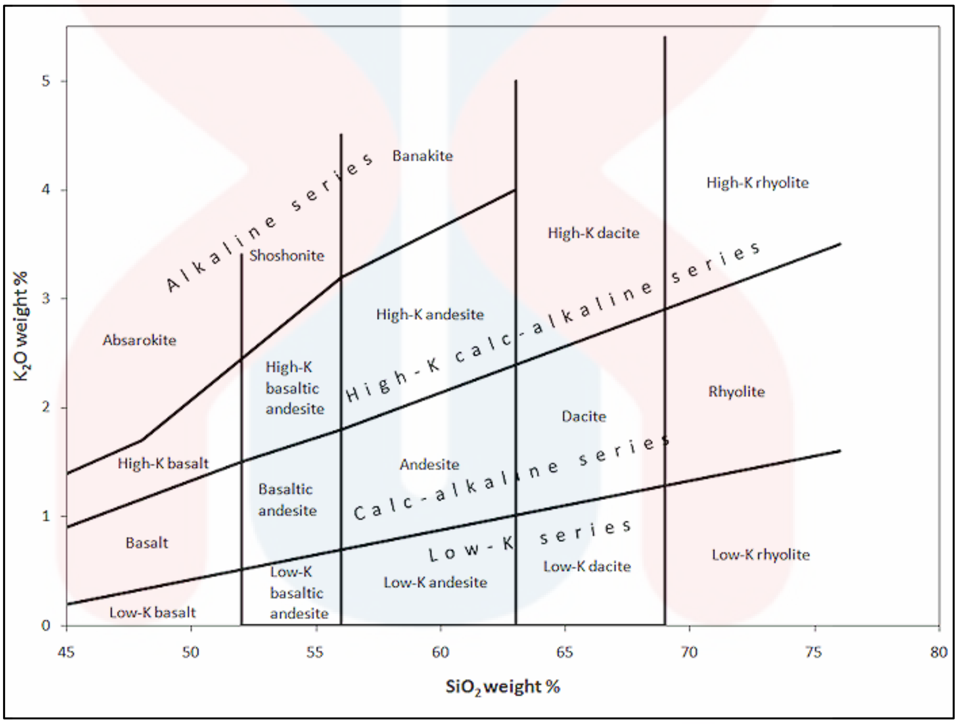


Figure 2.6 Alkali Lime Index

In order to identify the tectonic setting in which the magmas were formed, it is important to determine trace elements in the granitoid. The tectonic setting is determined by plotting the trace elements according to the Pearce Plot diagram (Figure 2.7). There are four types of the tectonic setting based on the Pearce plot diagram which are syn-collisional granite (syn-COLG), volcanic arc granite (VAG), within plate granite (WPG) and oceanic ridge granite (ORG). Ng et al. (2015) stated that their data of Western province granitoid are majority falls within the syn-COLG field with some outliers falling into WPG. For the Eastern province granitoid data, they stated that the data falls within the syn-COLG-WPG-VAG field where it conjectures the high field strength elements (HFSEs) enrichment such as Yttrium (Y) and Niobium (Nb).

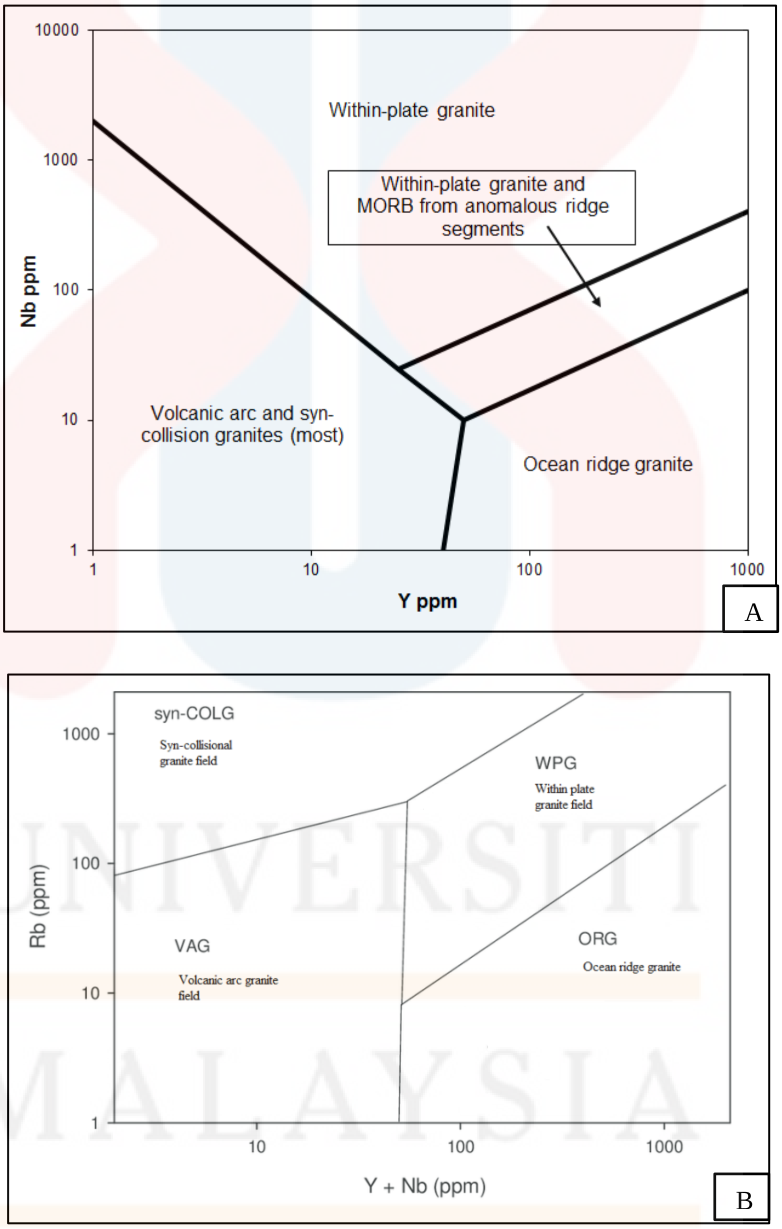


Figure 2.7 Pearce plot diagram. (A) Nb vs. Y plot diagram. (B) Rb vs. Y+Nb plot diagram.

Source: (Pearce, Harris, & Tindle, 1984)

Harker diagram is used to plot the major element versus SiO_2 in order to study the fractionation trends in Eastern province and Western province granitoids. Ng et al. (2015a) said that the western province granitoids are more fractionated than those in the Eastern provinces. The Titanium dioxide (TiO_2), Aluminium oxide (Al_2O_3), Iron Oxide (FeO), Magnesium Oxide (MgO), Calcium Oxide (CaO) and Phosphorus pentoxide (P_2O_5) contents is decrease as the silica contents increase (Ng et. al, 2015a). He also said that only K_2O shows the positive correlation with SiO_2 and Na_2O shows poor correlation.

Then, the bivariate diagram is used to study the trace elements. In this bivariate diagram, the compatible trace elements like Barium (Ba), Strontium (Sr), Zirconium (Zr) and Iron (Fe) versus the incompatible elements like Rb is plotted to study the fractionation of feldspar, biotite and hornblende mineral. Ng et. al (2015a) mentioned that decreased in Sr and Ba with increasing Rb contents shows the feldspar fractionation whereas decrease in Fe with increasing Rb contents shows the fractionation of biotite and hornblende.

Next, the spider diagrams is used to plot the trace element normalized to the primitive mantle in order to contrast the trace elements of the granitoid data with typical Cordilleran data of I-type and S-type granites (Ng et. al, 2015a). Besides, the spider diagram also used to plot the REE element normalized to the chondrites. The Malaysian granitoids are enriched in HFSEs and REEs than the typical Cordilleran I-type and S-type granites. Besides, from their result of Rb/Sr ratio, they suggested that the enrichment of HFSEs and REEs in Malaysia granitoids is possibly from the primary concentration inherited from the source instead of as a fractionation product.

(b) Rare earth elements (REE)

The REE has a 17 group of elements which are Scandium (Sc), Yttrium (Y) and other 15 are Lanthanoids (Ln). The Lanthanoids consists of Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Th), Ytterbium (Yb) and Lutetium (Lu). From 17 groups of elements, there are five light REE (LREE) and 12 heavy REE (HREE) elements. The LREE composed of La, Ce, Pr, Nd, Pm and Sm whereas the others are the HREE.

The ionic radii of REE is bigger than the ionic radii of rock forming elements reflecting that no crystal structure can be form from REE instead the REE elements aggregate in residual fluids and enriched there as accessories (Zepf, 2013). He also mentioned that, normally, REE occurrence is always associated with the oxide, silicates or phosphates, making them as lithopile elements. Besides, the Nd element is supposedly more available in the earth crust rather than La. But, since the ionic radii of La are higher than Nd, La is more readily built into rocks. Moreover, Lu and Th is the least abundance REE in rocks. The most abundance REE is Ce with 60 to 68 ppm followed by Nd and La (Bunzli, 2013).

According to Fuad and Hamzah (1999), Granitoids in Gua Musang have no apparent negative Eu anomaly. They said, based on the REE pattern in their research, the granitoidds in Gua Musang similar REE pattern to those in Noring granite, and they proposed that the granitoids is either related or not related to the Cretaceous granite of southern Peninsular. However, based on their result, Gua Musang granites have similar REE pattern to Noring granite of northern Central Province. The granites in Stong Complex including Noring granite has been classified as late

Cretaceous. Thus, they conclude that the granitoid in Gua Musang is related to the late Cretaceous of Southern Peninsular granites.

2.6.3 Overview of XRF (X-Ray Fluorescence)

XRF analysis is used to run the elemental analysis to the sample and the first person who discovered the X-rays was the German Physics Professor, Wilhelm Conrad Roentgen. The principle of XRF is the individual atoms will excited to the higher energy level and emits the x-rays photons. These atoms will moves from high to low energy level. The number of photons that each energy emitted from the sample will help in identify and quantify the presence of the elements (Guthrie, 2012). There are two types of XRF instruments which are the energy-dispersive spectrometer and wavelength dispersive spectrometer. The x-ray source of XRF is from the heating of the cathode and anode of the instrument. The sample in XRF can be in the form of solid, liquid and thin film samples (Guthrie, 2012). XRF is used to find both major and trace elements in the sample for the geochemical analysis.

2.6.4 Overview of ICP-MS (Inductively Coupled Plasma-Mass Spectrometry)

The ICP-Ms also used to run the elemental analysis on the sample. In geochemical analysis, this ICP-MS is used to detect the rare-earth elements (REE). The name of ICP-MS is developed from the combination of ICP source with the MS. The atom elements in the sample will be converted into ions by the ICP source and these ions then will be separated and detected by the MS.

The samples that were used to run this ICP-MS test can be in the form of aerosol, vapour and solid. Solid samples will be converted into aerosol by using the laser. The liquid or dissolved solid sample will converted into aerosol by aspirating it into a nebulizer (Wolf, 2005). As the aerosol sample is place into the ICP torch, the sample will be completely dried or desolvated (Wolf, 2005). Then, the conversion of the elements into gaseous atoms will take place first before the ionization process towards the end of plasma takes place. Furthermore, the recommended sample need to have not more than 0.2% of total dissolved solids (TDS) in order to ensure the stability and the performance of the instrument.

2.7 Previous Study

Generally, the Eastern province of Malaysia granitoids was emplaced into Indochina-East Malaya terrane, which is made up of Lower Carboniferous to Cretaceous marine-fluvial sediments and volcanics underlain by Mesoproterozoic continental basement (Hutchison, 2007; Metcalfe, 2013; Ng et. al, 2015a). However, the Malay Peninsular is not exposed to the continental basement and the granitoids are 1100-1300 Ma of zircon ages (Liew, 1983; Liew & McCulloch, 1985).

Then, further studied by Metcalfe (2013) suggested Eastern province granitoids are part of Sukhothai arc terrane, but this study is not supported because Ng et al. (2015) stated that there is no on land field evidence for Mesozoic back-arc rifting in Malay Peninsula, and this is not supported by the geochemistry of Eastern province granitoids. Moreover, the scattered Cretaceous granitoids now documented in Eastern province is also mineralogically and geochemically similar to the Permo-Triassic granitoids that dominate the belt (Ng et. al, 2015a).

Besides, the Western province of Malaysia granitoids was part of Sibumasu basement that comprises of Mesozoic carbonates and turbidites underlying the Upper Cambrian to Upper Permian metasediments and shallow marine shelf sediments (Abdullah, 2009; Azman Abdul Ghani et. al, 2013a). Hutchison (2007) then proposed that the northern and central part of Thailand have some metamorphic outcrops that represent the original Precambrian basement of the Sibumasu terrane.

The granitoids to the east Bentong Raub suture zone is dominated by hornblende-bearing I-type granites that formed above an east-dipping Paleo-Tethyan subduction zone (Beckinsale, 1979). He further suggested the granitoids to the west of Bentong Raub suture zone are younger and mostly with hornblende S-type granites that formed by a thickening of earth crust followed by the collision of Sibumasu and Indochina blocks. However, this study is not fully agreed by the other researchers because of the mineralogical and geochemical characteristics of two provinces shared many similarities and need to be studied furthur. For instances, both provinces comprise of hornblende-bearing and hornblende-free granitoids and both are made up of batholithic intrusion dimensions (Ng et. al, 2015a). Both of the provinces shared geochemical similarities in which both provinces have high alumina saturation index and decreasing trend in P_2O_5 (Phosphorus pentoxide) content as the granitoid rocks become more felsic.

The previous study also stated that Malaysia Peninsular is divided into four types of plutons which are Main Range plutons, Central belt plutons, Eastern belt plutons and Cretaceous plutons (Ghani, 2009). He stated that Main Range granites have more than 65% of SiO_2 (Silicon dioxide) concentration while the Eastern belt has the SiO_2 composition range from 50% to 78%. He also said that the Eastern and Central belt have both I-type and S-type granites. However, there is no further explanation about the central belt and only explain about the three plutons, Main Range, Eastern and Cretaceous plutonic rocks.

Later, Ng et al. (2015a) studied the Malaysian granitoids by studying its geochemical analysis of major and trace elements. They conclude that the Malaysian granitoids can be divided into I-type granites of Eastern province and a transitional I/S-type granites of Main Range province that separated by the Bentong Raub suture zone. Then, they further their studied by carried out U-Pb Zircon analysis. As a result, mostly I-type granitoids of Eastern province are interpreted as subduction related Andean-type magmas formed during the eastward subduction of Paleo-Tethys beneath the Indochina active plate margin during the Permian to Middle-Late Triassic (Ng et. al, 2015b).

This caused the Paleo-Tethyan Ocean closure along the Bentong-Raub suture zone. However, past research stated that the alkalic granites of the Eastern belt are neither collision nor subduction-related, and may be rift-related (Hutchison & Ghani, 2009). They also said that there are only few types of granite that originates from syn-collisional field at the Eastern Belt. The granitoids in the Western province are extremely voluminous and formed in a supra-subduction zone setting (Ng et. al, 2015a).

CHAPTER 3

MATERIALS AND METHOD

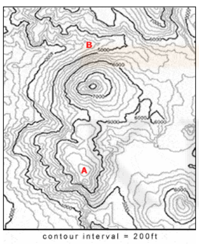
3.1 Introduction

Chapter 3 is briefly discussed about the materials and methods that were involved in the process of completing this research and in the process to meets the research's objectives.

3.2 Materials

3.2.1 Field equipment

Table 3.1 List of field equipment

Field Equipment	Name	Uses
	Base Map	The base map is the topographical map of the study area to determine our location in the field.

	Global Positioning System (GPS),	GPS is used to locate our coordinate and outcrop coordinate in the field. Then, Gps also is used to record the track in the field.
	Compass	Compass is used to fin the North direction and bearing in the field and to measure the strike and dip of the outcrop bedding.
	Geology Hammer	Geology hammer is used to breaks the outcrop into hand specimen.
	Measuring tape	A measuring tape is used to measure the outcrop dimension.
	Hydrochloric acid (HCl)	HCl is used to test the presence of quartz and calcite mineral.
	Hand lens	The hand lens is used to observe the mineral present in the hand specimen.
	Plastic sample	Plastic samples are used to place the rock samples.

	Camera	The camera is used to take a photo of the outcrop or the rock samples with the scale for further reference and as a proof.
	Notebook and stationary	Notebook and stationary use to sketch the outcrop discover in the field.

3.3 Methodology

3.3.1 Preliminary study

Preliminary study is the first step or as the preparation before going further in this study. A well carried preliminary study can give better information and will guide the researcher well in conducting and completing their research.

3.3.2 Field study

(a) Mapping

General geological mapping is involved with the observation of the structural geology, lithology, geomorphology and the stratigraphy towards the outcrop in the study area. The traversing method is the method that uses for the mapping process. This geological mapping process was done by referring to the base map, compass, and GPS. Strike and dip readings were taken when there was a bedding structure presence and the trend and plunge readings were taken for the presence of joint and fault structure. All of these readings are taken by using the compass. Next, the joint analysis reading in the field is done by taking the joint length by the measuring tape and its bearing by using the compass. Besides, all the outcrops that were found during the mapping activities at the study area, the coordinate must be marked in GPS or noted in the notebook.

(b) Sampling

The rock samples are very important in this research since the rock need to be observed to identify its rock's properties and its mineral characteristics. The rock samples were taken with the minimum size as large as the hand grip from the fresh outcrop that was found in the field by using the geological hammer. At the site, the sample was observed roughly.

3.3.3 Laboratory investigation

(a) Petrography study

The thin section of rock that has been prepared was examined under the plane polarized light (PPL) and under cross polarized light (XPL). For the sample preparation in thin section, first step is to cut the rock with the dimension of smaller than the glass slide by using the abrasive cut off machine. Next, the rock sample surface that have been cut and the glass slide are rubbed until the sample is flat and the glass slide become blurry or cloudy. After this process was done, the sample was undergoes the drying process at the room temperature followed by the drying process with the furnace. It is must be noted that the sample surface and the glass slide that have been rubbed must face above. While waiting the drying process to complete, the glue was made in which it was made from the mixture of Epoxy Hardener and Epoxy Resin with the ratio of 2:1 in a beaker and was stirred for about ten minutes until the bubble is disappearing.

When the mixture is already done, the mixture was put at the drying rock sample during the rock is still in hot and dry condition. The glass slide is then put at the rock sample. This rock sample was left for about one or two day or until the glue is completely dried before proceed to the next step. The next step is to cut the sample as thin as a paper by using the thin section thinning system machine. Last but not least, the sample was rubbed by using the Silicon Carbide Powder 320 (P400) Grit by using the grinder polisher machine. Careful step must be taken to run this step because if the process is too fast, the sample can be broken into pieces.

After the thin section is prepared, the rocks were observed under the polarizing microscope to study its mineralogical and rock's properties. During this observation, mineral textures and its composition were observed. The mineral texture is including the optical mineralogy of the rock like colour, cleavage, texture, twinning and other distinct mineral's characteristics. Besides mineral texture and its composition are being analysed, the percentage of the mineral presence was also determined.

Then, the percentage Q (Quartz), A (K-feldspar) and P (Plagioclase) was recalculated to plotted the mineral percentage in the Q-A-P classification diagram as discussed at the literature review section. The recalculation of the QAP percentage is calculated by using the formula as shown in Eq. (3.1) – (3.3). After that, the rocks were classified and named.

To plot the IUGS classification diagram, total QAP ($\sum QAP$) is determine first as shown in Eq. (3.1). Then, recalculate the QAP percentage as shown in Eq. (3.2). After recalculated the value, plot the Q concentration at the IUGS classification diagram based on its percentage.

$$\sum QAP = Q + A + P \tag{3.1}$$

$$\%Q = \frac{Q}{\sum QAP} \times 100 \ \ and \ \ \%A = \frac{A}{\sum QAP} \times 100 \ \ and \ \ \%P = \frac{P}{\sum QAP} \tag{3.2}$$

Next, recalculate again the percentage of A or P as shown in Eq. (3.3) to get their new percentage value before plotting it in IUGS classification diagram.

$$\%A = \frac{A}{\sum AP} \times 100 \ \ or \ \ \%P = \frac{P}{\sum AP} \times 100 \tag{3.3}$$

After all value was plotted, the rock then was being able to be named by finding the intersection between the Q percentage with A or P percentage.

(b) Geochemical study

In the geochemical study, the rock was crushed or grinded into powder before running the XRF test. The sample preparation for XRF analysis involved the process of turning the rock sample into powder. The rock was crushed and grinded by adding it to the grinding machine. Next, the powdered sample was filled into the spec-cap by using the spatula and was inserted to the press tool. Then, the top inlay was inserted to the press tool to cover the powdered material and then, insert the plunger to completely close the press tool. After the process was done, this press tool was put at the pellet press machine for one to two minutes to produce the pressed pellet. Take out the pressed pellet from the press tool and loaded it into the x- ray system for the sample analysis. It must be noted that the pressed pellet should be at least 3mm.

This XRF test was coupled with ICP-MS test to get more detail and accurate interpretation of elements in the sample since ICP-MS has low detection limits. ICP-MS only can receive the sample in the vapour form. Thus, the solid form of the granite rock samples needs to convert into liquid form first by acid digestion method. So, for the sample preparation method, first step is to turn the rock sample into the powder by using the grinding machine. Then, about 0.5g rock powder was dissolved by using 5ml of Nitric acid (HNO_3), 10ml of Hydrogen Fluoride (HF) and 1ml of Hydrochloric Acid (HCl). This dissolution process is done in the Teflon beaker. The sample then is covered by using the cap and is being heated at the hot plate with 120°C of temperature for about 12 hours in a closed digestion. After heated, the lid was removed to let the evaporation process takes place to let the removal of silica and fluoride to the air.

After the evaporation process is done, 5ml of HF and 10ml of HCL are added in order to incipient dryness. Fluorides element was break when HNO_3 was added to the sample. Finally, 15ml of concentrated HNO_3 is evaporated completely and 30ml of HCL is added to dry the residue in the Teflon beaker and heated gently to get a clear solution. This solution then was used to run the ICP-MS test.

Both XRF and ICP-MS was used to detect the major elements and both major and trace elements that presence in the rocks. Then, the data from both of this test were used to interpret the magma affinities and its tectonic setting.

3.3.4 Data processing

The geological map was processed by using the ArcMap software 10.2 versions. The track that recorded in GPS along the field study area was transferred and processed into ArcMap by using the Dnrgps software. The joints reading was processed by using the GeoRose software to know the major force that deformed the rock and the strike and dip readings were processed by using the StereoNet software.

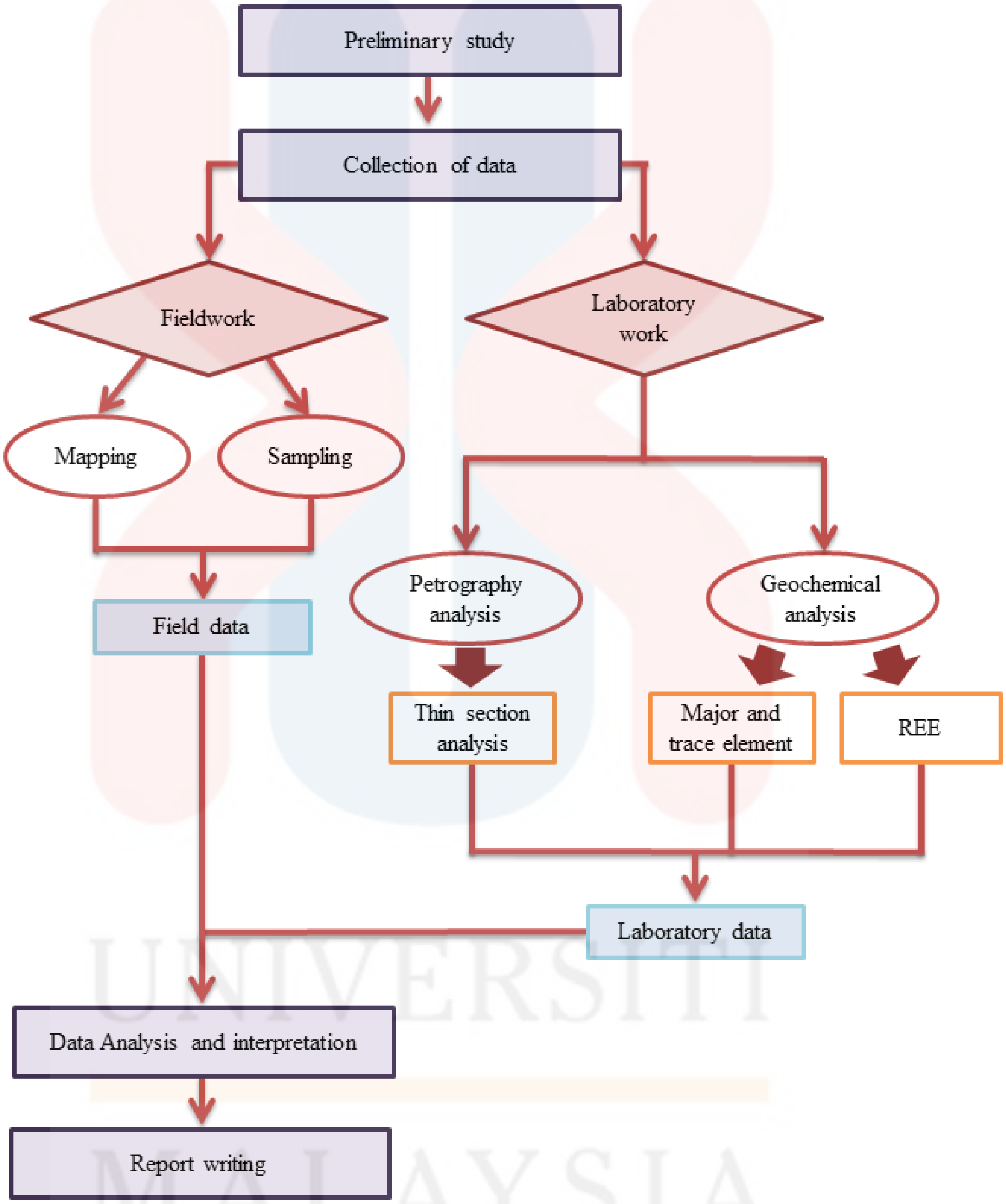
3.3.5 Data analysis and interpretation

The data that obtained from the mapping activities, stratigraphy analysis as well as structural analysis will be analysed and interpreted by using the related software or by self-interpretation to represent the general geology of the study area. Besides, the interpret data must in corresponding with the petrography and geology of the study area. Petrographic data of the granitoid rocks are used to identify the rock mineral composition and texture, and in turn to name the rock. The geochemical data is used to confirm the petrographic data in term of rocks name and classification, as well as to interpret the tectonic setting. Besides it is also used to determine the distribution of REE.

3.36 Report writing

After all the data collecting and analysis process is complete, the data then is recorded in the report by writing process and arranged by chapter following the report procedures and format.

RESEARCH FLOWCHART



CHAPTER 4

GEOLOGY

4.1 Introduction

In this chapter, all the data or information that have been collected and retrieved from the mapping activities in Bandar Utama Gua Musang are being discussed. The data or information covers all the geology of the study area which includes the geomorphology, lithostratigraphy, geological structure, historical geology and the mechanism of the structure. The traverse and observation map, geomorphology map, and drainage map were provided in this chapter for further understanding of the landform and characteristics of the study area. Besides, all the data and information in this chapter also were used to produce the geological map of Bandar Utama Gua Musang as shown in Appendix 1. However, the geological map with the scale 1:25,000 cannot be shown on the paper due to the different scale when saving the map from ArcGis into word or image. Thus, the geological map with the exact scale was only can be found in digital geological map.

This chapter is very important for the geologist to find out or identify the past event that had been occurred in the study area. Since the study area is at Bandar Utama Gua Musang and most of the area is a Palm Oil Plantation with main road and byroad respectively, the accessibility is quite good.

4.1.1 Accessibility

This accessibility section explored the capability of the study area for being reached from other locations to the other locations. In order to access or approach the area, it required road like main road, byroads or villagers pathway, certain transport mechanism like motorcycle, four wheel car or others transport that suitable with physical and size of the road and the telecommunication system. The telecommunication system in the study area is quite good. Only certain area like forest and some rural area have a low coverage. Moreover, accessibility is also related to the socioeconomic of the people in Bandar Utama Gua Musang. This is because with the presence of city, school, mosque and plantations that contribute much in the social and economy of Bandar Utama Gua Musang people, the main roads, by-road or off-road and railway accessibility were developed as shown in Figure 4.1. Thus, the mapping activities are thoroughly effective.

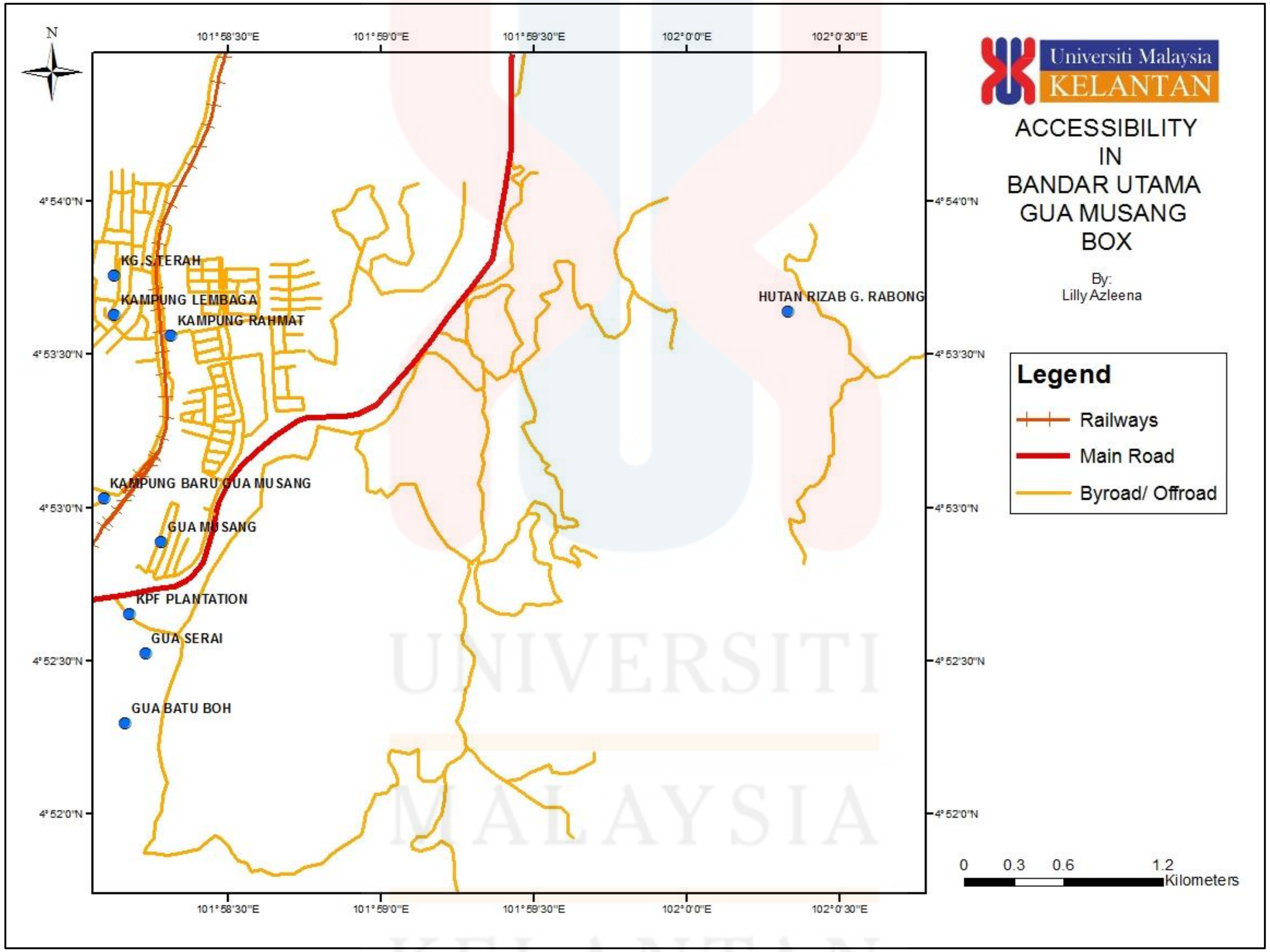


Figure 4.1 Accessibility map of the study area.

4.1.3 Settlement

Settlement explained the places that are being settled by humans involving the government agreement or private agreement in order to develop a community. According to the official portal of Gua Musang District Council website, Gua Musang district is the result of expansion area operations from 1.76 Km^2 to 129.5 Km^2 where it involving Kampung star, Kampung Pulai, Pasir Tumbuh, Chegar Bogor, Kampung Kerinting, Limau Kasturi, Batu Papan and Lepan Jaya. They also stated that total jurisdiction of Gua Musang district increased up to the 7,979.77 Km^2 with the addition of Galas District, Bertam District and Chiku District. There are several villages that settled in the study area which are Kampung Sungai Terah, Kampung Rahmat, Kampung Tembaga and Kampung Baru Gua Musang. All of these villages are located at the western part of the study area.

4.1.4 Vegetation

There are three major types of vegetation that can be found in Bandar Utama Gua Musang which are Palm oil Plantation, followed by Rubber plantation and forestry. About 80% of the study area was covered by Palm Plantation, 15% of rubber plantation and 5% of forestry. Vegetation like palm plantation and rubber plantation are the main contributors in opening the job opportunities for people in Gua Musang to enhance their economy and living cost.

Palm oil is the main vegetation that covers almost all the part of the study area. This Palm plantation is held by KPF Plantation Sdn. Bhd Company. Most of the palm trees were planted on hilly area where some of the places change the landscape of Bandar Utama Gua Musang. The changing of the landscape is due to the hill is being cut to plant the palm saplings. Thus, resulting in the changing of hill physical and the hill looks like a barren hill as shown in Figure 4.2.

The rubber plantation is found at the foothill of Gunung Rabong and area next to the KPF Plantation. Figure 4.3 shows the Rubber Plantation at Gunung Rabong foothill.

Figure 4.2 Palm saplings at KPF Plantation

Figure 4.3 Rubber Plantation at Gunung Rabong foothill

4.1.5 Traverses and observation

Mapping activities is done by using the traversing and observation method in order to collect the data and rock sampling process. This traverses and observation method is done by accessing the study area through the road or river. The river is being traversed because usually the fresh outcrop or well exposed outcrop can be found along the river. Before traversing and observation, the location is being set and the route is being planned. When traversing and observing, different contour pattern in Topographic Map is being studied first to identify the lithology on that area. The traverses route and observation point is recorded in GPS and plotted in the Map as shown in Figure 4.4. Besides, every observation points that being marked in GPS also being recorded in notebook for more detailed description. The description involved the information like coordinate, elevation, lithology, strike and dip, weathering level, rock's colour or vegetation types.

Based on the map in Figure 4.4, only about 80% of the study area is being covered. Certain part of the study area that does not being traversed because the areas have high slope and no accessibility

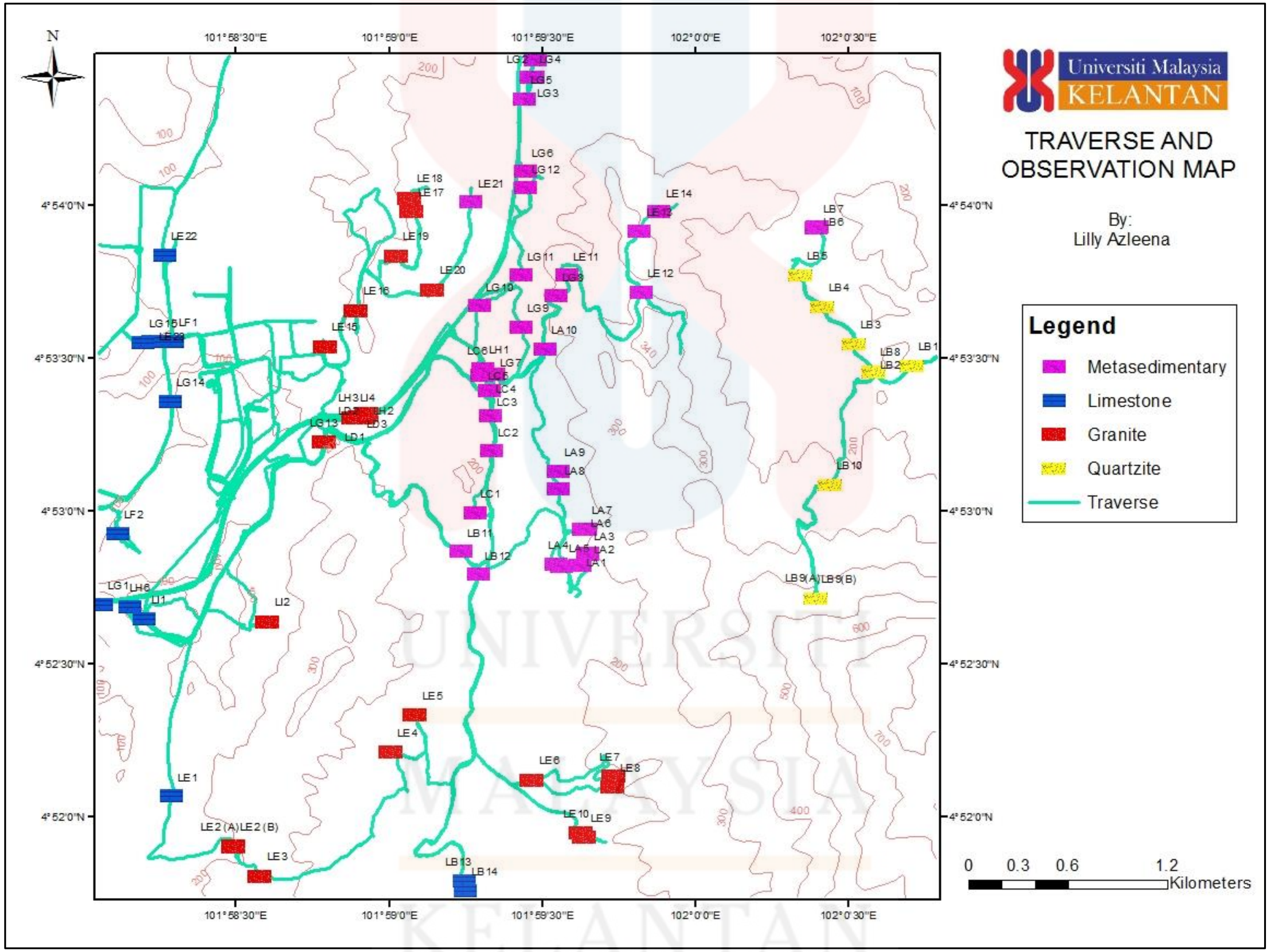


Figure 4.4 Traverses and waypoints

4.2 Geomorphology

Geomorphology section is discussed about the topography classification, weathering process and the drainage pattern in the study area. Observing and studying the geomorphology for a locations can help the observer to identify various types of landscape and landform features, detect the physical changes of the earth landforms and give a hint about the potential hazard that can be happen naturally or environmentally. Besides, by understanding the geomorphology, human can develop and planning their socioeconomic in the safe way and efficiently. Observing the geomorphology of a location is done by accessing the higher slope or higher elevation of the study all the area of Bandar Utama Gua Musang. Figure 4.5 shows the geomorphology of Bandar Utama Gua Musang.

Figure 4.5 Geomorphology of Bandar Utama Gua Musang

Endogenic and exogenic process is the key processes that contribute in the changes of the landform in the study area. Endogenic process is the process that driven by the forces that comes from within the earth whereas the exogenic process is the process that driven by the forces that comes from on or above the earth. This exogenic process can be accelerated by human activities. In the study area, the endogenic processes that involved are diastrophism, volcanism and metamorphism while the exogenic processes that involved are weathering and erosion, and mass movement.

4.2.1 Geomorphology classification

The geomorphology of Bandar Utama Gua Musang can be classified based on their topography and rock's type landform. The topography of the study area is divided into two which are hilly and mountainous and rolling and undulating. The rock's type landform also divided into two which are karst landform and the granite landform.

Based on the 2D and 3D geomorphology map in Figure 4.6 and Figure 4.7 respectively, hilly and mountainous landform is dominant in the study area with the mean elevation above the sea level range from 150m to 900m. The highest elevation is located at the south-eastern part of the map which is the Gunung Rabong. Next, rolling and undulating terrain is covered the western part of the study area. From the geomorphology map, flat land alternates with gentle and undulating slope indicates that the study area topography is a rolling and undulating. The mean elevation of this terrain is range from 0m to 150m. The Karst landforms give rises to the formation of rolling and undulating topography at Gua Musang. This karst landform is form by the carbonate bedrock that gives rise to the karstic landscapes like cave and steep rock cliff. Then, granite landform is one of the types of geomorphology in study area. The granite landform strikes from north to south of the western part of the study area with the mean elevation above the sea level range from 0m to 300m.

The granite landform can be seen along the main road Gua Musang to Kuala Krai as shown in Figure 4.8. The granite landform also can be found along the tributaries found at southern part of KPF Plantation with large boulders.

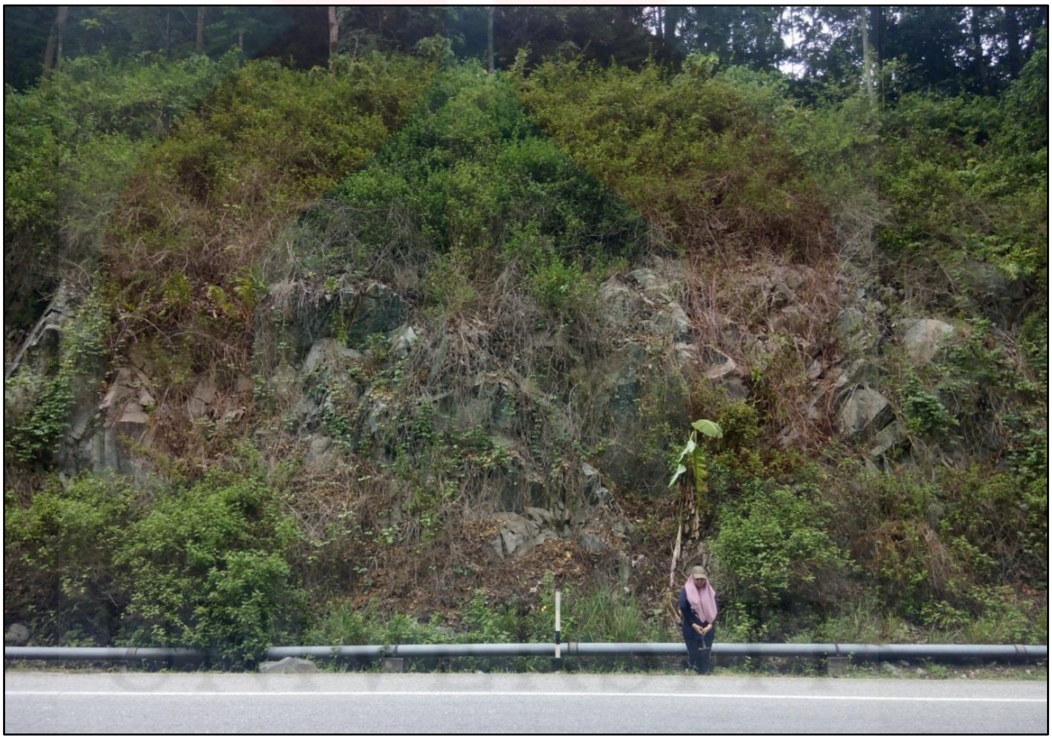


Figure 4.8 Granite landform Gua Musang-Kuala Krai main road

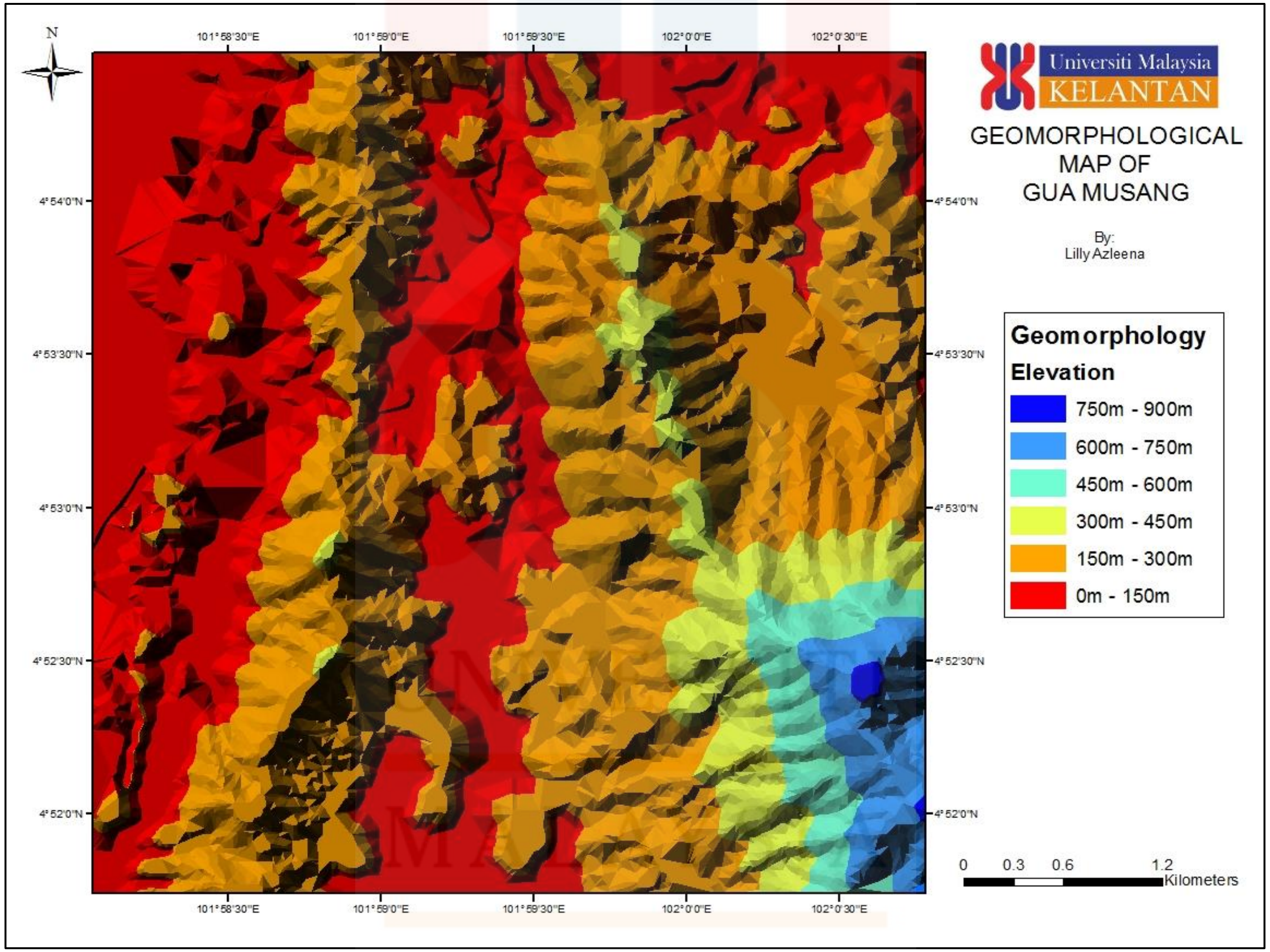


Figure 4.6 2D Geomorphological Map

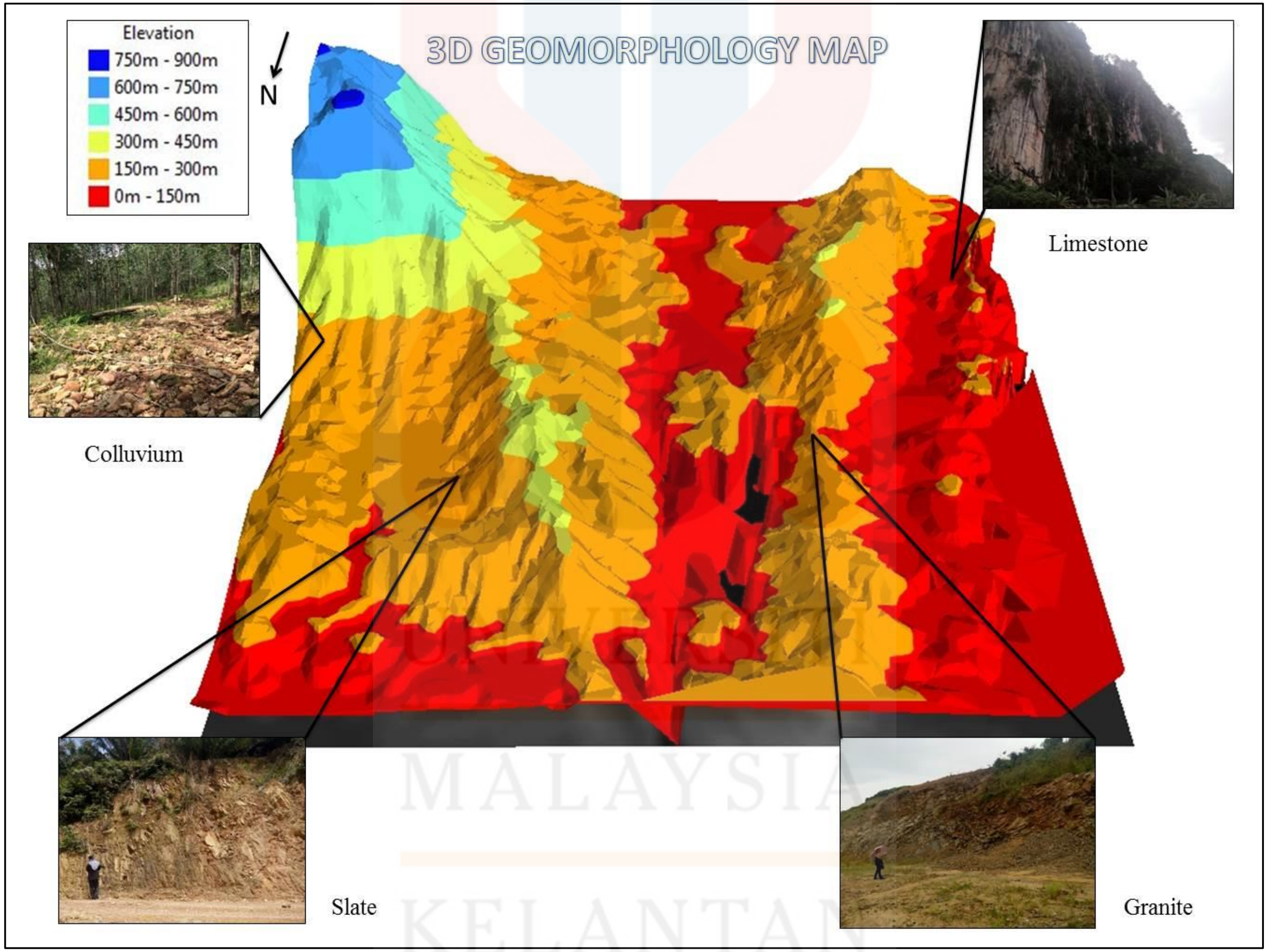


Figure 4.7 3D Geomorphological Map

4.2.2 Weathering

There are three types of weathering process that be found in the study area which are physical weathering, chemical weathering and biological weathering. Any rocks that undergo the weathering process will become regolith or soil. Thus, the soil composition is depends on what type of parent rock that have been weathered. Weathering process have a significant to human daily life because after the rock turns into the soil, the soil can be used to plant the vegetation, build the house, quarrying , making clay and others.

Physical weathering is the process of breakdown the rock into the smaller fragments without changing the composition of the rock. Physical weathering that be found in the study area are abrasion by water, wind and gravity, thermal expansion and frost wedging as shown in Figure 4.9.

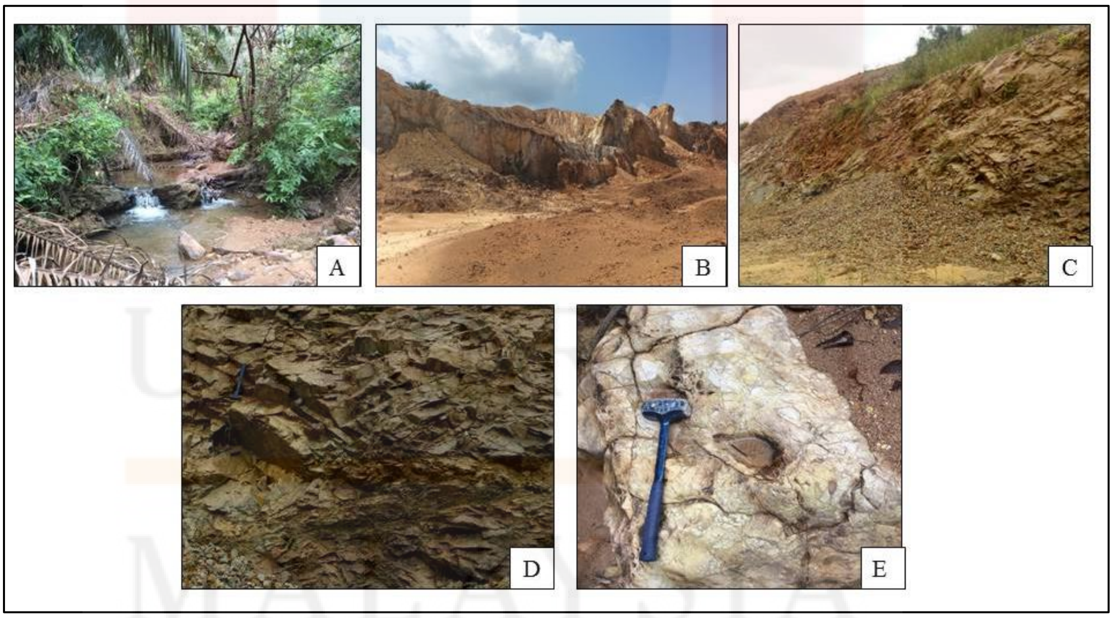


Figure 4.9 Physical weathering of rock. (A) Abrasion by water along river. (B) Abrasion by wind in Tuff quarry. (C) Abrasion by gravity. (D) Joint in rock cause by thermal expansion. (E) Pot holes that cause by the frost wedging process.

Furthurmore, chemical weathering is the process of breaking down the rock through chemical changes and it changes the rock composition. Chemical weathering that found in the study area are carbonation, oxidation and solution (Figure 4.10).

Figure 4.10 Chemical weathering of rock. Carbonation process forms a cave (A). Oxidation weathering that gives the rock rusty-like look (B). Solution weathering forming the stalactite on limestone cave (C)

Biological weathering is the weathering process where the rock is disintegrated by plants, animals or microbes. Root penetration by tree in rock and black algae growth on rock surface are two types of biological weathering found in the study area (Figure 4.11).

Figure 4.11 Biological weathering process where the tree and plant roots penetrate into the rock cause them to crack and breaks.

4.2.3 Drainage pattern

According to the drainage pattern map in Figure 4.12, there are three types of drainage pattern in the study area which are dendritic pattern, rectangular pattern and parallel pattern.

Dendritic pattern have a shaped like a tree-like pattern that composed of branching tributaries and main stream. Then, the rectangular pattern where the pattern that have an angle closely to 90° that usually cause by the fault or joint of the underlying bedrock. The pattern also usually associated with the massive, intrusive igneous and metamorphic rock. The parallel pattern shows the streams branching in the same direction. Normally, the parallel patterns are the indicative of beds that have a gentle dipping or uniformly sloping topography.

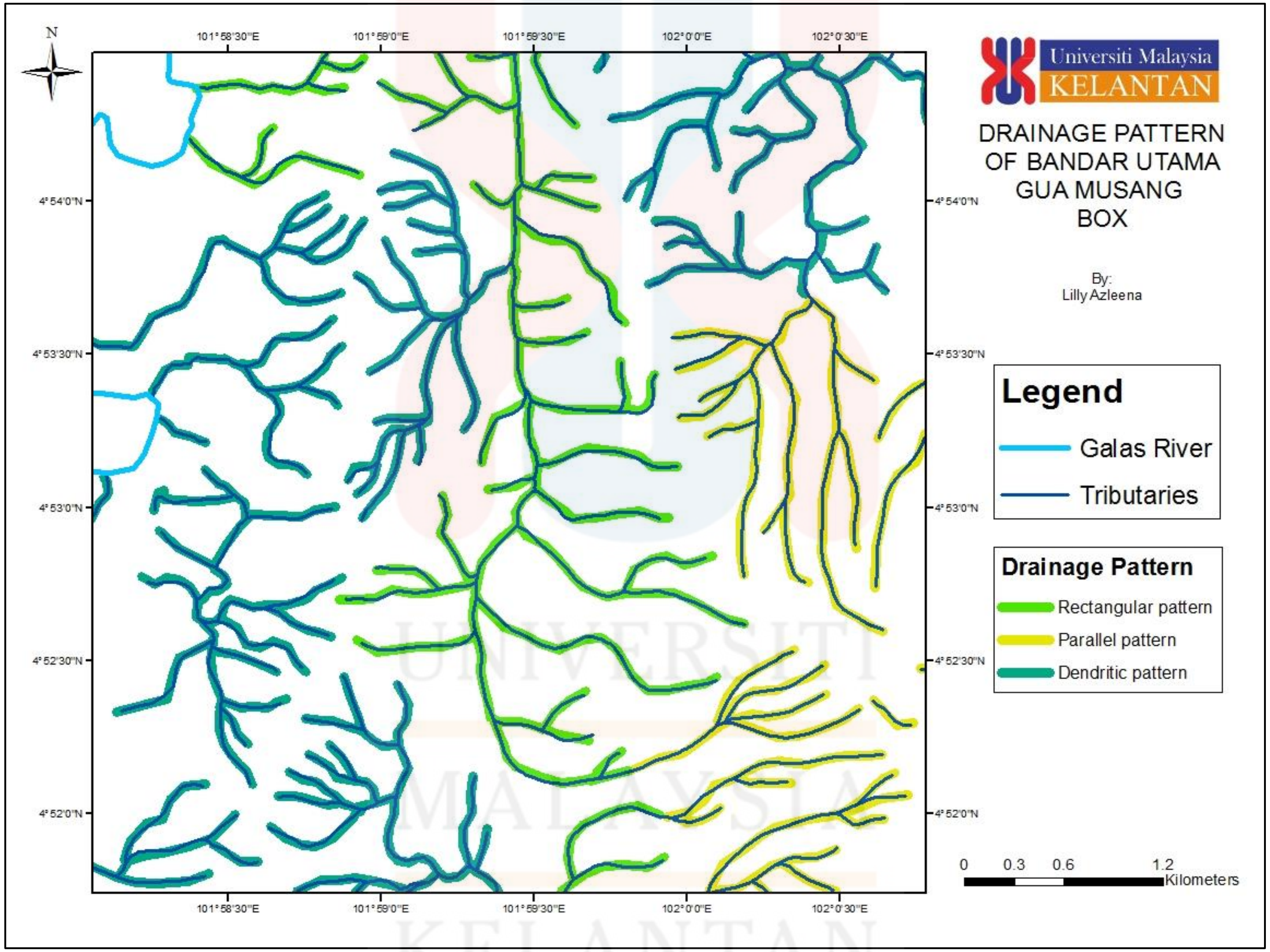


Figure 4.12 Drainage pattern map of Bandar Utama Gua Musang

4.3 Lithostratigraphy

Lithology is study of a body of rock unit where it is describe based on the physical properties of rock like colour, texture, composition and the grain size of the rock. Meanwhile, stratigraphy is defined as the study of the arrangement of rock formation, distribution, chronological succession or order. Thus, lithostratigraphy is the combination of the lithology and the stratigraphy where it carries the meaning of study the physical relationship among the rock units. Studying the lithostratigraphy is essential because it allow us to order the events that have happened in the study area.

4.3.1 Stratigraphy

Stratigraphy section is discussed about the chronological order of the rock unit in the study area. The rock unit is the rock that had major distribution in the field and it size is mapable within the scale 1:25, 000. Based on the geological map in Figure 4.13, there were five types of rock unit which are metasedimentary rock, limestone, granite, quartzite and alluvium. The oldest rock is the metasedimentary rock during the Early Triassic and the youngest is the alluvium which is recent as shows in the lithostratigraphy column in Figure 4.14.

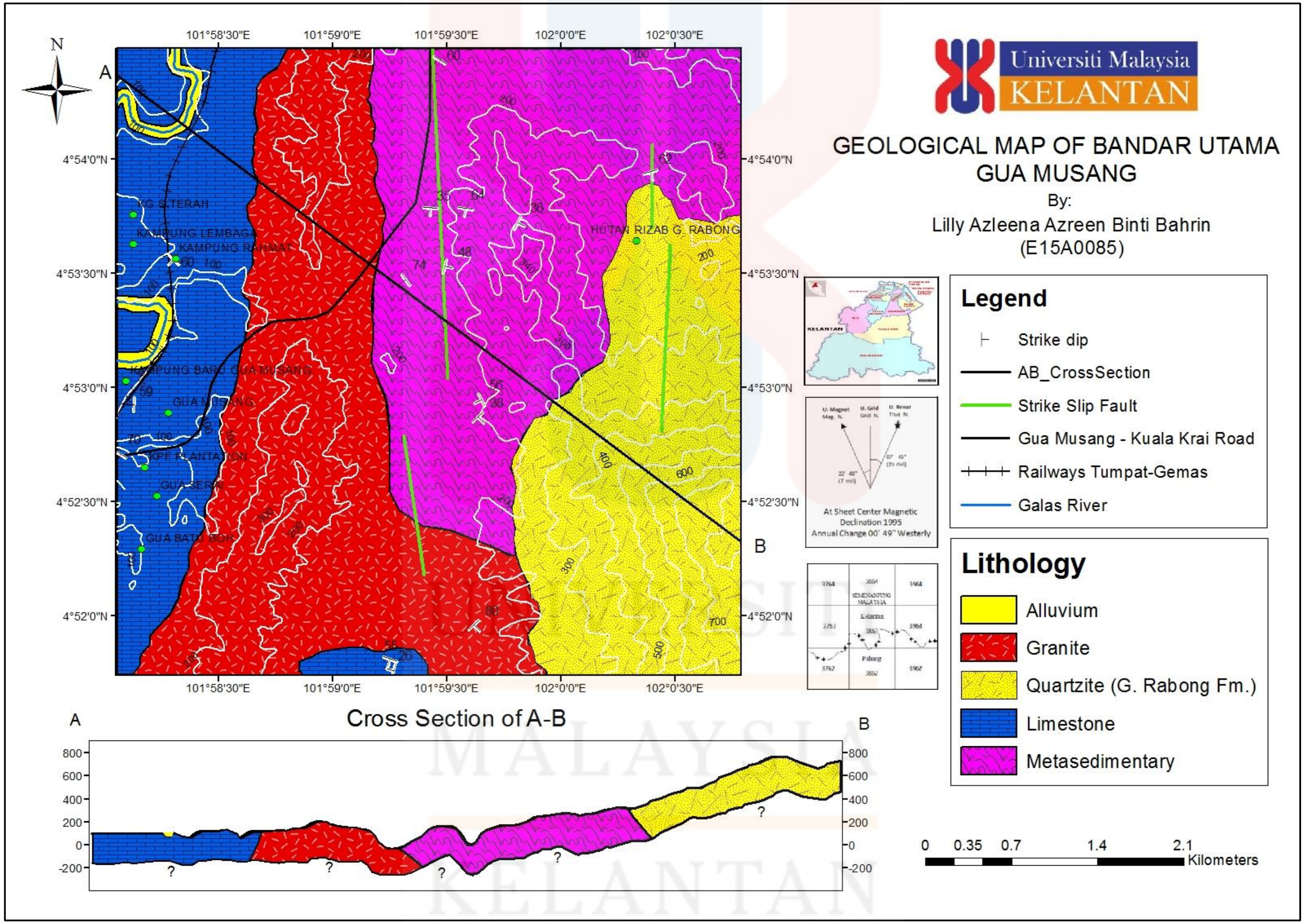
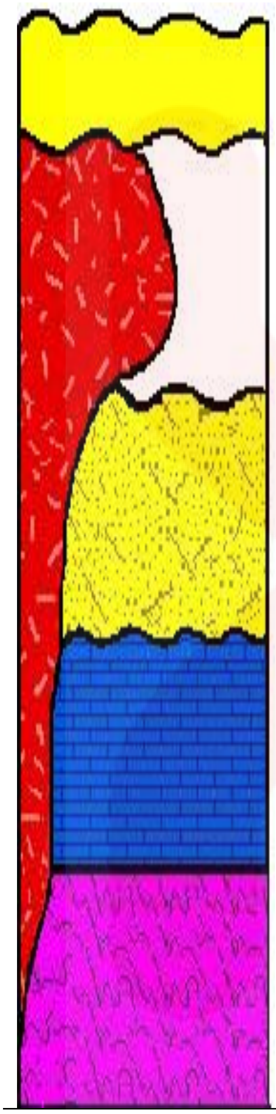


Figure 4.13 Geological map of Bandar Utama Gua Musang.

Lithology



		Age	Description
		Recent	**Alluvium**
Phanerozoic Eon	Mesozoic Era	Cretaceous	**Granite** - Consists of granite and alkali feldspar granite.
Phanerozoic Eon	Mesozoic Era	Cretaceous	**Quartzite** - Mainly quartzites subordinate with conglomerate.
Phanerozoic Eon	Mesozoic Era	Middle to Late Triassic	**Limestone/Marble** - Composed of limestone, and recrystallized limestone.
Phanerozoic Eon	Mesozoic Era	Early Triassic	**Meta-sediment** - Dominantly slate, slatey tuff, phyllite, meta-limestone,

Figure 4.14 Lithostratigraphy column of Bandar Utama Gua Musang

4.3.2 Unit explanation

In this subtopic, every unit as mentioned in section 4.3.1 will be discussed further with their petrography analysis.

(a) Metasedimentary rock

Metasedimentary rock in the study area can be divided into slate and phyllite. But, hornsfels rock also presence in this unit due to the intrusion of granite. The slate rock that found has a fine-grained in grain size and foliated as shown in Figure 4.15. In the slate facies, there is minor carbonaceous and tuffaceous shale that were also found. Then, phyllite (Figure 4.16) and hornfels (Figure 4.17) also found along the river near the Gunung Rabong foothill and along the main road of Gua Musang-Kuala Krai respectively. These hornfels rock is a non-foliated metamorphic rock and their formation is due to the alteration of heat causing the rock to change its mineral composition and hardened. The petrography analysis of slate, phyllite and hornfels are shown in Table 4.1, Table 4.2 and Table 4.3 respectively.

Figure 4.15 Tuffaceous slate. (A) Tuffaceous slate outcrop. (B) Tuffaceous slate rock hand specimen.

CODE: 18LALB7 (A)

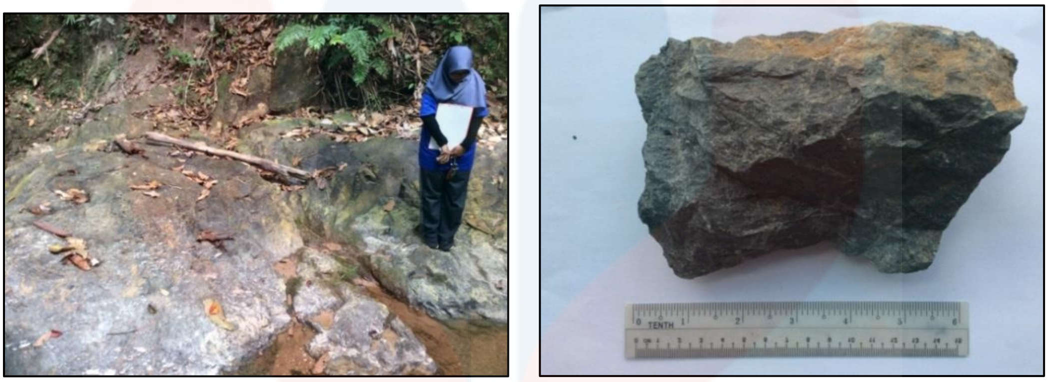


Figure 4.16 Phyllite. (A) Phyllite outcrop. (B) Phyllite rock hand specimen.

CODE: 18LALI3

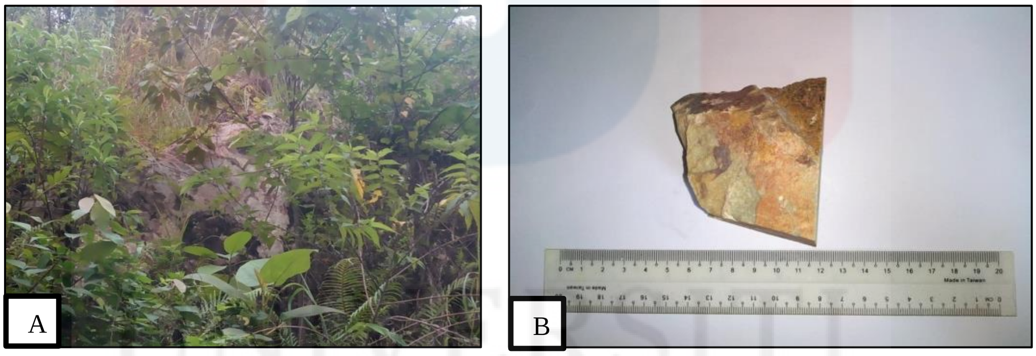


Figure 4.17 Hornfels. (A) Hornfels outcrop. (B) Hornfels rock hand specimen.

Table 4.1 Description of tuffaceous slate.

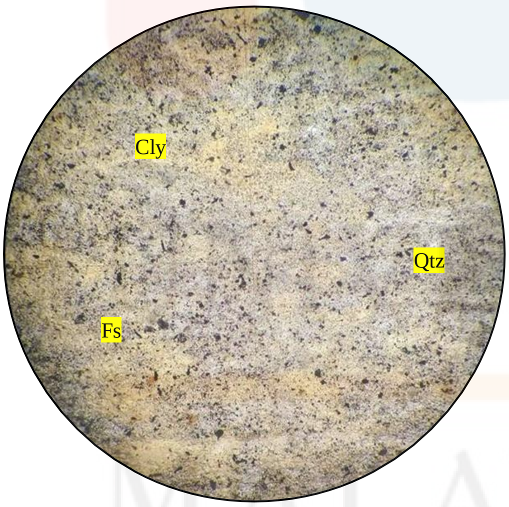
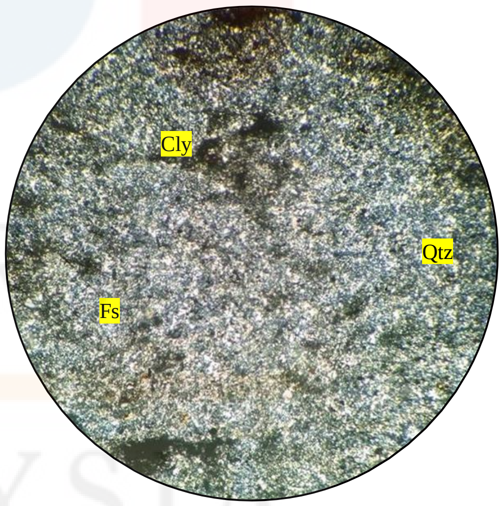
<table>
<tr><td>Sample code</td><td>:</td><td>18LALA14</td><td>Location : KPF Plantation, Gua Musang, Kelantan</td></tr>
<tr><td>Coordinate</td><td>:</td><td colspan="2">N 04° 53’ 31.8” / E 101° 59’ 30.6”</td></tr>
<tr><td>Rock Name</td><td>:</td><td colspan="2">Tuffaceous slate</td></tr>
<tr><td>Colour</td><td>:</td><td colspan="2">Dark grey</td></tr>
<tr><td>Structure</td><td>:</td><td colspan="2">In XPL, there is a folded structure (alternating of silty and clay materials)</td></tr>
<tr><td>Texture</td><td>:</td><td colspan="2">Very fine grained, foliated, the sortation is moderate sorted</td></tr>
<tr><td>Domination</td><td>:</td><td colspan="2">Matrix dominated</td></tr>
<tr><td colspan="4">Thin section Analysis</td></tr>
<tr><td>Minerals</td><td>%</td><td colspan="2">Description</td></tr>
<tr><td>Clay minerals (Cly)</td><td>40</td><td colspan="2">Altered feldspar mineral into a very fine grained size.</td></tr>
<tr><td>Quartz</td><td>25</td><td colspan="2">Colourless in PPL, light grey or white to dark black pleiochroism, low relief, no twinning, subhedral.</td></tr>
<tr><td>Feldspar</td><td>35</td><td colspan="2">Colourless, no twinning, altered (broken into small pieces), anhedral, low relief.</td></tr>
<tr><td colspan="4">Description
Slate rock has a very fine grained mineral. The folded structure reflects that the rock has a foliation.</td></tr>
<tr><td colspan="4">Image</td></tr>
<tr><td colspan="2">PPL

</td><td colspan="2">XPL

</td></tr>
<tr><td colspan="4">Magneficent: 10×/0.25 P</td></tr>
</table>

Table 4.2 Description of phyllite.

Sample code	:	18LALB7 (A)	**Location**	:	Gua Musang, Kelantan
Coordinate	:	N 04° 53’ 55.5” / E 102° 00’ 23.7”			
Elevation	:	120 m			
Rock Name	:	Phyllite			
Colour	:	Dark greenish			
Texture	:	Fine grained grain size, sub-angular grain shape, poorly sorted of sorting and the mineral fabric			
Structure	:	Foliation			
Domination	:	Fragment dominant			

Thin section Analysis

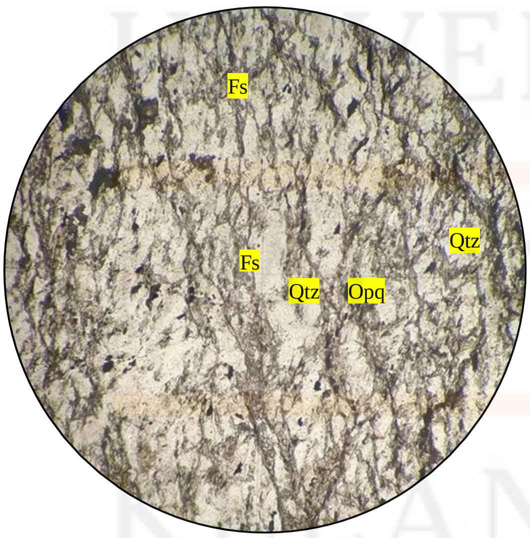
Minerals	**%**	**Description**
Feldspar (Fs)	35	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown, subhedral.
Quartz (Qtz)	50	Colourless in PPL, light grey or greyish white to dark black pleiochroism, low relief, no twinning, subhedral.
Opaque (opq)	15	Black colour in both PPL and XPL, no pleochroism, high relief.

Description

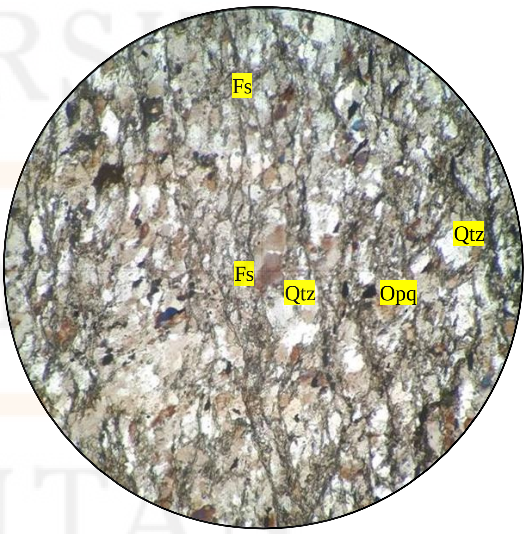
This rock is classified as the phyllite. From the thin section analysis, the rock has abundance mineral in which the mineral has same mineral composition like those in sedimentary rock. For more solid, the foliation is clearly seen from the thin section image below showing that this rock has undergoes the metamorphism process.

Image

PPL



XPL



Magneficent : 10x/0.25 P magnificent

Table 4.3 Description of hornfels.

Sample code	:	18LALI3	**Location**	:	Gua Musang, Kelantan
Coordinate	:	N 04° 53’ 19.2” / E 101° 58’ 46.0”			
Elevation	:	128 m			
Rock Name	:	Hornfels			
Colour	:	Light greenish			
Texture	:	Fine grained grain size, sub-angular grain shape, poorly sorted of sorting and the mineral fabric			
Structure	:	Non-foliated			
Domination	:	crystal dominant			

Thin section Analysis

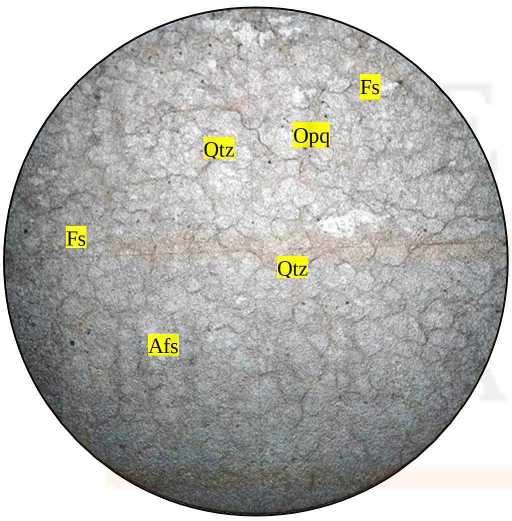
Minerals	**%**	**Description**
Feldspar (Fs)	25	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown, some altered
Quartz (Qtz)	50	Colourless in PPL, light grey or white to dark black pleiochroism, low relief, no twinning, subhedral.
Alkali Feldspar	15	Colourless in PPL, white to brown pleichroism, has twinning, subhedral.
Opaque (opq)	10	Black colour in both PPL and XPL, no pleochroism, high relief.

Description

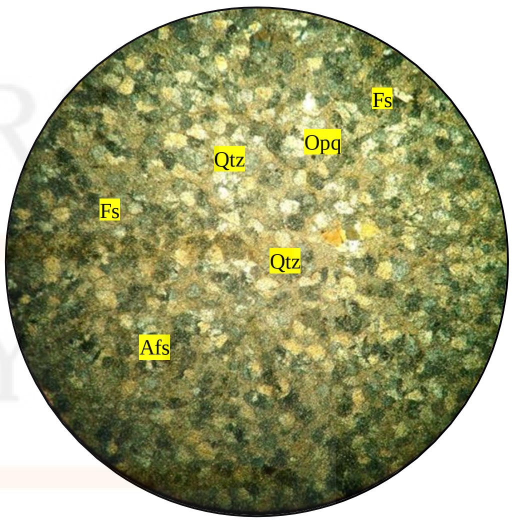
This rock is classified as hornfels or more specific is the politic hornfels because this hornfels is found near the granite intrusion.

Image

PPL



XPL



Magneficent : 4x/0.25 P magnificent

(c) Limestone

Limestone that found in the study area located at the western part of the map. Major limestone karst or hill that were found are Gua Musang cave and another cave (Gua Serai) that located across the main road that near to the Buddhism temple. Cave structure such as stalagmite, stalactite and pillar were found. Other limestone outcrop is found at Galas River, at the villages (western study area) and in KPF Plantation at the southern part of the map.

There are two types of limestone found in the study area which are recrystallize limestone (Figure 4.18) and marbelize limestone (Figure 4.19). These two types of limestones have difference formations which are limestone white in colour and carbonaceous limestones are black in colour. Normally, the limestone that white in colour is formed from direct precipitation of calcium carbonate ($CaCO_3$) from marine water and fresh water like rain. This formation is a chemical origin. The carbonaceous limestone is from a biological origin. Detail petrography description is shown in Table 4.4 and Table 4.5.

CODE: 18LALB13 (A)

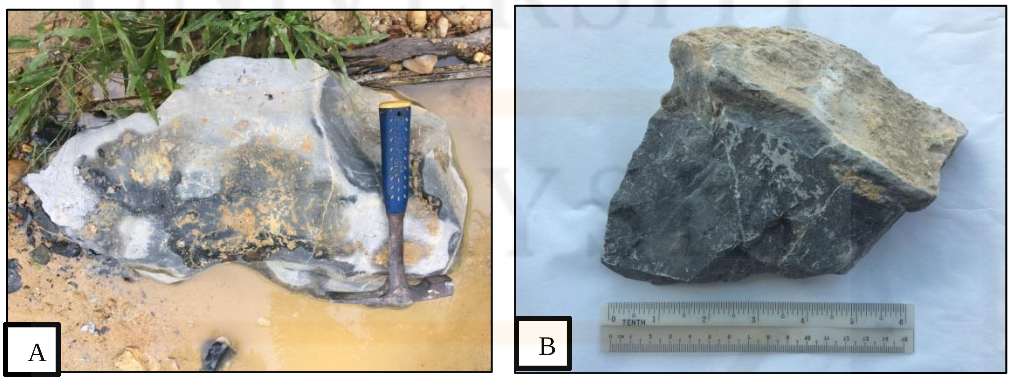


Figure 4.18 Recrystallize limestone (A) Recrystallize limestone outcrop at dry tributaries. (B) Recrystallized limestone hand specimen.

CODE: 18LALB14 (B)

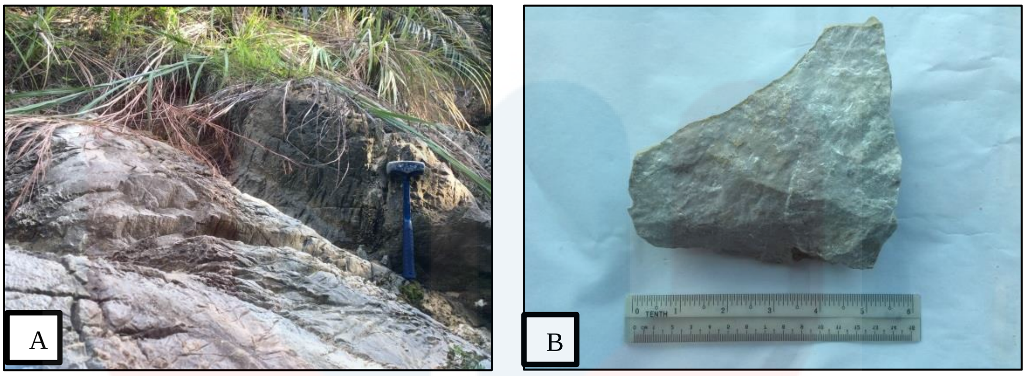


Figure 4.19 Marbelize limestone.(A) Marbelize limestone outcrop found at tributaries. (B) Marbelize limestone rock sample (B).

Table 4.4 Description of recrystallize limestone.

Sample code	:	18LALB13 (A)	**Location**	:	KPF Plantation, Gua Musang, Kelantan.
Coordinate	:	N 04° 51’ 47.5” / E 101° 59’ 14.7”			
Rock Name	:	Recrystalize limestone			
Colour	:	Black			
Texture	:	Fine grained limestone, sub-angular grain shape, poorly sorted.			
Domination	:	Crystal or fragment dominant			

Thin section Analysis

Minerals	**%**	**Description**
Calcite (Calc)	85	White to brownish, cleavage does not appear.
Clay minerals (Cly)	15	Altered feldspar mineral into a very fine grained sized.

Description

The rock is named meta-limestone because from the thin section image below, the rock is at the phase of recrystallized where the mineral starts to forming crystal together, compacted and arranged. Besides, the image shows that there is still some ooids that presence. This shows that the limestone is undergo metamorphism but not fully metamorphosed and still can be classified as limestone. Thus the rock is named as recrystallize limestone.

Image

PPL

XPL

Magnificent: 10x/0.25P

Table 4.5 Description of marbelize limestone.

Sample code	:	18LALB14 (B)	**Location**	:	KPF Plantation, Gua Musang, Kelantan.
Coordinate	:	N 04° 51’ 45.7” / E 101° 59’ 14.9”			
Rock Name	:	Marbelize limestone			
Colour	:	White			
Texture	:	Medium fine grain size, sub-angular grain shape, poorly sorted.			
Domination	:	Crystal dominant			

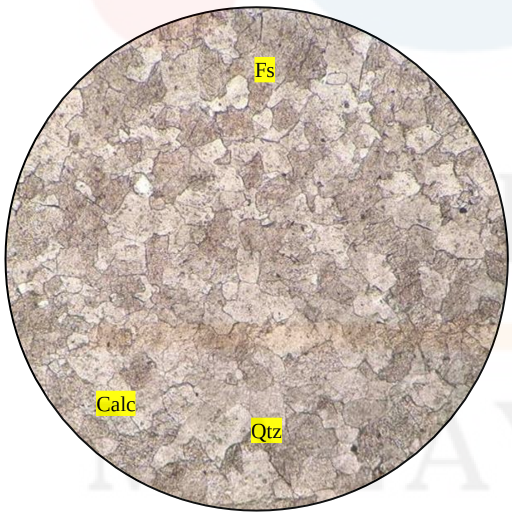
Minerals	**%**	**Description**
Calcite (Calc)	60	White to brownish, have a cleavage but not very clear, no cleavage appear.
Feldspar (Fs)	15	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown, subhedral
Quartz (Qtz)	25	Colourless in PPL, light grey or white to dark black pleiochroism, low relief, no cleavage.

Description

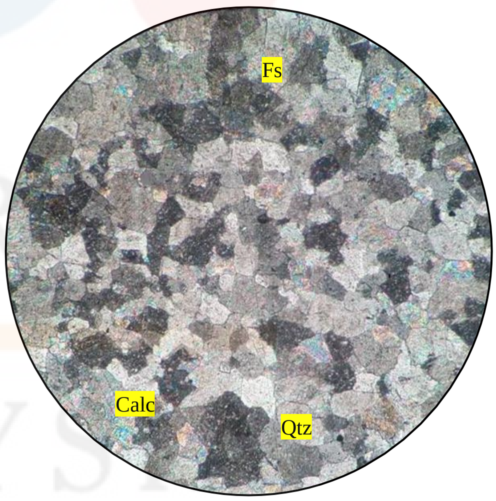
From the thin section image below, the grain of the rock is tightly packed together and arranged. This shows that the limestone undergo the metamorphism process becoming the marbelize limestone. The calcite cleavage is not very clear, thus hard to calculate its cleavage.

Image

PPL



XPL



Magnificent: 10x/0.25P

(d) Granite

Granite landform or granitoids were found along the Gua Musang – Kuala Krai main road, KPF Plantation and at Quarry near the Bandar Utama Gua Musang. There are two types of granitoid found in Bandar Utama Gua Musang which are biotite granite (Figure 4.20) and alkali feldspar biotite granite (Figure 4.21 and Figure 4.22). The difference between biotite granite and alkali feldspar biotite granite is based on the contents of the feldspar group mineral in rock which are plagioclase and orthoclase. Besides, quartz mineral also play important role in determine the granitoid types. Following the law of Cross-cutting relationships, anything that intrudes or disturbed the layer is the youngest one. Thus, the intrusion of the granite makes the granitoid is the youngest rock in Gua Musang Formation and overlies the Gunung Rabong Formation which are during the Createaceous age. The calculation for IUGS classification is shows in Appendix 1.

The biotite granite that found in the study area has moderately high of plagioclase mineral content. The plagioclase mineral gives rises to the grey colour of the granite. Besides, quartz and biotite minerals also abundance as shown in petrography analysis image in Table 4.6.

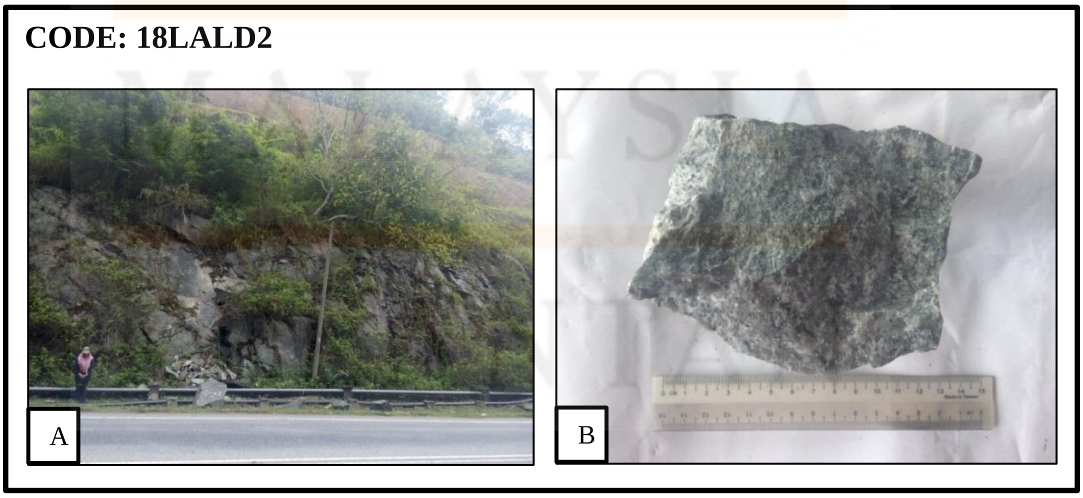


Figure 4.20 Biotite Granite rock. (A) Outcrop found along Gua Musang-Kuala Krai main road. (B) Hand specimen of granite.

Alkali feldspar granite is the granitic rock that abundance in Orthoclase mineral or known as the alkali feldspar. Since orthoclase mineral have a colour white to medium pink, it gives rises to the pink colour in granite as shown in the hand specimen in both Figure 4.21 and Figure 4.22. Besides, quartz and biotite are also abundance in pink granite mineral compositions. Detailed thin section of alkali feldspar biotite granite is in Table 4.7 and Table 4.8.

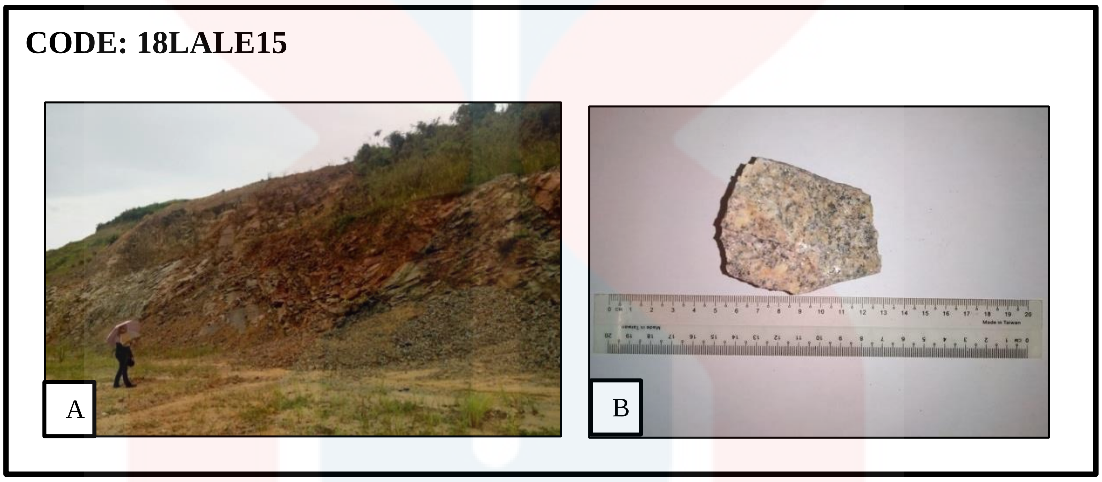


Figure 4.21 Alkali Feldspar Biotite granite(18LALE15). (A) outcrop found at quarry. (B) Hand

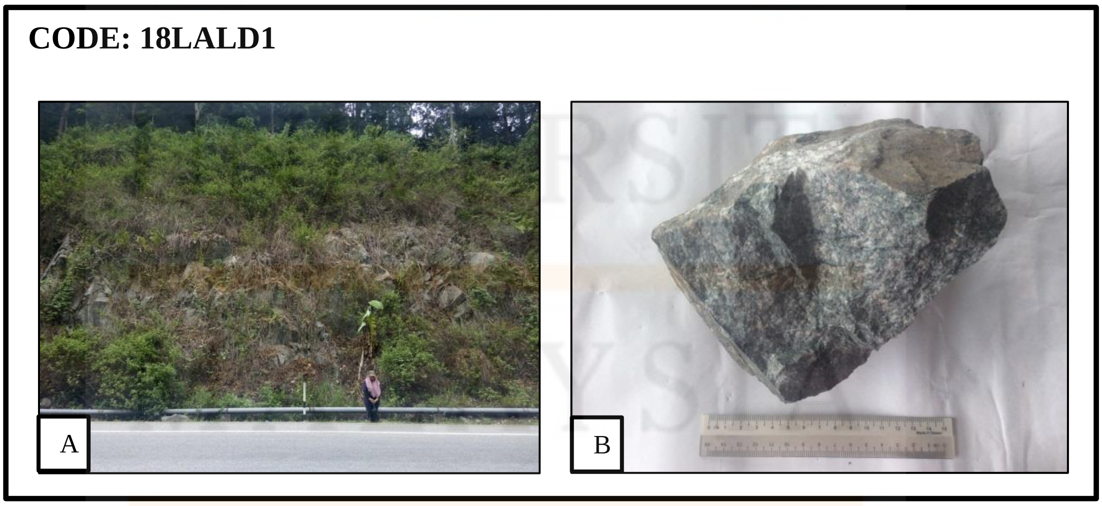


Figure 4.22 Alkali Feldspar Biotite granite (18LALD1). (A) Outcrop found Along Gua Musang-Kuala Krai main road. (B) Hand specimen.

Table 4.6 Description of Biotite granite

Sample code	:	18LALD2	**Location**	:	Along main road Gua Musang-Kuala Krai, Gua Musang, Kelantan.
Coordinate	:	N 04° 53’ 18.1” / E 101° 58’ 55.6”			
Classification	:	IUGS Classification			
Rock Name	:	Biotite granite			
Colour	:	Greyish			
Texture	:	Pheneritic with degree of crystalinity is holocrystaline. Subhedral and hypidiomorphic of crystal relationship.			

Thin section Analysis

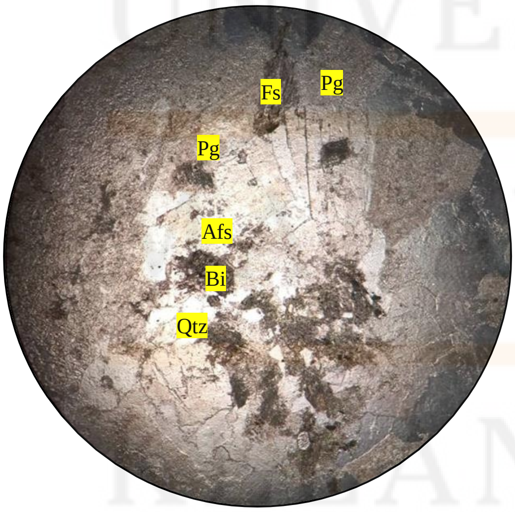
Minerals	**%**	**Description**
Plagioclase (pg)	17	Colourless in PPL, have twinning with the extension angle 5°, black to white pleichroism, subhedral.
Feldspar (Fs)	16	Altered feldspar, twinning is not clear, the mineral look like broken into very fine crystal.
Quartz (Qtz)	35	Colourless in PPL, light grey or white to dark black pleiochroism, low relief, no twinning.
Biotite (Bi)	20	Brownish to yellow with dark brown to black pleiochroic haloes, low relief, no cleavage appear, anhedral.
Alkali feldspar (Afs)	12	Have twining, black to light grey pleichroism, subhedral, the extension angle is 13°.

Description

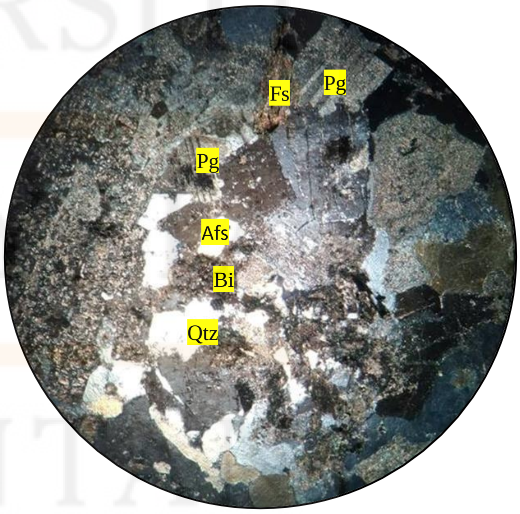
When preparing the thin section, the granite rock is moderately fresh and some of the biotite mineral is no longer shiny when observe with naked eyes. Since biotite mineral is abundance and based on the IUGS Classification in Appendix 1, the rock is named as biotite granite.

Image

PPL



XPL



Magneficent: 4x/0.1 P

Table 4.7 Description of Alkali Feldspar biotite granite (18LALD1)

Sample code	:	18LALD1	**Location**	:	Quarry, Gua Musang, Kelantan.
Coordinate	:	N 04° 53’ 18.1” / E 101° 58’ 54.9”			
Classification	:	IUGS Classification			
Elevation	:	135 m			
Rock Name	:	Alkali Feldspar Biotite granite			
Colour	:	Light green to slightly pink			
Texture	:	Phaneritic with degree of crystalinity is holocrystaline. The individual crystal is subhedral and hypidiomorphic of crystal relationship.			

Thin section Analysis

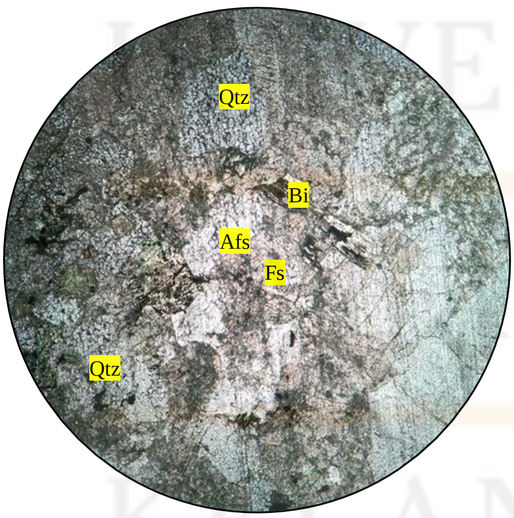
Minerals	**%**	**Description**
Biotite (Bi)	15	Brownish to yellow, low relief, no cleavage appear, anhedral.
Quartz (Qtz)	35	Colourless in PPL, light grey, bluish, brown to dark black pleiochroism, low relief, no twinning, subhedral.
Alkali Feldspar (Afs)	25	Colourless in PPL, Has a twinning with extension angle is 15°, subhedral
Feldspar (Fs)	25	Altered feldspar, twinning is not clear, the mineral look like broken into very fine crystal.

Description

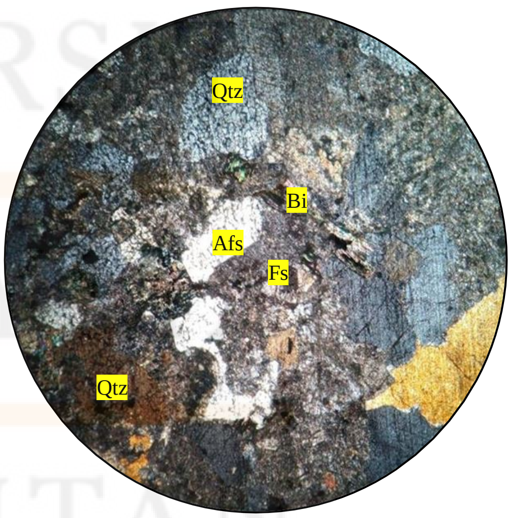
The hand specimen is moderately fresh. The rock is classified as alkali feldspar due to the abundance of Orthoclase mineral than plagioclase. With the presence of biotite, the rock is named as alkali feldspar biotite granite.

Image

PPL



XPL



Magneficent : 4x/0.1 P

Table 4.8 Description alkali feldspar biotite granite (18LALE15)

Sample code	:	18LALE15	**Location**	:	Quarry, Gua Musang, Kelantan.
Coordinate	:	N 04° 53’ 32.4” / E 101° 58’ 47.4”			
Classification	:	IUGS Classification			
Elevation	:	135 m			
Rock Name	:	Alkali Feldspar Biotite granite			
Colour	:	Light pink			
Texture	:	Pheneritic with degree of crystalinity is holocrystaline. The individual crystal is subhedral and hypidiomorphic of crystal relationship.			

Thin section Analysis

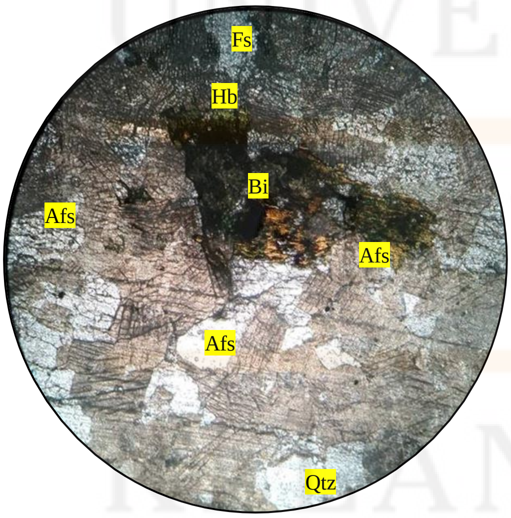
Minerals	**%**	**Description**
Biotite (Bi)	25	Brownish to yellow with dark brown to black pleiochroic haloes, low relief, no cleavage appear, anhedral.
Quartz (Qtz)	25	Colourless in PPL, light grey, bluish, brown to dark black pleiochroism, low relief, no twinning, subhedral.
Feldspar (Fs)	15	The plagioclase is weathered, twinning is not clear
Hornblende (Hb)	5	Greenish to brown pleiochroism.
Alkali feldspar (Afs)	30	Brown or black to white pleichroism, have twinning with the extension angle 19°, subhedral.

Description

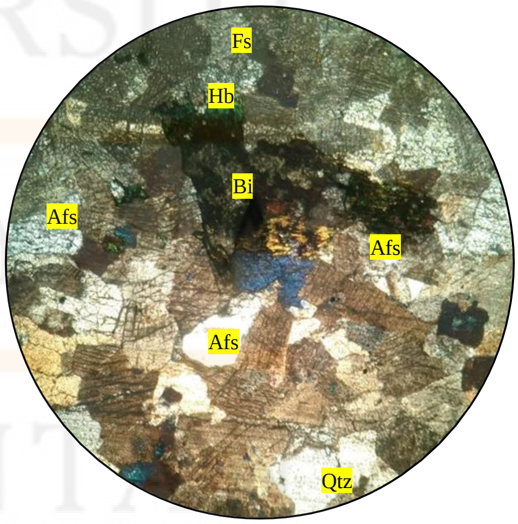
The hand specimen is slightly weathered. The rock also classified as alkali feldspar biotite granite due to the abundance of orthoclase (Afs) and biotite. Orthoclase mineral give rises to the pink colour of the granite.

Image

PPL



XPL



Magneficent : 4x/0.1 P

(e) Quartzite

This unit is under the Gunung Rabong Formation which is younger than Gua Musang Formation. This rock unit were found at the South-Eastern part of the map of study area. The quartzite is found along with a minor conglomerate. The quartzites is fine grained, purplish in colour (Figure 4.23b) at the contact with conglomerate whereas coarse grained quartzite with the presence of quartz vein at Gunung Rabong foothills (Figure 4.24) is in white in colour. The conglomerate are has a rounded to sub rounded large clasts (Figure 4.23c). The rounded clasts are dominantly quartz mineral with some feldspar mineral. All the thin section analysis in this unit is shown in Table 4.9, Table 4.10 and Table 4.11.

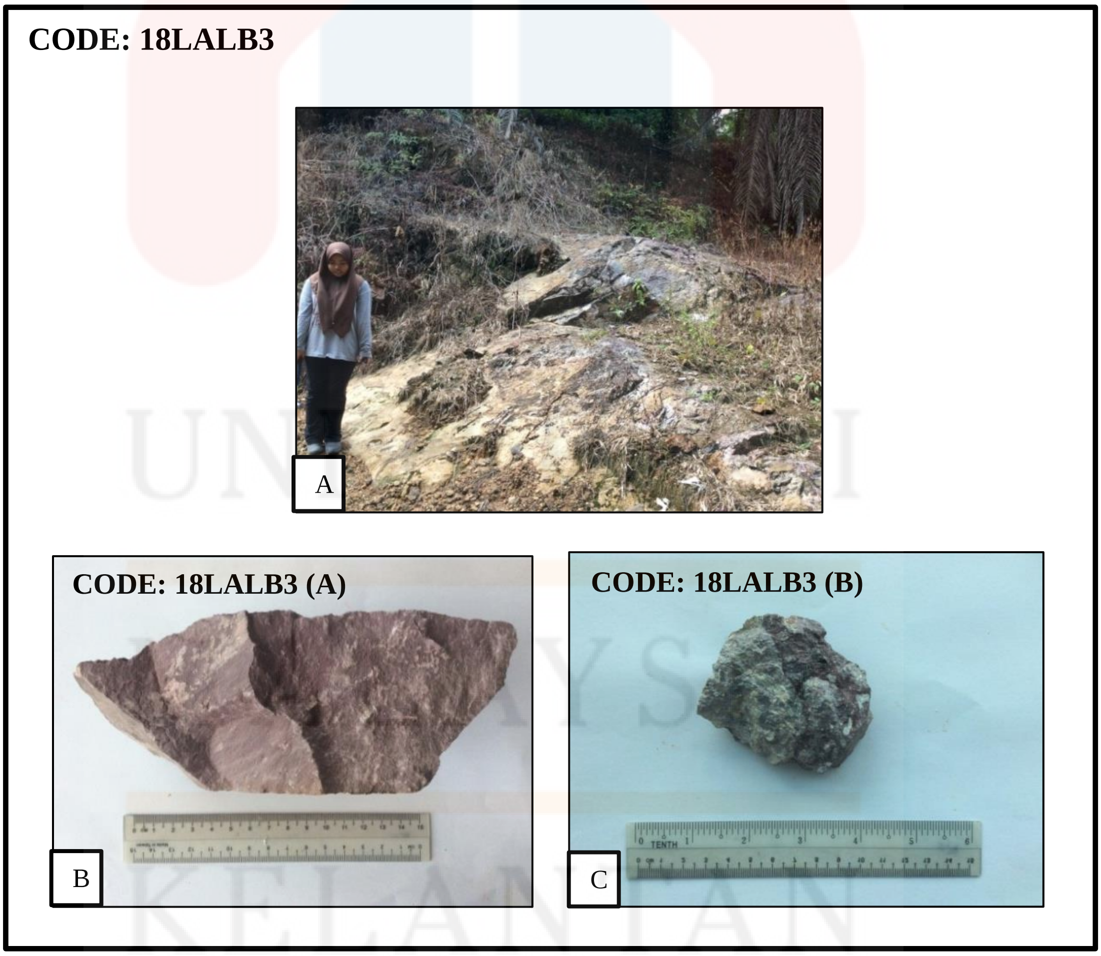


Figure 4.23 Quartzite and Conglomerate. (A) Outcrop of contact between quartzite and conglomerate. (B) Quartzite hand specimen. (C) Conglomerate hand specimen.

CODE: 18LALB7 (A)

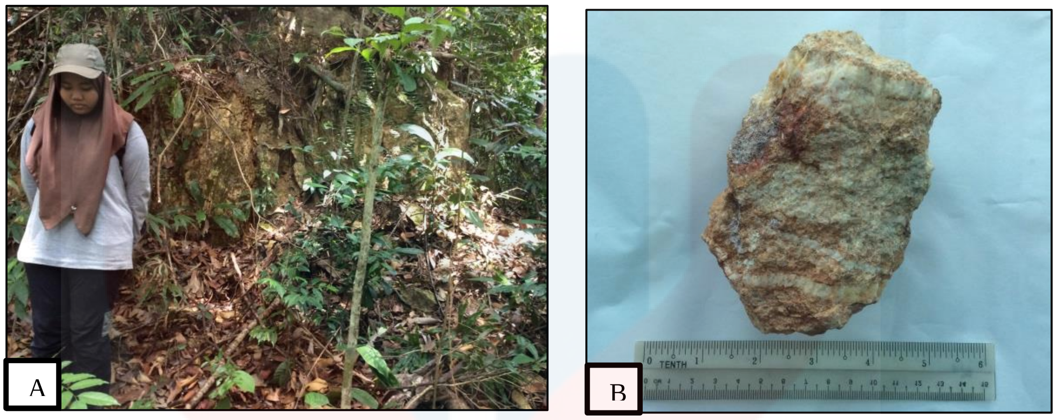


Figure 4.24 Quartzite. (A) Quartzite outcrop. (B) Quartzite hand specimen.

In addition, Gunung Rabong Formation also has minor tuff. There was silification process occurred in tuff unit forming the silicified tuff at the eastern part of the study area. This silification process replaced the mineral in the tuff with silicates mineral like quartz, feldspar and mica. The silicified tuff is harder than both fine grained and coarse grained tuff. Figure 4.25 shows the outcrop and hand specimen of the silicified tuff whereas Table 4.4 shows the description of the silicified crystal tuff.

CODE: 18LALB1

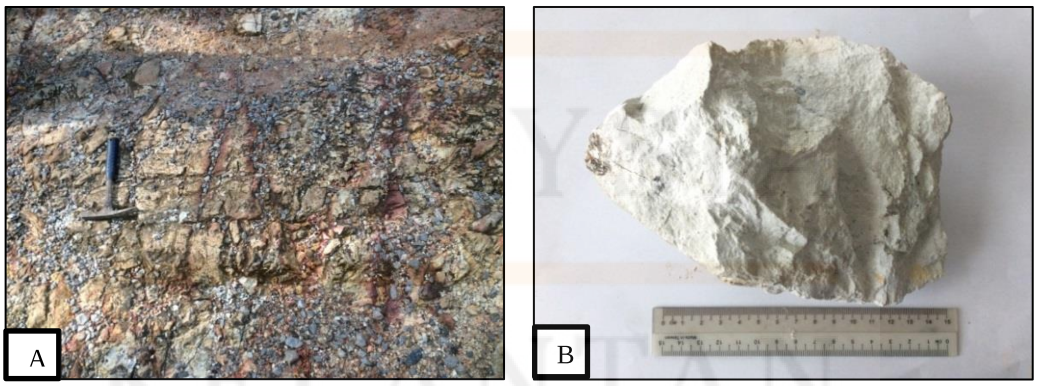


Figure 4.25 Silicified crystal tuff. (A) Silicified crystal tuff outcrop on the road. (B) Slicified crystal tuff rock hand specimen.

Table 4.9 Description of conglomerate

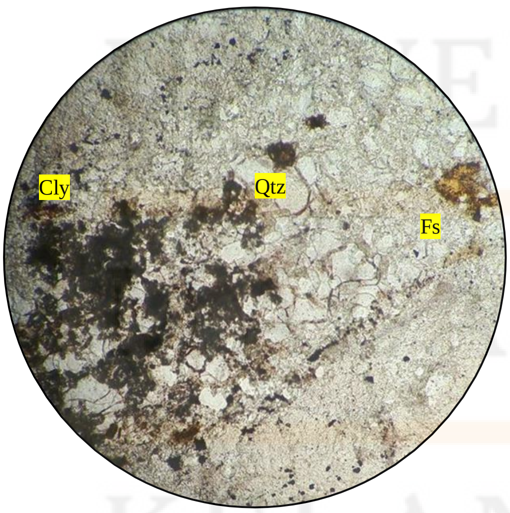
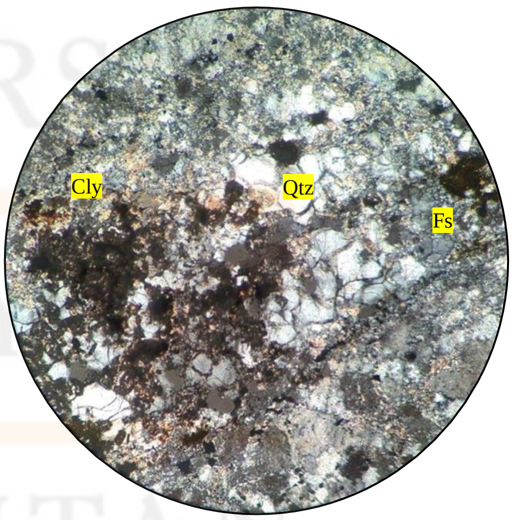
Sample code	:	18LALB3 (B)	**Location**	:	Palm Plantation, Gua Musang, Kelantan.
Coordinate	:	N 04° 53’ 32.8” / E 102° 00’ 31.1”			
Classification	:	-			
Elevation	:	140 m			
Rock Name	:	Conglomerate			
Colour	:	White clasts with purplish groundmass			
Texture	:	Very fine grained groundmass with sub-rounded crystal, sub-rounded to rounded grain shape, moderately sorted.			
Domination	:	Matrix dominated			

Minerals	**%**	**Description**
Quartz (Qtz)	30	Colourless in PPL, light grey or greyish white to dark black pleiochroism, low relief, no twinning.
Clay minerals (Cly)	50	Altered feldspar mineral into a very fine grained.
Feldspar (Fs)	20	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown.

Description

The hand specimen is moderately weathered. From the image of thin section below, only several quartz and feldspar clasts can be clearly seen. The shape of the granule is sub-rounded The black colour in both PPL and XPL is the mineral in the rock is being altered. The groundmass has altered feldspar classified as clay minerals with very fine grained grain size. The matrix that binds together the clasts may be the mixture of silt and clay with chemical cement.

Image

PPL	XPL
	

Magneficent : 10x/0.25 P

Table 4.10 Description of purplish quartzite.

Sample code	:	18LALB3 (A)	**Location**	:	Palm Plantation, Gua Musang, Kelantan.
Coordinate	:	N 04° 53’ 32.8” / E 102° 00’ 31.1”			
Elevation	:	140 m			
Rock Name	:	Quartzite			
Colour	:	purplish			
Texture	:	Fine grained, sub rounded to rounded grain shape, poorly sorted			
Domination	:	Fragments dominated			

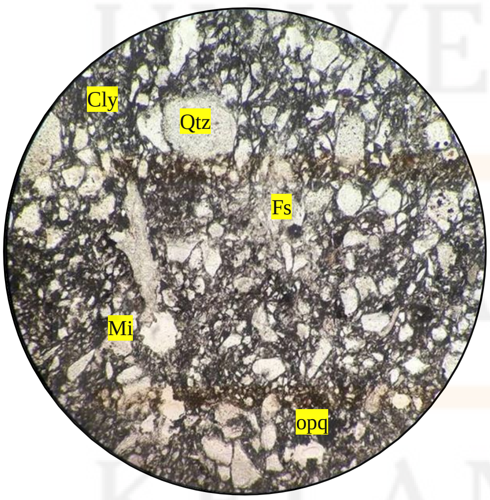
Minerals	**%**	**Description**
Quartz (Qtz)	45	Colourless in PPL, light grey or greyish white to dark black pleiochroism, low relief, no twinning, rounded to sub-angular.
Feldspar (Fs)	25	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown.
Clay minerals (Cly)	20	Altered feldspar mineral into a very fine grained.
Mica (Mi)	5	Bluish colour in XPL
Opaque minerals (Opq)	5	Black colour in both PPL and XPL

Description

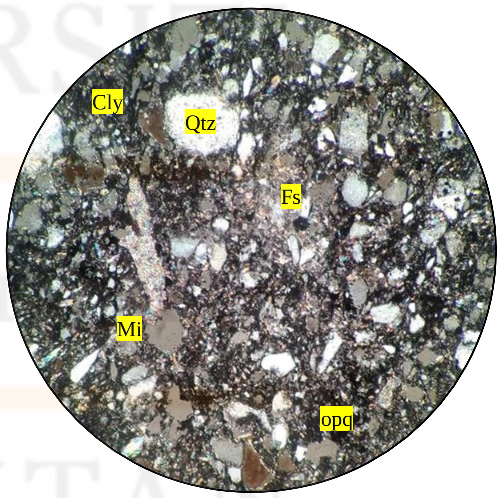
The hand specimen is fine grained in size with purplish colour, hard and foliated. In the thin section image below, the fragments has a rounded to sub-rounded grain shape and some fragments with sub angular grain shape. The matrix may compose of silt and mud particles that hold the clast together.

Image

PPL



XPL



Magneficent: 10×/0.25 P

Table 4.11 Description of white quartzite

Sample code	:	18LALB9	**Location**	:	Gunung Rabong, foothills
Coordinate	:	N 04° 52’ 42.8” / E 102° 00’ 23.6”			
Elevation	:	370 m			
Rock Name	:	Quartzite			
Colour	:	white			
Texture	:	coarse grained, sub rounded to sub angular grain shape, poorly sorted			
Domination	:	Fragments dominant			

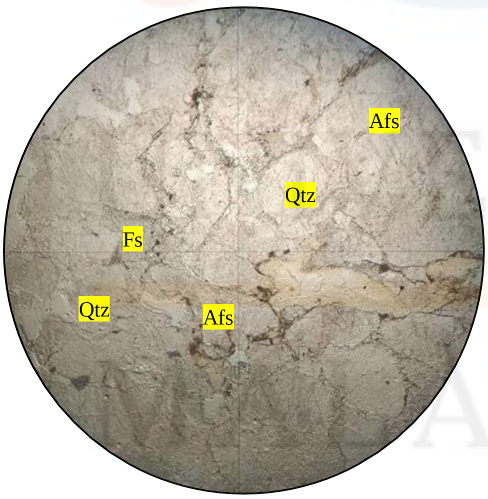
Minerals	**%**	**Description**
Quartz (Qtz)	50	Colourless in PPL, light grey or greyish white to dark black pleiochroism, low relief, no twinning, rounded to sub-angular.
Feldspar (Fs)	20	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown.
Alkali feldspar (Afs)	15	Bronish to black pleiochroism, have twinning, subhedral, colourless in PPL.

Description

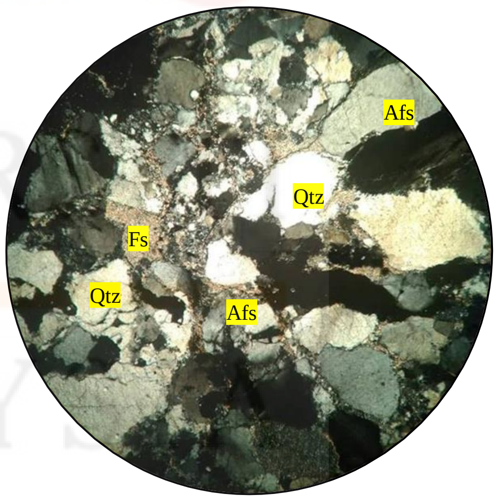
The hand specimen is coarse grain in size with white colour with quartz mineral is clearly seen. In the thin section image below, the fragments has a sub-rounded to sub angular grain shape.

Image

PPL

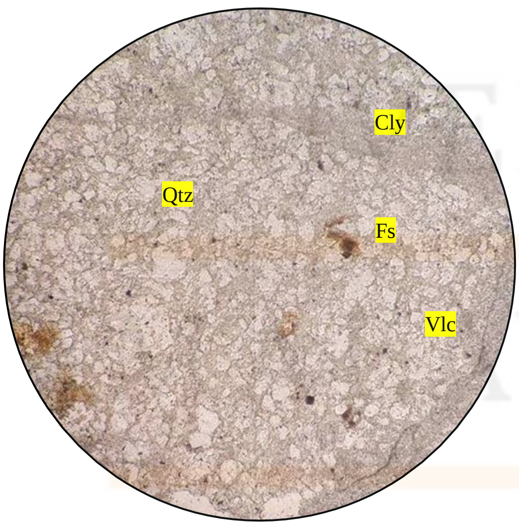
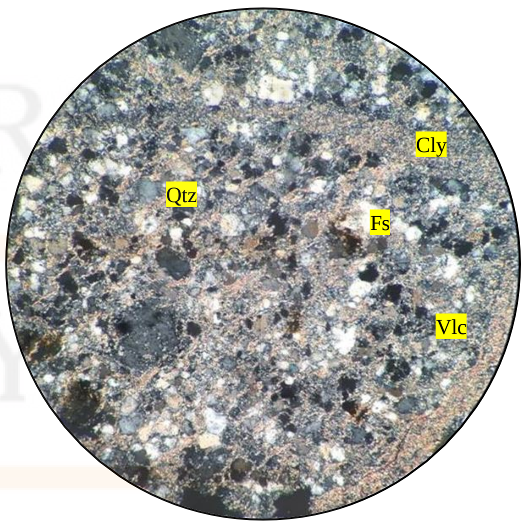


XPL



Magneficent: 4×/0.25 P

Table 4.12 Description of siliified crystal tuff

Sample code : 18LALB1		**Location** : Gua Musang, Kelantan
Coordinate : N 04° 53’ 28.5” / E 102° 00’ 42.5”		
Rock Name : Silicified crystal tuff		
Colour : white		
Texture : Fine grained with sub angular grain shape, poorly sorted.		
Domination : crystal dominant		
Thin section Analysis		
Minerals	**%**	**Description**
Quartz (Qtz)	30	Colourless in PPL, light grey or white to dark black pleiochroism, low relief, no cleavage.
Feldspar (Fs)	25	In PPL, Feldspar mineral is colourless and in XPL the colour have a range white to brown, has twinning
Clay minerals (Cly)	25	Altered feldspar mineral into a very fine grained sized.
Opaque minerals (Opq)	10	Black colour in both PPL and XPL, no pleochroism, high relief.
Volcanic ash (vlc)	10	Greyish, fine grained
Description The rock image from the thin section shows that the silicates mineral like feldspar and quartz is abundance in this rock. Besides, there is also presence of the volcanic ash that proved this rock is a tuff. Moreover, the mineral crystal is dominant. Thus, the rock is classified as the silicified crystal tuff.		
Image		
PPL		XPL
		
Magneficent: 10×/0.25 P		

(f) Alluvium

Alluvium is loose material, unconsolidated sediments that deposited or redeposited by the water in the river course (fluvial). The materials are composed of the fine particles like clay and silt and larger particles like sand and gravel. When this loose material is deposited, cemented and lithified, it is called as the alluvial deposits.

4.4 Structural Geology

In this section, all the structural geology that found in the study area like joints, fault, fold, and contact including their mechanisms are discussed. This section is essential to geologist because structural geology can tell the tectonic history of the study area, past environments that related to them and events that cause the rock to deform. As the rock deformed, it will changes it shape, positions and volume due to the forces that applied to them.

Before finding the regional structures in the study area, the lineament analysis in the study area is done as shown in Figure 4.26. The lineament analysis is done to identify the regional structure like faults in the study area. From the Figure 4.26, the lineament showing two major faulting which are sinistral strike slip faults on the centre of the map and dextral strike slip faults on the eastern part of the map.

Lineaments can be observed through satellite imagery or aerial image. Thus, in topographic map, any linear features like linear hill or linear river are the lineaments. This indicate that there is a structure that exerted in an area like faulting that can turns these features into a straight line shape.

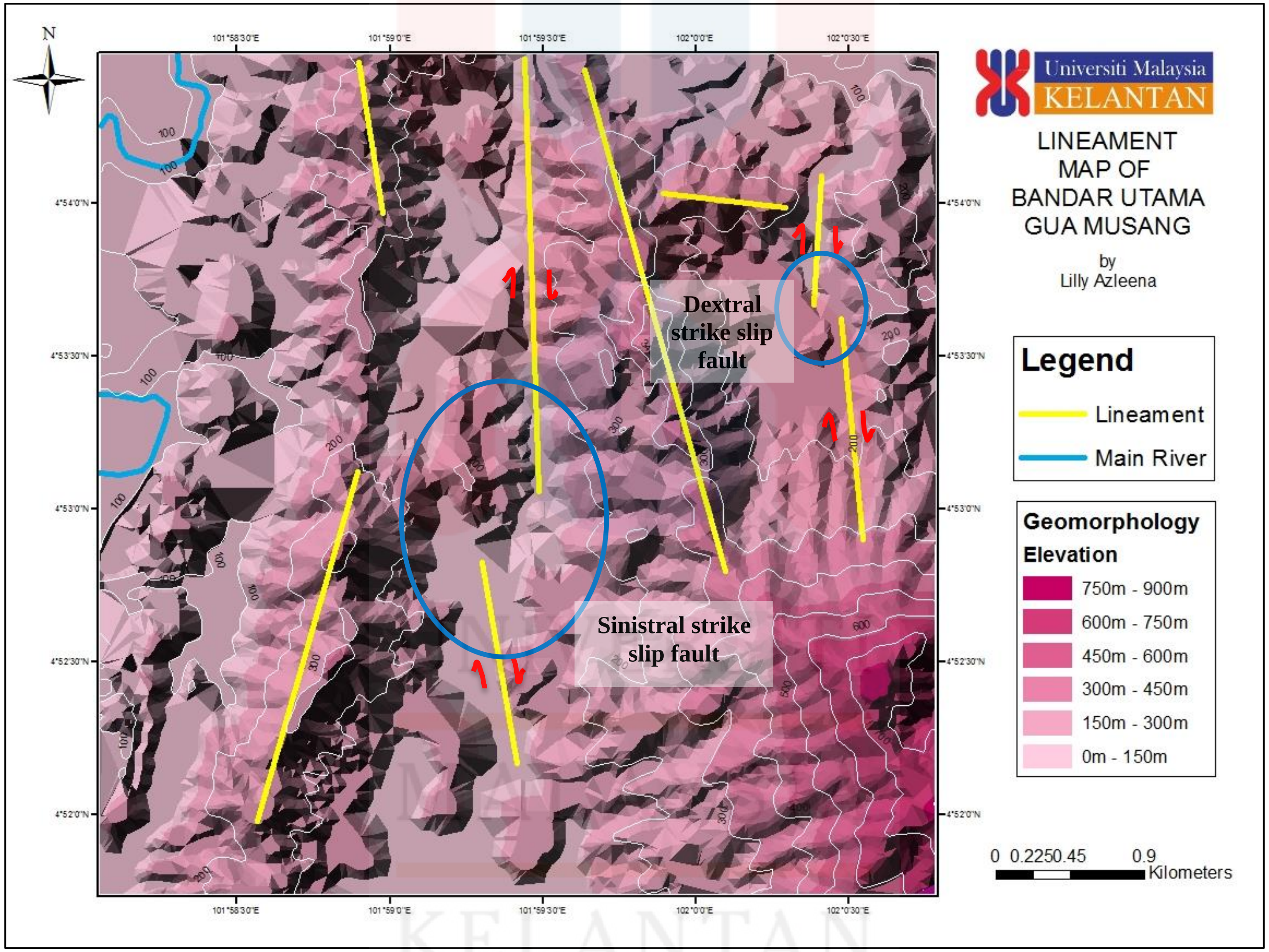


Figure 4.26 Lineament map of study area.

4.4.2 Contact

Geological contact is the boundaries between two bodies of rocks where the rocks can be distinguish from each other. There are two types of contact that be found in the study area which are depositional contact and intrusive contact. The depositional contact is the contact between the sedimentary rocks where the rocks deposits or overlies the older rock. The intrusive contract is occurred when other rocks intrude other rocks.

There are three depositional contacts that found in the study area which are contact between the conglomerate and quartzite (Figure 4.27), contact between the fine grained limestone and coarse grained limestone (Figure 4.28) and contact between the silicified tuff and the carbonaceous shale (Figure 4.29). In addition, the intrusive contact is between the hornfels and granite (Figure 4.30) that found at the roadside Gua Musang to Kuala Krai main road. This contact between hornfels and granite is known as a contact metamorphism.

Figure 4.27 Contact between conglomerate and quartzite.

Figure 4.28 Contact between Fine-grained and coarse-grained limestone.

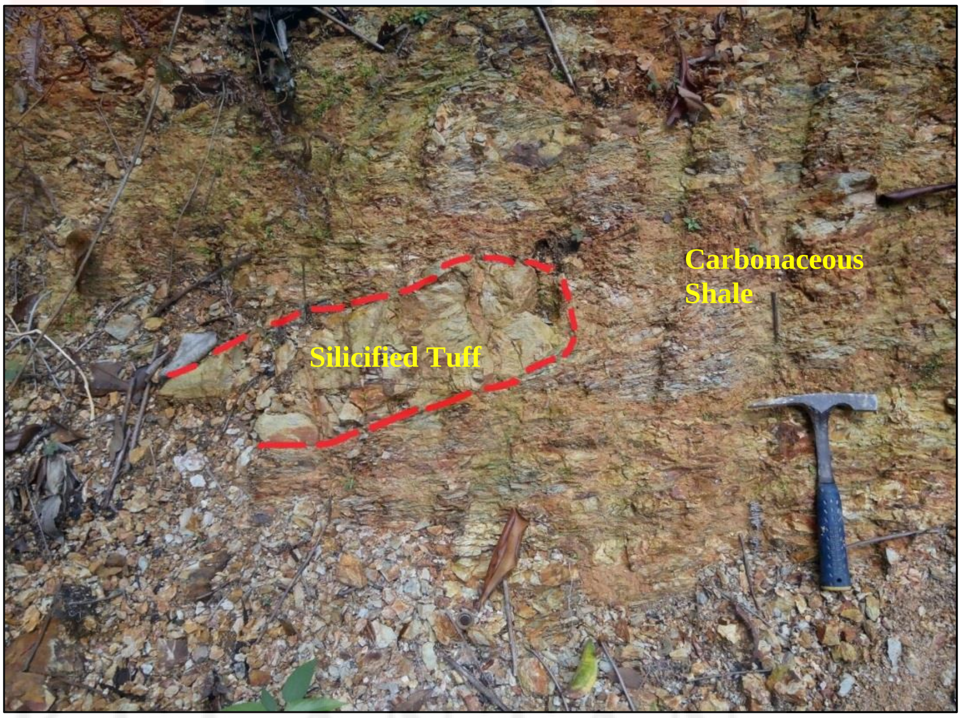


Figure 4.29 Contact between silicified tuff and carbonaceous shale.

Figure 4.30 Contact between hornfels and granite.

4.4.2 Joint

Joint is the break or crack on the rock surface where there is no displacement or motion of the rock (Parul, n. d). Break or crack on the rock surface is occurred as the brittle rock strength is exceeded. Joint usually occur as a sets rather than single. Each of the sets will have the joints that parallel or sub-parallel to each other. The main factors that contribute into the development of joint are the contraction of rock as a result of cooling or during rock consolidation and due to the forces that exerted on the rock either tensile forces or compressional forces. From mapping and observation activities, joint that be found in the study area are mural joint in granite and shear joint in tuffaceous slate.

Mural joint has a 3D network with the joint set is being mutually perpendicular to each other (Shambavi, n.d). These joint caused the granite rock block to be separated into cubical blocks as shown in Figure 4.31.

Figure 4.31 Mural joint of granite

Moreover, in slate rock, the joint that occurred is classified as shear joints (Figure 4.32) because these joint usually associated with the deformed and folded rocks. Based on the Figure 4.32, the slate rock beds have been deformed, folded and tilting almost 90°. Shear joints as intersecting or crisscrossing each other at the high angle (Shambavi, n.d). Normally, it produced by the shear stress action that occur in folding and faulting stages, narrowly spaced intersection joint.

Figure 4.32 Shear joints at slate rock

4.4.3 Fault

Fault occurred as the forces exerted on the rock cause the rock to break and displace or in other words the rock is moves due to the tectonic forces. The types of the fault are determined based on observation on a fault plane, hanging wall and foot wall. However, at field, certain fault cannot be determined its hanging wall, foot wall or the fault plane. Besides, no hanging wall or foot wall in the strike slip fault, only rock displacement is being observed.

Fault breccia that found in the study area was located at the river on the eastern side of the map. Fault breccia is occurred due to the tectonic forces where the rock moves along a localized zone of brittle deformation. Fault breccia also indicates that the area is near to the shear zone where the rocks are more highly strained. Based on the Figure 4.33, it is clearly seen that the rock within the fault breccia is highly cemented and it is composed of angular fragments within the fine grained groundmass which is hornfels. This type rock is known as cataclasite. The cataclasite is formed due to the temperature and pressure is higher deep in the earth crust, causing the rock still can be brecciated in the fault zone and keeping their internal cohesion.

Then, there is also a minor strike slip fault that found in the study area. This fault is found on the road where the slate rock bed is break and displaces as shown in Figure 4.34. The occurrence of the strike slip fault is due to the horizontal compression. However, energy released by the strike slip fault results in the displacement of the rock in a horizontal direction that almost parallel to the compressional force.

Figure 4.33 Fault breccia.

Figure 4.34 Minor strike slip fault.

4.4.4 Fold

Folding is occurred due to the compressional stress that acting on the rock caused the rock to deform into bending shape or curved shape without breaking the rock. Fold is made up of hinge where two different oriented limbs are connected to each other. In the study area, the types of folding that were found are the isoclinal fold and minor syncline. Figure 4.35 shows the fault terminology that consists of hinge line, limb and the axial plane.

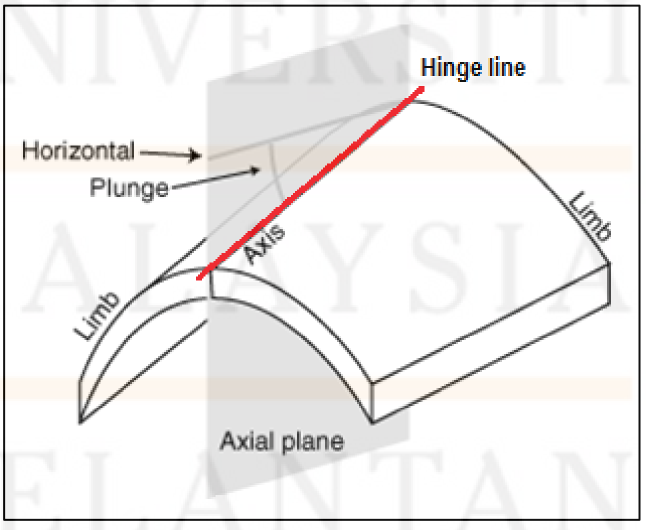


Figure 4.35 Fold terminology

Isoclinal fold (Figure 4.36) are symmetry with same angle of limbs and are parallel to each other. The interlimb angle of the isoclinal fold is between 0° to 10°. Limb on the left side of the isoclinal fold has 52° of dip angle reading whereas the limb on the right side of the isoclinal fold has 58° of dip angle reading. Thus, the interlimb angle is 6° reflecting that the fold is an isoclinal fold.

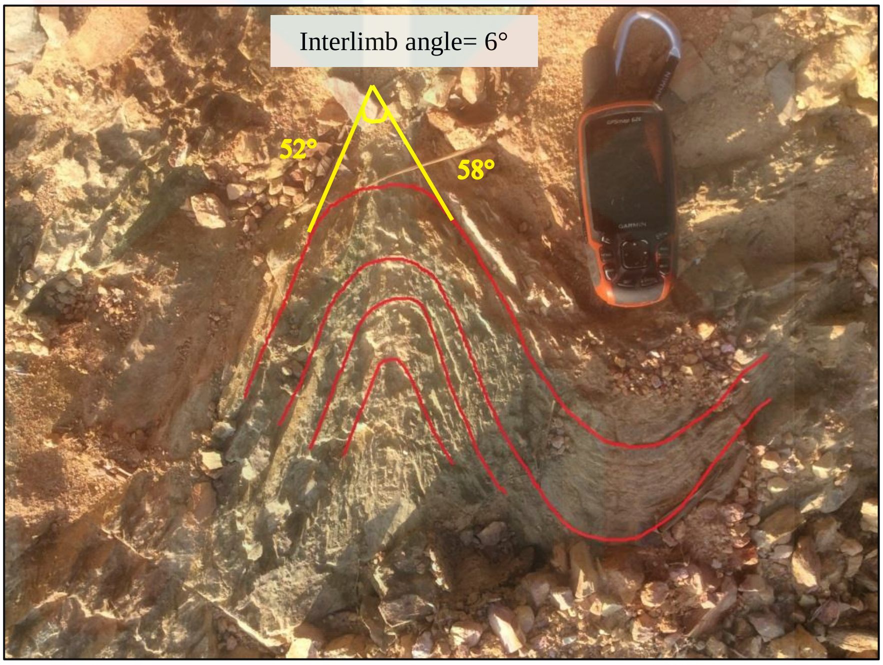


Figure 4.36 Isoclinal fold

Minor syncline with the interlimb angle of 14° also found at the study area. The syncline has a shaped like bottom of an S or in other words syncline is a downward folding with more open fold as shown in Figure 4.37. The difference between isoclinal fold and syncline fold are the isoclinal is tightly folded where the limbs almost close and parallel to each other whereas the syncline is like an open fold where the limb is not very close to each other. As a proof, the interlimb angle of syncline fold is bigger than the interlimb angle of isoclinal fold.

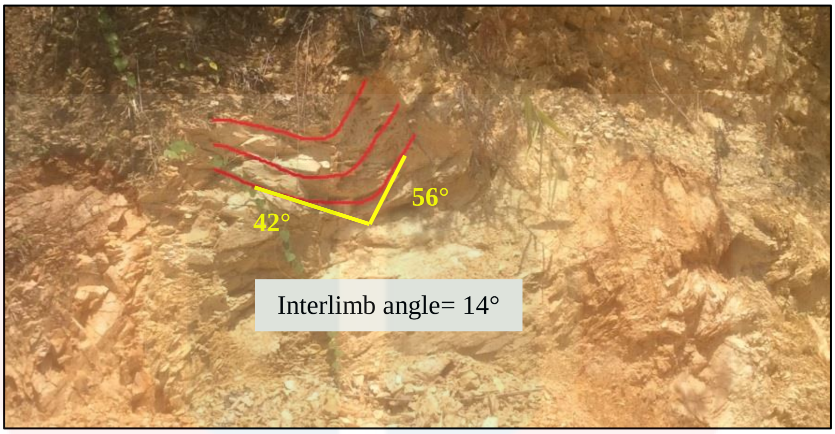


Figure 4.37 Minor syncline

4.4.5 Foliation

Foliation is defined as the repetitive layering of metamorphic rock. This occur is due to the flat or elongate mineral is being pressured within a rock, so that they become aligned. Thus, forming a platy or sheet like structure called foliation. From Figure 4.38, it shows the foliation of interlaminated tuffaceous shale and carbonaceous shale. The foliation has a 60° of dip angle with 32° dip direction.

Figure 4.38 Foliation of slate rock

4.4.6 Karst features

In Bandar Utama Gua Musang, many karst landforms are clearly seen. These karst landforms that give rise to the features like cave. In the cave, there are several structures that presence such as stalactite, stalagmite, pillars as shown in Figure 4.38 and cave window as shown in Figure 4.39. Stalactite is the rock formation that hanging on the ceiling of cave whereas stalagmite is the rock formation that form on the ground or the cave floor. As the stalactite and stalagmite continue forming until they combine each other, it will form a column known as a pillar. Cave window is one of the cave structures where people usually pass through it to enter the cave.

Figure 4.39 Stalactite, stalagmite and pillars found at Gua Musang

Figure 4.40 Cave window at Gua Musang

4.5 Mechanism of structure

In order to understand how the structure acts on the rock that caused them to deformed, it is important to do the joint analysis. The joint analysis is help in finding the major principal stress. From the joint analysis in Figure 4.41a, Figure 4.41b and the major principal stress, σ^1 is from East-West (E-W) direction whereas in Figure 4.41c, σ^1 is from North-South (N-S) direction. From both of the Figure 4.41a and Figure 4.41b, it is believed that the major principal stress is from E-W direction. Figure 4.41c may have an error during reading the data in the field. This stress gives rises to the strike slip fault at the study area. There are two types of strike slip fault in study area which are sinistral and dextral. This sinistral and dextral strike slip fault is classified based on the movements of the fault. Sinistral is where the rock moves left lateral and dextral is where the rock moves left lateral.

I. Coordinate: N 04°53’31.8”, E 101°59’30.6”

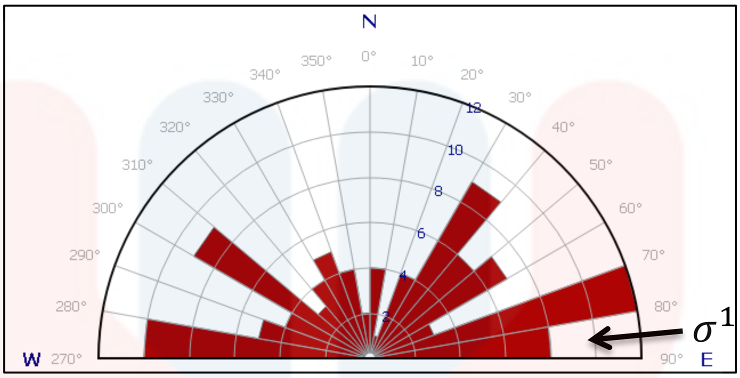


Figure 4.41a Joint analysis at Slate rock

II. Coordinate: N 04°52’4.44”, E 101°58’29.5”

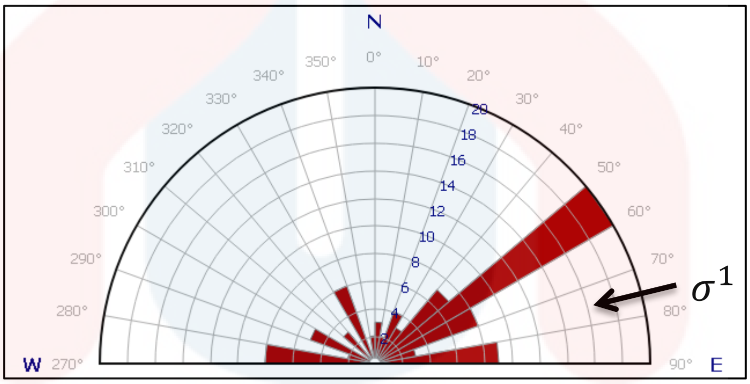


Figure 4.41b Joint analysis at Granite (18LALE2)

III. Coordinate: N 04°53’32.4”, E 101°58’47.4”

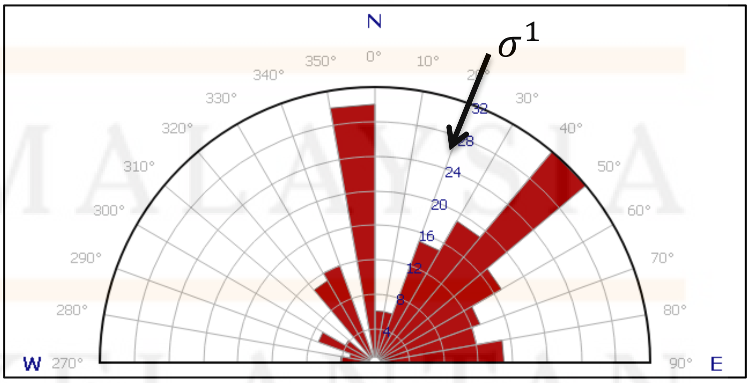


Figure 4.41c Joint analysis at Granite (18LALE15)

Besides, the mechanism of structure is studied through the stereonet projection. This stereonet projection is plotting the fracture in two types of rocks which are slate (Figure 4.42) and limestone (Figure 4.43). The Kamb contour is use to classified the contour with applying the Terghazi correction. Both stereonet projection use two interval, five maximum correlations and one significance.

From the slate rock stereonet projection, there is a folding occur where the hinge is narrow. The folding is reflects that anticline, chevron or isoclinal fold occured on the slate rock.

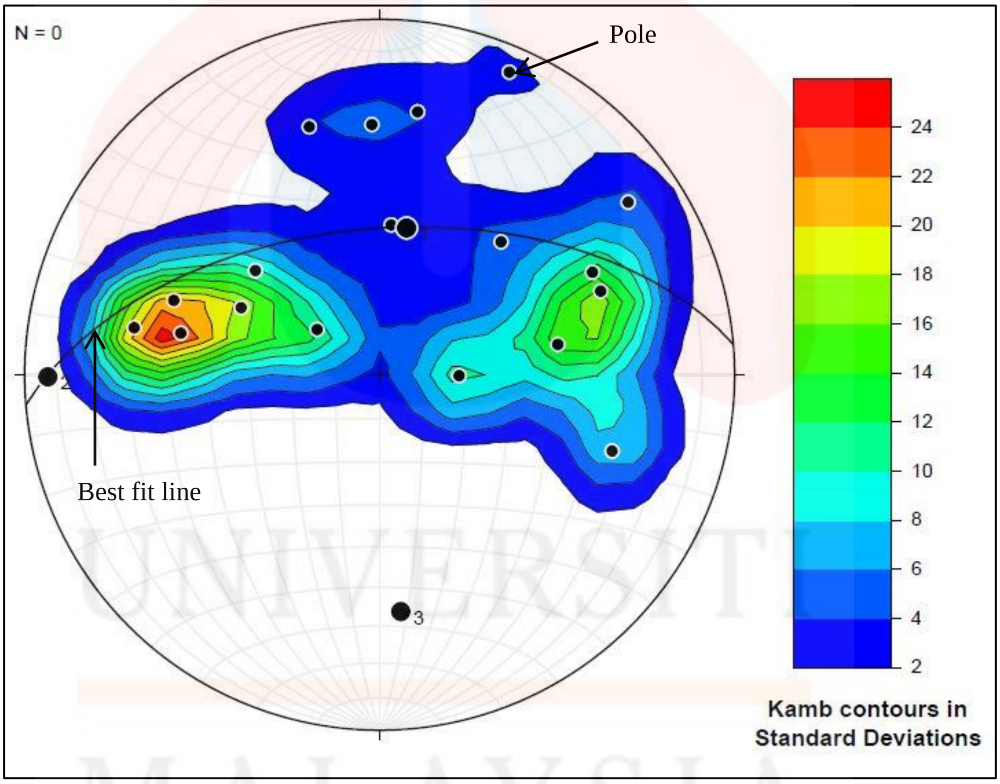


Figure 4.42 Stereonet projection of slate.

From the limestone stereonet projection, the projection shows that the there is an asymmetric fold occurrence. The asymmetric fold is the fold where its axial plane is inclined. Thus, it reflects that the overturned fold or recumbent fold occurence.

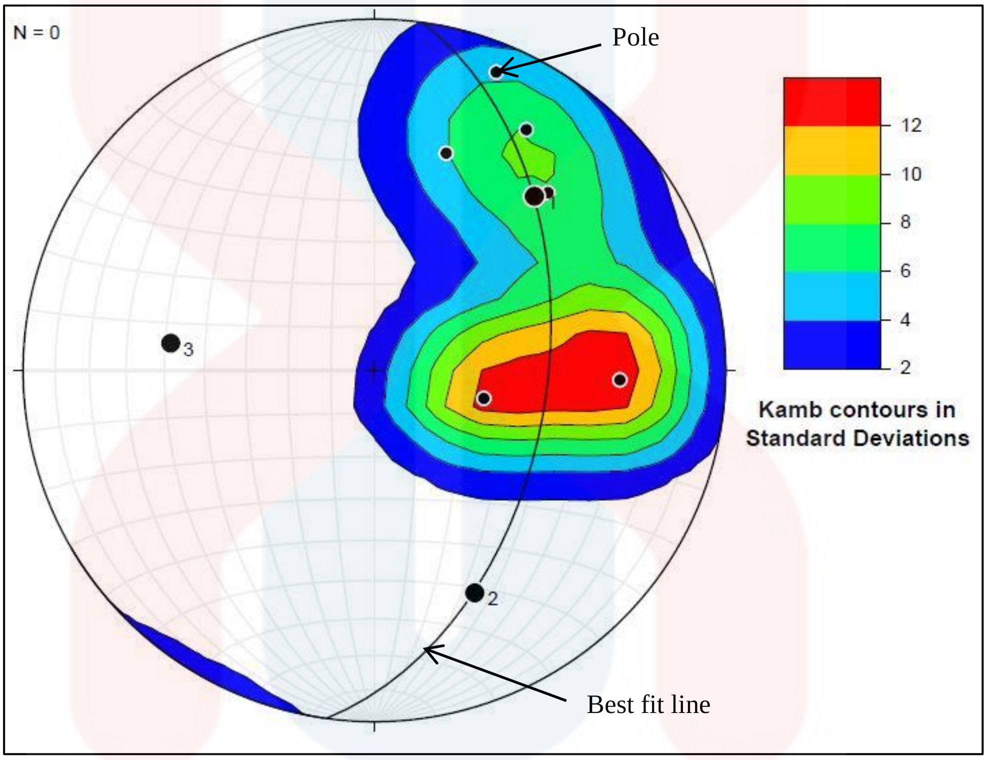


Figure 4.43 Stereonet projection of limestone.

4.6 Historical Geology

The study area consists of two formations which are the Gua Musang Formation and Gunung Rabong Formation. As mentioned by Abdullah (2009) and Yin (1965), Gunung Rabong is underlie by Gua Musang Formation reflects that Gunung Rabong Formation is younger than Gua Musang Formation. In Gua Musang Formation, the rock that found in the field consists of limestone unit, slate unit, volcanic tuff unit and granite unit. For Gunung Rabong Formation, it is composed of meta-sediment.

In limestone unit, there are two types limestone that found which are dark grey limestone and light grey limestone. Peng (2009) said that the dark grey is the recrystallize limestone whereas the light grey is the calcitic limestone. From the petrography analysis in limestone, the dark grey limestone consists of recrystallization of mineral calcite and some quartz whereas the light grey limestone is already marbelized. This prove that the limestone also undergo the metamorphism process.

The slate unit found in the field has a dark grey in colour, hard and foliated. According to (Peng, 2009), there is a presence of shale under the Gua Musang Formation. Thus, this unit is from the shale protolith. The shale undergoes the low grade regional metamorphism process becoming slate. To make it more solid, in this slate unit, there was found minor tuffaceous shale interlaminated with carbonaceous shale.

Furthermore, Peng (2009) have mentioned that one of the volcanics rock in Gua Musang is tuff and sometimes interlaminated with shale. The tuff that found in the study area is the silicified crystal lithic tuff. The contact found between tuff and the tuffaceous shale, carbonaceous shale and slate prove that tuff is interbedded with the slate.

The intrusion of granite give rises to the formation of hornfels in Gua Musang. This hornfels is the results of the contact metamorphism process between the granite intrusion and the country rock.

Under the Gunung Rabong Formation, the rocks that found are the quartzite with minor conglomerate intercalated with sandstone and siltstone. In contrast with Abdullah (2009), no shale was found. This is due to the rock have undergo the metamorphism process.

CHAPTER 5

GRANITOID GEOCHEMISTRY

5.1 Introduction

In this chapter, the study focuses on the data analysis and interpretation of grey granite and pink granite through geochemistry methods. Two geochemistry methods that are used to carry out this study are XRF analysis and ICP-MS analysis. The importances in carry out the geochemistry method are because the major elements, trace elements and rare earth elements in the granitoids can be identify. The major elements and trace elemeents is identified in order to determine the tectonic setting of the granitoid and classified the granitoid based on S-I-A-M classification whereas the REE elements is identified to investigate the distribution of the REE elements. Four granitoid rock samples that were being analyzd are 18LALD1 (G1), 18LALD2 (G2), 18LALD3 (G3) and 18LALE15 (G4).

5.2 Major elements

Table 5.1 shows the result of the major elements in four sample granitoid rock. Only one sample is biotite granite (G1) whereas the other two are the Alkali feldspar biotite granite. There are only six major elements from ten major elements is determined from the XRF analysis. All of these six major elements are being normalized into 100% first before proceed into plotting the geochemistry analysis graph as shown in Figure 5.1. The Harker diagram is used to plot all five major elements weight percentage (wt%) versus the SiO_2 major elements wt %. This major element are being analysed to study the fractionation of the elements trends in granitoid.

Table 5.1 Major elements normalized to 100%

Granite Rock	**Major Elements normalized to 100% (wt%)**						**TOTAL (wt%)**
	SiO_2	TiO_2	FeO	MnO	CaO	K_2O	
G1	65.5589	0.0000	4.3556	0.2033	21.0511	8.8311	100.0000
G2	71.7223	0.4086	5.7142	0.1542	8.8714	13.1293	100.0000
G3	60.4112	0.0000	6.2027	0.0000	8.1736	25.2125	100.0000
G4	88.0946	0.2334	1.3275	0.0000	2.2836	8.0610	100.0001

From the Harker diagram in Figure 5.1, the linear trends reflecting the fractionation trends of all the major elements. The result shows that are all the elements fractionation trend is decreasing as the SiO_2 increasing. The range of SiO_2 is from 65.5589wt% to 88.0946wt% reflecting that the rock is felsic. The TiO_2 and MnO content is low in the granitoid rock which is less than 0.5wt%. The FeO and CaO content is moderately high in granitoid rock range from 1.3275wt% to 6.2027wt% and from 2.2836wt% to 21.0511wt% respectively. Moreover, K_2O has higher wt% in granitoid with 25.2125wt% in G4.

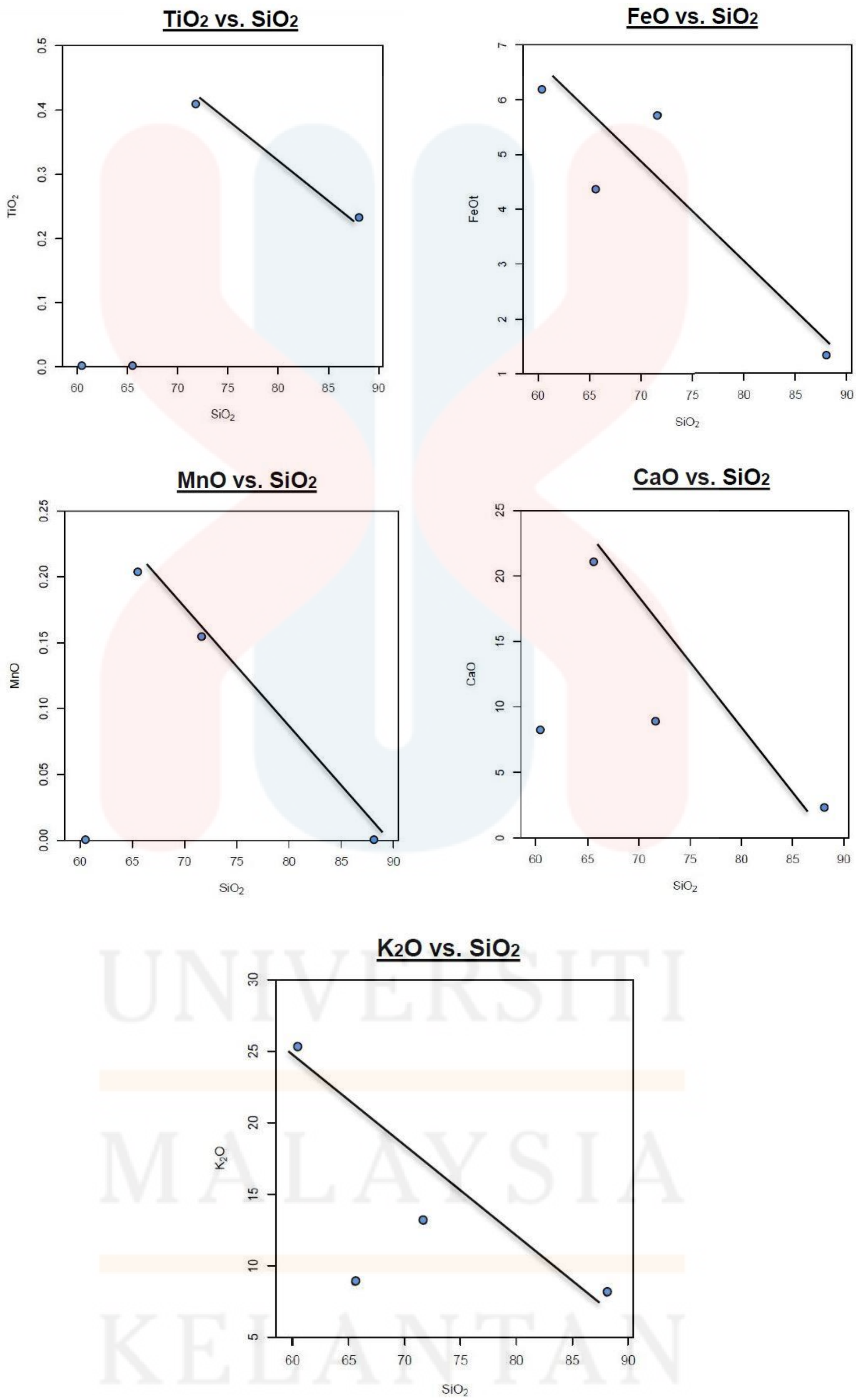


Figure 5.1 Harker diagram of major elements

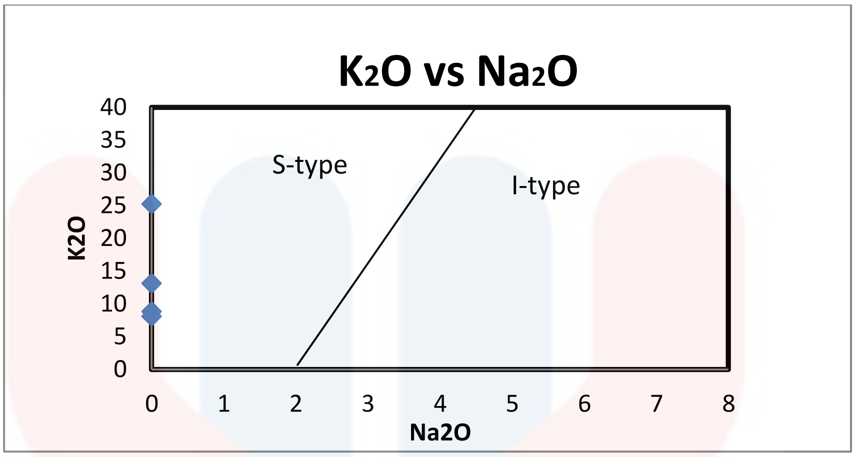


Figure 5.2 Na_2O vs. K_2O of the granitoids. The S-type and I-type division is after Chappell and white (1979).

Figure 5.2 shows the graph of K_2O versus Na_2O dividing the I-type or S-type granitoid. The result shows that all the Na_2O concentration is 0wt% resulting in all the major elements is the S-type granitoid with the highest reading 25.2125wt% of K_2O.

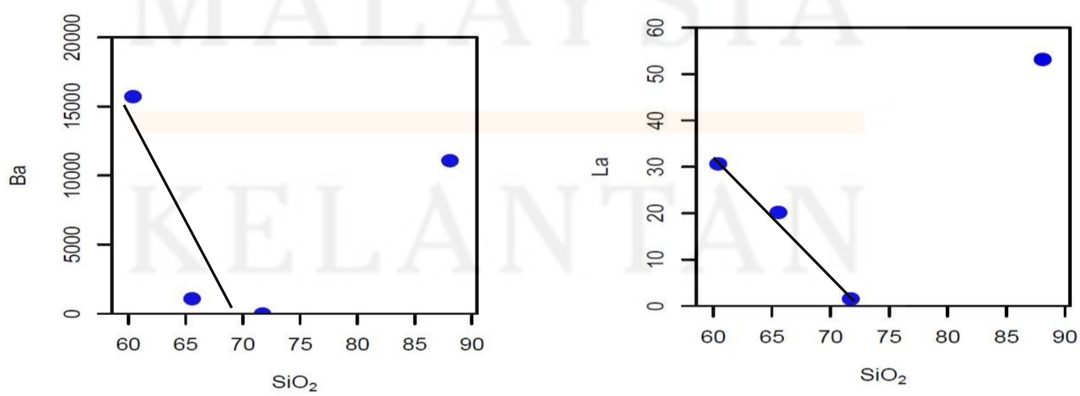
5.3 Trace elements

The wt% results of trace elements are all being standardized into ppm unit as shows in Table 5.2. Some of the trace elements like Nb, Zr, U, Gd and Pb are not available in this research. The Rb content is quite high in G2 and G4 with the value 2200.0ppm and 1300.0ppm respectively. The Rb element is not available in G1 and G3. The Sr element is only available in G3 with the value 1000.0ppm compare to Th elements that available in all four samples of granitoids. Ba elements in G3 and G4 have a value more than 10000.0ppm whereas in G1 only 1100.0ppm. Ba element is not available in G2 rock. Moreover, both Ti and Yb are not available in G2 and G3 rock. The rest of the trace elements are all available in the four samples of granitoid. Figure 5.3 represents the Harker diagram of trace elements whereas Figure 5.4

represents the trace elements normalised to chondrites. Further explanation of Figure 5.3 and Figure 5.4 are discussed in discussion section.

Table 5.2 Trace elements

Trace elements standardized to ppm unit				
Trace elements	G1	G2	G3	G4
Y	43.8	24.9	24.6	29.8
La	20.2	1.6	30.6	53.2
Ce	40.2	33.9	62.9	106.2
Sm	19.9	4.0	5.3	7.9
Th	53.4	9.6	27.5	42.9
Nd	130.0	17.4	27.5	43.2
Sr	0.0	0.0	1000.0	0.0
Yb	0.0	0.0	11800.0	0.0
Rb	0.0	2200.0	0.0	1300.0
Ba	1100.0	0.0	15700.0	11100.0
K	309100.0	614900.0	581700.0	354300.0
Al	286100.0	635600.0	581300.0	257500.0
Fe	5600.0	11100.0	9300.0	23500.0
Si	831200.0	2395200.0	1690200.0	627400.0
Na	225300.0	98300.0	7000.0	127100.0
Ti	93400.0	0.0	0.0	11600.0
Ca	40000.0	3400.0	13000.0	44900.0
Mg	341400.0	0.0	606200.0	0.0



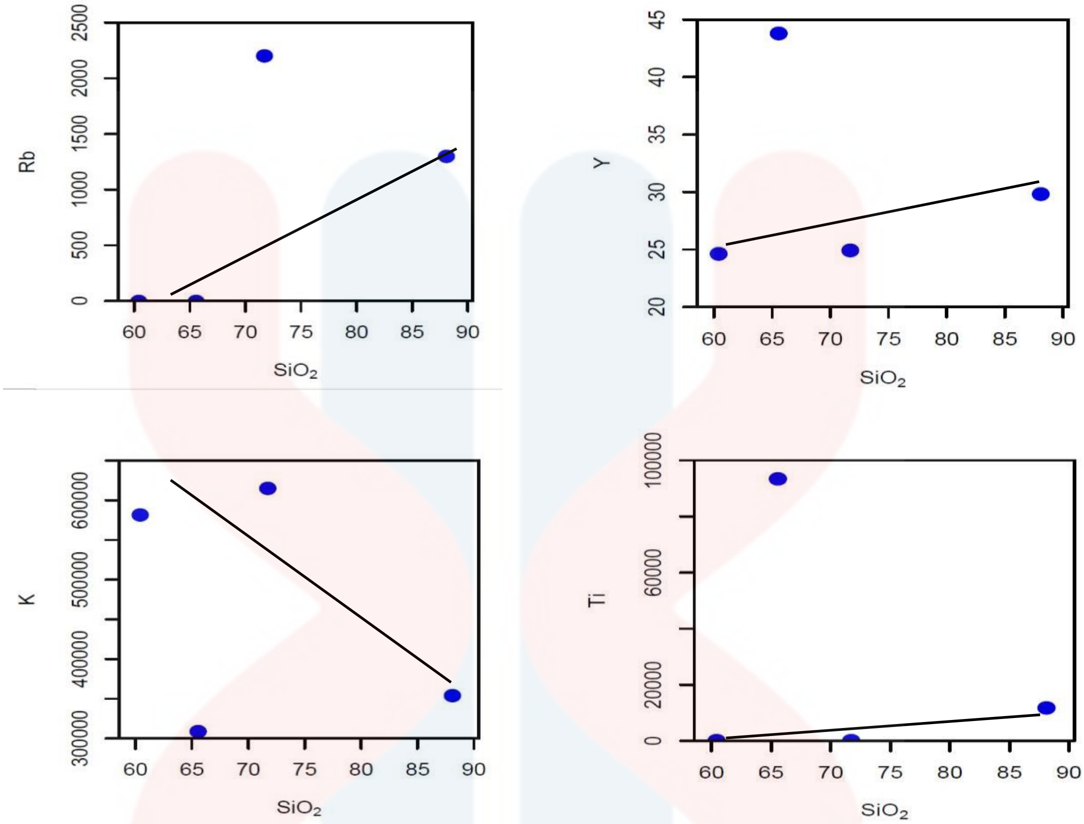


Figure 5.3 Trace elements Harker diagram (Ba, La, Rb, Y, K, and Ti Vs. SiO_2.

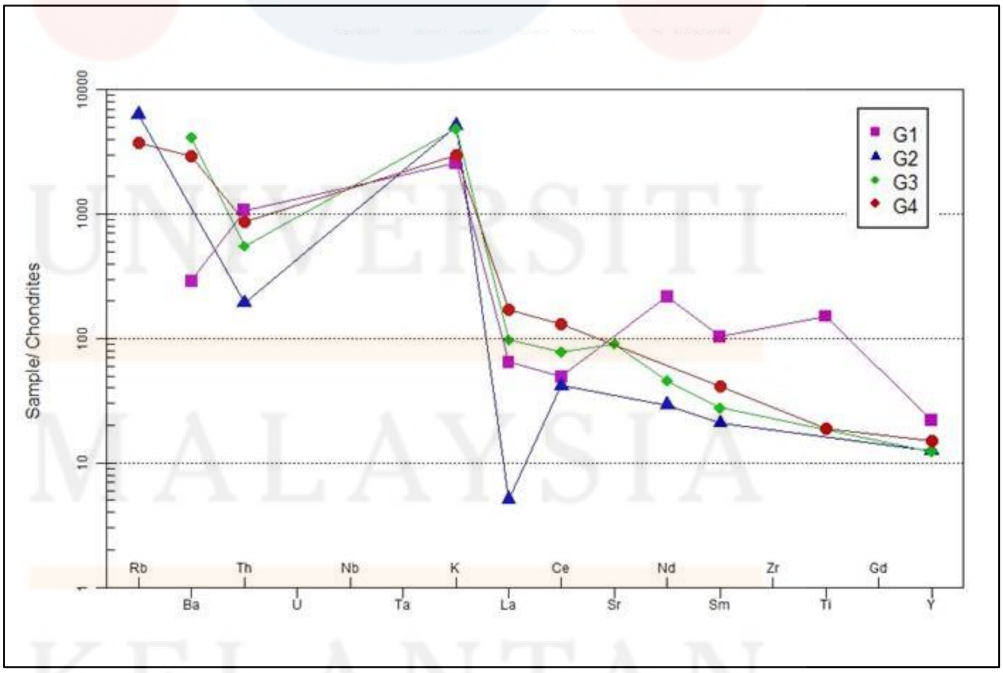


Figure 5.4 Chondrites normalised of trace elements.

5.4 REE elements

The REE elements are divided into two categories which are the Light REE (LREE) and Heavy REE (HREE). LREE is consists of Lantahnium (La), Cerium (Ce), Praseodyium (Pr), Neodymium (Nd) and Samarium (Sm) whereas the HREE consists of Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), Lutetium (Lu) and Yttrium (Y). Table 5.3 shows the LREE and HREE distributions in four granitoid measured in ppm unit. From the table, it shows that the LREE are lesser than HREE. However, when comparing both elements in terms of its abundance, LREE is more abundance rather than HREE as shown in Figure 5.5. The highest LREE and HREE distribution are in G1 with 250.5000 ppm and 61.1130 ppm respectively while the lowest LREE and HREE are in G2 with 57.3283 ppm and 30.2925 ppm respectively. Thus, in total, G1 has highest distribution of REE concentrations followed by G4, G3 and G2.

Table 5.3 LREE and HREE distribution in granitoid

Light Rare Earth Elements (LREE)					
No.	LREE	G1 (ppm)	G2 (ppm)	G3 (ppm)	G4 (ppm)
1	La	20.2000	1.6000	30.6000	53.2000
2	Ce	40.2000	33.9000	62.9000	106.2000
3	Pr	40.2000	0.4283	0.7282	1.2000
4	Nd	130.0000	17.4000	27.5000	43.2000
5	Sm	19.9000	4.0000	5.3000	7.9000
SUM		**250.5000**	**57.3283**	**127.0282**	**211.7000**
Heavy Rare Earth Elements (HREE)					
No.	HREE	G1 (ppm)	G2 (ppm)	G3 (ppm)	G4 (ppm)
6	Eu	0.1410	0.0478	0.0500	0.0331
7	Gd	15.0000	4.1000	5.0000	6.7000

8	Tb	0.1850	0.0739	0.0809	0.0994
9	Dy	0.9053	0.4543	0.4736	0.5652
10	Ho	0.1694	0.0974	0.0966	0.1124
11	Er	0.4383	0.2761	0.2689	0.3043
12	Tm	0.0595	0.0413	0.0381	0.0435
13	Yb	0.3634	0.2630	0.2261	0.2629
14	Lu	0.0511	0.0387	0.0312	0.0366
15	Y	43.8000	24.9000	24.6000	29.8000
SUM		**61.1130**	**30.2925**	**30.8654**	**37.9574**

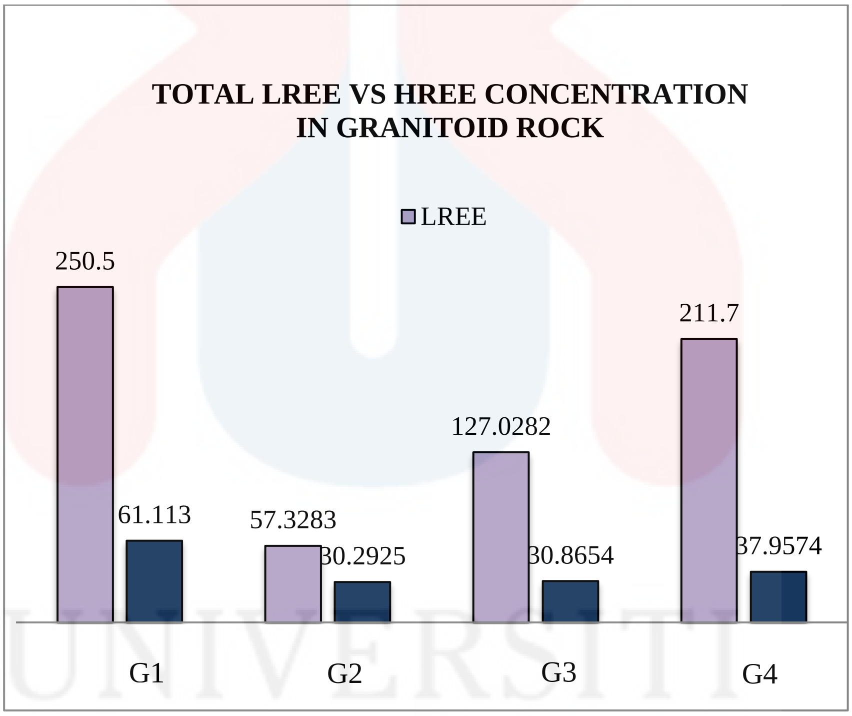


Figure 5.5 Bar chart of total LREE vs HREE concentration in granitoid rock.

In LREE, the highest concentration is the Nd with 130.0000 ppm in G1 followed by Ce in G4, La in G4, Pr in G1 and Sm in G1 with 106.2000 ppm, 53.2000 ppm, 40.2000 ppm and 19.9000 ppm respectively as shows in Figure 5.6. Then, based on HREE distribution in Figure 5.7, the highest concentration is the Y elements in G1 with 43.8000 ppm followed by Gd elements also in G1 with 15.0000 ppm. The other HREE has the concentration that less than 1 ppm.

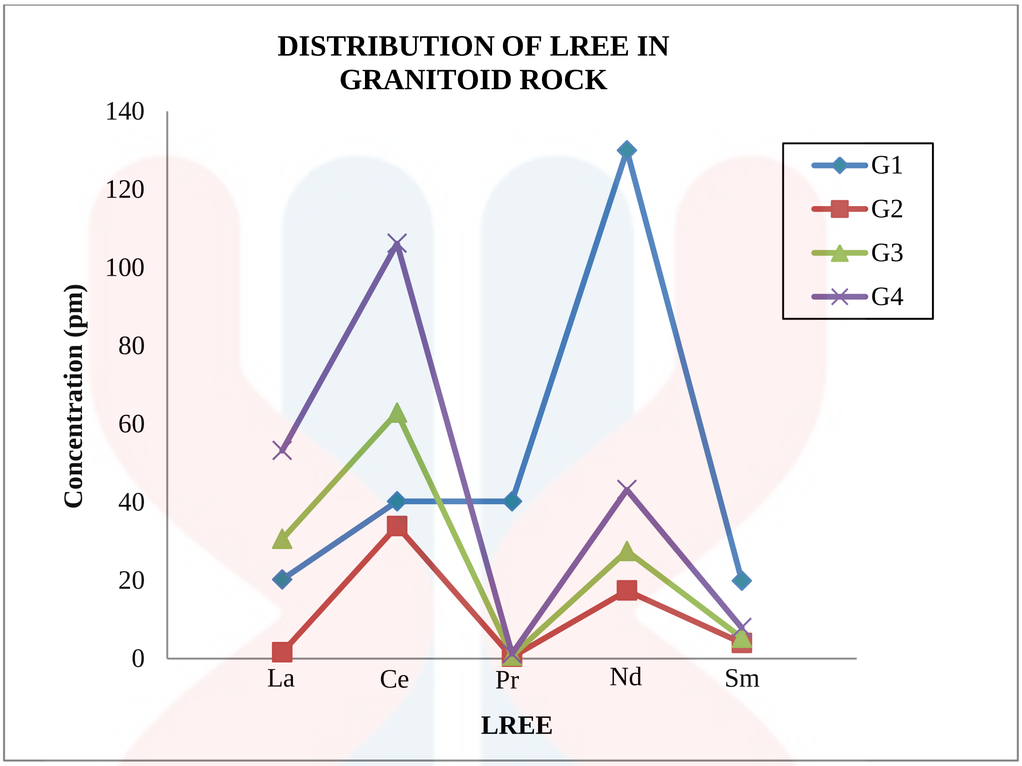


Figure 5.6 LREE distributions in granitoid rock

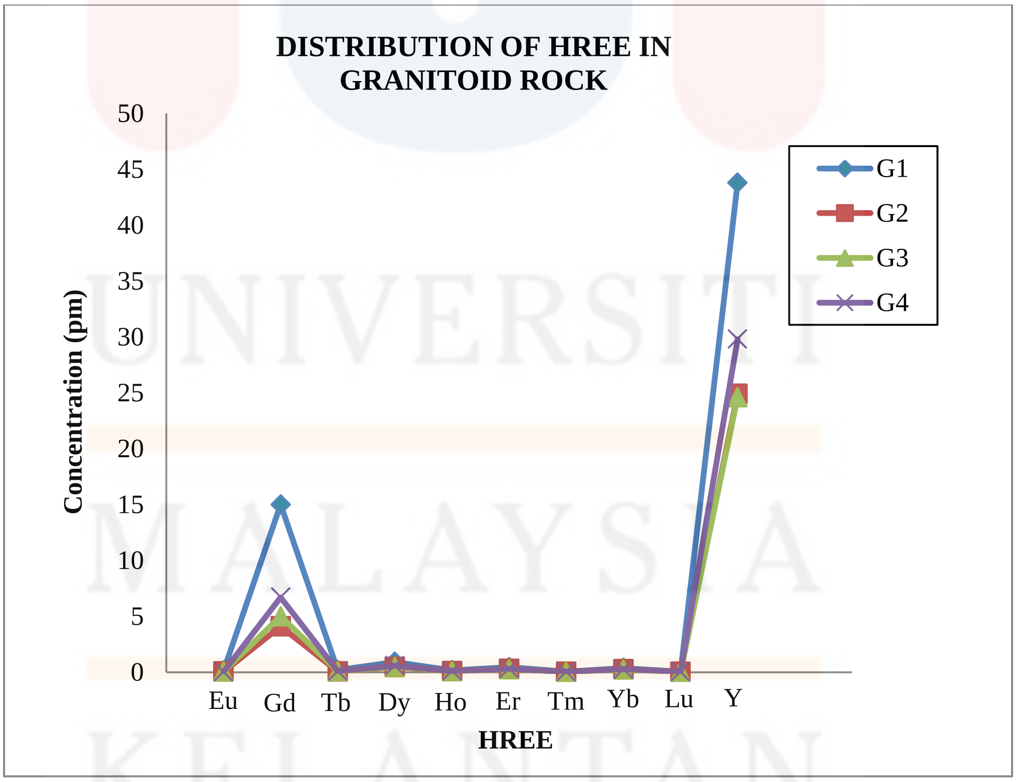


Figure 5.7 HREE distributions in granitoid rock.

Overall, the highest REE concentrations are in G1 whereas the lowest REE concentrations are in G2. Based on the Figure 5.8, Ce is the most abundance REE in Bandar Utama Gua Musang granitoid rock with total of the concentrations is 243.2000 ppm. The second most abundance REE is Nd with 218.1000 ppm total concentrations in granitoid rock. The fewest abundance of REE in granitoid of Bandar Utama Gua Musang is the Lu with total concentration is 0.1576 ppm followed by Tm with 0.1824 ppm.

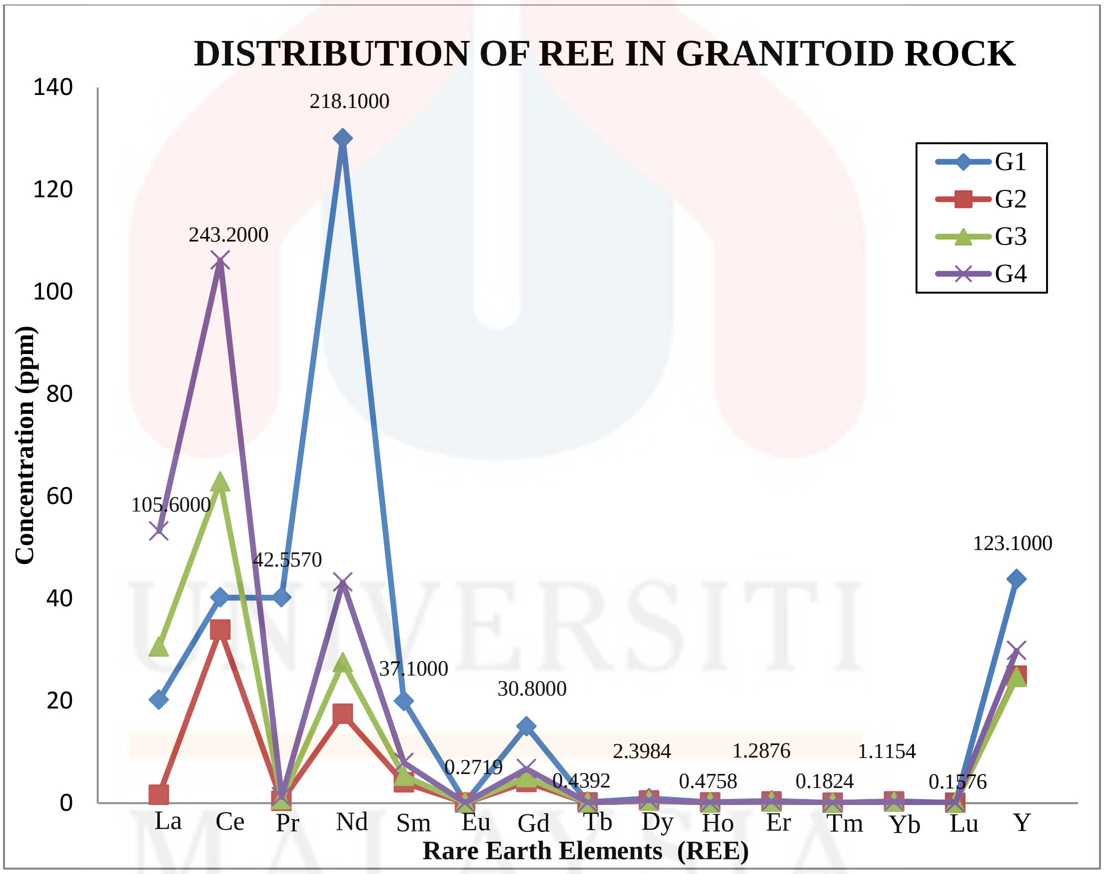


Figure 5.8 Distribution of REE in granitoid rock

5.5 Discussion

From the major elements analysis in section 5.2, only six elements are available in granitic rocks from 10 common major elements of granites. The availability of the major elements result shows that there is no presence of Al_2O_3 and Na_2O that so importance in order to identify the ASI of the granitoid rocks. From the Harker diagram plots of major elements, only five minerals (TiO_2, FeO. MnO, CaO and K_2O) versus SiO_2 is plotted. The graph shows that TiO_2, FeO and CaO aredecreased with increasing SiO_2 wt%. As mentioned by Ng et al. (2015a), TiO_2, FeO and CaO is decrease as the SiO_2 content is increased whereas the K_2O show the positive correlation with SiO_2. However, in contrast with Ng et al. (2015a), the result shows that K_20wt% also decreased as SiO_2wt% increased. The conflict between the fractionation trends of the study area with the fractionation trends stated by Ng et. al (2015a) may due to the lacks data and the data depends only on the four samples of granitoids.

From the K_2O versus Na_2O diagram, the results shows that the granitoid in the study area is S-type granite. However, the result is not very solid because the Na_2O wt% is all normalized to 0wt% because of the XRF analysis does not have any Na_2O reading. However, based on the SiO_2 wt%, it range from 60.4112wt% to 88.0946wt% reflecting that granitoid is likely to be in Eastern belt which is I-type granitoids. Based on the composition, the I-type is more sodic while S-type is more potassic (Chappell & White, 1974; A.A. Ghani et al., 2013b; Ng et al., 2015a). From the thin section, Orthoclase or Alkali Feldspar is more abundance rather than Plagioclase. This conclude that the granite in Gua Musang is more potassic rather than sodic in composition. Concreting this result is from the higher contents of K_2O in granitoids range from 8.0610wt% to 25.2125wt%.

In trace elements results, the Harker diagram shows that the La and K elements are decreasing as SiO_2 increasing whereas the Y, Rb, Ba and Ti elements are increasing as SiO_2 increasing. Increasing of Ba, Rb shows the granitoid is enriched in Large Ion Lithopile elements (LILE) and increase in Ti shows the granitoids is enriched in High Field Strength elements (HFSE). The spider diagram of the trace elements shows that there is no depletion of Sr element. This may suggest that the plagioclase mineral is not very important during the evolution of the magma. However, this result also is not very solid since the data from XRF analysis does not show any Sr concentrations in G1, G2 and G4.

In REE distributions, LREE distribution is higher than HREE distribution in Gua Musang granitoid rocks. From the distribution, Lu concentration is the less abundance REE as mentioned by Zepf (2013). The concentration of Nd and La shows that Nd has higher concentration than La. From this result, I concurred with Bunzli (2013) that mentioned Nd is the second higher abundance followed by La. This is because the atomic weight of Nd is higher than La. But, as mentioned by Zepf (2013), it is also possible that La can bu higher than Nd due to the atomic radii of La is bigger than Nd makes La is more easily to aggregate with the rocks. The most abundance is Ce as mentioned also by Bunzli (2013). Overall, the distribution or abundancity of REE elements is depends on the atomic radii and atomic weight of the REE elements.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As a conclusion, the objectives have been achieved where the geological map of Bandar Utama Gua Musang with scale 1: 25, 000 is able to produce. The major principal stresses are from the East-West direction. The principal stress give rises to the formation of dextral and sinistral strike slip fault in the study area. Besides, the lithology of the study area is proven by the thin section analysis for each rock unit. It is conclude that Bandar Utama Gua Musang comprises of two types of granitoids which are Biotite granite and Alkali Feldpar biotite granite. Moreover, the geochemistry data of from four samples of granitoid also has been analysed where the results reflects that Bandar Utama Gua Musang granitoid is S-type granitoid rock. From the REE distribution, it is clearly reflects that Gua Musang has higher enrichment of LREE rather than HREE.

6.2 Recommendations

As a recommendation, abundance minerals like feldapar, quartz and calcite had widely used in industries except for biotite mineral. For example, feldspar is widely used in ceramic and glass industries, quartz are also used in glass industries and other uses are in tiles industries like for kitchen countertops. Besides, calcite is mostly used in for construction materials. However, even biotite minerals are also abundance in earth, the uses of biotite minerals in industries and commercials is still lacks.

In addition, since at the study area has a large quartz vein at the intrusion of granites and near to the major faults, the area may have a potential for gold deposition. Thus, in the future, it is recommended to do the research on the gold deposition since the study area has high potential of gold deposition.

Besides, since Bandar Utama Gua Musang has many karst and metamorphic rocks, study on REE distribution in limestone and metamorphic rock is recommend. REE is very importance to our economics and research on REE in Gua Musang rock units is still lacks.

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IUGS Calculation

(a) Code: 18LALD2 (G2)

Alkali Feldspar (Afs)	12%	(A)
Feldspar (Fs)	16%	
Biotite (Bi)	20%	
Quartz (Qtz)	35%	(Q)
Plagioclase (Pg)	17%	(P)

$$\sum QAP = 35 + 17 + 12 = 64$$

Recalculate QAP %:

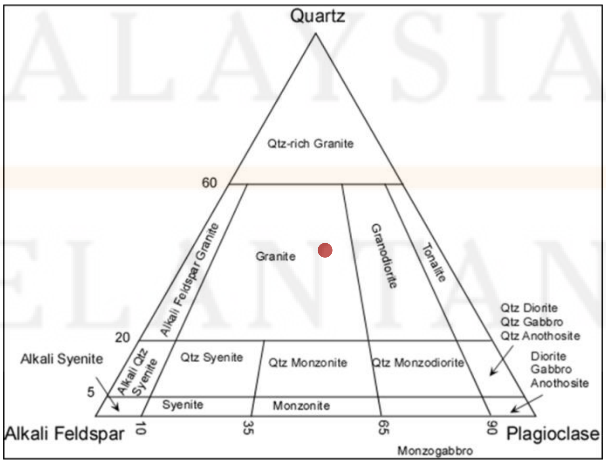
$Q,\ \frac{35}{64} \times 100 = 54.7\%$ $A,\ \frac{12}{64} \times 100 = 18.7\%$ $P, \frac{17}{64} \times 100 = 26.6\%$

∴ From Q percentage, the rock is lies below 60% of the Quartz concentration.

Recalculate A or P %:

$$P = \frac{26.6}{18.7+26.6} \times 100 = 58.7\%$$

∴ Since Afs concentration is 58.7%, Thus the granitoid is the Biotite Granite.



(b) Code: 18LALD1 (G1)

Alkali Feldspar (Afs)	25%	(A)
Feldspar (Fs)	25%	
Biotite (Bi)	15%	
Quartz (Qtz)	35%	(Q)
Plagioclase (Pg)	0%	(P)

$$\sum QAP = 25 + 35 + 0 = 60$$

Recalculate QAP %:

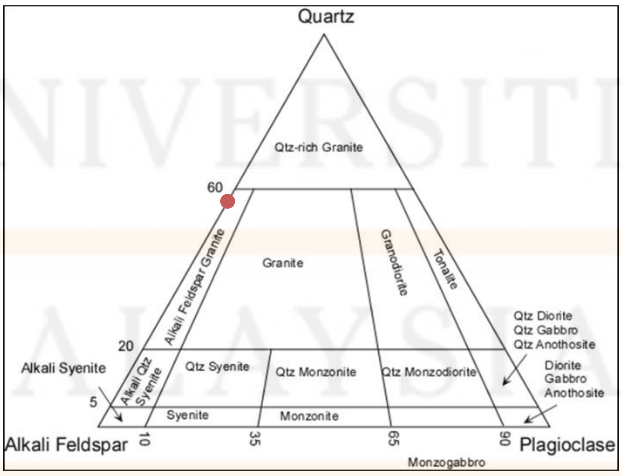
$Q, \quad \frac{35}{60} \times 100 = 58.3\%$ $\qquad A, \quad \frac{25}{60} \times 100 = 41.7\%$ $\qquad P, 0\%$

∴ From Q percentage, the rock is lies below 60% of the Quartz concentration.

Recalculate A or P %:

$$A = \frac{47.1}{47.1+0} \times 100 = 100\%$$

∴ Since Afs concentration is 100%, Thus the granitoid is the Alkali Feldspar granite.



(c) Code: 18LALE15 (G4)

Alkali Feldspar (Afs)	45%	(A)
Biotite (Bi)	30%	
Quartz (Qtz)	25%	(Q)
Plagioclase (Pg)	0%	(P)

$$\sum QAP = 25 + 45 + 0 = 70$$

Recalculate QAP %:

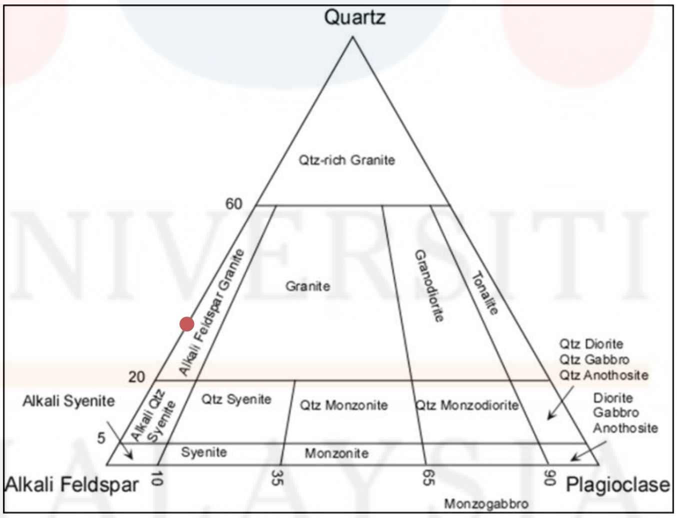
$$Q,\ \frac{25}{70} \times 100 = 35.7\% \qquad A,\ \frac{45}{70} \times 100 = 64.3\% \qquad P, 0\%$$

∴ From Q percentage, the rock is lies above 20% of the Quartz concentration.

Recalculate A or P %:

$$A = \frac{64.3}{64.3+0} \times 100 = 100\%$$

∴ Since Afs concentration is 100%, Thus the granitoid is the Alkali Feldspar granite.



APPENDIX II

Joint Data

(a) Coordinate: N 04°53’31.8”, E 101°59’30.6”

0° – 10°	/	121° – 130°	/	241° – 250°	
11° – 20°	////	131° – 140°		251° – 260°	
21° – 30°	~~////~~ ////	141° – 150°		261° – 270°	
31° – 40°	///	151° – 160°		271° – 280°	
41° – 50°	~~////~~ //	161° – 170°		281° – 290°	//
51° – 60°	///	171° – 180°	///	291° – 300°	~~////~~ //
61° – 70°	~~////~~ ~~////~~ //	181° – 190°		301° – 310°	//
71° – 80°	~~////~~ ///	191° – 200°		311° – 320°	////
81° – 90°	~~////~~ ~~////~~	201° – 210°		321° – 330°	~~////~~
91° – 100°	~~////~~	211° – 220°	///	331° – 340°	////
101° – 110°	//	221° – 230°		341° – 350°	//
111° – 120°	//	231° – 240°		351° – 360°	/

(b) Coordinate: N 04°52’4.44”, E 101°58’29.5”

0° – 10°	//	121° – 130°		241° – 250°	///
11° – 20°	///	131° – 140°		251° – 260°	~~////~~ ////
21° – 30°	///	141° – 150°		261° – 270°	~~////~~ ///
31° – 40°	~~////~~ //	151° – 160°		271° – 280°	//
41° – 50°	~~////~~ ~~////~~ ~~////~~ //	161° – 170°		281° – 290°	~~////~~
51° – 60°		171° – 180°		291° – 300°	
61° – 70°		181° – 190°		301° – 310°	///
71° – 80°		191° – 200°	/	311° – 320°	
81° – 90°		201° – 210°		321° – 330°	~~////~~ /
91° – 100°		211° – 220°		331° – 340°	

101° – 110°		221° – 230°	///	341° – 350°	//
111° – 120°		231° – 240°	𝍸 ///	351° – 360°	///

(c) Coordinate: N 04°53’32.4”, E 101°58’47.4”

0° – 10°	𝍸 /	121° – 130°		241° – 250°	𝍸 𝍸 ///
11° – 20°	𝍸 𝍸 𝍸	131° – 140°		251° – 260°	𝍸 𝍸 ////
21° – 30°	𝍸 𝍸 ////	141° – 150°		261° – 270°	////
31° – 40°	𝍸 𝍸 ///	151° – 160°		271° – 280°	///
41° – 50°		161° – 170°		281° – 290°	𝍸 //
51° – 60°		171° – 180°		291° – 300°	////
61° – 70°		181° – 190°		301° – 310°	
71° – 80°		191° – 200°		311° – 320°	𝍸 𝍸 /
81° – 90°		201° – 210°	𝍸	321° – 330°	𝍸 𝍸 ///
91° – 100°		211° – 220°	𝍸 𝍸 𝍸 ////	331° – 340°	
101° – 110°		221° – 230°	𝍸 𝍸 𝍸 //	341° – 350°	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸
111° – 120°		231° – 240°	𝍸 𝍸 ///	351° – 360°	𝍸 /

APPENDIX III

ICP-MS Result

(a) Code: 18LALD1 (G1)

Sample marking : 2018/456(6)
Sample description : **NSS-006**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	43.8	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	20.2	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	40.2	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	40.2	ppm	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	130.0	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	19.9	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	141.0	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	15.0	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	185.0	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	905.3	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	169.4	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	438.3	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	59.5	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	363.4	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	51.1	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	53.4	ppm	CENLAB/WI/CHEM-TM/008

(B) Code: 18LALD2 (G2)

Sample marking : 2018/456(5)
Sample description : **NSS-005**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	24.9	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	1.6	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	33.9	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	428.3	ppb	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	17.4	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	4.0	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	47.8	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	4.1	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	73.9	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	454.3	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	97.4	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	276.1	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	41.3	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	263.0	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	38.7	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	9.6	ppm	CENLAB/WI/CHEM-TM/008

(C) Code: 18LALD3 (G3)

Sample marking : 2018/456(4)
Sample description : **NSS-004**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	24.6	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	30.6	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	62.9	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	728.2	ppb	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	27.5	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	5.3	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	50.0	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	5.0	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	80.9	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	473.6	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	96.6	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	268.9	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	38.1	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	226.1	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	31.2	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	27.5	ppm	CENLAB/WI/CHEM-TM/008

(d) Code: 18LALE15 (G4)

Sample marking : 2018/456(7)
Sample description : **NSS-007**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	29.8	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	53.2	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	106.2	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	1.2	ppm	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	43.2	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	7.9	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	33.1	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	6.7	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	99.4	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	565.2	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	112.4	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	304.3	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	43.5	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	262.9	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	36.6	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	42.9	ppm	CENLAB/WI/CHEM-TM/008